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Plant Resources of South-East Asia

No 4

Forages

L. 't Mannetje and R.M. Jones (Editors)

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Foreword

According to FAO estimates, the livestock population of South-East Asia comprises approximately 55 million cattle equivalents. Of the 435 million ha of land in the region, only 16 million ha are classified as permanent grasslands, which is the typical form of land use devoted to livestock. Since the productivity of these grasslands is poor, they would be unable to carry these numbers of animals. Furthermore, the greatest livestock densities occur in the most densely populated regions, where grasslands are not common. These simple facts indicate that in South-East Asia livestock feed is not produced solely on permanent grasslands. Most of the livestock is kept on small mixed farms. Cattle and buffaloes provide draft power and they produce small amounts of milk, meat and manure. The cultivation of food crops has the greatest priority on these farms, so that there is little land available to grow forage. Instead, the animals are tethered on fallow land and along roadsides. Animals are also stabled, fed on harvested forage, whilst the manure is used to fertilize food crops, so that the soil fertility of forage-growing areas is gradually depleted. Additional animal feed is obtained from crop residues, such as straw, but these are generally of poor quality. However, by-products of industrially processed agricultural products provide better quality animal feed such as rice bran and molasses.

The quality of most tropical grasses is poor, leading to poor animal performance. Both their yield and crude protein concentration could be improved by the use of nitrogen fertilizer, as long as the forage is harvested at a young stage of growth. However, small farmers, who do not own the land from which they harvest forage, are not in a position to use fertilizers for forage production. For this reason the smallholder is better off using legumes which fix atmospheric nitrogen and which maintain a reasonable feeding value while ageing. Grass-legume mixtures which are used on large scale animal farms, however, are not feasible in the more densely populated areas of South-East Asia. Therefore, legumes in sole cropping, which can be used in rotation with crops, thus contributing to soil fertility, and woody legumes which can be grown as hedges or in alley cropping are a more appropriate way of improving the forage supply on small farms.

The improvement of native grasslands requires an inventory and evaluation of available grasses and legumes. Generally speaking, native forage species do not give an economic return to improved soil fertility, whilst most improved grasses and legumes are not productive and persistent on poor soils. Therefore, large-scale grassland improvement for extensive animal production has to rely on species which can thrive on poor soils. Introduced grasses require a source of nitrogen, which can be supplied by legumes that are adapted to poor soils (e.g. *Stylosanthes* spp.). However, native pastures, even *Imperata* grasslands, can also be improved by the addition of such legumes. Much knowledge and

experience in these matters has been accumulated by the CSIRO Division of Tropical Crops and Pastures in Queensland, Australia, with which the editors of this volume have been closely associated.
In this Prosea volume, much useful information is provided about the botany, ecology and agronomy of a large number of native and introduced grasses, legumes, and other forage species that can be gainfully used in South-East Asia. I hope that this information will be an inspiration to all those who are involved in the improvement of the forage supply in the region.

Wageningen, June 1992

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1 Introduction

1.1 Forages and livestock

Grassland and fodder plants serve as feed for domestic and wild herbivores. They mostly belong to the families Gramineae and Leguminosae, although other herbaceous and woody plants are also eaten by animals. Grassland and fodder plants are collectively named forages. Forage can be defined as feed for herbivores, usually with low nutrient concentration and low digestibility, thus contrasting with concentrates such as grain. Forage plants can occur in the wild, but are more commonly found in grasslands, in tree crop plantations or in open spaces in and near forests and along roads, bunds between rice paddies and canals. In South-East Asia such areas are sometimes termed 'waste' areas – this does not mean they do not provide useful forage, but that they are not used for food or forage crops. However, forages can be cultivated and sown for the specific purpose of producing feed for livestock. Residues or by-products from food crops, and weeds in cropping lands, are also very important sources of forage in South-East Asia. Forage is either grazed in situ by tethered or free ranging animals or is cut and carried to penned or tethered animals. Even within one region the proportion of forage obtained from grazing as compared with hand feeding can change appreciably between different sites and seasons, as is the case for West Java (Thahar & Petheram, 1983).

Although South-East Asian agriculture is mostly geared to the production of rice and plantation crops, livestock play an important role in providing draft power and for the production of meat, milk and dung. The estimated livestock numbers in South-East Asia comprise about 33 million cattle, 19 million buffaloes, 6 million sheep and 15 million goats (Table 1).

Most animals are kept in the densely populated areas and about 90% of ruminants occur on mixed farms run by smallholders. Such farms are typically of 1–2 ha with 1–4 large ruminants and a few sheep and goats (Ranjhan, 1986). Between 1969–1971 and 1988 the estimated number of cattle, sheep and goats increased, but the number of buffaloes did not change. Yet there are differences in the trends of large and small ruminants within and between countries. For example, in Indonesia and the Philippines the number of goats increased substantially, whereas there was no such increase in Malaysia. The estimated 20% increase in the numbers of large ruminants and 68% increase in the numbers of small ruminants between 1970 and 1988 clearly point to an increased demand for fodder. Moreover, many of these animals suffer malnutrition and also the demand for meat and milk is rising as a result of increased buying power of the population, so that the increase in animal numbers may underestimate the need for increased quantity and quality of forages. It has been estimated that the demand for forage would double by the year 2000 (Remenyi & McWilliam, 1986).

Table 1. Ruminant livestock ($\times 10^6$) in South-East Asia; means for 1969–1971 and 1988 (FAO, 1989).

Country[1]	Cattle		Buffaloes		Sheep		Goats	
	1969–1971	1988	1969–1971	1988	1969–1971	1988	1969–1971	1988
Burma	7.0	10.0	1.6	2.2	0.2	0.3	0.6	1.1
Cambodia	2.2	2.0	0.9	0.7	*	*	*	*
Indonesia	6.3	10.1	3.2	3.3	3.2	5.5	6.9	10.6
Laos	0.4	0.8	0.9	1.1	*	*	*	*
Malaysia	0.3	0.6	0.3	0.2	*	0.1	0.4	0.3
Philippines	1.7	1.5	4.4	2.8	*	*	0.8	2.2
Thailand	4.5	5.3	5.6	5.4	*	0.1	*	0.1
Vietnam	1.8	3.0	2.3	2.9	*	*	0.2	0.4
Total	24.2	33.3	19.2	18.6	3.4	6.0	8.9	14.7

1. Brunei and Singapore have been omitted because of small numbers of animals.
* Less than 100000 animals.

Although there have been considerable forage research programmes in the region (Blair et al., 1986; Halim, 1989), comparatively little use is made of improved forage plants. However, the use of these species is increasing and there is a large potential for increased forage production in the region.

1.2 Sources of forage

1.2.1 Grasslands

In tropical areas with high rainfall, grasslands are usually sub-climax vegetation, because the natural climax is almost always closed forest. These sub-climax grasslands have been formed by man clearing forest for shifting cultivation and are then maintained as a sub-climax by grazing and burning of abandoned cropland. These grasslands are almost always found on areas that are not suited to food crops by virtue of factors such as slope and soil type. Natural climax grasslands in South-East Asia are rare and usually restricted to frequently flooded lands, as has been reported for parts of Vietnam (Whyte, 1974).

Grasslands are sometimes referred to as 'savanna', a term that denotes a continuous graminoid stratum, more or less interrupted by trees or shrubs (Johnson & Tothill, 1985). One of the characteristics of savanna is that the climate is seasonal with wet, warm to hot periods alternating with more or less dry, warm to cool ones (Johnson & Tothill, 1985). But the term savanna is still subject to confusion and here the term 'grassland' is used, defined as vegetation types in which the tree cover is less than 40% (UNESCO, 1979). Grasslands can be divided into pure (i.e. treeless) and wooded grasslands.

It has been estimated by FAO (1989) that there are about 14 million ha of permanent grassland in South-East Asia and the western Pacific Islands, whereas Soerjani (1970) estimated that there were 16 million ha in Indonesia alone. The dominant species in these grasslands is usually *Imperata cylindrica* (L.) Raeuschel.

Major areas of grassland include:
- the large central plains of Thailand and the Korat plateau, which extend into Laos and the northern parts of Cambodia;
- parts of north and northwestern Thailand, extending into Burma and northern Laos;
- moderately high areas which are almost totally converted to wooded grasslands by livestock husbandry, especially on the plateaux of northern Laos and Vietnam.

The grazing lands of Indonesia are wooded grasslands resulting from degradation of climax forest. These may be the result of drier conditions combined with annual fires, as on the eastern islands (Nusa Tenggara), or they may be abandoned crop lands used for grazing. Very often these lands are impoverished as a result of frequent exploitative cropping. On Java and Madura grazing lands occupy less than 5% of the land. Nevertheless these two islands support 65% of the livestock of Indonesia, but their feed comes from roadsides, banks of canals, bunds between rice fields, open areas within and alongside forests and from crop residues. In the Nusa Tenggara region of Indonesia pure or wooded grasslands cover large areas, e.g. 35% on Lombok and 65% on Sumba and Timor. About 12% of the Philippines is grazing lands which are maintained by frequent fires.

There are approximately 15 million ha of plantation crops in South-East Asia (FAO, 1989). The area under many of these plantation crops is used for food crops, but often it has a herbaceous understorey of native species, or sown cover crops which can be grazed. There is a great opportunity for forage production from pastures consisting of improved forages under coconuts, and to a lesser extent under young stands of rubber and oil palm. Grazing can enhance nutrient cycling, control waste herbage and reduce use of weedicides, enable easier management of the plantation crop and may improve crop yields and income (Reynolds, 1988).

The species occurring in these unimproved grasslands are native or naturalized and, except for fire, no cultural or management practices are imposed. Dry matter yields and the nutritive quality of the species are frequently low. The grass genera most commonly encountered are: *Andropogon* L., *Arundinella* Raddi, *Arundo* L., *Axonopus* Beauv., *Capillipedium* Stapf, *Chloris* Swartz, *Chrysopogon* Trin., *Coix* L., *Cyrtococcum* Stapf, *Cymbopogon* Sprengel, *Dactyloctenium* Willd., *Digitaria* Haller, *Echinochloa* Beauv., *Eleusine* Gaertner, *Eragrostis* v. Wolf., *Heteropogon* Pers., *Hyparrhenia* Andersson, *Imperata* Cyr., *Ottochloa* Dandy, *Paspalidium* Stapf, *Paspalum* L., *Pennisetum* Rich., *Phragmites* Adanson, *Saccharum* L. and *Themeda* Forssk. None of the species concerned, except *Pennisetum purpureum* Schum., is purposely established as grassland or forage crop. There are few legumes in these grasslands, some of the more common species being *Desmodium heterophyllum* (Willd.) DC., *Desmodium triflorum* (L.) DC., *Mimosa pudica* L., *Mimosa invisa* Martius ex Colla and *Indigofera* spp. The species composition of grazing lands changes with the climatic regime and management imposed (Manidool & Chantkan, 1986).

Grass species of temperate origin (C_3-species) occur at high altitudes in the region, such as on Mt Kinabalu in Sabah and on mountains in Indonesia and in the highlands in Malaysia and New Guinea (Whyte, 1974).

1.2.2 Annual and perennial fodder crops

Fodder crops in present use fall into three categories, viz. herbaceous crops, root crops, and trees and shrubs. The herbaceous crops are mostly grasses and legumes. The main grass crops are: *Pennisetum purpureum* Schum., *P. americanum* (L.) K. Schum. ex Leeke, *P. purpureum* × *P. americanum*, *Panicum maximum* Jacq., *Tripsacum andersonii* J.R. Gray, *Saccharum officinarum* L. and *Zea mays* L. The second and the last two species listed are primarily used as food crops. The main herbaceous legume fodder crops are *Cajanus cajan* (L.) Millsp., *Lablab purpureus* (L.) Sweet and *Vigna unguiculata* (L.) Walp. and these are used primarily as food crops, and *Stylosanthes guianensis* (Aublet) Swartz. The root crops used for human and animal nutrition are *Manihot esculenta* Crantz and *Ipomoea batatas* (L.) Lamk. For further information from the viewpoint of forage, see Section 1.7.

Of the trees and shrubs *Leucaena leucocephala* (Lamk) de Wit is the most extensively used, but other species such as *Calliandra calothyrsus* Meissn., *Flemingia macrophylla* (Willd.) Merrill, *Gliricidia sepium* (Jacq.) Kunth ex Walp., *Sesbania grandiflora* (L.) Poiret and *S. sesban* (L.) Merrill are also important (Topark-Ngarm, 1990). Trees and shrubs can be used in many ways, as living fences, vegetation in uncropped areas, hedgerows in alley cropping and as component species in intercropping (Topark-Ngarm, 1990). There is great interest in fodder trees and shrubs in South-East Asia (Devendra, 1990).

Fodder crops are used by smallholder farmers as well as by large-scale animal production units, mostly dairy farms near the larger cities.

However, in most cases the cultivation of forage crops is subservient to that of food crops. Nevertheless, there is scope for forage crops in combination with food crops, either as alley cropping or undersown to provide better quantity and quality of forage after the food crop is harvested.

1.2.3 Crop residues and agricultural by-products

Nearly all food crops leave residues that can be used as forage. They are a very important forage resource in South-East Asia. Major sources include: rice hulls and straw, banana pseudostems, maize stover, sorghum stover, cassava leaves, sugar cane bagasse and tops, and pulse straws (Ranjhan, 1986). Residues from cereal crops are of poorer quality than residues from pulse crops and considerable research has been carried out on ways of improving their digestibility and intake (Wanapat & Devendra, 1985). The importance of different crop residues in animal feeding systems varies very widely between sites and between seasons at one site (Moog, 1986; Soedomo et al., 1986). In addition, by-products from crop processing, such as rubber seed meal and oil palm meal (Tinnimit, 1985), are used as concentrate feedstuffs.

1.3 Forage and livestock production systems

1.3.1 Current inputs to forage systems

Permanent native grasslands in this region can be classed as extensive forage production systems, as there are no managerial inputs such as irrigation, fertil-

izer or controlled grazing. Even though the pastures may be over-utilized to the point of overgrazing, the only inputs of fire and grazing are often uncontrolled. Semi-intensive forage production systems have inputs such as fertilizer, weeding and irrigation primarily applied to the main cash crop, which also benefit associated forage. Intensive forage production systems have inputs applied for the sole purpose of forage production. An example of this would be large-scale dairy farms near urban centres, where fertilizers could be used on planted forage crops.

Based on the classification of Perkins et al. (1986), five forage production systems, each with its typical level of input, can be distinguished in South-East Asia:

- extensive permanent grassland: (a) privately owned land, (b) communally grazed hill-land and (c) communally grazed and cut roadsides;
- semi-intensive permanent forages: (a) understorey of tree crop plantations, (b) forage from shade trees in plantations, (c) paddy field bunds and edges of crop fields, and (d) perennial forage in alley cropping;
- semi-intensive annual forages: (a) forage crops sown after harvest of food crops and (b) crop residues;
- intensive permanent forages: (a) improved grasslands, and (b) protein banks;
- intensive short-term forages: (a) fodder crops, replacing food crops and (b) fodder crops on special areas.

Hay or silage is not widely used in South-East Asia and is not likely to be so in the future (Ranjhan, 1986). However, conservation is successfully used in some situations. For example, in Indonesia some commercial dairy farmers are using silage of elephant grass (*Pennisetum purpureum*) and some smallholders are using dried grass for feed in the dry season.

1.3.2 Input of forage into different livestock production systems

All livestock production systems can conveniently be grouped into three categories: pastoralism, livestock–crop, and crop–livestock. In pastoral systems people are dependent for livestock on all their needs and there is no interaction with crops for human food. There are three main subgroups: nomadism, ranching and intensive dairying. Nomadism is widely practised in semi-arid and arid areas of Africa and is not applicable to South-East Asia. Ranching takes place in northern Australia and parts of South America, but is of very little importance in South-East Asia. Commercial dairying in South-East Asia is still restricted to areas with good access to large urban centres, but is likely to become more widespread in the future. The second or 'livestock–crop' production system, where there is some dependence on crop residues for feed, but livestock are more important in the farm system than cropping, is typified by many areas in Africa, but to a lesser extent in South-East Asia. The third or 'crop–livestock' system is typical of South-East Asia, where the crop can be an annual such as rice or a long-lived tree such as coconut. The food crops are the major and essential part of the farm system.

The conceptual potential for incorporating the different forage sources previously mentioned in Section 1.2 into these different systems of livestock production is summarized in Table 2. This table illustrates that there are potentially more ways of incorporating forages into crop–livestock systems than into

Table 2. Forage production systems used in different livestock production systems.

Forage production system	Livestock production system				
	nomadism	ranching	dairying	livestock–crop	crop–livestock
Extensive permanent grassland					
privately used	–	+	+	–	–
communally used	+	–	–	+	+
Semi-intensive permanent forages					
understorey tree crops	–	–	+	–	+
forage from shade trees	–	–	+	–	+
edges of crop fields	+	–	+	+	+
forage in alley cropping	–	–	+	–	+
Semi-intensive annual forages					
after harvest of main crop	–	–	–	+	+
crop residues	+	–	+	+	+
Intensive permanent forages					
improved grasslands	–	+	+	–	–
protein banks	–	+	+	+	+
Intensive short-term forages					
fodder crops	–	+	+	+	+

systems such as nomadism or ranching. But this potential is restricted by several important limitations to forage production.

1.4 Main limitations to forage production

Forage production constraints in South-East Asia can be attributed to climate, soil conditions, species, management and socio-economic conditions.

1.4.1 Climate

In humid regions without a dry season of any significance, climatic conditions are generally conducive to good forage growth. However, even in such areas cloud cover will frequently reduce incoming radiation, resulting in lower photosynthesis. Daylength in equatorial regions can also limit growth in comparison to higher latitudes. The combination of longer days and less cloud cover in northern Australia, for example, results in more total incoming radiation than at the equator (Cooper, 1970). Forage growth under trees is also restricted through the interception of light by the tree canopy, as well as by competition for nutrients and moisture.

Temperature is not a limiting factor in equatorial regions except at higher alti-

Table 3. The climatic zones of tropical and subtropical South-East Asia and adjacent regions as defined by Troll (1966).

Troll indice	Climatic zone	Number of humid months per year	Observations
V_1	tropical rainy climate	12–9.5	occurrence: wetter areas of Indonesia, Papua New Guinea, Malaysia, the Philippines, southern Thailand
V_2	tropical humid-summer climate	9.5–7	occurrence: eastern Java, Lesser Sunda Islands, southern New Guinea, western Philippines, Indo-China
V_3	wet-and-dry tropical climate	7–4.5	occurrence: central Thailand
IV_4	dry-winter climate with long summer-humidity	9–6	occurrence: northern Indo-China extending into southern China; basically this climatic zone is a subtropical extension of V_2 and V_3.
IV_{6+7}	permanently humid climate	10–12	occurrence: northern Vietnam with hot summer extending into eastern China; basically this climatic zone is a subtropical extension of V_1 and V_2.

tudes. However, as one moves away from the equator, temperature will be limiting during the time of year with the shortest daylengths. Both at high altitudes and latitudes, frosts can destroy leaves and stems or even kill the plants of tropical species, such as legumes and C_4-grasses. At high altitudes, where growing conditions are temperate, the adaptation of the vegetation is reflected in the increased presence of C_3-species. But at higher latitudes within and immediately north and south of the tropics of Cancer and Capricorn, the growing conditions are primarily tropical. This is because the period of adequate moisture coincides with that of high temperatures and longest daylength. The grasses occurring in these regions are mainly of the C_4-type, which cannot grow at temperatures below about 15 °C (McWilliam, 1978).

Rainfall is not often limiting in equatorial regions, although periods without rain of up to six weeks have been encountered (Niewolt, 1982). However, total rainfall and the period of the year in which it is received generally decrease with increasing distance from the equator.

Using the classification of Troll (1966), the following tropical climatic zones can be distinguished in South-East Asia (Table 3): tropical rainy climates (V_1), tropical humid-summer climates (V_2), and wet-and-dry tropical climates (V_3). To adequately describe South-East Asia, when the region is defined in broader terms, the following subtropical climatic zones should be included: dry-winter climates with long summer-humidity and cool dry winter (IV_4), and permanently humid climates with hot summer and maximum rainfall in the summer (IV_{6+7}). Mountainous areas in equatorial regions pose a problem in climatic classifica-

tion. From the point of view of forage plant adaptation, such areas can be regarded as equivalent to the subtropical climatic zones IV_{6+7} and IV_4, depending on rainfall distribution.
Soil moisture will be limiting in the climatic zones V_2, V_3 and IV_4 during the period of shortest daylength, and in the latter zone this will coincide with temperature constraints. In climatic zones V_3 and IV_4 the unreliability of rainfall during the rainy period also imposes strong limitations on forage production.

1.4.2 Soil conditions

Soil fertility varies widely over the region. The more fertile soils are derived from basic volcanic rocks, coralline material, or alluvium. These soils are intensively cropped. Some 60% of the soils in South-East Asia have severe nutrient deficiencies or toxicities (Kerridge et al., 1986), even though they have medium to excellent soil physical conditions. These soils are leached and have low organic matter levels and low cation exchange capacities. They are acid, with consequently high availability of soluble Al and Mn and low availability of P, Ca and some trace elements. Many tropical forage species, including legumes, are adapted to acid conditions and can tolerate high levels of available Al. Soils in Troll's V_3 and IV_4 climatic zones tend to be less acid than those in V_1, V_2 and IV_{6+7}. Regional studies of soil fertility, such as described by Kerati-Kasikorn (1984), can help document the severity of nutrient deficiencies on different soil types.

1.4.3 Species

The native and naturalized forage species are adapted to the prevailing climatic and soil conditions. Rainfall in climatic zones V_1, V_2 and IV_{6+7} is sufficiently regular that drought tolerance is not a requirement for the plants. Adaptation to dry conditions as a result of irregular and/or seasonally low rainfall is, however, required for plants in zones V_3 and IV_4. In all climatic zones soil fertility is a major constraint to growth although species differ in their adaptation to low fertility (Kerridge et al., 1986). Plant species that are adapted to the unfavourable rainfall and soil fertility have developed strong survival mechanisms. These are based on vegetative propagation and competitive ability to exclude other species (e.g. *Axonopus compressus* (Schwartz) P. Beauv. and *Imperata cylindrica*) or on the ability to produce copious seed (e.g. *Mimosa pudica*). High dry matter production and nutritive value are not necessary attributes for species to survive, and so some native species have low productivity and poor nutritive value.
Some introduced species would not persist unless soil fertility is amended, or if they do, they are often no more productive than native or naturalized species. Conversely, some native and naturalized species may yield as much as introduced species under improved conditions of soil fertility. Introduced legumes should be checked to ensure that they are nodulated. Preferably, introduced legumes should be able to nodulate with indigenous strains of rhizobia.
Species differ in their adaptation to defoliation. Some species, such as *Themeda triandra* Forssk., are unable to persist even under moderate grazing pressure. Other species, such as *Imperata cylindrica* and *Mimosa pudica*, avoid high graz-

ing pressures because of low palatability while others, such as *Axonopus compressus*, are resistant to grazing through their prostrate growth habit. Recent research has also shown that there is considerable variation between species in their ability to grow under the reduced light conditions in plantation crops (Wong et al., 1985a, 1985b; Ahmed Tajuddin, 1991; Shelton & Stür, 1991).

1.4.4 Management

The production of forage from a given area of land depends not only on climatic and edaphic conditions. Within these given limitations the farmer has a large influence on both quantity and quality of forage harvested. The options are:
- to return removed nutrients or not;
- to fertilize or not;
- to alter frequency and height of cutting;
- to alter numbers and movement of animals which are freely grazing or are tethered on grazing land;
- to alter the integration of fodder and food crops.

The first two options are seldom applied to native forage species. In fact the usual system is to remove forage, feed it to stalled or tethered animals and to use the excrement as manure on food crops. This amounts to mining of nutrients, leading to impoverishment of the soil under forages and consequently lower forage yields. In the case of grazing most of the nutrients are returned to the field, but the distribution is very uneven and losses of inorganic nitrogen will occur through volatilization of ammonia and leaching of nitrate.

A high frequency of harvesting can accelerate exploitation of nutrients and disappearance of species not morphologically adapted to frequent defoliation. On the other hand, forage harvested in a young stage of growth is of higher protein and mineral concentration and of higher digestibility than material harvested at an older stage of growth.

A stocking rate exceeding the carrying capacity of a grazed area will lead to overgrazing, often resulting in the disappearance of palatable species and the dominance of species that are not readily eaten, such as *Imperata cylindrica* and *Mimosa pudica*. Even *Imperata cylindrica* can be eliminated by very heavy grazing and be replaced by unpalatable weeds (Falvey & Hengmichai, 1979). Overgrazing thus leads to reduced productivity of the land. The unpalatable species at least protect the land against severe soil erosion which would otherwise occur. A detailed discussion of how grazing pressure effects pasture productivity, botanical composition of pastures and animal production is given by Humphreys (1991).

Food crops are the key to agriculture in South-East Asia and any attempt to improve fodder production must work within this limitation. However, there are possibilities for combining quality requirements for human food as well as for animal feed in one crop. For example, rice cultivars can be selected for grain as well as straw quality, and cassava for root quality as well as for low HCN content of the leaves.

1.4.5 Socio-economic constraints

The improvement of forage resources requires investment of money and labour

and therefore depends on factors such as:
- the economic value and marketability of the animal products;
- the availability of land and its lease conditions;
- accessibility to finances, knowledge and continued support;
- motivation of the farmer and his attitude to risk;
- cultural barriers;
- economic alternatives within the farm systems.

Much animal production in South-East Asia has no direct market value, as in the case of draft power. Many farmers have no land available for direct forage production, and if they do, they may not have access to finance or may not know how to improve their production of forage. In particular, there are major problems in improving communally grazed lands where any improvements are not for individual, but common use (Raghavan, 1990). Socio-economic barriers are, in general, the main limitation to improving animal production in South-East Asia. This is further illustrated by Ghani & Wong (1990), who list factors that constrain the adoption of improved agroforestry systems. These are factors of socio-economic, socio-cultural and institutional nature which are prevalent in South-East Asia, as in most developing countries. The most important of these are lack of motivation, lack of finance, lack of knowledge, lack of entrepreneurship, lack of community leadership, limitations caused by customs and tradition, lack of research and extension facilities and personnel, and problems of property rights.

1.5 Overcoming limitations to improving forage resources

1.5.1 Climate

Nothing can be done to alter the macro-climate for forage production, although it is possible to make the most of the potential for forage production in areas with a changed micro-climate as, for example, under coconut plantations. Where irrigation is available, it is usually used to grow food crops in preference to forage.

1.5.2 Soil fertility

It is highly unlikely that inorganic or organic fertilizers will be used on a widespread basis on extensive grasslands in South-East Asia in the near future. There are more prospects of fertilizers being applied to vegetables, grain or tree crops, thus having an indirect impact on forages in semi-intensive systems and to intensive forage production areas. Phosphorus will be the main element required for legumes though S, K, Cu, Mo, B and Ca may also be needed. Nitrogen is the primary limitation for grasses. In grass/legume systems the legume supplies some nitrogen to the grass, but rarely enough for the grass to reach maximum yield. In some localities there is potential for increasing animal production by supplying Co and Na directly to animals, as these elements can be deficient for animals but not for plants. Many tropical forages are low in Na (Little et al., 1989). Some forage species such as *Stylosanthes* spp. can grow at low levels of available soil P and so can have low P concentrations in their forage. In these cases, P can be a limiting factor for animal growth when it is not limiting for plant growth.

1.5.3 Improved species

The need for new forage species is obvious, because native and naturalized species frequently lack production capacity and/or nutritive value. Improved forage species have been selected for yield potential and nutritive value, but will frequently require amendments to soil fertility and some control of defoliation to express this potential.

Since the main emphasis of this book is on species and not on management, some of the very large number of native or naturalized species and potentially useful introduced species are described in detail in Chapter 2. They are also listed in Table 4, with an indication of the climatic zones to which they are best adapted. The importance of adequate nutrition and correct management in optimizing the use of these improved species is discussed in a series of reviews edited by Blair et al. (1986). There is considerable variability within many of the promising native and introduced pasture species and this variability needs to be evaluated and any weaknesses clearly defined before commencing breeding programmes. Where species are sown by seed, improving seed production can be important in reducing seed costs (Hopkinson, 1986) and in enhancing adoption by farmers. This is well illustrated by experience in Thailand where a government backed guaranteed price for seed of forage species has enabled smallholders to treat seed production as a cash crop. In 1990, about 3000 farmers participated in this programme and produced about 500 t of seed of grass and *Stylosanthes hamata* (L.) Taub. (Manidool, 1990).

Table 4. Important or potentially useful forage species for South-East Asia described in Chapter 2 and an indication of their adaptation to the climatic zones defined by Troll (1966) (x = adapted, – = not adapted).

Forage species	Climatic zones			
	V_1&V_2	V_3	IV_{6+7}[1]	IV_4
a. Native/naturalized grasses				
Arundinaria pusilla	–	x	–	–
Axonopus compressus	x	x	x	–
Brachiaria distachya	x	x	–	–
Centotheca latifolia	x	–	–	–
Chrysopogon aciculatus	x	x	–	–
Chrysopogon orientalis	x	x	–	–
Dactyloctenium aegyptium	x	x	x	x
Dichanthium annulatum	x	x	–	–
Echinochloa colona	x	x	–	–
Echinochloa crus-galli	x	x	–	–
Eragrostis tenella	x	x	–	–
Eragrostis unioloides	x	–	–	–
Heteropogon contortus	x	x	–	x
Hymenachne acutigluma	x	x	–	–
Imperata cylindrica	x	x	x	–
Ischaemum ciliare	x	–	–	–

Table 4. Continued.

Forage species	Climatic zones			
	V_1&V_2	V_3	IV_{6+7}[1]	IV_4
Ischaemum magnum	x	x	–	–
Ischaemum muticum	x	x	–	–
Ischaemum rugosum	x	x	–	–
Ischaemum timorense	x	x	–	–
Leptochloa chinensis	x	x	–	–
Microstegium ciliatum	–	x	–	–
Ottochloa nodosa	x	–	–	–
Panicum repens	x	x	–	–
Paspalum conjugatum	x	–	–	–
Pennisetum polystachion	x	x	–	–
Themeda triandra	–	x	–	x
Thysanolaena latifolia	x	x	–	–
Zoysia matrella	x	x	–	–
b. Selected grasses				
Andropogon gayanus	x	x	–	–
Bothriochloa pertusa	–	x	–	x
Brachiaria brizantha	x	x	–	–
Brachiaria decumbens	x	x	–	–
Brachiaria dictyoneura	x	x	–	–
Brachiaria humidicola	x	x	–	–
Brachiaria mutica	x	x	–	–
Brachiaria ruziziensis	x	x	–	–
Brachiaria subquadripara	x	x	–	–
Cenchrus ciliaris	–	x	–	x
Chloris gayana	–	x	x	x
Cynodon dactylon	x	x	x	x
Cynodon nlemfuensis	x	x	–	–
Digitaria ciliaris	x	x	x	–
Digitaria eriantha	x	x	x	–
Digitaria milanjiana	x	x	x	–
Oryza sativa[2]	x	x	–	–
Panicum maximum	x	x	–	–
Panicum maximum var. *trichoglume*	–	–	x	x
Paspalum dilatatum	–	–	x	–
Paspalum distichum	x	x	–	–
Paspalum notatum	x	x	x	x
Paspalum plicatulum	x	x	x	–
Paspalum scrobiculatum	x	x	x	–
Pennisetum americanum[2]	x	x	–	–
Pennisetum clandestinum	–	–	x	–
Pennisetum purpureum	x	x	–	–
Saccharum officinarum[2]	x	x	x	–
Saccharum spontaneum	x	x	x	–
Setaria sphacelata	x	x	x	–
Sorghum × *almum*	–	–	–	x
Sorghum (art. perennial hybrids)	–	–	–	x

Table 4. Continued.

Forage species	Climatic zones			
	V_1&V_2	V_3	IV_{6+7}[1]	IV_4
Sorghum × drummondii	x	x	x	x
Stenotaphrum secundatum	x	x	–	–
Tripsacum andersonii	x	–	–	–
Urochloa mosambicensis	–	x	–	–
Zea mays[2]	x	x	x	–
c. Shrub legumes				
Albizia lebbeck	–	x	–	x
Calliandra calothyrsus	x	–	–	–
Codariocalyx gyroides	–	x	x	–
Flemingia macrophylla	x	–	–	–
Gliricidia sepium	x	–	–	–
Leucaena leucocephala	x	x	x	x
Sesbania grandiflora	x	–	–	–
Sesbania sesban	x	–	–	–
d. Herbaceous legumes				
Aeschynomene americana	x	–	x	–
Aeschynomene falcata	–	–	x	x
Alysicarpus vaginalis	x	x	–	–
Arachis glabrata	x	x	x	–
Arachis pintoi	x	x	x	–
Cajanus cajan[2]	x	x	x	x
Calopogonium caeruleum	x	x	–	–
Calopogonium mucunoides	x	x	–	–
Canavalia ensiformis	x	x	–	–
Centrosema acutifolium	x	x	–	–
Centrosema macrocarpum	x	x	–	–
Centrosema pascuorum	–	x	–	–
Centrosema pubescens	x	x	–	–
Chamaecrista rotundifolia	–	x	–	x
Clitoria ternatea	–	x	–	–
Crotalaria juncea	x	x	x	–
Desmanthus virgatus	–	x	x	x
Desmodium heterocarpon	x	x	x	–
Desmodium heterocarpon ssp. *ovalifolium*	x	x	x	–
Desmodium heterophyllum	x	x	–	–
Desmodium incanum	x	x	x	–
Desmodium intortum	–	–	x	–
Desmodium triflorum	x	x	x	–
Desmodium uncinatum	–	–	x	–
Lablab purpureus[2]	x	x	x	x
Lotononis bainesii	–	–	x	–
Macroptilium atropurpureum	–	x	x	x
Macroptilium lathyroides	–	x	x	x

Table 4. Continued.

Forage species	Climatic zones			
	V_1&V_2	V_3	IV_{6+7}[1]	IV_4
Macroptilium longepedunculatum	–	x	–	–
Macrotyloma axillare	–	x	x	x
Macrotyloma uniflorum[2]	–	x	–	–
Medicago sativa	–	–	x	x
Mimosa pudica	x	–	–	–
Neonotonia wightii	–	–	x	–
Pueraria phaseoloides	x	x	–	–
Stylosanthes capitata	x	x	–	–
Stylosanthes guianensis	x	x	x	x
Stylosanthes hamata	–	x	–	x
Stylosanthes humilis	–	x	–	x
Stylosanthes macrocephala	x	–	–	–
Stylosanthes scabra	–	x	–	x
Trifolium repens	–	–	x	–
Trifolium semipilosum	–	–	x	–
Vigna parkeri	–	–	x	–
Vigna unguiculata[2]	x	x	–	x
e. Other species				
Asystasia gangetica	x	–	–	–
Ficus subcordata	x	x	–	–
Manihot esculenta[2]	x	–	–	–
Mikania cordata	x	–	–	–

1. Species adapted to climatic zone IV_{6+7} are also usually adapted to high altitudes in the wet tropics.
2. Species primarily in cultivation as a food crop, but frequently used as a forage (see Section 1.7).

The grasses and herbaceous legumes can be used in mixtures in grasslands and under plantation crops, or separately as forage crops. The tree and shrub legumes can be used in protein banks, in alley cropping, in hedges, or as shade trees or single trees. In selecting species for improving forage production, consideration should be given to particular management requirements. For example, in cut-and-carry systems, erect grasses such as *Panicum maximum* and *Pennisetum purpureum* have advantages over more prostrate grasses such as *Brachiaria* spp. which are better suited to grazing. Ability to tolerate shading is a very important selection criterion for species under plantation crops. Ease of establishment under realistic conditions is also important and experimental studies can help to define the most appropriate establishment techniques (Wilaipon & Pongskul, 1984). It is very advantageous if legumes can nodulate readily and consistently with native rhizobia.

1.5.4 Management and socio-economic constraints

In general terms, there is enough knowledge to predict the reaction of many introduced forage species to defoliation by cutting or grazing. This is shown by the many descriptions of the reaction of species to defoliation that are in the second chapter of this book, and, in the case of shrubs and trees, as indicated by Devendra (1990). However, much less is known about the potential benefits of controlled management or the introduction of herbaceous or tree legumes into natural grassland. Although our agronomic or biological understanding is still incomplete, it should be pointed out that socio-economic conditions are usually a greater constraint to introducing and managing forage species than our present understanding of their biology and agronomy.

1.6 Selection of species to be included in this volume

As indicated in the previous sections, a very wide range of plant species contributes to the forage resources of South-East Asia. Some of these species are native or naturalized and others have been deliberately introduced. Species evaluation throughout the region has also shown that there is considerable potential for using cultivars or accessions of forage species that have been developed in other countries. In most instances more is known about the ecology and agronomy of these introduced species than there is of the important native or naturalized species, though useful information on the agronomy of some native grasses is given by Mehra & Fachrurozi (1985) and Skerman & Riveros (1990).

Forage legumes are often also cover, green manure or pulse crops, particularly in humid climates. In many cases legumes serve more than one purpose simultaneously. The cover crops in plantation agriculture are grazed by or cut for domestic animals and the green manure crop can also be grazed or cut before being allowed to grow before being ploughed in.

It would be impossible to give details about every forage species used in South-East Asia in this book, so the species included in Chapter 2 were selected after consultation with specialists throughout the region. Important native and naturalized forage species were included, provided there was sufficient agronomic and ecological information. Section 1.7 gives some information about the forage properties of selected species that are primarily used for food crops, but where some parts of the crop are used for forage. (e.g., sugar cane, cassava and rice). In these cases, botanical and other relevant information will be included in the appropriate Prosea volumes.

Forage species that are commercially available from Australia and South and Central America, which are as yet little used in South-East Asia, have also been included. Many of these species are showing considerable promise in South-East Asia and are being used or are recommended for use on farms. They are also frequently mentioned in current documents such as journals or workshop proceedings. It was therefore appropriate to include them in this book so that their evaluation and subsequent use in farms may be made faster and more efficient by making readers more aware of their strengths and weaknesses. Some temperate and subtropical legumes have been included as they show potential in highland areas (e.g. Nurjaya et al., 1983).

An enumeration of species which were not included in Chapter 2, but are known

to be used as forages, is presented in Chapter 3. Although it does not include every species which is eaten by animals, it includes the species noted in the historical handbooks on plants of economic value in South-East Asia as being used for forage. Forages with another primary use are listed in Chapter 4.
Information given under the headings such as 'Properties' and 'Yield' which refers to nutrient concentrations or dry matter yield is usually only in the form of broad ranges. These properties are much more variable than they are in the case of commodity groups such as pulse crops. They vary with the age of the material sampled, the grazing or cutting regime practised, soil fertility, and climatic conditions during the growth period prior to sampling. Consequently, it is usually misleading to quote specific figures or even narrow ranges of nutrient concentration and yield. Where ranges are quoted, they merely serve to give some idea of the values that are likely to be achieved under the usual conditions of field variability. Furthermore, if pastures are grazed, the quality of the material ingested by animals will depend upon the opportunities for selective grazing.

1.7 Species primarily in cultivation as a food crop

Practically all grass and legume species which are palatable to livestock and of adequate yield and quality are used as forage. The primary use of some species depends on local conditions, tradition and on the availability of certain types of food. For example, *Cajanus cajan, Lablab purpureus, Macrotyloma uniflorum* and *Vigna unguiculata* are important pulse crops in many parts of Asia, but used only as forage in Australia. *Oryza sativa, Pennisetum americanum, Saccharum officinarum* and *Zea mays* are cereal and sugar-producing crops and *Manihot esculenta* is a starch crop in much of the tropics, but in many places they are solely or partially used as forage. In addition, when these crops are used for food, they leave residues that can be used as forage. Some information relating to the forage qualities of the species just mentioned follows below. The species are treated in detail in other Prosea volumes.
Cajanus cajan (L.) Millsp. (pigeon pea). A short-lived perennial shrub which can be grown as a protein bank or in alley cropping systems mixed with other food crops or grass as forage. The shrubs must be well established before they can be grazed intermittently, cut for forage, hay or silage. Defoliation should be lenient to achieve maximum persistence of up to about 5 years. It can produce DM up to 25 t/ha per year. Pigeon pea hay, made when a large percentage of pods are mature, serves as a substitute for industrial concentrate feed. The N concentration varies between 2.5% and 4.5%, and the plant is a good source of vitamin A. At the young stage, pigeon pea is not highly palatable, but it is readily eaten in the green pod stage (Skerman et al., 1988).
Lablab purpureus (L.) Sweet (lablab). An annual or short-lived perennial crop with potential to provide early dry season forage when sown at the end of the rainy season. It can be leniently grazed 10 weeks after sowing, 2 or 3 times in a season, but is not tolerant of heavy grazing. Livestock may require a few days before readily accepting the green material. Lablab can be cut for hay or silage. Dry matter yields of 20–30 t/ha can be expected during a 4–6 month growing period, with an N concentration of 2.5–4.2% and a DM digestibility between 50–65% (Skerman et al., 1988).

Macrotyloma uniflorum (Lamk) Verdc. (horse gram). An annual herb grown in the rainy season, with reasonable drought tolerance, which can be used as a dry season feed reserve. Dry matter yield of 6.6 t/ha, consisting of over 2 t of seed, has been recorded in Queensland (Australia). N concentration ranges between 2.5–4.0% (Staples et al., 1983).

Manihot esculenta Crantz (cassava). A perennial shrub with storage roots consisting mainly of starch. The roots and leaves are used as livestock feed, but both may contain high levels of cyanogenic glucosides (HCN), which can be poisonous if eaten in large quantities. Heat treatment of roots and wilting of green leaves detoxify the material sufficiently for safe use. The roots have an N concentration of about 0.5%, but leaves may contain up to 5% N. Cassava leaves are an excellent supplement to poor quality forage.

Oryza sativa L. (rice). An annual grass grown in either upland (dry) or lowland (flooded) conditions. Floating rice has a long vegetative growth period, and in deepwater rice areas in Bangladesh, India, Thailand and the Philippines the green vegetative material is harvested for forage for livestock, without reduction of the grain yield. N concentration of rice herbage ranges between 1.5–4.0%. The in vitro DM digestibility 40 days after transplanting lies between 70–84%. Deepwater rice cultivars have a greater nutritive value than lowland rice cultivars. In addition, throughout South-East Asia rice straw and bran are important livestock feeds. N concentration of rice straw ranges from 0.5–1.6% depending on maturity and cultivar and DM digestibility is about 50%. Straw quality can be marginally improved by treatment with urea. Rice bran is high in energy, but the N concentration varies greatly and ranges between 0.5–3.8% (Lopez & Vergara, 1988).

Pennisetum americanum (L.) K. Schum. ex Leeke (pearl millet). A robust annual grass used as a cereal crop in Africa and India, but elsewhere mostly as forage. Pearl millet should be grazed frequently but leniently, or cut at about 6-week intervals. DM yield up to 20 t/ha can be obtained with N concentration of young regrowth ranging from 2.4–3.8% and DM digestibility from 60–75%. Young pearl millet is very palatable (Skerman & Riveros, 1990).

Saccharum officinarum L. (sugar cane). A tall perennial grass used for the production of sugar and as a dry season forage for livestock. Sugar cane has a high sugar content, but low N concentration (1.0%). DM digestibility at stage of harvest is about 50%. The tops of sugar cane grown for sugar production or the whole crop can be cut for hand feeding or chopped for silage (Skerman & Riveros, 1990).

Vigna unguiculata (L.) Walp. (cowpea). An annual pulse crop which is also grown as a forage crop for grazing or cutting for hay or silage, giving DM yields of about 5 t/ha with a N concentration ranging from 2.5–4.5%. Cowpea is quite palatable to livestock after they have become accustomed to it in a few days. It can be grown together with annual grass forage crops (Skerman et al., 1988).

Zea mays L. (maize). A tall annual grass grown for grain or forage for fresh feeding or silage. Maize can yield up to 8 t/ha of DM, with a high energy content and N concentration ranging from 2.4% in young leaves to 1.4% in 10-week-old material (Skerman & Riveros, 1990).

1.8 Prospects

In most parts of South-East Asia animal production based on forages is one way of increasing the incomes and security of smallholder farmers. Although all the arable land in densely populated areas is usually already in use, there are still opportunities to either collect or cultivate forage to feed animals. The main restriction will often be lack of surplus labour.

Despite the importance of socio-economic limitations to forage production, there is ample evidence that improved practices will be adopted. This is illustrated by the use of *Stylosanthes* spp. in the dry tropics of Thailand, the use of *Leucaena leucocephala* in many countries and the promising early adoption of the 'three strata farming system' in the drier areas of Indonesia (Nitis et al., 1990). The agronomic areas where there is likely to be the greatest potential for improvement, within existing socio-economic conditions, are in the use of shrub or tree legumes, backyard or home garden forage production, making better use of bunds between rice paddies, forage under plantation crops – particularly coconuts, and use of annual legumes with or after food crops. Recent progress in improving animal production by shrub legumes or by forages under plantation crops has been reported by Devendra (1990) and Shelton & Stür (1991), respectively. A small but increasingly important system with the potential for improvement is that involved in the supply of milk to urban areas.

If improved forage systems can be effectively incorporated into individual smallholdings, as in the case of the 'three strata farming system', there is more likely to be ready acceptance of improvements than when they affect a community, as in the case of common grazing land. Forage improvement schemes will be accepted by a community much more easily, if the community 'owns' the scheme rather than if the scheme is imposed on the community. Nevertheless, governments can also encourage improvements, as in the case of leucaena and other shrub/tree legumes in Indonesia (Rangkuti et al., 1990) and the Philippines (Trung, 1990) and through the development of 'mini-farms' in Malaysia (Chin, 1989). It is highly desirable to have an effective and sustained educational and 'follow-up' scheme to support farmers adopting any improved practice (Nitis et al., 1990). The key point is that although the constraints imposed by socio-economic factors must be recognized, they are not insurmountable (Perkins et al., 1986).

There are many forage species to choose from and proven species are available for all climates in South-East Asia. This diversity should be utilized as much as possible, because it is undesirable to rely on one or a few species or cultivars. Reliance on a narrow germplasm base has the danger that a pest or disease will destroy all or a large part of the feed supply and thus endanger the income of farmers. This was well illustrated by the hardship experienced by farmers who were relying heavily on *Leucaena leucocephala* prior to the advent of the leucaena psyllid in South-East Asia (Trung, 1990).

2 Alphabetical treatment of species

Aeschynomene americana L.

Sp. Pl.: 713 (1753).
LEGUMINOSAE
$2n = 20$

Synonyms *A. javanica* Miquel (1855).

Vernacular names American jointvetch (Am). Indonesia: kacang meongan, asem-aseman, anjang. Philippines: makahiyang-lalaki (Tagalog), karaparak (Mar.). Thailand: sano-don, sano-bok (central), sano khon (north-east). Vietnam: pötuk, rokdönao, rui köjing.

Origin and geographic distribution American jointvetch is native to the Caribbean and adjacent areas of the Americas between latitudes 30°N and 30°S. It has been introduced into several countries in South-East Asia.

Uses American jointvetch is used as a cut-and-carry forage for animals, and as a hay crop. It is used as a pasture legume in Florida (United States), the tropical east coast of Australia, and Vanuatu. It is also applied as a green manure crop in rice and other cropping systems.

Properties Nitrogen concentrations of green leaf range from 2.5–4.0% and of stems from 0.3–1.0%. In vitro digestibility of leaves is 60–70%. Although tolerant of low soil P, yield and P concentrations respond greatly to applied P. Ripe pods divide into single-seeded segments (seed-in-pod) with 150–220 segments/g. Dehulled or naked seed varies in size with 350–400 seeds/g.

Description Annual or perennial herb or subshrub, growing 1–2 m tall and 1.5–2 m wide, glandular-hispid to subglabrous, with prostrate to erect, hard but pithy main stem 5–10 cm thick at base. Branches form roots where they touch the ground. Habit changes dramatically under grazing where plants branch close to the ground, forming a leafy sward. Leaf 2–7 cm long, pinnately compound, 20–60-foliolate; leaflet more or less sickle-shaped, 3–15 mm × 1–3 mm, glabrous but ciliate at least along one margin, 2–several-costate, folding together at night or when touched. Inflorescence axillary, racemose, few-flowered, about the length of the subtending leaf; pedicel ca. 1 cm long; flower papilionaceous, 3–10 mm long, yellow, orange or mauve, usually with red or purple stripes. Fruit a straight or slightly curved pod, 1–3 cm long, 3–9-articulate; articles (segments) 2.5–5 mm × 3–6 mm, glabrous to villous-hispid, light-brown, more or less muricate, margins thickened. Seed kidney-shaped, 2–3 mm × 1.5–2 mm, dark-brown to blackish.

Growth and development Plants are heavy seeding, self regenerating annuals or short-lived perennials with crowns surviving up to 2–4 years. The seedling phase is relatively slow, but subsequent growth is rapid in hot and moist conditions. Nodulation is prolific and, under waterlogged conditions, nodules form on lower parts of the main stem and branches. It has a short-day flowering response. Flowering commences 60–200 days after germination, with another 30–60 days to ripe seed. Away from the equator, perennial plants will also flower and seed in spring. Although most of the pollen is shed before flowers open, recent studies indicate that up to 30% outcrossing occurs. Yield of DM is higher in the late maturing types. Up to 90% of freshly harvested seed is 'hard' and requires scarification before sowing. Natural breakdown of hardseededness is sufficient to allow re-establishment in the field.

Aeschynomene americana L. – 1, branch with leaves; 2, flowering and fruiting branch.

Other botanical information Sometimes *A. americana* and *A. villosa* Poiret (syn. *A. javanica*) are considered as different species. In that view, *A. americana* originates from the Caribbean and adjacent areas, usually in wet or moist places, up to 1400

m altitude, and *A. villosa* originates from southern Arizona (United States) to northern South America and the Antilles, usually in drier areas up to 2250 m altitude. Discriminative morphological characteristics of *A. americana* and *A. villosa* would be respectively: flowers 6–8 mm versus 3–5 mm long; leaflets more than, versus less than, 5 mm long; mature fruit-centre muricate versus non-muricate. Young material of both species is impossible to distinguish. Unification of both taxa seems to be justified.

Cultivar 'Glenn' was registered for use in tropical coastal Queensland, Australia, in 1983 and 'Lee', a more perennial form, in 1991. Common American jointvetch has been used in Florida, United States, since the early 1970s. Descriptions of collections grown in Florida and Australia indicate wide diversity of material differing in range of maturity and perenniality, plant habit and size.

Ecology American jointvetch grows in poorly drained and waterlogged conditions. Best growth of American jointvetch occurs in tropical areas with hot, moist climates, normally with an annual average rainfall of over 1000 mm and most commonly in poorly drained or run-on situations. However, its natural distribution covers a wide range of latitude and altitude (up to 2250 m). It should be possible to select for cold tolerance and different rainfall requirements. 'Glenn' has a summer minimum rainfall requirement of about 1000 mm. It prefers wet, poorly drained or waterlogged areas on sandy to clay soils.

Propagation and planting Suggested seeding rate is 4–8 kg/ha seed-in-pod or 2–4 kg/ha dehulled seed. Half these rates can be used in a mixture. Dehulling is the best method of scarification and will raise germination to about 30%. When sown with a companion grass or grown as a pure stand for forage or hay, it is best sown into a well prepared seed-bed. Satisfactory establishment can be achieved by spreading seed onto the surface of well-grazed pasture.

Husbandry In grazed pastures, American jointvetch should be kept 50–60 cm tall to promote leaf production. Grazing pressure should be reduced after flowering to promote maximum seed production, particularly in the year of planting. Seed is spread in dung following ingestion by animals.

Diseases and pests Commercial seed crops may require control of *Heliothis* larvae which eat the flowers and green pods. Where cool, showery weather occurs at flowering, spraying with benlate may be required to control the fungal disease botrytis stem rot (*Botrytis cinerea*). In grazed situations neither disease is a problem. Powdery mildew (*Oidium* sp.) turns mature leaves white towards the end of the growing season, but does not affect quality or acceptability. In South America anthracnose (*Colletotrichum gloeosporioides*) has been found on American jointvetch but not in Australia or Florida.

Harvesting *A. americana* should be cut for hay or ploughed in for green manure at full flower. For cut-and-carry, the forage should be cut above 50 cm prior to flowering to encourage regrowth. Ripe seed remains on the plant so plants should be allowed to mature if commercial seed production is the aim. Ripe, dry seed will store and remain viable for many years.

Yield Dry matter yields of 10–15 t/ha for a full season's growth have been recorded in Queensland. In Florida, cutting for hay, initially at 30 cm with a second cut at 90 cm, yielded 4.5 t/ha of quality hay per season. Five cuts between March and November produced 7.5 t/ha of hay in Puerto Rico. For seed production, direct header harvesting yielded up to 1000 kg/ha seed-in-pod in northern Queensland.

Genetic resources Collections are held at CIAT (Columbia); CENARGEN/EMBRAPA (Brasília, Brazil); ATFRGRC (CSIRO, Australia); University of Florida, Fort Pierce, Florida; IPB, University of the Philippines (the Philippines).

Breeding Most effort is directed at evaluating existing collections, but limited breeding work is being undertaken at the University of Florida to achieve nematode resistance and increased forage yield.

Prospects American jointvetch is a high yielding, high N fixing legume which tolerates waterlogging and is palatable to stock. Its role in South-East Asian areas will include green forage in pure stands or in mixed pastures, hay production, green manure, and ley pastures for rice paddies. It should be possible to select cultivars to suit climatic and growth habit requirements.

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H.G. Bishop

Aeschynomene falcata (Poiret) DC.

Prodr. 2: 322 (1825).

LEGUMINOSAE

$2n$ = unknown

Synonyms *Hedysarum falcatum* Poiret (1804), *H. diffusum* Vellozo (1825, 1835), *Aeschynomene apoloana* Rusby (1910).

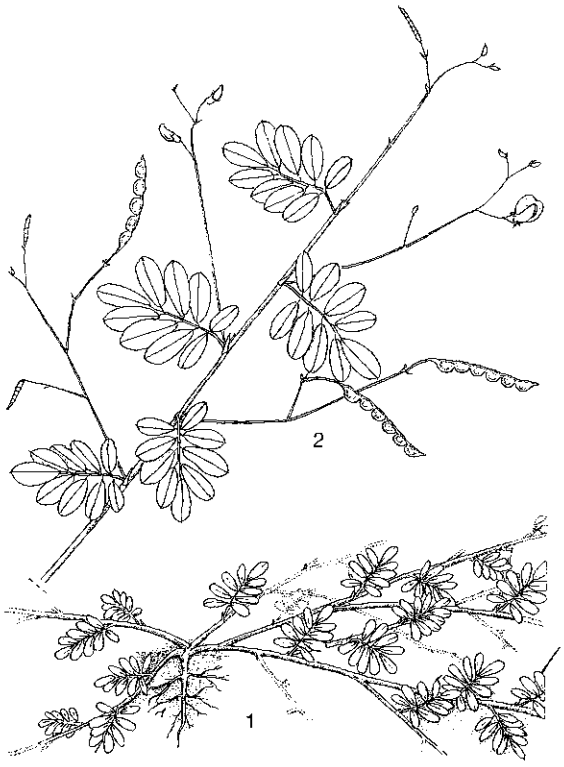
Vernacular names Jointvetch (used for all members of the genus) (En). Indonesia: turi rawa (Javanese). Philippines: torog-torog (Bikol).

Origin and geographic distribution *A. falcata* is native to the higher altitude tropical or subtropical parts of Argentina, Bolivia, Brazil, Colombia, and Paraguay. It has been introduced into many South-East Asian countries and Australia.

Uses *A. falcata* is used in grazed pastures and is not appropriate to cut-and-carry systems. It has been tested as a low-growing cover crop.

Properties Nitrogen concentrations range from 1–2%, and in vitro DM digestibilities from 42–65%. Phosphorus concentrations are typically 0.1–0.2%. *A. falcata* is readily eaten by livestock although older stems may be rejected in favour of young grass. In the Australian cultivar 'Bargoo' there are 375 seeds/g.

Botany A prostrate, herbaceous perennial with a short tough taproot. Stems up to 1 m long and 1–3 mm diameter, puberulent, decumbent, showing little tendency to produce roots at the nodes; small nodules to about 2 mm diameter occur on both the taproot and secondary roots; older stem bases woody to 3 mm thick. Leaf 5–7(–9) foliolate; leaflet obovate-elliptical, 6–12 mm × 2.5–4 mm, pubescent. Inflorescence with usually only 1 or 2 flowers developing, longer than the subtending leaf; flower 7–10 mm long, yellow, with orbiculate standard. Pod 4–8-articulate, puberulent, slightly curved, stipe 6–14 mm long; articles 3–4 mm × 2.5–3.5 mm, the body of the articles tending to break away from the margins. Seed yellowish-brown to black, 2–2.5 mm × 1.4–1.7 mm.



Aeschynomene falcata (Poiret) DC. – 1, habit; 2, flowering and fruiting branch.

'Bargoo' plants develop slowly and may take several years to reach maximum size. They flower throughout the growing season provided moisture is adequate. Pod segments open when seed is ripe. Spread of seed is assisted by passage through the grazing animal. Persistence is ensured by build-up of soil seed levels from 1000 to 8000/m^2, depending on management history and environment.

Ecology *A. falcata* occurs naturally on rocky hillsides, in savannas, and in cultivated fields, at elevations to about 1800 m. 'Bargoo' originates from 25°30'S in central Paraguay where it was growing on a rocky sandstone ridge in forest country. In eastern Australia, 'Bargoo' is adapted to a variety of poor to moderately fertile soils derived from sandstone, shale and granite between 20–30°S. Most areas where 'Bargoo' has proven successful have an annual rainfall between 700–1200 mm. It can tolerate temporary waterlog-

ging and periods of drought, but grows best on moist, well-drained soils. It does not tolerate sustained wet conditions. On suitable soils it is a very persistent legume.

Agronomy 'Bargoo' is readily established from seed. Because it is often extremely hard, seed may need scarification if a high level of immediate germination is desired. Seed should be inoculated with an appropriate *Bradyrhizobium* strain, although effective nodulation may be achieved from native strains in some soils. Best establishment is obtained from shallow or surface sowing on a clean, well prepared seed-bed. Although tolerant of low fertility, it can respond to applications of P.

The only disease of any consequence is caused by *Colletotrichum* sp. which attacks the stem near the growing tip, ultimately resulting in tip death. This is a problem in humid environments, particularly in seed crops. 'Bargoo' is not affected by amnemus weevil (*Amnemus quadrituberculatus*) and is resistant to rootknot nematodes (*Meloidogyne* spp.)

It is extremely tolerant of, and can still produce seed under heavy grazing. 'Bargoo' is too low-growing for ease of hand harvest, and is therefore grazed. Yields are generally low and may not exceed 1–2 t/ha of DM per year. 'Bargoo' is not suitable for hay as leaves shed readily.

Genetic resources and breeding A small collection, including 'Bargoo', is held at ATFGRC (CSIRO, Australia). No breeding programmes are anticipated. It was tested with moderate short-term success on Sumba Island (10°S, 770 mm rainfall with a 4 month wet season) in eastern Indonesia.

Prospects Since the only commercial cultivar ('Bargoo') originates from near the southern extremity of its natural distribution, which has only been evaluated to a limited extent globally, it is difficult to speculate on the prospects of the species. 'Bargoo' should have a role in those parts of the sub-humid tropics and subtropics with heavily grazed pastures on light, infertile and well drained soils.

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B.G. Cook

Albizia lebbeck (L.) Benth.

Lond. Journ. Bot. 3: 87 (1844).
LEGUMINOSAE
$2n = 26$

Synonyms *Mimosa lebbeck* L. (1753), *Mimosa sirissa* Roxb. (1832), *Albizia latifolia* Boivin (1838).

Vernacular names Siris, koko, East Indian walnut (En). Indonesia: tekik (Javanese), kitoke, tarisi (Sundanese). Philippines: aninapla, langil (Tagalog). Cambodia: chreh. Thailand: kampu (general), chamchuri (central). Vietnam: bô kêt tây, lim xanh, trât.

Origin and geographic distribution Siris is indigenous to the Indian subcontinent and to those areas of South-East Asia with a marked dry season (e.g. north-east Thailand, the eastern islands of Indonesia) and to the monsoon areas of northern Australia. It has been introduced widely throughout the tropics and has become naturalized in many places.

Uses The green leaf is a valued forage for ruminants and it should be useful in extensive grazing systems because of the feed value of the natural drop of leaves, flowers and pods. Free-standing trees appear to enhance pasture production and quality beneath the canopy due to increased N status of the soil. In India plantation-grown siris yields a high quality hardwood traded in Europe as 'Indian walnut' or 'koko'. More generally it is useful for fuelwood because of its high productivity. It is a valued honey tree because of its production of both nectar and pollen. It is a popular amenity tree throughout the dry tropics because of its shady spreading habit, although the copious litter is often regarded as a disadvantage.

Properties In feeding experiments with sheep, DM digestibility and N concentration, respectively, were as follows: green leaf fed fresh: 64% and

3.5%; mature green leaf fed dry: 48% and 3.0%; fallen leaf: 42% and 1.6%; fallen flower: 57% and 3.8%; fallen pods: 44% and 3.0%. Leaf is notable for the absence of antinutritional factors such as phenolics, but pods contain saponins. There are 7–8 seeds/g.

The wood is dense (specific gravity 0.5–0.6), easily worked, yellow-brown, with a very distinct boundary between heartwood and pale sapwood. A range of uses such as cabinet timber have been listed, including the doors of Chinese temples. The massic energy of air-dried wood is 21840 kJ/kg (5200 kcal/kg).

Description Deciduous tree, in plantations 3–15 m tall, bole length 3 m with diameter 45 cm; when grown in the open, often much larger, up to 25 m tall, often multi-stemmed and widely spreading (up to 30 m diameter); bark rough, grey, somewhat flaky; inner bark reddish; branches terete, puberulous or pubescent when young. Leaves bipinnate with 1–5 pairs of pinnae on a rachis of 8–9 cm length; leaflets in 3–11 pairs, oblong to elliptical-oblong, 1.5–6.5 cm × 0.5–3.5 cm, somewhat asymmetrical with midrib nearer upper margin, subglabrous, initially bright green and folding at night, maturing to a duller glaucous green with position fixed on rachis. Inflorescence a terminal and axillary globular cluster of 15–40 pedicellate flowers, often 2 or more together per axil; peduncle up to 10 cm long, pedicel 1.5–5(–7.5) mm long; calyx tubular, 2–5 mm long, ending in 5 triangular teeth; corolla tubular, 5–11 mm long, ending in 5 triangular lobes which are hairy at the apex; stamens at base united in a tube, free filaments numerous, 1.5–3 cm long. Pod flat-oblongoid, 12–35 cm × 3–6 cm, much swollen on the seeds, subglabrous, glossy, veined, pale yellowish, dehiscent. Seeds 3–12 per pod, flattened ellipsoidal, 7–11 mm × 6–9 mm × 1–1.5 mm, brown.

Albizia lebbeck (L.) Benth. – 1, flowering branch; 2, flower; 3. fruit.

Growth and development Siris has a strongly seasonally-dependent growth pattern with a leafless period of 1–2 months in the middle of the dry season. Production of new season growth commences in the dry season, shortly followed by abundant flowering which produces very little seed. Further growth and fruiting occur as the wet season develops. Flowers are insect pollinated. Pods mature in the early dry season but remain on the tree for 3–4 months.

Seed dispersal seems to occur mainly due to strong wind, when intact pods can be carried hundreds of metres. Some seed passes through the digestive tract of cattle but not of smaller ruminants. Light transmission through the canopy of free-standing trees is 40–50%. In an open woodland environment it has been repeatedly observed that there is modification of the ground cover with enhancement of grass production and quality beneath the canopy.

Growth stops in the early dry season, 2–3 months before leaf drop. New growth may be induced by fire damage, grazing or lopping.

Other botanical information *Albizia* Durazz. is a large genus and in parts of its range non-fertile material of siris may be quite similar to other local species. There is little problem with identification when both flowers and pods can be examined. Use of 'albizia' as a vernacular name should be avoided as some workers apply it also to *Paraserianthes falcataria* (L.) I. Nielsen, a very important species in South-East Asia and quite different from siris. *Albizia* is often misspelt as *Albizzia* and *lebbeck* as *lebbek*.

Ecology Although siris will grow in the humid tropics, its natural range is in semi-arid to subhumid areas with marked dry and reliable wet seasons. However, it may be established under condi-

tions of low (400 mm/year) and irregular rainfall. Seedlings will not tolerate frost or waterlogging. Reserves in the root system enable young plants to survive total defoliation from fire or grazing, but with an obvious setback in growth. Siris is tolerant of salinity and can be established on most soils except cracking clays.

Propagation and planting The species is not particularly hard-seeded and requires only mild treatment (e.g. in water at 50°C for 3 minutes) to germinate successfully; a proportion of seeds germinate immediately without any treatment. There is nothing published on preferred rhizobial strains but it appears to nodulate readily without inoculation. Plants can be direct-sown, container grown, or raised in a massed seed-bed and planted out as bare-rooted stems.

Husbandry Siris is probably not productive under repeated cutting (more than 2 cuts per year). It does not develop a shrubby habit and is thus not suitable for direct browsing. However, larger trees can be lopped annually with removal of the entire green crown without loss of vigour.

Diseases and pests Establishment can be adversely affected by grazing of young plants by mice, rabbits and other wildlife. Leaves are largely unaffected by insects, but young leaves may be subject to heavy predation by larvae of the grass yellow butterfly (*Eurema hecoba*); this appears to be a short-lived effect. The most serious pests are bark-feeding larvae of longicorn beetles. These do not affect small stems and have little effect on large stems, but through complete girdling can cause dieback in stems with diameters ranging from 4–10 cm. There is considerable variation in susceptibility of individual trees. Trees may be more susceptible under prolonged drought stress.

Harvesting Branches may be lopped for fuel and forage. In extensive grazing systems, the free-standing tree itself provides feed. Production of sawn timber involves felling the whole tree, with concommittant production of fuelwood and forage.

Yield Comprehensive yield data have not been published. Under best conditions plants can grow 5 m/year. Fuelwood plantations produce 5 m^3/ha per year. Isolated mature trees produce edible DM at the rate of 100–120 kg/year. Roadside trees in the dry tropics show a crown diameter expansion of 2–2.2 m/year until mature.

Genetic resources The wide natural range suggests a broad genetic base, but there are no comprehensive germplasm collections.

Breeding There are no reported programmes in breeding, collection, or evaluation of existing accessions. The value of siris is critically dependent upon resistance to insect attack and this should be the first objective of development work on the species.

Prospects Siris offers excellent prospects for developing more productive agroforestry systems in areas in the semi-arid tropics. It would appear to have excellent multipurpose aspects, being potentially useful for cabinet timber, fuelwood, animal feed, and for enhancing crop production. Perhaps most remarkable is the prospect of obtaining enhanced pasture production in addition to the tree products. Despite its great economic importance on the Indian subcontinent and its widespread distribution in South-East Asia, its qualities are little known there. This may reflect a lack of research and development in the drier ('outer') areas in the region. Other species of *Albizia* are worth considering for the same purposes, in particular *A. procera* (Roxb.) Benth.

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J.B. Lowry

Alysicarpus vaginalis (L.) DC.

Prodr. 2: 353 (1825).
LEGUMINOSAE
$2n = 16, 20$

Synonyms *Hedysarum vaginale* L. (1753), *Alysicarpus nummularifolius* (Willd.) DC. (1825).

Vernacular names Alyce clover, buffalo clover, one-leaf clover (En, Am). Indonesia: bro-

bos, gudé oyod, tebalan (Java). Malaysia: akar seleguri. Philippines: banig-usa, mani-manian (Tagalog). Thailand: thua lisongna. Vietnam: cây me dât, cây the the.

Origin and geographic distribution *A. vaginalis* is native to and widespread throughout East Africa including Madagascar, the Indian sub-continent, South-East Asia and the Pacific, and is naturalized in northern Australia (especially in the Northern Territory), in South America and the United States.

Uses *A. vaginalis* is a useful component of native pastures in Fiji and northern Australia, especially where fertilizer has been applied, and is a useful fodder legume in the Philippines, Indonesia and southern China. It has been used as a cover crop in Papua New Guinea and in rubber plantations in Java, and also as a hay crop in the United States. In Indonesia and Malaysia a decoction of roots is applied against coughs. In Vietnam an infusion of powdered seeds is used against dysentery and colics.

Properties The few recorded analyses of nutrient concentration and nutritional value of *A. vaginalis* are within the usual ranges reported for tropical legumes. There are about 650 seeds/g.

Alysicarpus vaginalis (L.) DC. – 1, flowering and fruiting branch; 2, flower; 3, fruits; 4, seed.

Botany Annual or short-lived perennial, erect to prostrate herb with many stems 10–100 cm long emanating from the rootstock. Stem glabrous to pubescent, rooting at the nodes under sustained moist conditions. Leaf unifoliolate; leaflet lanceolate to ovate, 5–65 mm × 3–25 mm, glabrous to puberulous; petiole 4–15 mm long; stipules lanceolate. Flowers about 6 mm long in terminal and leaf-opposed inflorescences up to 13 cm long; corolla orange to purple and very variable. Fruit 12–25 mm long, well exserted from the calyx, puberulent, reticulate, not or slightly constricted between the 4–7 articles which are subcylindrical, 2.5–3 mm long with raised ridges. Seeds dark red, 1–1.5 mm long, copiously produced.

The species is extremely variable in habit, leaf shape and flower colour. Annual specimens with lax inflorescences have been distinguished as *A. ovalifolius* (Schum.) Leonard in West Africa. Distinction below the species level seems more appropriate.

Ecology *A. vaginalis* grows on a wide range of soil types, from coraline sands to clays, but prefers lighter soils. It has been collected from very acid ($pH(H_2O)$ 4.5) to neutral soils. The species usually occurs in seasonally dry climates with total annual rainfall of between 700 and 1700 mm. It does not tolerate waterlogging and good drainage is essential. The species is a common weed of lawns throughout the Asian region and so appears adapted to frequent defoliation and grazing. It is in these situations that the species perennates, whereas in the seasonally dry climates it usually behaves as an annual. Stands in northern Australia are variable between seasons and this can be attributed in part to the species behaving as an annual in this environment and to the high proportion of hard seed.

Agronomy Propagation is by seed, which usually has a high percentage of hard seed. Scarification is then required for immediate germination. Sowing rates of 2–4 kg/ha should be adequate, although in the United States, where it is used as hay crop, rates of up to 16 kg/ha are recommended. Rhizobia requirements are non-specific so inoculation prior to sowing is unnecessary.

It is susceptible to root-knot nematodes (*Meloidogyne* spp.) so may sometimes be restricted to heavier soils where nematodes are less of a problem. On soils with high populations of nematodes, yields decline after the first year. Germplasm has not been evaluated for resistance to nematodes.

A. vaginalis is palatable to livestock and is usually grazed directly, but it can be made into hay. Al-

though it will persist on soils of low fertility, productivity in northern Australia has been markedly improved by the addition of P. When grown in pure swards, DM yields are typically 4–6 t/ha.

Genetic resources and breeding Germplasm collections are maintained by ATFGRC (CSIRO, Australia) and CIAT (Colombia).
No breeding programmes are in progress or have been attempted. The extreme variation in plant morphology and in climatic and edaphic origin has enabled the selection of accessions for advanced evaluation from wild collections.

Prospects *A. vaginalis* is a useful forage legume in parts of the tropics and subtropics both for hay and as a component in permanent pastures. The wide range of genetic material available should enable further development of the species within South-East Asia.

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R.A. Halim & B.C. Pengelly

Andropogon gayanus Kunth

Enum. Pl. 1: 491 (1833).
GRAMINEAE
$2n$ = 20 (var. *tridentatus* (Hochst.) Hack.), 40 (other varieties)

Synonyms *Andropogon bisquamulatus* Hochst. (1842), *A. squamulatus* Hochst. (1842), *A. tridentatus* Hochst. (1842).

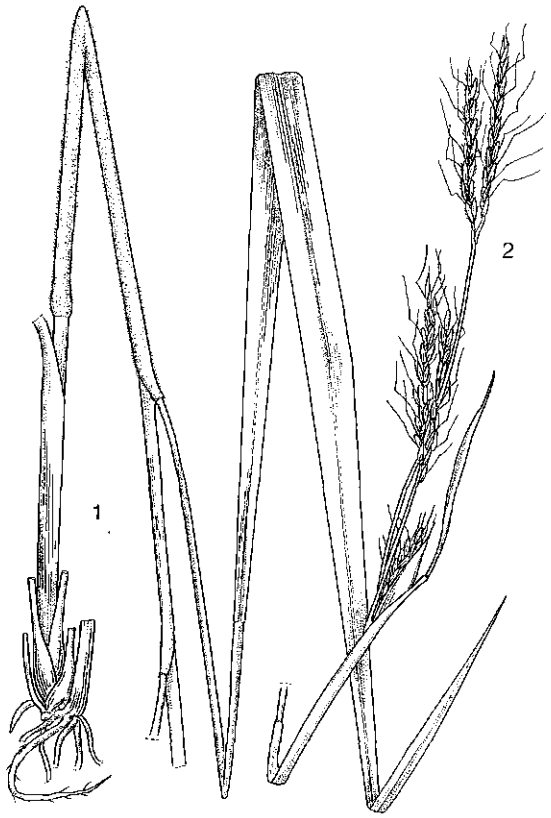
Vernacular names Gamba grass (En). Philippines: batag (Tagalog), batad (Bikol), bukakau (Ilokano). Thailand: ya kumba. Vietnam: hung th'ao.

Origin and geographic distribution Gamba grass originates in Africa where it extends throughout the tropical region from 15°N to almost 25°S. Var. *bisquamulatus* (Hochst.) Hack., which is of particular interest as a forage, only occurs as an important component of fire-climax savanna vegetation north of the equator from Senegal to Sudan in regions with annual rainfall of between 400–1500 mm. Commercial or semi-commercial gamba grass cultivars or lines have spread to most tropical regions of the world, particularly in tropical America.

Uses The main use of gamba grass is as forage in permanent pastures grazed by ruminants. The stems are used for thatching, and when flattened, for coarse matting.

Properties Gamba grass provides a palatable forage when young but feeding value declines rapidly with forage age and a decreasing leaf/stem ratio. Nitrogen concentrations range from 0.5–2%, and in vitro DM digestibilities from 40–55%. Mineral contents are low (0.08–0.14% P and 0.27–0.39% Ca). Seed of commercial quality contains 60–120 viable seeds/g.

Botany An erect, coarse, and tussock-forming, perennial bunch grass with short rhizomes and stems 1–3 m high. Root system consists of fibrous, horizontally growing roots, vertical roots penetrating as deep as 2–3 m and strong cord roots containing starch granules. Leaf-sheath up to 20 cm long, densely hairy at base; leaf-blade linear-lanceolate, up to 100 cm × 4–30 mm, acute, usually narrowed to the prominent midrib at the base to form a pseudopetiole; pubescent on both sides, particularly when young. Inflorescence consists of paired racemes, 4–9 cm long, bearing about 17 spikelet pairs; sessile spikelet up to 8 mm long, with a long (10–30 mm) conspicuous awn; pedicelled spikelet 5–8 mm long, hairy (var. *bisquamulatus*), with a short (1–10 mm) awn; each spikelet with 2 florets, but only upper floret of sessile spike-



Andropogon gayanus Kunth – 1, plant part with stem and leaf; 2, flowering stem.

let is bisexual and fertile. Caryopsis oblong, planoconvex, 3 mm × 0.75 mm, purple or hyaline (var. *bisquamulatus*). Germination of fresh seed is often reduced by dormancy, but under appropriate storage conditions, improves within nine months after harvest. Initial growth is slow but once established, the grass is very competitive and, despite its erect growth habit, it may consequently affect persistence of associated legumes. It has a short-day flowering response with a critical photoperiod of 12–14 hours.

In *A. gayanus* four botanical varieties are distinguished by morphological and ecological characteristics. Of these, the most important one as a forage is var. *bisquamulatus*. Most *A. gayanus* literature refers to this variety, with the possible exception of cultivar 'Kent' in northern Australia. All commercial cultivars released in tropical America belong to var. *bisquamulatus;* they are derived from accession CIAT 621, an introduction from Shika, Nigeria.

Ecology Gamba grass is best adapted to the sub-humid tropics with an annual rainfall between 800–1500 mm. It still grows well in environments with annual rainfall up to 2500 mm with a marked dry season. Due to its deep rooting, it is remarkably drought-tolerant and survives up to 6 dry months. It is also tolerant of fire. It is adapted to a wide range of soils, but grows best on those that are medium-textured. It has low nutrient requirements and exhibits excellent growth on acid, highly Al-saturated oxisols and ultisols of low fertility, including low available P.

Agronomy Gamba grass is established by drilling or broadcasting viable pure seed at a rate of 0.75–1.25 kg/ha (equivalent to 10–15 kg/ha of average-quality commercial seed). Seed should not be sown immediately after it is harvested, as dormancy will result in poor establishment. If the seed-bed is not too fine, adequate plant populations can be obtained even by surface-sowing. Fertilization with P and K is generally necessary for establishment on low-fertility soils. Newly sown gamba grass pastures are quite susceptible to weed infestation because of slow initial growth.

Gamba grass can be successfully associated with legumes of creeping, climbing, semi-erect to erect growth habit such as *Centrosema* spp., *Pueraria phaseoloides* (Roxb.) Benth. or *Stylosanthes* spp. The grass requires a grazing management which prevents it from becoming mature and stemmy (reduced quality), and, in mixtures with legumes, from becoming too vigorous and too tall (increased competition affecting legume persistence). Rotational grazing at appropriately high stocking rates is recommended. Although its soil-fertility requirements are low, gamba grass responds to fertilization with N, P, and K.

The major pest problem of gamba grass, which is restricted to tropical America, is leaf-cutting ants of the genera *Atta* and *Acromyrmex*. Not only can they completely destroy a pasture in the seedling stage, but they can also severely affect the persistence of an established pasture.

Gamba grass is usually harvested by grazing animals but can be used to make hay. Depending on soil fertility, moisture and cutting regimes, it produces DM yields ranging from 1–18 t/ha per year. Under favourable conditions, however, 12-week DM yields as high as 5–15 t/ha are possible. Gamba grass is a prolific seeder with potential pure seed yields as high as 350 kg/ha. Animal production from pure gamba grass pastures is low in savanna climates (90–120 kg liveweight gain per head per year) because of liveweight losses during the dry season; by introducing a legume, annual weight

gains of about 150 kg per head can be achieved.

Genetic resources and breeding There is considerable variation within the gamba grass cultivars. As the grass reproduces sexually by cross-pollination, there is a continuous recombination of genes. Additional variability within var. *bisquamulatus* seems to be adequately represented in the major germplasm collections of tropical forage grasses at CIAT (Colombia) and ATFGRC (CSIRO, Australia). Several exploratory breeding efforts aimed at improving gamba grass cultivars are under way in Colombia and Brazil.

Prospects Because of its adaptation to acid, low-fertility soils, to burning and drought, and also its high productivity, gamba grass is likely to continue playing an important role in pasture development in low-input systems of the subhumid tropics characterized by acid soils and savanna climate. In more humid environments, other grasses (such as *Brachiaria* spp.) seem to have a comparative advantage.

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R. Schultze-Kraft

Arachis glabrata Benth.

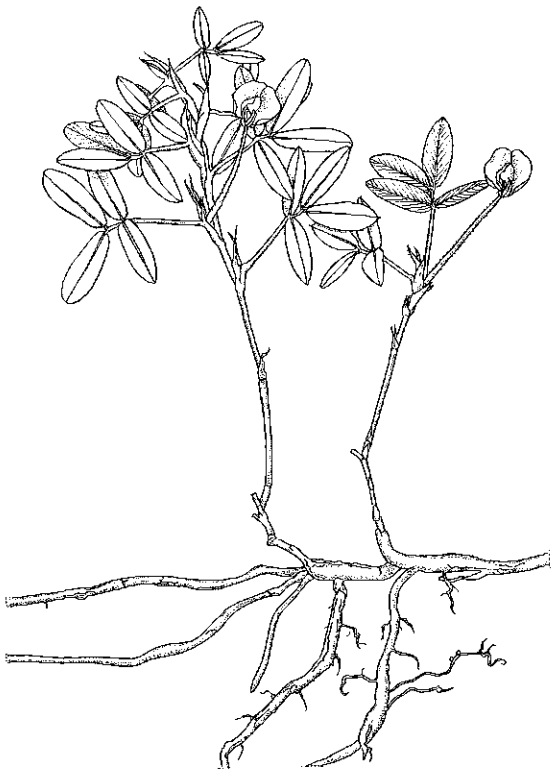
Linn. Soc. London, Trans. Bot. 18: 159 (1841).
LEGUMINOSAE
$2n = 40$ (tetraploid)
Synonyms *Arachis prostrata* Benth. (1841).
Vernacular names Rhizoma peanut (Am).

Origin and geographic distribution *A. glabrata* and its near relatives are native to Brazil, Argentina and Paraguay in a large triangular area between 13°S and 28°S. Over the last 50 years, various sets of the group have been sent to Australia and the United States, and more recently to India, Thailand, Malaysia and Indonesia.

Uses Although *A. glabrata* is primarily used as a high quality forage legume for intensively grazed pastures on infertile, acid soils, it also has potential for soil conservation and as an ornamental. It has proven useful for hay production in Florida, and is showing promise under coconuts in Indonesia.

Properties In the United States, in vitro organic matter digestibility (IVOMD) values ranging from 45–68%, and N concentrations from 1.6–2.9%, have been measured in DM from stands cut twice a year. Up to 74% IVOMD and 3.5% N have been measured from stands cut every two weeks. In Australia, IVOMD of 6-week-old regrowth of seven accessions varied from 70–77% with N varying from 2.5–3.5%. Phosphorous levels in the DM largely reflect soil P levels, and have been measured from 0.15% in *A. glabrata* growing in extremely infertile soils to 0.52% in well-fertilized soils.

Description Herbaceous perennial with erect to decumbent unbranched, hollow above-ground stems 5–35 cm long, 2–3 mm thick, arising from a mat of rhizomes which range in thickness from 3–5(–10) mm. Rhizomes which form a dense mat in the top 5 cm of soil arise from the deep, woody taproot; roots covered with a multitude of small, oblate nodules. Leaf glabrous to sparsely pubes-



Arachis glabrata Benth. – habit flowering plant with rhizomes.

cent, tetrafoliolate; leaflet ranging from linear-lanceolate to oblanceolate, obovate or cuneate up to 4 cm × 2 cm; apex acute to mucronate, base mostly obtuse; petiole grooved, up to 7.5 cm long, 1–2 mm diameter with pulvinus 10–15 mm above axil; stipules linear-lanceolate, falcate, up to 3 cm long, adnate to the petiole and membranous below the pulvinus; petiolule about 1 mm and rachis 10–15 mm long. Flowers sessile, axillary; hypanthium filiform, tubular, up to 10 cm long, pilose, containing the ovary at its base; standard more or less orbicular, 15–25 mm wide, yellow, soft orange to brilliant orange without red veins on back. Fruit set geocarpic, but usually scarce; fruit ovoid ca. 10 mm × 5–6 mm. Seeds ovoid, whitish.

Growth and development Because seed set is rare, *A. glabrata* is usually propagated from rhizomes. With adequate temperature and moisture, shoots usually emerge 2–3 weeks after planting; dense swards develop as rhizomes form and extend the margins of the stand at up to 2 m per year in the absence of competition, or 5–30 cm per year with grass competition. Accessions differ in rate of spread. Despite often dense flowering, few seeds are set, except in some accessions prior to dense sward development. Seedlings are usually quite large before they form rhizomes.

Other botanical information Although not validly published according to the International Code of Botanical Nomenclature, there is a system of classification in common use which divides the genus *Arachis* L. into a number of sub-generic sections and series, based largely on the diversity of growth habits within the genus. Section *Rhizomatosae* Krap. & Greg. (nom. nud.) which comprises the rhizomatous types is divided into series *Prorhizomatosae* Krap. & Greg. (nom. nud.) and *Eurhizomatosae* Krap. & Greg. (nom. nud.). The former is a group of delicate diploids, the latter is a group of more robust tetraploids of which *A. glabrata* is a member. In the absence of current description, it is not clear which of the 100 extant representatives of the *Eurhizomatosae* actually belong to *A. glabrata*. The foregoing description of *A. glabrata* was drawn from a diverse set of *Eurhizomatosae*. Four cultivars of *A. glabrata* have been released in Florida: 'Arb', 'Arblick', 'Florigraze' and 'Arbrook'. 'Arb' and 'Arblick' were selected initially, based on productivity and spreading ability respectively; 'Florigraze' was selected because it combined both characteristics, and 'Arbrook', the most recent release, because it is more drought-tolerant than 'Florigraze' but is of similar productivity. One accession known as the Maiwa peanut (probably the Australian accession CPI 12121) has persisted well in Indonesia.

Ecology *A. glabrata* is productive from about latitudes 30°N and °S to near the equator. It has persisted in areas receiving rainfall as low as 750 mm per year but is probably best suited to areas receiving 1000–2000 mm. It grows successfully on soils with textures ranging from sands to clays provided they are well-drained. While apparently preferring acid soils, it has produced good yields on neutral to slightly alkaline soils. It grows well on soils low in P. Unlike many tropical legumes, *A. glabrata* can compete successfully with sward-forming grasses such as bahia grass (*Paspalum notatum* Flueggé), narrowleaf carpet grass (*Axonopus affinis* A. Chase), pangola grass (*Digitaria eriantha* Steudel) and bermuda grass (*Cynodon dactylon* (L.) Pers.).

Moderate to heavy grazing pressures are necessary for best performance. It grows best when mean monthly temperatures are above about 20°C. Although tops are cut by frost, plants regrow vigorously with the onset of warmth and moisture. During very dry conditions, top growth may die off, but rhizomes mostly survive, providing a nucleus for recovery.

Propagation and planting *A. glabrata* is best propagated from rhizomes. While pieces of rhizome as short as 5 cm may strike, it is generally considered best to plant 30 cm square pieces of rhizome mat about 1.8 m apart. Alternatively, the rhizomes can be teased out, broadcast over the soil surface and disked in. In either case, it is best to plant about 3.5 m^3 of rhizomes/ha at a depth of 3 cm in clay soils to 6.5 cm in coarse sands. It is generally not necessary to inoculate rhizomes. A clean seed-bed is preferable, to minimize competition for the developing plants. Ideally, rhizomes should be produced in sandy soils for ease of digging. Planting appears to be most successful when rhizomes are dormant.

Husbandry Weeds should be controlled during establishment. This can be achieved through manual weeding or through use of pre- and post-emergence herbicides such as trifluralin or vernolate, post-emergence applications of alachlor and dinoseb, and routine applications of bentazon or 2,4-DB for broadleaf weed control, and sethoxydim and fluazifopbutyl for grass control, as required. Mowing reduces shading from taller weeds and promotes spread of *A. glabrata*. A dressing of P fertilizer may be advisable if soils are extremely low in P. However, liming is rarely necessary.

Diseases and pests *A. glabrata* is rarely trou-

bled by insects or disease. It is immune to the common groundnut leaf-spots caused by *Cercospora arachidicola* and *Cercosporidium personatum*, and most accessions are immune to groundnut rust (*Puccinia arachidis*). Although susceptible to other leaf-spots caused by *Phyllosticta* and *Stemphylium*, and to white mould (*Sclerotium rolfsii*), these diseases have not caused serious long-term damage. Resistance to root-knot nematodes (*Meloidogyne* spp.) has been recognized in a number of studies.

Harvesting Low-growing accessions are best used in grazed pastures. Taller-growing accessions also lend themselves to hay-making or cut-and-carry systems.

Yield Dry matter yields of up to 16 t/ha have been measured in Florida and up to 12 t/ha in Australia. Yields of only 5 t/ha have been obtained in Malaysia and Indonesia, but these may have been influenced by shading from rubber and coconuts.

Genetic resources Large collections are held by various germplasm banks at Texas A & M University (Stephenville, United States) and North Carolina State University (Raleigh, United States), at CENARGEN/EMBRAPA (Brasília, Brazil) and at ICRISAT (Patancheru, India). A more limited set is held at ATFGRC (CSIRO, Australia) and QDPI (Gympie, Queensland, Australia).

Breeding 'Florigraze' is the result of a chance intra-specific cross in Florida. While *A. glabrata* is compatible with species from sections *Arachis* and *Erectoides* Krap. & Greg. (nom. nud.), the resultant hybrids are infertile. An intersectional rhizomatous hybrid, more productive than either parent, has been developed in Tamil Nadu, India.

Prospects *A. glabrata* is a persistent, very productive, high-quality forage, well-adapted to the often infertile, acid soils and heavy grazing pressures encountered in the humid and sub-humid tropics and subtropics. The main constraint to evaluation and adoption is the need to propagate from rhizomes. With the development of mechanical methods or with the availability of manual labour for propagation, *A. glabrata* may prove to be one of the more useful forage legumes in South-East Asia.

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B.G. Cook

Arachis pintoi Krap. & Greg., nom. nud.

In: Wilson, C.T. (Editor): Peanuts – culture and uses: 121 (1973).

LEGUMINOSAE

$2n = 20$

Vernacular names Pinto peanut (En). Thailand: thua lisong tao.

Origin and geographic distribution Pinto peanut originates from the valleys of the Jequitinhonha, Sao Francisco and Tocantins rivers in central Brazil. Since its collection in 1954, it has been distributed to Argentina, Australia, Colombia and the United States, and more recently to many countries in South-East Asia, Central America and the Pacific.

Uses Because of its high degree of shade tolerance, pinto peanut is finding application as a pasture legume in tree plantations, but also as a ground cover in plantations from which grazing animals must be excluded. It is showing potential in intensively managed grass/legume pastures on cleared land.

Properties In vitro digestibility of pinto peanut varies from 60–76%, N concentrations from 2.5–3.0% and P concentrations from 0.18–0.37%. It is well accepted by cattle at all stages of growth. There are 6–8 seeds in pod/g.

Description A stoloniferous, perennial herb developing a strong taproot on the older crowns and large numbers of small oblate nodules, mostly to 2 mm diameter, on both taproot and subsidiary roots. Stems initially prostrate, becoming ascendant to 20 cm height in dense swards. Leaves tetrafoliolate, margins entire, ciliate; distal leaflets obovate and proximal leaflets oblong-obovate, obtuse at the apex and slightly cordate at the base; leaflets may attain 4.5 cm × 3.5 cm, but are smaller in regularly defoliated stands; the upper surface of leaflets is glabrous and a darker green than the

Arachis pintoi Krap. & Greg., nom. nud. – 1, habit flowering plant; 2, fruits.

pubescent lower surface. Flowers emerge individually from short axillary racemes and are similar in shape to commercial groundnut (*A. hypogaea* L.), but smaller (standard 12–17 mm wide) and yellow. The terminal pod on the peg usually contains a single seed but may contain 2, while pods formed along the peg contain only one. Pod moderately reticulated, 10–14 mm × 6–8 mm, containing mostly a single seed. Seed light-brown, 8–11 mm × 4–6 mm, weighing 0.11–0.20 g.

Growth and development Seedlings of pinto peanut develop quickly following epigeal germination, and with good growing conditions and several plants per square metre, complete ground cover can be achieved by a network of stolons in less than six months. Flowering commences three to four weeks after emergence and continues through the growing season, appearing to intensify following rain or irrigation. The ovary is borne on a gynophore or peg, which elongates to up to 27 cm after pollination and pushes the ovary up to 7 cm depth into the soil. Seed remains viable in the ground for more than one season.

Other botanical information The genus *Arachis* L. has been divided into a number of invalidly published sections based on growth form and gross morphology. *A. pintoi* is one of two species in the section *Caulorhizae* Krap. & Greg., (nom. nud.), a section defined by the possession of stolons. The original line collected by G.C.P. Pinto near the mouth of the Jequitinhonha River in 1954 and variously catalogued as GK 12787 (Collection Number), PI 338314 (United States), CPI 58113 (Australia) and CIAT 17434 (Colombia), has been released as cultivar 'Amarillo' in Australia. More recent collections of the species differ slightly from the original in leaf shape and size, and internode length.

Ecology The climate in central Brazil is humid tropical, with some 1800–2000 mm of rain falling in the October–May wet season, and an additional 200 mm in the June–September dry season. Pinto peanut has been mostly collected in red, sandy-loam alluviums, apparently growing best in low areas which are wet to flooded during the wet season. Soils are generally of low fertility with high Al content. Native vegetation is low forest with a fairly dense canopy. In cultivation, pinto peanut has proven adaptable to soils ranging from sand to clay texture, with low to neutral pH and low to high fertility. It failed to persist on seasonally waterlogged, poorly structured clays. In pot experiments, it has shown a tolerance of soil Mn at levels detrimental to many other legumes, a fair tolerance of soil Al, and a low tolerance of salinity. It is capable of growing under shaded conditions, often appearing more vigorous in shade than in full sunlight.

Propagation and planting Fresh seed of pinto peanut has a high level of dormancy which may be reduced by drying the seed at 35–40°C for 10 days. Seed should be inoculated with a specific strain of *Bradyrhizobium*, which is different from that used on commercial groundnuts. A well-prepared seed-bed is desirable but not essential. Seed should be sown 2–6 cm deep at 10–15 kg seed in pod/ha, followed by rolling. If seed is not available, pinto peanut is readily propagated from cuttings.

Husbandry Pinto peanut is tolerant of and increases under heavy grazing, but, under light grazing, is not shaded out by taller grasses. It does not require highly fertile soil, but on an oxisol in Colombia it responded to additions of P, K, Ca and Mg.

Diseases and pests The only information available relates to 'Amarillo', which is resistant to the

major groundnut diseases, rust (*Puccinia arachidis*) and leaf-spot (*Mycosphaerella* spp.). Other fungi (*Phomopsis* sp., *Cylindrocladium* sp. and *Colletotrichum gloeosporioides*) have been isolated from leaf-spots, the latter also being associated with black stem lesions in Colombia. None of these diseases causes long-term or serious damage. 'Amarillo' has moderate to high resistance to the various root-knot nematodes (*Meloidogyne* spp.) but is susceptible to the root-lesion nematode (*Pratylenchus brachyurus*). Leaves of some plants have an apparently non-pathogenic variegation. Rats and mice are attracted to the nuts and can be a problem in stands of pinto peanut.

Harvesting Being a low-growing, ground cover species, pinto peanut is more readily grazed than hand-harvested. Seed should be dried in the sun or in an artificial drier and stored under cool conditions with low humidity.

Yield In Colombia, pinto peanut had an annual DM production ranging from 5 t/ha growing with *Brachiaria dictyoneura* (Fig. & De Not.) Stapf, which produced 20 t/ha, to 10 t/ha when grown with *B. ruziziensis* Germain & Evrard, which produced 11 t/ha. It has yielded 5 t/ha of DM in pure stands under 30% shade in Indonesia and 3 t/ha in full sunlight in Malaysia. Yields of seed in pod from 1–2 t/ha have been recorded.

Genetic resources A number of accessions have been collected, most of which are held by CENARGEN/EMBRAPA in Brazil. A more limited range is held at Texas A & M University (Stephenville, United States), CIAT (Colombia), and ATFGRC (CSIRO, Australia).

Breeding Breeding mechanisms are well understood, since *Arachis* wild types have largely been collected as a source of genetic material in groundnut improvement programmes, but there are no breeding programmes.

Prospects Pinto peanut has only been assessed as a forage over the last 10 years. At this stage it appears to have great potential in the wet tropics, especially in more shaded situations under plantation crops.

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B.G. Cook

Arundinaria pusilla A. Chevalier & A. Camus

Bull. Mus. Hist. Nat. Paris 27: 450 (1921).

GRAMINEAE

$2n$ = unknown

Vernacular names Bamboo grass (En). Philippines: utod (Igorot). Cambodia: rüssèi préich. Laos: ph'ek. Thailand: ya-phek, ya-phet. Vietnam: le, truc th'ao.

Origin and geographic distribution *A. pusilla* occurs in South-East Asia, particularly between latitudes 13–17°N in Thailand and Indo-China.

Uses *A. pusilla* is primarily used for traditional grazing of village cattle and buffaloes, particularly on new growth at the onset of the rainy season.

Properties Leaves are palatable but stems rapidly become woody and unacceptable to livestock. Leaves collected at the beginning of the rainy season contain up to 1.7% N with 52% organic matter digestibility. The average dry matter intake by sheep is 620 g/head per day. When mixed with *Stylosanthes hamata* (L.) Taub. cultivar 'Verano' and *Arundinaria ciliata* A. Camus, it can produce enough feed to support cattle at 1.2–1.8 animals per ha throughout the dry season of north-eastern Thailand.

Botany A shallow rooting, erect, perennial bamboo with short, strong woody rhizomes; leafy stems 0.5(–1.5) m tall and up to 8 mm diameter, branching at the nodes. Leaf-blade 8–14 cm × 1 cm, contracted into a short stalk at the junction with the sheath, pubescent, acuminate at the top. Flowering stems 15–75 cm long, often fascicled on the rhi-

Arundinaria pusilla A. Chevalier & A. Camus – 1, habit of plant with rhizome; 2, leafy stem; 3, part of flowering stem.

zome clumps of burned plants, usually without leaves. Inflorescence narrow, consisting of 2–8 groups of 1–5 spikelets in the axil of a glume-like bract or sometimes on a short stalk. Spikelets 3–4 cm long with 7–9 florets, the lowest 3–5 bisexual, the upper ones male, the terminal one sterile; styles 3, stamens 6. Little or no seed is produced. In Thailand, it flowers in February and March.

Ecology *A. pusilla* is adapted to warm environments with a short wet and a long dry season at altitudes from sea-level to 1500 m. It tolerates moderate shade but is intolerant of waterlogging. It is usually found in *Dipterocarpus* forests, growing as a lower canopy, on moderately acid upland soils.

Agronomy *A. pusilla* spreads naturally by short rhizomes, but can be propagated by dividing clumps of roots and stubble, or by stem cuttings. Light grazing is recommended as it is intolerant of heavy grazing. It is not used in cut-and-carry systems and is not suitable for making hay or silage. Edible DM yields range between 0.8 and 2.5 t/ha per year.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects *A. pusilla* is usually not cultivated and its use is limited to grazing. Its value increases when grown with suitable legumes.

Literature |1| Camus, E.G. & A., 1923. Graminées. In: Lecomte, H. & Gagnepain, F. (Editors): Flore générale de L'Indo-Chine. Tome 7(5). pp. 585–587. |2| Gutteridge, R.C., Shelton, H.M., Wilaipon, B. & Humphreys, L.R., 1979. A comparison of cattle liveweight gains on native and improved pastures in northeast Thailand. Annual Report Faculty of Agriculture. Khonkaen University, Thailand. |3| Manidool, C., 1989. Natural grassland and native grasses of Thailand [in Thai]. Technical Bulletin No 1301–26–32. Division of Animal Nutrition, Department of Livestock Development, Bangkok. 45 pp. |4| Manidool, C. & Tor Sakool, P., 1971. Digestibility of pek grass (Arundinaria pusilla). Thai Journal of Agricultural Science 4: 119–124. |5| Robertson, A.D. & Humphreys, L.R., 1979. Effects of frequency of heavy grazing and P supply on Arundinaria ciliata association oversown with Stylosanthes humilis. Thai Journal of Agricultural Science 9: 131–138.

C. Manidool

Asystasia gangetica (L.) T. Anderson

Thwaites, Enum. pl. zeyl. 3: 235 (1860).

ACANTHACEAE

$2n$ = unknown

Synonyms *Justicia gangetica* L. (1759), *Asystasia coromandeliana* Nees (1832).

Vernacular names Malaysia: rumput bunga putih, rumput hantu, rumput nyonya. Philippines: asistasiya (Tagalog), bulak-bulak (Subanun). Thailand: baya, yaya.

Origin and geographic distribution *A. gangetica* is indigenous in tropical Africa and Asia, but has been distributed pantropically. In South-East Asia it is recorded from Malaysia, Thailand, Indonesia and the Philippines.

Uses *A. gangetica* provides excellent feed for cattle, goats and sheep. In cocoa, oil palm, rubber, vegetables and field crops it is not regarded as useful, though its ground cover checks erosion and prevents the infestation by other weeds such as *Mimosa pigra* L. and *Imperata cylindrica* (L.) Raeuschel which are considered to be more noxious. It is liked as a naturally occurring plantation cover in some orchards because the bees which pol-

linate the flowers of fruit trees such as starfruit or durian, are attracted to the orchard by the flowers of *A. gangetica.*

A. gangetica is also used as a village medicine. Chinese medicine shops sell it as 'kaw kua chai'. In the Moluccas, its juice, together with lime and onion juice, is recommended for dry coughs with an irritated throat and discomfort in the chest. Young shoots are used as a food ('ulam') by farmers in south-western Johore.

Properties *A. gangetica* has high concentrations of N, P, K, Mg and Cu in its leaves and exceptionally high concentrations of K in its stems and roots. The nutrient concentrations in leaves and young stems, expressed on a dry matter basis, typically range from 0.30–0.42% P, 4.56–5.83% K, 0.98–1.08% Mg. Large accumulations of Cu (12–19 mg/kg) occur. Potassium concentrations of 3.6% and 1.6% have been measured in stems and roots respectively. In vitro DM digestibilities of 3, 6, 9, 12 and 16 weeks old top growth were 71%, 71%, 69%, 61% and 61% respectively. Leaf digestibility increased from 69–74% under plantation crops as illumination declined from 54–7% full sunlight.

Asystasia gangetica (L.) T. Anderson – 1, flowering and fruiting branch; 2, flower, cut lengthwise; 3, ripe fruit.

Botany An erect, ascending or clambering herb, 0.3–1.25 m high, with quadrangular pilose stem. Leaf ovate to deltoid, 3–7.5 cm × 1.5–5 cm, base obtuse to truncate, apex acuminate, glabrate to sparingly pilose, especially on the veins, numerous bar-like cystoliths visible on the upper surface; petiole 1–3 cm long. Inflorescences in terminal racemes, up to 16 cm long, with flowers directed to one side only; flowers on short pedicels, white to yellow, white with purplish throat, or violet; calyx 5-lobed, lobes lanceolate 5–7 mm long; corolla funnelform, up to 4 cm long, with 5 semiorbicular lobes ca. 1 cm wide; stamens 4; stigma 2-lobed. Fruit an oblongoid capsule, up to 13 mm × 2 mm. Seeds 2–4, ovoid, flat, ca. 1 mm × 0.75 mm.

Seeds germinate readily, with a germination percentage of up to 90%. The period from seedling emergence to seed dispersal can be as early as 8 weeks in open areas but, in partially shaded areas, this can take 2 weeks longer.

It takes one month from floral initiation to seed dispersal. The seeds are thrown as far as 6 m by an explosive mechanism on hot afternoons.

Ecology *A. gangetica* is found along roadsides and riverbanks, in semi-waterlogged areas as well as well drained cultivated areas. In 1976 it became very widespread in oil palm plantations in Peninsular Malaysia and by 1983 it had infested large tracts of pineapple land on peat soils in the south-eastern region of Johore. It is a shade-loving plant and optimum photosynthesis occurs between $\frac{1}{8}$ to $\frac{1}{2}$ full sunlight. With no weeding, its proportion in the undergrowth of young oil palm plantation increased in a period of 2 years from 25% to 84%. It grows, even if slowly, under a closed canopy of oil palm with less than 10% full sunlight. However, in areas with a dry season of 4 months or more, it may not survive. It thrives on sedentary soils, coastal alluvium, peat soils with 85% organic matter and pH(H_2O) 3.5–4.5, sandy loams and clays.

Agronomy *A. gangetica* can be propagated from seeds or by stem cuttings with 1, 2 or 3 nodes. Single node cuttings buried in soil produce flowers and fruits within 6 weeks. It is difficult to establish in unshaded open areas.

The high palatability and digestibility of *A. gangetica* make it attractive to grazing animals. Its agressiveness, high uptake of soil nutrients and ability to smother other species have characterized it as a weed in plantation management. However, when grazing animals are introduced, it is a useful plant. Villagers hand harvest its forage to

supplement the forage which they feed to their animals at night. Good cattle production under oil palm from native forages mixed with *A. gangetica* can be achieved within the range of 110–135 kg/ha per year, equivalent to 270–310 g/head per day.
Care is needed when grazing with sheep, since if they graze for extended periods on swards containing more than 60% *A. gangetica* they can accumulate toxic levels of over 1000 mg/kg Cu in their liver. Excessive consumption by sheep can also result in bloat.
No major diseases or pests have been observed on *A. gangetica*.
A. gangetica is harvested by grazing animals or by cutting for stall feeding. Frequent cutting induces early dieback because the stems have long internodes and growing points high up in the canopy. Low grazing pressures or long intervals between grazing allow the plant to flower and set seed. It is usually consumed fresh by animals but it can be conserved as hay if properly dried. Pure swards are rarely found in full sunlight. Under heavy shade (6–16% full sunlight) DM yields under cutting from 2–5 t/ha have been recorded, but under a more open canopy of *Leucaena leucocephala* (Lamk) de Wit at 2 m × 1 m spacing, yields between 3.5–8 t/ha were obtained.

Genetic resources and breeding There are no known germplasm collections of *A. gangetica* and no breeding programmes.

Prospects Due to its ability to grow under shade and its high nutritive value, *A. gangetica* is an important forage species in South-East Asia, either when grazed or cut for stall feeding. It could have potential as a substitute for legumes in the production of leaf meal.

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S.A. Lee & C.P. Chen

Axonopus compressus (Swartz) P. Beauv.

Ess. Agrost.: 12, 154, 167 (1812).
GRAMINEAE
$2n = 40$

Synonyms *Milium compressum* Swartz (1788), *Paspalum platicaulon* Poiret (1804), *Anastrophus compressus* Schlechtendal ex Doell. (1877).

Vernacular names Broadleaf carpet grass (En). Indonesia: rumput pahit (Indonesian), papahitan, jukut pahit (Sundanese). Malaysia: rumput parit. Philippines: kulape (Tagalog). Thailand: ya baimaln, ya-malaysia.

Origin and geographic distribution It is native to the southern United States, and from Mexico to Brazil, and has been introduced into many warm countries, including South-East Asia.

Uses Broadleaf carpet grass is used for grazing, especially in plantation crops, particularly coconut. It is also a good lawn grass and can be used for controlling soil erosion. It can be a troublesome weed. Under dense shade in established oil palm and rubber plantations, it is often allowed to grow as a soil cover.

Properties Nitrogen concentrations of broadleaf carpet grass range between 1–2%. It is reported to have an ability to fix atmospheric N through associated micro-organisms.

Botany A perennial, stoloniferous, short spreading grass; stolons often long, branched, rooting at the nodes; culms geniculately ascendent, 20–50 cm tall, solid, laterally compressed. Leaf-sheath strongly compressed, finely hairy along the outer margin, the nodes densely pubescent; ligule very short, fringed with short hairs; leaf-blade lanceolate, flat, 2.5–38 cm × 2.5–16 mm, base broadly rounded, margin ciliate, apex obtuse. Inflorescence compound, 1–2(–8) peduncles exserting from the final sheath, each composed apically of 2 conjugate, one-sided spikes 3–11 cm long, lower down often with a third, rarely a fourth; spikelets oblong, rather acute, 2–3.5 mm × 1–1.25 mm, pale green or purplish tinged, 1-flowered, solitary on alternate sides of rachis and forming two rows, ciliate on the margins; lower glume absent, upper glume and lemmas equalling the spikelet in length. Caryopsis elliptical, 1.25 mm long, dorsally compressed, yellow-brown.
Broadleaf carpet grass flowers all year round, although little seed is produced in some environments. Young plants start growth in a circular patch. If it has no serious competition, the patch may reach a size of up to 1 m in diameter in one

Axonopus compressus (Swartz) P. Beauv. – habit.

season. It often crowds out all other weeds and grasses and forms a dense mat-like cover.

Ecology Broadleaf carpet grass is best adapted to moist warm environments. It is moderately shade tolerant but grows well in full sunlight. It occurs in Indonesia up to 2300 m altitude. It is frequently noted as being one of the most persistent and productive native grasses in plantations and will persist under heavy shade where introduced grasses may not survive. It will not stand waterlogged conditions although it grows on a range of soil types, particularly sandy soils. It is dormant during cool periods.

Agronomy Broadleaf carpet grass is usually vegetatively propagated by planting stolons. When seeded, a seeding rate of 6 kg/ha is recommended. Frequent grazing is preferred, to maintain its palatability and quality. It is encouraged by close grazing, and will oust other grasses. Broadleaf carpet grass is usually grazed by tethered or freely grazing animals; it is rarely used in a cut-and-carry system. When used as a lawn grass, it should be frequently mown. With mixed fertilizer application at 300 kg/ha it has yielded up to 5 t/ha of DM. Under oil palm plantations in Malaysia, yields up to 1 t/ha have been measured. In Brazil, Zebu steers grazing over 672 days achieved an average daily gain of 0.18 kg. *A. compressus* is an alternate host of *Rhizoctonia solani*. In Malaysia the grass as weed is controlled by spraying with 1.1 kg MSMA + 0.6 kg sodium chlorate in 273 l water.

Genetic resources and breeding It is unlikely that any substantial germplasm collections are being maintained.

Prospects Broadleaf carpet grass is a useful forage source for livestock raised under plantation crops, particularly under heavy shade, and it is adapted to extremes in soil types. Studies are warranted to see if its productivity can be improved.

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C. Manidool

Bothriochloa pertusa (L.) A. Camus

Ann. Soc. Linn. Lyon 76: 164 (1931).

GRAMINEAE

$2n = 40$ (tetraploid), 50 (pentaploid), 60 (hexaploid)

Synonyms *Holcus pertusus* L. (1771), *Andropogon pertusus* (L.) Willd. (1806), *Amphilophis pertusa* (L.) Nash ex Stapf (1916).

Vernacular names Indian couch grass, Indian bluegrass, sweet pitted grass (En). Indonesia: suket putihan (Javanese), rebha las-alasan

(Madura). Malaysia: rumput embun. Philippines: salay-parang (Tagalog), salay (Pangasinan). Thailand: ya-hom (central), ya-hangma (northeast). Vietnam: huyêt tha'o lô.

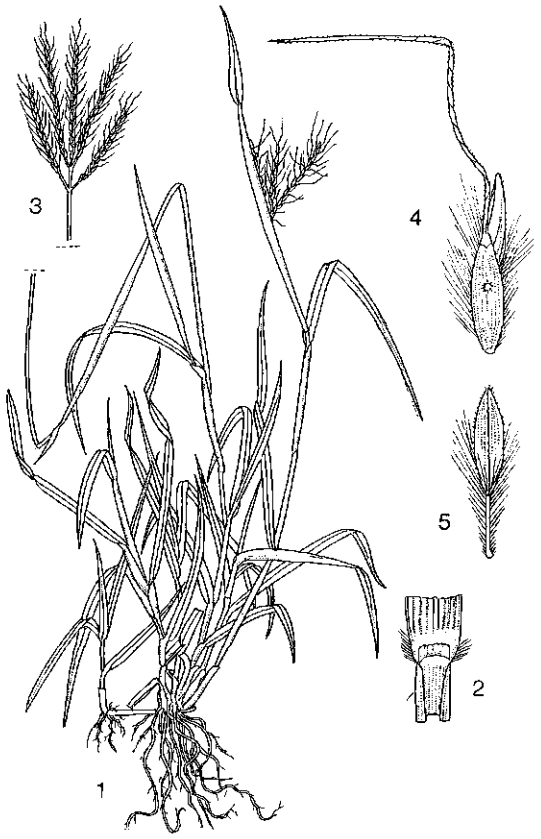
Origin and geographic distribution Indian couch grass is widely distributed in Asia from Arabia to South-East Asia, and is particularly prominent on the Indian subcontinent. It has been introduced to other tropical areas and is now naturalized in tropical America, Australia and on several island groups (e.g. Hawaii).

Uses Indian couch grass is used mainly as a forage for ruminants, but also for soil conservation, revegetating mine sites, lining floodways, lawns, recreation areas and playing fields.

Properties Chemical composition and nutritive value depend upon age and soil fertility. Young green leaves may contain more than 2% N and 0.2% P, and be 70% digestible. These values decrease with age and at the end of the wet season will be considerably lower. Indian couch grass develops a high stem to leaf ratio with age and this reduces both the quality and palatability of herbage. Standing forage in the dry season may contain only 0.5% N, 0.05% P and be 45% digestible. Indian couch grass is moderately palatable as cattle sometimes avoid eating it whilst other grasses are available. It has a strong odour when crushed. There are 650–750 seeds/g.

Botany A low growing, stoloniferous perennial of variable size and growth habit. Stolons root readily at the nodes and produce small tufts of leaves. Culms are smooth, erect or geniculately ascending, up to 60 cm tall and 3 mm in diameter; nodes are prominent and may be glabrous or covered with hairs up to 3 mm long. Leaf linear-acuminate, 5–10(–30) cm × 4–6 mm, bright to dark green, usually glabrous except for a few hairs up to 3 mm long especially in the throat; ligule a shallow membrane surrounded by long ciliate hairs. Inflorescence 3–6 cm long, subdigitate, bearing 3–13 racemes each 2–7 cm long; spikelets in alternate pairs, one sessile, one pedicelled, on a slender rachis; sessile spikelet with a short blunt ciliate-hairy callus, a lower glume with a circular depression (pit) in upper half and upper lemma with a kneed and twisted scaberulous awn 1.5 cm long; pedicelled spikelet usually neuter, pitless. Seed awned, with weak antrorse hairs.

Seeds germinate early in the wet season and vegetative growth continues until soil water is exhausted. Time of flowering varies widely between strains but may commence 3–4 weeks after the start of the wet season and continue until growth ceases. Seed matures in 3–4 weeks. The onset of flowering can be delayed by poor growing conditions and flowering is checked by frost.



Bothriochloa pertusa (L.) A. Camus – 1, flowering plant; 2, ligule; 3, inflorescence; 4, sessile spikelet; 5, pedicelled spikelet.

B. pertusa is morphologically indistinguishable from the mainly African *B. insculpta* (A. Rich.) A. Camus, but they do not interbreed. *B. pertusa* is less robust, more stoloniferous, and bears fewer and shorter racemes. It is also closely related to *B. decipiens* (Hack.) C.E. Hubbard, *B. longifolia* (Hack.) Bor, *B. panormitana* (Parl.) Pilger and *B. radicans* (Lehm.) A. Camus.

Seed of naturalized strains (particularly Bowen strain) is available in northern Australia. Cultivars 'Medway' and 'Dawson' were released in Queensland in 1991. They are later flowering and leafier than the Bowen strain. 'Dawson' is particularly useful as a lawn grass.

Ecology Indian couch grass grows in tropical areas with warm season dominated rainfall of 500–1400 mm per year. It survives in areas which

are subject to frost, although its vigour is reduced, as frost kills the plant tops leaving only the basal parts alive. Indian couch grass hays off rapidly when soil moisture becomes depleted but can withstand moderate drought. Prolonged drought or fire will substantially reduce the basal area of the stand, although regrowth is rapid when growing conditions become favourable. Indian couch grass is found on a wide range of soil types. It is most competitive on infertile to moderately fertile soils. Prolonged waterlogging will kill or reduce its basal area.

Agronomy Indian couch grass can be established vegetatively from runners, but is normally established from seed. Freshly harvested seed is dormant, but dormancy breaks down after 4–8 months storage. It can be established under a variety of conditions, but best results are obtained by sowing on or near the soil surface of a well cultivated seed-bed during the early wet season. Some seed-harvesting ants remove the seed, so early sowing should be avoided where these are present. Seeding rate is 1–3 kg/ha.

Indian couch grass can be used by continuous or rotational grazing, or cutting. It will stand close defoliation and is most prominent in heavily grazed or closely mown areas. It is used in association with legumes, although some problems have been experienced as it may exclude *Stylosanthes hamata* (L.) Taub. and other low-growing legumes. Indian couch grass is usually grown without fertilizers. However, yields can be increased substantially by fertilization as it responds well to both N and P. There are no important diseases or pests although it is attacked by rust. Indian couch grass is harvested by grazing animals but can be made into hay. It produces 1–5 t/ha of dry matter depending on seasonal conditions, soil fertility and associated species.

Genetic resources and breeding There is a wide variation in Indian couch grass in morphological, flowering and agronomic characteristics. Collections, mainly originating from India, are held by ATFGRC (CSIRO, Australia) and the Queensland Department of Primary Industries.

There are no breeding programmes and any improvement will depend on selection from naturally occurring populations. Important objectives for any selection process will be to increase herbage yield, quality and palatability whilst maintaining the adaptability to a range of environments, ability to provide effective soil cover, persistence under heavy grazing and colonizing ability.

Prospects Indian couch grass is an effective colonizing grass which provides good ground cover, reasonable quality herbage, is tolerant of heavy grazing and suited to the drier regions of South-East Asia. It has no rhizomes and is easily killed by cultivation so is unlikely to become a weed in cropping areas.

Literature [1] Bisset, W.J., 1980. Indian bluegrass has special uses. Queensland Agricultural Journal 106: 507–517. [2] de Wet, J.M.J. & Higgins, M.L., 1963. Species relationships within the Bothriochloa pertusa complex. Fyton 20: 205–211. [3] McIvor, J.G., 1984. Phosphorus requirements and responses of tropical pasture species: native and introduced grasses and introduced legumes. Australian Journal of Experimental Agriculture and Animal Husbandry 24: 571–578. [4] Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 230–233. [5] Truong, P.N. & McDowell, M., 1985. Indian bluegrass for soil conservation and land stabilization in Queensland. Journal of Soil Conservation Service of New South Wales 41: 38–44.

J.G. McIvor & S.M. Howden

Brachiaria brizantha (A. Rich.) Stapf

Flora of Trop. Africa 9: 531 (1919).

GRAMINEAE

$2n = 36, 54$

Synonyms *Panicum brizanthum* Hochst. ex A. Rich. (1851).

Vernacular names Palisade grass, palisade signal grass (En). Thailand: ya siknaentontang.

Origin and geographic distribution The origin of *B. brizantha* is Africa where the species has a very wide distribution throughout the wetter tropics. In recent decades, experimental lines and cultivars have been introduced to other parts of the world, including tropical Asia and the Pacific region.

Uses The main use of palisade grass is as forage in permanent pastures for grazing or for cut-and-carry systems. It has also proved useful as grazed ground cover in tree plantations.

Properties Palisade grass provides a more palatable forage than signal grass (*B. decumbens* Stapf) but of similar N concentration (2.5%) and in vitro DM digestibility (75%) in 2-week-old regrowth, falling to 1.0% N and 55% digestibility in 12-week-old regrowth. Like signal grass, *B. brizantha* can cause photosensitization in sheep and goats, but in Brazil, where the grass is widely used in pastures, no photosensitization effects on cattle

have been observed. There are 130–180 seeds/g.

Botany A tufted, prostrate or semi-erect to erect perennial with short rhizomes and stems 30–200 cm tall. Leaf linear to broadly linear, 10–100 cm × 3–20 mm, glabrous or hairy. Inflorescence consisting of 2–16 relatively long racemes (4–20 cm), with spikelets generally in one row; rachis 1 mm wide, usually purple; spikelets elliptic, 4–6 mm long, glabrous or with a few hairs at the tip; lower glume $\frac{1}{3}$ the spikelet length, clasping; upper glume cartilaginous, dully shining; upper lemma granulose.

B. brizantha intergrades with *B. decumbens* and the species are difficult to distinguish. It is, therefore, likely that in the literature the name *B. brizantha* sometimes actually refers to *B. decumbens*, and vice versa. The main difference between the cultivars or lines of *B. brizantha* and *B. decumbens* is in the growth habit: *B. brizantha* is tufted with a rather erect growth whereas *B. decumbens* is low-growing and forms a dense cover. Two cultivars have been released in South America: the best known and most widespread is 'Marandú' (Brazil) whereas 'La Libertad' is a recent Colombian release.

Brachiaria brizantha (A. Rich.) Stapf – habit.

Ecology Like signal grass, palisade grass is well adapted to the humid and sub-humid tropics where it can withstand dry seasons of up to 5 months. It grows well on a range of soils including sandy and acid soils, but it requires more fertile soil than signal grass. It does not tolerate poorly drained soils. Like signal grass, it tolerates light to moderate shade.

Agronomy Although palisade grass can be established by spreading out stolon cuttings, it is mainly sown at rates of 1.5–12 kg/ha, depending on seed quality. Seed is broadcast or drilled 2–4 cm deep into conventionally prepared seed-bed. As germination of fresh palisade grass seed is affected by dormancy (hard-seededness), seed should be scarified with concentrated sulphuric acid, or seed that has been stored for 6–8 months should be used.

Palisade grass grows quickly, and 3–5 months after sowing, it can be ready for a first, light grazing. It responds well to fertilization with N, but also with P and K.

Although experience regarding persistence of legumes in association with palisade grass is limited, the less competitive growth habit of this grass, as compared with signal grass, suggests that it can be grown with a range of legumes representing distinct growth habits, such as *Desmodium heterocarpon* (L.) DC. ssp. *ovalifolium* (Prain) Ohashi (prostrate-stoloniferous), *Centrosema pubescens* Benth. or *Pueraria phaseoloides* (Roxb.) Benth. (trailing-climbing), *Stylosanthes guianensis* (Aublet) Swartz (semi-erect herb/subshrub) and *Leucaena leucocephala* (Lamk) de Wit (shrub/tree).

Like signal grass, palisade grass pastures can be severely affected in their productivity and persistence by spittlebug (mainly the genera *Aeneolamia, Deois* and *Zulia* in the *Cercopidae* family). This pest, however, seems to be restricted to tropical America. The most wide-spread cultivar, 'Marandú', is spittlebug-resistant.

Palisade grass can be continuously or rotationally grazed down to a height of 20–30 cm. It is harvested by grazing animals or is mown and fed fresh to animals in cut-and-carry systems. Dry matter yields of palisade grass vary, according to growth conditions, from 8–20 t/ha per year. At stocking rates of 1.5 steers/ha during the dry season and 2.5 steers/ha during the rainy season, annual liveweight gains can range between 400–500 kg/ha. It flowers and sets seed abundantly; a first seed crop is possible 6–8 months after sowing. Depending on

environmental conditions, up to 3 seed crops per year can be obtained with a total seed yield of 100–500 kg/ha.

Genetic resources and breeding Palisade grass, particularly the material from East Africa, is well represented in the major germplasm collections of tropical forage grasses such as CIAT (Colombia). At CIAT, parallel to evaluation and selection within the available large *B. brizantha*/*B. decumbens* gene pool, a breeding programme is in progress aiming at cultivars that combine spittlebug resistance, low soil-fertility requirements, and high nutritive value.

Prospects Palisade grass, mainly the spittlebug-resistant cultivar 'Marandú', will continue to play an important role in the development of tropical pastures in regions where spittlebug is a major constraint until new *Brachiaria* cultivars with spittlebug resistance as well as lower soil-fertility requirements become available.

Literature |1| Bogdan, A.V., 1977. Tropical pasture and fodder plants. Longman, London. p. 54. |2| Cuesta, P.A. & Pérez, R.A., 1987. Pasto La Libertad. Instituto Colombiano Agropecuario (ICA), Bogotá, Colombia. Boletín Técnico No 150. 16 pp. |3| Empresa Brasileira de Pesquisa Agropecuária, Centro Nacional de Pesquisa de Gado de Corte, 1984. Brachiaria brizantha cv. Marandú. EMBRAPA-CNPGC, Campo Grande-MS, Brazil. Documento No 21. 31 pp. |4| Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 234–237.

R. Schultze-Kraft

Brachiaria decumbens Stapf

Flora of Trop. Africa 9: 528 (1919).
GRAMINEAE
$2n = 36$

Synonyms *Brachiaria bequaertii* Robyns (1932).

Vernacular names Signal grass (En). Malaysia: rumput signal. Thailand: ya-siknaentonnon, ya-surinam.

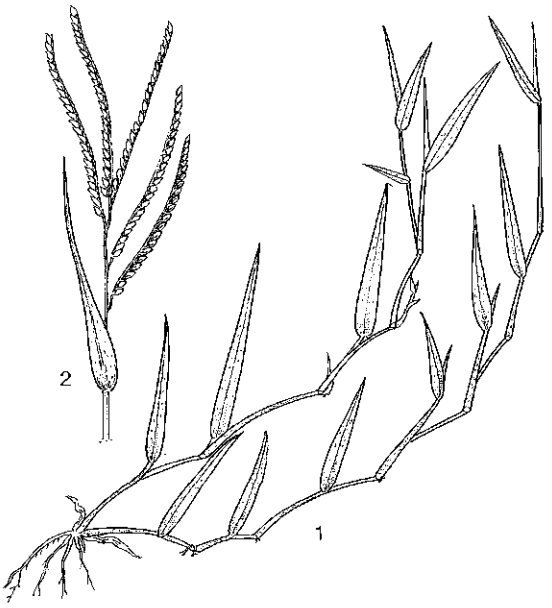
Origin and geographic distribution The origin of signal grass is in East Africa (Uganda, Kenya, Tanzania, Rwanda, Burundi, Zaire). Experimental lines and cultivars have spread very widely to all tropical regions of the world. Thus, signal grass is becoming increasingly naturalized in South-East Asian countries and the Pacific region.

Uses The main use of signal grass is as forage in permanent pastures that are grazed. It has also proved to be useful as grazed ground cover in tree plantations, and is suitable for erosion control.

Properties Signal grass provides a forage that is palatable to ruminants (but not to horses); depending on regrowth age, it is of moderate to high quality. Nitrogen concentrations decrease from 2.7–0.7% and in vitro DM digestibility from 75–50% as age of regrowth increases. When consumed as a pure diet, signal grass can occasionally cause skin-photosensitization combined with hepatic disorders, particularly in sheep and goats, and also in young cattle. There are 200–300 seeds/g.

Botany A low-growing, decumbent, rhizomatous and stoloniferous, apomictic (in cultivation) perennial forming a dense soil cover. Stem prostrate to ascending, 30–150 cm high. Leaf broadly linear to narrowly lanceolate, 5–25 cm × 7–20 mm, sparsely to densely pubescent, bright green. Inflorescence composed of 2–7 racemes on an axis 2–10 cm long; racemes 1–5 cm long, often borne at almost right angles to the axis (hence the name 'signal' grass), bearing spikelets usually in 2 rows on a broad, flattened rachis; spikelets elliptic, 4–5 mm long, pubescent at the tip; lower glume $\frac{1}{3}$–$\frac{1}{2}$ the spikelet length, clasping; upper glume membranous; upper lemma granulose.

B. decumbens intergrades with *B. brizantha* (A. Rich.) Stapf, and the species are difficult to dis-



Brachiaria decumbens Stapf – 1, habit leafy stems; 2, inflorescence.

tinguish. Therefore, in the literature the name *B. decumbens* probably sometimes actually refers to *B. brizantha*, and vice versa. The main difference between the cultivars or lines of *B. brizantha* and *B. decumbens* is the growth habit: *B. decumbens* is low-growing and forms a dense cover whereas *B. brizantha* is tufted with a rather erect growth. The best-known and most widely used cultivar of signal grass is 'Basilisk', released in Australia.

Ecology Signal grass is well adapted to the humid and sub-humid tropics where it withstands dry seasons of up to 5 months but does not tolerate flooding for more than a couple of days. It grows well on a range of soils, provided they are well drained, including acid, highly Al-saturated soils of medium to low fertility. It is moderately shade tolerant.

Agronomy Signal grass is easily established by seed, at rates that vary according to seed quality from 2–10 kg/ha. Germination of fresh seed may be poor because of dormancy (hard-seededness), but improves with time (up to one year of storage) or through scarification with sulphuric acid (10–15 minutes). Signal grass can also be propagated vegetatively by stem cuttings that are planted 60–100 cm apart in moist soil, or are broadcast and then disked in. The highly competitive vigour exhibited by signal grass under appropriate conditions helps in suppressing growth of weeds but creates problems with legume persistence. In spite of the competitive vigour of signal grass, persistent associations with legumes are feasible in certain environments. Suitable legumes are mainly stoloniferous species such as *Arachis pintoi* Krap. & Greg., nom. nud. (Pinto peanut), *Desmodium heterophyllum* (Willd.) DC. (hetero) and *D. heterocarpon* (L.) DC. ssp. *ovalifolium* (Prain) Ohashi, but also the trailing-climbing *Centrosema pubescens* Benth. (centro) and *Pueraria phaseoloides* (Roxb.) Benth. (tropical kudzu), the herbaceous to shrubby *Stylosanthes guianensis* (Aublet) Swartz (stylo), and the shrub/tree *Leucaena leucocephala* (Lamk) de Wit.

Although it is tolerant of low soil-fertility, it responds well to fertilization with N, P and K. Flowering and seed-setting can occur year-round and high seed yields can be obtained.

The major pest problem of signal grass (which, however, seems to be restricted to tropical America) is spittlebug (mainly the genera *Anaeolamia, Deois* and *Zulia* in the *Cercopidae* family). This pest can very severely affect the productivity and persistence of signal grass.

Signal grass is harvested by grazing animals or is mown in cut-and-carry systems and fed as fresh material. It withstands heavy grazing and trampling and thus can be grazed continuously or rotationally at stocking rates that should be high enough to prevent the grass from becoming old and of poor quality. Depending on soil fertility and moisture regime, DM yields of signal grass range between 6–36 t/ha per year. Animal production varies accordingly (liveweight gain of 250–800 g/steer per day and up to 1200 kg/ha per year).

Genetic resources and breeding There is no variability within cultivars or lines of signal grass. As their reproduction is apomictic, progenies are essentially clones of the mother plant. However, the major germplasm banks of tropical forage grasses at ATFGRC (CSIRO, Australia) and CIAT (Colombia) hold a range of quite variable, distinct *B. decumbens* accessions. At CIAT, besides selection within a recently assembled, large *B. decumbens/B. brizantha* gene pool, a breeding programme is in progress aimed at *B. decumbens/B. brizantha* cultivars that combine spittlebug resistance, low soil fertility requirements, and high nutritive value.

Prospects Until new lines from breeding and selection programmes become available, signal grass cultivars or lines will continue playing a very important role in tropical pasture development in regions where spittlebug is no major constraint, and where other *Brachiaria* species such as *B. brizantha, B. dictyoneura* (Fig. & De Not.) Stapf or *B. humidicola* (Rendle) Schweick. have no comparative advantage.

Literature |1| Bogdan, A.V., 1977. Tropical pasture and fodder plants. Longman, London. pp. 54–57. |2| Loch, D.S., 1977. Brachiaria decumbens (signal grass) – a review with particular reference to Australia. Tropical Grasslands 11: 144–157. |3| Oram, R.N., 1990. Register of Australian herbage plant cultivars. CSIRO, Australia. pp. 89–90. |4| Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 238–242. |5| Toutain, B., 1985. Graminées fourragères des genres Brachiaria et Urochloa pour le Pacifique. Revue d'Elevage et de Médecine Vétérinaire de Nouvelle Calédonie 7: 47–56.

R. Schultze-Kraft & J.K. Teitzel

Brachiaria dictyoneura (Fig. & De Not.) Stapf

Flora of Trop. Africa 9: 512 (1919).
GRAMINEAE
$2n = 42$

Synonyms *Panicum dictyoneurum* Fig. & De Not. (1854), *Brachiaria obvoluta* Stapf (1919), *B. keniensis* Henr. (1940).

Vernacular names Thailand: ya signal luey.

Origin and geographic distribution *B. dictyoneura* has its origin and natural distribution in eastern and southern Africa. It is increasingly being introduced to South-East Asia and the Pacific region and is spreading quite quickly in tropical America.

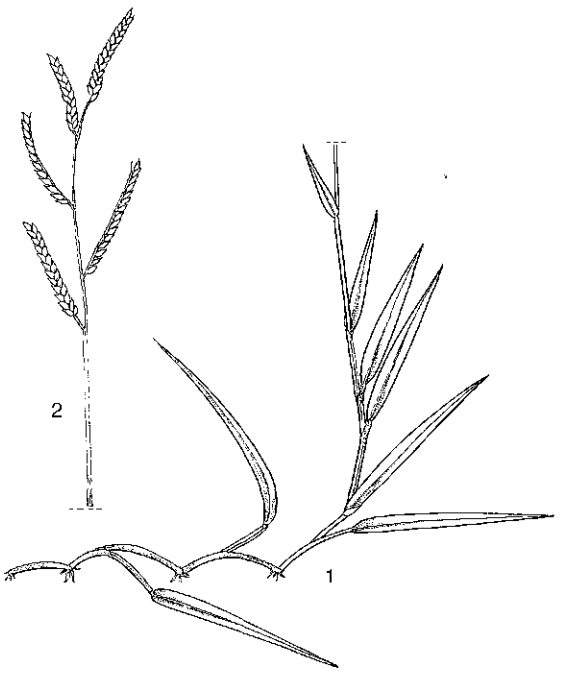
Uses *B. dictyoneura* is used as a forage in permanent pastures that are grazed. It has potential for erosion control and also as ground cover in tree plantations.

Properties The nutritive value of *B. dictyoneura* is regarded as moderate, yet higher than that of koronivia grass (*B. humidicola* (Rendle) Schweick.). Nitrogen concentrations range mostly between 1–2% but can be as low as 0.5% during the dry season. The range for in vitro DM digestibility is 55–70%. The grass has a high seed-production potential; there are about 170 seeds/g.

Botany A densely tufted, semi-erect, stoloniferous perennial with short rhizomes and with stems 40–120 cm high; stolons slender but strong and of reddish colour. Leaf linear to lanceolate, 4–40 cm × 3–18 mm, glabrous and with strongly denticulate margins. Inflorescence consisting of 3–8 racemes on an axis 5–25 cm long; racemes 1–8 cm long, bearing spikelets in two rows; spikelets elliptic, 4–7 mm long, pubescent; lower glume 75–100% of spikelet length, 11-nerved; upper glume 7–9-nerved; lower lemma 5-nerved; upper lemma slightly papillose.

Flowering seems to be long-day induced, and seed-setting improves at higher latitudes. In cultivars, reproduction is apomictic.

B. dictyoneura can easily be confused with *B. humidicola* (koronivia grass). The latter is, however, much more stoloniferous than *B. dictyoneura*. Further important differences, at least regarding the cultivars or commercial lines, are that *B. dictyoneura* has a noticeable, undulating protuberance along the leaf-collar (outer surface of the junction of leaf-sheath and blade), and that the raceme-rachis of *B. dictyoneura* is remarkably long-ciliate at the margins. The only cultivar released so far is 'Llanero' in Colombia.



Brachiaria dictyoneura (Fig. & De Not.) Stapf – 1, habit leafy stem; 2, inflorescence.

Ecology *B. dictyoneura* is well adapted to the humid and sub-humid tropics where it withstands dry periods of up to 4–5 months. It grows well on a wide range of soils, provided they are well drained, including acid and highly Al-saturated soils of low fertility.

Agronomy *B. dictyoneura* is preferably propagated by seed, but can be propagated vegetatively by rooted stem segments or stolons. Recommended seeding rate is 2–12 kg/ha, depending on seed quality. Germination of fresh seed is very poor because of dormancy, mainly physiological. Scarification with sulphuric acid improves germination only slightly; therefore, it is recommended to use seed that is 6–8 months old.

Its slow intial growth and weakly stoloniferous growth habit enable association with a range of legumes of varying growth habits, such as *Desmodium heterocarpon* (L.) DC. ssp. *ovalifolium* (Prain) Ohashi (prostrate-stoloniferous), *Centrosema pubescens* Benth. or *Pueraria phaseoloides* (Roxb.) Benth. (trailing-climbing), *Stylosanthes guianensis* (Aublet) Swartz (semi-erect herb/subshrub), and *Leucaena leucocephala* (Lamk) de Wit (shrub/tree).

Although its soil-fertility requirements are low, *B. dictyoneura* responds well to fertilization, particu-

larly with N. *B. dictyoneura* should be leniently grazed until it is fully established. Then, using continuous or rotational grazing, stocking rates can be relatively high (2–4 steers/ha), with seasonal adjustments as necessary. The grass should be grazed down to 15–20 cm height.

Like most other species of *Brachiaria, B. dictyoneura* is affected by spittlebug (species of the genera *Aeneolamia, Deois,* and *Zulia* in the *Cercopidae* family) in tropical America. However, unlike signal grass (*B. decumbens* Stapf), it recovers quickly.

B. dictyoneura is usually harvested as fresh material by grazing animals. Depending on growth conditions, including the severity of the dry season, the grass produces DM yields ranging from 4–11 t/ha per year on acid, low-fertility soils. Animal production on a hectare basis varies accordingly. Daily liveweight gains of 250–500 g/steer can be expected.

Genetic resources and breeding There is no variation within 'Llanero'; as its reproduction is apomictic, the progenies are essentially clones of the mother plant. The species is not very well represented in the major germplasm banks of tropical forage grasses at ATFGRC (CSIRO, Australia) and CIAT (Colombia), and only a few but distinct accessions are so far available. There are no breeding programmes involving *B. dictyoneura*.

Prospects Compared with other *Brachiaria* species adapted to acid, low-fertility soils, *B. dictyoneura* offers the advantage of being less affected by spittlebug than signal grass and the advantage of better forage quality and compatibility with legumes than koronivia grass. For these reasons, it has excellent potential for pasture development in acid-soil regions.

Literature |1| Centro Internacional de Agricultura Tropical, 1983–1990. Annual reports. Tropical Pastures Program. CIAT, Cali, Colombia. |2| Instituto Colombiano Agropecuario, 1987. Pasto 'Llanero'. ICA, Bogotá, Colombia. Boletín Técnico No 151. 12 pp. |3| Keller-Grein, G. (Editor), 1990. Red Internacional de Evaluación de Pastos Tropicales RIEPT-Amazonia. I Reunión-Lima, Perú, 6–9 Noviembre 1990. Documento de Trabajo No 75. Centro Internacional de Agricultura Tropical, Cali, Colombia. 2 Vols. 1119 pp.

R. Schultze-Kraft

Brachiaria distachya (L.) Stapf

Flora of Trop. Africa 9: 565 (1919).
GRAMINEAE
$2n = 36$

Synonyms *Panicum distachyon* L. (1771), *Digitaria distachya* (L.) Pers. (1805), *Urochloa distachya* (L.) Nguyen (1966).

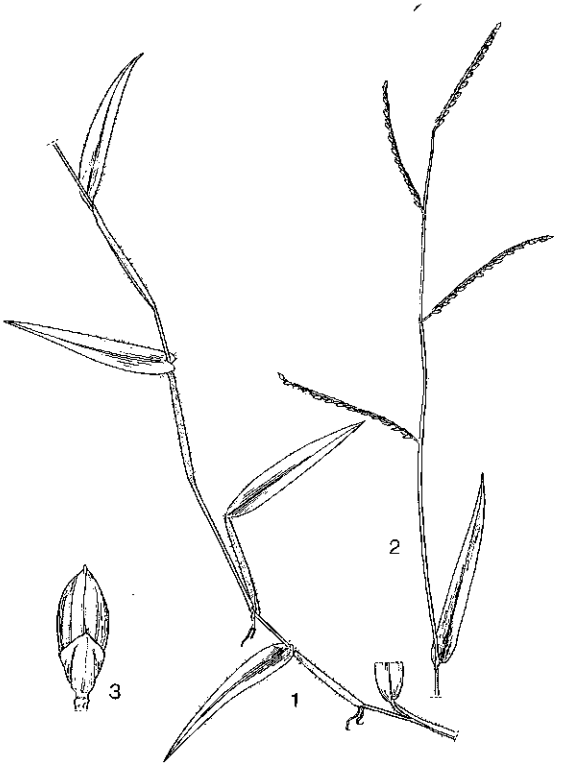
Vernacular names Green summer grass (En). Indonesia: blembem, kadalan, blabakan (Java). Malaysia: rumput minyak, rumput melera minyak. Philippines: gome-gome, tanageb. Thailand: yateenka. Vietnam: co' mât.

Origin and geographic distribution *B. distachya* originates and occurs from the Indian subcontinent throughout South-East Asia, Australia and the Pacific Islands.

Uses *B. distachya* is used primarily as forage. In coastal sand dunes it acts as a soil-binder.

Properties Results from Thailand have shown that 8-week-old growth of *B. distachya* had 65% digestible DM and low N concentrations of 1.5% at 4 weeks and 0.9% at 12 weeks.

Botany Creeping annual; stems up to 50 cm tall,



Brachiaria distachya (L.) Stapf – 1, habit leafy stem; 2, inflorescence; 3, spikelet.

ascending from a prostrate base, on the soil surface rooting at the nodes. Leaf broadly linear to narrowly lanceolate, 2–8 cm × 3–7 mm; sheath keeled, up to 3 cm long, hairy at the margin when young. Inflorescence consisting of 2–3 racemes on an axis 0.5–2 cm long; racemes 1–3 cm long with spikelets attached singly on either side of the median ridge of the rachis; spikelets narrowly elliptic, 2.5–3 mm long, glabrous, acute; lower glume $\frac{1}{3}$–$\frac{1}{2}$ as long as the spikelet, clasping; upper glume separated from the lower by a short internode; upper lemma rugulose. Caryopsis flattened ovoid, 1.6 mm long, light yellow.

B. distachya commences flowering early in the growing season and then flowers continuously throughout the year, but little seed is set. *B. distachya* much resembles *B. subquadripara* (Trin.) Hitchc., with which it is sometimes united. The range of spikelet length seems to be disjunct (2.5–3 mm and 3.3–3.7 mm respectively), thus also justifying the maintenance of two species.

Ecology *B. distachya* is adapted to humid tropical lowlands. It can grow under light shady conditions such as occur in old coconut plantations or orchards. It is often found in small patches along forest edges and waste places where it is freely grazed by village cattle. It does not tolerate waterlogging but is well adapted to sandy loam soils.

Agronomy *B. distachya* is vegetatively propagated through division of root stocks. It is very palatable and light grazing is preferred. Yields of 3 t/ha of DM without fertilizer and 9 t/ha with mixed fertilizer have been obtained in southern Thailand.

Genetic resources and breeding It is unlikely that any substantial germplasm collections are being maintained.

Prospects *B. distachya* is an interesting natural forage grass in South-East Asia, deserving more attention because of its high palatability and its tolerance of light shade and poor soils.

Literature |1| Gilliland, H.B., Holttum, R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Vol. 3. Government Printing Office, Singapore. pp. 176–178. |2| Holm, J., 1971. Feeding tables. Nutrition Laboratory of Thai-German Dairy Project, Livestock Breeding Station, Chiangmai, Thailand. pp. 9–10. |3| Kotepat, W. & Sookasem P., 1989. Effects of cow dung and chemical fertilizer on the yields and nutritive values of Brachiaria distachya on Banthon soils [in Thai]. 1987–89 Research Report. Lampang Animal Nutrition Research Center, Department of Livestock, Bangkok. 42 pp.

C. Manidool

Brachiaria humidicola (Rendle) Schweick.

Kew Bulletin 1936: 297 (1936).
GRAMINEAE
$2n = 72$

Synonyms *Panicum humidicola* Rendle (1899).

Vernacular names Koronivia grass (En). Thailand: ya humidicola.

Origin and geographic distribution The origin and natural distribution of *B. humidicola* extends throughout eastern and southern Africa. During the past 2–3 decades, it has been introduced to other tropical regions and has become a fairly widespread species in South-East Asia and the Pacific region.

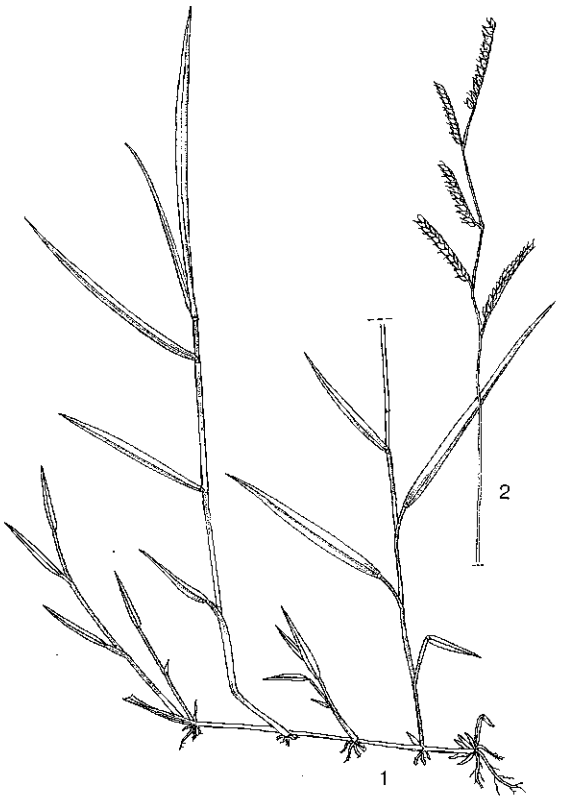
Uses Koronivia grass is mainly used as a forage in permanent pastures that are grazed, and for erosion control. It has also proved to be useful as grazed ground cover in tree plantations.

Properties Koronivia grass has a reputation as a palatable forage with very low N concentrations, even during the growing season (0.6–1.0%), which can severely limit forage intake by ruminants. In vitro DM digestibility values range from 50–70%. The grass tolerates shade and poor drainage and is an effective seed producer. There are 200–260 seeds/g.

Botany A prostrate, strongly stoloniferous and rhizomatous perennial, forming a dense ground cover. Stolons slender but strong and of reddish colour; flowering stems ascend up to 100 cm. Leaf linear to narrowly lanceolate, 4–30 cm × 3–10 mm, glabrous. Inflorescence consisting of 2–5 racemes on an axis 2–13 cm long; racemes 2–7 cm long, bearing the spikelets in two rows; spikelets broadly elliptic, 4–6 mm long, slightly pubescent; lower glume 75–100% of spikelet length; 11-nerved; upper glume 5–9-nerved; lower lemma 5-nerved; upper lemma slightly papillose.

Koronivia grass can easily be confused with *B. dictyoneura* (Fig. & De Not.) Stapf. The main difference is that koronivia grass is very strongly stoloniferous while *B. dictyoneura* is distinctly tufted and considerably less stoloniferous. There are several cultivars throughout the tropics; however, they probably represent the same genotype. Officially released cultivars are 'Tully' in Australia and 'INIAP–701' in Ecuador. The reproduction in cultivars is apomictic.

Ecology Koronivia grass is well adapted to the humid tropics but also thrives under sub-humid tropical conditions where it withstands 3–4 dry months. It grows well on a range of soils, including



Brachiaria humidicola (Rendle) Schweick. – 1, habit leafy stems; 2, inflorescence.

moist, poorly drained sites. It is particularly well adapted to acid, highly Al-saturated soils of low fertility.

Agronomy Koronivia grass can be propagated and established by seed at a rate of 2–8 kg/ha depending on seed quality, or vegetatively by rooting stolon cuttings that are spread and disked in, or planted by hand, at 1 m × 1 m distances or less. The latter method is particularly convenient in smallholder systems.

Under favourable conditions, koronivia grass can grow very quickly and form a dense ground cover ready for grazing 3–5 months after sowing. Because of its growth habit and highly competitive vigour, the growth of weeds is easily suppressed, but associations with legumes are difficult to maintain.

In contrast to lower altitudes, koronivia grass grown at higher altitudes has the potential to flower profusely and to produce seed yields of up to 150 kg/ha during the first year. Once the pasture is fully established, flowering and seed production are scarce.

Because of its strongly stoloniferous growth habit, koronivia grass can withstand very heavy grazing. Overstocking, however, will result in very low animal growth rates. Prostrate-stoloniferous legumes such as *Arachis pintoi* Krap. & Greg., nom. nud. (Pinto peanut), *Desmodium heterophyllum* (Willd.) DC. (hetero), and *D. heterocarpon* (L.) DC. ssp. *ovalifolium* (Prain) Ohashi have the potential to persist readily in associations with koronivia grass. However, when all soil nutrient deficiencies have been corrected, *Centrosema pubescens* Benth. and *Pueraria phaseoloides* (Roxb.) Benth. have also persisted with it. Although its requirements for soil fertility are low, it responds to fertilization.

As with most other *Brachiaria* species, the productivity of koronivia grass can be affected by spittlebug (*Aeneolamia* spp., *Deois* spp., and *Zulia* spp. in the *Cercopidae* family). Unlike most other *Brachiaria* species, however, it recovers quickly from attacks by this insect pest. Rust (*Uromyces setariaitalicae*) has recently been identified as a potential major disease in tropical America.

Koronivia grass is regarded as a high-yielding grass. Depending on climate and soil fertility, DM production ranges from 7–33 t/ha/ per year. Because of its high carrying capacity, liveweight gain per ha can be high, but with rather low growth rates (150–500 g/steer per day). Although the grass is usually consumed fresh by grazing animals, hay making is occasionally practised in subhumid environments in Brazil and Venezuela.

Genetic resources and breeding There is no variation in cultivars of koronivia grass as their reproduction is apomictic, resulting in progenies being clones of the mother plant. The major germplasm banks of tropical forage grasses at CIAT (Colombia) and ATFGRC (CSIRO, Australia) hold a range of quite variable *B. humidicola* accessions. At present, there are no *B. humidicola* breeding programmes. Research activities to improve the species are limited to evaluation of the available genepool.

Prospects Because of its aggressive, weed-suppressing growth, tolerance of overgrazing, adaptation to poorly drained sites, and low requirements regarding soil fertility, the present Koronivia grass cultivars will continue to play an important role in tropical pasture development. Their importance will only decline when new cultivars or other species become available which combine the above-mentioned features with better forage quality.

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57–58. |2| Centro Internacional de Agricultura Tropical, 1983–1990. Annual reports, Tropical Pastures Program. CIAT, Cali, Colombia. |3| Oram, R.N., 1990. Register of Australian herbage plant cultivars. CSIRO, Australia. pp. 91–92. |4| Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 245–248. |5| Toutain, B., 1985. Graminées fourragères des genres Brachiaria et Urochloa pour le Pacifique [Grass forages of the genera Brachiaria and Urochloa for the Pacific]. Revue d'Elevage et de Médecine Vétérinaire de Nouvelle Calédonie 7: 47–56.

R. Schultze-Kraft & J.K. Teitzel

Brachiaria mutica (Forssk.) Stapf

Flora of Trop. Africa 9: 526 (1919).
GRAMINEAE
$2n = 36$

Synonyms *Panicum muticum* Forssk. (1775), *P. purpurascens* Raddi (1823), *Brachiaria purpurascens* (Raddi) Henr. (1940).

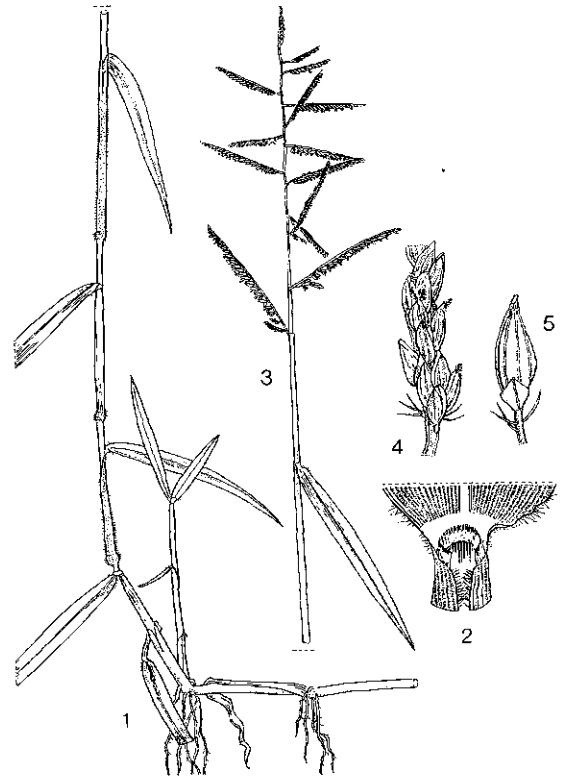
Vernacular names Para grass, Mauritius grass (En). Herbe de para (Fr). Indonesia: rumput malela, sukut kolonjono, jukut inggris. Malaysia: rumput melela, rumput para. Philippines: babakanalabaga, mara-kawayan (Ilokano). Cambodia: smau kôô. Thailand: ya khon. Vietnam: co' lông tây.

Origin and geographic distribution The origin of para grass is probably tropical Africa. Today, the grass occurs naturally all over the tropical world, including South-East Asia and the Pacific region.

Uses It is mostly grazed but can also be cut and fed to tethered animals or animals confined in stalls. It is suitable for erosion control at moist sites, e.g. on river banks. As a cover crop in plantations it is often considered too agressive.

Properties Para grass is a palatable forage of reputedly high quality. Depending on plant age, N concentrations can range from 1.6–2.2% for leaves and from 0.5–1.0% for stems, and in vitro DM digestibility from 40–65%.

Botany A robust, coarse, creeping perennial with short rhizomes and long stolons. Stems decumbent to ascending, rooting at nodes, densely covered with long, white hairs. Leaf-sheath hairy or glabrous on upper portion, with densely hairy collar; leaf-blade linear to lanceolate, 6–30 cm × 5–20 mm, flat, glabrous or slightly hairy. Inflorescence a panicle 6–30 cm long with 5–20 densely flowered racemes somewhat separated; racemes



Brachiaria mutica (Forssk.) Stapf – 1, habit culm with leaves; 2, ligule; 3, inflorescence; 4, part of raceme; 5, spikelet.

2–15 cm long, basal ones generally branched; spikelets paired (often single in upper part), elliptic, 2.5–5 mm long, glabrous, in several untidy rows; fertile (upper) floret 3 mm long, pale yellow when ripe. Reproduction is mainly apomictic.
Under appropriate conditions, para grass is very competitive and vigorous, thus suppressing growth of weeds and making persistent associations with legumes difficult. Flowering and seed-setting occur, particularly at low latitudes and in humid environments. There is no formally released cultivar of para grass. Para grass closely resembles tanner grass (*Brachiaria arrecta* (Th. Dur. & Schinz) Stent from tropical and southern Africa, but the latter species always has single spikelets.

Ecology Para grass is best adapted to poorly drained (swampy or periodically waterlogged) and wet areas of the warm tropics with soils of medium to high fertility; it tolerates salinity. As long as soil moisture is appropriate, it also thrives in well-drained areas. Growth is poor on dry sites. It can become a weed in irrigation ditches and drains.

Agronomy Although establishment by seed is feasible (using 4 kg/ha), para grass is usually and easily established from stem cuttings with at least 3–4 nodes each, two of which should be buried 10–15 cm deep. Planting density depends on weed potential of the site and desired speed of ground cover, and should not be at spacings wider than 1 m × 1 m. If machinery is available, spread stem cuttings can be disked in. It responds to fertilization, mainly N but also P and K, which become particularly important if the grass is cut regularly. Legumes compatible with para grass at poorly drained sites are the annuals *Macroptilium lathyroides* (L.) Urban (phasey bean) and *Aeschynomene americana* L. (American jointvetch), and at well-drained sites the perennials *Pueraria phaseoloides* (Roxb.) Benth. (tropical kudzu), *Centrosema pubescens* Benth. (centro), and the shrub *Leucaena leucocephala* (Lamk) de Wit.

Para grass can be grazed continuously, or rotationally at intervals of 5–8 weeks, but a residual height of 15–20 cm should be maintained.

In Australia, para grass is attacked by a leafhopper which sucks the sap and severely reduces pasture productivity.

Para grass is harvested by grazing animals or cut for stall-feeding. It can be used for hay-making if environmental conditions allow but is difficult to dry. Depending on growth conditions, DM yields can range between 3–39 t/ha per year, mostly 5–12 t/ha per year. Animal production varies accordingly and annual liveweight gains of 300–800 kg/ha can be expected from para grass. Depending on N fertilization, seed yields of up to 60 kg/ha are possible. However, except in Australia, commercial seed production of para grass is practically non-existent because of the ease of establishment from stem cuttings.

Genetic resources and breeding Para grass is not well represented in the major germplasm collections of tropical forage grasses held by CIAT (Colombia) and ATFGRC (CSIRO, Australia). The variability in the available gene pool is limited because of the species' apomictic reproduction and clonal propagation. However, important varietal differences have been observed in Thailand and Burma. Because of lack of a gene pool, there has been no description of the variation within para grass and no evaluation or breeding programmes to select improved lines.

Prospects Para grass will continue to be one of the most widely used good-quality forages for low-lying, seasonally waterlogged areas of the tropics. In Australia it has also become popular for use in 'ponded pastures' (shallow earth dams) in drier environments. However, because of insect problems, it is gradually being replaced by *B. humidicola* (Rendle) Schweick. in the humid tropics of Australia.

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R. Schultze-Kraft & J.K. Teitzel

Brachiaria ruziziensis Germain & Evrard

Bull. Jard. Bot. Etat Brux. 23: 373 (1953).

GRAMINEAE

$2n = 18, 36$

Vernacular names Ruzi grass, Congo grass, Congo signal grass (En). Thailand: ya ruzi.

Origin and geographic distribution Ruzi grass has its origin in the Ruzizi valley in eastern Zaire and Burundi. It is widely distributed on farms and experiment stations in most tropical countries including South-East Asia and the Pacific region.

Uses Ruzi grass is used as a forage for direct grazing of permanent pastures, in the open or under coconuts, and for feeding tethered or stalled ruminants.

Properties Ruzi grass is palatable and of excellent quality, with N concentrations ranging from 1.5–2.5% and in vitro DM digestibility from 50–75% (4–16 weeks old regrowth). It tolerates shade moderately, and drought fairly well. It has a high seed production potential. There are 230–250 seeds/g.

Botany A tufted, creeping perennial, forming a dense and leafy cover. Stems leafy and hairy, arising from many-noded, creeping shoots and short rhizomes up to 1.5 m high when flowering. Leaves hairy, broad-lanceolate, 10–25 cm × 10–15 mm. Inflorescence consisting of 3–9 relatively long (4–10 cm) racemes, bearing spikelets in 1 or 2 rows on one side of a broad, flattened and winged rachis

Brachiaria ruziziensis Germain & Evrard – *1, habit flowering culm; 2, inflorescence.*

of generally purplish colour; spikelets hairy, 5 mm long; lower glume 3 mm long, 0.5–1 mm distant (= below) from rest of spikelet. It produces seed abundantly.

Brachiaria ruziziensis is very closely related to *B. decumbens* Stapf, but differs morphologically (in *B. ruziziensis* the rachis is subfoliaceous and 2–3.5 mm wide and the lower glume is at a considerable distance from rest of spikelet; in *B. decumbens* the rachis is flat, 1–1.7 mm wide and internode between lower and upper glume is shorter) and in reproduction (sexual in *B. ruziziensis*, apomictic in *B. decumbens*). The best known cultivar is 'Kennedy', released in Australia.

Ecology Ruzi grass is well adapted to the warm tropics with annual rainfall in excess of 1000 mm; it can withstand up to 5 dry months. It tolerates a range of soils but requires very fertile soil. It thrives best on well-drained sites.

Agronomy Although it can also be propagated vegetatively by stem cuttings with rooting nodes, ruzi grass is easily established by seed at rates of 2.5–10 kg/ha, depending on seed quality. Seed should not be sown deeper than 1.5–2.5 cm. Germination of fresh seed is poor because of dormancy, but increases following storage or treatment with concentrated sulphuric acid.

Because of its high soil-fertility requirements, adequate N, either through a legume or fertilizer, P and K must be supplied in order to maintain high productivity of ruzi grass, particularly under cutting.

Ruzi grass can be sown with a range of legumes such as stylo (*Stylosanthes guianensis* (Aublet) Swartz), greenleaf desmodium (*Desmodium intortum* (Miller) Urban), centro (*Centrosema pubescens* Benth.), and the shrub legume *Leucaena leucocephala* (Lamk) de Wit.

No diseases or pests of economic importance are known to affect ruzi grass in South-East Asia. In tropical America it can be severely damaged by spittlebug (*Aeneolamia* spp., *Deois* spp., and *Zulia* spp. in the *Cercopidae* family). In Zaire the inflorescences are parasitized by the fungus *Sphacelia* sp.

Ruzi grass is harvested by grazing animals or cut for stall-feeding, and is also suitable for making hay. Depending on growth conditions (mainly soil fertility), annual DM yields of 10–20 t/ha can be expected from ruzi grass. Annual liveweight gains of beef cattle can be higher than 500 kg/ha, depending on soil N status.

Genetic resources and breeding The gene pool of ruzi grass is limited to a few accessions held in the collections of ATFGRC (CSIRO, Australia) and CIAT (Colombia). Because of its sexual reproduction and a high degree of cross-pollination, these accessions are quite variable. There are no ruzi grass breeding programmes, but a tetraploid form of this species is used at CIAT as a source of sexuality in a breeding project involving the tetraploid, apomictic *B. decumbens*/*B. brizantha* complex.

Prospects The main value of ruzi grass lies in its reasonably high nutritive value and high seed production potential, but it is markedly less productive than *B. decumbens*. Its importance will decrease rapidly as current *Brachiaria* selection programmes result in alternatives which combine the above mentioned attributes with adaptation to low-fertility soils.

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R. Schultze-Kraft & J.K. Teitzel

Brachiaria subquadripara (Trin.) Hitchc.

Lingnan Sci. Journ. 7: 214 (1931).
GRAMINEAE
$2n = 54–56, 72$

Synonyms *Panicum subquadriparum* Trin. (1828), *P. miliiforme* J. & C. Presl (1830), *Brachiaria miliiformis* (J. & C. Presl) Chase (1920).

Vernacular names Cori grass (En).

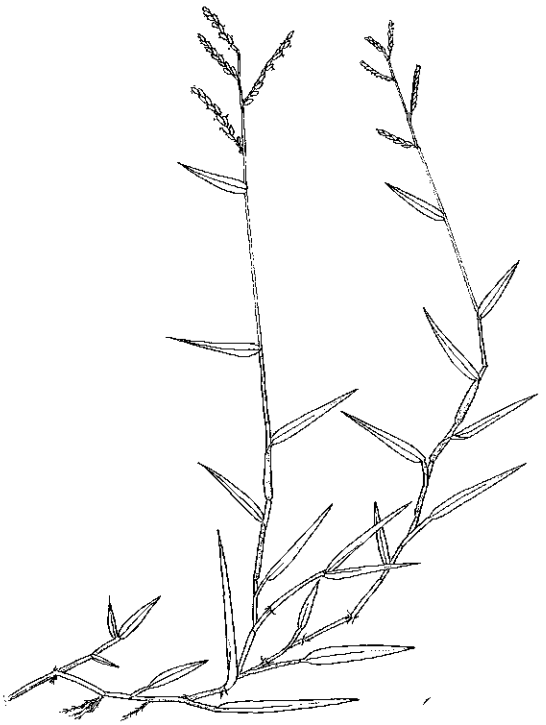
Origin and geographic distribution Of tropical Asian origin (India, Sri Lanka, Burma, Malaysia, Pacific Islands), this grass has been introduced to other regions such as tropical Africa.

Uses The main use of cori grass is as a forage for ruminants in coconut plantations where it is grazed by animals, and as a shade-tolerant ground cover.

Properties Cori grass is very palatable, and young regrowth is of acceptable forage quality (1–2% N at 4–8 weeks).

Botany A creeping stoloniferous perennial (reported as annual by some authors), mat-forming under close grazing, with slender stems up to 1 m long, ascending from a prostrate base up to 50 cm high, rooting at hairless nodes. Leaf broadly linear to narrowly lanceolate, 2–20 cm × 5–10 mm, glabrous, with rounded base and sharp tip. Inflorescence consisting of 2–5 widely spaced racemes on an axis 3–10 cm long; racemes 1–6 cm long, bearing singly attached spikelets in two rows; spikelets narrowly elliptic, 3.3–3.7 mm long, glabrous, pale green; lower glume shorter, upper glume as long as spikelet; upper lemma rugulose; stigmas purple. The taxonomic situation of *B. subquadripara* and *B. miliiformis* is not clear. Some authors consider them to be synonymous whereas others claim these species are distinct but closely related, with *B. subquadripara* being a perennial with $2n = 72$ and *B. miliiformis* an annual with $2n = 54$ chromosomes.

Ecology Cori grass is widely adapted to the warm lowland tropics, but particularly suited to monsoon environments. It prefers medium- to light-textured soils of medium to high fertility. It is one of the most shade-tolerant tropical grasses, and this makes it particularly valuable for pastures in tree plantations.



Brachiaria subquadripara (Trin.) Hitchc. – habit.

Agronomy Cori grass is easily and quickly propagated and established by stolon cuttings partially buried 10–15 cm deep. Planting density depends on weed potential and desired speed of ground cover; establishment of a minimum of 1 plant/m^2 is recommended.

Once well established, Cori grass can withstand heavy grazing and competes well with weeds, particularly under some shade. Under coconuts, annual DM yields vary from 4–9 t/ha. Suggested stocking rates are 1.5–2.0 steers/ha, and annual liveweight gain up to 400 kg/ha can be expected without affecting yields of coconuts.

The grass responds well to N fertilization and is considered to be moderately drought-tolerant. Legumes suitable for association with Cori grass are centro (*Centrosema pubescens* Benth.) and tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.).

Genetic resources and breeding In the major germplasm collections of tropical forages, CIAT (Colombia) and ATFGRC (CSIRO, Australia), *B. subquadripara* seems to be represented by only one distinct genotype.

Prospects Further development of the existing genotype to improve adaptation, production or

quality is unlikely. However, the genetic base of Cori grass should be broadened through plant collection in view of its potential for pastures in tree plantations, particularly under coconuts.

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R. Schultze-Kraft

Calliandra calothyrsus Meissn.

Linnaea 21: 251 (1848).
LEGUMINOSAE
$2n = 22$

Synonyms *Calliandra confusa* Sprague & Riley (1923).

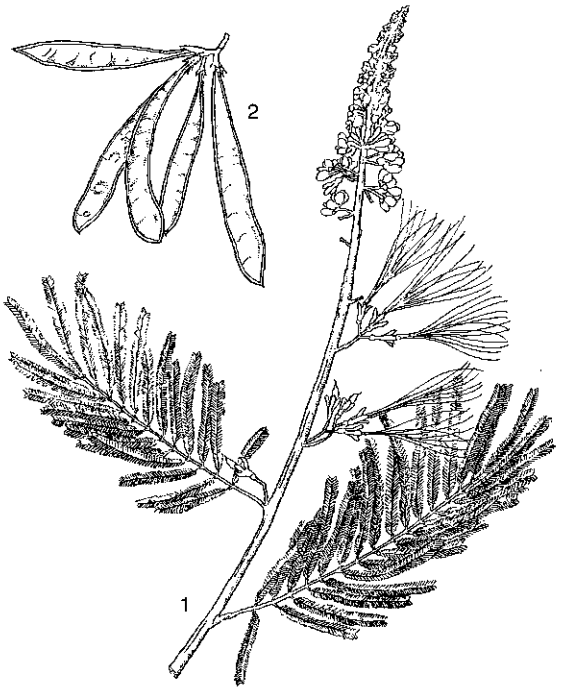
Vernacular names Calliandra (En).

Origin and geographic distribution Although originally described from Surinam, *C. calothyrsus* is native in humid and sub-humid Central America from southern Mexico to north-western Panama, between 8–16°N. From Guatemala it was introduced into Java in 1936. During the 1970s it became well established in Indonesia, with over 30000 ha of plantations. In view of its excellent performance in Indonesian plantations and its multiple uses, it is now being planted in many other countries of South-East Asia and to a lesser extent in other tropical areas.

Uses Calliandra is used as a high quality protein leaf crop to supplement low quality forages and crop residues. Only the leaves and young stems are used for fodder. In Indonesia calliandra is primarily used for fuelwood for households and small industries. The wood can also be used for pulp and paper production but its small dimensions make handling and chipping difficult. It is widely planted to control erosion on sloping lands and ravines. It is used to improve soils by nitrogen fixation and good litter production by cultivating it in rotation with arable crops. It is also incorporated in alley-cropping systems as a source of green manure, or used as a nurse tree for partially shade-tolerant timber species. Calliandra is also planted in firebreaks. Its beautiful red flower clusters make it a popular ornamental, and the flowers are a good nectar source for bees. It is a suitable host for shellac insects (*Kerria lacca*). It has shown promise as an understorey in coconut plantations with about 60% light transmission.

Properties Calliandra leaves contain (DM based): N 3–3.5%, fibre 30–75%, ash 4–5% and fat 2–3%. No toxic substances have been reported, but high concentrations of condensed tannins (up to 11%) are responsible for the rather low in vitro digestibility of 35–40%. The wide range of recorded tannin contents may reflect differences in analytical procedures as much as variation due to growth stage and environment. The digestibility data should also be treated with caution, as when dried, material with a high tannin content can have a marked effect on digestibility and intake by animals. There is increasing evidence that wilted or dried material is less acceptable to animals than fresh material. There are 14–19 seeds/g.

Description Shrub or small tree, (1.5–)4–6(–12) m tall, with trunk diameter up to 30 cm, blackish-brown bark and a dense canopy. Leaves bipinnate, alternate, rachis 10–17 cm long, without glands, pinnae 4–7 cm long in 15–20 pairs with 25–60 pairs of dark green leaflets each; leaflets linear, 5–8 mm × 1 mm. Inflorescences composed of few to many flowered heads, in terminal raceme-like clusters of



Calliandra calothyrsus Meissn. – 1, flowering branch; 2, branch with fruits.

10–30 cm length. Flower showy, purplish-red, 4–6 cm long; calyx 2 mm long; corolla 5–6 mm long, pale green; stamens numerous, 4–6 cm long, purplish-red. Fruit broadly linear, flattened, 8–11 cm × 1 cm, slightly tapering from top to base, margins thickened and raised, finely pubescent or glabrous, brownish, dehiscent, 3–15-seeded. Seed ellipsoidal, flattened, 5–7 mm long, dark brown.

Wood characteristics The wood of calliandra is moderately heavy, volumic mass 510–780 kg/m^3, strong and easy to saw. It provides good fuelwood (massic energy 18900–19950 kJ/kg) and is suitable for charcoal production. Cellulose content varies from 44–56%, fibre length from 0.66–0.84 mm, extractive material 3% DM.

Growth and development Mature seeds germinate readily. Seedlings grow quickly up to 2.5–3.5 m in 6 months and up to 3–5 m in the first year. Trees mature rapidly; flowering may start in the first year, but good fruit setting normally starts the second year. Normally large quantities of seed are produced each year. In its native region, flowering is concentrated at the end of the rainy season and the beginning of the dry season, and fruits are set in the dry season. On Java, calliandra flowers and fruits throughout the year, but most seeds are produced in the dry season. Flowers are insect-pollinated and seeds mature 2 months after pollination. Fruits are mature when they turn brown. The stem turns brittle around the age of 12 years, but the rootstock remains vigorous and new sprouts are easily formed. After cutting, trees coppice vigorously. With annual coppicing of stems of 3–5 cm in diameter, plants can survive for many years. Roots develop quickly and may reach 1.5–2 m in plants of 4–5 months old. Both surface and deeply penetrating roots are formed.

In humid climates the tree is evergreen, in areas with a long dry season it is semi-deciduous. In severe dry conditions, trees die back but recover at the beginning of the rainy season.

Other botanical information *Calliandra* Benth. is a genus of about 100 species of shrubs and small trees of tropical and warm temperate regions, some of which are widely cultivated as ornamentals. Together with the introduction of *C. calothyrsus* in Java, the white-flowered *C. tetragona* Benth. was also introduced from Guatemala. Because of its slower growth, this species became less popular for plantations.

Ecology In its native habitat *C. calothyrsus* grows at altitudes of 400–1800 m in areas with an average annual precipitation from 700 mm to 3000 mm and with 1–7 dry months per year. Best development occurs at moderate elevations below 1300 m. On Java the species is planted up to 1500 m altitude, but it grows best between 250–800 m in areas with 2000–4000 mm annual rainfall and a 3–6 month dry period. The plants require a mean annual temperature of (20–)22–28°C, with mean maximum temperature in the hottest month between 24–30°C and mean minimum temperature in the coldest month between 18–24°C. The species occurs in secondary vegetations, often in thickets. It is an aggressive colonizer on disturbed sites such as recent landslides and roadsides. It grows on a large variety of soil types ranging from deep, volcanic, sandy loams to alluvial soils and shallow or eroded metamorphic sandy clays. It is well adapted to acid soils of poor fertility but can respond to fertilizer application on such soils.

It prefers light soil textures and slightly acid conditions. Best growth is obtained on acid soils of volcanic origin. Growth decreases on compacted soils and trees die after 2 weeks of oxygen depletion due to waterlogging.

Propagation and planting Calliandra is normally propagated by seeds, directly in the field or in the nursery. Seeds germinate without pre-treatment, but best germination is obtained if seeds are briefly treated with almost boiling water and soaked for 24 hours. Seeds retain their viability for at least 2–3 years if stored in a refrigerator but viability decreases within one year at room temperature. Direct sowing in the field can be done in planting holes or by broadcasting on previously ploughed or burned lands. Seedlings usually nodulate with native rhizobia and inoculation is not required. Potted plants and transplants can be raised with standard nursery techniques. Potted plants are transplanted when they are 20–50 cm tall and have a root collar of 0.5–1 cm. Plants approximately 1 m tall can be transplanted after cutting the stem back to 30 cm and the roots to 20 cm. Spacing within plantations varies according to purpose. For firewood, planting distances are 1 m × 1 m to 1 m × 2 m; in alley-cropping, spacing of 25–50 cm in the contour lines is used. Areas to be planted are cleared completely. To provide fodder calliandra is often planted in fences, rows or in small blocks, usually under a cut-and-carry regime. For optimal leaf production dense stands of up to 40000 trees/ha can be used.

Husbandry Because seedlings grow quickly, no special plantation management is needed, except for weeding in the first year. As yet there is not much specific knowledge on management practices for optimal fodder and wood production from

C. calothyrsus. Neither is much known about the feasibility of combining calliandra and cultivated forage grasses.

Diseases and pests There are no serious diseases or pests recorded in Indonesia, but in the Philippines trees are damaged by a stem-borer. In Kenya, damage from *Pachnoda ephippiata* (a rose flower beetle) has restricted seed production to the extent that it has been suggested that the insect could limit the use of *C. calothyrsus*.

Harvesting Harvesting of calliandra can normally start after the first year. Forage is usually cut by hand. In Indonesia a cutting height of 35 cm is commonly used, although forage yields may be slightly larger with a cutting height of 100 cm.

Yield In plantations, forage DM yields are typically in the range of 7–10 t/ha per year, although yields will be lower in areas of low rainfall or infertile soil. In one experiment, leaf yields were slightly higher when harvested at intervals of 12 weeks instead of 6 weeks. When grown as fences, fodder DM yields of 1.8–3.2 t/km in 10 months have been obtained. In one trial, yields of *Panicum maximum* Jacq. cultivar 'Riversdale' were similar to those of *C. calothyrsus*, *Leucaena leucocephala* (Lamk) de Wit and *Gliricidia sepium* (Jacq.) Kunth ex Walp. Yields of the three legumes were also similar. When plots were harvested every 6 weeks, grass yields were higher at denser tree spacings, but when harvested every 12 weeks, grass yields were higher at the wider tree spacings. On reasonable soils on Java first wood harvests produced 5–20 m^3/ha per year of fuelwood. On favourable sites annual coppice harvests continued for 10–20 years with yields of 35–65 m^3/ha per year.

Genetic resources A collection of *C. calothyrsus* germplasm has been made by CATIE (Turrialba, Costa Rica) and the Oxford Forestry Institute (United Kingdom).

Breeding *C. calothyrsus* was introduced in Java as part of a trial of green manure crops for timber plantations. Its introduction was based on only two seed samples from Guatemala. All existing plantations in Indonesia are derived from this first introduction. In Central America the species did not receive any attention until its success as a firewood crop in Indonesia became known in the early 1980s. The species in Central America has a wide geographic distribution and is quite variable. It seems that the seeds introduced from Guatemala to Indonesia were derived from a fast-growing, lesser branched and taller ecotype. In some trials specific calliandra accessions have been observed which produce root suckers, but this seems to be exceptional. Further provenance trials are needed to assess species variability, forage quality, and adaptability to different environmental conditions.

Prospects *C. calothyrsus* has become popular because it can readily produce high-quality fuelwood in annual coppice rotations, can be used in different farm systems as an auxiliary crop, and can grow under a wide range of soil fertility. Special attention has been given to the use of this species as an alternative to *Leucaena leucocephala* on acid lands or areas infested with *Leucaena* psyllid. Its high potential production and high protein content make it a promising fodder species to supplement low-quality forages. However, due to high tannin content, the palatability of calliandra is less than that of *L. leucocephala* or *Gliricidia sepium*. Further studies are needed to ascertain its full potential as a fodder crop, including its true nutritive value and its value as a plant for grazing. Care must also be taken that this hardy species does not become a weed.

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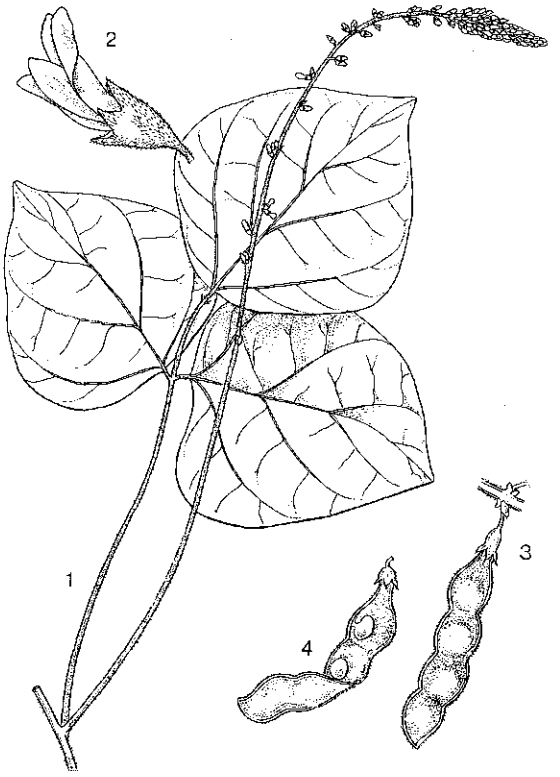
K.F. Wiersum & I.K. Rika

Calopogonium caeruleum (Benth.) Sauv.

Ann. Acad. Habana 5: 337 (1869).
LEGUMINOSAE
$2n$ = unknown
Synonyms *Stenolobium caeruleum* Benth. (1837).
Vernacular names Caeruleum calopo (En). Thailand: thua sealulium.
Origin and geographic distribution Native to Mexico, Central America and the West Indies and eastern tropical South America, *C. caeruleum* is now widespread throughout the humid tropics. It was introduced to South-East Asia in 1940.
Uses *C. caeruleum* is a forage of low palatability, but it gives good soil cover, builds up soil fertility as a green manure crop, and can be used to smother weeds such as *Imperata cylindrica* (L.) Raeuschel.
Properties Mineral concentrations in top growth usually range from 2.1–3.6% N, 0.17–0.29% P, 2.4–2.6% K and 0.91–1.05% Ca. In vitro DM digestibility was not affected by shading. It is much less palatable to animals than *C. mucunoides* Desv.



Calopogonium caeruleum (Benth.) Sauv. – 1, flowering branch; 2, flower; 3, fruit; 4, opened fruit.

Botany A sturdy, somewhat woody, twining, short-lived perennial with pubescent or glabrescent stems up to several m long, rooting at nodes when in contact with moist soil. Leaves trifoliolate, petiole up to 16 cm long; leaflets elliptical, ovate or rhomboid-ovate, (1.5–)6–9(–20) cm × (1–)4–6(–15) cm, the lateral ones oblique, pubescent above, velvety pubescent below. Inflorescences elongated many-flowered racemes, up to 50 cm long; peduncle 1–5(–17) cm long; rachis sulcate, tomentose; calyx campanulate, 5-lobed; corolla blue or violaceous, ca. 1 cm long. Pod linear-oblong, 4–8 cm × 0.8 cm, straight or curved, impressed between the seeds, pubescent. Seeds 4–8 per pod, orbiculate, 4–5 mm across, shiny brown, compressed.
In the literature, the species name is also written '*coeruleum*', but Bentham published the name as '*caeruleum*' (= blue).
Although it grows vigorously once established, growing as high as 1 m in a pure sward, its growth is not compact and it allows free aeration of the soil. When grown as a cover crop it will smother young oil palms and rubber trees unless weeded out from around the base of the trees. It is a poor seeder in the first and second years after establishment.
Ecology *C. caeruleum* is adapted to the humid tropics but it is more drought-tolerant than *C. mucunoides* and *Pueraria phaseoloides* (Roxb.) Benth. It grows better in cooler conditions than centro (*Centrosema pubescens* Benth.) and in the elevated tropics can grow up to an altitude of about 800 m. It is very tolerant of shading. *C. caeruleum* is adapted to a wide range of soil textures and soils with a pH(H_2O) as low as 4.0. It grows best on well-drained soils.
Agronomy *C. caeruleum* is usually established from seed, sowing at the start of the wet season into a seed-bed prepared mechanically or by hand. Fertilizing and weeding aids establishment and development of the sward. However, the use of *C. caeruleum* seed is restricted by its high cost, which is a reflection of its poor seed production. It can be vegetatively established from stem cuttings, but only about 5% of the cuttings may establish. The best success is obtained from using older stem material, 50 cm or more away from the terminal growing point. Establishment from stem cuttings can be improved by hormone treatments to induce root development. It is slower to establish than tropical kudzu (*Pueraria phaseoloides*) and may take 20 months to establish a complete ground cover. It persists longer under the increasing shade of

young oil palm or rubber than most other legumes. In Malaysia it still produced DM 1 t/ha 5 years after planting.

Although *C. caeruleum* is a productive species, especially under shade, it has very limited value as a forage because of its low palatability. Experience in Malaysia and northern Australia has shown that it can become dominant in grazed pastures because it is virtually ungrazed, whereas the companion species are selectively grazed. It is probably eaten slightly more during the dry season, when there is less opportunity for animals to graze selectively. The herbage can be harvested and then spread onto the soil and ploughed in as a green manure crop, but it is better to leave the sward untouched and to allow leaf fall and decomposition. Leaf fall can be as much as 7 t/ha of DM per year.

No major diseases or pests have been reported on this species in South-East Asia.

It is one of the most productive herbaceous legumes, with DM yields of 10 t/ha in the year of establishment and up to 15 t/ha in following years. Under low light intensities of 6–16% of full sunlight under an oil palm canopy, *C. caeruleum* outyielded other herbaceous legumes such as *Stylosanthes guianensis* (Aublet) Swartz, *Macroptilium atropurpureum* (DC.) Urban, *Centrosema pubescens* Benth., *Desmodium heterocarpon* (L.) DC. ssp. *ovalifolium* (Prain) Ohashi, *Desmodium heterophyllum* (Willd.) DC. and *Calopogonium mucunoides* with DM yields of 1–1.5 t/ha. It also had the best survival rate. No information is available on its use as hay or silage, although it is possible that such treatment could increase its palatablity.

Genetic resources and breeding Limited collections of *C. caeruleum* are held by CIAT (Colombia) and ATFGRC (CSIRO, Australia). There are no breeding programmes on this species.

Prospects The potential of *C. caeruleum* as a forage is limited unless genotypes of better palatability can be identified. The potential benefits of using this species to improve soil fertility in farm systems involving forage production could be explored further. It is likely to become a standard component of mixed cover crops in plantation crops.

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C.P. Chen & Y.K. Chee

Calopogonium mucunoides Desv.

Ann. Sci. Nat. Sér. 1, 9: 423 (1826).

LEGUMINOSAE

$2n = 36$

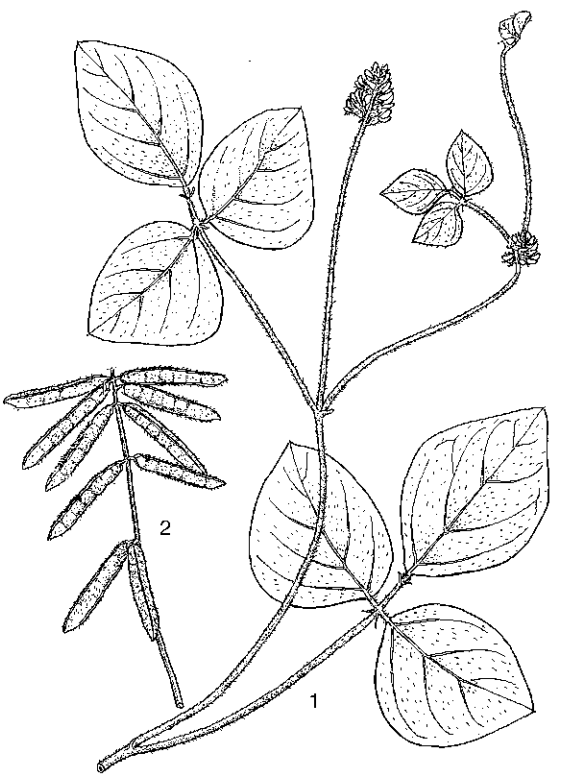
Vernacular names Calopo (En). Indonesia: kacang asu (Javanese), kalopogonium (Indonesian). Philippines: santing (Sulu), karaparapak sara naw (Mar.). Thailand: thua karopo.

Origin and geographic distribution Calopo is indigenous to tropical America and the West Indies. It was introduced in the early 1900s to tropical Africa and Asia. Calopo was used as a green manure and cover crop in the central and eastern parts of Java from 1922 onwards. It was brought to Malaysia soon after that as a cover crop for rubber. It became naturalized in Malaysia and Indonesia, and has spread to most humid tropical areas of the world. It was introduced to Australia in 1930, but has not been widely used there.

Uses Calopo is used as forage for animals during the latter part of the dry season, and is an important cover crop for plantations and as green manure for soil improvement. It is well recognized as being a valuable pioneer legume to protect the soil surface, reduce soil temperature, fix nitrogen and improve soil fertility.

Properties Considering that calopo is widely used as a green manure crop, there are few published data on its chemical composition. Nitrogen percentages of 2.6–3.8% have been recorded, but lower values can be anticipated in older, stemmy material. Calopo forage is not very palatable to cattle, but animals are forced to eat it during the dry season when little green feed is available. Its low palatibility is usually ascribed to the abundance of hairs on the stems and leaves. There are 70–75 seeds/g.

Description A vigorous, creeping, twining or trailing herb, up to several m long, forming a tangled mass of foliage 30–50 cm deep, with densely pilose stems with long spreading ferruginous hairs. Leaves trifoliolate, petiole up to 16 cm long, pilose; leaflets elliptic, ovate or rhomboid-ovate, (1.5–)4–10(–15) cm × (1–)2–5(–9) cm, the laterals oblique, adpressed pilose or pubescent on both surfaces. Inflorescence a slender raceme, up to 20 cm long, peduncle 0–17 cm long, ferruginous pilose; flowers in fascicles of 2–6, blue or purple; calyx campanulate, unequally 5-lobed; corolla with emarginate standard, about 1 cm long. Pod linear-oblongoid, 2–4 cm × 3.5–5 mm, straight or curved, softly pilose with coarse reddish-brown hairs, impressed between the seeds. Seeds 3–8, compressed squarish, 2–3 mm long, yellowish or reddish-brown.



Calopogonium mucunoides Desv. – 1, flowering branch; 2, fruiting branch.

Growth and development Calopo grows rapidly, able to form a dense entangled sward in 4–5 months after sowing, but the plants are short-lived and may only persist for 1–2 years. When grown in a mixture with puero (*Pueraria phaseoloides* (Roxb.) Benth.) and centro (*Centrosema pubescens* Benth.), calopo is the first one to become established but also the first one to be shaded out. Long-term persistence is through recruitment of new plants from seedlings. Flowering in calopo is initiated by short days. It is self-pollinated and seeds freely.

Other botanical information The name 'Tortilla' is used to indicate seed of calopo sometimes harvested from naturalized stands in the Adelaide River area of the Northern Territory (Australia). It was at one time thought to have been a long-term locally adapted ecotype, but it is now believed to have come to the area as a contaminant in puero seed from Queensland which had been sown in the late 1960s at the Tortilla Flats Research Farm. 'Tortilla' is likely to be similar to Queensland commercial material, which is rarely harvested and has never been allotted a cultivar name.

Ecology Calopo is suited to the hot humid tropics with an annual rainfall exceeding 1250 mm. It grows at altitudes from sea-level to 2000 m but is more suited to altitudes from 300–1500 m. It is moderately drought tolerant but may die out if the dry season is prolonged. Vigorous growth occurs on soils of all textures, even with a low pH(H_2O) range of 4.5–5. As a result of its self-seeding nature and twining growth habit, calopo is well adapted to a range of ecological conditions. It can be used in a mixture of species provided it does not become too dominant.

Calopo is poorly adapted to shade, with top growth, root growth and nodulation declining markedly with decreasing light intensities. This may be attributed to the 'non-plasticity' of leaves under shade as compared with other shade-tolerant plants such as *Desmodium heterocarpon* (L.) DC. ssp. *heterocarpon* var. *ovalifolium* (Wallich ex Prain) Rugayah, *Centrosema pubescens* Benth., and *Calopogonium caeruleum* (Benth.) Sauv. Under low light intensitites (< 20%), calopo leaves are reduced in size by 70% compared with leaves in full sunlight. In contrast, centro and *C.*

caeruleum leaves are reduced by only 10–25% and leaves of var. *ovalifolium* are 20% larger under such a low light intensity.

Propagation and planting Calopo is normally propagated by seed. Seed is sown at 1–3 kg/ha, usually drilled in rows when sown into new plantations or broadcast in stands to be used for forage production. After seed is broadcast, the seed-bed should be rolled to improve establishment. Newly harvested seed usually has a high percentage of hard seed (> 75%). Consequently, mechanical scarification, soaking in concentrated sulphuric acid for 30 minutes, or soaking in hot water (75°C) for 3 minutes is recommended. Although calopo stems root at the nodes when in contact with moist soil, there is usually poor establishment of stem cuttings placed directly into soil. Seeds are usually not inoculated, as this species nodulates promiscuously with native rhizobia. If inoculum is applied then cowpea strains such as the Australian CB 756 are used. When planted as a cover crop in plantations, it is usually sown in a mixture with other legumes such as *Centrosema pubescens*, *Calopogonium caeruleum* and *Pueraria phaseoloides* with 1–3 kg/ha of calopo in a total mixture of 12–15 kg/ha of legume seed. When sown for forage production, calopo has been successfully used in mixtures with stoloniferous grasses, such as molasses grass (*Melinis minutiflora* Beauv.) and Rhodes grass (*Chloris gayana* Kunth), and with tussock grasses such as setaria (*Setaria sphacelata* (Schumacher) Stapf & Hubbard ex M.B. Moss). Good results have been obtained from oversowing it into existing stands of pangola grass (*Digitaria eriantha* Steud.) which have been harrowed.

Husbandry Because of the vigorous growth of calopo, a large amount of leaf litter falls onto the soil. Fertilization with ground dolomite and Mo in acidic soils results in higher yields. Use of pre- and post-emergence herbicides reduces weed infestation and results in faster establishment of calopo. The effect of calopo and associated legumes in improving soil fertility may last for 14–16 years. If calopo is grazed, it is advisable to use rotational grazing with rest periods of from 8–12 weeks when calopo growth is erect rather than prostrate. With calopo as cover in young oil palm and rubber plantations, regular slashing is needed to prevent the cover from overgrowing the trees.

Diseases and pests Calopo is susceptible to viruses in Guatemala, Costa Rica and Panama. Although leaf-eating caterpillars and beetles have been observed on calopo in Malaysia, they have not been a serious problem.

Harvesting Whether grazed or cut and fed, calopo is often refused by cattle although they eat it less reluctantly during the dry season. It is usually cut by hand and is seldom conserved as hay or silage.

Yield When pods are mature, peak DM yields of up to 14 t/ha can be obtained in a single cut. Lower yields of 4–6 t/ha per year are obtained when calopo is cut every 9–12 weeks. Seed yields of 200–300 kg/ha have been recorded.

Genetic resources Collections of calopo are held at CIAT (Colombia) and ATFGRC (CSIRO, Australia).

Breeding There are no breeding programmes on calopo.

Prospects Low palatability is perhaps the main reason why interest in this species as a forage plant has faded during the last decade. However, this low acceptability may open up opportunities for incorporating calopo into forage systems as a way of improving soil fertility and the growth rate and quality of pastures.

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C.P. Chen & A. Aminah

Canavalia ensiformis (L.) DC.

Prodr. 2: 404 (1825).
LEGUMINOSAE
$2n = 22$

Synonyms *Dolichos ensiformis* L. (1753), *Canavalia gladiata* (Jacq.) DC. var. *ensiformis* (L.) Benth. (1859–1862).

Vernacular names Jack bean, horse bean (En). Fève Jacques (Fr). Indonesia: kacang parang (Malay), kara bedog, kacang mekah (Sundanese). Malaysia: kacang parang putih. Philippines: habas (Tagalog), lagaylay (Visaya), badang-badang (Ilokano). Cambodia: tiehs. Laos: thwâx fak ph'aaz. Thailand: thua khaek. Vietnam: (cây) dâu ra, dâu tây, dâu ngua.

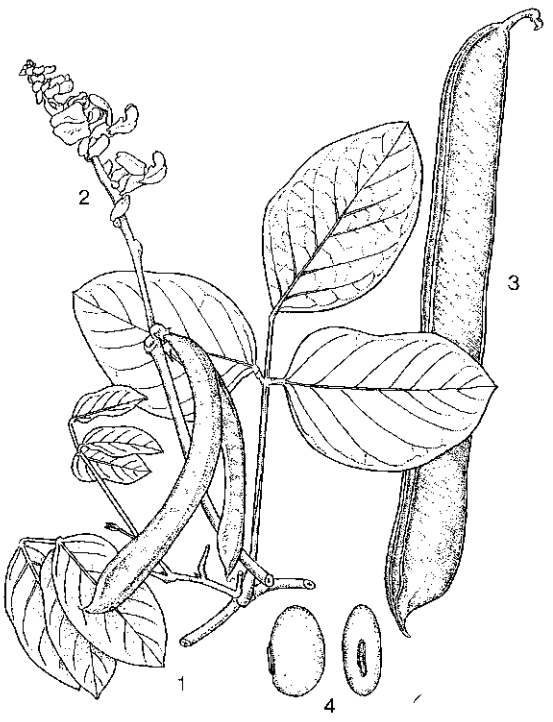
Origin and geographic distribution Jack bean originates from South and Central America. It is widely cultivated in the southern United States since prehistoric times, and has been discovered in archaeological sites in Mexico dated 3000 BC. Now it is commonly cultivated throughout the tropics.

Uses Jack bean is a forage for ruminants and is grown extensively as a cover crop or green manure crop in rotation with a wide range of crops. As a forage it is usually sun-dried before feeding to cattle, but may also be made into silage. Heat-treated ripe seed, when ground, is used as a concentrate in cattle and poultry rations. Half-ripe seeds are mixed with sorghum for feeding cattle in Hawaii. Young seeds and pods may be used in human nutrition as a vegetable but only when cooked. Soaked and roasted ripe seeds are eaten as a delicacy in Indonesia, but outside Japan and tropical Asia, the species is now little grown as a food crop for humans. The seed is sometimes roasted and ground to make a coffee substitute. In Indonesia flowers and young leaves are steamed and used as a flavouring.

Urease extracted from the seed is used in analytical laboratories. In Indonesia and China, heat-treated seeds and pods are used as medicine, and it has been suggested that some of the chemical constituents of jack bean might be used for medicinal purposes or for control of pests.

Properties The forage is not especially palatable, but cattle can acquire a taste for it; dry forage is more palatable than fresh. Nitrogen concentrations of the forage and seed are 2.2–2.6% and 3.8–5.7% respectively. Non-ruminants fed on the seed show reduced weight gains, due mainly to the toxic amino-acid canavanine, which is an antimetabolite of arginine. Lectins (concanavalin A and B) are present in the seed and can inhibit the absorption of nutrients. Heat treatment of the seed overcomes the toxic effects. Seed weight ranges from 0.85–1.65 g/seed.

Description Annual or short-lived perennial climber with a deep root system, bushy, twining or prostrate, up to 2–3 m long. Stems become somewhat woody with age; branching is at lower nodes and some secondary branching also occurs. Leaves alternate, 3-foliolate; petiole 11–17 cm long, rachis 3–4.5 cm; leaflets ovate-elliptic, 5–20 cm × 3–12 cm, acute or rounded and mucronate at top, sparsely covered with short hairs on both surfaces, venation raised and reticulate. Flowers mauve to purple, or sometimes white, borne on an axillary raceme with swollen nodes each bearing 1–3 flowers on pedicels 2–5 mm long; peduncle 10–35 cm, raceme up to 20 cm long; calyx campanulate, 5-lobed, sparsely pubescent; corolla with rounded standard, 2.7 cm long, rose to purplish. Pod oblongoid, laterally compressed, 15–35 cm × 3–3.5 cm, containing 8–20 seeds, each valve with a sutural rib and an additional rib just below it. Seed oblongoid, laterally compressed, ca. 21 mm × 15 mm × 10 mm, ivory or white, the hilum brown, 6–9 mm long.



Canavalia ensiformis (L.) DC. – 1, branch with leaves; 2, flowering and fruiting branch; 3, fruit; 4, seeds.

Growth and development Germination is epigeal; the juvenile leaves are fully expanded about a week after sowing. Hard-seededness has not been recorded. Early growth is slow, but after establishment the species is capable of rapid growth. Jack bean flowers 50–110 days after sowing, depending

on the accession and on climate and soil conditions. The time from sowing to seed harvest is normally about 170 days. In temperate regions it flowers in summer or autumn; in the tropics it flowers throughout the year. In temperate areas beans remain unaffected when light frost kills the foliage.

Other botanical information In the literature on *Canavalia* Adans., confusion exists on the identity of 3 closely related species: *C. ensiformis* (jack bean), *C. gladiata* (Jacq.) DC. (sword bean) and *C. virosa* (Roxb.) Wight & Arnott. *C. ensiformis* and *C. gladiata* are cultivated taxa, possibly derived from the wild (occasionally cutivated) *C. virosa*. These 3 taxa are considered as one species by some, and by others they are kept separate. A thorough taxonomic revision is needed to bring clarification. Most recent floras separate the 3 taxa as follows:

- *C. ensiformis*: standard ca. 2.5 cm long, rose to purple; pod up to 35 cm × 3.5 cm; seed ivory or white, hilum less than half as long as the seed.
- *C. gladiata*: standard ca. 3.5 cm long, white; pod up to 40 cm × 5 cm; seed red or red-brown, rarely white, hilum more than half as long as the seed.
- *C. virosa*: standard ca. 3 cm long, whitish veined mauve; pod up to 17 cm × 3 cm; seed brown or red-brown, marbled with black, hilum ca. half the length of the seed.

There are several cultivars and accessions of jack bean which differ in their growth habit. They are being tested and produced in Venezuela (Universidad de Venezuela, Facultad de Agronomía, Maracay). The bushy types are early-flowering, better adapted to low-rainfall areas and have low capacity for forage production. The viny or twining types are late-flowering but are better adapted to more humid areas and produce greater amounts of forage.

Ecology Jack bean is well adapted to the humid tropics, yet is hardy and can withstand periods of drought. Consequently, it grows in regions with annual rainfall ranging from 700–4000 mm. Although jack bean is a lowland plant, it is also grown at altitudes up to 1800 m. It grows best in full sunlight but has moderate shade tolerance. It is tolerant of a wide range of soil conditions including acid soils and highly-leached infertile tropical soils. It is less affected by waterlogging or salinity than other pulses.

Propagation and planting Jack bean is propagated by seed in a range of densities from 30 cm × 30 cm to 100 cm × 150 cm at shallow depth. For green manure crops, it is sown at a rate of about 50 kg/ha in rows 0.6–1 m apart. With accurate placement, sowing rates of 10 kg/ha will suffice. Sowing at the start of the wet season is preferred in regions with about 1000 mm annual rainfall, but in more humid environments sowing should be delayed until the end of the wet season.

As a pulse, jack bean may be grown with other crops such as maize or cassava. Although the grain yield of jack bean is then likely to be reduced, sometimes by as much as 50 %, the total productivity of the system is improved.

Husbandry Inoculation is normally unnecessary as jack bean nodulates promiscuously and effectively with rhizobia present in most soils. Twining forms grown for grain are sometimes grown on trellises since the improvement in light utilization improves pod yield and the pods are kept off the ground.

Diseases and pests Jack bean is little affected by diseases and pests. A fungal root disease and a stem-borer sometimes cause serious losses. *Platiprosopus acutangulus*, a leaf-eating chrysomelid beetle, may cause serious problems during the early growth of the crop. Stored seed is quite resistant to pests and diseases, but can become infested with *Tricorinus tabaci*.

Harvesting Forage and seeds are mostly harvested by hand. Although flowering is fairly well synchronized, some green pods may still be present at harvest time, especially if water is still available.

Yield Forage DM yields of up to 23 t/ha have been obtained in Hawaii and green fodder yields may exceed 50 t/ha. Grain yields average 800–1000 kg/ha (range: 400–1500 kg/ha, depending on rainfall distribution) but in experimental plots yields as high as 6000 kg/ha have been recorded in highly intensive agriculture.

Fresh forage is not palatable to ruminants and is eaten only in small amounts, although cattle gradually become more accustomed to it. Consequently, it is usually fed after drying as this increases intake. Ruminants can consume small quantities of untreated grain or meal without ill effects, but larger quantities can be toxic. Affected animals have a clear nasal discharge, become lame and cannot rise. Mucous membranes become muddy in appearance and clear urine is passed more frequently than usual. Heat-treatment overcomes this toxicity. Meal prepared from jack bean seed is more palatable to cattle if molasses is added to it. For non-ruminants, extensive boiling with one or two changes of water and peeling off the seed-coat is required before the mature seeds are

edible. The beans may also be processed to produce a protein concentrate for use in formulated foods.

Genetic resources There are very limited genetic resources available of this species. Germplasm collections are available at the Faculty de Agronomía of the Universidad de Venezuela (Maracay, Venezuela) and the USDA (Georgia, United States).

Breeding Although largely self-pollinating, some 20% of flowers may be cross-pollinated by insects. Some selection for lines with low concentrations of canavanine has been carried out in Venezuela. Also, some cultivars have been selected with climbing or dwarf attributes.

Prospects As a forage crop, prospects for jack bean are limited since it is of only mediocre acceptability to ruminants, and has toxic properties if eaten when fresh. Furthermore, other annual leguminous forages are equally or more productive. As a leguminous crop with the residue providing useful forage, the comparative freedom of jack bean from disease and pest problems and its high yield in low input systems justifies the development of jack bean as a sole crop or in intercropping systems as a vegetable or a pulse crop.

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Y.K. Chee, J.B. Hacker, L. Ramirez & C.P. Chen

Cenchrus ciliaris L.

Mant. pl. alt.: 302 (1771).

GRAMINEAE

$2n$ = 32, 34, 36 (tetraploid), 40, 52, 54

Synonyms *Pennisetum cenchroides* Rich. (1805), *P. ciliare* (L.) Link (1827).

Vernacular names Buffelgrass (Australia) (En). African foxtail (Am). Philippines: kawit-kawitan (Tagalog), sagisi (Ilokano). Thailand: ya-bupfen.

Origin and geographic distribution Buffulgrass naturally occurs throughout Africa and from Arabia and the Middle East to India. It has been widely introduced and is naturalized throughout the semi-arid and sub-humid tropics and subtropics

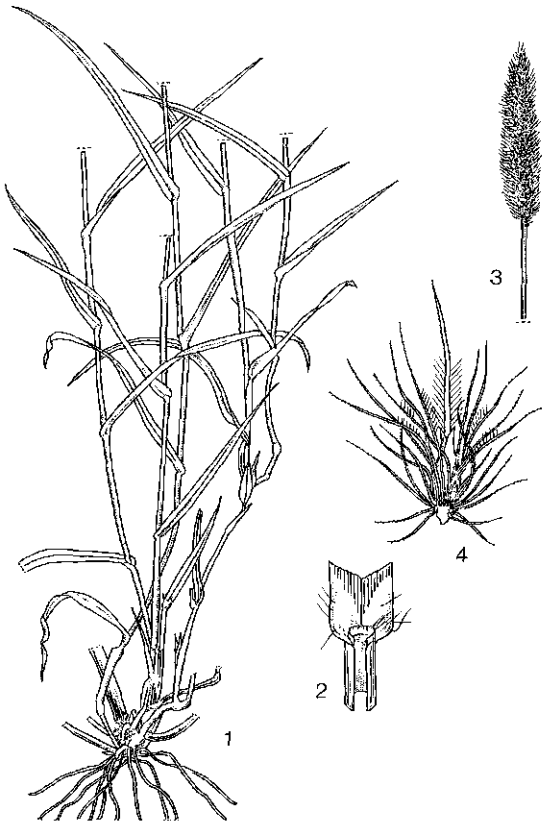
Uses The main use of buffelgrass is as a pasture grass for ruminants and horses. It is usually grazed, but can be used as silage or hay.

Properties The N concentration of green buffelgrass ranges from 1.0% to 3.0% of the dry matter, depending on growth stage, soil fertility, fertilization rate and cultivar. Phosphorus concentration is usually adequate for animal requirements and higher than that of most other tropical grasses, with published values up to 0.65% of the DM. The DM digestibility of green buffelgrass leaves ranges from 65–70%. Buffelgrass is highly palatable to all kinds of grazing animals.

Horses eating this grass can develop a calcium deficiency syndrome ('bighead disease') caused by soluble oxalate (concentrations of 1–2% of the DM have been recorded). Variation in the diet or supplementation with limestone or dolomite will control it. Ruminants are able to break down the oxalate in the rumen, although occasionally toxicity symptoms have been recorded with sheep and cows.

There are 90–1200 fascicles/g. A fascicle is a cluster of spikelets which may contain one to five caryopses, making up 25–30% of the fascicle weight.

Description A tufted or rarely spreading perennial, often with short rhizomes. Culm 10–150 cm tall, erect or ascending, branching and rooting at the nodes. Leaf-sheath compressed; ligule a hairy ring, up to 1.5 mm tall; leaf-blade linear, 3–30 cm × 2–13 mm, glabrous, but hairy at the mouth. Inflorescence a cylindrical to ovoid panicle, 2–14 cm × 1–2.6 cm, grey, purple or straw-coloured, bearing numerous clusters of spikelets (fascicles), each fascicle surrounded by an elongated involucre of bristles 6–16 mm long; rachis angular and puberulous; inner bristles much exceeding the spikelets, somewhat flattened and connate at the base, ciliate below, one of them longer and stouter than the rest; outer bristles shorter, filiform; spikelets 1–4 per cluster, acutely lanceolate, 2–5.5 mm long, sessile; glumes distinct, acute, upper ones up to as long as the spikelet; lemmas subequal, 2.5–5 mm long, minutely awned. Caryopsis ovoid, 1.5–2 mm × 1 mm.



Cenchrus ciliaris L. – 1, habit; 2, ligule; 3, inflorescence; 4, spikelet with involucre.

Growth and development Buffelgrass seed germination rate can be as low as 15% soon after harvest, when the caryopses remain within the fascicles, but over 90% germination has been measured. Naked caryopses have a higher germination rate, but seedlings are then more sensitive to drought. Glumes contain water-soluble germination inhibitors, which is the main cause of the seed dormancy.

Germination rate improves with storage of 6–18 months. Seedling growth rate is relatively slow. Buffelgrass has a deep root system with coarse roots. Maximum rate of tiller formation occurs just after first inflorescence appearance; tillering is sustained at a reduced rate during seed maturation. Buffelgrass is an early flowering short-day plant with an optimal photoperiod of 12 hours.

Other botanical information Most cultivars are developed in Australia: 'Biloela' (tall growing, rhizomatous, greyish leaves), 'Nunbank' (similar to 'Biloela'), 'Boorarra' (similar to 'Biloela', but less rhizomatous), 'Tarewinnebar' (similar to 'Biloela', but with green leaves), 'Molopo' (tall growing with a lower tiller density, more rhizomatous and distinctly glaucous leaves, more greyish), 'Lawes' (similar to 'Molopo'), 'Gayndah' (short, semi-prostrate to ascending, non-rhizomatous), 'American' (short, similar to 'Gayndah'), 'West Australian' (short, non-rhizomatous, least productive, highly palatable, most drought tolerant). Cultivars are very homogeneous, because buffelgrass is an apomict, although there is a small percentage of sexual seed production. 'Higgings grass' was developed from a single sexual plant in Texas. There are also some African cultivars.

Ecology Buffelgrass grows best in climates with 300–750 mm annual summer-dominant rainfall. Nevertheless it also grows well in the Philippines on 1600–2900 mm annual rainfall. Optimum temperature is about 35°C and minimum temperature between 5–16°C. Buffelgrass prefers free-draining, light-textured neutral to alkaline soils ($pH(H_2O) \geq 6.0$). 'American' is more tolerant to acid soils than the other cultivars. The more rhizomatous cultivars also grow well on many clay soils.

Buffelgrass is sensitive to soils containing high levels of Al, has a moderate tolerance to salinity and is intolerant of flooding. It tolerates fire.

Propagation and planting Seed dormancy can be broken by high temperatures (60°C) for 4–12 weeks, by removal of the hulls of the fascicle by hammermilling, or by storing the seed for up to 18 months. Treatment of the seed with sulphuric acid also improves germination. Seeds are not easy to clean; hammermilling to pulverize stems and bristles improves seed handling and sowing. The seed can be sown in soil without or with light tillage, on the surface followed by rolling, but germination is best when sown at a depth of 1–2 cm. Suggested seed rates vary from 0.5 kg/ha of caryopses to 12 kg/ha of fascicles; good results have been obtained with 4 kg/ha of fascicles.

Sowing whole fascicles is preferred to sowing naked caryopses. In India vegetative propagation from tuft splits or replanting of young plants sown in a nursery has also been advocated.

Buffelgrass can be grown in association with *Stylosanthes hamata* (L.) Taub., *Macroptilium atropurpureum* (DC.) Urban, *Chloris gayana* Kunth and *Panicum maximum* Jacq. var. *trichoglume* Robijns.

Husbandry Buffelgrass grown as a sole crop is usually not fertilized, although it responds well to P and N fertilizer.

When grown in association with a legume, fertil-

ization with superphosphate is beneficial on poor soils. Irrigation is not usual or necessary as the grass is drought tolerant.

Diseases and pests Buffelgrass is quite free of diseases or pests. In wetter areas the seed can be destroyed by ergot or smut.

Harvesting First harvest of buffelgrass can be 4–6 months after sowing by cutting or grazing. Suggested cutting height is about 7 cm above ground level, with 6–8 week intervals. For hay, buffelgrass is usually cut in the early flowering stage. Buffelgrass can be grazed continuously or rotationally.

Yield Dry matter yields range from 2–9 t/ha per year without fertilizer and up to 24 t/ha per year with complete fertilizer. Seed production depends on cultivar and growing conditions and recorded (fascicle) yields range from 150–500 kg/ha. Mean liveweight gains of steers of 160 kg/annum grazing buffelgrass pastures with *Macroptilium purpureum* at 1 steer/ha have been recorded in a subhumid subtropical climate in south-east Queensland.

Genetic resources A large collection of buffelgrass germplasm is held at ATFGRC (CSIRO, Australia).

Breeding The apomixis of buffelgrass is linked with pseudogamy. Hybridization is possible because of the discovery of a rare fertile female. Male pollen from the apomictic lines are used to fertilize the rare fertile female with consequent release of much variation. A selection programme is in progress at CSIRO, Brisbane, Australia with the objectives of developing cultivars of better quality forage and better spring vigour.

Prospects Buffelgrass has little prospect in humid climates, but can play a major role in forage production in areas with a dry season in South-East Asia.

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L. 't Mannetje & S.M.M. Kersten

Centotheca latifolia (Osbeck) Trinius

Fund. Agrost.: 141 (1820).

GRAMINEAE

$2n = 24$

Synonyms *Holcus latifolius* Osbeck (1757), *Cenchrus lappaceus* L. (1763), *Centotheca lappacea* (L.) Desv. (1810).

Vernacular names Indonesia: jukut kidang (Sundanese), suket lorodan (Javanese), karetet lempad (Alfuru). Malaysia: rumput lilit kain, rumput darah, rumput temaga. Papua New Guinea: kuang. Philippines: baylu-patong (Tagalog), andudukot aridekdiket (Bikol). Thailand: ya khon moi maemai, ya-enieo. Vietnam: co' móc.

Origin and geographic distribution *C. latifolia* is widely distributed in the tropics of the Old World, from Africa to Polynesia and Australia. It is abundant in southern Thailand and in Peninsular Malaysia.

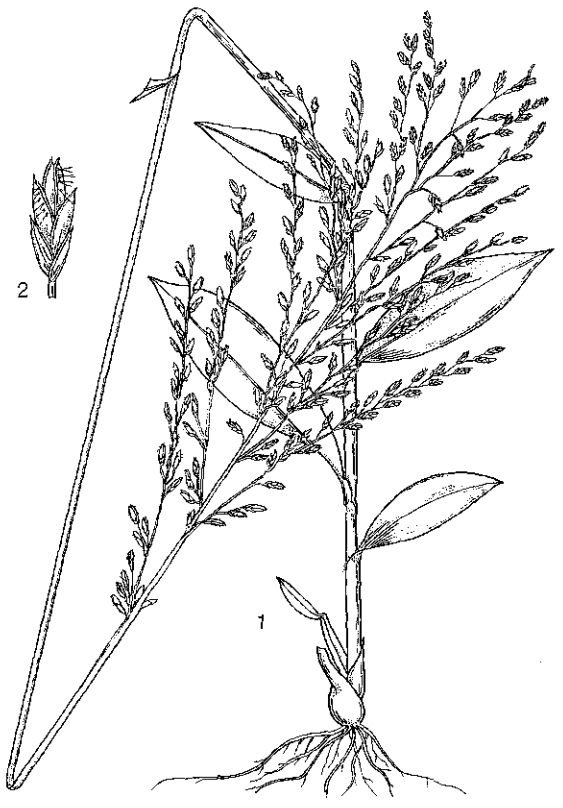
Uses *C. latifolia* is grazed by village cattle and regarded as a good fodder.

Botany A perennial rosette grass with erect culms up to 1.25 m tall. Leaf-sheath closely striate, 4–6 cm long; leaf-blade elliptical or ovate-oblong, 4–30 cm × 0.8–3.5 cm, hairy to glabrescent; ligule membraneous, 2–3 mm tall. Inflorescence a branching terminal panicle, up to 40 cm long; spikelets 2–3-flowered, about 8 mm long; lemma of upper floret(s) ca. 3 mm long, 5-nerved with 2 prominent rows of bulbous-based retrorse spiny hairs on either side of the back. Caryopsis about 1 mm long, dark brown, glossy.

Adjacent branches from inflorescences become entangled at maturity because of the reflexed hairs on the lemmas. These hairs also adhere to hair or fur of passing animals, thus providing effective dispersal of the seeds.

Some spikelets seem to be viviparous; the upper lemmas each grow into a small leaf-blade and when the whole spikelet eventually falls, it has the ability to grow into a new plant.

Flowering occurs throughout the year. Often seedlings can be found around older plants.



Centhotheca latifolia (Osbeck) Trinius – 1, flowering plant; 2, spikelet.

Ecology *C. latifolia* grows from sea-level to 1500 m altitude in humid shady places receiving over 2000 mm of rain per year. The species is often found on disturbed sites along shaded roads, fields and plantations but is natural in swamps and open places in rain forests and thickets.

Agronomy *C. latifolia* is propagated vegetatively or by seed. It is moderately palatable and is usually eaten by grazing stock but can be cut and fed to animals. Animals avoid eating the seed heads. Regrowth is very slow so frequent defoliation is not recommended.

Genetic resources and breeding It is unlikely that substantial germplasm collections of *C. latifolia* are being maintained.

Prospects *C. latifolia* is shade tolerant and should be evaluated for its suitability in agroforestry systems.

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C. Manidool

Centrosema acutifolium Benth.

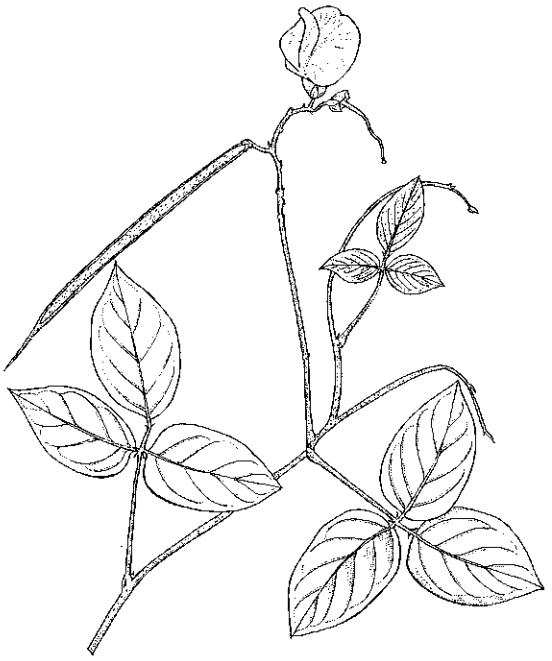
Comm. legum. gen.: 54 (1837).
LEGUMINOSAE
$2n = 20$?

Origin and geographic distribution The origin of *C. acutifolium* is in tropical America, restricted to 4–6°N in Colombia and Venezuela, and in central-west and south-east Brazil. A cultivar and several experimental lines have been spread for testing from South America to other tropical regions, including South-East Asia.

Uses *C. acutifolium* is used as forage for ruminants in grazed pastures or in cut-and-carry systems.

Properties *C. acutifolium* is similar to centro (*C. pubescens* Benth.) in several regards, including nutritive value. Depending on plant age, N concentrations in leaves range from 3.5–5.0%, and in vitro DM digestibility from 45–75%. Phosphorus concentrations in leaves range from 0.14–0.27%, and Ca from 0.38–1.13%. There are 15–20 seeds/g.

Description A perennial, trailing-twining herb; stems slender, pubescent, with tendency to root at nodes. Leaves trifoliolate, young leaflets distinctly purplish; stipules deltoid-acuminate, pubescent; petioles and petiolules pubescent, reddish at their base; leaflets ovate to ovate-lanceolate, apically acuminate, membranaceous, puberulous to subglabrous on both surfaces; central leaflet symmetrical, 5–8.5 cm × 3–3.5 cm; lateral leaflets asymmetrical, 4–7.5 cm × 2.5–4 cm. Inflorescence an axillary raceme with up to 24 flowers inserted by pairs along the rachis; peduncle conspicuously long, up to 24 cm, pubescent; flower papilionaceous, subtended by a pair of short, ovate-acuminate bracteoles; calyx campanulate, 5-toothed, pilose, carinal and lateral teeth short; petals light violet; standard orbicular emarginate, 28–35 mm × 32–40 mm, pubescent outside. Pod linear, straight to slightly bent, up to 20 cm long, beaked, scabrid, containing 10–15 seeds, dehiscent. Seed cylindrical, 5–7 mm × ca.



Centrosema acutifolium Benth. – flowering and fruiting branch.

3 mm, greenish-yellow with dark, fine mottles.

Growth and development *C. acutifolium* flowers late in the season, and this can reduce seed production in years with an early onset of the dry season. Seed yields are, therefore, often low, but under adequate soil-moisture conditions, seed production potential is high.

Other botanical information *C. acutifolium* has only recently been rediscovered. Germplasm now known to be *C. acutifolium* was, until recently, frequently referred to as *Centrosema* sp., *Centrosema* sp. nov., or *Centrosema* new sp. No 2. There are two morphologically and physiologically distinct forms of *C. acutifolium* related to their geographical origin: (1) var. *orinocense* nom. nud. from a small distribution niche in Colombia and Venezuela, and (2) var. *matogrossense* nom. nud. from central-west Brazil. The species description given above refers to var. *orinocense;* it is represented by cultivar 'Vichada' recently released in Colombia.

C. acutifolium is closely related to *C. pubescens* Benth. and the species are morphologically very similar. The main characteristics that distinguish *C. acutifolium* are: (1) the purplish colour of young leaflets, (2) the short bracteoles and calyx teeth, (3) the scabrid pod indumentum, and (4) the cylindrical seeds.

Ecology *C. acutifolium* is best adapted to sub-humid, tropical environments with 1000–2500 mm rainfall per year and a distinct dry season. It tolerates up to 5 dry months. Var. *orinocense* requires well-drained, light-textured soils, whereas var. *matogrossense* grows particularly well on heavier soils, including those with seasonal drainage problems. *C. acutifolium* tolerates soil acidity and toxic levels of Al and Mn very well; its nutrient requirements are low; its shade tolerance is moderate.

Propagation and planting *C. acutifolium* seed is drilled in rows or broadcast, alone or simultaneously with a grass, or strip-sown into an existing grass-sward at a rate of 3–4 kg/ha. Mechanical or acid-scarification of seed is necessary in order to overcome hard-seededness. Although it can nodulate from native cowpea rhizobia, inoculation with a *Bradyrhizobium* strain of known effectiveness is recommended. Grasses suitable for association with *C. acutifolium* are bunch grasses such as guinea grass (*Panicum maximum* Jacq.) on fertile soils, or gamba grass (*Andropogon gayanus* Kunth) on infertile soils. However, successful associations have also been obtained with the stoloniferous *Brachiaria dictyoneura* (Fig. & De Not.) Stapf.

Husbandry Fertilization with P and K enhances establishment of *C. acutifolium* on most tropical soils. Despite the legume's adaptation to soils of medium to low fertility, it responds well to maintenance fertilization with these nutrients. Besides maintenance fertilization, appropriate grazing management is needed to maintain an adequate legume proportion in a *C. acutifolium*/grass association. Grazing must allow sufficient seedling recruitment and/or rooting from stolons to maintain plant density.

Diseases and pests *C. acutifolium* shows good tolerance, mainly in sub-humid environments, to the major *Centrosema* diseases. It is, however, more susceptible to *Pseudomonas* bacterial blight than other *Centrosema* species. Leaf-eating insects can be a problem during dry periods.

Harvesting The legume is usually harvested by grazing but can be cut and fed to animals. Cutting intervals will depend on soil moisture and fertility; a 10–14 week cutting interval and a 10–15 cm cutting height are suggested.

Yield Wet-season DM yields on acid soils of low fertility range mostly between 1–3 t/ha per 12 weeks; on soils of somewhat better fertility they can be as high as 5 t/ha. Dry-season DM yields seldom reach 1 t/ha per 12 weeks. Year-round animal production can be improved considerably if it is

present in a pasture. For example, in association with *Andropogon gayanus*, 180 kg liveweight gain per steer per year has been measured as compared with 110 kg/steer per year from *A. gayanus* alone. The seed production potential is high; up to 700 kg/ha can be obtained.

Genetic resources A limited number of accessions of both *C. acutifolium* forms is available at CIAT (Colombia). They appear to adequately represent its natural variability.

Breeding Some exploratory cross-compatibility studies have been conducted with *C. acutifolium* and closely related species such as *C. pubescens* and *C. macrocarpum* Benth. However, there is currently no programme to improve *C. acutifolium* through breeding.

Prospects The main value of *C. acutifolium* lies in the fact that it combines the high nutritive value and drought tolerance of the closely related *C. pubescens* with adaptation to acid, low-fertility soils and good disease tolerance. For cut-and-carry systems, however, it is inferior to *C. macrocarpum* because of lower DM production.

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R. Schultze-Kraft

Centrosema macrocarpum Benth.

Ann. Nat. Hist. (Paris) 3: 436 (1839).
LEGUMINOSAE
$2n = 22, 20$

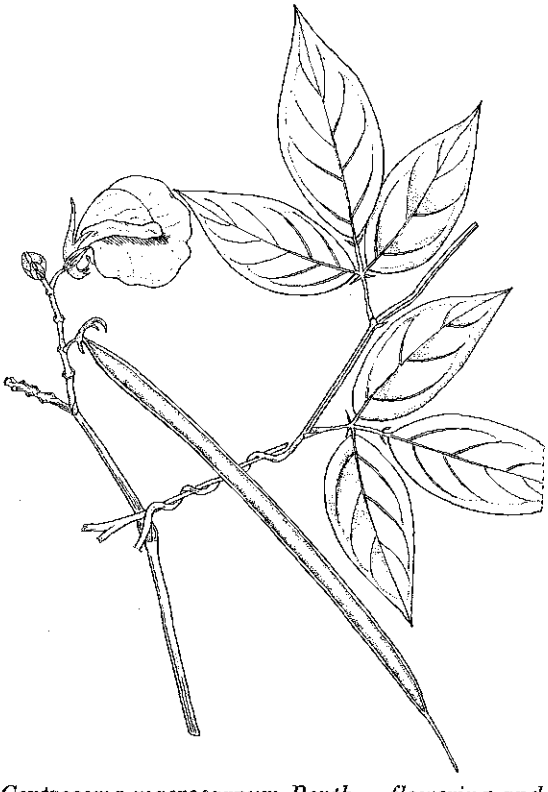
Synonyms *Centrosema lisboae* Ducke (1922).

Origin and geographic distribution *C. macrocarpum* is of tropical American origin, and occurs naturally between latitudes 20°S and 20°N; it is particularly frequent north of the equator where it extends from the extreme north of Brazil to Venezuela, Colombia and all Central American countries north to Mexico. Experimental lines have spread to many tropical countries for testing, including in South-East Asia.

Uses The main use of *C. macrocarpum* is as a forage for ruminants. In pasture systems it can be grazed in pure legume stands ('protein bank') or in a mixture with grass. It is suitable for cut-and-carry systems and can also be used as ground cover in plantation agriculture.

Properties *C. macrocarpum* provides a palatable, high-quality forage. Depending on plant age and soil fertility, N concentration in leaves ranges from 3.5–5.0% and in vitro DM digestibility from 45–70%; P concentrations are about 0.20%. There are 15–25 seeds/g.

Description A robust perennial, taprooted vine, prostrate in absence of a support; trailing stems with variable tendency to root at nodes. Stem pilose with greyish hairs when young, glabrescent, lignified at base. Leaves trifoliolate; stipules triangular, petioles and petiolules pubescent; leaflets broadly to narrowly ovate, apically acute to acuminate, rounded or slightly wedge-shaped at the base; central leaflet larger and longer petiolated than laterals, mostly 8–13 cm × 3–8 cm, papyraceous to subcoriaceous, almost glabrous to pubescent on lower or both surfaces; frequently with a light-green marking along midrib. Inflorescence an axillary raceme with up to 30 flowers inserted



Centrosema macrocarpum Benth. – flowering and fruiting branch.

in pairs along rachis; flower papilionaceous, subtended by a pair of ovate-lanceolate-falcate bracteoles; calyx campanulate, 5-teethed with carinal tooth considerably longer than others; petals showy and cream-coloured with purple centre; standard orbicular-emarginate, 3–6 cm in diameter, pubescent outside; wings and keel much smaller than standard, directed upwards. Pod linear, compressed, up to 30 cm × 1 cm, straight to slightly bent and beaked, subglabrous, containing up to 25 seeds, dehiscent. Seeds transversely oblong to rectangular, on average 5 mm × 3 mm, yellowish-brownish unicoloured, mottled or marbled.

Growth and development *C. macrocarpum* is extremely photoperiod-sensitive. Even as close as 3° to the equator, flowering is induced by shortening of daylength. Further conditions which promote flowering are the removal of accumulated biomass and the provision of support for plants to climb up.
Tripping of flowers, usually by large insects such as bumblebees, is required for seed-setting. The legume has specific *Bradyrhizobium* strain requirements.

Other botanical information There are several groups of distinct *C. macrocarpum* forms related to their geographical origin. Of these, the low-altitude ecotypes from northern South America (Colombia, Venezuela) are particularly promising as forage plants. As yet, no cultivar has been released. *C. macrocarpum* has occasionally been confounded with *C. grandiflorum* Benth.

Ecology *C. macrocarpum* is best adapted to the humid and sub-humid tropics with annual rainfall above 1000 mm. Once established, it is very drought-tolerant and can remain green during dry seasons as long as 3–4 months. It tolerates moderate shade. The legume grows well on a range of soils, provided they are well drained, but preferably on medium-textured soils. It has good tolerance of soil acidity including Al and Mn toxicity, and of low available P.

Propagation and planting *C. macrocarpum* seed is drilled in rows or broadcast, alone or simultaneously with a grass, or strip-sown into an existing grass sward, at a rate of 3–5 kg/ha. In order to break hardseededness, mechanical or acid-scarification of seed is necessary. As it has specific *Bradyrhizobium* requirements, seed must be inoculated with an appropriate strain if the legume is to be established where it has not been sown before. Grasses suitable for association with *C. macrocarpum* are bunch grasses such as gamba grass (*Andropogon gayanus* Kunth) and guinea grass (*Panicum maximum* Jacq.); however, successful associations have also been obtained with the stoloniferous *Brachiaria dictyoneura* (Fig. & De Not.) Stapf.

Husbandry Fertilization with P and K enhances establishment of *C. macrocarpum* on most tropical soils. Despite the legume's adaptation to moderately fertile to infertile soils, it responds well to maintenance fertilization with these nutrients.
When used in grazed pastures, legume persistence will be enhanced if *C. macrocarpum* is allowed to establish well before it is first grazed and if stocking rates are not excessive.

Diseases and pests *C. macrocarpum* is one of the *Centrosema* species most tolerant of diseases and pests. None of the economically important diseases of the genus (*Rhizoctonia* foliar blight, anthracnose, *Cercospora* leaf-spot, and bacterial blight) has been observed to affect *C. macrocarpum* seriously. Leaf-eating insects can be a problem during dry periods.

Harvesting The legume is usually grazed or is consumed as fresh material after mowing. When mown, cutting intervals will depend on soil moisture and fertility; 10–14 weeks is suggested as an adequate interval with a cutting height of 10–15 cm.

Yield Depending on soil-moisture conditions, DM yields on acid, moderately fertile to infertile soils range from less than 1 t to almost 5 t/ha per 12 weeks; annual DM yields in Colombia, at a site with bimodal rainfall distribution and a highly Al-saturated ultisol, averaged 15 t/ha. Under optimum conditions seed production reaches 800 kg/ha.

Genetic resources and breeding Evidence of considerable outcrossing has been observed in *C. macrocarpum*. This is a consequence of the tripping of flowers by bumblebees which also transfer pollen. Because of the large degree of outcrossing, plant populations within a given ecotype can show considerable variation. The species is well represented in the collection held by CIAT (Colombia) where a large number of quite variable accessions are available. A breeding project aimed at introducing the acid-soil tolerance of *C. macrocarpum* into *C. pubescens* Benth. is presently being concluded in Brazil.

Prospects Because of its adaptation to acid, infertile soils and drought, and its high productivity and nutritive value and good disease tolerance, *C. macrocarpum* is a valuable legume for the humid and sub-humid tropics. Its potential seems to be

greater in cut-and-carry systems and for protein banks than as a component in a grass-legume pasture, where it is sensitive to grazing mismanagement.

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R. Schultze-Kraft

Centrosema pascuorum Martius ex Benth.

Comm. legum. gen.: 56 (1837).
LEGUMINOSAE
$2n = 22$

Vernacular names Centurion (Australia) (En).

Origin and geographic distribution The origin and natural distribution of this species is in tropical South and Central America, mainly in semi-arid regions in north-eastern Brazil, Venezuela, Guyana, Ecuador, Panama, Costa Rica, Honduras, Guatemala and southern Mexico. *C. pascuorum* also occurs naturally in the Brazilian Pantanal. It has been introduced recently to Australia (Northern Territory and Queensland) and to most countries in South-East Asia, including Indonesia, Malaysia, the Philippines and Papua New Guinea.

Uses *C. pascuorum* is sown as a pasture legume in northern Australia, mainly in regions with a long dry, but reliable wet season, or in seasonally flooded parts of the Northern Territory. It is sometimes cut for hay. It has been planted experimentally in South-East Asia.

Properties *C. pascuorum* is regarded as a relatively palatable, high quality tropical forage. Nitrogen concentrations range from 2.5–4.3%. In vitro DM digestibility of young plant material has been measured at 64%, and P concentrations varies from 0.15–0.18%. There are 48–58 seeds/g in the two Australian cultivars.

Description An annual, herbaceous plant with a twining or scrambling habit, producing roots on trailing stems in moist conditions. Stem cylindrical, glabrous to scarcely pilose, branched at the nodes, up to 2 m long. Leaf trifoliolate and often held erect; stipules narrowly triangular, 4–9 mm long; petiole 1.7–5 cm long including the upper rachis; leaflets long and narrow, 2–15 cm × 0.3–1.7 cm, glabrous to scarcely pilose, with acute to acuminate apices. Inflorescence racemose, with 1–2 peduncles per leaf axil; flower resupinate, singly or in pairs at the end of a short (0.5–2 cm) peduncle; pedicel 4–10 mm long, subtended by a single ovate bract 2–4 mm long with at the distal end two conspicuously paired bracteoles which are ovate, 4–6 mm × 2–4 mm, with acuminate apices; calyx tube 3–4 mm long, with 5 narrow teeth 3–7 mm in length; the lowest tooth (4–7 mm) is the longest; corolla wine red, 15–25 mm long and wide; the standard with a spur on the back towards the base. Pod linear, 4–8 cm × 3–4 mm, laterally compressed, with a dark longitudinal stripe near each suture, containing up to 15 seeds; the pod shatters at maturity. Seed ovoid to cylindrical, ca. 4 mm long, slightly compressed laterally, greenish-yellow to brown, rarely mottled (accessions from Venezuela).

Minute hooked hairs occur on the outer surfaces of the calyx, bracts and bracteoles, and more sparsely on the leaves and stems.

Centrosema pascuorum Martius ex Benth. – 1, flowering branch; 2, calyx; 3, flower; 4, fruits.

Growth and development Photoperiod and temperature influence flowering and seed production. In cultivar 'Cavalcade', flowering occurs in short days (12 hour photoperiod or less). In longer days (13 hour photoperiod) buds may be produced, but they abort at high temperatures (33/28°C day/night) and no seeds are produced. Soil seed reserves of 250 kg/ha are common in good pastures. Hard seed content is high (90–100%) when seeds ripen, but declines to 10–30% at the end of the dry season.

Other botanical information Two botanical varieties of *C. pascuorum* have been named, but neither is widely recognized. Ecotypes from Ecuador often have larger leaves and seeds, and paler flowers, than those from elsewhere. Ecotypes from Venezuela have smaller, mottled seeds. Accessions from north-eastern Brazil are more diverse and usually more vigorous than those from elsewhere. A few accessions from Brazil and Venezuela have ovate leaflets. Two cultivars, 'Cavalcade' and 'Bundey', have been released in Australia.

Ecology *C. pascuorum* is adapted to tropical regions having reliable wet (4–6 months, 700–1500 mm) and dry seasons. It is drought resistant, but can also survive prolonged waterlogging or flooding (partial immersion). It will not persist in the subtropics and is not frost-tolerant. It is adapted to soils of near-neutral pH, ranging from sand to heavy clay.

Propagation and planting *C. pascuorum* is propagated by seed, at a seeding rate of 2–5 kg/ha. Heat treatment to reduce hard-seededness may be necessary for hand-harvested seed. Inoculation of seed with an appropriate strain of *Bradyrhizobium* is advised, but is usually not essential. A cultivated seed-bed is required, and the seed should be covered with soil to a depth of 1–2 cm. Seed should be planted at the start of the wet season. Control of existing weeds and grasses during establishment is helpful. Grasses such as *Cenchrus ciliaris* L., *Urochloa mosambicensis* (Hack.) Dandy and *Andropogon gayanus* Kunth can be planted with *C. pascuorum*.

Husbandry Heavy applications of fertilizer are not required, but *C. pascuorum* will usually respond well to low rates of P (5 kg/ha). In pastures it is a valuable dry season forage, but it can be grazed throughout the year provided the stocking rate during the second half of the wet season is low enough to allow good seed production. In Australia, 2–3 steers/ha can be carried during the dry season on good pastures.

Diseases and pests *C. pascuorum* is susceptible to the fungal pathogens *Cercospora canescens* (leaf-spot), *Colletotrichum truncatum* (anthracnose), *Pseudocercospora bradburyae* (leaf-spot), *Rhizoctonia solani* (foliar blight) and *Neocosmospora vasinfecta*. However, these diseases are usually not serious in areas where it is well-adapted. It is also susceptible to root-knot nematodes (*Meloidogyne* spp.), and to sucking insects during seed production. Control by chemicals usually is not economic except for commercial seed production.

Harvesting *C. pascuorum* is usually grazed, or is cut for hay.

Yield Annual DM yields of 4–6 t/ha are obtained from legume-dominant pastures in the semi-arid tropics. In small plots, yields of up to 9 t/ha have been measured in Thailand. Under favourable conditions, large quantities of seed are produced, exceeding 1 t/ha in pure stands.

Genetic resources Representative germplasm collections (80 accessions) are held by ATFGRC (CSIRO, Australia) and by CIAT (Colombia).

Breeding There are no active plant improvement programmes at present. A breeding programme in Australia from 1976–1981 led to the release of 'Cavalcade'. The breeding objectives were seed and forage yield, and freedom from symptoms of nematode infestation. Small numbers of accessions have been tested in most South-East Asian countries, notably Thailand.

Prospects *C. pascuorum* has potential for wider use as a pasture or hay legume in semi-arid tropical regions. Its ability to tolerate both drought and prolonged waterlogging is unusual in legumes. However, its proven area of adaptation in Australia is limited, and its variable performance in trials in South-East Asia suggests that its use may be restricted to a few areas in the drier parts of the region.

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R.J. Clements

Centrosema pubescens Benth.

Comm. legum. gen.: 55 (1837).
LEGUMINOSAE
$2n = 22$

Synonyms *Centrosema molle* Martius ex Benth. (1837).

Vernacular names Centro, butterfly pea (En). Indonesia: sentro. Philippines: dilang-butiki (Tagalog), lesu-kesu (Subanun). Thailand: thua-lai, thua-sentro. Vietnam: day trung châu lông.

Origin and geographic distribution Originating in South and Central America, centro is now one of the most widely distributed of all legumes in the humid tropics.

Uses Centro has been used as a green manure and plantation ground cover in Java and Peninsular Malaysia since the 19th century. Centro is widely used as a plantation cover and/or pasture legume in South-East Asia, the Pacific Islands, the wet tropics of Australia and indeed much of the humid tropics worldwide.

Properties Centro is an efficient fixer of N with N concentrations generally ranging from 2.4–2.7%. Centro is one of the most palatable tropical legumes. There are about 40 seeds/g.

Description A vigorous, climbing, perennial herb; trailing runners have a tendency to root at the nodes if soil moisture is high, giving it a stoloniferous appearance; roots deeply penetrating; development of taproots and lateral roots is almost equal, although soil type exerts some influence. Stems leafy, arising from the main runners at 0.5–1.5 m intervals, climbing rather than trailing, slightly hairy, possibly becoming woody when older than 18 months. Leaves trifoliolate; leaflets elliptical, ovate-oblong or ovate-lanceolate, 1–7 cm × 0.5–4.5 cm, rounded at the base, rounded to acuminate at the apex, dark green, slightly hairy especially on the lower surface; petiole up to 5.5 cm long, stipules 2–4 mm long, persistent. Flower papilionaceous, cleistogamous, large, pale mauve with purple lines in the centre, borne in axillary racemes, 3–5 per raceme, subtended by 2 striate bracteoles; calyx tube campanulate, teeth unequal, 2 upper ovate triangular 1.5–3 mm long; standard rounded, up to 3 cm in diameter, hairy on the outside, bright or pale lilac on either side of a median greenish-yellow band with numerous dark violet stripes or blotches. Pod linear, 4–17 cm × 6–7 mm, flattened, margins prominent, straight or slightly twisted, acuminate, dark brown when ripe, containing up to 20 seeds. Seed shortly oblongoid to squarish with rounded corners, 4–5 mm × 3–4 mm × 2 mm, brownish-black, with mottled darker blotches.

Centrosema pubescens Benth. – 1, flowering branch; 2, fruits; 3, seed.

Growth and development Centro is notoriously slow to establish and requires good conditions during the establishment period, but when grown in a pure sward it forms a dense, compact cover 35–45 cm deep, 4–8 months after sowing. It is fully established and vigorous by at least the 2nd year. In ungrazed mixtures with *Panicum maximum* Jacq. it forms an impenetrable vine canopy some 2 m high. In a mixture with calopo (*Calopogonium mucunoides* Desv.) and puero (*Pueraria phaseoloides* (Roxb.) Benth.), centro persists longest under the closing canopy of plantation crops. Up to 60% of the seed may be hard, requiring scarifica-

tion before planting. In Australia, common centro flowers in April and October with main seed harvesting periods in June–July and November–December. Cultivar 'Belalto' flowers in June and has a main seed harvesting period in early August. Nodulation occurs with a range of rhizobia but optimal growth has been achieved with very few strains. Inoculation with an effective strain of *Bradyrhizobium* is, therefore, recommended. Estimates of N fixation range from 120–270 kg/ha per year.

Other botanical information Two lines of centro are in commercial use: common centro and cultivar 'Belalto'. 'Belalto' is now identified as *C. schiedeanum* (comb. ined., syn.: *Clitoria schiedeana* Schlecht.) rather than as *C. pubescens* as was listed originally. It was selected as an improvement over common centro because of its superior cool season growth, greater tolerance of pests and diseases, and its stronger stoloniferous growth.

Ecology In the humid tropics, the preferred legumes for fertile and infertile soils have traditionally been centro and stylo (*Stylosanthes guianensis* (Aublet) Swartz) respectively. However, when soil mineral deficiencies are corrected and seed is inoculated with an effective *Bradyrhizobium*, centro has been more productive than stylo on all land classes. The preferred annual rainfall for centro is 1500 mm or more but it has also proved to be more tolerant of lower rainfall than once considered, having persisted in pastures receiving an average annual rainfall of 800 mm. Centro tolerates waterlogged conditions when grazing is lenient and it will survive a 3–4 month dry season but is not adapted to prolonged drought. It is intolerant of low temperatures, growing poorly when temperatures fall below 15 °C. It is one of the shade-tolerant legumes and can persist under 80 % shade. Centro combines well with other species in mixed pastures or ground covers under plantation crops.

Propagation and planting Centro is propagated by seed. Hand harvested seed has a high proportion of hard-seededness and mechanical scarification is desirable. Seeding rate is about 5 kg/ha. Full seed-bed preparation and careful crop planting procedures are generally recommended, especially since centro is somewhat slow to establish. However, centro has been successfully sod-seeded directly into a run-down grass pasture, following heavy grazing and low slashing of the residual grass.

Husbandry Properly fertilized and carefully grazed grass/centro associations have been persistent, productive and competitive against weeds and timber regrowth. The tolerance of centro to certain herbicides has been determined, which can assist in weed control. In mixtures with grasses, notably *Panicum maximum*, centro tolerates rotational or continuous grazing, but is intolerant of grazing in pure stands. Under acidic soil conditions, centro is more responsive to Mo, Ca, K and P than puero which, in turn, is more responsive than stylo. Centro is more sensitive than stylo to soil P deficiency but is less sensitive to Cu and possibly S deficiencies.

Diseases and pests Centro has been relatively free of major diseases and pests. Some virus and bacterial diseases have been noted from time to time and there are seasonal infestations of *Cercospora* leaf-spot and red spider (*Tetranychus* sp.). In the humid tropics it is noticeable that the infestation of foliar blight (*Rhizoctonia solani*) may cause some dieback and that the attack of ladybird beetles may affect plant growth. The damage can be severe when centro is planted in a pure sward, especially during the wet season. However, none of these have warranted commercial control measures.

Harvesting Harvesting is by grazing animals, when it can be selectively overgrazed unless care is taken, or it can be cut for stall feeding. Centro has persisted for decades as plantation cover or in well-managed grazed associations with grasses, but it has not been very stable in cut-and-carry systems. Centro is usually consumed fresh but it can be ensiled or dried for hay or pellets.

Yield Pure stands of centro have produced DM yields of up to 12 t/ha per year. In mixed pastures, this is more likely to be about 3 t/ha per year. Standing DM yield of centro in grazed mixed pastures is unlikely to exceed 1 t/ha. Well managed grass/centro pastures have consistently supported stocking rates of 2.5 steers (375 kg liveweight) per ha in the Australian tropics and 4 steers (250 kg) in the Malaysian wet tropics, producing about 500 kg/ha of liveweight gain per year. Seed production can reach more than 200 kg/ha.

Genetic resources Seed of centro has been sold for many decades in South-East Asia and other humid tropical areas. Large germplasm collections are held by ATFGRC (CSIRO, Australia), CENARGEN/EMBRAPA (Brazil) and CIAT (Colombia).

Breeding Plant breeding programmes have been undertaken by QDPI and CSIRO in Australia and CIAT in Colombia. However, the most promising lines are beginning to emerge from plant collections in South and Central America.

Prospects Except for the humid tropics of Australia and a few areas of Malaysia and the Philippines, the potential of centro as a component of grazed pastures has been largely unrealized. Most pasture developments in South-East Asia have been on infertile soils which are not suitable for cropping. Similar developments in Australia have only been successful after careful studies of the nutritional status of the soil with respect to centro in particular. Very few studies of this type have been undertaken in South-East Asia. Centro is a recommended legume in the 'Three Strata Forage System' in Bali, Indonesia.

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J.K. Teitzel & C.P. Chen

Chamaecrista rotundifolia (Persoon) Greene

Pittonia 4: 31 (1899).
LEGUMINOSAE
$2n = 16$

Synonyms *Cassia rotundifolia* Persoon (1805).

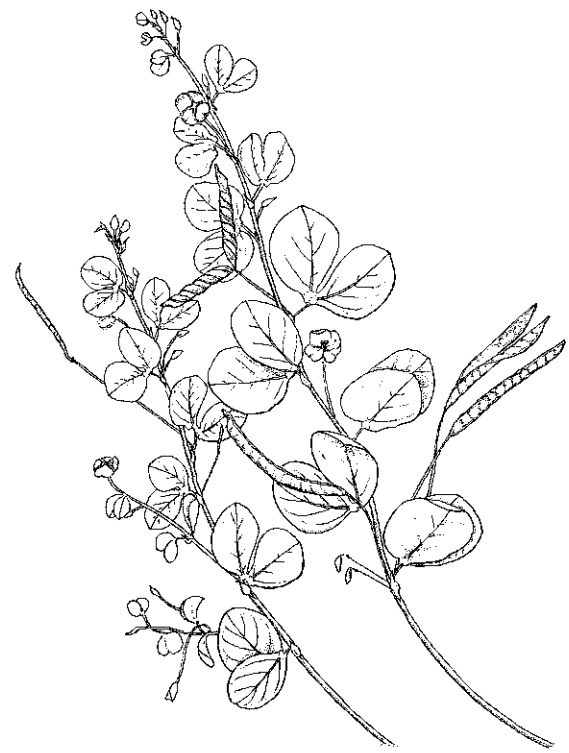
Vernacular names Roundleaf cassia, roundleafed cassia (En). Vietnam: muôn'g lá tròn.

Origin and geographic distribution Roundleaf cassia is native to an area extending from Mexico through Brazil and Uruguay, including the Caribbean region. It has been introduced and naturalized in the southern United States and in parts of West Africa. It has been introduced in Australia and is used commercially.

Uses Roundleaf cassia is only used for grazing, although good silage has been obtained experimentally.

Properties Preliminary data indicate that nutrient levels in cassia are average for tropical legumes, with N concentrations of 1–3%. Although some species of *Cassia* are toxic, 6 accessions of roundleaf cassia have been fed to rats and there were no symptoms of toxicity. The live weight gains and intake of rats fed with roundleaf cassia have been found to be marginally better than with rats fed lucerne. Cultivar 'Wynn' was also found to be free of toxic compounds in studies with pen-feed sheep. There are 200–500 seeds/g.

Botany An annual or weak perennial semi-erect to prostrate herb, in age basally suffrutescent, with woody-fibrous blackish taproot up to 1 cm in diameter; stems up to 1 m long, not rooting at nodes. Leaves ascending, bifoliolate, petiole up to 1 cm long; leaflets subrotund to broadly obovate, 0.5–5 cm long, by day ascending, face upward from tip of petiole, folded face-to-face at night, venation slightly prominent on both surfaces; petiolule only a thickened pulvinule, without a gland. Flowers in racemose axillary clusters of 1–3; pedicel up to 6 cm long; sepals 5, greenish or reddish-brown, 3–13 mm long; petals 5, yellow, as long as or slightly longer than sepals. Pod linear-oblongoid, straight or slightly curved, (1.5–)2–5.5(–6) cm ×



Chamaecrista rotundifolia (Persoon) Greene – flowering and fruiting branches.

0.3–0.5(–0.6) cm, blackish-brown when ripe, dehiscent. Seed rectangular in outline, flattened, 2–3 mm long.

The species is quite variable in its stature, pubescence and size of flower parts and leaves, allowing distinction of many ecotypes. Provisionally (until better studied), only two varieties have been distinguished by Irwin & Barneby based on size and proportion of the flowers alone:

- var. *rotundifolia*: flowers small, the largest petal up to 7 mm long, the longest fertile anther up to 4.4 mm, the style up to 2 mm long. Range: from Florida (United States) and Sinaloa (Mexico) to Argentina. Synonyms: *Cassia bifoliolata* DC. ex Colladon (1816), *C. fabaginifolia* Kunth (1824), *C. monophylla* Vellozo (1825).
- var. *grandiflora* (Bentham) Irwin & Barneby: flowers larger, the longest petal up to 17 mm, the largest fertile anther up to 11.5 mm, the style up to 8.5 mm long. Range: more local within that of var. *rotundifolia*, but never associated with it. Synonym: *Cassia bauhiniifolia* Kunth (1819).

Growth is indeterminate and will continue after flowering for as long as temperatures and moisture conditions are suitable.

One cultivar, 'Wynn' (belonging to the var. *rotundifolia*), has been released in Australia. It can seed freely throughout the growing season, but primarily in autumn. Other lines flower much later and, in areas with a reliable and longer growing season, are higher yielding.

Ecology Roundleaf cassia is best suited to areas receiving from 700–1400 mm rainfall in the seasonally dry tropics and subtropics. It is not suited to poorly drained sites or heavy textured soils, and is very intolerant of waterlogging. It grows best on free-draining, friable sandy soils. Top growth is readily killed by frost.

Agronomy Seed germination should be checked before sowing to ensure that hard-seededness is not excessive. Seed can be broadcast into closely grazed pastures, but establishment is more reliable with some form of soil disturbance. Seeding rates of 2–4 kg/ha are recommended, but lower rates can be used especially if sown in a mixture with legumes. It nodulates readily with native cowpea rhizobia and there are no records of failure to nodulate. Long-term persistence is assisted by regular recruitment from soil seed reserves, which are frequently 3000/m^2 and can be as high as 15 000/m^2. No serious disease or pest problems have been recorded although the species is a known host of several viral and fungal diseases.

To date, roundleaf cassia has only been used for grazing, where it has proved to be persistent under a wide range of grazing pressure, although persistence and productivity are poorer with vigorous grasses and also at light grazing pressures. In mixed cassia/grass pastures, cattle tend to selectively graze the grass at the beginning and middle of the growing season, and the percentage of cassia in the diet increases at the end of the growing season. Seed pods are eaten by cattle, and peak levels of 1–3 seeds per g of dry cattle faeces aid in the natural spread of the species. Roundleaf cassia can give DM yields of over 5 t/ha in pure swards, but annual yields are lower in grass/legume pastures. Seed yields can range from 200–800 kg/ha. Roundleaf cassia is suited to either direct heading or hand harvesting of seed.

Genetic resources and breeding The largest germplasm collection is held at ATFGRC (CSIRO, Australia). The main variation is in the time of flowering and growth habit.

Prospects Within its adaptation limits of rainfall and soil type, roundleaf cassia shows considerable promise. It may provide an alternative legume in some of the areas suitable to shrubby stylo (*Stylosanthes scabra* Vogel). New cultivars of mid- and late-season maturity, as compared to the early-flowering 'Wynn', will be required to exploit its full potential.

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R.M. Jones

Chloris gayana Kunth

Révis. gramin. 1(18): 293 (1830).
GRAMINEAE
$2n = 20$ (diploid), 30, 40

Synonyms *Chloris abyssinica* A. Richard (1851), *C. glabrata* Anderss. (1864).

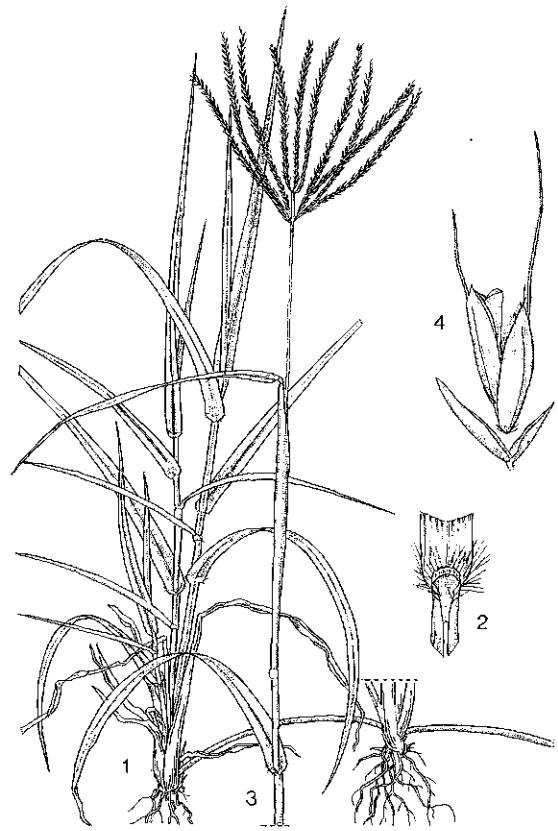
Vernacular names Rhodes grass (En, Am). Herbe de Rhode (Fr). Philippines: koro-korosan (Tagalog), banuko (Ilokano). Thailand: ya-rot. Vietnam: tucgiéâń.

Origin and geographic distribution Rhodes grass is native to East, Central, and the eastern part of West and southern Africa. It was first cultivated in South Africa, and at the beginning of the 20th Century it was introduced to a wide range of regions in Africa, South and Central America, the United States, Australia, South Asia, Japan, Italy and the southern part of the former Soviet Union. The grass is grown in Indonesia (Java, Irian Jaya, northern Sumatra), the Philippines and Thailand.

Uses Rhodes grass is used in pastures for grazing, hay and silage making. It is an important grass for sub-humid subtropical regions.

Properties Rhodes grass has an N concentration ranging from 2.7% of the DM in very young leaves to 0.5% in old leaves. The P concentration ranges between 0.1% and 0.4% depending on age of material and soil fertility. DM digestibility of green material is about 60% (ranging from 40–82%) depending on growth stage and cultivar. Crude protein digestibility can be as high as 70%. Palatability is good, but varies with cultivar. Cultivar 'Katambora' is used as nematode suppressor in crops of tobacco. There are 7000–10000 seeds/g.

Description A perennial, stoloniferous (varies with cultivar), creeping or occasionally tufted grass, 0.5–2 m tall. Stem fine and leafy, erect or ascending, occasionally rooting at the lower nodes. Leaf-sheath glabrous except near the blade; ligule about 1 mm long, including a fringe of short hairs, with long hairs on the blade close to it; leaf-blade flat, rarely involute, (15–)25–50 cm × (1.5–)3–9 mm, tapering towards the apex, margins rough, glabrous except near the base, lateral veins strongly developed. Inflorescence consisting of (3–)6–15(–20) digitate ascending to spreading spikes 4–15 cm long, all attached at the top of the culm, or a few a little below the others; spikelets green or purplish, about 3.5 mm long; florets 3(–4), with usually one hermaphrodite (lemma with an awn of 1–10 mm long), one male (awn 1.5–5.5 mm) and one rudimentary; sometimes all florets are hermaphrodite and fertile.



Chloris gayana Kunth – 1, habit; 2, ligule; 3, inflorescence; 4, spikelet.

Growth and development Seed germination is optimal between 8 and 18 months after harvest. The seed germinates quickly (in 1–7 days, depending on temperature) and seedlings establish rapidly. The seedlings produce erect tillers, with stolons appearing later and these grow and branch rapidly. Widely scattered seedlings can quickly produce dense stands.

Rhodes grass is a short-day plant, flowering throughout or at the end of the growing season depending on cultivar. The caryopsis is fully ripe 23–25 days after flowering.

Other botanical information Most cultivars are selected from natural stands. Diploid cultivars are fine-stemmed, fine-leaved and less vigorous than tetraploid cultivars which are robust and vigorous. Giant Rhodes grass (tetraploid), released as cultivar 'Callide' in Australia is late flowering and robust, with thick stems and broad long leaves, long awns (6–9 mm) and a long tuft of hairs at the awn base.

Other Australian cultivars are 'Pioneer' (diploid, with lower nutritive value than other cultivars), 'Katambora' (diploid, with many tillers and good seed production), 'Samford' (tetraploid, vigorous stolon development, late flowering and with high palatability). Several cultivars have also been released in Africa. 'Pokot' is a bred cultivar (leafy, vigorous, late flowering and high yielding), 'Nzoia' (very leafy with high seed yields), 'Masaba' (quite leafy and productive) and 'Karpedo' (good drought tolerance).

Ecology The natural habitats of Rhodes grass are grasslands, open or with scattered trees or shrubs, river banks, lake margins and seasonally waterlogged plains.

Rhodes grass has some drought tolerance, but less than *Panicum maximum* Jacq. var. *trichoglume* Robijns. The optimum annual rainfall for Rhodes grass is between 600–1000 mm but it can withstand a dry season of up to six months. The grass responds well to irrigation and is moderately tolerant of flooding (up to 10–15 days with less than 30 cm of water).

The optimum temperature for photosynthesis is 35 °C. The temperature range for growth is very broad, from about 0 °C to 50 °C. Rhodes grass is more tolerant of low temperatures than most other subtropical grasses.

Seed germinates best at temperatures between 20–35 °C.

The optimal daylength for growth is between 10–14 hours. Herbage yields are considerably reduced at photoperiods outside this range.

Rhodes grass is tolerant of fire, but not of shade.

Rhodes grass will grow on a wide range of soils, from heavy clays to sandy loams. Optimum pH lies between 4.5 and 7. Rhodes grass tolerates a high salinity and it can accumulate high concentrations of Na in the leaves without suffering damage.

Propagation and planting Rhodes grass can be propagated from seed and stolons. Propagation from seed gives more rapid establishment. The seed is small and should be sown very shallow, or preferably broadcast on top of a well prepared seed-bed or rather loose rough soil, covered lightly and/or rolled. It can be sown from the air into the ashes after burning. Seed sown below a depth of 25 mm will not germinate.

Naked caryopses germinate slightly better than those enclosed in glumes. Seed purity is usually not more than 25–35 %, with germination of 30–55 %. The seeding rate should be 0.5–1 kg/ha of pure viable seed.

Rhodes grass grows well in mixtures with a wide range of legumes such as *Stylosanthes guianensis* (Aubl.) Swartz, *Vigna unguiculata* (L.) Walp., *Medicago sativa* L., *Macroptilium lathyroides* (L.) Urban, *M. atropurpureum* (DC.) Urban and *Lotononis bainesii* Baker and as a companion crop under wheat and maize.

Husbandry Rhodes grass responds well to N and P fertilizer. On fertile soils it is usually grown without fertilization.

Diseases and pests Most cultivars are little affected by diseases or pests, but major damage can be caused by *Helminthosporium* spp. in 'Nzoia', causing dieback of leaves and shoot bases. 'Masaba' suffers from smut caused by *Fusarium gramineum* giving rise to seed loss in wet years.

Harvesting Rhodes grass can be grazed continuously or rotationally from 4–6 months after sowing, but high grazing pressure decreases vigour. Grazing pressure should be aimed at preventing flowering, as the nutritive value declines rapidly towards maturity.

The best time to cut for hay is just before flowering. Six harvests a year are possible with cutting intervals of 25–50 days. The best time for harvesting seed is at the early stage of seed shedding.

Yield In North Sumatra 38 t/ha of DM has been harvested in 236 days and it was one of the highest yielding grasses tested. Seed yields range between 100–650 kg/ha. Annual liveweight gains of up to 160 kg/animal and 850 kg/ha have been recorded from well fertilized Rhodes grass pastures.

Genetic resources and breeding A large collection of Rhodes grass germplasm is held at ATFGRC (CSIRO, Australia). Rhodes grass is cross-pollinating with a self compatibility of 1–4 %. Breeding work is being done in Kenya ('Pokot') and the United States (Texas). Plants are being selected on leafiness and late flowering characteristics.

Prospects Because of its wide adaptability, ease of establishment and acceptable nutritive value, Rhodes grass will continue to play an important role in pasture improvement in subtropical regions with a pronounced dry season.

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Africa. Gramineae (Part 2). Crown Agents for Oversea Governments and Administrations, London. p. 346. |5| Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 283–288.

L. 't Mannetje & S.M.M. Kersten

Chrysopogon aciculatus (Retzius) Trinius

Fund. Agrost.: 188 (1820).

GRAMINEAE

$2n = 20$

Synonyms *Andropogon aciculatus* Retzius (1789).

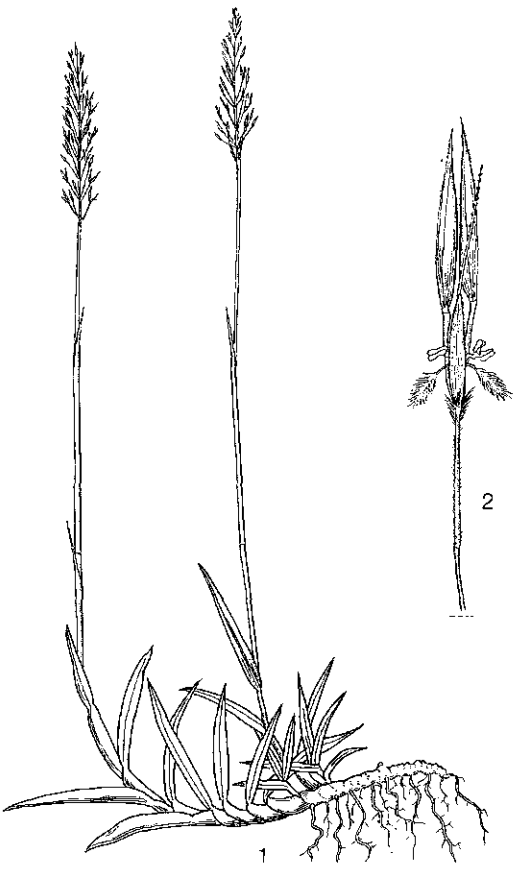
Vernacular names Love grass (En). Amorseco (Sp). Indonesia: salohot (Batak), jukut domdoman (Sundanese). Malaysia: temuchut, kemuchut, kemunchup. Philippines: marisekos (Tagalog), amorseko (Visaya), pangrot (Bikol). Cambodia: smau kântraëy. Thailand: ya-chaochu, ya-khikhrok (central), ya-khitroei (south). Vietnam: co'may, co'bông.

Origin and geographic distribution *C. aciculatus* originates from tropical Asia, Australia and Polynesia and is very abundant in all South-East Asian countries. It has been introduced to other parts of the tropics, e.g. West and Central Africa.

Uses *C. aciculatus* is used for grazing, as a lawn grass, and for control of soil erosion. However, it can annoy humans and livestock due to its prickly spikelets that stick to and penetrate clothing or skin. The culms are used to make brushes and to weave small cases.

Properties The leaves are highly palatable, but the abundant flowering culms and spikelets have low palatability. No data on nutritive value are available.

Botany A perennial, spreading, stoloniferous, mat-forming grass. Culms solid, glabrous, erect or creeping, up to 75 cm tall, often branching, rooting at all nodes when creeping. Leaf-sheath glabrous, often pierced by roots; ligule membranous, truncate, very short; leaves 2–20 cm × 4–8 mm; leaf-blades on creeping culms ovate-lanceolate, short, pressed flat against soil; leaf-blades on flowering culms more linear. Inflorescence a rigidly erect panicle, 5–12 cm long, composed of several whorls of short reddish branches which gradually spread horizontally when ripe, each branch bearing at its end a group of 3 spikelets, each group with 1 bisexual sessile and 2 male or neuter pedicelled spikelets; sessile spikelet with at base a pointed callus, 4–6 mm long, which is bearded with short yellowish-brown hairs on one side and at top an awn 2–8 mm long. Caryopsis yellowish-brown, 2–3 mm long.



Chrysopogon aciculatus (Retzius) Trinius – 1, flowering plant; 2, triad of spikelets.

At maturity the callus at the base of a sessile spikelet separates from the supporting branch near its base and the sharp free tip easily catches on passing animals or humans. This tip penetrates clothing or hairy skins and is difficult to remove owing to the stiff appressed hairs. The fruit may work its way into the flesh, causing extensive ulceration.

C. aciculatus spreads and forms a firm mat over the ground, starting to flower within 6–8 weeks after establishment. It flowers throughout the year.

Ecology *C. aciculatus* can grow from sea-level to 1500 m altitude. It is adapted to moderately dry to humid environments and to sandy loamy soils of pH 5–6. It is frequently found in overgrazed areas, resisting trampling. It cannot withstand prolonged dry periods. It is a vigourous colonizer

of denuded ground and tends to dominate with regular burning.

Agronomy *C. aciculatus* is propagated by seed or rooting tillers. The bristles on the spikelets adhere to the hair of livestock and provide an effective method of seed dispersal. Close grazing is necessary to keep it in a young growth stage. Cutting is not practised for forage production. When used as a lawn grass, it should be mown frequently to keep it green and free of inflorescences. It is a low-yielding species.

Genetic resources and breeding It is unlikely that any substantial germplasm collections are being maintained.

Prospects The main use of *C. aciculatus* is as a naturally occurring grass for livestock, and as a control against soil erosion. In improved pastures it is often considered as a noxious weed.

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C. Manidool

Chrysopogon orientalis (Desv.) A. Camus

Lecomte, Fl. Gén. de l'Indo-Chine 7: 332 (1922).
GRAMINEAE
$2n$ = unknown

Synonyms *Rhaphis orientalis* Desv. (1831), *Andropogon wightianus* Nees ex Steudel (1854), *Chrysopogon wightianus* (Nees ex Steudel) Thwaites (1864).

Vernacular names Philippines: tinloy (Tagalog), rukut dukut (Visaya), salsapot (Ilokano). Laos: hnha:z khwa:k. Thailand: ya-phungchu. Vietnam: co' may dông.

Origin and geographic distribution *C. orientalis* originates from and is distributed in coastal Malaysia, Thailand, Indo-China and India.

Uses *C. orientalis* is used as green forage. In a traditional grazing system in Thailand, cattle and buffaloes from distant villages are herded on it during the daytime and return in the evening. It also protects sandy coastal areas from wind erosion.

Properties Nitrogen concentrations in leaves from flowering plants of *C. orientalis* range from 0.5–0.7%. The leaf/stem ratio is low and this stemmy condition persists almost throughout the year. A DM digestibility of 46% has been measured for flowering plants.

Botany A perennial grass with culms up to 80 cm tall, creeping and branching or sometimes densely tufted, with short stout stolons. Leaf-sheaths and internodes distinct below, tight and more overlapping above; leaf-blades basal and cauline, linear-acuminate to oblong, 6–10(–30) cm × 3–4 mm, flat or folded, usually glabrous. Inflorescence a terminal panicle, 10–18 cm long, with whorls of slender branches, each branch with a terminal tuft of red-brown persistent hairs at the base of a group of 3 spikelets (1 sessile, 2 pedicelled); sessile spikelet bisexual, with an oblique slender golden-hairy basal callus 2.5 mm long below the base of the lower glume, glumes spinulose-hairy, upper glume with awn up to 1–5 cm long, upper lemma with awn to 6 cm long; pedicelled spikelets with lower glume awned to 1.5 cm, upper glume and upper lemma awnless.

Chrysopogon orientalis (Desv.) A. Camus – 1, culm with leaves; 2, inflorescence; 3, triad of spikelets.

When fully mature the panicles become a golden colour. Seed production is abundant. First flowering starts about 11 weeks after germination, and seed reaches maturity at 13 weeks after sowing.

Ecology *C. orientalis* is adapted to warm, high rainfall climates. It is well adapted to sandy soils but also grows vigorously on heavy soils in central Thailand. It grows best on open fields but can also invade old coconut plantations.

Agronomy *C. orientalis* can be planted vegetatively or sown at a seeding rate of 10–12 kg/ha. Seed germinates within 5 days after sowing. A spacing of 50 cm × 80 cm is recommended for vegetative planting, using 3 rooted tillers per hill. *C. orientalis* responds well to higher fertility and appropriate rates of complete fertilizer can be used. It is palatable and tolerates heavy grazing and fire; frequent grazing and/or burning of old swards is recommended to keep the plants in a leafy condition. It can be cut and fed to animals, but grazing is more appropriate since the leaves are normally concentrated at the base of the plant and are too low to be cut by large mowers. Annual DM yields of 5–8 t/ha are obtained in Thailand. It may be conserved as hay but it is then too coarse with little leaf. It is not suitable for silage making.

Genetic resources and breeding It is unlikely that any substantial germplasm collections are being maintained. No variation in growth form and adaptation has been observed. Irradiation of seeds to obtain leafy mutations has been tried in Thailand but without success.

Prospects The species has many advantages, such as its ability to grow on extremely infertile soils on sandy coastal land, its tolerance of heavy grazing and light shade and its good seed production. It has particular potential where cattle graze under old coconut plantations or sandy soils, such as occur in southern Thailand. Accessions with a higher leaf/stem ratio may increase the yield of useful forage.

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C. Manidool

Clitoria ternatea L.

Sp. Pl.: 753 (1753).
LEGUMINOSAE
$2n = 16$

Synonyms *Clitoria zanzibarensis* Vatke (1878), *C. tanganicensis* Micheli (1897), *C. mearnsii* De Wild. (1925).

Vernacular names Butterfly pea, K(C)ordofan pea, blue pea, Asian pigeon-wings (En). Indonesia: bunga biru (Malay), kembang telang (Javanese, Sundanese). Malaysia: bunga biru, kacang telang. Philippines: kolokanting (Tagalog), giting princesa (Bikol), balog-balog (Visaya). Cambodia: rum'choan. Laos: 'ang s'an dam, bang s'an dam. Thailand: anchan. Vietnam: dâu biê'c.

Origin and geographic distribution *Clitoria ternatea* is pantropical (20°N–24°S). Its true origin is obscured by extensive cultivation or naturalization in the humid lowland tropics of Asia, Africa, the Pacific Islands, and the Americas. It is widespread throughout South-East Asia.

Uses Butterfly pea has a reputation as a potential fodder plant, hay or cover crop. It has been extensively tested as such, especially in the subhumid to semi-arid tropics. It has never been used in extensive areas, although it is used by smallholders. It is used as a cover crop in coconut in southern India and in rubber in Malaysia. It is widely grown as an ornamental on fences and trellises because of its showy blue or white flowers, and is grown for dye production and medicinal purposes in India. In the Philippines young pods are eaten as a vegetable.

Properties Nitrogen concentrations of whole tops range from 1.7–4.0% depending on the season and stage of growth. For example, in Brazil, hay cut every 42 days had 3.7% N whereas hay cut every 84 days had 3.0%. Hays from Brazil and India contained 24–38% crude fibre, 38–47% acid detergent fibre, 11–16% lignin and 21–29% cellulose (44% crude cellulose).
Seeds contain 38% protein (2.5% lysine), 5% total sugars, 10% oil and a powerful cathartic compound. Seed size ranges from 15–35 seeds/g.

Description Perennial climbing, scrambling or trailing herb with a strong woody rootstock. Stems do not root at the nodes, slender, 0.5–3 m long, mostly pubescent or glabrescent, sometimes suberect at the base. Leaves pinnate with 5 or 7 leaflets; leaflets elliptical, oblong, oblong-lanceolate, or almost round, 1–7 cm × 0.3–4 cm, acute, rounded or emarginate at the apex, acute to rounded at the base, glabrescent above, adpressed pubescent be-

Clitoria ternatea L. – 1, flowering branch; 2, flower; 3, fruit.

neath; petiole 1–3 cm long; rachis 1–6 cm long; petiolules 1–3 mm long; stipules persistent, lanceolate, (2–)4–10 mm long, veined. Flowers axillary, solitary or paired; peduncle 3–10 mm long; pedicel 6–9 mm long and twisted 180° so that the standard is held lowermost; bracteoles ovate or round, 4–17 mm × 2.5–15 mm, veined; calyx pubescent, veined, tube 8–12 mm long, lobes oblong-lanceolate or triangular, 7–10 mm × 2.5–3 mm, acute or acuminate, the upper pair joined for less than one third of their length; standard oblong-obovate, 25–50 mm × 15–35 mm, white or greenish-white often blue margined or entirely blue, basal central area often yellow or greenish, very finely puberulous, margins sometimes finely ciliate. Pod linear-oblong, flattened, 6–12.5 cm × 7–12 mm, margined, apiculate, glabrous or with a mixture of sparse adpressed long hairs and very short hairs. Seeds 8–10, ellipsoid, oblong or oblong-reniform, sometimes truncate at one end, 4.5–7 mm × 3–4 mm, 2–2.5 mm, olive, pale brown or deep reddish-brown with dark mottling, or almost black, minutely pitted.

Growth and development Germination is epigeal; the radicle emerges within 48–72 hours and seedlings emerge in 3–6 days, depending on planting depth. Early growth is rapid in warm moist conditions.

Growth of established plants is mostly from the apices of the main axis and axillary branches; very few new shoots arise from ground level. Flowers are cleistogamous but a small level of outcrossing occurs. Time to flowering in a collection of 58 lines (sown in January at 19°40'S) ranged from 7–11 weeks, with most lines flowering 8–9 weeks after sowing. Subsequent flowering flushes overlap pod maturation from the previous flush, and they continue throughout the year in frost-free regions. At higher latitudes in the tropics, there is usually a peak at the end of the wet season and again at the end of the cool season, if moisture is available. Pods mature in 8–10 weeks after flowering and shatter readily once fully dry. Growth is more or less continuous in the humid tropics, or with irrigation in other hot regions. Individual plants may live for several years and grow into large vines if undisturbed.

Other botanical information There is considerable variation in the size of flowers and leaflets. Most 'cultivars' mentioned in the literature to date are ecotypes or agrotypes, not named cultivars in the true sense. However, cultivar 'Milgarra' was released in Australia in 1990.

Ecology Butterfly pea is essentially a plant of the humid and subhumid tropical lowlands, but it has a reputation for drought tolerance in the seasonally dry tropics (500–900 mm rainfall) and it has survived moderate frost damage in the subtropics (26°S). It occurs in grassland, open woodland, bush, riverine vegetation, and disturbed places throughout its natural range.

Butterfly pea grows best in full sun. Its annual rainfall requirements for survival may be as low as 400 mm, but it requires about 1500 mm (or supplementary irrigation) for best production. Its altitudinal range is 0–1600(–1800) m and annual mean temperature range is 19–28°C.

It has wide soil adaptation (pH 5.5–8.9), but prefers fertile friable soils and grows poorly on infertile sandy soils if not fertilized. It is one of the few herbaceous legumes well adapted to heavy clay soils in the subhumid to semi-arid tropics and the only one with potential in irrigated pasture mixtures on these soils. It will not tolerate flooding or waterlogging.

In the seasonally dry tropics and in cool regions, growth is limited by lack of moisture or low temperatures. Leaves are shed in response to these

stresses and top growth may be killed by frost or fire. However, recovery during the following growing season is usually good, provided grazing is not heavy and continuous.

Propagation and planting It is propagated by seed and readily self-propagates and spreads under favourable conditions by seed thrown vigorously from the dehiscing dry pods. Seed is also spread in cattle dung.

Normally sown from the beginning until the middle of the wet season at rates of (1–)3–5 kg/ha in well-prepared seed-beds with seed placement 1.5–4 cm deep and lightly covered. Higher rates (5–8 kg/ha) may be required when sowing pastures in rough conditions.

Successful stands have been established by broadcasting seed (10 kg/ha) into burnt or heavily grazed grassland, but success is very dependent on good seasonal conditions following planting.

Hand-harvested seed often remains hard-seeded for a long time and requires scarification prior to sowing. Mechanical abrasion, hot water or sulphuric acid can be used to break this dormancy. Mechanically harvested or threshed seed is usually satisfactory for sowing the following wet season without further treatment.

Inoculation of butterfly pea seed with rhizobia is not usually necessary; but, if it is required, broad spectrum cowpea inoculum should be used.

Husbandry Butterfly pea competes fairly well with weeds once established and can cover the ground in 4–6 weeks when sown at a population of 4 plants/m^2. Establishment may be a problem on fertile soils if sown with a vigorous companion grass or oversown into an existing pasture. It combines better with tussock than stoloniferous grasses in mixed pastures.

If a pure stand is required (e.g. for seed production), cultivation or hand weeding will be required during early growth. Alternatively, trifluralin (800 g/ha) may be incorporated pre-planting to control grass weeds, and bentazone may be used at rates up to 1900 g/ha to control susceptible broad-leafed weeds.

Because butterfly pea is very palatable it must be carefully managed to avoid overgrazing and loss of the stand. The location of its growing points at the ends of the main branches makes it susceptible to frequent low cutting as well as to continuous heavy grazing (for example, it did not persist in irrigated pastures on a heavy clay soil in northwest Australia when grazed at a stocking rate of 2.5 steers/ha). Superphosphate fertilizer application will increase DM yield and plant density on infertile soils.

For seed production on a small scale, plants may be grown on trellises to maximize yield and to make hand harvesting easier. However, for large-scale mechanized seed production, butterfly pea is best grown as an annual row crop suitable for direct heading.

Diseases and pests Various fungi (e.g. *Cercospora, Colletotrichum, Oidium* and *Rhizoctonia)* and nematodes (*Meloidogyne* and *Pratylenchus)* have been recorded on butterfly pea but damage is rarely bad and control measures are unpractical or uneconomic in pastures. Fungicides such as benomyl may be useful in seed crops if diseases break out. Grass hoppers and leaf-eating caterpillars have caused damage in Australia.

Harvesting Pasture forage is normally harvested by direct grazing or as cut-and-carry forage. Rotational grazing is preferred rather than set stocking whenever the plants are growing actively. Butterfly pea makes good quality palatable hay but it is difficult to harvest and handle because of its viny nature.

Yield Yields of butterfly pea vary enormously because of highly variable growing conditions and management. Moreover, levels of productivity projected from short-term trials are probably unrealistic because of its susceptibility to frequent cutting. For example, when mixed pastures in Colombia were harvested every 6–8 weeks, the amount of butterfly pea in the sward declined from 25–35% to 5% in one year. Worldwide, reported DM yields have ranged 0.2–16.5 t/ha in forage crops and pastures. Crops grown under irrigation on good soils in the lowland dry tropics generally yield 7–13 t/ha DM, whereas dryland crops usually yield 3–5 t/ha on good soils and 1–2.5 t/ha on light soils or under low rainfall.

Under upland conditions in the Philippines butterfly pea produced only 0.1–0.6 t/ha forage DM in the first season and 1.3–2.8 t/ha in the second when grown as an intercrop with grain legumes under dry conditions. When sown following rice under lowland conditions the DM yield of butterfly pea was 8.8 t/ha (4 cuts) as a forage crop and 3.6 t/ha (3 cuts) as an intercrop with mungbean (*Vigna radiata* (L.) Wilczek). *Lablab purpureus* (L.) Sweet produced twice as much forage as an intercrop but it reduced mungbean grain yield whereas butterfly pea did not.

Seed yield may reach 300 g/plant hand harvested but it varies widely among lines. Yields of up to 700 kg/ha have been recorded for direct headed seed crops in northeast Australia.

Liveweight gain of steers on irrigated pastures in

northeast Australia was 0.68 kg/head per day over 41 weeks for a mixture of butterfly pea and para grass (*Brachiaria mutica* (Forssk.) Stapf) compared with 0.58 kg/head per day for centro (*Centrosema pubescens* Benth.) and para grass. In Mexico, cattle grazing butterfly pea and pangola grass (*Digitaria eriantha* Steudel) produced 0.40 kg/head per day over 16 weeks compared with 0.24 kg/head per day from siratro (*Macroptilium atropurpureum* (DC.) Urban) and pangola grass, but both groups were also fed 1.5 kg/head per day of supplement containing 11.5% crude protein and 64% TDN.

Genetic resources The main collections are held at ATFGRC (CSIRO, Australia) and CIAT (Colombia).

Breeding Variation exists among lines in flowering time, pod dehiscence, seed and total dry matter yield, and plant habit. No breeding programmes are known but a major objective would be to improve persistence under grazing and cutting, perhaps by developing forms with more growing points at ground level.

Prospects Butterfly pea has been considered a promising forage plant wherever it has been evaluated throughout Australia, Africa, Central and South America and South-East Asia. It may have wider application to smallholder farm systems in South-East Asia. Its drought tolerance and adaptation to heavy clay soils, and the palatability and quality of its forage, suggest it could be used to improve natural grassland in extensive farm systems in the subhumid to semi-arid tropics, given appropriate grazing management. Its susceptibility to close grazing or cutting is a major limitation to general use.

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I.B. Staples

Codariocalyx gyroides (Roxb. ex Link) Hassk.

Flora 25, Beibl. 2: 49 (1842), pro parte.

LEGUMINOSAE

$2n = 20, 22$

Synonyms *Hedysarum gyroides* Roxb. ex Link (1822), *Desmodium gyroides* (Roxb. ex Link) DC. (1825), *D. papuanum* C.T. White (1922).

Vernacular names Codarrio (En). Indonesia: sanagori, kadatuwa (Sundanese), julukan (Javanese). Cambodia: kâm'phé:m. Thailand: thua desmodium.

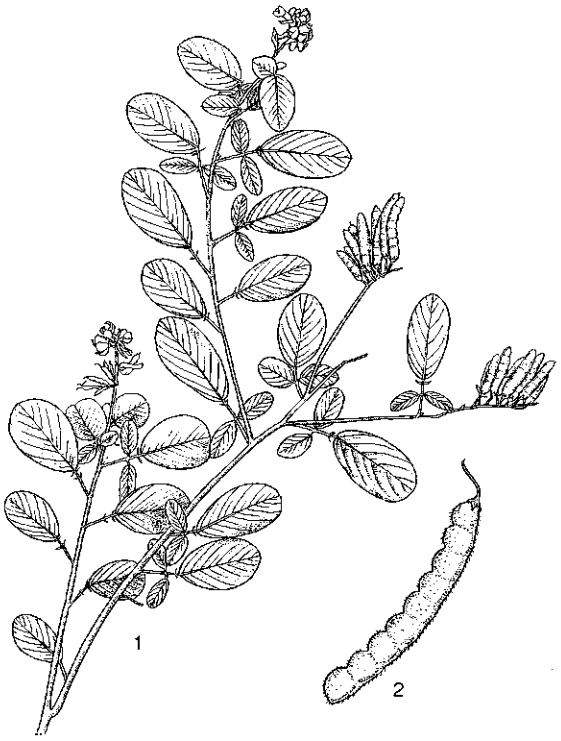
Origin and geographic distribution Codarrio is native to the area extending from Nepal and India through southern China and Indo-China and throughout Malesia. It has been introduced on an experimental basis into many countries.

Uses Codarrio is of increasing interest as forage and at the same time is used as green manure and as a shade tree in coffee and cocoa plantations.

Properties Preliminary information indicates that leaves and young edible stems of codarrio may have a slightly lower N but similar P concentration than similar regrowth from leucáena (*Leucaena leucocephala* (Lamk) de Wit) cut at the same height and frequency. Lower digestibility has been reported but this may possibly reflect the presence of tannins. If so, the reported values may not be a true indication of the nutritional quality of codarrio to ruminants. In feeding experiments with rats, codarrio gave the same weight gains as equivalent diets with lucerne and there was no evidence of anti-nutritional substances.

Botany An erect, usually multi-branched, shrub 1–3 m tall with sparsely to densely pubescent stems; older stems can exceed 4 cm diameter. Leaf 1–3-foliolate, petiole 1–3 cm long; leaflets 1 or 3, elliptical to obovate, 2–8 cm × 1–5 cm, obtuse to emarginate at the apex, rounded to cordate at the base, densely adpressed pubescent, sometimes glabrescent above, usually silvery white beneath; lateral leaflets usually smaller than terminal leaflet. Flower about 1 cm long, usually with 2 together in dense terminal and axillary inflorescences 5–15 cm long; corolla initially pinkish turning blue to mauve; pedicel ca. 1 cm long. Fruit 2.5–5 cm × 4–6 mm, densely yellowish hairy, with 5–13 segment-like parts but not splitting into articles, the whole fruit opening along the lower margin. Seed about 2.5 mm × 4 mm × 1.5 mm.

Away from the equator codarrio flowers in the latter part of the wet season and early dry season. Late-flowering introductions set very little seed in



Codariocalyx gyroides (Roxb. ex Link) Hassk. – 1, flowering and fruiting branch; 2, fruit.

the subtropics. In Indonesia, codarrio flowers in April. Individual plants survive for 2–4 years. Codarrio nodulates with native cowpea rhizobia.
C. gyroides is closely related to *C. motorius* (Houtt.) Ohashi, which occurs largely in the same area (not in Papua New Guinea).

Ecology Codarrio occurs up to an altitude of 1900 m (e.g. in Papua New Guinea). It grows well on sites with a shallow water table and poor drainage, and is not drought-resistant. It is tolerant of acid and infertile soils with much available Al. It can survive burning when growing in *Imperata cylindrica* (L.) Raeuschel grasslands in Indonesia.

Agronomy In Indonesia, it is planted at spacings of 0.5 m × 1.0 m. Growth may be slow for the first 2 months, but is possibly faster than leucaena. It usually flowers within 12 months. In Indonesia codarrio is cut and fed to animals, but plants do not survive low and frequent cutting. A cutting height of 0.5–1.5 m and cutting frequency of 6–10 weeks is provisionally suggested. Bushes can develop 50 or more basal branches.
Codarrio can be grazed, but in Australia more damage to plants was observed than to grazed leucaena. Reports from Belize and Australia suggest that poor persistence of codarrio may be caused in part by damage from insect larva burrowing in stems, fungal diseases and root-knot nematodes, the latter found particularly on sandy, well-drained soils. Where plants are allowed to seed, recruitment of new plants may be able to compensate for death of older plants.

Genetic resources and breeding Collections are held by CIAT (Colombia) and ATFGRC (CSIRO, Australia). Preliminary assessment of lines collected in Sumatra in 1986 is being carried out at CIAT.

Prospects Codarrio is showing promise as a forage plant, particularly on poorly drained and low fertility sites. In Indonesia further 'on-farm' testing is in progress. Although it may not be persistent in the long term, it could be planted out with slower growing but longer-lived shrub species which may yield less forage initially.

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R. Soedomo

Crotalaria juncea L.

Sp. Pl. 2: 714 (1753).
LEGUMINOSAE
$2n = 16$

Vernacular names Sunn hemp, Indian hemp, Madras hemp (En). Chanvre indien (Fr). Indonesia: orok-orok lembut (Java). Philippines: putok-putukan (Tagalog), karay-kagay (Bikol). Cambodia: kâk'tung. Laos: po: th'üang, thwax chu:b. Thailand: po-thuang. Vietnam: suc sat, luc lac.

Origin and geographic distribution Sunn hemp originates from India but is now widely grown throughout the tropics and subtropics.

Uses The major significance of sunn hemp lies in its valuable fibre which is extracted from the bark and used to make twine and cord, canvas, fishing nets, etc., and also to make paper and pulp. Moreover, sunn hemp is commonly used as forage, as green manure, and as a cover crop. It is one of the most widely grown green manures throughout the tropics. In Sri Lanka dried leaves, bark and boiled seeds are fed to cattle. With restrictions, seed has been used as fodder in the former Soviet Union and southern Africa. It is showing promise as a forage legume for intercropping with upland rice. In Indo-China it is used medicinally to treat urticaria.

Properties Although sunn hemp contains poisonous glucosides, it is widely used as forage. The presence of compounds which cause unpalatability and/or are poisonous under some conditions is typical of the genus *Crotalaria* L. Nitrogen concentrations of about 3% in hay and 5–10% in seeds have been reported from the former Soviet Union, but normally they are lower. Seeds may contain about 40% starch while stems contain about 40% fibre. There are about 33 seeds/g.
Sunn hemp fibre has greater tensile strength and is more durable under exposure than jute. It is not as strong as hemp (*Cannabis sativa* L.).

Botany An erect, laxly branched annual, up to 3.5 m tall, with long strong taproot, many lateral roots and numerous irregularly branched and lobed nodules. Stem ribbed, pubescent, up to 2 cm in diameter. Leaves simple; blade oblong-lanceolate, 4–13 cm × 0.5–3 cm, pilose; petiole up to 0.5 cm long. Inflorescence a lax terminal raceme, up to 25 cm long; flowers yellow, showy; sepals 5, hairy; standard erect, suborbicular, ca. 2.5 cm in diameter. Pod cylindrical, 3–6 cm × 1–2 cm, tomentose, light brown, containing ca. 6 seeds. Seed heart-shaped, with narrow end strongly incurved, up to 6 mm long, dark brown to black.
It is very fast-growing. Normally multibranched, it may have a single stem up to 3.5 m tall in dense stands. It has vigorous lateral roots and a long taproot that can exploit deeply stored soil moisture. Sunn hemp is a short-day plant and long daylengths favour vegetative growth and reduce seedset, although daylength neutral selections exist. Extensive cross-pollination occurs.

Ecology Sunn hemp is drought resistant and is adapted to hot, semi-arid and arid areas, yet can tolerate light frosts. It grows on poor soils, but

Crotalaria juncea L. – 1, flowering branch; 2, part of stem; 3, fruits; 4, opened fruit; 5, seeds.

growth on such soils is improved by fertilization. It is not tolerant of salt, nor of sustained waterlogging.
For fibre production, light, loamy, well-drained soils are preferred; on low-lying clay soils it makes vigorous growth, but the fibre is coarser and yields are lower.

Agronomy Sunn hemp is established by seed. Sowing rates of 40–45 kg/ha are used when it is sown as a forage crop or as green manure, but when it is sown for fibre, rates of 100–240 kg/ha are used. It nodulates readily with native cowpea type rhizobia. Seedlings emerge 3 days after sowing, and rapidly produce a thick ground cover that smothers weeds.
Sunn hemp is attacked by many diseases and pests, including viruses, fungi, insects and nematodes, but they usually cause little economic damage. In India, wilt and caterpillar larvae of the moth *Utetheisa pulchella* can be serious. Pod-boring insects can reduce seed production. Beetles of the genus *Exora* can sometimes cause serious defoliation. Damage from insects is more severe if crops

are planted in the same area for more than 3 consecutive years.

It can be harvested by hand or by machine. Total green matter yields average from 18–27 t/ha with forage yields ranging from 5–19 t/ha. When sown as a green manure crop after rice in Thailand, sunn hemp yielded 2 t/ha of high quality DM in 6–8 weeks. When grown for forage it can be harvested 4 times, starting 6–8 weeks after sowing and subsequently every 4 weeks. Sunn hemp should be cut for hay or ploughed in for green manure in the early flowering stage when it is 1.5–2.5 months old. Leaves and stems are dried since animals do not eat sunn hemp when it is green. Sheep will not suffer any adverse effects if forced to eat dried forage, but will suffer from toxicity if fed large quantities of seed. It should not be fed to horses, and the intake of sunn hemp hay by cattle should be restricted to about 10% of their diet.

When grown for fibre the plants are usually harvested at the flowering stage or when the stems turn yellow. Stems are retted either in concrete tanks or in shallow open water for periods of 4–14 days, depending on the temperature, thickness of stems, and quantity of stems in relation to volume of water. After retting the material is dried, decorticated by machine and the fibre is then stripped from the stems by hand, washed, and hung up to dry in the sun for bleaching. For seed production the crop is harvested when the seeds are ripe; fibre is extracted from the stems afterwards.

Genetic resources and breeding There are no significant forage breeding programmes with sunn hemp, and few cultivars with predictable qualities are available. Cultivar 'Tropic Sun', of unknown origin, was selected in Hawaii as a green manure. Seeds and forage were found to be nontoxic in feeding trials. In India 'Kanpur 14' is the most common cultivar, and 'T6' flowers in 30 days after sowing. Existing lines of sunn hemp are usually variable, and it would appear there is scope for selecting in specific regions for specific objectives such as disease and pest resistance and yield of fibre or forage.

Prospects Sunn hemp is a fast growing species, tolerant of low fertility and of soil moisture stress. Since the crop is extensively cultivated for fibre or green manure, there is good potential for using sunn hemp foliage as a high protein source to supplement other feeds. It is also showing promise as a forage intercrop. Research is warranted on selection of improved lines and on clarifying and overcoming problems associated with its toxicity.

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Y.K. Chee & C.P. Chen

Cynodon dactylon (L.) Pers.

Syn. Pl. 1 : 85 (1805).

GRAMINEAE

$2n = 18, 36$

Synonyms *Panicum dactylon* L. (1753), *Cynodon glabratus* Steudel (1854), *C. polevansii* Stent (1927).

Vernacular names Bermuda grass (Am). Couch grass (En). Chiendent dactyle (Fr). Indonesia: jukut kakawatan, gigirinling (Sundanese), sukit grinting (Javanese). Malaysia: rumput minyak. Philippines: kawad-kawad (Tagalog), kapot-kapot (Visaya), bakbaka (Ilokano). Burma: mye-sa-myet. Cambodia: smao anchien. Laos: hnha:z ph'è:d. Thailand: ya-phraek. Vietnam: cò' chi', co'ôńg.

Origin and geographic distribution Bermuda grass is thought to originate from Africa and South and South-East Asia but it has been introduced to all tropical and subtropical regions of the world and has been found to survive at 50°N in Europe and to 4000 m elevation in the Himalayas. It is also found on islands in the Pacific, Atlantic and Indian Oceans.

Uses Bermuda grass is grazed by ruminants,

used in cut-and-carry systems, to control erosion, and as a turf grass. In the United States improved hybrids are also cut for hay. Worldwide it is also a serious weed in maize, cotton, sugar cane, vineyards and plantation crops.

Properties In vitro digestibility of 5-week-old forage of 500 introductions, uniformly managed, ranged from 40–69%. Nitrogen concentrations of adequately fertilized Bermuda grass range from 2–3%, whereas inadequately fertilized grass or old material may only contain 0.5–1.5% N. It contains low levels of prussic acid, but toxicity symptoms in animals are very rare. There are 3000–4000 seeds/g.

Botany A stoloniferous, prostrate, sward-forming perennial herb with underground rhizomes penetrating the soil to a depth of 1 m or more. Culms 8–40 cm tall (rarely taller) and 0.5–1 mm in diameter. Leaf-blade linear-lanceolate, 1–16 cm × 2–5 mm, glaucous, glabrous or hairy on upper surface, midrib prominent with two primary and 8–9 secondary nerves on either side; leaf-sheath up to 15 mm long, smooth, hairy or glabrous; ligule a conspicuous ring of white hairs. Flowering stems erect, terminated by 3–6 slender radiating 1-sided racemes 1.5–10 cm long arranged in 1 (rarely 2) whorls; spikelets 2–3 mm long, in two rows tightly appressed to one side of the rachis; glumes 1-nerved, the upper $\frac{1}{2}$–$\frac{3}{4}$ as long as the spikelet; lemma silky pubescent on the keel; palea glabrous. Caryopsis ovoid, 1.5 mm long, yellow to reddish.

Cynodon dactylon (L.) Pers. – 1, flowering plant part; 2, ligule; 3, spikelet.

Six botanical varieties have been recognized; var. *dactylon* is distributed worldwide, the other 5 varieties have a limited distribution in Africa and Afghanistan. Improved hybrid cultivars developed in the United States for higher DM yield and improved DM digestibility include 'Coastal', 'Coastcross-1', 'Tifton 78', 'Tifton 68', 'Hardie', 'Oklan', and 'Brazos'.

Ecology Bermuda grass grows best where mean daily temperatures are above 24°C. Temperatures of −2 to −3°C usually kill leaves and stems back to the ground but rhizomes survive these temperatures and regrowth is rapid in spring. It is deep-rooted and drought-tolerant. It grows best on well-drained soils, but will tolerate long periods of flooding. It will tolerate a broad soil pH range, but grows best with a soil pH above 5.5. It also tolerates low fertility, but it is intolerant of shade.

Agronomy Bermuda grass can be propagated by planting either seeds or stolons. Good stands can be obtained by planting 5–10 kg/ha hulled seed but higher rates can be used for rapid sward development. Improved hybrid Bermuda grass can only be vegetatively propagated. Plantings of fresh vegetative material should be made in moist soil followed by a roller to compact the soil. A small nursery for vegetatively planting larger areas can easily be established from one or a few vegetative sprigs or stolons.

With adequate fertilization, improved hybrid Bermuda grasses will produce twice as much forage as common types. A minimum of 10 kg/ha of N per month of growth is needed for moderate to high productivity but Bermuda grass, especially the improved hybrids, will respond to rates of up to 60 kg/ha N per month of growth. 'Coastal' Bermuda grass at Georgia, United States, produced 1.8, 4.7, and 7.2 t/ha DM with 1.1, 1.2 and 1.3% N when fertilized with 0, 52, and 112 kg/ha N, respectively. Common Bermuda grass could be expected to yield significantly less DM. Low-growing legumes can be grown with Bermuda grass, which improves forage quality and provides some of the N requirements of the grass. Applications of lime may be needed to bring soil pH to 5.5.

Rust and *Helminthosporium* leaf-spot are the major diseases on common Bermuda grass. The improved hybrids are resistant to these diseases. Armyworm *(Spodoptera frugiperda)* and spittlebug

(Prosapia bicinata) are the major insects that attack Bermuda grass. Adequate fertilization and defoliation that allows less than 8 cm growth to accumulate will help control pests. Burning dead top growth after frosting or after a dormant stage will help control spittlebug and the diseases.

Bermuda grass should be cut for hay or silage when it is 30–40 cm tall or after every 4–6 weeks growth. It can be grazed year-round if not dormant due to frost or drought. A stubble height of 5–10 cm should be maintained under grazing or left if cut for hay. Bermuda grass is best utilized by grazing. It can also be stored as hay after drying, or green-chopped and fed directly to animals, or made into silage.

Genetic resources and breeding Active breeding programmes (each with over 500 introduced accessions) to improve Bermuda grass are located in Stillwater, Oklahoma and Tifton, Georgia, United States. *C. dactylon* is highly variable and present collections do not adequately represent the species. Major breeding objectives include increased yield and digestibility, pest resistance, and improved cold tolerance.

Prospects Much opportunity exists for genetic improvement in yield, pest resistance, and quality. Proper fertilization and management and use of current improved cultivars would have major impact on improving animal nutrition and soil conservation.

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W.W. Hanna

Cynodon nlemfuensis Vanderyst

Bull. Agric. Congo Belge 13: 342 (1922), (11: 121 (1920), provisional name *C. lemfuensis*).

GRAMINEAE

$2n = 18, 36$

Vernacular names Stargrass, African stargrass (En, Am). Philippines: kolatay (Tagalog), rukut-dukut (Visaya), galud-galud (Ilokano). Thailand: ya-sata.

Origin and geographic distribution Stargrass occurs naturally in East and Central Africa, from Ethiopia and Sudan through Zaire to Malawi and Angola. In other parts of the tropics, including South-East Asia, it has been introduced as a fodder grass.

Uses Stargrass is grazed by ruminants, and used in cut-and-carry systems and to control erosion.

Properties Nitrogen concentration and DM digestibility of improved selections range from 1–2% N and 40–70%, respectively. Most stargrass has medium to high levels of prussic acid, which is increased with high nitrogen fertilization. However, only few reports of livestock death due to prussic acid poisoning have been reported.

Botany A stoloniferous sward-forming perennial without rhizomes; stolons stout, woody, lying flat on the ground; culms robust to fairly slender, 30–60 cm high and 1–3 mm in diameter at the base. Leaf-blade flat, linear-lanceolate, 5–16 cm × 2–6 mm, thin and green or rather stiff and glaucous, scaberulous, with or without scattered hairs; ligule a scarious rim 0.3 mm long. Inflorescence of 4–13 digitate 1-sided spikes, usually in 1, sometimes in 2 whorls; spikes 4–10 cm long; spikelets 2–3 mm long, green or purplish-green, 1-flowered, strongly laterally compressed, imbricate in 2 rows, awnless; glumes 2, 1–3 mm long; lemma silky pubescent to softly ciliate on the keel; palea glabrous. Caryopsis ellipsoid, laterally compressed.

Two varieties have been distinguished, but since they intergrade, distinction is often impossible and thus questionable:

- var. *nlemfuensis*: culm 1–1.5 mm in diameter; leaf-blade 2–5 mm wide; spikes of 1 inflorescence 4–9, each 4–7 cm long.
- var. *robustus* Clayton & Harlan: culm 2–3 mm in diameter; leaf-blade 5–6 mm wide; spikes of 1 inflorescence 6–13, each 6–10 cm long; a more robust plant than var. *nlemfuensis*.

C. nlemfuensis much resembles *C. dactylon* (L.) Pers., the main difference being the absence of underground rhizomes and the lack of hardiness.

Stargrass grows vigorously and roots at nodes as

Cynodon nlemfuensis Vanderyst – 1, flowering plant part; 2, spikelet.

it spreads. Some genotypes have a bunch-habit type of growth, even though they spread by stolons.

Improved cultivars include: 'Florico', 'Florona', 'Ona', and 'Costa Rica'.

Ecology Productivity and persistence of stargrass are limited to lower elevations or where temperatures do not fall below −4°C, as growth rapidly ceases with low temperatures. In its area of origin it occurs up to 2300 m altitude. It does not tolerate long periods of flooding. It grows on many soil types but does best on moist, well-drained soils. It will tolerate a broad soil pH range but best growth is made on soils with a pH above 5.5.

Agronomy Improved selections of stargrass are sterile or almost sterile. It can be propagated by planting stolons or stem pieces. Plantings of fresh vegetative material should be made in moist soil followed by a roller to compact the soil. A small nursery for vegetatively planting larger areas can easily be established from one or a few vegetative sprigs or stolons.

Fertilizer will need to be added to most soils to obtain high DM yields. With adequate fertilization, selected stargrasses will produce more than twice as much forage as common types. A minimum of 10 kg/ha N per month of growth is needed for moderate to high productivity, but stargrass (especially the improved selections) will respond to higher rates. Low-growing legumes can be grown with stargrass which improves forage quality and provides some of the N requirements of the grass. Applications of lime may be needed to bring soil pH to 5.5.

Rust and *Helminthosporium* leaf-spot are the major diseases of common stargrass. Foliar blight (*Rhizoctonia solani*) has been observed on some of the selected cultivars. Armyworm (*Spodoptera frugiperda*) and spittlebug (*Prosapia bicinata*) are the major insect pests. Adequate fertilization and defoliation that allows less than 15 cm growth to accumulate will help control pests. Burning dead top growth if grass is frosted or after a dormant stage will help control spittlebug and the diseases.

Stargrass should be cut for hay or silage when it is 30–40 cm tall or after every 4–6 weeks growth. It can be grazed year-round if temperatures and rainfall are favourable. Overgrazing will decrease stands. A stubble height of 15–25 cm should be maintained under grazing or cutting. Dry matter yields of improved selections vary with climate and soil fertility but are at least twice the yield of local or common types. Stargrass is best utilized by grazing. It can also be stored as hay after drying.

Genetic resources and breeding Individual researchers around the world have a few accessions. *C. nlemfuensis* is extremely variable and systematic germplasm collection and maintenance is needed. Isolated improvement programmes have emphasized selection for higher dry matter yield and digestibility among introduced accessions.

Prospects Much opportunity still exists for genetic improvement in yield and quality. Hybrids need to be produced and evaluated. Proper fertilization and management and wider use of current improved cultivars could have major impact on improving animal nutrition and for soil conservation purposes.

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W.W. Hanna

Dactyloctenium aegyptium (L.) Willd.

Enum. Pl. Horti Berol.: 1029 (1809) ('*aegyptiacum*').

GRAMINEAE

$2n = 20, 36, 48$

Synonyms *Cynosurus aegyptius* L. (1753), *Eleusine aegyptia* (L.) Desf. (1798).

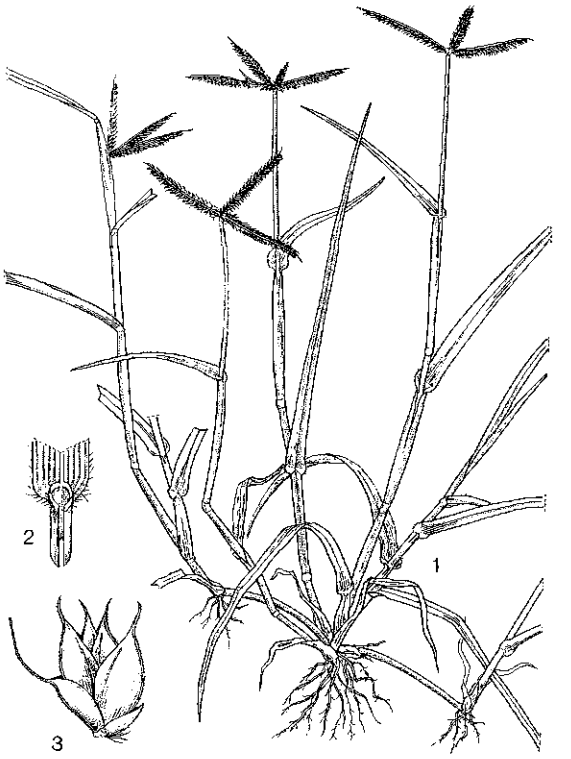
Vernacular names Crowfoot grass (East Africa), coast button grass (Australia) (En). Indonesia: tapak jalak (Sundanese), suket dringoan (Javanese), rebha kartuut (Madura). Malaysia: rumput miuyak. Philippines: krus-krusan (Tagalog), damong-balang (Visaya), tugot-manok (Ilokano). Burma: didok-chi, myet-le-gra, mye-sa myet. Thailand: ya-pakkhwai (central). Vietnam: co' chân gà, co chi.

Origin and geographic distribution *D. aegyptium* is widely distributed throughout the tropics, subtropics, and warm temperate regions of the Old World. It has been introduced to America.

Uses *D. aegyptium* is widely used as forage and is relished by all types of ruminants. Although a valuable forage, it can also be a troublesome weed of cultivation. It makes excellent hay. In times of scarcity it is used as a food grain.

Properties Nitrogen concentrations in *D. aegyptium* range from 1.2%–2.5%, depending on the stage of growth and soil fertility. It contains high levels of HCN at some stages of its growth. The grain is said to have an unpleasant taste and to cause internal disorders in humans.

Botany Slender to robust spreading annual, up to 1 m tall, usually geniculately ascending and rooting at the lower nodes, frequently shortly stoloniferous and mat-forming. Leaf-sheath up to 4 cm long, glabrous, compressed; leaf-blade flat, 3–25 cm × 0.25–1.2 cm, with bulbous-based hairs, especially along the margins; ligule a narrow fimbriate membrane. Inflorescence composed of up to 9 spikes up to 6.5 cm long, ascending or often radiating horizontally from the top of the culm; spikelets 3–4-flowered, flattened, 3–4 mm long, in 2 alternate rows at the underside of a flattened rachis; glumes subequal, the lower one with a scabrid keel, the upper with a smooth keel extending into a stout divergent scabrid awn up to 2 times as long as the glume; lemmas ending in a stout cusp or mucro 1 mm long. Caryopsis broadly obovate to obtriangular in outline, ca. 1 mm long, transversely rugose, orange-brown.



Dactyloctenium aegyptium (L.) Willd. – 1, flowering plant; 2, ligule; 3, spikelet.

The inflorescence is similar to that of *Eleusine* Gaertn. It can be distinguished by its awned upper glume, its 2-ranked spikelets, and by its stoloniferous habit.

D. aegyptium flowers early in the rainy season and seeds profusely; it is an exceedingly variable grass.

Ecology *D. aegyptium* can grow from sea-level up to 2100 m altitude and in areas receiving 400–1500 mm rainfall annually. It is adapted to a wide range of soil types but is particularly well suited to disturbed areas on light-textured soils. It will not stand prolonged flooding.

Agronomy *D. aegyptium* is established by sur-

face sowing at 0.25 kg/ha. It grows very vigorously and can be cut or grazed early in the growing season. In grazed areas it can be top dressed with N fertilizer after its first grazing to stimulate regrowth. It can be cut as a fodder and fed fresh to livestock and it also makes excellent hay. Farmers normally dig up whole plants when weeding and feed these fresh to their livestock. A DM yield of at least 3 t/ha per season can be expected in unfertilized open fields on loamy sand soils.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects *D. aegyptium* is a valuable native forage. Studies should be carried out on its agronomy, nutritive value and grazing management.

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C. Manidool

Desmanthus virgatus (L.) Willd.

Sp. Pl. ed. 4, Vol. 4(2): 1047 (1806).
LEGUMINOSAE
$2n = 28$

Synonyms *Mimosa virgata* L. (1753).

Vernacular names False tamarind (En). Acacia courant, acacia savane (Caribbean) (Fr). Thailand: thua desmanthus. Vietnam: cây diên keo.

Origin and geographic distribution *D. virgatus* originated in the Americas where it is widespread, occurring from Arizona, Florida and Texas in the United States, throughout much of Mexico and has been recorded in most countries south to Argentina as well as in the Caribbean and the Galapagos Islands. The main centre of diversity of the genus is Mexico and that is probably true of *D. virgatus* as well. The species is naturalized in some regions of the tropics including the island of Sulawesi (Indonesia) and in the Pacific islands (New Caledonia).

Uses At present *D. virgatus* is not yet sown on farms in South-East Asia despite recent promising results from species evaluation experiments. In the Americas it makes a contribution to native pastures but is not yet developed to the point of commercial release. In India it is used in hedges to provide cut forage, and is being evaluated in Australia as a species for permanent pastures.
In some areas the species has become a weed.

Properties Nitrogen concentrations of 3.6% in the leaves and of 1.1% in the stems have been measured.
There are 170–340 seeds/g.

Botany A perennial or sometimes annual shrub or herb, prostrate to erect, 0.5–3 m tall, taprooted (the taproot develops into a storage organ in some forms); stem unbranched or sparingly branched, hollow, subglabrous, ridged. Leaves bipinnate, 2–8 cm long, with 1–7 pairs of pinnae, usually with a petiolar gland between the lowest pair of pinnae; petiole up to 5 cm long; pinnae up to 7 cm long with

Desmanthus virgatus (L.) Willd. – 1, flowering branch; 2, leaflet; 3, flower; 4, infructescence.

10–25 pairs of leaflets; leaflets linear to linear-oblong, 4–9 mm × 1–2 mm, oblique and eccentric at the base, obtuse to apiculate at the apex; stipules linear-subulate, up to 6 mm long. Inflorescence a small globose 6–10-flowered head; peduncle up to 7.5 cm long; flowers bisexual or with some neuter lower flowers; petal white to cream, ca. 4 mm long, sometimes absent; stamens 10. Fruit linear to falcate, 3–10 cm × 3–4 mm, dehiscing with 2 valves, smooth or subseptate, red-brown, shiny, 20–30-seeded. Seed ovoid to ellipsoid, ca. 2 mm long, glossy brown.

D. virgatus is extremely variable in habit and in other characters such as pod shape and size and leaf morphology. Four varieties are recognized by Isely: var. *virgatus*, var. *glandulosus* Turner, var. *depressus* (Humb. & Bonpl. ex Willd.) B. Turner and var. *acuminatus* (Benth.) Isely. These are separated by habit, leaf characteristics, and the number and location of glands on the petiole and leaf. Most accessions belong to var. *virgatus*.

D. virgatus is a copious seed producer with many forms acting as annuals if not cut or grazed.

Ecology *D. virgatus* is adapted to a wide range of tropical and subtropical environments. It has been collected at sites in the Americas with annual rainfall ranging from 250–2000 mm and altitudes from sea-level to 2000 m. Most commonly the species is associated with neutral to alkaline clay or clay-loam soils. Crowns survive frosting but top growth is frost-sensitive.

Agronomy Propagation is by seed. Seed usually has a high proportion of hard seed and hard-seededness can be broken by mechanical scarification or hot water treatment. Seeding rates of between 2–6 kg/ha should be adequate. *D. virgatus* should preferably be inoculated prior to sowing by a specific strain of *Bradyrhizobium*. It is adapted to defoliation and should have cutting or grazing applied soon after establishment to induce branching and crown development. DM yields of 7.6 t/ha have been obtained in Fiji, and fresh material yields of 23 t/ha (Hawaii) and 70 t/ha (Australia) have also been reported.

Genetic resources and breeding *D. virgatus* germplasm is available from the ATFGRC (CSIRO, Australia) and from CIAT (Colombia). No breeding programmes are in progress. The extreme natural variation in climatic origin, plant morphology and flowering time of the species has enabled the selection of accessions for advanced evaluation from wild collections.

Prospects Three cultivars have recently been released in Queensland, Australia. They differ mainly in their time of flowering in the subtropics and higher latitude tropics. Cultivar 'Marc' is early flowering, 'Bayamo' is mid-flowering and 'Yuman' is late flowering. 'Marc' has a lower yield potential but is more likely to persist in grazed pastures in the long term. The existence of adventive populations in Sulawesi (Indonesia) and in the Pacific shows that the species has potential as a forage in Asia especially on neutral to alkaline soils. There is also interest in the species as a forage legume for upland intercropping. The wide range of material available should enable the development of commercial material for the region.

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B.C. Pengelly & A. Topark-Ngarm

Desmodium heterocarpon (L.) DC.

Prodr. 2: 337 (1825) (*heterocarpum*).

LEGUMINOSAE

$2n = 22$

Synonyms *Hedysarum heterocarpon* L. (1753).

Vernacular names Carpon desmodium (En). Indonesia: buntut meyong sisir (Sundanese), kaci (Javanese), akar entimor (Belitung). Malaysia: rumput kerbau derapah, kacang kayu betina. Philippines: mangkit-parang (Tagalog), mani-mani (Visaya), huyo-huyop (Ifugao). Cambodia: baay dâm'nnaëp. Vietnam: trang qu'a di qu'a.

Origin and geographic distribution Carpon desmodium is distributed naturally from India and Sri Lanka through Burma, Thailand, Indo-China, Malesia, China, Taiwan, Ryukyu, Japan, to the Pacific Islands and Australia.

Uses Although native to South-East Asia, carpon desmodium is grazed as a wild plant, but is not sown in the region. Cultivar 'Florida' has been sown to a limited extent in Florida (United States) where it is used for grazing in mixtures with perennial grasses.

Properties Carpon desmodium is lower in quality than many other forage legumes. A study done in the United States found that foliage contained 1.5–3.2% nitrogen. Tannin percentages of 2.1–3.1% have been measured. There are 700–800 seeds/g.

Description A perennial herb or low shrub with ascending or creeping stems 0.5–3.0 m long from a woody rootstock. Stems mostly much-branched at the base, and when young variously hairy, from almost glabrous to densely covered with more or less appressed hairs. Leaves with 3 leaflets, or often with 1 leaflet on seedlings or at the base of older stems; leaflets variable in texture, shape and size, mostly papery; the terminal one elliptical, ovate or obovate, (1.5–)2–6(–9) cm × (1–)1.5–3(–4) cm, indented or more or less pointed at the tip, sparsely covered with appressed hairs on the upper surface, the lower surface more densely covered with appressed silvery hairs and with prominent nerves; the lateral ones with the same proportions but up to 4 cm long. Inflorescence a dense axillary or terminal raceme; flowers pink, mauve, purple, violet or white, 4–7 mm long, mostly in pairs, each on a 3–5 mm long pedicel within the axil of a 5–8 mm long pointed bract. Pod 10–28 mm × 2–3 mm, erect to ascending, straight along the upper margin, undulate along the lower margin, the isthmus between the 4–8 articles 2/3–4/5 as wide as the pod which splits along the lower margin when ripe; articles quadrate, 2.5–3 mm long, glabrous or hairy. Seed broadly elliptical, ca. 1.5 mm × 2 mm.

Desmodium heterocarpon (L.) DC. – 1, fruiting branch; 2, fruit; 3, seeds.

Growth and development Seedling growth of carpon desmodium is slow. Once established, it is a very long-lived legume which can persist for over 10 years regardless of grazing management. It requires a moderate soil P status for maximum growth. In Florida, 65% of the growth is during the summer and early autumn growing seasons. Under heavy grazing it develops a prostrate growth habit. It is self- or cross-pollinating; it selfs when flowers are tripped.

Other botanical information *D. heterocarpon* is very polymorphic and has been variously delimited. In the last revision and emendation of *Desmodium* Desv. for Asiatic species, Ohashi defined this species in its widest sense and characterized it as having 1–3-foliolate glabrous leaves, elliptical, ovate or obovate terminal leaflets, inflorescences 3–13 cm long and erect or ascending pods with 4–8 transverse-oblong or tranverse-obovate articles shorter than 4.5 mm long and less than twice as long as broad. He subdivided the species as follows:

- ssp. *angustifolium* Ohashi: synonym: *D. reticulatum* Champ. ex Benth.; terminal leaflets narrowly ovate, acute or obtuse at apex, 3–6.5 times longer than broad; inflorescence 10–30 cm long, not branched; Burma, Thailand, Indo-China and China; with 2 formae.
- ssp. *ovalifolium* (Prain) Ohashi: see separate treatment.
- ssp. *heterocarpon*: terminal leaflets obovate, elliptical or oblong, sparsely to subdensely hairy above; inflorescence elongated; flowers 3–4 mm long, pedicels 4–7 mm long; pods sparsely to densely pubescent with white hooked and straight hairs up to 1.5 mm long; with 4 varieties.

Ecology Carpon desmodium is adapted to a fairly high rainfall of over 1200 mm a year, can withstand short periods of drought but does not tolerate prolonged flooding. It is tolerant of repeated light frosts, and in the tropics it grows up to 2500 m altitude. It prefers better-drained soils of light texture. It tolerates soil pH values of 4.3–5.0 with high Al saturation.

Agronomy Establishment is by seed, sown at a

rate of 3–10 kg/ha. A clean, firm seed-bed is desirable. It nodulates with native cowpea rhizobium. On neutral and alkaline soils, it may become micro-nutrient deficient.

Carpon desmodium is free of major fungal diseases, but is sensitive to various leaf-spots (*Cercospora* sp., *Pestalotiopsis versicolor*). Anthracnose (*Colletotrichum gloeosporioides, C. truncatum*) occurs in the south-eastern United States and South America but usually causes only slight to moderate damage. Powdery mildew (*Oidium* sp.) and wilt (*Sclerotium rolfsii*) have also been recorded. Root-knot nematodes (*Meloidogyne arenaria, M. incognita, M. javanica*) have been described as the worst pests of 'Florida' in the south-eastern United States, but their significance in South-East Asia has not been documented. Little leaf, caused by mycoplasma-like organisms, has caused slight to severe symptoms in Central and South America. Web-worms and other insects, including bean leaf roller (*Urbanus proteus*) sometimes attack foliage and pods in rank stands. They may be controlled by grazing and then de-stocking for a period before harvesting the seed crop.

It is harvested by grazing, and in Florida (United States), it is reported to be very tolerant of heavy grazing.

Genetic resources and breeding The wide diversity in the species could indicate potential for genetic improvement. Studies in Florida, largely based on accessions from Thailand, have suggested that some accessions are resistant to root-knot nematodes. Germplasm collections are maintained at ATFGRC (CSIRO, Australia), CIAT (Colombia) and USDA (Fort Pierce, Florida, United States). Breeding work is being carried out in Florida.

Prospects There has been little interest in this species outside of the south-eastern United States since its initial release as a pasture legume in 1979, and it is not anticipated that future plantings will be widespread.

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J.B. Hacker & A.E. Kretschmer, Jr.

Desmodium heterocarpon (L.) DC. ssp. ovalifolium (Prain) Ohashi

Journ. of Jap. Bot. 66: 21 (1991).

LEGUMINOSAE

$2n = 22$

Synonyms *Desmodium polycarpum* DC. var. *ovalifolium* Wallich ex Prain (1897), *D. ovalifolium* Wallich ex Merrill (1910), *D. heterocarpon* (L.) DC. ssp. *heterocarpon* var. *ovalifolium* (Wallich ex Prain) Rugayah (1987).

Vernacular names General: desmodium (South-East Asia). Thailand: khonthi din. Vietnam: trang qu'a xoan.

Origin and geographic distribution Ssp. *ovalifolium* originates in tropical South-East Asia where it occurs naturally from northern Thailand to southern Sumatra between 98°E and 105°E. It is particularly frequent in southern Thailand and is probably also native to the southern parts of Burma, Laos, Vietnam, and Cambodia. The accession marketed in Singapore has spread, at least for experimental purposes, to most tropical countries of the world.

Uses In South-East Asia, ssp. *ovalifolium* is mainly used as a cover crop in tree-plantation agriculture where it can be opportunistically grazed. Outside South-East Asia, its main use is as forage in permanent grass/legume pastures.

Properties Its nutritive value, including palatability, is commonly considered moderate to poor, mainly because of high tannin content (21–43%) and subsequent low intake and poor digestibility (28–51%) of DM. Tannin levels can be reduced and intake of ssp. *ovalifolium* can be increased by sulphur fertilization. Nitrogen concentrations in the herbage range from 1.5–3.0%. Other mineral concentrations are low to moderate (0.10–0.24% P and 0.27–0.57% Ca). There are about 500 seeds/g.

Desmodium heterocarpon (L.) DC. ssp. ovalifolium (Prain) Ohashi – 1, fruiting branch; 2, rooting branch.

Description A creeping, stoloniferous herb, in dense stands or under competition ascending up to 1 m. Stems many-branched, glabrous except for silky pubescence on young (apical) portions; old stems woody at base. Leaves 1- and 3-foliolate, in young plants always 1-foliolate; leaflets variable, mostly ovate or broad-elliptical, sometimes round or obovate; terminal leaflet larger than laterals; 1-foliolate leaves and terminal leaflets on adult plants on average 3–4.5 cm × 1.5–3 cm; leaflets coriaceous and without any markings, glabrous and glossy on upper surface, whitish pubescent on lower surface, sometimes only along the central vein. Inflorescence a densely flowered raceme, 2–5 cm × 1–2 cm; flower papilionaceous, small, with an obovoid standard about 6 mm × 4 mm, purple to dark-pink during anthesis, bluish when wilting. Pod erect or falcate, mostly densely pubescent, dehiscent, comprising 2–8 almost quadrate articles 2.5–3.5 mm long. Seed yellow when ripe.

Growth and development The initial growth of ssp. *ovalifolium* is slow, but once established, plants exhibit excellent vigour and competitiveness. Flowering and seed setting occur in the late wet and early dry seasons.

Other botanical information In the literature, this taxon is best known as *D. ovalifolium*, a name still often used in agricultural publications. In 1973, Ohashi considered it as belonging to the complex species *D. heterocarpon*, and within this species to ssp. *heterocarpon*. Rugayah gave it a varietal status under Ohashi's ssp. *heterocarpon* in 1987, justifying this separation by some morphological and anatomical distinguishing characteristics. In 1991 Ohashi agreed that *D. ovalifolium* deserved a special status, and he gave it the actual subspecific rank. Nevertheless, in the whole *D. heterocarpon* complex, intermediate forms blur the distinctions between the different subspecies recognized by Ohashi. More research is needed to unravel this complex satisfactorily.

All ssp. *ovalifolium* used in South-East Asian plantation agriculture seems to belong to a single accession marketed in Singapore. The same accession is also spreading in tropical America for use in pastures. It was recently released in the humid tropics of Bahia, Brazil, as 'Itabela'.

Ecology Ssp. *ovalifolium* is well adapted to the humid and sub-humid tropics with not more than 2–3 consecutive dry months and is very shade-tolerant. It grows well on a range of soils, including light-textured as well as seasonally poorly drained, heavy-textured soils. The species is well adapted to acid, low-fertility oxisols and ultisols with high Al saturation and low available P.

Propagation and planting Ssp. *ovalifolium* is established by seed, at rates of 0.5–2 kg/ha. Seed samples frequently have a high percentage of hard seed, particularly if newly harvested, and will require treatment by heat or acid or mechanical scarification to break hard-seededness prior to sowing.

To establish pastures, seed is broadcast or drilled at the same time that the associated grass is sown or planted, or it is strip-sown into an existing grass sward. Because of its stoloniferous growth habit, ssp. *ovalifolium* associates well with aggressive, stoloniferous grasses. The species most frequently recommended for association with ssp. *ovalifolium* is koronivia grass (*Brachiaria humidicola* (Rendle) Schweick.). Although the legume nodulates freely and effectively with native rhizobia, the inoculation of seed with a *Bradyrhizobium* strain of known effectiveness is recommended.

For use as a ground cover in plantation agriculture, a species mixture with centro (*Centrosema pubescens* Benth.), tropical kudzu (*Pueraria pha-*

seoloides (Roxb.) Benth.), calopo (*Calopogonium mucunoides* Desv.) and *C. caeruleum* (Benth.) Sauv. is recommended. Ssp. *ovalifolium* will be the most persistent in the mixture because it is the most shade-tolerant component.

Husbandry Fertilization with P and K enhances establishment, and despite its undemanding requirements regarding soil fertility and nutrients, ssp. *ovalifolium* responds to maintenance fertilization with these nutrients.

Because of its stoloniferous growth habit, ssp. *ovalifolium* tolerates heavy grazing well. Ssp. *ovalifolium*/*Brachiaria humidicola* pastures can be grazed rotationally or continuously, though stocking rate might have to be reduced during drier periods.

Diseases and pests Pink disease, caused by *Sclerotium* (formerly *Corticium*) *salmonicolor*, and root-knot nematode *Meloidogyne javanica* have been reported as major problems in South-East Asia.

A false rust or wart disease caused by *Synchytrium desmodii* was accidentally introduced to South America with commercial ssp. *ovalifolium* seed produced in Sri Lanka. In order to prevent this disease from becoming a major constraint in South-East Asia, and as the fungus survives on the seed surface and mainly in the seed debris, all seed lots should be treated with concentrated sulphuric acid prior to sowing.

In tropical America, a stem-gall nematode (*Pterotylenchus cedidogenus*) can be a serious pest.

Harvesting When used as a forage, ssp. *ovalifolium* is usually harvested by grazing animals rather than in cut-and-carry systems.

Yield The average range of DM yields reported for ssp. *ovalifolium* grown on acid, poorly fertile soils but under adequate soil-moisture conditions is 2–3.5 t/ha per 12 weeks. On more fertile soils, yields as high as 6 t/ha per 12 weeks can be obtained. Liveweight gain per animal from a ssp. *ovalifolium*-based pasture is moderate to low, but animal production per hectare can be high, because of the high carrying capacity of such pastures.

Seed yields range from 150–300 kg/ha given adequate soil moisture.

Genetic resources The genetic base of commercially available ssp. *ovalifolium* is narrow. However, the species is well represented, in the form of a large number of quite variable ecotypes collected in Thailand, Malaysia and Indonesia, in the two major collections of tropical forage legume germplasm at CIAT (Colombia) and ATFGRC (CSIRO, Australia). Planned plant collection in Burma, Laos, Vietnam and Cambodia should provide important additional variation.

Breeding Ssp. *ovalifolium* can be crossed with other subspecies and varieties of *D. heterocarpon*; such crosses sometimes occur even in nature. At present no breeding programme to improve ssp. *ovalifolium* is in progress.

Prospects Its excellent adaptation to acid, poorly fertile soils and its aggressive, stoloniferous growth habit combined with remarkable shade tolerance make ssp. *ovalifolium* valuable for plantation agriculture and pastures. Efforts are justified to overcome the constraints of low nutritional quality and disease susceptibility by systematic germplasm evaluation and, eventually, breeding.

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R. Schultze-Kraft

Desmodium heterophyllum (Willd.) DC.

Prodr. 2: 334 (1825).

LEGUMINOSAE

$2n = 22$

Synonyms *Hedysarum heterophyllum* Willd. (1802), *Meibomia heterophylla* (Willd.) Kuntze (1891).

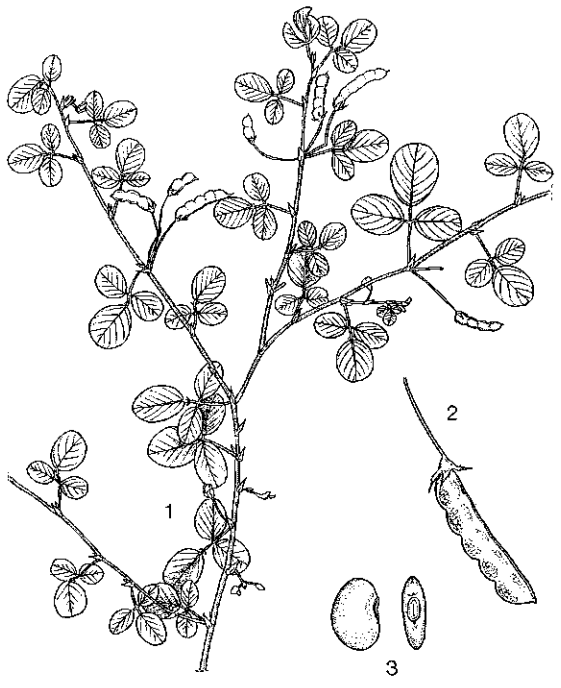
Vernacular names Hetero, Spanish clover (En). Indonesia: sisik betok (Indonesian), heuheulangan (Sundanese), sukut jareman (Javanese). Malaysia: rumput sisek naga, rumput sisek betok, rumput telinga tikus. Cambodia: trôm' préi, smau 'âm'bôk. Laos: padông môd liinz. Thailand: yamaengmi (northeast). Vietnam: hạ̀n the, tràng qu'a di diệp (southern).

Origin and geographic distribution Hetero is native to tropical Asia and adjacent islands, occurring naturally in Mauritius, India, Nepal, Sri Lanka, Burma, Thailand, Indo-China, Malesia, China and Taiwan. It is adventive to the South Pacific and naturalized in parts of north-eastern Australia.

Uses Hetero is primarily used as a legume for heavily grazed pastures in the wet tropics, and is recommended as such in Malaysia. It is also used as a cover crop, e.g. in pepper gardens in Sarawak. It is not suitable for cut-and-carry systems.

Properties Nitrogen concentration in new growth of hetero is about 2.8–3.0%. When grown in mixtures with pangola grass (*Digitaria eriantha* Steudel) it increased the N concentration of the grass from 0.86% to 1.12%.

Botany A prostrate or ascending perennial undershrub, with woody rootstock. Stems up to 1.5 m long, freely branching and covered with spreading reddish-brown hairs. Leaves trifoliolate, on lower parts often unifoliolate; petiole 5–15 mm long; leaflets obovate or elliptical, usually 10–25 mm × 8–14 mm, laterals smaller than the terminals, rounded or indented at the tip, hairless on the upper surface, sparsely covered with long hairs on the lower surface. Inflorescence a few-flowered axillary or terminal raceme to 6 cm long, and/or leaf-opposed clusters of 1–3 flowers; pedicel 10–25 mm long; flower about 5 mm long, purple or white. Pod narrowly oblong, 10–20 mm × 3–5 mm with 3–6 broadly oblong or quadrate articles 3–4 mm long, densely covered with minute hooked hairs, the isthmus between the articles ca. ¾ the width of the pod, dehiscing along the lower margins when ripe. Seed transversely elliptical, about 1.5 mm × 2 mm. Hetero is self-compatible but normally cross-pollinated. Cultivar 'Johnstone' was released in Australia in 1973.



Desmodium heterophyllum (Willd.) DC. – 1, flowering and fruiting branch; 2, fruit; 3, seeds.

Ecology Hetero is adapted to the humid tropics with annual rainfall exceeding 1500 mm, and to a wide range of soils from sands to clays. It is reported to be less tolerant of soil acidity than *D. heterocarpon* (L.) DC. It is intolerant of fire and salinity, and susceptible to frost.

Agronomy Seed production of hetero is not easy, owing to poor synchrony within the crop (associated with the indeterminate nature of the plant and the two inflorescence types) and the fragility of ripe pods which are carried within or close to the upper levels of the herbage. Therefore, it is commonly established vegetatively by cuttings. However, because hetero requires a specific strain of *Bradyrhizobium*, it is preferable to plant out sods which contain vegetative material, seed and *Bradyrhizobium*. Fresh seed has some hard-seededness, which may be broken by scarification. Seed should be sown no deeper than 5 mm and should be inoculated with the appropriate *Bradyrhizobium*, if possible. Early growth has been noted as slightly unpalatable, but this is an advantage as it promotes successful establishment.

Hetero occurs as a component of native pastures in parts of Indonesia and Fiji, where its poor productivity as a naturally occurring species can be improved by applying P fertilizer. Unlike most tropical pasture legumes, hetero tolerates heavy grazing. It has an excellent ability to spread naturally, both by means of its freely-branching stolons and its free-seeding habit, and competes well against low-growing weeds. Reports on its tolerance to shade are confusing, but recent experience suggests that, when adequately fertilized, it is one of the most shade-tolerant of the pasture legumes.

Hetero is sensitive to cercospora leaf-spot *(Cercospora* sp.) and to foliar blight *(Rhizoctonia solani)*, which is frequent in humid regions of the tropical American lowlands. Wilt *(Sclerotium rolfsii)* has caused seedling mortality in greenhouse tests and little leaf (mycoplasma-like organisms) has caused

damage, but these diseases are considered to be unimportant under grazing. Root-knot nematodes *(Meloidogyne arenaria, M. incognita)* can also cause damage.

Since hetero can withstand heavy grazing, it has the ability to persist in mixtures with vigorous creeping grasses where twining and shrubby legumes would be grazed out. However, persistence has been poor on soils of poor fertility, particularly those deficient in trace elements, and in ungrazed or lightly grazed stands with tall-growing grasses such as guinea grass (*Panicum maximum* Jacq.). Cattle grazing north-eastern Australian pastures based on hetero and either *Digitaria eriantha* or *Brachiaria decumbens* Stapf had liveweight gains of over 750 kg/ha per year.

Genetic resources and breeding Collections of *D. heterophyllum* are held by ATFGRC (CSIRO, Australia) and CIAT (Colombia). No breeding has been carried out in this species.

Prospects The relatively unusual ability of hetero to withstand and spread under heavy grazing and its tolerance of shade suggests that it is likely to be more widely used in the humid tropics.

Literature |1| Bogdan, A.V., 1977. Tropical pasture and fodder plants. Longman, London. pp. 343–344. |2| Halim, R.A. (Editor), 1989. Grassland and forage production in South-east Asia. Proceedings of first meeting of the regional working group on grazing and feed resources of South-east Asia, 27 Feb – 3 Mar, 1989. FAO, Rome. 216 pp. |3| Knaap-van Meeuwen, M.S., 1962. Preliminary revisions of some genera of Malaysian Papilionaceae 5. – A census of the genus Desmodium. Reinwardtia 6: 251–252. |4| Lenné, J.M. & Stanton, J.M., 1990. Diseases of Desmodium species. Tropical Grasslands 24: 1–14. |5| Ohashi, H., 1973. The Asiatic species of Desmodium and its allied genera (Leguminosae). Ginkgoana 1: 239–241. |6| Partridge, I.J., 1986. Effect of stocking rate and superphosphate level on oversown fire climax grassland of mission grass (Pennisetum polystachion) in Fiji. Tropical Grasslands 20: 166–173. |7| Skerman, P.J., Cameron, D.G. & Riveros, F., 1988. Tropical forage legumes. FAO, Rome. pp. 271–274.

J.B. Hacker & J.K. Teitzel

Desmodium incanum DC.

Prodr. 2: 332 (1825).
LEGUMINOSAE
$2n = 22$

Synonyms *Hedysarum racemosum* Aublet (1775), *Aeschynomene spicata* Poiret (1797), *Desmodium canum* Schinz & Thellung (1913, nom. illeg.).

Vernacular names Kaimi, kaimi clover, creeping beggar weed (En). Pega-pega (Port).

Origin and geographic distribution Originally from southern United States to Uruguay and Argentina, this species is now widely distributed in the wet tropics and some areas of the wet subtropics. It is abundant on volcanic soils in Hawaii, Fiji, Vanuatu and other Pacific Islands.

Uses A potentially useful pasture species in mixed grass/legume pastures, especially under conditions of heavy grazing or low soil fertility. Reported to be a promising pasture species in Fiji and Vanuatu but not widely recommended elsewhere in the Pacific region.

Properties Kaimi is not toxic to livestock, but palatability is reduced by tannins. Nitrogen concentrations of 2.0–2.5 % have been reported.

Botany Ascending to erect perennial herb or low shrub to 60 cm tall, rarely to 3 m, but in a grazed pasture situation it is typically prostrate and less than 20 cm tall. Stem trailing, fibrous to woody, sometimes beneath the soil surface, root-

Desmodium incanum DC. – 1, habit leafy plant; 2, flowering branch; 3, flower; 4, fruit; 5, seed.

ing readily at the nodes; root system deep, well-branched. Leaves trifoliolate, stipulate, petiolate; stipules at least partially connate abaxially, 3–11 mm × 1–3 mm, long persistent; petioles up to 3.5 cm long; leaflets very variable, mostly elliptical, terminal leaflets 2–9 cm × 1.5–4.5 cm, lateral ones up to 6 cm × 3 cm; leaflets on upper leaves tending to be narrower than those on lower leaves, dark green on the upper surface and often with a paler streak along the midrib, paler and densely pilose beneath. Inflorescence a terminal or axillary raceme, up to 20 cm long; flowers solitary or in fascicles of 3; pedicel 4–10 mm long; flower blue, red or purple, the standard up to 6 mm long. Pod up to 4 cm long, the upper margin straight, the lower strongly indented, covered with hooked hairs, with up to 8 articles of 3.5–5 mm × 2–3.5 mm. Seed oblongoid to kidney-shaped, 1 mm × 0.5 mm, light brown.

D. incanum is a very variable species and has been described many times; hence its nomenclature is quite complicated. The texture of the leaflets and the characters of the fruits are less variable.

Initial growth is slow, but later growth rates improve, provided moisture is adequate. Trailing stems begin to develop some 6 months after sowing. In regions with a pronounced seasonal climate, growth during the dry season is slow. At higher latitudes, flowering occurs when daylengths shorten. It is naturally spread by animals and humans, the hooked hairs on the pod adhering to fur or clothing.

Ecology *D. incanum* grows best in regions with annual rainfall of 1500–3000 mm, but will persist and spread in areas receiving 1000 mm. Optimum temperatures are reported to be 30°/25°C during the growing season. The species is tolerant of light frosts and temporary flooding. In regions where it is naturalized, it is particularly common along roadsides, wasteland and other disturbed ground. *D. incanum* is apparently best adapted to fertile, neutral to slightly alkaline soils, but may be grown on a wide range of soil types from sands to light clays, pH 4.0–8.0.

Agronomy *D. incanum* is propagated by seed. Seed is often hard and may require treatment with concentrated sulphuric acid for 10 minutes before sowing. It is recommended that the seed be inoculated with the special *Desmodium* strain of *Bradyrhizobium*. It requires a well-prepared seed-bed for the most reliable establishment but may also be broadcast into an existing pasture. Recommended sowing rate is 5 kg/ha at ca. 5 mm depth. It responds to lime and P, but these are not normally considered essential. It grows with a range of pasture grasses, but is usually associated with stoloniferous or rhizomatous species.

D. incanum is reported to be sensitive to Peanut Mottle Virus and may act as a source for this virus for cultivated groundnuts in the United States. Several fungal diseases have been recorded on *D. incanum*, as well as little leaf and desmodium mosaic virus, but they rarely cause serious problems. Seedlings may be damaged by cutworms, and in Hawaii the rose beetle and the cyst nematode *Heterodera trifolii* may cause damage.

The stoloniferous habit of this species enables it to withstand heavy grazing. A 30–40 day rest period between grazings has been recommended, but the species can persist under close continuous grazing. It is amongst the more persistent legume species under heavy grazing. *D. incanum* can yield up to 6500 kg/ha of DM but is normally considered to be low-yielding. Seed yields may exceed 200 kg/ha, but lower yields are more usual. Under lenient defoliation, and particularly with high P input, it is reported to be lower-yielding and to fix less N than the more widely grown *D. intortum* (Miller) Urban.

Genetic resources and breeding No cultivars are available. Collections are maintained at ATFGRC (CSIRO, Australia), EMBRAPA (Brazil), CIAT (Colombia), and USDA (Fort Pierce, Florida, United States). *D. incanum* is self-fertile, but some outcrossing is believed to occur. It has been hybridized with *D. uncinatum* (Jacq.) DC., but the hybrid is sterile.

Prospects *D. incanum* is a species which could warrant further investigation for South-East Asian pastures since it tolerates heavy grazing or cutting. Early results from Hawaii were extremely promising, but interest in the species has not been maintained.

Literature 1| Cameron, D.G., Jones, R.M., Wilson, C.P.M., Bishop, H.G., Cook, B.G., Lee, C.R. & Lowe, K.F., 1989. Legumes for heavy grazing in coastal subtropical Australia. Tropical Grasslands 23: 153–161. |2| Imrie, B.C., Jones, R.M. & Kerridge, P.C., 1983. Desmodium. In: Burt, R.L., Rotar, P.P., Walker, J.L. & Silvey, M.W. (Editors): The role of Centrosema, Desmodium and Stylosanthes in improving tropical pastures. Westview Press, Boulder, Colorado, United States. pp. 97–140. |3| Lenné, J.M. & Stanton, J.M., 1990. Diseases of Desmodium spp. – a review. Tropical Grasslands 24: 1–14. |4| Nicolsen, D.H., 1978. Illegitimate 'basionyms', impact on priority and author citation or, the rise of Desmodium incanum

and fall of D. canum (Fabaceae). Taxon 27(4): 365–370. |5| Schubert, B.G., 1980. Desmodium. In: Dwyer, J.D. (Editor): Flora of Panama. Part 5: Family 83, Leguminosae subfamily Papilionoideae. Annals of the Missouri Botanical Garden 67: 640–643. |6| Skerman, P.J., Cameron, D.G. & Riveros, F., 1988. Tropical forage legumes. FAO, Rome. pp. 263–267.

J.B. Hacker

Desmodium intortum (Miller) Urban

Symb. Antill. 8: 292 (1920).
LEGUMINOSAE
$2n = 22$

Synonyms *Hedysarum intortum* Miller (1768), *Desmodium aparines* (Link) DC. (1825).

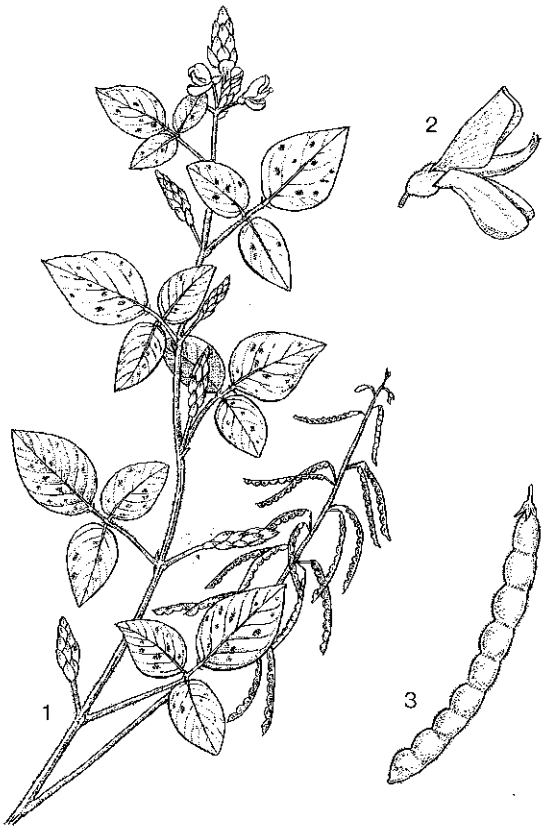
Vernacular names Greenleaf desmodium (En). Pega-pega (Sp). Philippines: karikut-ritkut (Bagobo). Thailand: thua kleen leap.

Origin and geographic distribution Greenleaf desmodium is native to the Americas, from southern Mexico to as far south as southern Brazil. Following widespread testing as a forage legume, it is now naturalized in small areas of the higher rainfall subtropics and elevated tropics. In South-East Asia it occurs most in Papua New Guinea, the Philippines and Thailand.

Uses Greenleaf desmodium is mostly utilized as a pasture legume in mixed sowings with grasses. It can also be cut for use as fresh fodder or for hay or made into silage.

Properties Nitrogen concentrations in top growth range from 2–4.2%. In one sampling the N concentration in leaves (3.7%) was double that of the stems (1.7%). Phosphorus concentrations in leaf material range from 0.10–0.45%. Tannin levels in leaves range from 3–9% which may account for the somewhat low in vitro digestibility range of 55–60%.

Botany A robust taprooted perennial herb with trailing stems and stolons to several metres long. Stems form roots if in contact with moist soil and may scramble, but not twine, over the surrounding vegetation; they are grooved, often reddish in colour, densely covered with short hooked hairs, glandular, sticky to the touch. Leaves with three leaflets; petiole up to 5 cm long; leaflets usually ovate, 3–12 cm × 1.5–7 cm, the lateral ones smaller than the terminal, often with sparse reddish-brown marks on the upper surface, covered with ascending hairs on both surfaces. Inflorescence a quite dense terminal or axillary panicle up to 30 cm long; flowers pink to purple, 8 mm long, borne in pairs within the axils of caducous bracts. Pod 15–50 mm × 3–4 mm, curved, up to 12-articulate, covered with short hooked hairs and hence adhering to animals and clothing, slightly indented along the upper margin, more strongly indented along the lower margin between the 3–7 mm long articles, breaking up at maturity. Seed reniform, 2 mm × 1.3 mm.



Desmodium intortum (Miller) Urban – 1, flowering and fruiting branch; 2, flower; 3, fruit.

D. intortum is closely related to *D. uncinatum* (Jacq.) DC., together forming a complex which is taxonomically not well separated and in which more names are involved (e.g. *D. aparines* ((Link) DC.).

Greenleaf desmodium is self fertile but flowers may require tripping for pollination to occur. Seedlings develop slowly and require favourable conditions during the first weeks of growth.

Once established, greenleaf desmodium makes vigorous growth. In the higher latitude tropics and in the subtropics it has a long growing season

before flowering late in the wet season. It does not spread readily from seed but individual plants can spread quite a long distance by means of stolons. Well-known cultivars are 'Greenleaf' (Australia) and 'Tengeru' (Tanzania).

Ecology Greenleaf desmodium usually requires more than 1100 mm annual rainfall. It can be grown at sea-level in the subtropics, but favours elevated areas (500–2000 m) in the tropics. Hence it has shown promise in the wetter Australian subtropics and in elevated tropical areas as in Papua New Guinea, Thailand and the Philippines. It is tolerant of shade, but not adapted to the lowland tropics where the major plantation crops are grown. It is susceptible to heavy frosts and also to extended dry spells during the growing season. It will grow satisfactorily on a range of soils, from sandy soils to clay loams, provided the pH(H_2O) is not less than 5.0 (preferably 5.5) and they are not saline. It is intolerant of fire.

Agronomy 'Greenleaf' is sown by seed into a well-prepared seed-bed, or more rarely established by rooted cuttings. Seed may be drilled to a depth not exceeding 10 mm, or broadcast; seeding rates are generally 1–2 kg/ha. It does not establish satisfactorily when oversown into an existing pasture. Mechanically-harvested seed exhibits negligible hard-seededness, but hand-harvested seed may benefit from treatment with sulphuric acid for five minutes, followed by washing. Seed should be inoculated with a specific 'desmodium' culture of *Bradyrhizobium*. It is generally sown with a companion grass such as *Setaria sphacelata* (Schumacher) Stapf & C.E. Hubbard ex M.B. Moss and sometimes together with other tropical pasture legumes. Greenleaf desmodium requires moderate to high levels of P, S, K and Mo for growth. It has a higher requirement for Mo than most tropical legumes.

Several fungal diseases have been reported on greenleaf desmodium but usually they have had minimal impact on persistence and production. Little leaf, caused by a mycoplasma-like organism also occurs but usually only affects isolated plants. In Australia, the most important pests are weevil larvae of *Amnemus* and *Leptopius* spp. which damage or even sever taproots and larger adventitious roots, making 'Greenleaf' more susceptible to soil moisture stress.

It will usually be eliminated from a pasture by frequent close cutting or heavy grazing, as this removes axillary and terminal buds and reduces the plant's ability to recover. Even with appropriate grazing management and a suitable environment, 'Greenleaf' may only persist for 5–10 years.

'Greenleaf' is usually grazed by cattle, although it can be used in a cut-and-carry system. Annual DM yields of 12–19 t/ha have been recorded from 'Greenleaf' grown in pure stands or in mixtures with grasses. Liveweight gains from 'Greenleaf'/grass pastures usually range from 250–600 kg/ha per year, although higher gains have also been recorded. Given low grazing pressure, liveweight gains of over 200 kg/head per year can be obtained from good 'Greenleaf' pastures. Milk production from Jersey cows grazing pure 'Greenleaf' was only 7.7 kg/day. This may have been associated with difficulties in achieving a high intake from the open sward; higher milk production figures have been obtained from 'Greenleaf'/grass pastures.

Genetic resources and breeding Germplasm collections are available at ATFGRC (CSIRO, Australia) and CIAT (Columbia). There is little variation within the species in most agronomic characters, but there is variation in resistance to nematodes. This suggests that, where this is a problem, genetic advances can be made. Breeding in Australia to improve seedling vigour, by hybridization with the related *D. sandwicense* E. Meyer and selection for large seed size, was discontinued.

Prospects Greenleaf desmodium has a restricted range of adaptation and will be further restricted by its inability to withstand sustained heavy cutting or grazing. However, within the limited areas and farm systems to which it is suited, it is a productive legume.

Literature 1 Bogdan, A.V., 1977. Tropical pasture and fodder plants. Longman, London. pp. 344–348. 2 Imrie, B.C., Jones, R.M. & Kerridge, P.C., 1983. Desmodium. In: Burt, R.L., Rotar, P.P., Walker, J.L. & Silvey, M.W. (Editors): The role of Centrosema, Desmodium and Stylosanthes in improving tropical pastures. Westview Press, Boulder, Colorado, United States. pp. 97–140. 3 Jones, R.M., 1989. Productivity and population dynamics of silverleaf desmodium (Desmodium uncinatum) and greenleaf desmodium (Desmodium intortum) and two D. intortum × D. sandwicense hybrids at two stocking rates in coastal south-east Queensland. Tropical Grasslands 23: 43–55. 4 Lenné, J.M. & Stanton, J.M., 1990. Diseases of Desmodium species. Tropical Grasslands 24: 1–14. 5 Skerman, P.J., Cameron, D.G. & Riveros, F., 1988. Tropical forage legumes. FAO, Rome. pp. 274–282.

J.B. Hacker

Desmodium triflorum (L.) DC.

Prodr. 2: 334 (1825).
LEGUMINOSAE
$2n$ = unknown

Synonyms *Hedysarum triflorum* L. (pro parte) (1753), *Desmodium parvifolium* Blanco (1845), *Meibomia triflora* (L.) Kuntze (1891).

Vernacular names Three-flowered beggarweed (Hawaii) (Am). Indonesia: daun mules (Indonesian), jukut jarem (Sundanese), delilan (Javanese). Malaysia: rumput barek sisek putih, sisek tenggiling. Philippines: kaliskis-dalag (Tagalog), himbispuyo (Visaya), gumadep (Ifugao). Cambodia: smau kaè lolook. Thailand: ya-klethoi, ya-tanhoi (central), ya-tansai (norhtern). Vietnam: tràng qu'a ba hoa.

Origin and geographic distribution *D. triflorum* is pan-tropical. In the Asian region, its distribution includes India, Sri Lanka, Burma, Thailand, Indo-China, China, Taiwan, Malaysia, Indonesia, the Philippines, Papua New Guinea, Australia and the Pacific Islands.

Uses *D. triflorum* is widespread as a naturally occurring forage component of short grasslands. It is also used as a green manure and ground cover.

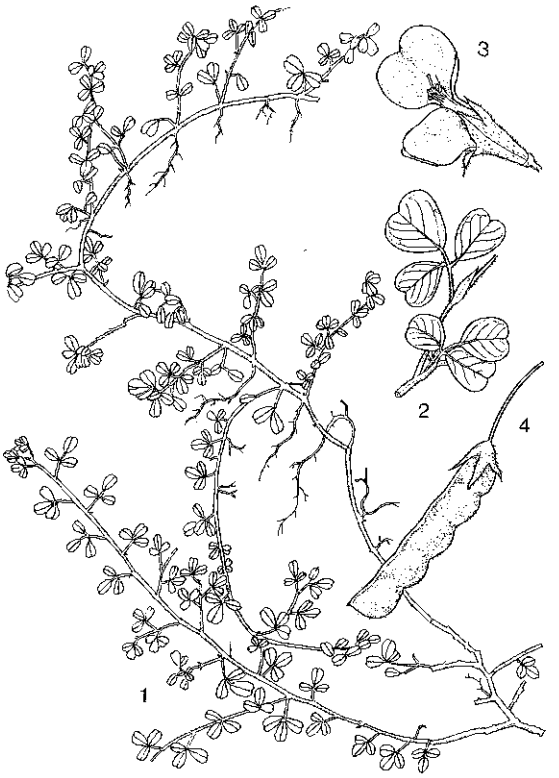
Properties Nitrogen concentrations of 2–3% have been recorded. Dry matter production is low. It is resistant to heavy grazing.

Botany Mat-forming prostrate annual or perennial herb, with woody rootstocks and long thickened taproot; stem 8–50 cm long, much branched, sometimes rooting at the nodes, white hairy. Leaves trifoliolate, occasionally unifoliolate; leaflets obovate-oblong, obovate or obcordate, 4–14 mm × 4–12 mm, rounded to emarginate at the apex, rounded to cuneate at the base, more or less hairy beneath. Flowers 1–3 in leaf axils, about 5 mm long; pedicel 5–10 mm long; corolla usually pink to purple. Fruit flat, 6–18 mm × 2–3 mm, 3–5 articled, indehiscent, glabrous to uncinulate-pubescent; the upper suture straight, the lower margin constricted between the articles which are 2–3.5 mm long and wide with a strong reticulation of raised nerves. Seed quadrangular to nearly orbicular in outline, ca. 1.2 mm × 1.7 mm.

Ecology *D. triflorum* is widespread throughout the wet tropics and appears to be well adapted to a wide range of soils. It is usually found in heavily grazed or closely cut areas.

Agronomy *D. triflorum* is resistant to heavy grazing, but it produces little dry matter. However, it provides forage of reasonable N status to animals. It is not cultivated.

Genetic resources and breeding Germplasm collections are present at ATFGRC (CSIRO, Australia) and CIAT (Colombia).



Desmodium triflorum (L.) DC. – 1, habit; 2, part of branch; 3, flower; 4, fruit.

Prospects Because *D. triflorum* produces so little dry matter, it is unlikely to be considered in plant improvement programmes.

Literature [1] Ohashi H., 1973. The Asiatic species of Desmodium and its allied genera. (Leguminosae) Ginkgoana 1: 245–249. [2] Skerman P.J., Cameron, D.G. & Riveros, F., 1988. Tropical forage legumes. FAO, Rome. pp. 285–286. [3] Verdcourt, B., 1979. A manual of New Guinea legumes. Botany Bulletin No 11. Office of Forests, Division of Botany, Lae, Papua New Guinea. p. 409.

B.C. Pengelly

Desmodium uncinatum (Jacq.) DC.

Prod. 2: 331 (1825).
LEGUMINOSAE
$2n$ = 22

Synonyms *Hedysarum uncinatum* Jacq. (1798), *Meibomia uncinata* (Jacq.) Kuntze (1891).

Vernacular names Silverleaf desmodium, silverleaf Spanish clover (En). Indonesia: semanggi. Philippines: pega-pega (Tagalog), koer (Bagobo). Thailand: enieo.

Origin and geographic distribution Silverleaf desmodium is indigenous to the Americas, from northern Argentina to Mexico. Since first released as a pasture plant in 1962, it now occurs in isolated localities in the more humid regions of the subtropics and elevated tropics, including South-East Asia.

Uses Silverleaf desmodium is used as a pasture legume in combination with a range of tropical pasture grasses. It can be made into hay.

Properties Nitrogen concentrations in whole top growth have ranged from 1.9–3.7%, and N concentrations in the leaves were approximately double those of the stems. Tannin levels of 3.6% have been measured in the leaves.

Botany Robust perennial herb with trailing stems to several metres long, ascending to about 1 m at flowering, densely covered with short hooked hairs, sticky to the touch. The stems form roots if in contact with moist soil and may scramble but not twine through the surrounding vegetation. Leaves with 3 leaflets; petiole up to 5 cm long; leaflets usually ovate, 2–10 cm × 1–4.5 cm, dark green with a characteristic narrow elliptical silvery shiny area about the midrib above, covered on both surfaces with ascending hairs. Inflorescence a terminal or axillary raceme up to 50 cm long, sometimes branching at lower floral nodes; flowers pink, 7–12 mm long, borne in pairs within the axils of caducous bracts. Pod 10–50 mm × 3–4 mm, curved, up to 12-articulate, covered with short hooked hairs and hence adhering to passing animals and clothing, slightly indented on the upper margin and deeply indented along the lower margin between the 5 mm long articles, breaking up at maturity.

Desmodium uncinatum (Jacq.) DC. – 1, flowering and fruiting branch; 2, flower; 3, fruit.

Silverleaf desmodium is not vigorous in the seedling stage, but in warm conditions and in the absence of moisture stress, grows vigorously thereafter.

In the subtropics and elevated tropics, it flowers at the end of the wet season, earlier than *Desmodium intortum* (Miller) Urban. It is self-fertile, but flowers may require tripping.

The only cultivar of this species is 'Silverleaf', released in Australia in 1962.

Taxonomically *D. uncinatum* belongs to a not well separated complex of species (including the closely related *D. intortum*).

Ecology Silverleaf desmodium requires an annual rainfall exceeding 1000 mm, well distributed through the growing season, and has some tolerance of flooding and shallow water tables. It grows at sea-level in the subtropics but favours elevations of 500–2000 m in the tropics. It has little tolerance of salinity or moisture stress during the growing season, but is more cold-tolerant than most other tropical pasture legumes. It will grow on a range of soils from sands to clay loams, but not heavy clays. It requires a soil of at least pH(H_2O) 5.0, preferably 5.5. It will recover from moderate fires, but burning is not recommended.

Agronomy Ideally, 'Silverleaf' should be sown into a well-prepared seed-bed, but it has also successfully been sod-seeded into an existing pasture following treatment with a herbicide. It is normally sown with pasture grasses such as *Setaria sphacelata* (Schumach.) Stapf & Hubbard ex M.B. Moss. Seed should be inoculated with a special *Bradyrhizobium* strain to ensure effective nodulation. 'Silverleaf' has a requirement for P, K, S and Mo, and these should be applied where they are

naturally in short supply.
Several fungal diseases have been reported on 'Silverleaf', but they have usually not restricted its production and persistence. Little leaf, caused by a mycoplasma-like organism also occurs, but usually only affects isolated plants. It is also susceptible to root-knot and other nematodes. In Australia, the most important pests are weevil larvae of *Amnemus* and *Leptopius* species, which damage or even sever taproots and larger adventitious roots, increasing its susceptibility to moisture stress.
Frequent cutting or grazing to < 10 cm will result in disappearance of the legume from a pasture. Even with appropriate grazing management and a suitable environment, 'Silverleaf' may only persist for 3–10 years. Herbage is normally grazed. The species is not always particularly palatable to stock, which may take some time to get used to it.
Annual DM yields of 1.6–15 t/ha have been recorded from 'Silverleaf' and 'Silverleaf'/grass pastures. Studies have shown that nodulated 'Silverleaf' in a grass/legume pasture can increase soil nitrogen by 90–160 kg/ha per year.

Genetic resources and breeding Germplasm collections are held by ATFGRC (CSIRO, Australia) and CIAT (Colombia). There have been no breeding programmes with this species.

Prospects Silverleaf desmodium has a restricted range of adaptation and will be further restricted by its inability to withstand sustained heavy grazing or cutting. However, within the limited areas and farm systems to which it is suited, it is a productive legume.

Literature [1] Bogdan, A.V., 1977. Tropical pasture and fodder plants. Longman, London. pp. 350–354. [2] Imrie, B.C., Jones, R.M. & Kerridge, P.C., 1983. Desmodium. In: Burt, R.L., Rotar, P.P., Walker, J.L. & Silvey, M.W. (Editors): The Role of Centrosema, Desmodium and Stylosanthes in improving tropical pastures. Westview Press, Boulder, Colorado, United States. pp. 97–140. [3] Jones, R.M., 1989. Productivity and population dynamics of silverleaf desmodium (Desmodium uncinatum) and greenleaf desmodium (Desmodium intortum) and two D. intortum × D. sandwicense hybrids at two stocking rates in coastal south-east Queensland. Tropical Grasslands 23: 43–55. [4] Lenné, J.M. & Stanton, J.M., 1990. Diseases of Desmodium species. Tropical Grasslands 24: 1–14. [5] Skerman, P.J., Cameron, D.G. & Riveros, F., 1988. Tropical forage legumes. FAO, Rome. pp. 286–296.

J.B. Hacker

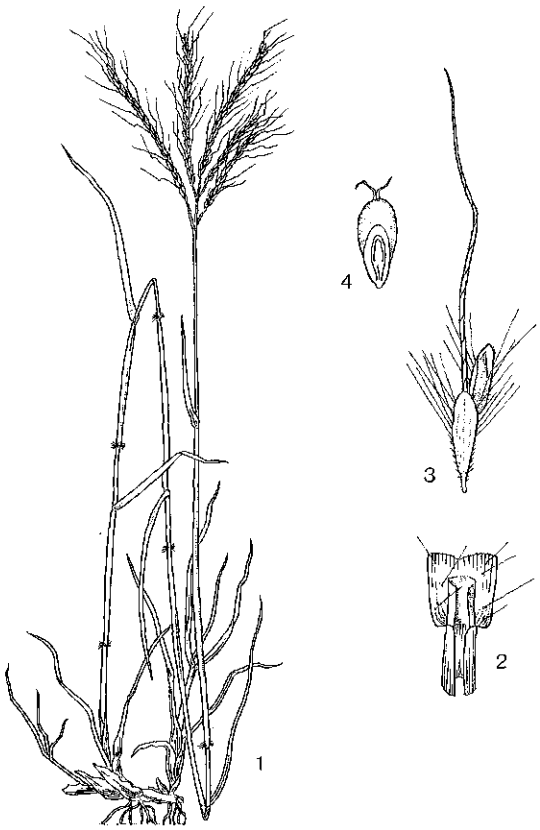
Dichanthium annulatum (Forssk.) Stapf

Fl. Trop. Afr. 9: 178 (1917).
GRAMINEAE
$2n = 20$ (diploid), 40 (tetraploid), 60 (hexaploid)
Synonyms *Andropogon annulatus* Forssk. (1775).
Vernacular names Hindi grass, sheda grass (En). Philippines: alabang-grass. Thailand: ya hindi, ya waen. Vietnam: song tha'o to.
Origin and geographic distribution *D. annulatum* is a grass occurring in tropical and North Africa, through the Middle East to Malesia, southern China, and the Pacific Islands. It has been introduced to southern Africa, tropical America and Australia. In the Northern Hemisphere it is mainly found between latitudes 8° and 28°.

Uses An excellent and widely used fodder grass which is sought out by stock from a mixture of grasses and is preferred to all others. In India it is promising for grazing or hay-making after reseeding into degraded grassland.

Properties Nitrogen concentrations of *D. annulatum* range from 0.4–1.7%, depending on the stage of growth. It can support 7 sheep per ha in India. It gives a good 'standing hay'.

Botany A perennial grass, often tufted, spreading and stoloniferous, with erect, branched or rarely geniculate culms up to 1 m tall, hairy at the nodes. Leaf-sheath terete, 3–4 cm long, sparsely hairy at the margins; ligule truncate, 2–4 mm long, membranous; leaf-blade linear, 3–30 cm × 2–8 mm, often hairy above, at the margins and in the throat. Inflorescence composed of up to 15 subdigitate, shortly peduncled racemes each 3–7 cm long; spikelets paired, one pedicelled, one sessile, alternately arranged along a filiform axis; the lowest 1–2 pairs similar, male or neuter, awnless and persistent; all other pairs dissimilar and deciduous; sessile spikelet 2–5 mm long, bisexual, upper lemma with a 1–2.5 cm long, kneed and twisted awn; pedicelled spikelet male or neuter; lower glumes pubescent to villous in lower half, upper half with long bulbous-based hairs especially on the margins. Caryopsis obovoid.
D. annulatum is a very variable species, morphologically as well as cytologically. Several varieties have been distinguished, mainly based on size and number of spikes, on hairiness of the spikelets, and on ploidy level.
Flowering commences early in the growing season and continues throughout the year. In India, recommended selections include 'Marvel 8', and lines 485, 487 and 490.



Dichanthium annulatum (Forssk.) Stapf – 1, flowering plant; 2, ligule; 3, spikelet; 4, caryopsis.

Other species of the genus, occurring in Malesia, are often also good fodder grasses, e.g. *D. caricosum* (L.) A. Camus and *D. mucronulatum* Jansen.

Ecology *D. annulatum* is adapted to the drier areas of the tropical and subtropical zones. It does not thrive in waterlogged places nor in shady environments, but is tolerant of grazing, burning and saline soils.

Agronomy *D. annulatum* can be established by seed or by rooted tillers planted at 60 cm spacing. It is a good seed producer, but slow growing at the seedling stage. It is highly palatable when young and fresh. Frequent grazing is required to maintain it in a leafy condition, although cattle will eat the stems. In Thailand, observations of a mixture of this species and Caribbean stylo (*Stylosanthes hamata* (L.) Taub.) on road edges indicate that it may be possible to improve its quality as a forage by oversowing with a legume. Dry matter yields of 1.4–2.0 t/ha have been obtained. It can be preserved as 'standing' or cut hay but not as silage.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained. In India some breeding programmes on *D. annulatum* are being carried out.

Prospects *D. annulatum* will have a place in grazing lands in drier areas. It is a promising species as it is drought-tolerant, persistent and resistant to heavy grazing. The prospects of selecting leafy strains could be investigated.

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C. Manidool

Digitaria ciliaris (Retzius) Koeler

Descr. Gram.: 27 (1802).
GRAMINEAE
$2n = 54$

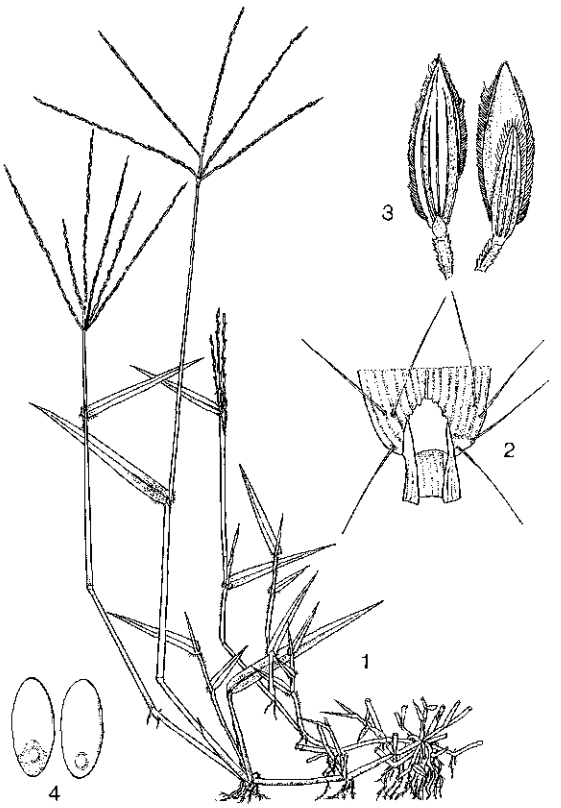
Synomyms *Digitaria marginata* Link (1821), *D. sanguinalis* auct., non Scop. (e.g. in Heyne, 1927), *D. adscendens* Henrard (1934).

Vernacular names Tropical finger grass, summer grass (Australia) (En). Crab grass (Am). Indonesia: jelamparam, suket ceker ayam (Javanese), jampang jemprak (Sundanese). Malaysia: caker ayam, bamboo grass. Philippines: baludyangan (Tagalog), saka-saka (Ilokano). Thailand: yah-tinnok, ya-plongkhaonok (central). Vietnam: túc hình leo.

Origin and geographic distribution *D. ciliaris* is widely distributed throughout the tropics and subtropics, especially in Asia. It is much less common in Africa.

Uses Although a bad weed in cropping areas, *D. ciliaris* provides good forage, assists in protecting soil against erosion and provides material for mulch or compost.

Properties *D. ciliaris* is a palatable grass, especially when young. Pen feeding trials in the United States showed that it had a similar digestibility and higher N concentration than sudan grass (*Sorghum* × *drummondii* (Steud.) Millsp. & Chase or pearl millet (*Pennisetum americanum* (L.) K. Schum. ex Leeke).



Digitaria ciliaris (Retzius) Koeler – 1, flowering plant; 2, ligule; 3, spikelets; 4, caryopsis in two views.

Botany Tufted annual, rarely short-lived perennial; culms erect, ascendent or prostrate, 50–100 cm long, often rooting at the lower nodes and forming loose mats. Leaf-sheath loose, variously pilose; ligule membranous, truncate, up to 3 mm long; leaf-blade lanceolate to linear, 2–25 cm × 3–13 mm, short bristly on both sides or glabrous. Inflorescence consisting of 2–10 racemes, each up to 15(–22) cm long, digitately arranged or in 2–3 whorls; peduncle up to 40 cm long; rachis characteristically winged, serrate, spicules at least 0.05 mm long; spikelets binate, homomorphous, lanceolate, 2.5–3.5 mm long, smoothly hairy; two florets per spikelet, the upper bisexual, the lower neutral. Caryopsis oblongoid, about 2 mm long, golden brown to grey.

A very variable species, about which much confusion exists in the taxonomic literature where it has been given more than 50 different names. Four variable characters are responsible: the hairs on the rachis, the ciliate frill around the spikelets, the occurrence of glassy bristles, and the spacing of the nerves in the lower lemma.

D. ciliaris is an agressive and opportunistic colonizer of bare, disturbed or newly cleared habitats due to its prolific seed production, vigorous growth and rapid development of rooted stolons. Seeds germinate in spring or summer in temperate or subtropical areas or with the onset of rains in the tropics.

Ecology In the tropics, *D. ciliaris* grows at altitudes from sea-level up to 1600 m (Indonesia) or 2000 m (Papua New Guinea). It grows best in moist, sandy or loamy soils and is very responsive to high soil fertility.

Agronomy *D. ciliaris* is propagated vegetatively or by seed. If newly ripened seed is being used for sowing, treatment with alternating temperatures and scarification helps to reduce dormancy. Germination is also stimulated by exposure to light. The spikelet scales act as a barrier to oxygen entry for up to 4 months storage time. A relatively high N level in the substrate seems to be needed for optimal germination. Seed dormancy can last up to 7 months. Good seed-bed preparation and sowing rates of 2–3 kg/ha of seed help to ensure good establishment. Planting with rooted cuttings, at spacings of about 10 cm × 10 cm, gives more rapid establishment than sowing seed.

D. ciliaris is usually eaten by grazing animals, but it can be cut for stall feeding or for silage. It is tolerant of close cutting or grazing. It may produce several seed crops per year if periodically grazed or mown. Its presence in pastures is usually a sign of newly established pastures, recent cultivation or disturbance, or deterioration of perennial grasses. It is usually a minor component or is not found in vigorous stands of perennial grasses. Pure stands have produced DM yields of 10–12 t/ha per year. One disadvantage of *D. ciliaris* is that it is an alternative host of the viruses that produce stripe disease and black-streak dwarf disease in rice.

Genetic resources and breeding *D. ciliaris* is a very variable species, but it is unlikely that substantial germplasm collections are being maintained. There are no known breeding programmes.

Prospects *D. ciliaris* will continue to be a useful natural forage in specific situations, usually associated with disturbance or cropping. It is unlikely that it will be deliberately propagated more widely than at present. In Malaysia, where *D. ciliaris* prevails as a weed under rubber and oil palm, sheep grazing will reduce its weed impact.

Literature 1| Holm, L.G., Plucknett, D.L., Pan-

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B.B. Baki, C.P. Chen & I.B. Ipor

Digitaria eriantha Steudel

Flora 12: 468 (1829).

GRAMINEAE

$2n$ = 18, 27, 36, 45, 50, 54

Synonyms *Digitaria smutsii* Stent (1924), *D. decumbens* Stent (1930), *D. pentzii* Stent (1930), *D. valida* Stent (1930), *D. pentzii* Stent var. *stolonifera* (Stapf) Henrard (1950); *D. eriantha* Steudel with 4 subspecies: ssp. *eriantha*, ssp. *pentzii* (Stent) P.D.F. Kok (1981), ssp. *stolonifera* (Stapf) P.D.F. Kok (1981), ssp. *transvaalensis* P.D.F. Kok (1981).

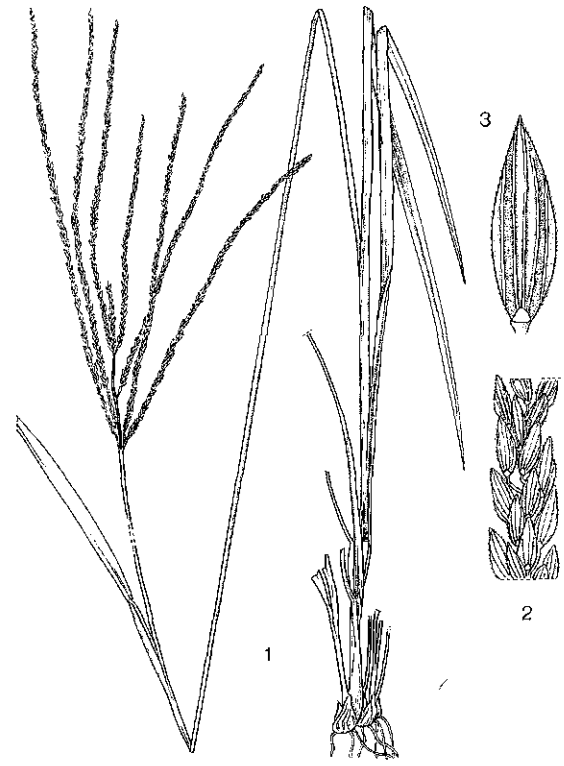
Vernacular names Common finger grass, digit grass (also used for other spp.), pangola or pongola grass (*Digitaria decumbens*) (En).

Origin and geographic distribution *D. eriantha* is a species of subtropical southern Africa. A single clone, commonly referred to as pangola grass, is now widespread in grazing areas throughout the world's humid tropics and subtropics, including South-East Asia, having been extensively planted from the 1960s to the 1980s. Many other lines have been distributed for evaluation.

Uses It is utilized extensively as a grass for grazing, mostly with N fertilization rather than a companion legume. It is also utilized as a hay crop.

Properties *D. eriantha* is often considered to be one of the higher quality tropical grasses. Pangola grass has been extensively studied but there is relatively little information on other genotypes. Pangola grass has an N concentration of (0.5–)1.5–2.0(–4)%. Phosphorus concentration can be too low for livestock on low-P soils in the absence of P fertilizer. Dry matter digestibility varies between 45–70%. Pangola grass has relatively high concentrations of Na in its tissues, compared with many other tropical grasses.

Description More or less robust perennial, growing either as a dense tussock, with or without extended stolons or as a continuous stoloniferous sward. Stolon internodes with or without hairs. Culms erect or ascending, sometimes rooting at the nodes, to 1.5 m tall. Leaf-sheath scabridulous, glabrous to hairy; ligule subtriangular, 2–4 mm long, shortly ciliate; leaf-blade linear, 5–60 cm × 1.5–12 mm, glabrous or hairy, but minutely scaberulous on both surfaces. Inflorescence a racemose panicle, composed of 3–14 erect racemes 6–18 cm long, borne in loose whorls and with some racemes single on an axis up to 7 cm long; spikelets 2–4 mm long, conspicuously hairy; lower glume to 0.5 mm long, the upper $\frac{2}{3}$ as long as the spikelet and appressed hairy; lower lemma minutely hairy, characteristically with 7 smooth rather than scabrous nerves. Many clones are sterile or almost sterile.



Digitaria eriantha Steudel – 1, flowering plant; 2, part of raceme; 3, spikelet.

Growth and development In subtropical areas, pangola grass flowers in mid-summer; flowering time differs with other genotypes, with cultivar 'Premier' (ssp. *eriantha* in the sense of Kok) flowering in late spring and again in autumn.

Other botanical information *D. eriantha* is extremely diverse but it is probable that 80% of

agronomic publications are concerned with a single genotype. Performance data should therefore not be generalized for the species as a whole. *D. eriantha* is closely related to the tropical *D. milanjiana* (Rendle) Stapf, from which it may only be distinguished by the absence of scabrosity on nerves of the lower lemma, a characteristic which may be difficult to determine, even with a lens. Frequently in the agronomic literature, accessions are described simply as *Digitaria* sp., which is of little help when documenting species characteristics.

In the taxonomic literature, the tremendous variability of this species has resulted in numerous names and subclassifications (see Synonyms). Much more research is needed to unravel the *D. eriantha* complex. In 1981 Kok distinguished 4 subspecies for the South African taxa, but in 1984 he reduced them to synonyms of the whole species complex. Two seed-producing cultivars, 'Premier' and 'Advance', belonging to *D. eriantha* ssp. *eriantha* (in the sense of Kok), have recently been released in Australia. Pangola grass belongs to *D. eriantha* ssp. *pentzii* (in the sense of Kok), and cultivars 'Taiwan', 'Transvala' and 'Slenderstem' have been developed in the United States from southern African introductions of this subspecies.

Ecology Accessions of ssp. *pentzii* (in the sense of Kok) (pangola, 'Slenderstem') are recommended in Malaysia and the Philippines for poorly drained soils. They are tolerant of flooding, and any areas where the grass dies out are rapidly re-invaded by stolons from the surrounding sward. Pangola grass is intolerant of shade and is therefore not suitable for integrating with plantation agriculture, but can grow on a wide range of soil types from sands to heavy clays. Cultivars 'Premier' and 'Advance' are adapted to sub-humid subtropical conditions and they have markedly better cool-season growth than other cultivars. In general, the seed-producing lines of the species tend to be better adapted to sandy loam soils as seedling establishment can be difficult on heavier soils. However, once satisfactorily established, they also grow vigorously on clays.

Propagation and planting Stoloniferous genotypes are planted vegetatively. Actively growing swards are allowed to become stemmy and are then cut and the material spread on a cultivated surface at 0.5–2 t of green matter per hectare. This is then disked in, or trampled in by cattle if the ground is too wet for implements. In warm moist environments, pastures establish rapidly by this method and in general weeds are suppressed by the planted grass. Seed-producing cultivars such as 'Premier' and 'Advance' require a reasonable seed-bed for establishment and an absence of serious competition in the early stages. Establishment is most satisfactory on sandy to sandy-loamy soils. Once established, however, they have the capacity to thicken up and spread from the sown area. *D. eriantha* is an aggressive species and does not generally combine well with pasture legumes.

Husbandry Once established, *D. eriantha* tolerates heavy stocking rates. On infertile soils it benefits from heavy fertilizer application, especially N. Stoloniferous cultivars can become sodbound and may benefit from periodic renovation by disking.

Diseases and pests Susceptibility to the rust *Puccinia* oahuensis a widespread disease occurring in the Americas and Australia, varies between genotypes, with 'Transvala' showing some resistance. The most serious disease of *D. eriantha* is pangola stunt virus, a dwarfing disease which has seriously reduced the usefulness of pangola since it was first reported in Surinam in 1960. The disease is transmitted by an aphid, *Sogatella furcifera,* or in Australia by the related *S. kolophon.* 'Transvala' has some resistance to this disease but trials in Australia on a number of lines of digit grasses failed to show any resistance.

Insects which cause damage include spittlebugs (*Tomaspis flavopicta, T. humeralis, Prosapia bicincta*) in Brazil and Taiwan, Rhodes grass mealy bug (*Antonina graminis*) (also in Brazil and Taiwan), chinch bug (*Blissus leucopterus*) in Taiwan, sugar-cane aphid (*Sipha flava*) in the Caribbean region and Taiwan, army worms (*Laphigma* spp., *Spodoptera* spp. and *Mocis* spp.), and the root-knot nematodes *Belonolaimus longicaudatus* and *Platylenchus brachyurus* in the Americas.

Harvesting *D. eriantha* is usually grazed, but is also suited to cut-and-carry feeding systems or hay making.

Yield Herbage DM yields as high as 36 t/ha per year have been reported for pangola grass, but production is more normally in the range 11–22 t/ha per year. Beef production from N fertilized pangola can exceed 1000 kg/ha per year. Grown with tropical legumes, 'Transvala' digit grass produced an average liveweight gain of 350 kg/ha under continuous grazing at a stocking rate of 2.6 steers/ha in Malaysia. From ssp. *eriantha* (in the sense of Kok) in South Africa, beef production ranged from 84–110 kg/head per season at a stocking rate of 7.5 animals per hectare. Milk yields of 6000 kg/ha per year have been obtained from well-fertilized pangola grass pastures.

Genetic resources Germplasm collections are available at ATFGRC (CSIRO, Australia).

Breeding There is a continuing interest in selecting and breeding *D. eriantha* and the closely related *D. milanjiana*, with which it is often confused.

Prospects Future work is likely to result in the commercialization of seed-producing cultivars which should extend the usefulness of this important species.

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J.B. Hacker

Digitaria milanjiana (Rendle) Stapf

Fl. Trop. Afr. 9: 430 (1919).

GRAMINEAE

$2n = 18, 36, 54$

Synonyms *Digitaria swynnertonii* Rendle (1911), *D. endlichii* Mez (1921), *D. setivalva* Stent (1924), *D. mombasana* C.E. Hubbard (1926), *D. polevansii* Stent ssp. *peterana* Henrard (1950).

Vernacular names Digit grass, (woolly) finger grass, Milanje finger grass (En, not restricted to this species). Thailand: ya mardi digit (for 'Mardi').

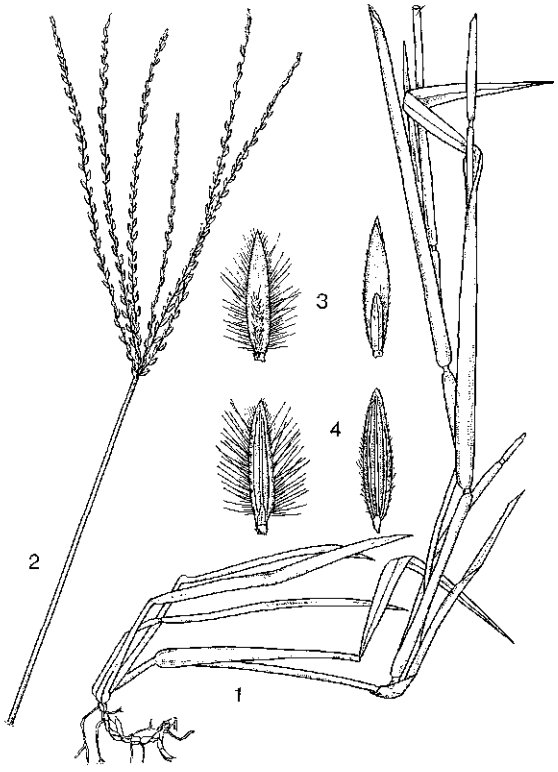
Origin and geographic distribution *D. milanjiana* naturally occurs in tropical East and southern Africa, from Ethiopia and Somalia southwards to South Africa. It has been introduced as a fodder grass to other tropical areas, including several countries in South-East Asia.

Uses *D. milanjiana* is used as a forage for grazing by cattle and goats. It has also proved to be useful in banana plantations in tropical Australia for the control of burrowing nematodes.

Properties Nitrogen concentrations of the cultivar 'Mardi' ranging from 1.3–3.0% have been recorded in Malaysia. In Australia, genetic differences in leaf Na concentration of 0.01–2.30% of the dry matter were shown to be associated with provenance, the high Na ecotypes being of coastal African origin. Differences in leaf digestibility were also demonstrated.

Botany Perennial with erect or geniculately ascending culms to 2.5 m tall from a loosely tufted more or less rhizomatous base, sometimes stoloniferous. Culm nodes glabrous, rarely hairy. Leaf-blade 15–30 cm × 3–13 mm, the blade and sheath more or less hairy to densely villous. Inflorescence a digitate or subdigitate panicle with 2–18 racemes on an axis up to 6 cm long, the racemes 5–25 cm long; spikelets paired on a triquetrous winged rachis, lanceolate, usually 2.5–3 mm long; lower glume 0.2–0.5 mm long, the upper $\frac{1}{3}$–$\frac{2}{3}$ as long as the spikelet; lower lemma as long as the spikelet, 7-nerved, more or less hairy and with shortly ciliate margins, the nerves characteristically scabrid and often with stiff spreading brown glassy bristles. Caryopsis ellipsoid, greyish-brown.

In subtropical latitudes *D. milanjiana* flowers



Digitaria milanjiana (Rendle) Stapf – 1, habit leafy culm; 2, inflorescence; 3, dorsal view of two spikelet types; 4, ventral view of two spikelet types.

freely during the growing season. In the tropics, flowering time appears to be more seasonal and seed set is often poor. It is extremely variable in growth habit and with regard to presence or absence of setae (spiny bristles) on the lemmas. Genotypes which have these setae are frequently referred to as *D. setivalva*. The essentially tropical *D. milanjiana* may be distinguished from related subtropical taxa (e.g. *D. eriantha* Steudel) by the presence of scabrosity along the outer nerves of the lower lemma. Due to the extreme variability, the taxonomy of *D. eriantha* is complicated. In the literature, both narrow and wide species concepts have resulted in numerous names and subdivisions. More research is needed to solve all problems of this complex.

Cultivar 'Mardi' has been released in Malaysia and 'Jarra' in tropical Australia.

Ecology *D. milanjiana* occurs naturally in a wide range of habitats which are mostly subject to some degree of disturbance, at altitudes up to 2000 m, with an annual rainfall of 400–800 mm. It is well-adapted to the humid lowlands of Malaysia and cultivar 'Mardi' (generally referred to as *D. setivalva*) is suitable for peat and alluvial soils. The cultivar is recommended for smallholdings and commercial enterprises on well-drained, fertile soils and can tolerate brief periods of moisture stress. It is neither shade-tolerant nor tolerant of waterlogging. It is reported to combine well with *Leucaena leucocephala* (Lamk) de Wit on alluvial soils in Malaysia.

Ecotypes have been shown to differ in seed-dormancy depending on provenance. Accessions from regions with a protracted dry season have an extended period of dormancy which may be broken by high temperature.

Agronomy 'Mardi' is vegetatively propagated. Stolons are planted into a cultivated seed-bed and, provided the seed-bed is kept moist, intervening spaces are rapidly filled in. Vegetative propagation should be carried out in the first half of the growing season, so as to allow sufficient time for the cuttings to establish.

Some accessions of *D. milanjiana* produce adequate quantities of seed for commercial seed production. The conditions necessary for good establishment from seed are likely to be similar to those required by other small-seeded tropical grasses.

D. milanjiana is susceptible to pangola stunt virus, but this is not a major problem in Malaysia.

Annual DM yields of 25 t/ha have been recorded in Malaysia for 'Mardi' in trials which were harvested every 6 weeks. Swards of *D. milanjiana* should be grazed relatively frequently to prevent them from becoming too stemmy. A grazing trial in Malaysia on 'Mardi' indicated that higher stocking rates could be maintained better on rotationally grazed pastures than on set-stocked pastures. The optimal stocking rate in Malaysia, when fertilized with 150 kg/ha per year of N, is 20–40 goats/ha, giving a liveweight gain of 450 kg/ha per year. Also in Malaysia, liveweight gains of cattle of from 700–1200 kg/ha per year have been recorded from the same cultivar given N fertilizer, although with a high level of year-to-year variation. Milk yields of 16.4 kg/day have been obtained from Friesian cows grazing a genotype selected for high leaf digestibility in Australia, in the absence of any supplementary feeding.

Genetic resources and breeding Germplasm collections are held by ATFGRC (CSIRO, Australia). Selection trials have identified promising accessions in Australia and Malaysia. Experimental breeding studies in Australia have contributed to an understanding of variation in a number of morphological, developmental and chemical attributes.

Prospects *D. milanjiana* is a species with considerable potential. Its extreme variability leads to the possibility of developing improved cultivars for both the wet and seasonally dry tropics. Cultivars with higher seed yields than 'Mardi' are needed and there are reasonable prospects for achieving this as seed production is very variable between accessions.

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J.B. Hacker & C.C. Wong

Echinochloa colona (L.) Link

Hort. Berol. 2: 209 (1833).
GRAMINEAE
$2n = 36, 48, 54, 72$

Synonyms *Panicum colonum* L. (1759). *Echinochloa crus-galli* P. Beauv. ssp. *colona* (L.) Honda (1923). The specific epithet is also spelled *'colonum'*.

Vernacular names Jungle rice, awnless barnyard grass (En). Indonesia: rumput jajagoan kecil (Sundanese, Javanese), rumput bebek (Indonesian), tuton (Javanese). Malaysia: padi burung, rumput kusa-kusa. Philippines: pulang-puwit (Tagalog), guinga (Visaya), dakayang (Ilokano). Burma: myet-thi, pazun-sa-myet. Laos: khauz nôk. Thailand: ya noksichomphu (central), ya-nokkhao (northeast). Vietnam: co' lôùg vu'c.

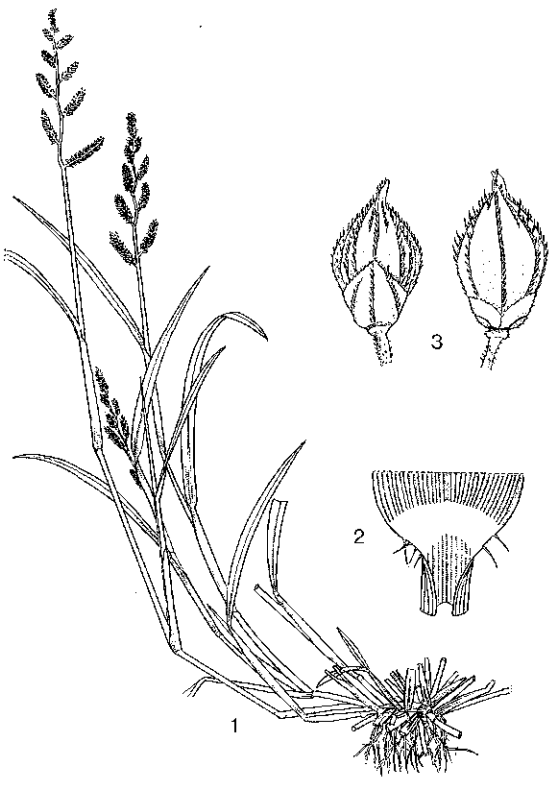
Origin and geographic distribution *E. colona* is widely distributed throughout the tropics and subtropics, including South-East Asia.

Uses *E. colona* is used as forage and is grazed by all kinds of stock. During famines, the seeds are eaten by humans. In rice fields, jungle rice can be a serious problem because the young plants closely resemble young rice plants. It can also be a weed in other crops.

Properties Nitrogen concentrations of *E. colona* range from 1.0–2.5%, depending on the growth stage.

Botany A tufted annual grass with erect or ascending culms up to 1 m tall, often rooting at the lower nodes. Leaf-sheath 3–4 cm long, glabrous, often reddish; ligule absent; leaf-blade linear-acuminate, 5–30 cm × 2–8 mm, sometimes marked with purple bars. Inflorescence up to 15 cm long, composed of 3–10 short racemes up to 3 cm long; racemes neatly 4-rowed, simple, commonly half their length apart and appressed to the axis but sometimes subverticillate and spreading; spikelets numerous, ovate-elliptical to subglobose, 1.5–3 mm long, pubescent; lower floret male or barren, acute to cuspidate; upper lemma 2–3 mm long, sharply pointed. Caryopsis ellipsoid to subglobose. The absence of a ligule, the purplish-tinged leaves and the neatly 4-rowed racemes are characteristic of this species. Less constant are the awnless soft indumented spikelets – some forms tend to intergrade with *E. crus-galli* (L.) P. Beauv. which has awned spikelets.

E. colona is a fast growing grass. Seeds germinate quickly with the onset of the first rains and it can cover other cultivated forages in the first few weeks. Axillary shoots develop during the second week after emergence. It flowers throughout the year, commencing 3–4 weeks after emergence, and seeds abundantly.



Echinochloa colona (L.) Link – 1, flowering plant; 2, ligule; 3, two views of a spikelet.

Ecology *E. colona* grows in swampy places in environments receiving from 400 to 1200 mm rainfall per year and at altitudes ranging from sea-level to 2000 m. It is adapted to full sunlight or partial shade and grows on loam, silt and clay soils, but it does not tolerate dry periods.

Agronomy *E. colona* is established by seeds or rooted tillers. It requires high soil moisture levels to get good establishment. It is very palatable, even when flowering. Light stocking rates and long intervals between grazing are recommended. It can be cut 3 to 4 times during the wet season when flower heads are in full bloom. The common practice in many countries of South-East Asia is to remove whole plants out of rice fields where it is regarded as a weed. The collected material is then fed to the ruminants. It can be conserved as hay but will take several days to dry as it is very succulent.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects *E. colona* is a valuable grass. Selection could be made to obtain accessions that produce higher yields when grown on upland soils as these soils are easier to work than the swampy or lowland areas.

Literature |1| Department of Livestock Development, 1986. Report on feed analysis [in Thai]. Technical Bulletin No 13–0116–29. Division of Animal Nutrition, Department of Livestock Development, Bangkok. |2| Gilliland, H.B., Holttum, R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Vol. 3. Government Printing Office, Singapore. pp. 167–168. |3| Häfliger, E. & Scholz, H., 1980. Grass weeds 1. Ciba-Geigy Ltd., Basel, Switzerland. p. 54. |4| Mehra, K.L. & Fachrurozi, Z., 1985. Indonesian economic plant resources: forage crops. Lembaga Biologi Nasional – LIPI, Bogor, No 31. p. 14 |5| Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 370–372.

C. Manidool

Echinochloa crus-galli (L.) P. Beauv.

Ess. Agrost.: 53, 161 (1812).
GRAMINEAE
$2n = 42, 48, 54$
Synonyms *Panicum crus-galli* L. (1753).

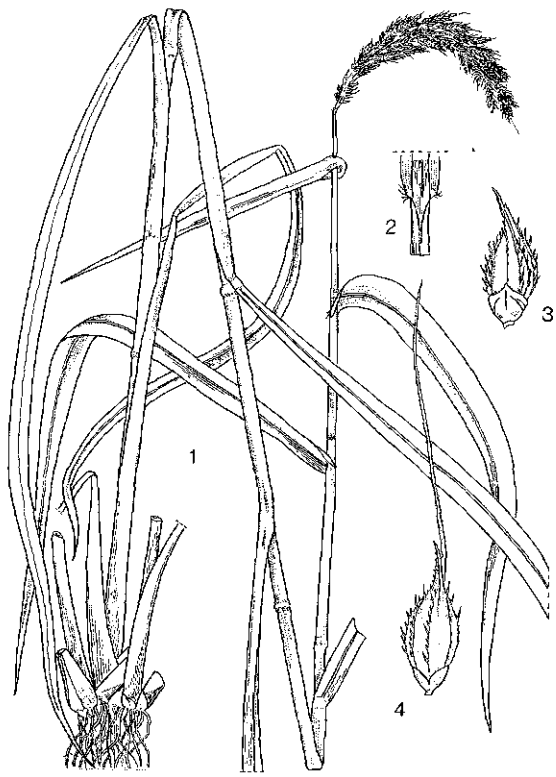
Vernacular names Barnyard millet, chicken-panic grass, cock's foot (En). Crête-de-coq, pattes de poule (Fr). Indonesia: jajagoan (Sundanese), jawan (Javanese). Malaysia: padi burung, rumput kekusa basar. Philippines: bayokibok (Tagalog), lagtom (Bikol), marapagay (Ilokano). Burma: myet-ihí. Cambodia: smao bek kbol. Thailand: ya-plonglaman, ya-khaonok (central). Vietnam: cỏ' lồng vực, song chong.

Origin and geographic distribution Barnyard millet is widespread throughout the tropics, e.g. Africa, India, Burma, Thailand, Indo-China, Malesia and Australia, and extends to the subtropics and some warm temperate regions.

Uses Barnyard millet is used as fodder but it is also regarded as the world's worst weed in paddy rice. However, in times of scarcity the grain is eaten by people.

Properties Barnyard millet is a palatable and succulent feed which produces copious quantities of seed.

Botany A robust annual, tufted grass with erect or geniculate culms, up to 1.5 tall, often rooting and branching near the base. Leaf-sheath 9–13 cm long, glabrous or hairy; ligule absent; leaf-blade



Echinochloa crus-galli (L.) P. Beauv. – 1, flowering plant; 2, ligule; 3, short-awned spikelet; 4, long-awned spikelet.

linear-acuminate, 5–50 cm × 0.5–2 cm, glabrous. Inflorescence erect or nodding, 6–22 cm long, green or purple-tinged, composed of 9–12 racemes, 2–4(–10) cm long and sometimes branched; racemes untidily 2–several-rowed, hispidulous on the back, scaberulous on the margins; spikelets crowded, hispid, ovoid-ellipsoid, 3–4 mm long excluding the awns; lower floret barren with lemma acuminate or awned, awn up to 0.5–1(–5) cm long; upper lemma pointed, shiny. Caryopsis ovoid, 2–3 mm long, brownish, dorsally flattened, with longitudinal ridges on the convex surface.
An extremely variable species which frequently has been split into various varieties and forms, sometimes even into different species. This complex still needs thorough investigation.
The species flowers over a wide range of photoperiodic conditions. Flowering is quicker and more abundant under short-day circumstances, but under long-day conditions the vegetative and generative parts are much more robust.

Ecology Barnyard millet is adapted to wet

places and waterlogged land, and grows very vigorously in hot wet conditions from sea-level to 2500 m altitude. It grows best in rich moist soils with high N content, but it can also thrive on sandy and loamy soils.

Agronomy Barnyard millet is propagated by seed or rooted tillers. Sometimes the seeds have a dormancy period (in Japan 4–8 months; in the United States 4–48 months). Optimum temperature for germination ranges from 32–37°C. Seeds germinate under water provided it is not more than 15 cm deep. It needs very moist conditions for establishment by rooted tillers. Permanent flooding is recommended if vigorous stands are to be maintained. As a weed in rice, fertilizer applications favour the growth of *E. crus-galli* more than they do the rice crop. Rice yields can be severely reduced, especially when more than 20 plants/m^2 are present.

Hand harvesting is a common practice where the grass grows in swampy places. The upper parts of the stem above water are cut and carried to feed to animals. It can be made into hay but is difficult to dry as it is very succulent. Several cuts are possible if plants are kept submerged in water. In paddy fields where barnyard millet is the main species, yields of 4–11 t/ha of green material are obtained. It is relished by cattle and water buffaloes.

Genetic resources and breeding No data are available, but observations suggest that there are different strains which may occur in different habitats. It is unlikely that any substantial resource collections are being maintained.

Prospects As it grows in wet areas, barnyard millet can supply feed at the times when other dryland grasses are not available. Agronomic studies should be conducted on mixtures of rice and barnyard millet to find out how to optimize the yield of barnyard millet without unduly reducing the yield of rice.

Literature |1| Bor, N.L., 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, London. p. 310. |2| Gilliland, H.B., Holttum R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Vol. 3. Government Printing Office, Singapore. pp. 168–169. |3| Holm, L.G., Plucknett, D.L., Pancho, J.V. & Herberger, J.P., 1977. The world's worst weeds: distribution and biology. The East-West Center, University of Hawaii Press, Honolulu, Hawaii, United States. pp. 32–40. |4| Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 373–375.

C. Manidool

Eragrostis tenella (L.) P. Beauv. ex Roemer & Schultes

Syst. Veg. 2: 576 (1817).

GRAMINEAE

$2n$ = unknown

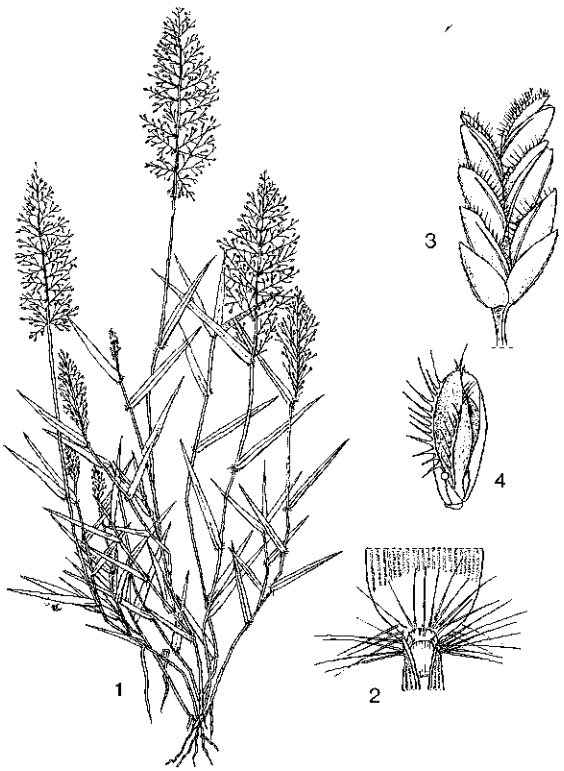
Synonyms *Poa tenella* L. (1753), *P. amabilis* L. (1753), *Eragrostis amabilis* (L.) Hook. & Arnott (1840).

Vernacular names Bug's egg grass, Japanese love-grass (En). Indonesia: suket emprit-empritan (Javanese), jukut karukuan (Sundanese), luhbuluhan (Madura). Laos: hnhaaz nhung. Thailand: ya harng krarork. Vietnam: xuân tha'o min.

Origin and geographic distribution *E. tenella* occurs throughout the tropics of the Old World, also in South-East Asia. It has been introduced to tropical America.

Uses *E. tenella* is grazed by cattle and water buffaloes in traditional feeding systems. It is a weed of minor agricultural importance.

Properties It is regarded as a low quality forage because of its low leaf/stem ratio. The grain is said



Eragrostis tenella (L.) P. Beauv. ex Roemer & Schultes – 1, flowering plant; 2, ligule; 3, spikelet; 4, floret.

to be very nutritious.

Botany A small tufted annual grass, with erect or ascendent culms, up to 60 cm tall. Leaf-sheath 2–4 cm long, light purple, hairy at the mouth; ligule a ring of fine soft hairs; leaf-blade narrowly linear with broad base and acute tip, up to 13 cm × 7 mm, glabrous, often tinged purple. Inflorescence a terminal panicle, up to 35 cm long, open, sometimes hairy at the axils, the branches spreading and bearing oblong not sticky yellowish glands; spikelets 4–8-flowered, up to 3.5 mm long, strongly compressed, breaking up from the apex, all flowers bisexual or the upper ones rudimentary; palea-keels ciliate. Caryopsis ellipsoidal, 0.5–0.7 mm long, golden-brown.

Based on the habit of the inflorescence (spreading or more contracted), two botanical varieties have been distinguished.

Seeds of *E. tenella* germinate very quickly at the beginning of the rainy season. It flowers profusely throughout the year, producing a very small amount of leaf.

Ecology *E. tenella* is common on open waste ground and is adapted to sandy soils from sea-level up to 1400 m altitude. It can be found on old walls, roadsides and dykes, usually in areas with a pronounced dry season.

Agronomy It is not deliberately sown but spreads naturally by seed. It grows quickly with the onset of the first rains and thus produces green feed early in the season. It can be cut by hand, but as it has a very weak root system farmers normally dig up whole plants and feed them to livestock. Yields are low. It is fed green but could be dried and conserved.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects It is unlikely that *E. tenella* will ever be deliberately established as a forage crop.

Literature |1| Gilliland, H.B., Holttum, R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Vol. 3. Government Printing Office, Singapore. pp. 71–73. |2| Häfliger, E. & Scholz, H., 1981. Grass weeds 2. Ciba-Geigy Ltd., Basel, Switzerland. p. 75. |3| Holm, J., 1971. Feeding tables. Nutrition Laboratory of Thai-German Dairy Project, Livestock Breeding Station, Chiangmai, Thailand. |4| Mehra K.L. & Fachrurozi, Z., 1985. Indonesian economic plant resources: forage crops. Lembaga Biologi Nasional – LIPI, Bogor. p. 17.

C. Manidool

Eragrostis unioloides (Retzius) Nees ex Steudel

Syn. Pl. Glum. 1: 264 (1854).

GRAMINEAE

$2n$ = unknown

Synonyms *Poa unioloides* Retzius (1789).

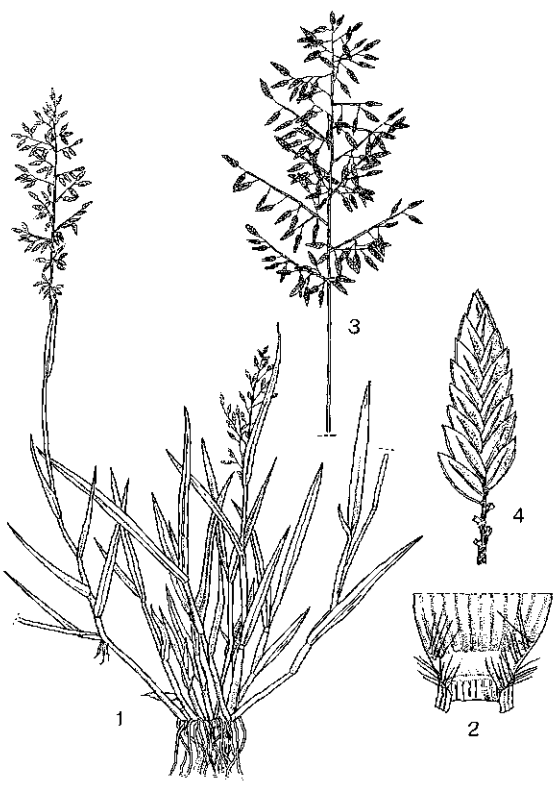
Vernacular names Indonesia: padang togu (Batak), rumput udang (Indonesian). Malaysia: ramput kolam padang. Thailand: ya-khaipu (northern). Vietnam: xuân tha'o do'.

Origin and geographic distribution *E. unioloides* is native to South-East Asia. It is also found in the Indian subcontinent, Sri Lanka and the Pacific Islands.

Uses *E. unioloides* is used as a forage. Its abundance in irrigated rice fields makes it also useful for grazing after the rice harvest and as a green manure.

Properties No information on chemical composition is available, but its quality is likely to be low because of its low leaf/stem ratio.

Botany Annual or short-lived perennial grass,



Eragrostis unioloides (Retzius) Nees ex Steudel – 1, flowering plant; 2, ligule; 3, inflorescence; 4, spikelet.

tufted, with culms 10–80 cm tall, erect or geniculately ascending, sometimes rooting from the lower nodes. Leaf-sheath about 1.5 cm long, striate, purplish, hairy at the mouth; ligule a fringe of hairs; leaf-blade linear with broad base and acute top, 2–20 cm × 2–8 mm, flat or inrolled. Inflorescence a loose or contracted, terminal, usually stiffly erect panicle, up to 20 cm long; spikelets 8–60-flowered, ovoid to oblongoid, 4–16 mm × 2.5–4 mm, strongly compressed, on up to 15 mm long peduncles, usually yellowish but reddish-purple tinged; lower florets all fertile, upper ones caducous, but florets falling in succession from the base up; glumes very densely packed, keel scabrid. Caryopsis obovoid to ellipsoid, laterally compressed, ca. 0.7 mm long, orange-brown.

Flower heads emerge 6–8 weeks after seedling emergence and plants flower throughout the year. It is a very variable species, the main variation being in the annual to perennial type and in the degree of stoloniferous habit.

Ecology *E. unioloides* can grow from sea-level up to 1250 m altitude, in open or moderately shaded areas, in swampy or paddy fields, roadsides and cultivated land.

Agronomy *E. unioloides* is grazed but does not withstand heavy grazing. In northern Thailand, villagers may pull up whole plants and feed them fresh to cattle.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects Although this species contributes to the feeding of livestock, it is not of great importance.

Literature |1| Backer, C.A. & Bakhuizen van den Brink, R.C., 1968. Flora of Java. Vol. 3. Wolters-Noordhoff, Groningen, the Netherlands. p. 531. |2| Gilliland, H.B., Holttum, R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Vol. 3. pp. 66–68. |3| Häfliger, E. & Scholz, H., 1981. Grass weeds 2. Ciba-Geigy Ltd., Basel, Switzerland. p. 78. |4| Mehra, K.L. & Fachrurozi, Z., 1985. Indonesian economic plant resources: forage crops. Lembaga Biologi Nasional – LIPI, Bogor, No 31. p. 18.

C. Manidool

Ficus subcordata Blume

Bijdr.: 440 (1825).

MORACEAE

$2n = 26$

Synonyms *Ficus garciniifolia* Miquel (1867), *F. calophylloides* Elmer (1911), *F. fairchildii* Backer (1947).

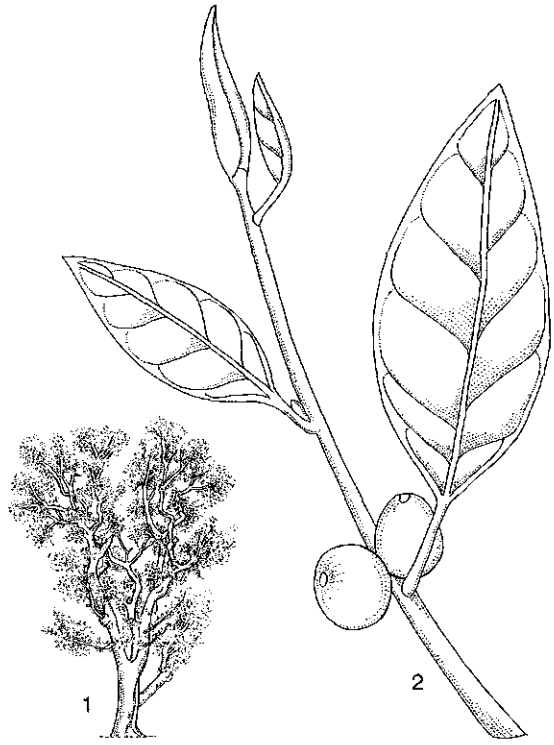
Vernacular names Indonesia: bunut lengis (Bali), wunut (Javanese), sipadi (Sumatra). Philippines: marabotum (Bagobo), balete (Tagalog), tibi (Bikol). Thailand: sai (Nakhon Si Thammarat).

Origin and geographic distribution *F. subcordata* is widespread in South-East Asia, from northern Vietnam to the New Hebrides. It is also occasionally cultivated in this area.

Uses The foliage of *F. subcordata* is used as a feed supplement during the wet season and as the sole diet during the dry season for ruminants in some dryland farming areas. The young fruit can be fed to ruminants. The wood is used as fuel for brick and limestone kilns, and the smaller branches are used for household firewood. The mature stem is used for farmyard posts. The bark is used for making string for farm tools. The timber is not hard enough for building houses, making farm implements or woodcarving. The tree is used as shade for livestock, for storing crop residues, for reclamation of denuded land, for protecting soil on sloping land and as a windbreak.

Properties The leaves contain 1.2–1.8% N, crude fibre 26–30%, N-free extract 42–47%, ash 8–11%, total digestible nutrient 33–35%, and massic energy of DM is 10000–19000 kJ/kg. Cut stems exude white latex but this does not affect the palatability of the leaves.

Description Strangling deciduous tree, without aerial roots, up to 30 m tall and 70 cm in diameter; branching starts 2 m above the ground and twigs are brownish-grey; in shallow soil the lateral roots near the soil surface can spread 4–7 m away from the base of the trunk. Bark whitish-grey, slightly smooth and fissured, flexible and durable, 10–17 mm thick; inner bark whitish, exuding white sap. The blunted spearhead-like bud extends from the node while the leaf is still intact. Leaves alternate, oblong, ovate-oblong, or elliptical, 9–20 cm × 4–10 cm, with a prominent light green midrib and a light green petiole of 2–5 cm length; leaf margin entire; leaf-blade broadly cuneate or rounded at base, pointed at apex, smooth to hairy, purple when young, light green beneath and dark green above when mature. Fruit a short-ellipsoid fig, 3–5 cm × 2–2.5 cm, solitary, occasionally in pairs,



Ficus subcordata Blume – 1, habit tree; 2, fruiting branch.

green when young, gradually turning from yellow to reddish-brown or black when ripe. Seeds small, hard and numerous. Weight of a fresh fruit ranges from 10–20 g, and there are 1000–2000 ripe seeds per g.

Growth and development Under natural conditions, reproduction starts when the tree is 5–6 years old. Flowering and fruiting take place during the dry season when the tree sheds its old leaves. The mature fruit falls off when the new season's leaves are fully expanded. Under favourable conditions the small seeds will germinate in 3–4 weeks. Under natural conditions, the seeds may germinate in a crack in other trees and develop into a stunted tree (known in Bali as 'bunut panggang'). Once the aerial roots reach the ground they can develop into a normal tree that can kill the host.

Other botanical information *F. subcordata* is subdivided into two varieties by Corner: var. *subcordata*, the typical variety; and var. *malayana* Corner, with large subcylindrical figs 3.5–5 cm × 2–2.5 cm, and elliptical to narrowly obovate, thick leaves, 11–16 cm × 4–7 cm, occurring in Peninsular Malaysia and in northern Borneo.

Besides *F. subcordata*, in dryland farming areas in Bali (Indonesia), farmers plant also 3 other *Ficus* species vegetatively:

- *F. stricta* Miquel ('bunut bingin' in Bali): evergreen tree, up to 18 m tall with deeply fluted bole and large spreading crown; leaves elliptical, 7–12 cm × 3–6 cm, with numerous almost parallel secondary nerves; figs globose, 1.5 cm in diameter, orange; Indo-China, Malaysia, Indonesia, the Philippines.
- *F. elastica* Roxb. ex Hornem. ('bunut lulub' in Bali): large strangling fig developing many aerial roots from the trunk and main branches; young parts reddish; leaves elliptical, 7–15 cm × 4–7 cm, larger in saplings; figs oblongoid, 1.25 cm × 0.8 cm, yellow. Formerly used for rubber production (India rubber tree); originally distributed from India through Indo-China and Malaysia to Sumatra; now cultivated all over the tropics, mainly as an ornamental.
- *F. drupacea* Thunb. ('bunut bulu' in Bali): big tree with brown woolly hairs on buds, twigs and underside of leaves; leaves oblong–elliptical, 11–23 cm × 4–11 cm, tri-nerved at base; figs oblongoid, 2–3 cm × 1–2 cm, yellow; widely distributed from India, throughout South-East Asia to Australia.

Ecology In Indonesia, *F. subcordata* grows well in dryland and hilly areas with annual rainfall ranging from 900–2500 mm, mean daily maximum temperatures from 26–39°C and altitudes ranging up to 800 m. It tolerates a wide range of soil types, growing well on limestone-based soil and on sloping land of 25 cm soil depth.

Propagation and planting Even though *F. subcordata* can be propagated by seed or layering, propagation by cuttings is most commonly practised by farmers. For direct planting, healthy and straight 2-year-old stems of 5–10 cm in diameter and 1.5–2.5 m length are cut from the parent tree. The end to be planted should be even and free from splitting, and any leaves and twigs should be removed. Each cutting should be planted in a prepared hole of 25 cm depth and 15 cm width, then covered with soil in such a way that the planted stem cannot move. Direct planting should be carried out at the onset of the rainy season, since planting during the wet season causes the buried cambium to rot. Twelve weeks after planting 75% of the cuttings can develop buds and about 70% survive after 52 weeks. Twenty-six weeks after planting a cutting, there can be 8–13 main branches of 45–55 cm length and 10–12 leaves per branch. For planting in nurseries, twigs with

50–100 cm length are inserted in 10–15 cm of soft and moist soil. Such cuttings are not ready for transplanting until the roots are well developed. Since *F. subcordata* seed is very small, it is preferably sown under nursery conditions. After development of the cotyledons and a few secondary leaves, seedlings should be transplanted into pots. Planting into permanent sites is carried out during the rainy season when the plants are 6–12 months old. It can be planted at 5–10 m spacing when used as fence border and at 10 m × 10 m within and between rows spacings when used as windbreak or fodder bank.

Husbandry When planted as a cutting, it can be lopped 3 years after planting. Complete defoliation can be carried out before the end of the dry season every year, or partial defoliation twice during the wet season and twice during the dry season. For accumulation of in situ fodder, the tree should be lopped 3–4 months before the dry season so that the foliage is well developed during the dry season, otherwise the leaves will shed during the period of flower and seed formation.

Many species can be grown with *F. subcordata* including grasses such as *Cenchrus ciliaris* L., *Panicum maximum* Jacq. and *Urochloa mosambicensis* (Hack.) Dandy; herbaceous legumes such as *Stylosanthes hamata* (L.) Taub., *Stylosanthes scabra* Vogel, and *Centrosema pubescens* Benth.; shrub legumes such as *Leucaena leucocephala* (Lamk) de Wit and *Gliricidia sepium* (Jacq.) Kunth ex Walp. and fodder trees such as *Lannea coromandelica* (Houtt.) Merrill and *Hibiscus tiliaceus* L.

Diseases and pests *F. subcordata* is generally resistant to diseases and pests. Red ants (*Phagiolepis longipis*) and black ants (*Formica fusa*) living in the foliage cause no ill effect to the host, but may inconvenience the farmer lopping the tree.

Harvesting and yield Fruits of *F. subcordata* are not regularly harvested since they lack commercial or socio-cultural value. The annual fodder and firewood DM yields of a 3-year-old *F. subcordata* range from 12–20 kg and 30–65 kg per tree respectively. As the tree grows older, the annual fodder and firewood DM yields can increase up to 140–225 kg and 240–350 kg per tree respectively. The foliage of a 25-year-old tree can feed one animal of 250 kg live weight for 20–30 days.

Genetic resources and breeding Germplasm has been collected but there are no breeding programmes of *Ficus* species in South-East Asia. Germplasm collection and breeding of *Ficus* species has been initiated in Nepal.

Prospects *F. subcordata* is a location-specific species rather than of regional importance. However, once established, it produces a year round supply of fodder for ruminants in dryland farming areas. *F. subcordata* is one of the fodder trees integrated in the 'Three Strata Forage System' currently under test to increase the productivity of dryland farming in Indonesia. In this system the 1st, 2nd and 3rd strata consist of grass and herbaceous legumes, shrub legumes and fodder trees, respectively. Establishment of *F. subcordata* from seeds, so as to increase its distribution and role as a multipurpose tree, should be explored.

Literature |1| Backer, C.A. & Bakhuizen van den Brink, R.C., 1965. Flora of Java. Vol. 2. Noordhoff, Groningen, the Netherlands. pp. 20–35. |2| Corner, E.J.H., 1965. Check-list of Ficus in Asia and Australasia with keys to identification. The Gardens' Bulletin Singapore 21: 1–186. |3| de Guzman, E.D., Umali, R.M. & Sotalbo, E.D., 1986. Non-Dipterocarps. Ficus. In: Umali, R.M., Zamora, P.M., Gotera, R.R. & Jara, R.S. (Editors): Guide to Philippine flora and fauna. Vol. 3. Natural Resources Management Center and University of the Philippines, Manila. pp. 123–130. |4| Kochummen, K.M., 1978. Moraceae, Ficus. In: Ng, F.S.P. (Editor): Tree flora of Malaya. A manual for Foresters. Vol. 3. Longman Malaysia, Kuala Lumpur. pp. 135–162. |5| Nitis, I.M., Lana, K., Suarna, M., Sukanten, W., Putra, S. & Arga, W., 1989. Three strata system for cattle feeds and feeding in dryland farming area in Bali. Final report to IRDC, Canada. 252 pp. |6| Panday, Kk., 1982. Fodder trees and tree fodder in Nepal. Swiss Development Cooperation, Berne and Swiss Federal Institute of Forestry Research, Birmensdorf, Switzerland. 107 pp. |7| Sukarji, N.W., Puger, A.W. & Nitis, I.M., 1990. Draft performance of Bali steers fed grass, shrub legume and fodder tree [Indonesian]. National Seminar on Bali cattle, September 20–22, 1990, Denpasar, Bali. 5 pp.

I.M. Nitis

Flemingia macrophylla (Willd.) Merr.

Philip. Journ. Sci. 5: 130 (1910).
LEGUMINOSAE
$2n = 22$

Synonyms *Flemingia congesta* Roxb. ex Ait. f. (1812), *F. latifolia* Benth. (1852), *Moghania macrophylla* (Willd.) Kuntze (1891).

Vernacular names Indonesia: apa apa (Javanese), hahapaan (Sundanese), pok kepokan (Madura). Malaysia: serengan jantan, beringan.

Philippines: laclay-guinan (Tagalog), gewawini (Ifugao), malabalatong (Pampanga). Laos: thwàx h'èè h'üad, hom sam muang (Xieng Khouang), thoua huat (Vientiane). Thailand: mahae-nok (northern), khamin naang, khamin ling (central). Vietnam: tóp mo' láto, cây dau ma (Vinh phu), cai duoi chon (Thuan Hai).

Origin and geographic distribution *F. macrophylla* originates from and is widely distributed in South-East Asia and in Taiwan, southern China, India, Sri Lanka and Papua New Guinea. It has been introduced and naturalized in East, Central and West Africa.

Uses *F. macrophylla* is grown in hedges and provides forage and also mulch for associated food crops grown in alley cropping systems. It is also grown in terraces to control soil erosion and is used to provide dry season forage in the savanna zone of Nigeria. In Malaysia, Indonesia, Sri Lanka, West Africa and Madagascar the plant is used as a cover crop and as a shade crop in young plantations of cacao, coffee, banana and rubber. It is one of the sources of the Arab dye which is called 'warrus' or 'waras'. 'Waras' is a purple or orange-brown coarse powder, consisting of the glandular hairs rubbed from dry *Flemingia* fruits, capable of dying silk but not wool or cotton, and which is called flemingin. It is a minor host of the Indian lac insect. The stems are a source of flavonoid compounds. In Indonesia and Malaysia the leaves are used as a source of medicine. In the Ivory Coast it is used to reduce nematodes in pineapple plantations and as green manure and mulch.

Properties Leaf nutrient contents (based on DM) are: N 2.3–3.8%, P 0.19–0.25%, K 1.00–1.40%, Ca 0.55–0.75%, and Mg 0.18–0.28%. In vitro digestibility of the leaves is much lower than that of *Leucaena leucocephala* (Lamk) de Wit. The leaves decompose relatively slowly and are useful as mulch material. Under humid tropical conditions, losing half of an initial quantity of 4 t/ha of dry matter took 53 days.
There are 55 seeds/g.

Botany Woody, deep-rooting, tussock-forming shrub, 1–4 m tall. Young branches greenish, ribbed, triangular in section, silky. Old stems brown, almost round in section. Leaves digitately trifoliolate; petioles narrowly channelled, slightly winged, up to 10 cm long; leaflets lanceolate, 6–16 cm × 4–7 cm, papery, veins covered with silky hairs, dark green. Inflorescence a dense axillary raceme, subspiciform, sessile, 2.5–10 cm long, silky; bracts ovate, 3–6 mm long; calyx green, 6–13 mm, pale velutinous with 5 lanceolate lobes; corolla with greenish elliptical standard and distinct parallel red veins, wings narrow and much shorter than the keel, light purple at the apex. Pod oblong, inflated, 8–15 mm × 5 mm, covered with fine glandular hairs, dehiscent, dark brown, 2-seeded. Seed globular, 2–3 mm in diameter, shiny black.
Nodulation is often difficult to locate, partly because the nodules are very small.

Flemingia macrophylla (Willd.) Merr. – 1, flowering branch; 2, fruiting branch.

Ecology *F. macrophylla* can be found from sea-level up to 2000 m altitude, within a wide range of rainfall patterns, from sub-humid to humid (1100–2850 mm/year). It cannot tolerate long dry spells and is capable of surviving on very poorly drained soils with waterlogging. Its natural habitat is along watercourses, both on clay and lateritic soils, as well as under drier conditions such as in fields infested with *Imperata cylindrica* (L.) Raeuschel. The plant tolerates shade and poor soils.

Agronomy *F. macrophylla* is propagated by seed. Since untreated seed is hardseeded, scarification is usually required to increase the germination percentage of seed prior to sowing. A good weed-free seed-bed should be prepared, and the

necessary fertilizers for a particular soil worked in prior to sowing or banded beneath the row of seed. Seed should be inoculated with a suitable strain of *Bradyrhizobium* such as CIAT 4203 or 4215. Planting density varies according to the projected use of the stand. In Indonesia seed is often sown in rows 90 cm apart with 3–4 seeds planted every 60 cm along the row. Good weed control is required during the first six months after sowing, since the plants are relatively slow to establish. Once established, they require little attention.

Under humid, lowland tropical conditions in the Ivory Coast, with 10000 plants/ha and 9 regrowth cycles of 3 months each, an average annual production of 12 t/ha of leaf DM has been achieved, although typical yields in South-East Asia may be closer to 8 t/ha. Plants can be cut more frequently than every 3 months, but preferably not at intervals of less than 40 days. They will survive under this cutting regime for many years.

Insect pests such as the fly *Agromyza* sp. reduce seed production by laying eggs in green pods. In Malaysia, spraying with Endrex (1:800) once every two weeks after flowering has begun gives effective control.

Genetic resources and breeding Germplasm collections are located at CIAT (Colombia), the Research Institute for Animal Production (Ciawi, Indonesia), LBN/LIPI (Bogor, Indonesia), ATFGRC (CSIRO, Australia), IBPGR (Bangkok, Thailand) and ICRISAT (Hyderabad, India).

Prospects *F. macrophylla* has excellent coppicing capacity and is showing promise when used in hedges to provide forage or mulch to associated food crops in alley cropping. As a feed *F. macrophylla* is inferior to species such as *Leucaena leucocephala* (Lamk) de Wit and *Gliricidia sepium* (Jacq.) Kunth ex Walp. since it is less easily digested. Owing to its slow decomposition, the mulch has long-term effects in weed control, moisture conservation and soil temperature reduction. Furthermore, the species is useful as a cover crop in perennial plantations, as a shelter belt, in erosion control, and in planted fallows for soil improvement. Improvement of the plant's early development and its integration into alley cropping systems and planted fallows deserve priority in research.

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A. Budelman & M.E. Siregar

Gliricidia sepium (Jacq.) Kunth ex Walp.

Repertitorium bot. syst. 1: 679 (1842).

LEGUMINOSAE

$2n = 20$

Synonyms *Gliricidia maculata* (Kunth) Kunth ex Walp. (1842).

Vernacular names Gliricidia, mother of cocoa, quick stick (En). Indonesia: gamal (Javanese), liriksidia (Indonesian). Philippines: balok-balok (Tagalog), apatot (Bikol), kukuwatit (Pangasinan). Laos: kh'è: nooyz, khê fàlangx. Thailand: khae-farang. Vietnam: anh dào gi'a, sát thu, hông mai.

Origin and geographic distribution Gliricidia is a native of the seasonally dry Pacific Coast of Central America from sea-level to 1200 m, but has been long cultivated and naturalized in tropical Mexico, Central America and northern South America, up to 1500 m altitude. The species was also transported to the Caribbean and later to West Africa. It was introduced to the Philippines by the Spaniards in the early 1600s, and to Sri Lanka in the 18th century; from there it reached other Asian countries including Indonesia (about 1900), Malaysia, Thailand and India.

Uses In the past, gliricidia forage was often collected from trees which had been planted for other purposes, but increasing attention is now given to options for cultivating it specifically for fodder production either in cut-and-carry or grazing sys-

tems. It provides useful forage in the form of leaves, green stem and bark, and is commonly used to supplement poor quality, low protein roughage, especially in dry seasons when it may become a major source of feed for goats and cattle in dryland cropping areas. Its forage has been reported to be toxic to horses, but clear confirmation is lacking. Leaf meal can also be fed to poultry and rabbits.
The tree is widely used for many other purposes. The wood is often utilized as firewood, charcoal or as posts and farm implements, and locally for furniture, construction purposes and railway sleepers. The species is extensively used in different cropping systems, e.g. as a shade tree in tea, cocoa or coffee plantations, as live stakes to support vanilla, black pepper and yams (in West Africa), as a hedge, a green manure crop in intercropping systems with arable crops; it is also being tested in alley-cropping systems. The tree has also been planted to reclaim denuded or lands invested with *Imperata cylindrica* (L.) Raeuschel. Seeds, bark, leaves and roots may be used as a rodenticide and pesticide after fermentation; flowers serve for honey production. The tree is often planted as an ornamental. In the Philippines juice of the leaves, bark and roots is used to alleviate itches and wounds.

Properties The leaves contain from 3–5% N, 13–30% crude fibre and 6–10% ash. Digestibility ranges from 48–77%. Forage quality varies with age, plant parts, season and genotype. It is highest in the youngest leaves; with maturity N concentrations decrease slightly and crude fibre increases. In 3-month-old growth, gliricidia bark had lower N concentrations than the leaves, but higher levels than the stem. Palatability can be a problem as the forage contains some anti-nutritional factors, with 1–3.5% flavonol and 3–5% total phenols on a DM basis. Ruminants unaccustomed to it may not eat the foliage when introduced to it for the first time. However, once initial aversion has ended, animals will eat a high proportion in their diet for extended periods of time, especially when mixed with other species. In some cases it has been observed that day-old wilted leaves are preferred to fresh leaves; also silage is more palatable than fresh foliage. Leaves also contain carotene.
There are about 80 seeds/g.

Description A small deciduous tree up to 12 m tall with a short trunk up to 50 cm in diameter, with smooth or slightly fissured, whitish-grey to light brown bark, often branching from the base; the mature tree has an irregular spreading crown

Gliricidia sepium (Jacq.) Kunth ex Walp. – 1, leaf; 2, flowering branch; 3, fruiting branch.

of thin foliage. Leaves alternate, pinnate, 15–40 cm long, with slender, yellow-green, finely hairy rachis; leaflets 7–17 per leaf, opposite except in upper part of rachis, elliptical or lanceolate, 3–6 cm × 1.5–3 cm, rounded or cuneate at base, acuminate at top, thin, dull green and glabrous above, grey-green and often pubescent beneath; petiole 5 mm long. Flower in a 5–12 cm long, axillary raceme, about 2 cm long, on an 8–12 mm long, slender pedicel; calyx campanulate, 5-toothed, light green tinged with red; corolla whitish-pink or purple, with a broad standard, turned back and yellowish near the base, 2 oblong, curved wings, and a narrow keel; stamens 10, white, 9 united in a tube and 1 separate; pistil with stalked, narrow red ovary and whitish curved style. Pod narrow, flat 10–15 cm × 1.2–1.5 cm, yellow-green when immature, turning yellowish-brown, shortly stalked and with a short mucro, splitting open at maturity. Seeds 4–10 per pod, ellipsoidal, ca. 10 mm long, shiny, dark reddish-brown.

Wood characteristics Light-brown sapwood and dark-brown heartwood turning reddish on exposure to air, hard, coarse-textured with irregu-

lar grain. It is very durable and termite-resistant. The dense wood, with a volumetric mass up to 750 kg/m^3, is difficult to work. Wood does not reach large dimensions, the bole seldom has a diameter of more than 40 cm and a length of 8 m; normally dimensions are smaller, especially if the tree is regularly coppiced. In young coppices the wood is less dense, with a volumetric mass of about 500 kg/m^3.

Growth and development Seeds germinate in 7–10 days. Early seedling growth is slow, but once established, growth is fast (up to 3 m/year). Flowering and fruiting take place during the dry season, when the tree has shed its leaves if it has not been cut. Flowers are insect-pollinated and the species is outcrossing. Pods ripen 40–55 days after flowering, seeds are mature when pods turn yellow-brown; fruiting is relatively uniform with about 20 days from first to last seed dispersal. In its native area seed production is usually abundant and can be predictably timed. In more humid zones, shoot growth tends to be continuous and the evergreen tree flowers only sporadically on the basal parts of twigs from which the leaves have fallen.

Other botanical information *G. maculata* has been used extensively as a synonym for *G. sepium*. Recently *G. maculata* has been proposed as a distinct species with a different natural geographic distribution. i.e. Yucatan Peninsula, northern Guatemala and Belize. It differs from *G. sepium* by having white flowers rather than whitish-pink or purple, and it has smaller pods and seeds. Most gliricidia planted as an exotic can be attributed to *G. sepium*, but former introductions of *G. maculata* cannot be ruled out.

Ecology In its native range the climate is relatively uniform sub-humid with an annual rainfall of 900–1500 mm and a five-month dry period. The species has been introduced successfully in more humid zones with up to 3500 mm annual rainfall and no marked dry season. In its native range, mean annual temperature varies from 20–29°C, maximum temperature below 42°C; light night frost is tolerated, but not prolonged frost. Gliricidia occurs naturally in early and middle successional vegetation types on disturbed sites such as coastal sand dunes, river banks, floodplains and swidden lands. It tolerates a wide range of soil types, both alkaline and acidic, but prefers free drainage. It is more tolerant of acid and poorly fertile soils than leucaena (*Leucaena leucocephala* (Lamk) de Wit), but will respond to fertilizer application on such soils. It is not as well adapted to the subtropics as leucaena; leaves are shed with the onset of lower temperatures during winter, and plants are less resistant to frosts. However, it is more tolerant of waterlogged conditions than leucaena. The tree resprouts after fire.

Propagation and planting Gliricidia is easily propagated from seed or cuttings. Direct seeding is not often used and potted plants or bare rooted stock are raised in nurseries. Freshly harvested seed or seeds that have been preserved in cold storage have a germination percentage of 80–90%. Seed pretreatment is not necessary and seeds may be sown directly. Nursery stock can be transplanted after 10–12 weeks. It can be propagated very easily by large cuttings, 3–6 cm thick and 0.5–2 m long; the bark may be incised to assist rooting. Cuttings should be taken from mature branches with brownish-green bark and planted fresh. Rooting starts 6–7 weeks after planting. Plants grown from cuttings may have 50–150 nodules after 3 months, compared with 20–70 nodules after 6 months on plants from seed. Trees obtained from cuttings are often more shallow-rooted than trees grown from seed.

Gliricidia may be planted in hedges spaced 4–10 m apart with 10–50 cm between trees in the rows, or as live fences with 20–100(–200) cm spacing. In fodder plots, spacings of 0.25 m × 1.0 m or larger may be used; yields of leaves are little affected by planting densities ranging from 5000–40000 trees/ha. Sometimes trees are used at wide spacings (e.g. 10 m × 10 m) over pasture lands. Where animals are grazed in young plantations, young trees must be protected. Growth on degraded lands may be stimulated by inoculation with an appropriate strain of *Bradyrhizobium* and fertilization. When the tree is used as a live post for black pepper or vanilla, the crops can be planted at the same time as the tree. Such live posts provide some protection against climatic stress. In woodlots spacings of 1.5 m × 2 m to 2 m × 2.5 m are common.

Husbandry Fodder from gliricidia can be produced in various systems. Protein banks consist of dense plots which are periodically harvested for fodder or grazed; hedges may be planted in existing pasture lands and interplanted with grasses; living fences may be established around pasture lands or agricultural fields and homesteads; or spaced trees may be used in pastures to enhance livestock production by providing fodder and shade. In Sri Lanka the tree has also been integrated in pastures under coconut to produce dry season fodder. In Bali (Indonesia), gliricidia has been incorporated in a 'Three Strata Forage System' consisting of a strip of 5 m wide, in which fodder trees (e.g. *Ficus*

subcordata Blume, *Hibiscus tiliaceus* L., *Lannea coromandelica* (Houtt.) Merrill), shrub legumes (e.g. gliricidia) and grasses (e.g. *Cenchrus ciliaris* L.) and herbaceous legumes (e.g. *Stylosanthes* spp.) are combined; cattle feed mainly on the grass-legume stratum in the wet season, the shrub legumes in the mid-dry season and leaves from the fodder trees in the late dry season. Variable amounts of fodder may also be collected from plantations established for other primary purposes such as erosion control or green manure contour plantings in cropped fields.

The influence of gliricidia on pasture grass production depends on the grass species, site conditions and management. Even if grass production is decreased, gliricidia production may compensate for this loss with the total production being more evenly distributed over the year. A wide range of grasses and legumes can be grown together with gliricidia, including *Panicum maximum* Jacq. var. *trichoglume* Robijns, *Cenchrus ciliaris, Urochloa mosambicensis* (Hack.) Dandy, *Stylosanthes scabra* Vogel, and *Stylosanthes hamata* (L.) Taub. When fed as a supplement to poor quality grass, it improved the survival of ewes and lambs, lambing percentage, and birth weight and growth of lambs. It is normally recommended that when feeding cattle, goats and sheep, gliricidia be used at levels of 10–30% fresh weight mixed with either grass, straw or other roughages. Levels of 2–4% should be used when it is fed to poultry as a replacement for lucerne (*Medicago sativa* L.).

Diseases and pests Few diseases and pests have been recorded on gliricidia, and only sporadically do these cause noticeable damage. Very little information is available on the effect of pests and diseases on fodder quality and palatability, but in Indonesia it was observed that buffelgrass (*Cenchrus ciliaris*) was adversely affected by an attack of *Aphis craccivora* on gliricidia. When intercropped the tree may either positively or negatively affect crop pests. In several cases the tree has been reported to control pests, e.g. in Sri Lanka termite damage to tea and in the Philippines stemborer damage to rice were minimized. In India, on the other hand, the tree was found to enhance the transmission of aphids (*Aphis craccivora*) causing rosette disease in groundnuts.

Harvesting The first harvest can be as early as 6–8 months on plants grown from cuttings and 12–16 months on plants grown from seedlings. There should be only one or two harvests per year during the first 2 years. Trees must be well-established, 18–24 months old, before regular harvesting is possible. During the dry season, harvesting should be less intensive (every 3–4 months) than during the rainy season (every 2–3 months). Regrowth should be 1–2 m in height before each harvest. To obtain fodder during the dry season trees should be cut about 3 months before the onset of this season. If trees are uncut for more than 4–6 months before the dry season commences, they will shed their leaves during the dry season. Cutting heights commonly range from 0.5–2 m. Trees grown in contour lines and fodder banks are usually cut lower than those cultivated in living fences or as shade trees in pastures, where browsing cattle may interfere with regrowth.

Forage from gliricidia is usually cut by hand and left on the ground for grazing or carried to paddocks or stalls. Acceptable silage can be prepared using standard techniques; the chopped forage may be mixed with grasses or maize and additives such as molasses and sugar cane or formic acid (0.85%) should be added to provide fermentable carbohydrate.

In woodlots, first harvesting can be after 3–4 years, giving wood yields of 8–15 m^3/ha. Subsequent coppicing is done every 2–3 years and yields up to 40% more than the first harvest.

Yield Under average conditions, yields of 3–4 kg DM per tree per harvest may be achieved. In fodder plots, annual yields of 9–16 t/ha of leaf DM or up to 43 t/ha fresh leaves have been obtained. In Nigeria gliricidia hedgerows interplanted with 4 rows of *Panicum* grasses yielded 20 t/ha per year of mixed DM, which was sufficient to feed 3 head of cattle.

In woodlots, when coppiced every 2–3 years, wood yield varies from 10–20 m^3/ha. Wood production in living fences has been reported at 9 m^3/km per year. All harvested produce is usually used locally.

Genetic resources Major germplasm collections have been made by the Oxford Forestry Institute (United Kingdom), CATIE (Turrialba, Costa Rica), and ILCA Humid Zone Programme (Ibadan, Nigeria). The Oxford Forestry Institute administers an international network of provenance evaluation involving 29 provenances from 8 South and Central American countries. The ILCA Humid Zone Programme has developed a high-yielding bulk composite from four Costa Rican accessions.

Breeding There are no known breeding programmes. Early introductions in many countries usually had a very narrow genetic base and distinct indigenous ecotypes have evolved in several areas. Recent provenance evaluations indicate significant differences in growth rates. Further

rapid genetic gains can be expected, as seed production starts early, superior types can be cloned and production cycles are short.
Distinct selection programmes for high-yielding, palatable fodder cultivars and for arboreal cultivars combining wood and foliage production are desirable.

Prospects Gliricidia is showing considerable promise as a fodder species throughout the tropics. It is a multipurpose tree well adapted to humid areas and acid and infertile soils. Although most fodder is produced in the wet season, the tree can be managed to provide fresh leaf during the dry season. Favourable properties include its versatility in production systems and the ease with which it can be grown together with grasses or herbaceous legumes. Its prospects may be further enhanced by further selection programmes and development of innovative production systems such as the 'Three Strata Forage System'. It has excellent properties for various forms of agroforestry, as well as for site reclamation, including suppression of such obnoxious weeds as *Imperata cylindrica* (L.) Raeuschel.

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K.F. Wiersum & I.M. Nitis

Heteropogon contortus (L.) P. Beauv. ex Roemer & Schultes

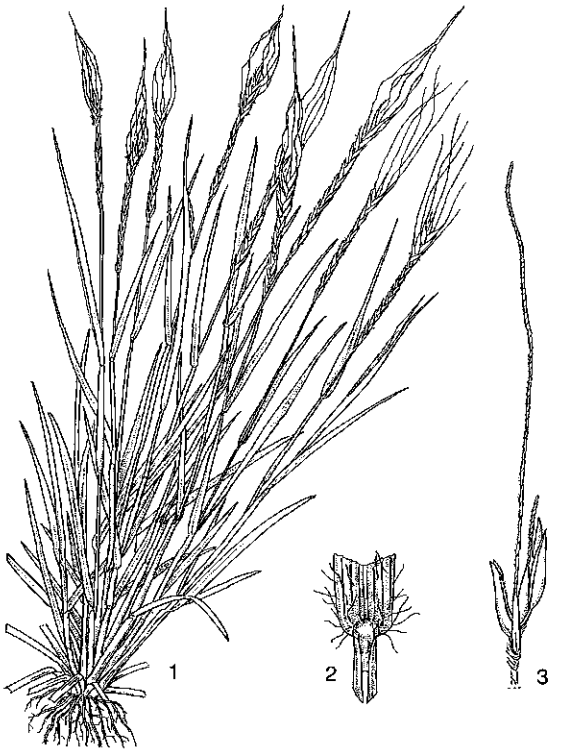
Syst. Veg. 2: 836 (1817).
GRAMINEAE
$2n$ = 20, 40, 44, 60, 80
Synonyms *Andropogon contortus* L. (1753).
Vernacular names Speargrass, black or bunch speargrass (En). Tanglehead (Am). Herbe polisson (Fr). Indonesia: bejeng-benjeng, merakan (Javanese). Philippines: sibat-sibatan (Tagalog). Thailand: ya-nuatrusi (central), ya-lem (northern).

Origin and geographic distribution The natural distribution of speargrass is pantropical/subtropical. It is most likely of Gondwanan origin with a predominant distribution in Australia, the Indian subcontinent and Africa. However, it may be found throughout South-East Asia and the Pacific and in South and Central America in sporadically occurring suitable habitats.

Uses Speargrass is used as part of the naturally occurring savanna pasture resources for domestic livestock production and wildlife. However, pastures containing speargrass are not suitable for wool-producing sheep. The most severe limitation to animal production from speargrass pastures is the wide fluctuation of growth and herbage quality between wet and dry season.

Properties In unimproved pasture its N concentration ranges from 2.5% in very young green material from the early flush of the growing season to as low as 0.3% in dry forage by the end of the dry season. Digestibility varies similarly from 60% down to 40%. The sharply pointed and barbed seeds can be a problem to both humans and animals, particularly woolly sheep.

Botany A tufted perennial, 0.5–1.5 m tall, rather variable in habit with stems erect to geniculate at the base, often branched above, particularly at flowering, flattened towards the base. There is a tendency to being weakly rooted late in the dry season. Stem nodes smooth and hairless. Leaves green or bluish, basal and on the culm; leaf-sheath smooth, compressed, keeled, striate, sometimes with a few hairs near the ligule; ligule a short membranous rim; leaf-blade linear, 3–30 cm × 2–8 mm, folded in the lower part, becoming flat, slightly rough to the touch with a few long hairs, particularly towards the base, apex blunt, almost canoe-shaped. Inflorescence a simple raceme of spikelet pairs arranged in two rows, 3–8 cm long (excluding the awns), the outermost of these are pedicellate and overlapping and enclosing the innermost sessile spikelets; at the base of the raceme the lowermost spikelets are similar and unawned, male or neuter, while the uppermost pairs are of dissimilar bisexual awned sessile and male or neuter unawned pedicellate spikelets; the base of the spikelet has a pronounced callus which is strongly bearded upwards, which at maturity disarticulates obliquely to form a very sharp point, the whole structure forming a most effective barb; the awns,



Heteropogon contortus (L.) P. Beauv. ex Roemer & Schultes – 1, flowering plant; 2, ligule; 3, two pairs of heterogamous spikelets.

which tangle conspicuously at maturity, are an extension of the inner lemma of the fertile spikelet and 5–12 cm long; they are geniculate, twisted and hygroscopically active, enabling them to bore into the ground. Caryopsis cylindrical, 3.5–4.5 mm long, grooved, whitish.

Speargrass exhibits a high degree of embryo and seed-coat dormancy in freshly ripened seed. This declines over the dry season to a high level of germination at the opening rains of the next wet season, following which the germination falls off rapidly with little or no survival beyond one year. Seeds which are burrowed into the soil are in a favourable environment for germination. Flower initiation is obligately to facultatively short-day, the former being characteristic of the intertropical forms, which flower late in the wet season, and the latter of the subtropical forms which flower early to mid-season. Speargrass is an apomict and this has led to a considerable amount of localized variation, resulting in the proliferation of local species and varieties in the early botanical literature.

An annual form has been reported from India, but this could be a short-lived perennial form growing in a difficult environment. The late-flowering forms have higher yields of leaves and are more responsive to increased soil fertility.

Ecology As a typical member of the grass tribe *Andropogoneae* Dumort., speargrass is a savanna grass in seasonally warm wet and cooler dry climates of moderate rainfall. It is relatively drought-tolerant and intolerant of prolonged waterlogging or high salinity. Its main range of distribution is in areas of 600–1100 mm of annual rainfall with some extension below this (on deep sands of drainage lines) and above this (on well-drained sites). It will grow on a wide range of well to moderately free-draining soil types. Speargrass appears not to have been a climax dominant but it has become so, particularly in Australia, India and Africa, through habitat disturbance such as heavy grazing and burning.

Agronomy In its naturally occurring state in savanna, speargrass has a relatively short period of growth and adequacy for good livestock nutrition. This causes a large part of the annual biomass production to become unusable and left as dry standing material. Commonly this material is burnt off during or at the end of the dry season so that the new season's growth may come away cleanly. This procedure leads to increasing dominance of speargrass in the pasture, especially in conjunction with grazing. However, speargrass can be reduced to a minor component of pastures when subjected to sustained overgrazing, particularly on poorly fertile soils or where high stocking rates are sustained through supplementary feeding. Up to an 8-fold improvement of livestock production from pastures based on naturally occurring speargrass can be achieved by introducing tropical legumes such as *Stylosanthes* spp. or *Macroptilium atropurpureum* (DC.) Urban in the subtropical zones. This improvement comes from both increased carrying capacity and rate of growth of the livestock. However, care must be taken, especially in the more strongly seasonal tropics, not to overgraze speargrass as a result of the increased stocking rates.

The following smut diseases of the inflorescences have been reported: *Sorosporium antheseriae, S. caledonicum* and *Sphacelothica monilifera*.

Annual DM yields can range from less than 500 kg/ha in very dry years to 8000 kg/ha in very good years when associated with an effective legume or on fertile soils.

Genetic resources and breeding It is unlikely that substantial germplasm collections of spear-

grass are being maintained. There are no breeding programmes. While there is considerable genetic variability for selection, there are two serious obstacles to breeding: it is an obligate apomict and it has a most unpractical seed morphology for easy seed production.

Prospects If speargrass is not overgrazed during the growing season, it can perform very well as the basic component of native or improved pastures in the tropical and subtropical savanna zone. It is more likely to be used in extensive commercial beef cattle production than by smallholders.

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J.C. Tothill

Hymenachne acutigluma (Steudel) Gilliland

Gard. Bull. Sing. 20: 314 (1964).
GRAMINEAE
$2n$ = unknown

Synonyms *Panicum acutigluma* Steudel (1854), *Hymenachne pseudointerrupta* C. Mueller (1861), *H. myurus* sensu Burkill, Dict.: 1234 (1966), *H. amplexicaulis* sensu Backer, F. Java 3: 561 (1968).

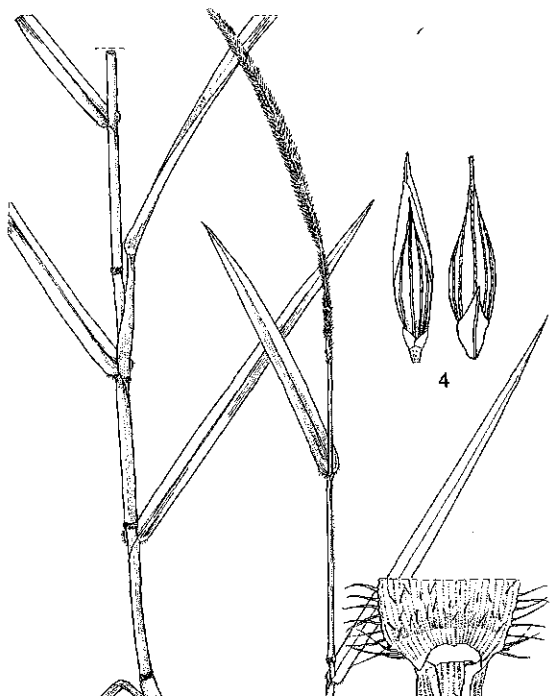
Vernacular names Wick grass, dal grass (En). Indonesia: rumput kumpai (Indonesian), jujuket (Sundanese), blem bem (Javanese). Malaysia: rumput kumpai. Philippines: lagtom (Bikol). Thailand: ya plong. Vietnam: bâć nhon.

Origin and geographic distribution *H. acutigluma* is widespread in wet habitats throughout South-East Asia. It is abundant in peat swamps in southern Thailand and is also found in India, Bangladesh, Burma, Indo-China, China, Japan, Australia and Polynesia.

Uses The foliage is used as fodder. The pith of the culms is used for making lamp wicks. Sometimes the plant becomes a troublesome weed in irrigated rice.

Properties *H. acutigluma* is very palatable. Nitrogen concentrations in 6 samples from Thailand ranged from 0.8–1.7%, but concentrations of 2.5% N in whole plants and 3.6% in leaves have been recorded in Surinam. The average intake of dry matter by sheep in Thailand was 506 g/head per day.

Botany A perennial, aquatic grass, erect in shallow water, in deep water with very long floating stolons which may reach 4–6 m; culms and stolons hollow or filled with a white spongy pith, branched and rooting at nodes to form a bunch of feathery rootlets; culms erect, up to 1 m tall. Leaf-sheath up to 9 cm long, hairy at the margins; ligule membraneous, 1–2.5 mm long; leaf-blade linear to lanceolate, 1.5–40 cm × 1–3.5 cm, shiny dark green, amplexicaul at the base, tapering towards the apex, glabrous except at the margins at the base.



Hymenachne acutigluma (Steudel) Gilliland – 1, part of culm with leaves; 2, ligule; 3, flowering culm; 4, two views of a spikelet.

Inflorescence a terminal, spike-like panicle reaching 55 cm in length, branched at the base but remaining very narrow, cylindrical, 1–3.5 cm wide; number of branches varying, 1–10 cm long; spikelets narrow, long pointed but awnless, 3–5.5 mm long, with one bisexual floret (the upper one) and one neuter (the lower one), green. Caryopsis ellipsoid, up to 1.5 mm long.

A very variable species in its leaves, inflorescences and spikelets. The species has long been thought to be identical to the American *H. amplexicaulis* (Rudge) Nees, causing confusion in botanical literature.

New shoots grow from the old plants at the beginning of the rainy season. Very few seeds are produced in Thailand, although it sets seed during autumn in Australia. It flowers from the middle of the rainy season onwards. Cultivar 'Olive' has been released in Australia.

Ecology *H. acutigluma* thrives in open swamps and ditches from sea-level up to 1200 m altitude. It is adapted to acid soils in peat swamps having pH 4–4.8. It is intolerant of shade. It grows best in high rainfall regions. It can tolerate water up to 1 m deep, but is better adapted to seasonal immersion than to permanent water.

Agronomy Propagation by rooted stolons and division of rootstocks is best. Good soil moisture is needed for its establishment; cuttings should be planted deeply in saturated soils. It is not drought-tolerant, but has been observed to recover from seedlings when flooding recommenced after extended drought periods in Australia. Topgrowth of *H. acutigluma* above water level can be cut several times throughout the rainy season. The tops are then carried to animals. In Thailand it is also grazed by cattle or water buffaloes when flood water recedes. In Australia it is established behind ponding banks where it tolerates deeper water than para grass (*Brachiaria mutica* (Forssk.) Stapf) and is only used for grazing. In Thailand, it is estimated that a minimum yield of 24 t/ha of fresh grass can be obtained from peat swamps. It does not make a good hay as the succulent stems take a long time to dry.

Genetic resources and breeding There is a noticeable variation within the species. It is unlikely that any substantial germplasm collections are being maintained, although small collections are held by ATFGRC (CSIRO, Australia).

Prospects It is a good source of feed for livestock in lowland areas that are subject to lengthy periods of flooding, especially when no other quality forage is available. Research on its agronomy and nutritive value, and on selection of better cultivars, is warranted.

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C. Manidool

Imperata cylindrica (L.) Raeuschel

Nomencl. bot., ed. 3: 10 (1797).

GRAMINEAE

$2n = 20$

Synonyms *Lagurus cylindricus* L. (1759), *Imperata arundinacea* Cyr. (1792), *I. cylindrica* (L.) Raeuschel var. *major* (Nees) C.E. Hubbard (1940).

Vernacular names Blady grass (Australia), cogongrass, satintail (En). Paillotte (Fr). Indonesia: alang-alang, ilalang (Indonesian), kambengan (Javanese). Malaysia: lalang, alang-alang. Papua New Guinea: kunai. Philippines: kogon (Tagalog), gogon (Bikol), bulum (Ifugao). Burma: kyet-mei. Cambodia: sbö':w. Laos: hnha:z kh'a:. Thailand: ya-kha. Vietnam: co'tranh.

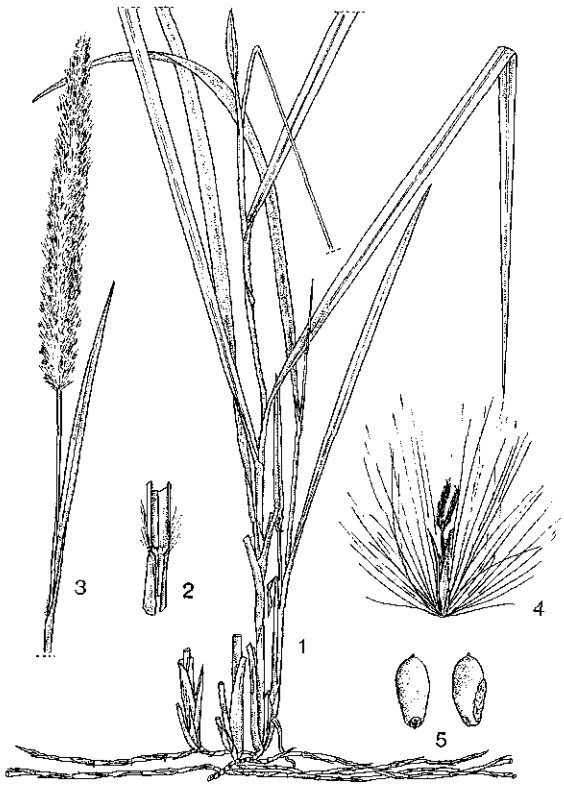
Origin and geographic distribution A native of the Old World tropics that is widely distributed throughout the tropics and subtropics of South-East Asia, Africa, the Indian subcontinent and Australia. It occurs to a lesser extent in North, Central and South America. It also occurs in warm temperate areas and has been recorded at latitudes of 45° in New Zealand and Japan.

Uses *I. cylindrica*, in an early stage of growth, is widely used as feed for ruminants, including cattle, buffaloes, goats and wild herbivores. It is traditionally used in the countryside as roofing material as it is readily available and durable. It has also been used to make paper. It is useful for mulching or controlling soil erosion, and the rhizomes are used medicinally in a decoction to purify the blood and as a diuretic. The rhizomes contain a fair amount of starch and a kind of beer can be made from them. It is regarded as a serious weed in cropping systems.

Properties *I. cylindrica* is regarded as a low

quality grass. Nitrogen concentrations may only remain above 1% for some 6 weeks where it grows rapidly, but can remain above this level for up to 20 weeks with slower growth at higher latitudes and altitudes. Very young growth may have digestibilities of 70%, falling to below 40% after 150 days. Where there is opportunity for selective grazing, other species are usually selected ahead of it.

Description Aggressively rhizomatous, robust perennial with white, deeply buried (up to more than 1 m), branched, fleshy, scaly rhizome, forming loose to compact tufts of leaves. Culms erect, 0.1–1.2(–3 m) tall, 1–4(–8)-noded, unbranched, solid, usually hairy at the nodes. Leaf-sheath with ciliate margins, lower ones broad and leathery, overlapping, the upper ones finally splitting into thin fibres; ligule membraneous, truncate, up to 1 mm tall; leaf-blade linear-lanceolate, 10–180 cm × 5–25 mm, flat, erect, spreading or drooping, pilose at the base, when old with hard, serrate, cutting edges and a stout whitish midrib. Inflorescence a spiciform panicle, cylindrical, 6–30 cm × 2 cm, its branches ascending close to the main axis especially at anthesis; spikelets paired, bisexual, 3–6 mm long, 1-flowered, at the base with a dense whorl of silky white hairs up to 2.5 cm long; pedicels unequal, up to 1 mm long; glumes equal, 3–9-nerved; lower floret reduced to a hyaline lemma; stamens 2, anthers orange to purple; stigmas 2, purple. Caryopsis ellipsoid, ca. 1 mm long, brown.



Imperata cylindrica (L.) Raeuschel – 1, habit; 2, ligule, 3, inflorescence; 4, spikelet; 5, two views of a caryopsis.

Growth and development *I. cylindrica* is a prolific seed producer and the light seeds are readily dispersed by wind. There is no dormancy and seeds may give 95% germination within one week after harvest. The optimum temperature for growth is about 30°C with negligible growth at 20°C and 40°C. Some individual plants flower frequently, some never flower, and other are intermediate. The rhizomes are highly competitive and penetrate the roots of other plants, causing rot or death.

Other botanical information Based on e.g. appearance of leaf-blades (rolled or flat), size of spikelets and hairiness of the node, several botanical varieties have been distinguished in the taxonomic literature. All varieties, however, intergrade so much that individual specimens are often unidentifiable. It seems best, therefore, to ignore the varietal classification, with the understanding that there are a number of imperfectly separable geographical variants. Cultivars have never been developed as research activities are much more directed towards the eradication of *I. cylindrica* than towards its cultivation!

Ecology *I. cylindrica* is often found in areas receiving more than 1000 mm rainfall, but has been recorded in sites receiving from 500–5000 mm. It can withstand waterlogging but not continuous flooding. It grows at altitudes from sea-level up to 2000 m in several countries and has been recorded at 2700 m in Indonesia. It has been estimated that it covers some 500 million ha worldwide including 200 million ha in South-East Asia.

Whereas *I. cylindrica* may have originally been restricted to very low fertility and acid soils in the tropics, it has become widely spread through man's intervention, particularly following slashing and burning of forest lands. Its resistance to burning is associated with its vigorous underground rhizomes, but seedlings also establish after burning. It is found in a wide range of habitats including dry sand dunes of seashores and deserts, as well as swamps and river valleys. It grows in grassland, cultivated areas, and plantations. It quickly invades abandoned farmland and occurs on railway and highway embankments and in deforested

areas. It is regarded as a light-loving plant and will not persist under heavy shade in plantations. Although it grows in a wide range of soil types with widely differing fertility levels, it grows most vigorously in wet soil of reasonable fertility. It has been reported to grow on soils with pH ranging form 4.0–7.5. It can even tolerate very hot, steamy and sulphurous conditions near an active volcanic fumarole or vent.

Propagation and planting *I. cylindrica* is seldom propagated deliberately, but spreads by rhizomes and seed. If rhizomes are cut by cultivation, they can establish from pieces with as few as 2 nodes.

Husbandry *I. cylindrica* is favoured by burning, which can lead to virtually monospecific swards. If it is to be used for thatching, swards are left ungrazed until after the mature growth is removed. It can be eliminated by heavy continuous grazing, where it may be replaced by inedible weeds; vigour will be reduced by close, frequent cutting and rhizomes can be destroyed by frequent intensive cultivation. If *I. cylindrica* is being regularly used for grazing, it has been suggested that it be rotationally grazed when 15–25 cm high.
Because of its aggressiveness and low quality, it is widely regarded as a weed and research has been carried out on improving its quality through introducing legumes or even replacing it with other grasses. However, it is not easy to maintain herbaceous legumes with *I. cylindrica*, though some promising results have been achieved with stylo (*Stylosanthes guianensis* (Aublet) Swartz) and with leucaena (*Leucaena leucocephala* (Lamk) de Wit).

Diseases and pests There are no records of major diseases or pests on *I. cylindrica*.

Harvesting *I. cylindrica* is either grazed or cut for thatch when mature. It is little used as a species for cut-and-carry grazing systems.

Yield Reported DM yields of *I. cylindrica* range from 2–11 t/ha per year. Weight gains of 0.25 kg/head per day have been recorded from *I. cylindrica* pastures in the Philippines and Papua New Guinea. In each case, gains from alternative, improved pastures were two or three times higher. Very low liveweight gains of 0.04 kg/head per day were recorded in northern Thailand.

Genetic resources and breeding There are no known breeding programmes on this species.

Prospects Although *I. cylindrica* is a low-quality forage, it is an important forage resource in South-East Asia and is often inadequately appreciated. Although there is potential for improving its productivity through growing associated with legumes, this will only take place very slowly. Care should be exercised that replacement of this species does not lead to invasion of inedible weeds and/or increased soil erosion.

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N.O. Aguilar

Ischaemum ciliare Retzius

Observ. bot. 6: 36 (1791).
GRAMINEAE
$2n = 36$

Synonyms *Ischaemum indicum* auct. (non (Houtt.) Merrill, 1938), *I. aristatum* auct., (non L., 1753).

Vernacular names Batiki blue grass, smutgrass (En). Indonesia: blembem (Javanese), rumput padang (Billiton). Malaysia: rumput gerek telinga. Thailand: ya wai (eastern), ya-yonhu (southern).

Origin and geographic distribution Batiki blue grass is native to South and South-East Asia. It was introduced to West Africa, southern Europe, Australia and the Pacific Islands.

Uses It is used as forage and also as a cover grass to bind soil and reduce erosion. A dwarf form is used for lawns.

Properties Nitrogen concentrations ranged in experiments from 2.2% at 3 weeks to 1.7% at 6 weeks, 1.3% at 8 weeks and to below 1.0% in mature forage. There have been reports that it taints milk.

Botany A perennial, spreading or tufted stoloniferous grass rooting at the nodes, with erect or geniculate culms up to 60 cm tall, often branching

Ischaemum ciliare Retzius – 1, habit flowering plant; 2, habit stoloniferous plant part; 3, ligule; 4, pair of spikelets.

and hairy at the nodes. Leaf-sheath 3–6 cm long, often tight, glabrous or sparsely hairy; ligule membranous, truncate, 1–2 mm long, entire or lacerate; leaf-blade narrowly lanceolate, up to 20 cm × 1 cm, acuminate at apex, usually sparsely to densely hairy. Inflorescence well exserted, composed of two terminal, closely opposed or somewhat divergent racemes 2–10 cm long; spikelets paired, bisexual, one sessile, one pedicelled, alternately on one side of the triangular rachis; rachis and pedicel hairy along angles; lower glume winged at apex, forming 2 large obtuse lobes; upper lemma deeply notched, excurving into a long kneed and twisted awn 8–15 mm long.

Seeds have a dormancy period and germination improves after 9–10 months storage. Seedling growth is vigorous.

It is a short-day plant, flowering throughout the year in Malaysia, in June–July in Thailand, and in July–August and January–February in India. Seed set is often poor and the grass spreads primarily by stolons.

I. ciliare is a very variable species, subdivided into 3 varieties with one variety divided into 3 subvarieties, but the whole complex needs a thorough investigation with modern experimental taxonomical methods. The species has for a long time been considered to be *I. aristatum* L., but this has glabrous nodes, an unlobed lower glume and only its sessile spikelets are awned. Since 1938 this species has been known as *I. indicum* (Houtt.) Merrill. In 1991, however, Veldkamp discovered that the basionym for *I. indicum*, *Phleum indicum* Houtt., was another species (*Polytrias indica* (Houtt.) Veldk.) and consequently the correct name for this species became *I. ciliare*.

Ecology Batiki blue grass is an opportunistic invader of open or disturbed habitats. It is adapted to a wide range of rainfall regimes, including waterlogged areas in the wet tropics receiving over 2000 mm annual rainfall and to seasonally dry monsoonal areas of India. It has been reported as having some shade tolerance. It tolerates acid soils and soils with poor fertility, but responds to applications of fertilizer on such soils.

Agronomy Batiki blue grass can readily be established from rooted cuttings and a spacing of 30 cm × 30 cm has been recommended. Establishment from seed is much slower and requires good seedbed preparation. It is usually harvested by grazing animals, but can be cut and fed fresh or used to make hay and silage. It should be cut at booting as quality is poor if left for longer. Four cuts a year are possible.

In Malaysia flowers are often infected with a smut fungus resulting in diseased inflorescences that do not emerge from the uppermost leaf-sheaths.

Dry matter yields of Batiki blue grass have ranged from 3–20 t/ha per year depending primarily on soil fertility and fertilizer application. When grown with *Stylosanthes guianensis* (Aublet) Swartz in Sarawak, the mixture yielded 14.5 t/ha of DM.

Genetic resources and breeding Although it is a very variable species, it is unlikely that substantial germplasm collections are being maintained and there are no breeding programmes.

Prospects Batiki blue grass is a useful forage plant in several areas of South-East Asia and the Pacific Islands. It is a competive grass and resists weed invasion. It is palatable, well grazed and can persist under heavy grazing. There are good prospects for its use, especiallly in plantation crops and in moist areas. Germplasm collections of this species are needed so that its variability can be assessed and utilized in agronomic studies for the release of new cultivars to farmers.

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B.B. Baki, I.B. Ipor & C. Manidool

Ischaemum magnum Rendle

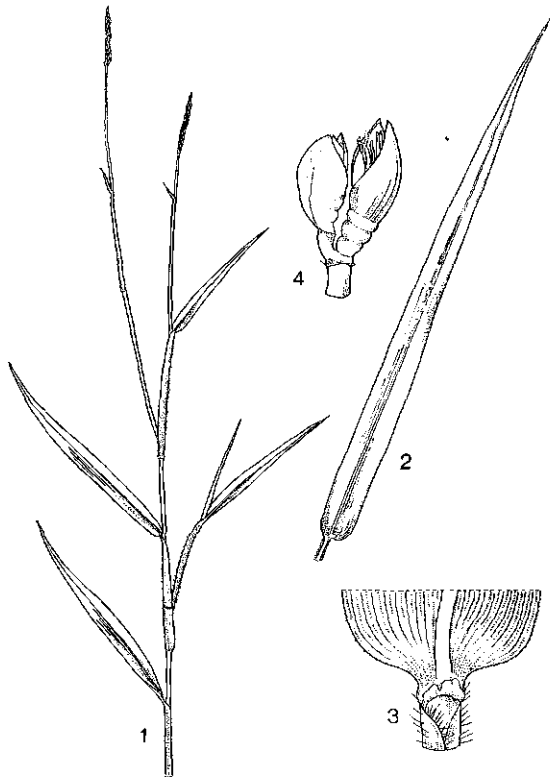
J. Bot. 32: 102 (1894).
GRAMINEAE
$2n$ = unknown
Synonyms *Ischaemum laeve* Ridley (1905).
Vernacular names Malaysia: rumput melayu, rumput tembaga kasar.

Origin and geographic distribution *I. magnum* occurs in restricted areas of Peninsular Malaysia, Singapore, Borneo, Thailand and Burma between latitudes 20°N and 5°S.

Uses *I. magnum* is not well recognized as a forage grass for grazing but its young growth is readily eaten by free-ranging cattle and goats.

Properties Herbage obtained from cutting experiments contained 0.6–1.3% N, 0.10–0.20% P and 1.2–2.6% K depending on the age of regrowth and soil fertility. There are about 400 seeds/g.

Botany A perennial tussock grass with stout culms, up to 2 m tall and a strong root system. Leaf-sheath terete, up to 16 cm long, fringed with fine hairs; ligule a prominent membrane fused with the auricles, 4 mm long; leaf-blade large, lanceolate-acuminate, up to 30 cm × 1.8 cm, abruptly narrowed to a petiole at the base, often hairy near the base, the margins scabrid. Inflorescence composed of two terminal, well-exserted, one-sided racemes closely appressed together, 9–18 cm long, usually



Ischaemum magnum Rendle – 1, flowering culm; 2, leaf; 3, ligule; 4, pair of spikelets.

without, seldom with small awns; each raceme with spikelets arranged in pairs, one sessile, one pedicelled, on one side of a triangular hairy rachis; spikelets similar but the pedicelled spikelet has a lower glume with a narrow wing all down one side. It flowers and sets seed throughout most of the year, but the peak flowering time in Malaysia is in October–November. The maturation of the spikelets is not synchronized and seeds easily shatter. This makes seed harvesting difficult and also means that it has the potential to be a weed in cultivated areas.

Ecology *I. magnum* is found abundantly in both full sunlight and under shade and is a common component of natural pastures. The optimum temperature for growth in its natural habitat is 30–35°C (day) and 22–24°C (night) with 12 hours daylength varying by only 30 minutes throughout the year. It grows in areas receiving 2000–4000 mm annual rainfall. It is highly tolerant of flooding and waterlogged conditions and hence is found in ditches and canals. It is adapted to a wide range of soils ranging from sands, marine peats to heavy

clays. It grows aggressively and can compete with common weeds including *Imperata cylindrica* (L.) Raeuschel. It can also survive short, dry periods.

Agronomy *I. magnum* can be established by seed or by vegetative propagation. Seed is sown into a prepared seed-bed and usually about 30% germinates. Rooted tillers are planted about 1 m apart in wet soil. Seedling growth is slow, but once established, the plants are able to regrow despite severe slashing or annual burning.

No serious pests and diseases have been recorded but predation by birds reduces seed set.

Herbage is well grazed by cattle when it is young but palatability declines towards maturity. Grass swards containing *I. magnum* are usually burnt yearly to obtain new growth. It is compatible with *Centrosema pubescens* Benth. and *Stylosanthes guianensis* (Aublet) Swartz.

Legumes such as *Centrosema pubescens*, *Desmodium heterocarpon* (L.) DC. ssp. *ovalifolium* (Prain) Ohashi and *Stylosanthes guianensis* tend to dominate the grass under continuous grazing. Herbage can be cut for stall feeding but it is usually grazed by free-ranging animals. Under heavy grazing or regular cutting it develops a more prostrate growth habit.

In a 3-year cutting trial in Malaysia, the mean annual DM yield of pure swards of *I. magnum*, fertilized with 200, 25 and 190 kg/ha of N, P and K, respectively, and cut every 8–10 weeks, was 13.7 t/ha. When grown with the legumes *Centrosema pubescens*, *Pueraria phaseoloides* (Roxb.) Benth. and *Macroptilium atropurpureum* (DC.) Urban, total DM yields were about 10 t/ha. These DM yields were similar to those from comparable swards of *Brachiaria decumbens* Stapf, although the total yield of N from *I. magnum* swards was slightly less. Yields declined markedly when the cutting interval was reduced to 4 weeks.

Genetic resources and breeding It is unlikely that any germplasm collections are being maintained and there are no selection or breeding programmes with *I. magnum*.

Prospects *I. magnum* has many advantages including hardiness, persistence and productivity in harsh environments, as well as acceptability by livestock. Research into all aspects of the agronomy of *I. magnum* would be warranted.

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T.T. Ng

Ischaemum muticum L.

Sp. Pl.: 1049 (1753).

GRAMINEAE

$2n$ = unknown

Synonyms *Ischaemum repens* Roxb. (1820), *I. glabratum* Presl (1830), *Andropogon repens* (Roxb.) Steud. (1854).

Vernacular names Seashore centipede grass, drought grass (En). Indonesia: suket resap (Javanese), rumput kerupet (Bangka). Malaysia: rumput kemarau, rumput tembaga jantan. Thailand: ya-waitham (eastern). Vietnam: môm trui.

Origin and geographic distribution *I. muticum* is indigenous to South and South-East Asia. It is widely distributed in Malaysia, particularly near the sea and in sandy places, and in Thailand, Indonesia, the Philippines, Sri Lanka, India, Burma, and some islands in the western Pacific Ocean. It has been introduced to West Africa and Australia.

Uses *I. muticum* provides fodder, but is also used to protect soil from erosion (especially coastal sand dunes) and to make compost and mulch. It is a weed in many annual and perennial crops.

Properties *I. muticum* is a palatable and nutritious grass and N concentrations of 1.5–2.4% have been measured.

Botany A leafy, much branched, stoloniferous spreading perennial, rooting at the nodes where they touch the soil, sometimes scrambling several m high among and over shrubs; stolons long, up to 5 m or more, with numerous joints and up to 6 mm in diameter, covered by slightly overlapping pale or purple leaf-sheaths with extremely short leaf-blades, resembling culm-sheaths in bamboos; flowering culms up to 60 cm tall, glabrous, often red. Leaf-sheath ciliate along outer margin; ligule truncate, small, shortly ciliate; leaf-blade ovate-lanceolate to linear, 2–18 cm × 0.5–2 cm, apex acute, base cordate, narrowing into a short pseudo-petiole. Inflorescence terminal, composed of 2 racemes closely pressed together, each 1.5–5.5 cm long, rarely fully exserted; spikelets arranged in pairs, one sessile and one pedicelled, on one side of a triangular rachis, straw-coloured; the sessile spikelet glabrous, lower glume distinctly reticula-

Ischaemum muticum L. – 1, habit leafy plant part; 2, ligule; 3, flowering culm; 4, pair of spikelets.

tely nerved near the apex, enfolding the spikelet base, upper glume with a strongly keeled acute apex; lower floret male or hermaphrodite, upper floret hermaphrodite; the pedicelled spikelet hairy, lower glume chartaceous, with a winged keel, upper glume subchartaceous; the upper lemma of both spikelets short-awned, awn included in spikelet.

Ecology *I. muticum* is an opportunistic and agressive colonizer of open or disturbed habitats and can develop into huge thickets in drainage canals and ditches. On the edges of secondary forest, plants grow very large, scrambling among bushes. It tolerates wet conditions, especially flooding, and short dry periods. It is usually found in areas receiving more than 1500 mm rainfall annually. Its presence is sometimes regarded as indicative of poor soil fertility.

Agronomy *I. muticum* can be propagated by stem cuttings and by seed. Newly harvested seed is dormant, so scarification is desirable to improve germination. Planting with stem cuttings gives faster establishment than sowing seed.
Although adapted to infertile conditions, it responds to fertilizer application on such soils.
There are no serious diseases and pests of *I. muticum* although it is occasionally infested with smut. High DM yields of up to 25 t/ha per year have been measured. It is usually harvested by grazing animals and only occasionally by cutting. Both fresh and dry foliage can be used for composting or mulch.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained and there are no breeding programmes.

Prospects *I. muticum* is a useful forage in specific situations, but it is uncertain whether it will be specifically cultivated in the future.

Literature |1| Backer, C.A. & Bakhuizen van den Brink, R.C., 1968. Flora of Java. Vol. 3. Wolters-Noordhoff, Groningen, the Netherlands. p. 592. |2| Barnes, D.E. & Chan, L.G., 1990. Common weeds of Malaysia and their control. Ancom Berhad, Shah Alam, Malaysia. p. 22. |3| Gilliland, H.B., Holttum, R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Vol. 3. Government Printing Office, Singapore. pp. 255–257.

I.B. Ipor & B.B. Baki

Ischaemum rugosum Salisb.

Icon. Stirp. Rar.: 1, fig. 1 (1791).
GRAMINEAE
$2n = 18, 20$

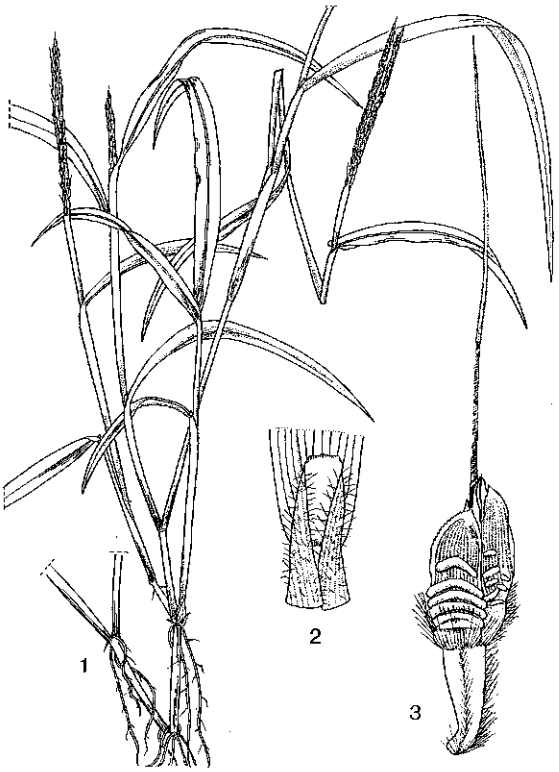
Synonyms *Ischaemum colladoa* Sprengel (1825), *I. segetum* Trinius (1832).

Vernacular names Wrinkle duck-beak, saramattagrass, wrinkled grass (En). Indonesia: suket blembem (Javanese), jukut randan (Sundanese). Malaysia: rumput mele (Sarawak), rumput ekor chawi, rumput colok cinia (Peninsular Malaysia). Philippines: tinitrigo (Tagalog), daua (Subanum), gulong lapas (Pangasinan). Burma: ka-gyi-themyet. Cambodia: smao srauv. Thailand: ya daeng (central), ka-du-ai-nu, ya-noksichomphu. Vietnam: môm u.

Origin and geographic distribution *I. rugosum* is indigenous to tropical Asia and is widely distributed throughout the tropics.

Uses *I. rugosum* is used as forage. It is a serious weed in many crops, particularly in rice fields. It also provides suitable material for compost and mulch. In times of scarcity the grain is eaten by people.

Properties The forage quality of *I. rugosum* declines quickly with age of the material. Nitrogen concentration ranges from 0.5–1.2%.



Ischaemum rugosum Salisb. – 1, habit flowering plant; 2, ligule; 3, pair of spikelets.

Botany A vigourous perennial or annual (in strongly desiccating soil) tufted grass, sometimes with stilt roots, rooting at the nodes, with erect, slanting or ascending, often much branched culms, up to 1.5 m tall. Leaf-sheath long-auricled, ciliate along outer margin, densely soft hairy on node; ligule a brownish truncate membrane, 1–7 mm long; leaf-blade linear, 10–40 cm × 1–4 cm, apex acute, rarely hairy with long slender hairs. Inflorescence terminal, well exserted, composed of 2 racemes that are firmly appressed together and interlocked when young, separating when mature, each 3–12 cm long; spikelets binate, dissimilar, one sessile at the abaxial side of the rachis, one stalked at the adaxial side, provided with a short blunt hairy callus; sessile spikelet 5–6 mm long, 2-flowered, lower floret male or neuter, upper one bisexual; lower glume strongly transversely 5–7-ribbed, and winged above; upper lemma deeply 2-cleft and with 1–2 cm long awn which is twisted basally; pedicelled spikelet more or less reduced, pedicel up to 2 mm long, hairy, confluent with the callus. Caryopsis ovoid, 2 mm long, brown.

It is a very variable species. Two varieties have been distinguished: var. *rugosum*, with developed pedicelled spikelets, and var. *segetum* Hackel, with much reduced pedicelled spikelets; they are not separated geographically.

Seeds germinate early in the wet season and grow vigorously. Swards may form a dense mass of sturdy culms 25–30 weeks after germination.

Ecology *I. rugosum* is an opportunistic and effective coloniser of open, disturbed or newly cleared areas. Although a sun-loving plant it can persist in sites receiving only 30–35% of full sunlight. It occurs at altitudes of up to 2400 m in the Philippines. *I. rugosum* is particularly well adapted to wet sites, and is often found in rice fields or low lying areas that are periodically flooded. It tolerates acid soils of pH(H_2O) 4.0.

Agronomy *I. rugosum* can be established by seeds or rooted culms. Newly harvested seeds appear to have innate or induced dormancy, and scarification is desirable to reduce hard-seededness. When sowing seed, good seed-bed preparation assists in obtaining good establishment and seedling growth. Planting rooted culms at a 25 cm × 25 cm spacing will result in faster sward development than using seed. Although it will persist on soils of poor fertility, it will respond to fertilizer application.

I. rugosum has no major diseases or pests. Infestations by *Puccinia* spp. are commonly observed; they may reduce the quantity and quality of feed available, but control by chemicals is not warranted. It is an alternative host of the viruses causing rice and maize leaf blight galls and of *Piricularia* sp.

It can be grazed, but will not persist when continuously grazed by large ruminants at high stocking rates. When it is growing in water, the tops above water level can be cut and fed to animals. It is usually fed when fresh, but can be ensiled or dried and conserved for dry season feeding.

Genetic resources and breeding It is a very variable species, but it is unlikely that substantial germplasm collections are being maintained.

Prospects *I. rugosum* will continue to provide useful forage in existing feeding systems. As it is a very variable species, there is potential for selecting for better forage types and for studies on its agronomic requirements and grazing management.

Literature |1| Bor, N.L., 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, London. pp. 184–185. |2| Gilliland, H.B., Holttum, R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of

Malaya. Vol. 3. Government Printing Office, Singapore. p. 259. |3| Holm, L.G., Plucknett, D.L., Pancho, J.V. & Herberger, J.P., 1977. The world's worst weeds: distribution and biology. The East-West Center, University of Hawaii Press, Honolulu, Hawaii, United States. pp. 295–298. |4| Manidool, C., 1989. Natural grassland and native grasses of Thailand [in Thai]. Technical Bulletin No 1301–26–32. Division of Animal Nutrition, Department of Livestock Development, Bangkok. p. 19. |5| Mehra, K.L. & Fachrurozi, Z., 1985. Indonesian economic plant resources: forage crops. Lembaga Biologi Nasional – LIPI, Bogor, No 31. p. 21. |6| Soerjani, M., Kostermans, A.J.G.H. & Tjitrosoepomo, G., 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta. No 3521. pp. 440–441.

B.B. Baki & C. Manidool

Ischaemum timorense Kunth

Révis. gramin. 1: 369, t.98 (1830).
GRAMINEAE
$2n = 20, 36$

Synonyms *Ischaemum macrurum* Stapf ex Ridley (1925).

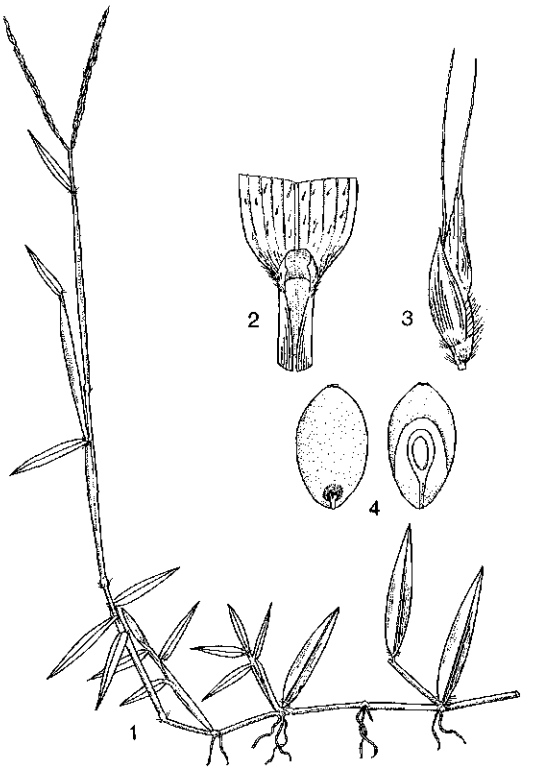
Vernacular names Centipede grass, lucuntu grass (En). Indonesia: jukut jampang manggung (Sundanese), rumput apet (Sumbawa). Malaysia: rumput sarang buaya. Vietnam: môm timor.

Origin and geographic distribution *I. timorense* is indigenous to tropical Asia and is widely distributed from India to Malesia and Polynesia.

Uses *I. timorense* is a fodder species of minor importance in South-East Asia. It is useful for protecting soil against erosion and in providing material for mulch, but can be a weed in annual and perennial crops. Particularly in Indonesia it is a common weed in rainfed rice.

Properties When well fertilized with N, P and K, three-week-old herbage had a N concentration of 3.2%, falling to 2.6% at 6 weeks. The N concentration of leaves was approximately double that of the stems.

Botany A spreading stoloniferous perennial or annual, creeping and rooting in lower part, erect, slanting or scrambling in upper part with culms up to 1 m high. Leaf-sheath 3–6 cm long, white-hairy on the nodes and often with long hairs at the mouth, the outer margin and the back; ligule a short fringed membrane, sometimes long ciliate; leaf-blade lanceolate to linear-lanceolate, 2–16 cm × 3–15 mm, base obtuse or petiole-like, apex acute, adpressed long-hairy, or glabrous above.



Ischaemum timorense Kunth – 1, flowering plant part; 2, ligule; 3, pair of spikelets; 4, caryopsis in two views.

Inflorescence terminal, composed of 2(–3) closely opposed racemes, each 2–15 cm long; spikelets in pairs, one sessile, one pedicelled; alternately on one side of the triangular rachis; spikelets similar, 2-flowered, green or tinged with purple, lower floret male, upper floret bisexual; sessile spiklet 5–7 mm long, at the base swollen and stipe-like and white-hairy, lower glume with two acute lobes at apex, upper glume with a short 2–3 mm long awn, upper lemma 2-lobed with a 10–16 mm long awn in the middle. Caryopsis ellipsoid, 1–2 mm long. The flowering season in Indonesia is April–November.

Ecology As *I. timorense* establishes readily from seed and spreads by rooted stolons, it is an opportunistic colonizer of bare or disturbed areas. Hence it is common along roadsides, terraces, ditches and forest margins, and it is a weed in agricultural crops. It is found most frequently in areas with 800–2000 mm annual rainfall, but is not adapted to either dry or waterlogged sites or to heavy soils. It grows under full or partial (30–50%) sunlight. It is tolerant of high soil acidity and poor soil fertility.

Agronomy *I. timorense* can be established by sowing 3–6 kg/ha into a well prepared seed-bed. If recently harvested seed is used, scarification may be required to break dormancy. It can also be established by spreading cut grass on to the surface of moist soil and disking it in.
There are no serious diseases or pests of *I. timorense*, although spikelets are often infected by smut. *I. timorense* is usually harvested by grazing animals and only rarely by cutting. It is well grazed by cattle, horses and sheep. Some form of resting or rotational grazing may be required so that sufficient seeding can take place to ensure long-term persistence. It is not a particularly vigorous grass, although it is more productive in very fertile situations. Yields of 30 t/ha per year of fresh forage have been obtained. Both fresh and dry foliage can be used for composting and mulching, and it can be conserved as hay.

Genetic resources and breeding It is unlikely that there are substantial germplasm collections and there are no known breeding programmes.

Prospects Although *I. timorense* is a useful forage in specific situations, its dry matter yield is too low to warrant cultivation.

Literature |1| Bogdan, A.V., 1977. Tropical pasture and fodder plants. Longman, London. p. 161. |2| Gilliland, H.B., Holttum, R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Vol. 3. Government Printing Office, Singapore. pp. 264–265. |3| Mehra, K.L. & Fachrurozi, Z., 1985. Indonesian economic plant resources: forage crops. Lembaga Biologi Nasional–LIPI, Bogor, No 31. p. 22. |4| Soerjani, M., Kostermans, A.J.G.H. & Tjitrosoepomo, G., 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta. pp. 442–443.

I.B. Ipor, B.B. Baki & C.P. Chen

Leptochloa chinensis (L.) Nees

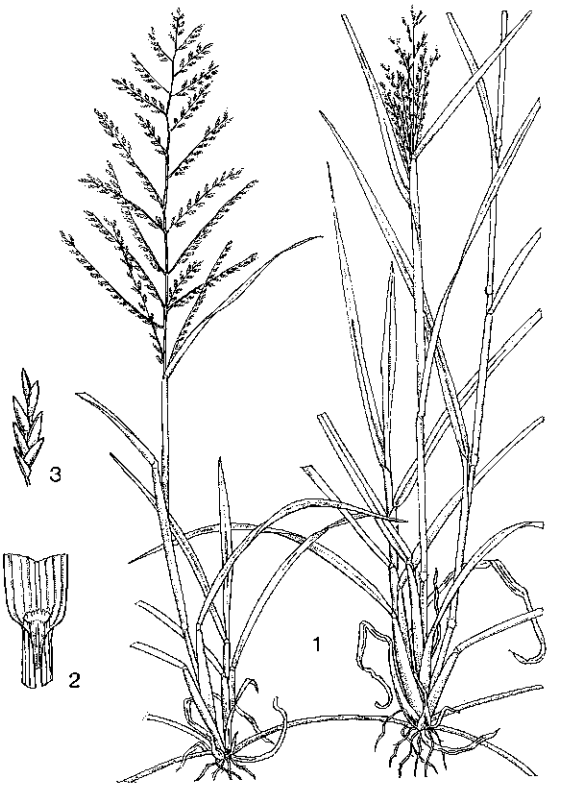
Syll. Ratisb. 1: 4 (1824).
GRAMINEAE
$2n = 40$
Synonyms *Poa chinensis* L. (1753).
Vernacular names Indonesia: timunan (Javanese), bebontengan (Sundanese), jangkiri (Flores). Philippines: palay-maya (Tagalog), karukauáyan (Bikol). Thailand: ya-yonhu, ya-dokkhao (central), ya-metnga (northeast). Vietnam: cò duói phung.

Origin and geographic distribution *L. chinensis* originated in tropical Asia and is distributed throughout South-East Asia, Burma, Sri Lanka, India, China, Japan, Australia and from East to South Africa.

Uses *L. chinensis* is used as fodder. Normally it is regarded as a weed in paddy fields but livestock owners collect and feed it to their animals. In East Africa the grain is used as famine food.

Properties It is highly palatable and very leafy, but there is no information on its nutritive value.

Botany An aquatic or semi-aquatic tufted annual or perennial, with stout to slender, erect or geniculate culms up to 1.5 m tall, often rooting at the lower nodes. Leaf-sheath loose, subglaucous, smooth, up to 10 cm long; ligule a fringed, hairy membrane, 1–2 mm long; leaf-blade linear, up to 50 cm × 1 cm, long-attenuate, flat or folded, scabrid above. Inflorescence 10–60 cm long, composed of numerous slender racemes scattered along an elongate central axis; racemes flexuous, 2–13 cm long, erect or laxly ascending; spikelets 3–7 flowered, narrowly elliptical-oblong, 2–3 mm, subsessile, often purplish, disarticulating above the glumes and between the florets; glumes unequal,



Leptochloa chinensis (L.) Nees – 1, habit flowering plants; 2, ligule; 3, spikelet.

scabrid on the back of the nerves; lemmas hairy on the nerves, awnless. Caryopsis ellipsoid-oblongoid, 6–9 mm long, brown, smooth or wrinkled.

L. chinensis is an abundant seed producer. The seedlings develop quickly so that they can keep pace with the rising level of flood water and thus survive. It flowers over most of the year.

The related, more widely spread *L. panicea* (Retzius) Ohwi (*L. polystachya* Benth. sensu Burkill) is eaten by cattle when young. It differs by the longer leaf-sheaths (up to 13.5 cm), the papillate-pilose hairs on the leaves and the 2–5-flowered spikelets. *L. panicea* much resembles the American *L. filiformis* (Lamk) P. Beauv.

Ecology *L. chinensis* grows from near sea-level up to 1400 m altitude. It is adapted to moist, swampy places in open habitats, especially if disturbed, on heavy or light soils.

Agronomy *L. chinensis* is propagated by seed or by rooted tillers. Adequate soil moisture is the main factor affecting the growth of this aquatic plant, although it has been observed that improved soil fertility in rice fields also results in better growth.

It is harvested by cutting forage above the water level in paddy fields or by grazing.

No yield data are available, but in open waste places it should give reasonable yields. It can make good hay but when cut it is normally collected and fed green to livestock.

Genetic resources and breeding It is unlikely that any germplasm collections are being maintained.

Prospects *L. chinensis* will continue to be a useful supplementary feed source in lowland areas.

Literature |1| Gilliland, H.B, Holttum, R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Vol. 3. Government Printing Office, Singapore. pp. 73–75. |2| Häfliger, E. & Scholz, H., 1981. Grass weeds 2. Ciba-Geigy Ltd., Basel, Switzerland. p. 94. |3| Mehra, K.L. & Fachrurozi, Z., 1985. Indonesian economic plant resources: forage crops. Lembaga Biologi Nasional – LIPI, Bogor, No 31. p. 24. |4| Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G., 1987. Weeds of rice in Indonesia. Balai Pustaka No 3521, Jakarta. pp. 446–447.

C. Manidool

Leucaena leucocephala (Lamk) de Wit

Taxon 10: 53 (1961).

LEGUMINOSAE

$2n = 104$

Synonyms *Leucaena glauca* (Willd.) Benth. (1842), *Leucaena latisiliqua* (L.) Gillis (1974).

Vernacular names Leucaena (En). Indonesia: lamtoro, klandingan (Javanese), petai cina (Indonesian). Malaysia: petai belalang, ipil-ipil. Papua New Guinea: kunai. Philippines: ipil ipil, elena (Tagalog), palo-maria (Bikol), kariskis (Ilokano). Cambodia: ka-thum' théét. Laos: kathin, kh'oonz koong khaaw. Thailand: krathin (general), to-bao (southern). Vietnam: keo dâu, bo chét.

Origin and geographic distribution Leucaena evolved in the Guatemalan centre of origin, as a probable tetraploid hybrid of diploid species in that region. Two major forms are found. The 'common' shrubby form grows up to 8 m tall and is evidently indigenous to the Yucatan Peninsula. The arboreal 'Salvador' type grows to 16 m and appears to have originated in the regions of Salvador, Guatemala and Honduras. Both forms were distributed widely throughout Mexico and Central America to northern South America prior to 1500 AD. The common form was probably brought by Spanish galleons to the Philippines in the early 1600s, from whence it was pantropically distributed in the 19th Century. The Salvador forms are more recent in distribution and are known by names such as 'lamtoro gung' in Indonesia, 'giant ipil-ipil' in the Philippines and 'subabul' in India. Leucaenas are found throughout South-East Asia; on many islands common leucaenas dominate the vegetation on coralline soils.

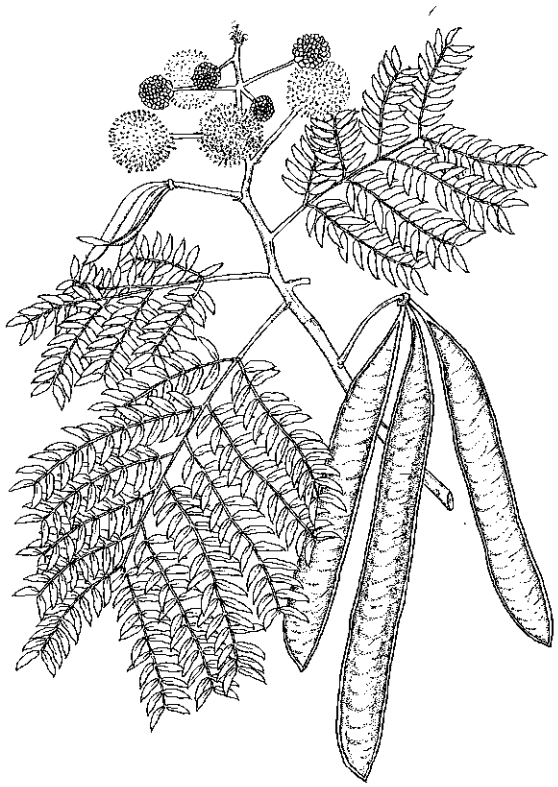
Uses Leucaenas are versatile multipurpose trees. In South-East Asia they usually provide a combination of fodder, fuelwood, posts, shade, food and green manure. Foliage is fed to ruminant animals as browse or by cut-and-carry methods, or is milled for poultry and pelleted for export. Wood is cut for home fuelwood and used in industries such as ceramics or electrical power generation; it is also converted into charcoal. Increasing use is made of the wood for posts and props, in chipboard and plywood, for paper pulp, and for furniture and parquet flooring. In Asia people eat the young green shoots prior to leaflet unfolding, but in the Americas the green seeds are eaten. Alley cropping involves planting leucaena hedges on contours at intervals of 3–6 m with crops in between. Hedges provide a high-nitrogen green manure, protect against soil erosion and can be har-

vested for fodder or wood.
Other uses include living fences, support systems for vines like pepper and passionfruit, shade trees for coffee and cocoa and ornamental plantings. Throughout the tropics leucaenas provide a major nitrogen-fixing component of lowland forests, notably on wasteland where they are often a primary source of fixed nitrogen in the ecosystem. The dried seeds are widely used for ornamentation and household items.

Production and international trade Leucaena leaf meal is milled, pelleted and shipped internationally in a very variable annual volume, largely to Japan and Europe for animal feed. Demand is estimated to be up to 1 million t/year, far exceeding production, with world prices similar to those for alfalfa pellets or hay. Prices in local markets in Asia vary widely for both fodder and wood. However, leucaena is the primary leguminous feed in large regions of Indonesia and the Philippines, and the trees are a major source of fuelwood in these and other countries. Most production is on communal lands or small farms. Attempts to commercialize production on large plantations (1000 ha or more) for dendrothermal energy in the Philippines have not been a great success.

Properties Leucaena foliage is noted for its good digestibility and high protein values. Typical values for 'browse fraction' of foliage include 55–70% digestibility, 3–4% N, 6% ether extract, 6–10% ash, 30–50% N-free extract (neutral detergent fibre 20%), 1.5–2.5% tannins, 0.8–1.87% Ca and 0.23–0.27% P. However, the Na levels are invariably low: 0.01–0.05%. The seeds and leaves contain galactomannan gums that block protein extraction and possibly its utilization by animals; they may potentially have useful biomedical properties.
Leucaena also contains the toxic amino-acid mimosine which has antimitotic and depilatory effects on animals. It occurs in high concentrations in the growing tips (8–12%), young leaves (4–6%) and young pods and seeds (4–5%). For this reason leucaena leaf cannot safely be included in rations for non-ruminants at a level above 5% on a DM basis. The mimosine ingested by ruminants is converted to 3-hydroxy-4(IH)-pyridone(DHP) by plant enzymes and rumen bacteria. The DHP is goitrogenic and, if not degraded, can result in low serum thyroxine levels, ulceration of the oesophagus and reticulo-rumen, excessive salivation, poor appetite and low liveweight gains especially when the diet contains more than 30% leucaena. Fertility may also be reduced. In most countries in South and Central America, the United States, Mexico, Indonesia, the Philippines and India, rumen microbes can completely detoxify mimosine and DHP. Isolation of specific bacteria has enabled the DHP-degrading bacteria to be transferred successfully to Australia, Africa and China with beneficial effects for ruminants on diets containing much leucaena.
The trees occasionally exude a gum very similar to gum arabic, with similar uses and properties; sterile hybrids exude copiously.

Description Shrub or tree up to 18 m tall, forked when shrubby or after coppicing, with greyish bark and prominent lenticels. Leaves bipinnate with 4–9 pairs of pinnae, variable in length up to 35 cm, with a large gland (up to 5 mm) at base of petiole; leaflets 11–22 pairs per pinna, 8–16 mm × 1–2 mm, acute. Flowers numerous, in globose heads with a diameter of 2–5 cm, white, calyx ca. 2.5 mm, corolla ca. 5 mm, stamens (10 per flower) and pistil 10 mm long, anthers pilose, dehiscing at dawn. Pod 14–26 cm × 1.5–2 cm, pendant, brown



Leucaena leucocephala (Lamk) de Wit – flowering and fruiting branch.

at maturity. Seeds 18–22 per pod, 6–10 mm long, brown.

Wood characteristics Leucaena produces a medium hardwood with specific gravity between 0.5 and 0.6 and a moisture content which varies between 30–50% depending on maturity. Heating values (bone-dry) average 19250 kJ/kg. Bark is thin. The wood turns well, matures to a golden-brown colour and is hard enough for flooring. It accepts preservatives well but does not resist termites. Pulp yields are high (50–52%), lignin levels low, fibres short (1.1–1.3 mm); paper quality generally is considered excellent.

Growth and development Leucaena sets pods cyclically every 6–8 months if moisture is sufficient, and this is associated with suppression of vegetative growth during fruiting. Arboreal cultivars have been selected for greatly reduced flowering. Fruits ripen in 10–15 weeks. The flowers are self-fertile and most seed results from self-pollination (this is not true for related species with $2n = 52$ or $2n = 56$). Seeds have a hard seed-coat and survive for a long time in the soil. Seedlings produce a single strong taproot in the first month, followed later by feeder roots. Nodulation is often slow, but occurs within 2 months. Rates of growth usually increase after 3 months, continuing linearly for 3–4 years. Coppiced stems sprout 5–15 branches, depending on diameter of the cut surface, and 1–4 stems dominate after a year of regrowth. Individual leaves persist from 4–6 months and fold at night or under stress.

Other botanical information The common and giant forms of *L. leucocephala* are distinguished taxonomically as *L. leucocephala* var. *leucocephala* (common form, shrubby, small plant parts, pubescent shoot tips) and *L. leucocephala* var. *glabrata* Rose (giant form, arboreal, with large plant parts, glabrous shoots). Intermediate types are referred to as the 'Peru' form. The giant or 'glabrata' form gives the highest yields of fodder with infrequent cutting. The best known cultivars in South-East Asia are 'K8', 'K29', 'K67', 'K156' (a cultivar of *L. diversifolia* (Schlecht.) Benth.) and 'K636' which resulted from research work in Hawaii, and the cultivar 'Cunningham' in Australia. Psyllid-resistant cultivars 'KX1', 'KX2' and 'KX3' are interspecific hybrids and are becoming popular in Asia.

Ecology Leucaena is found from lowlands up to 1000 m elevation, but new hybrids such as 'KX3' greatly extend this range to cooler climates. Leucaena generally requires annual rainfall of 650–1500 mm, but can be found in drier and wetter sites depending on competitive vegetation. It thrives under irrigation regimes similar to those used for crops like maize (i.e. > 1200 mm/year). Leucaena favours soils with pH > 5, and has a low tolerance of free Al. It performs best on coralline and other calcareous soils, but can be found on saline soils and on alkaline soils up to pH 8. Leucaena is not suited to acid soils with $pH(H_2O) < 4.5$ or to waterlogged conditions.

Propagation and planting Leucaena establishes fairly slowly, particularly in competition with weed species and when grown on soils which are acid or low in nutrient status. For best results, leucaena should be planted on well-drained soils with a pH above 5.5 and with a deep soil profile. This is particularly important if productivity during the dry season is required.

Seeds must be scarified to improve germination, usually by placing the seeds for 3 minutes in water at 80°C and then allowing them to cool. Inoculation using peat cultures of improved strains such as CB81 or CB3060 (TAL 1145) is important for early nodulation and growth. In the absence of peat inoculants, the soil under well-established stands of leucaena could be used to promote early establishment. This may also promote early infection by mycorrhiza. It is important not to sow the seed too deeply (below 2 cm) and, where possible, competing species should be controlled either by slashing or by appropriate chemicals. For forage, seeds are usually sown in rows 1–5 m apart with a seeding rate of 5–7 kg/ha using fertilizer where necessary to correct known soil deficiencies. In cut-and-carry systems, closer plant spacing gives higher yields of leucaena but in grazed situations the wider row spacings of 2–5 m are more appropriate to enable the grass to grow between the rows to prevent soil 'plugging' during wet weather. Leucaena can also be established by raising seedlings in the nursery in long narrow containers (3 cm × 15 cm), accommodating the strong taproot without coiling. Transplanting is done when seedlings are 3–5 months old, preferably after a month in the full sun. Bare-rooted seedlings can be transplanted effectively if shoot and roots are topped.

Establishment is often more successful on areas which were previously under grassland than on areas which were previously cropped and therefore contain large numbers of weed seeds. Despite weed competition, leucaena is often able to survive because of its ability to tolerate shade, thereby eventually growing above the weed canopy, provided the area is not closely grazed or mown.

Husbandry For grazing situations, leucaena can be grown with many grasses. In the subtropics,

rhodes grass (*Chloris gayana* Kunth) and setaria (*Setaria sphacelata* (Schumach.) Stapf & Hubbard ex M.B. Moss) have been suitable companion grasses. Pangola grass (*Digitaria eriantha* Steudel), guinea grass (*Panicum maximum* Jacq.), signal grass (*Brachiaria decumbens* Stapf) and Sabi grass (*Urochloa mosambicensis* (Hack.) Dandy) are suitable in the tropics.

Leucaena is very palatable and stands can be easily weakened by heavy continuous grazing. Several rotational grazing strategies have been successful, including a simple 2 paddock system of 4 weeks grazing / 4 weeks rest and a 4 paddock system of 2 weeks grazing / 6 weeks rest. The main principle is to move the animals before they graze new leucaena regrowth. Specific paddocks of leucaena can also be used in conjunction with areas of native pasture, using the rotational principle to prevent overgrazing of the palatable leucaena. When adequate leucaena is available, cattle should be capable of weight gains of about 1 kg/head per day provided the Na level in the diet is adequate.

Diseases and pests Diseases of leucaena are few and include seedling rots such as *Phytophthora drechsleri* and *Fusarium semitectum* that attack primarily under waterlogged conditions. Until the mid-1980s leucaena was relatively free of serious diseases and pests. However, devastating effects of the leucaena psyllid (*Heteropsylla cubana*), a small aphid-like sucking insect, have been experienced in many areas where leucaena is grown for fodder. Psyllid damage is rarely seen in leucaena's centre of origin in South and Central America, and damage caused by the psyllid has decreased with time in other areas. Populations of these insects fluctuate through the season and can cause losses of over 50% in yield. Attempts to use predatory and parasitic insects for control have been variably successful. This pest is now limiting the further development of leucaena for forage in some areas. Other leucaena species show resistance to psyllids, and have been used in the breeding of resistant hybrids 'KX1', 'KX2' and 'KX3'.

On plants allowed to grow tall, attacks of soft scale (*Cocus longulus*) and an associated sooty mould can be serious. Seed crops can also suffer yield reduction through attacks on the inflorescences and young pods from the larvae of the moth *Ithome lassula*. In some areas, notably Central America, bruchid beetles can seriously reduce or destroy seed crops.

Seedlings can suffer attack from cutworms and termites, but, provided there is an adequate stand density, subsequent production is usually not reduced.

Harvesting In cut-and-carry systems, the plants are cut back to 0.5–1.0 m height every 6–8 weeks during the growing season and fed fresh to ruminants. In many situations, leucaena is fed as a protein supplement to grass or cereal straws. Sometimes the feeding of leucaena improves the intake of the basal diet, but generally it improves the total intake of DM, protein and digestible nutrients. The extent of the improvement depends on the amount of leucaena that is fed.

In some of the Indonesian islands (particularly Timor), fresh leucaena may form a large part of the diet of tethered animals intended for slaughter. Banana pseudostems are also fed to provide water. Such a diet is grossly deficient in Na, and salt supplementation is required for good production.

Wood harvest periods range very widely, from 1–8 years, depending on size of desired product and harvesting equipment. Machetes are commonly used in Asia, but bandsaws and chainsaws can also be used.

Yield Yields of forage vary with soil fertility, rainfall, altitude and cutting management from 1–15 t/ha of DM per year. Total yields are reduced by frequent cutting, though leaf yield per day may vary little between cutting at 6, 8 or 12 weeks. Highest yields are obtained under wet tropical lowland conditions on deep well-drained, neutral to alkaline soils. Although leucaena is drought-tolerant, yields in the dry season are low unless the plants have access to sub-surface water or are irrigated.

Wood yields compare favourably with the best tropical trees, with height increments of 3–5 m/year and wood increments of 20–60 m^3/year for arboreal varieties.

Handling after harvest Fodder is commonly fed fresh or provided as a browse. Sun-drying is practised for leaf pelleting and marketing, often by placing branches over trelliswork or on asphalt to allow the leaflets to drop. Wood handling is similar to that of other fuelwood or pulpwood species.

Genetic resources Two major collections are held at NFTA (Hawaii) and ATFGRC (CSIRO, Australia). They comprise all 14 *Leucaena* species and total 1800 accessions derived largely from 7 expeditions to Mexico and Central or South America. They are identified by K numbers (Hawaii) or CPI numbers (Australia). Naturalized populations of leucaena in Asia show limited genetic variation and are not recommended for production as they are out-yielded by improved cultivars.

Breeding Breeding of leucaena is in progress at NFTA (Hawaii) and CSIRO (Australia). The key

objective is to incorporate psyllid resistance from other *Leucaena* species (primarily *L. diversifolia* and *L. pallida* Britton & Rose) into agronomically desirable forms of *L. leucocephala*.

Prospects Over the last 2 decades, leucaena has been one of the most promising forage legumes in South-East Asia. The arrival of the psyllids has curbed the previous enthusiasm. However, partial control of the problem with natural or introduced predators, and the prospect of new lines or hybrids more tolerant or resistant to the psyllid, have renewed interest in this and related species.
Newly-bred cultivars widen the climatic range of leucaena to the highlands and subtropical regions, with great cold tolerance characterizing some new hybrids ('KX3'). Improved bole shape ('K636'), psyllid resistance ('KX1', 'KX2'), low mimosine content ('KX3') and increased vegetative vigour are among other advances in breeding. Improved alley cropping methods of managing leucaena have been developed in Africa and Indonesia. These are expected to improve crop yields in association with leucaena and aid in the stabilization of shifting systems of agriculture and of fragile tropical soils.

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R.J. Jones, J.L. Brewbaker & C.T. Sorensson

Lotononis bainesii Baker

Fl. Trop. Afr. 2: 6 (1871).
LEGUMINOSAE
$2n = 36$

Vernacular names Lotononis (En). Thailand: thua-lotononit.

Origin and geographic distribution The natural distribution of lotononis is confined to southern Africa, mainly between latitudes 20°S and 30°S in Namibia, South Africa and Zimbabwe. There are now isolated occurrences in many countries as a result of experimentation. It is naturalized in areas of subtropical Australia, particularly along roadsides.

Uses Lotononis is used as a pasture legume, mainly in the subtropics.

Properties Lotononis forage is of better quality than most tropical legumes, particularly in terms of N concentration which ranges from 1.5–4.0%. Digestibility is good for a tropical legume, and Na concentrations also tend to be higher. Seeds are very small with 3000–4000 seeds/g.

Botany A stoloniferous, prostrate, creeping, short-lived perennial, with a primary taproot and smaller adventitious roots arising from stolons. The plant canopy is seldom more than 30 cm high, but stems may reach 1.8 m length. Leaves usually trifoliolate; petiole up to 7.5 cm long; stipules leafy, up to 1 cm long; leaflets polymorphic, oblong to lanceolate, up to 6.5 cm × 1.5 cm, glabrous or slightly pubescent, margins entire. Flowers about 1 cm long in head-like inflorescences 1–3 cm long with few to more than 20 flowers; peduncle up to 27 cm long; calyx hairy; corolla yellow to reddish. Pod linear-oblong, 8–12 mm × 2 mm, densely white hairy, with long persistent style.
Lotononis flowers early in the wet season.
Cultivar 'Miles' has been released in Australia.

Ecology As a sown pasture species, lotononis is best suited to areas receiving 700–1200 mm annual rainfall in the subtropics or tropical highlands, although it occurs naturally in areas with rainfall as low as 250 mm/year. It is one of the best subtropi-

Lotononis bainesii Baker – 1, flowering and fruiting branchlet; 2, flower; 3, fruit.

cal legumes in terms of winter growth and is resistant to light frosts. It grows best on well-drained sandy soils under moderate to heavy grazing, particularly with more open grass swards. It has good tolerance of low levels of available soil P and Mo.

Agronomy Seed is often hard-seeded and scarification may be required before sowing. Lotononis can be established by sowing into a seed-bed or broadcasting into undisturbed swards using a seeding rate of 0.5–1.0 kg/ha. As seed is very small it is best sown on top of cultivated soil and then rolled in so that it is not buried too deeply. Sowing in the hottest months should be avoided. Seedling emergence is often slow and erratic.

Inoculation with a specific *Bradyrhizobium* strain such as CB 376 is essential. Lotononis is usually sown as a component of a mixture of legumes. It persists poorly with lightly grazed, vigorous grass. The productivity of lotononis tends to be erratic, but once established in a suitable site, it is rarely lost completely. Recovery is aided by a large seed bank in the soil of up to 100000 seeds per m^2. The best lotononis years are those with good rainfall early in the wet season; there is less response to rainfall late in the wet season. Lotononis responds to applied P, but will persist on soils of low P status.

Lotononis is most susceptible to diseases during very wet periods if growth is lush. It is susceptible to *Cercospora* leaf-spot, *Botrytis* flower blight, *Sclerotium rolfsii*, *Fusarium* and *Pythium* root and stolon rots and legume little leaf.

Genetic resources and breeding Cultivar 'Miles' is available commercially. A germplasm collection is held by ATFGRC (CSIRO, Australia), but preliminary testing suggests that there is no substantial variation within this collection.

Prospects Lotononis will not be suited to most of South-East Asia, but could be a useful pasture component in the humid subtropics and tropical highlands.

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R.M. Jones

Macroptilium atropurpureum (DC.) Urban

Symb. Antill. 9: 457 (1928).

LEGUMINOSAE

$2n = 22$

Synonyms *Phaseolus atropurpureus* DC. (1825).

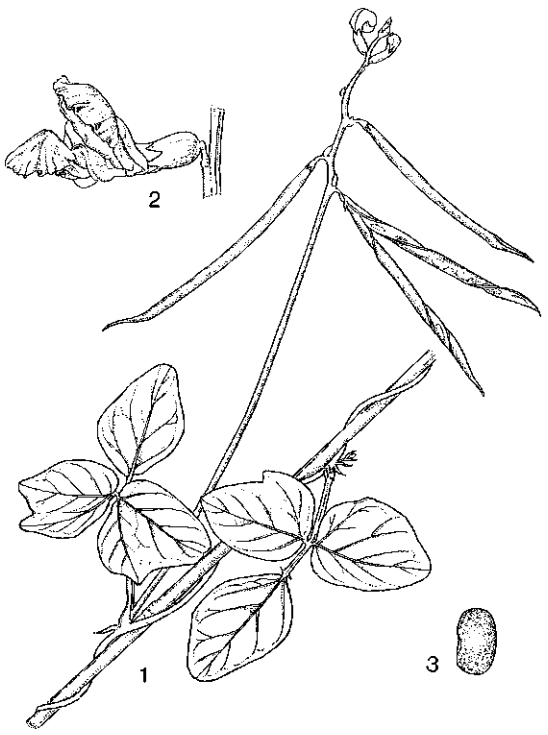
Vernacular names Siratro, atro, purple bean (En). Thailand: thua-sirato.

Origin and geographic distribution This species occurs naturally from northern Mexico to Colombia and northern Brazil. The greatest diversity is in Mexico. Being one of the first commercially available tropical legumes, siratro cultivar 'Siratro' is now widespread throughout the tropics and subtropics.

Uses Siratro is primarily used as a pasture legume with introduced or natural grasses but could be useful as a cover crop or as a fallow crop in shifting cultivation. Siratro is used for revegetation and stabilization of earthworks, and in road and railway cuttings and embankments. It has shown promise as a leguminous forage crop sown in conjunction with upland rice or after harvesting of lowland rice.

Properties Nitrogen concentrations range from 2–4%, higher than some other tropical legumes such as *Stylosanthes* spp. Digestibility of young material ranges from 60–70%, but in older material with a lower leaf percentage this may decrease to 45%. It tends to have higher P concentrations than *Stylosanthes* spp. with levels usually above 0.2%, reflecting its higher P requirement. Sodium concentrations are usually less than 0.02%. It is a palatable legume though cattle prefer to eat grass early in the growing season and siratro later in the growing season. There are 70–90 seeds/g.

Description A perennial herb with twining stems arising from a taproot of up to 2 cm diameter. Stems close to the ground may develop secondary roots, usually on light textured soils when the soil surface remains continuously moist for some weeks; trailing stems rarely greater than 5 mm diameter but may exceed 5 m in length. Leaf trifoliolate, often 2–3-lobed, dark green and slightly hairy on the upper surface, silvery and very hairy on the lower surface; petiole up to 5 cm long; leaflets ovate to rhomboid, 2.5–8 cm × 2.5–5 cm, often asymmetrically lobed. Inflorescence a raceme; peduncle 10–30 cm long with 6–10 deep purple flowers, about 2 cm long, crowded at the apex; calyx campanulate, 5-lobed; standard orbicular with 2 small basal auricles; wings long stipitate, longer than standard and keel; keel petals apically spiralled, basally adnate to the staminal tube. Pod linear, straight, 4–8 × 4–6 mm, adpressed pubescent, usually with 10 seeds, dehiscing violently when ripe, throwing seed for up to 5 m. Seed oblong-ovoid, 3–4 mm long, light brown, black or mottled, the latter usually with greater hard-seededness.



Macroptilium atropurpureum (DC.) Urban – 1, flowering and fruiting vine; 2, flower; 3, seed.

Growth and development Siratro sown into a seed-bed grows vigorously and will flower and produce seed in the first year. When broadcast into undisturbed pasture or emerging from seed in undisturbed grassland, growth is slower and seed production is unusual in the first year. The half-life of established plants is 1–4 years. Siratro is a short-day plant. The main flowering period is in the late wet season, but flowering also occurs in the early and mid wet season. The onset of flowering during the wet season partially relates to onset of moisture stress. Under light grazing pressure in higher rainfall areas and on sandy soils, siratro develops stolons. These can live for several years and attain 5 mm diameter. Siratro plants survive dry periods by shedding leaves and then through death of stems to reduce the area of transpiring leaves.

Other botanical information Only one cultivar of siratro, 'Siratro', is presently available. It was developed in Queensland about 1960 from a cross between two Mexican introductions.

Ecology Siratro grows best under rainfall regimes ranging from 700–1500 mm, but in Mexico has been collected from sites receiving annual rainfall as low as 250 mm. It is not suited to the wet tropics or to the very hot, dry tropics, nor to elevations above 1600 m in the tropics or to latitudes higher than 30°. Top growth is killed by frost, but the taproots survive frosts in subtropical regions. Growth is optimal at day/night temperatures of 30/25°C. It grows best on light to medium textured soils and does not persist on poorly drained sites. It requires a soil available P level of at least 10 mg/kg (bicarbonate extraction) or

preferably 15 mg/kg. It tolerates a pH(H_2O) range of 5–8. There is considerable variation within siratro and some characters, such as an erect growth habit and fewer days to flowering, are related to drier areas of origin.

Propagation and planting Siratro is established by seed. It is not as hard-seeded as many tropical legumes, but scarification may still be required. Establishment is faster and more reliable when sown into a seed-bed, but it can be established into undisturbed pasture or with minimal cultivation if conditions are favourable. Seeding rates of 2–6 kg/ha are recommended when sown alone. Siratro nodulates freely with native cowpea rhizobia and there are no records of nodulation failure.

Husbandry In permanent grasslands siratro must be allowed to seed since recruitment of new plants to replace older plants is essential for long-term persistence. Soil seed banks of over 200 seeds/m^2 are desirable for persistence; levels below 50 seeds/m^2 may lead to extinction. Siratro responds well to P fertilizer, if required. Liming may be required if soil pH(H_2O) falls below 5.0.

Diseases and pests The main diseases of siratro are leaf blight *(Rhizoctonia solani),* which is more serious in the wetter end of its zone of adaptation and limits the use of siratro in the wet tropics, and rust *(Uromyces appendiculatus).* Rust is not a lethal disease but has been shown to reduce the yield and seed set of 'Siratro' by 30%. There are different races of the rust pathogen but some lines of siratro have resisted a range of races under experimental conditions. Violet root rot *(Rhizoctonia crocorum)* has led to death of taproots. It is susceptible to halo blight *(Pseudomonas phaseolicola)* which, although of minimal consequence to siratro, can act as a source of infection to nearby crops of *Phaseolus* spp. Seedlings of siratro can be killed by larvae of bean fly *(Melanagromyza phaseoli).* Siratro is resistant to root-knot nematodes *(Meloidogyne javanica).*

Harvesting Siratro is usually harvested by grazing animals, but can be cut for stall feeding, or for hay or silage. Siratro pastures can be continuously or rotationally grazed but cannot withstand sustained heavy grazing. If cut, a rest period of at least 6 weeks and a stubble height of at least 10 cm is suggested.

Yield Under cutting, legume DM yields of 7 t/ha have been measured in pure swards and 5 t/ha in siratro/grass swards, although siratro yield declines markedly with more frequent cutting. DM yields of over 5 t/ha have been reported when used as an intercrop legume. It seldom contributes more than 30% of dry matter in grazed legume/grass pastures. Siratro can yield up to 1 t/ha of seed, although seed yields are usually 100–300 kg/ha. High seed yields can be obtained from hand harvesting seed from plants grown on wire trellises. Good siratro pastures can give the same animal production as grass-only pastures fertilized with 100 kg/ha of N in 700–1000 mm rainfall areas.

Genetic resources The main germplasm collections are held at ATFGRC (CSIRO, Australia) and CIAT (Colombia).

Breeding A plant breeding programme to incorporate rust resistance into siratro, based at CSIRO, Brisbane, is nearing completion. There is scope for further development to select and breed cultivars of siratro for specific regional adaptation.

Prospects Although siratro is not as persistent as initially thought, it is still a very useful legume. Its ability to provide high yields of quality material, fix N and improve grass growth and quality, and its fairly wide area of adaptation, mean that further work on the development of new cultivars is justified.

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R.M. Jones & L. 't Mannetje

Macroptilium lathyroides (L.) Urban

Symb. Antill. 9: 457 (1928).
LEGUMINOSAE
$2n = 22$
Synonyms *Phaseolus lathyroides* L. (1763).
Vernacular names Phasey bean (En). Wild pea bean (Am). Indonesia: kacang batang. Thailand: thua-phi.

Origin and geographic distribution Phasey bean originated in tropical America and is now widely distributed, although usually of only minor importance, throughout Central and South America, the Caribbean, Australia, South-East Asia and parts of Africa.

Uses Phasey bean is primarily used as a forage plant, but can be used as a cover crop in rotations and as green manure.

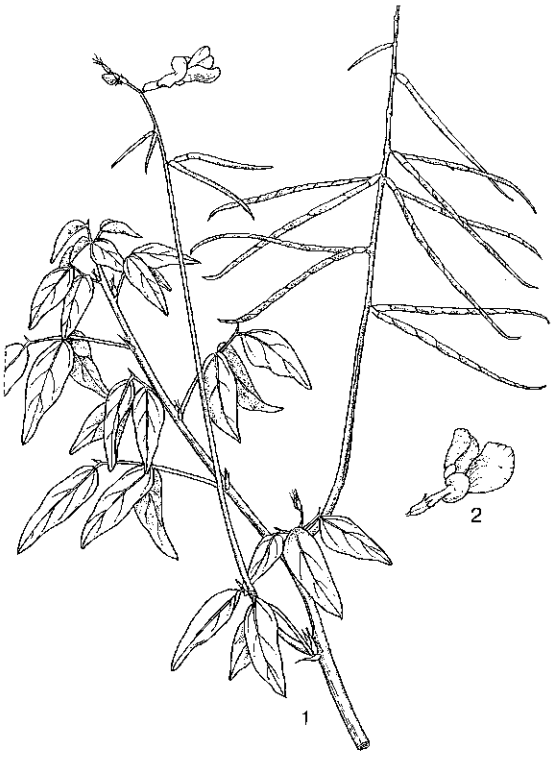
Properties Nitrogen concentrations range from 4% in young vegetative growth to 1% when most leaves have fallen off and the sample is primarily old green stem. Similarly, digestibility can range from 70–40%. There are 110–120 seeds/g.

Botany Herbaceous annual or less commonly short-lived perennial, erect with variable branching, 0.5–1.5 m tall, with base of stem becoming somewhat woody, sometimes becoming trailing or twining, especially under shade. Stems terete, with long deciduous reflexed hairs. Leaves trifoliolate; leaflets ovate-lanceolate to elliptical, 3–8 cm × 1–3.5 cm, not lobed. Inflorescence a semi-erect or erect raceme up to 15 cm long, borne on peduncle up to 40 cm long; pedicels very short; flowers red-purple, about 1.5 cm long. Pod subcylindrical, 5–10 cm × 3 mm, containing 18–30 seeds, abruptly dehiscent. Seeds oblongoid to rhomboidal, 3 mm long, mottled light and dark grey-brown.

Sometimes a subdivision of the species into two varieties is made:

- var. *lathyroides*: leaflets narrowly lanceolate, often more or less lobed; only in tropical America;
- var. *semierectum* (L.) Urban (synonym *Phaseolus semierectus* L.): leaflets ovate to elliptical, not lobed; this variety is the widely distributed forage plant.

Phasey bean is day-neutral for flowering and can flower throughout the wet season but under shaded and humid conditions flowering and seed production are depressed and the plant assumes a twining growth habit. There is evidence that twining is initiated by shading whereas flowering is depressed by high humidity, even though these environmental factors often occur together in the field. It is strictly self pollinated. The only cultivar is 'Murray', developed in Australia, which is taller and more robust than most of the lines evaluated.



Macroptilium lathyroides (L.) Urban – 1, flowering and fruiting branch; 2, flower.

Ecology Phasey bean is adapted to a wide rainfall range of 500–3000 mm. The optimum day/night temperature for growth is 35/20°C. Plants are killed by frost but usually seed before frosting. It is adapted to acid and alkaline soils, and a wide range of soil textures from sand (given reliable rainfall) to heavy clay. It is tolerant of waterlogging and poor drainage and frequently grows in drains along the edges of roads. Drought survival is achieved by soil seed reserves.

Agronomy Phasey bean is easy to establish from seed and seeding rates of 3–10 kg/ha are recommended. Establishment in undisturbed soil, particularly in existing pasture, is rarely successful, except under favourable moisture conditions with scarified seed. In subtropical regions, it can be sown during spring and summer when moisture conditions are favourable. Seedlings nodulate freely with native cowpea rhizobia, and seedling growth is vigorous when sown into a prepared seed-bed.

Seedlings are susceptible to attack from bean fly *(Melanagromyza phaseoli)* and plants are susceptible to *Phaseolus* virus 2, root-knot nematode *(Meloidogyne javanica),* especially on sandy soils, and to mildew.

It can be cut or grazed, but does not tolerate sustained heavy cutting or grazing which can greatly reduce or even eliminate seeding. If grazing animals have scope for selection, they may avoid grazing phasey bean till after seeding.

DM yields of 13 t/ha at 90 days after sowing have been reported. Although phasey bean seeds readily, seedling recruitment is usually poor and so persistence is poor in permanent pastures after the second year. Recruitment can be aided by rough cultivation. Hence its main use is as a component of a mixture to give grazing in the first year but it also shows some promise as a one year legume ley or as a forage intercrop. Plants are killed by fire, but stands can recover through seedling germination after fire. Good hay can be made if loss of leaves is avoided. Harvested seed yields are typically 200–250 kg/ha but much seed is lost through dehiscence and the true seed yields would be higher.

Genetic resources and breeding There are no breeding programmes on phasey bean. Germplasm collections are held by ATFGRC (CSIRO, Australia) and CIAT (Colombia). There is known variation for mildew resistance and in the intensity of branching.

Prospects It is likely that the potential for phasey bean lies in its use in short leys and as an intercrop, or to provide first-year feed when sown as part of a mixture for permanent pastures. Further exploitation of the variability within this species may make it more suited to these roles.

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R.M. Jones & L. 't Mannetje

Macroptilium longepedunculatum (Benth.) Urban

Symb. Antill. 9: 457 (1928).

LEGUMINOSAE

$2n = 22$

Synonyms *Phaseolus longepedunculatus* Bentham (1837), *P. campestris* Bentham (1837, non Bentham 1859).

Vernacular names Llanos macro (En).

Origin and geographic distribution The natural distribution of llanos macro is from southern Brazil to northern Mexico. It was taken into cultivation outside tropical America only recently, e.g. in Australia.

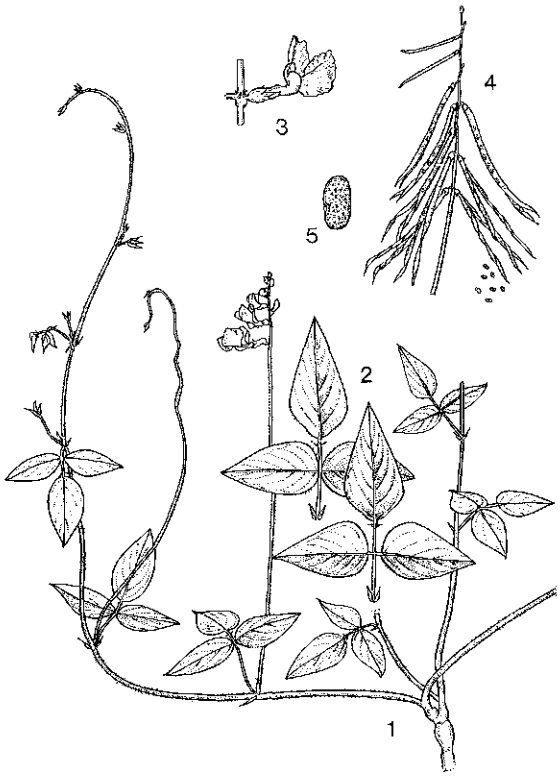
Uses *M. longepedunculatum* is a pasture legume for monsoonal lowland regions. It can be grazed during the growing season, or used as a fodder crop to make hay, as saved standover fodder or as green manure.

Properties Nitrogen concentrations range from 1.4–3.0% during the growing season but decline to 1–1.4% during the dry season. DM digestibility of plant material during the growing season ranges from 57–67%, falling to 47–53% during the dry season. Phosphorus concentrations range up to 0.23% during the growing season and from 0.06–0.13% during the dry season. Sulphur concentrations range up to 0.21% during the growing season and from 0.06–0.10% during the dry season. There are approximately 300 seeds/g.

Botany Short-lived perennial twining herb to 60 cm high with trailing stems; vegetative parts shortly pilose, hairs of the stem retrorse to spreading. Leaf pinnately 3-foliolate; petiole, petiolule and rachis grooved above and closely ribbed; petiole 24–45 mm long; lateral leaflets ovate with asymmetrical bases, 2–4 cm × 1–3 cm; terminal leaflet broadly lanceolate to deltoid, 2.5–5 cm × 1–3 cm. Inflorescence an axillary raceme, 20–40 cm long; flowers shortly pedicelled, solitary or in pairs and threes; standard greyed orange, concave, obovate, emarginate, ca. 14 mm long; wings purple, partly adhering to the keel petals, limb orbicular, ca. 15 mm long, apex curved and slightly twisted. Pod linear, 3–7 cm × 2–3 mm, containing 10–18 seeds; valves twisted on drying. Seed small, flattened ovoid, mottled light and dark grey.

Llanos macro has a juvenile phase during which floral initiation will not take place. It flowers and seeds prolifically, producing up to 240 kg/ha of seed. Freshly harvested seed has a very variable (20–80) percentage of hard seed.

M. longepedunculatum is a new species to cultiva-



Macroptilium longepedunculatum (Benth.) Urban – 1, flowering branch; 2, two types of leaves; 3, flower; 4, infructescence; 5, seed.

tion and has not been closely studied. It is closely related to *M. atropurpureum* (DC.) Urban, *M. gracile* (Poepp.) Urban and *M. domingense* Urban, but further biotaxonomic studies are needed. There is only one cultivar, 'Maldonado', released in the Northern Territory of Australia. 'Maldonado' is a late flowering cultivar, flowering from mid-April in northern Australia. It appears to be a short-day plant, but the critical photoperiod has not been determined.

There are a number of lines of *M. longepedunculatum*, some of which flower earlier than 'Maldonado', and some of which are amphicarpic.

Ecology In its region of origin llanos macro occurs generally at low altitudes (up to 250 m) in areas with rainfall between 950–1300 mm per year. It is adapted to tropical monsoonal regions with strongly seasonal rainfall between 1100–1600 mm. It is not adapted to the humid tropics. It is tolerant of drought, burning, waterlogging and flooding for up to three months.

Agronomy Llanos macro is propagated by seed using seeding rates of 2–4 kg/ha. A good seed-bed preparation is desirable for establishment. It can be sown as a mixed pasture or a pure stand. It nodulates freely and effectively with natural cowpea type rhizobia and does not need inoculation.

Llanos macro grows best with good soil fertility, but will persist at low soil fertility levels after being established with minimal non-N fertilizer as required.

After periods of wet weather small patches of dead leaves (leaf blight) are caused by *Rhizoctonia* spp. The areas involved are only small and no control measures are required.

DM yields of llanos macro in well-fertilized pure swards reach 5–7 t/ha. In mixed swards, they can be 3–4 t/ha. It is usually consumed fresh or as a saved standover fodder. Seed formation is essential for long-term persistence, particularly in the year of establishment. It should not be severely defoliated early in the wet season.

Genetic resources and breeding Llanos macro 'Maldonado' is new to cultivation, and seed production is increasing. Small quantities of seed are available for sale. A germplasm collection is held by ATFGRC (CSIRO, Australia). There is scope for further development of cultivars as some lines have different flowering times than 'Maldonado' and some lines are amphicarpic.

Prospects 'Maldonado' is recommended for tropical monsoonal areas with annual rainfall between 1100 and 1600 mm. It may grow in wetter monsoonal environments. Other cultivars may be developed for cooler, subtropical regions.

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A.G. Cameron

Macrotyloma axillare (E. Meyer) Verdc.

Kew Bulletin 24: 402 (1970).
LEGUMINOSAE
$2n = 20$

Synonyms *Dolichos axillaris* E. Meyer (1836).

Vernacular names Axillaris, perennial horse gram (En).

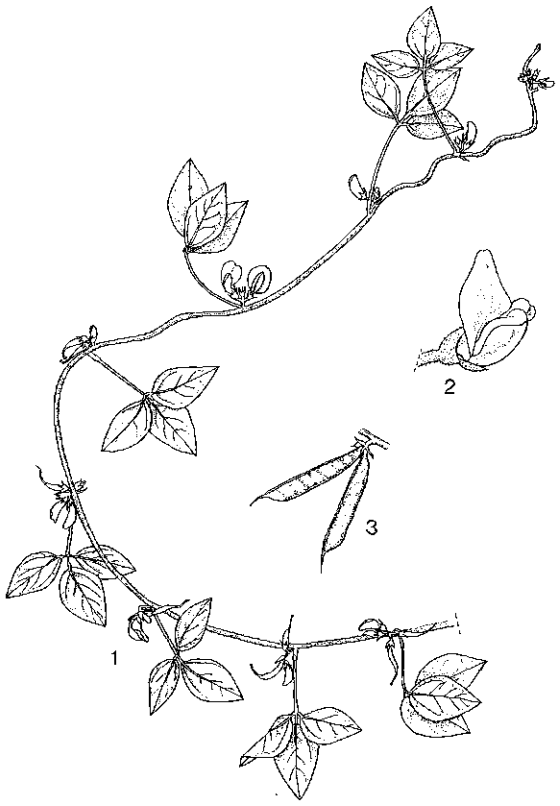
Origin and geographic distribution Axillaris originates in sub-Saharan Africa, from Ethiopia to Senegal and south to the Transvaal and Natal in South Africa (16°N to 31°S latitude). Var. *axillare* extends to Madagascar and Arabia, and var. *glabrum* (E. Meyer) Verdc. to Madagascar, Mauritius and Sri Lanka, but var. *macranthum* (Brenan) Verdc. is more restricted and is only found from Tanzania to Zimbabwe. Cultivar 'Archer' has become naturalized in small areas of eastern Australia and Papua New Guinea.

Uses Axillaris is used as a perennial sown pasture legume in Australia where it is grazed during the growing season or used as stand-over feed early in the dry season.

Properties In Australia N concentrations of whole tops of 'Archer' fell from 2% in the early wet season to 1% in the dry season. Phosphorus concentrations, on a high-P soil, fell from 0.25–0.30% (early wet season) down to 0.12–0.17% (dry season). Seed contains about 4% N and 0.45% P.

The plant is not toxic, but has a bitter taste which may cause stock to reject it until they get used to it. It sometimes taints the meat of lambs when fed as a large part of their diet for a long time, and so could taint milk in similar circumstances. Across a range of accessions, there were 50–200 seeds/g (80–90 in 'Archer').

Description Perennial climbing or trailing twining herb with a strong woody taproot and rootstock. Stems do not root at the nodes; stems cylindrical, glabrescent or hairy, > 5 m long if climbing, otherwise usually < 3.5 m; the main axis is strongly ascending on young plants. Leaves trifoliolate; leaflets entire, elliptical, ovate-lanceolate, ovate or subrhombic, 1.1–7.5 cm × 0.7–4.2 cm, rounded to acuminate and mucronulate at the apex, rounded to subacute at the base, glabrous to pubescent, somewhat glossy above and paler beneath; stipules ovate-lanceolate, 2–5 mm long, veined. Flowers axillary in 2–4(–10)-flowered clusters; peduncles very short or absent; standard oblong-elliptical, 1–2.4 cm × 0.6–1.5 cm, whitish or greenish-yellow with a crimson or purplish spot inside near the centre; stigma surrounded by a ring of short dense hairs. Pod shortly stipitate, linear-oblong, 3–8 cm × (5–)6–8 mm, glabrous or pubescent, containing (5–)7–8(–9) seeds. Seed rounded or ellipsoid, compressed, 3–4.2 mm × 2.5–3 mm × 0.6–1.5 mm, smooth and hard, buff to dark red with sparse to very dense black mottling.



Macrotyloma axillare (E. Meyer) Verdc. – 1, flowering and fruiting branch; 2, flower; 3, fruits.

Growth and development Flowering is delayed in the year of sowing, but not subsequently, which is indicative of a juvenile phase during which flowering is inhibited. This also seems to apply to the regrowth of individual shoots on mature plants. Flowers are cleistogamous but honey bees can transfer pollen between them once they are open. Pods usually mature 4–8 weeks after flowering and shatter readily once dry.

Other botanical information Three varieties are recognized; var. *axillare* and var. *glabrum* have flowers 1.2–1.5(–2) cm long; those of var. *macranthum* are larger, (1.5–)2–2.4 cm long. The first two varieties may be distinguished by stem indument: var. *axillare* has dense, spreading hairs and var. *glabrum* has sparse, adpressed hairs although in-

termediate types are fairly common. 'Archer', which is the only cultivar, released in Queensland, Australia, is close to var. *glabrum*.

Ecology Axillaris is essentially a tropical or subtropical short-day plant from grassland, woodland, forest margins and coastal dunes. It is common in disturbed places such as fallow land and roadsides in its natural range. It prefers relatively mild conditions (optimum day/night temperature for growth is about 26/21°C) so is better adapted to low altitudes in the subtropics and higher altitudes, up to 2250 m, in the tropics. Although top growth is killed by frost, it regrows from the rootstock in spring in the subtropics. It is drought-hardy but not very productive if rainfall is less than 800 mm/year. It grows best on well-drained soils such as alluvial sandy loams and basaltic clay loams, and it is moderately shade-tolerant. It is not well adapted to heavy clays, or infertile, acid ($pH(H_2O) < 5.5$) solodic soils, and it will not tolerate waterlogging or saline soils.

Natural ecotypes have been collected under a range of conditions: rainfall 700–1400 mm/year; growing season 140–365 days; mean maximum temperature of the hottest month of the growing season 26–31°C; mean minimum of the coldest month of the growing season 11–24°C; and mean minimum of the coldest month of the dry season 3–18°C.

Propagation and planting Hand harvested and threshed seed may be very hard and require scarification. Mechanically harvested or threshed seed is usually satisfactory for sowing without further treatment to break hard-seededness.

In prepared seed-beds, seed may be drilled 1–2.5 cm deep and lightly covered, or else broadcast and harrowed. Axillaris can also be established in natural woodland by broadcasting seed mixed with fertilizer into the ashes after burning at the beginning of the wet season. Recommended sowing rates are 2–4 kg/ha in pure stands and 0.5–1 kg/ha in mixtures. Inoculation is not usually necessary, but the rhizobium strain CB 1024, or its equivalent, should be used if inoculation is required. Early growth is rather slow. Axillaris combines well with a wide range of grasses and is often sown in mixtures with other twining or scrambling legumes.

Husbandry Axillaris competes very well with weeds once established and has been deliberately used to control shrubby weeds by allowing the axillaris to grow without grazing from winter into spring in Australia. Axillaris will usually overtop weedy grasses by early autumn in the year of sowing. 'Archer' will not grow well on soils poor in P or S without fertilizer. Compared with centro (*Centrosema pubescens* Benth.), it has a higher requirement for K, but similar requirements for Cu.

Diseases and pests There are no serious disease or pest problems with axillaris. Individual plants may be stunted and killed by the mycoplasma 'legume little leaf', but the productivity of the sward is scarcely affected. It is susceptible to root-knot nematodes (*Meloidogyne* spp.) but control measures are unpractical.

Harvesting Axillaris is harvested by grazing animals rather than by cutting, although hay making is possible provided care is taken to conserve leaf. Its major strength lies in providing better stand-over feed in the early part of the dry season and faster growth in the early part of the wet season than most other tropical legumes which shed their leaves more readily and only grow slowly in the early wet season. Thus it is often sown on ridges above the frost line. Rotational grazing is best, and swards should not be grazed lower than 15 cm because axillaris will not withstand frequent close grazing.

Yield In Australia, axillaris has yielded 16 t/ha of DM under irrigation and 3–4 t/ha without irrigation. In India, green yield of an axillaris/green panic (*Panicum maximum* Jacq. var. *trichoglume* Robijns mixture (39 t/ha) exceeded that of the grass alone (24 t/ha). DM yields of fertilized swards under regular cutting at three sites in the highlands (1200–1500 m) of northern Thailand ranged between 1.5–7.6 t/ha in the second year.

Seed yields of 100–150 kg/ha are common. Yields of more than 550 kg/ha are possible from small areas, especially if the sward is harvested just before the pods start to shatter and is then allowed to dry. Large-scale seed crops are difficult to handle with normal heading equipment because the pods are borne closely intermixed with the long tough stems and shatter as soon as they are dry.

Genetic resources The present world collection of axillaris is held at ATFGRC (CSIRO, Australia) and CIAT (Colombia). It contains a fair representation of material from Kenya to South Africa, but the remainder of the natural range is poorly represented.

Breeding There are no known breeding programmes. Its main limitations of pod shattering, which increases the cost of seed production, lack of long-term persistence under continuous heavy grazing and limited adaptation to relatively mild climates could possibly be overcome by further collection from other parts of the natural range or by

gene transfer from related species (e.g. indehiscent pods from *M. uniflorum* (Lamk) Verdc.).

Prospects The main strengths of axillaris are its drought and disease resistance, its vigorous growth in summer, and the valuable grazing it provides in early winter and early spring in the subtropics. However, unless its climatic adaptation can be broadened and its resistance to heavy grazing improved, then it is only likely to play a minor, though locally very useful, role. It is showing promise in Bolivia, Brazil, China (Hainan Island), Ghana, Guatamala, India, Panama, the Philippines, and Thailand, and could play a useful role in upland areas in most tropical countries.

Literature |1| Blumenthal, M.J., O'Rourke, P.K., Hilder, T.B. & Williams, R.J., 1989. Classification of the Australian collection of the legume Macrotyloma. Australian Journal of Agricultural Research 40: 591–604. |2| Cameron, D.G., 1986. Tropical and subtropical pasture legumes. 10. Axillaris (Macrotyloma axillare): a legume with limited roles. Queensland Agricultural Journal 112: 59–63. |3| Gillett, J.B., Polhill, R.M. & Verdcourt, B., 1971. Macrotyloma. In: Milne-Redhead, E. & Polhill, R.M. (Editors): Flora of tropical East Africa. Leguminosae 4 – Papilionoideae 2. Crown Agents for Oversea Governments and Administrations, London. pp. 581–594. |4| Luck, P.E., 1965. Dolichos axillaris – prospects in Queensland. CSIRO Australia, Division of Plant Industry, Plant Introduction Review 1(3): 50a–51a. |5| Oram, R.N., 1990. Register of Australian herbage plant cultivars. CSIRO, Australia. pp. 177–178. |6| Skerman, P.J., Cameron, D.G. & Riveros, F., 1988. Tropical forage legumes. FAO, Rome. pp. 346–349.

I.B. Staples

Medicago sativa L.

Sp. Pl.: 778 (1753).

LEGUMINOSAE

$2n = 32$ (tetraploid in cultivated forms), $2n = 16$ (diploid in wild forms).

Vernacular names Lucerne (En), alfalfa (Am). Luzerne (Fr). Philippines: galeria (Visaya). Thailand: thua-anfanfa.

Origin and geographic distribution Lucerne is believed to have originated in the highlands of Transcaucasia, Asia Minor and north-western Iran, and/or Central Asia. It has been cultivated for thousands of years and introduced to most countries of the world. It is only a minor species in South-East Asia.

Uses Lucerne is the world's most important forage crop and is cultivated mainly to provide feed for ruminants, but is also used as an ingredient of rations for poultry and pigs. Protein is extracted from the forage for consumption by humans and a wide range of animals. Seeds are sprouted for human consumption.

Properties Lucerne provides highly palatable, highly nutritious forage, hay, silage and pellets. At the early flowering stage, when it is commonly harvested, the dried forage contains 2.5–4.0% N and is 60–70% digestible. There are 400–1000 seeds/g.

Botany A herbaceous perennial with deeply penetrating taproot. Stems procumbent, ascending to erect, arising from woody base, branching at base and rising to 30–80(–120) cm. Leaf trifoliolate; stipules triangular, 5–15 mm long, pubescent on lower surface, glabrous on upper surface, joined at base, coarsely-toothed; petiole pubescent, 5–30 mm long; leaflets narrow, oblong to ovate or obovate, 8–28 mm × 3–15 mm, dentate near apex, glabrous on upper surface, slightly pubescent on lower surface. Inflorescences in dense racemes

Medicago sativa L. – 1, flowering branch; 2, flower; 3, infructescence; 4, fruit.

containing 10–35 flowers, on peduncles 1–5 cm long; pedicel 1.5–2 mm long; calyx 5-lobed, 3–6 mm long, tube and pointed teeth about equal in length; corolla purple or blue, rarely white, with some yellow-flowered plants in cultivars containing *M. falcata* genes. Pod curled through 2–5 coils of 3–10 mm in diameter, indehiscent, not spined, containing 2–6 seeds. Seed yellow to brown, kidney-shaped to ovoid, 1–2.5 mm × 1–1.5 mm.

The taxonomy of *M. sativa* is confused and the cultivated forms may well be a tetraploid of hybrid origin. Because *M. sativa* is part of a species complex including *M. falcata* L., *M. glutinosa* M. v. Bieb. and *M. glomerata* Balbis, many hybrid forms have erroneously been given specific names.

Most cultivars flower in long days (> 10–12 hours) but vary in their quantitative response, which depends also on temperature. In suitable areas, individual plants are long-lived (up to 20 years or more). In tropical regions, plants persist for only 1–5 years. Regeneration from seed is usually poor in uncultivated ground. Soil seed reserves are low because plants are rarely allowed to set seed.

Lucerne ecotypes vary considerably, particularly in winter dormancy. Diversity has been increased by natural and artificial hybridization. There are hundreds of cultivars.

Ecology Lucerne is adapted to temperate and Mediterranean climates and to heavy, neutral or alkaline soils. Suitable cultivars can survive extremely cold winters and hot, dry summers. It is drought-resistant because of its deep root system, but its water use efficiency is poor. It cannot tolerate waterlogging. In the tropics, lucerne is adversely affected by hot, humid conditions which promote several major diseases, by the absence of winter cold and by acid and waterlogged soils.

Agronomy Lucerne is propagated from seed, at seeding rates of 2–12 kg/ha, sown at a depth of 5–15 mm into cultivated seed-beds, usually in pure stands. Control of existing vegetation is essential. The time of planting varies to suit local conditions. Inoculation of seed with suitable strains of *Rhizobium* is recommended where lucerne has not previously been grown. It is commonly irrigated and heavily fertilized with P and K fertilizers to enhance forage yield.

Many diseases and insect pests attack lucerne. The most important diseases in the tropics are root and crown rots caused by fungal pathogens such as *Phytophthora megasperma* and *Colletotrichum trifolii*. Some cultivars, notably 'Trifecta', have improved resistance to these diseases. Plant parasitic nematodes are probably important pathogens in the tropics. The most significant insect pests worldwide are the alfalfa weevil (*Hypera postica*) and several aphid species.

Lucerne is usually cut at intervals of 4–8 weeks while it is growing, but can be grazed provided adequate rest periods are allowed. Defoliation at the early flowering stage is preferable as this coincides with the development of new stems from basal buds. Longevity is reduced under continuous grazing. Frequent cutting is common in the tropics but reduces quantity and stand life.

In parts of the world where lucerne is a major crop, annual DM yields of 10–20 t/ha are obtained. In South-East Asia, lucerne is usually fed green to ruminants. It is a high quality feed but cattle grazing green or freshly cut lucerne may suffer bloat (tympanitis).

Genetic resources and breeding Significant germplasm collections are held in many countries. The internationally recognized centre for *Medicago* germplasm is ICARDA (Aleppo, Syria). Other major collections are held by the USDA (Ames, Iowa, United States) and the South Australian Department of Agriculture (Adelaide, Australia). Commercial and government-funded breeding programmes are in progress in many countries. Disease resistance is a key objective.

Prospects Lucerne will continue to have a minor role in South-East Asia. It will be restricted to suitable soils receiving adequate rainfall in elevated areas. It will have greater use in suitable sites in the subtropics.

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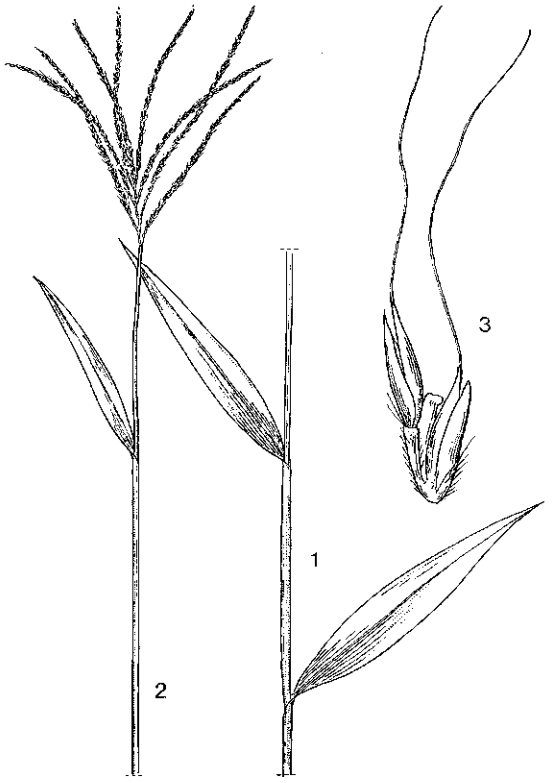
R.J. Clements

Microstegium ciliatum (Trinius) A. Camus

Ann. Soc. Linn. Lyon 68: 201 (1921).
GRAMINEAE
$2n = 40$
Synonyms *Pollinia ciliata* Trin. (1832).
Vernacular names Indonesia: banyonan tembaga (Javanese), jukut canklor (Sundanese). Philippines: bariri magwakat (Han.). Laos: hnhaaz nhung. Thailand: ya kom ka.
Origin and geographic distribution *M. ciliatum* occurs widely throughout South-East Asia; it is also found in India, Sri Lanka, southern China, Taiwan and Japan.
Uses *M. ciliatum* is used for cattle and water buffaloes through grazing or cut-and-carry in traditional farm systems.
Properties It is regarded as a good quality forage.
Botany A perennial grass growing in dense masses with branched culms, in lower part prostrate or creeping and rooting at the nodes, in upper part erect or scrambling, up to 2 m tall. Leaf-sheath 4–5 cm long, glabrous to long-hairy; ligule up to 2 mm long, glabrous to densely appressed-hairy at the back, not ciliate; leaf-blade narrowly lanceolate, up to 25 cm × 2.5 cm, narrowed at base and acuminate at apex, glabrous, but hairy near the base. Inflorescence composed of 2–22 subdigitate racemes, each 3–16 cm long; spikelets in alternate pairs, one sessile, one pedicelled, along a flattened axis; spikelets with small callus which has a few stiff setose hairs; lower floret male or neuter; upper lemma with a long kneed and twisted smooth awn of up to 1.5 cm length. Caryopsis oblongoid, 1.5 mm long, brown.



Microstegium ciliatum (Trinius) A. Camus – 1, leafy culm part; 2, inflorescence; 3, pair of spikelets.

A very variable species. In the Flora of Java this taxon is considered as a complex of 3 species which are separated by the number of racemes (*M. rufispicum* (Steud.) A. Camus: normally 2–5; *M. ciliatum* s.s.: 3–22; *M. montanum* (Nees) Henrard: 5–12).
M. ciliatum grows slowly out in the open. In shady environments growth continues until September. It flowers from September through the wet season in Thailand.
Ecology It is adapted to light shade at altitudes up to 2400 m in high rainfall areas, preferably with 2000 mm per year or more. It is common in rubber plantations, in disturbed and cultivated sites, and in open places and along the margins of rain forests. It grows in patches and its trailing culms scramble over other low herbs. It is said to be able to suppress *Imperata cylindrica* (L.) Raeuschel, hence the name 'kom ka' meaning, in Thai, that it weakens *Imperata cylindrica*.
Agronomy *M. ciliatum* is established by rooted stems spaced at 40 cm × 60 cm. Wider spacing allows excessive growth of weeds that interfere with *M. ciliatum* which is slow to establish. Newly planted stands should be kept weed free. A cutting height of 10–15 cm is recommended as it does not tolerate close defoliation. DM yields of 2 t/ha have been obtained from 4 cuts per year. It is a palatable species and is offered fresh to cattle or buffaloes, but it does not tolerate frequent grazing. It is not conserved.
Genetic resources and breeding Although it is a variable species, it is unlikely that substantial germplasm collections are being maintained.
Prospects *M. ciliatum* will continue to be an important source of feed in plantations. Research objectives would be to increase its yield and to develop mixtures with legumes.
Literature [1] Backer, C.A. & Bakhuizen van den Brink, R.C., 1968. Flora of Java. Vol. 3.

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C. Manidool

Mikania cordata (Burm.f.) B.L. Robinson

Contrib. Gray Herb. 104: 65 (1934).
COMPOSITAE
$2n$ = unknown

Synonyms *Eupatorium cordatum* Burm.f. (1768), *Mikania volubilis* (Vahl) Willd. (1803), *M. scandens* Hook.f. (1881), non (L.) Willd. (1803).

Vernacular names Mile-a-minute (En). Indonesia: brodjo lego (Javanese), hila hitu lama (Ambon), blukar (Sumatra). Malaysia: ceroma, akar lupang, selaput tunggul. Philippines: bikas (Bagobo), detidid (Igorot), uoko (Bontok). Thailand: khikaiyan.

Origin and geographic distribution *M. cordata* is native to tropical Asia and Africa and is widespread throughout South-East Asia and the Pacific Islands.

Uses Leaves of *M. cordata* constitute a highly palatable forage, especially to sheep. They are also used as a poultice for swellings (Taiwan), itches (Malaysia) and wounds (Indonesia). In South Africa it is used as a cure for snake and scorpion bites.

Properties The DM digestibility is about 50% and N concentrations range from 2.6–3.4%, Ca concentrations from 1.5–1.9% and P concentrations from 0.6–0.9%. It has high concentrations of Cu, about 18 mg/kg. It has been reported from Malaysia that *M. cordata* contains phenolic or flavenoid substances that inhibit the growth of rubber, tomato and tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.), and depress nitrification in soils.

It can be an important weed in cropped land and areas under young plantation crops.

Botany Scandent perennial herb, often forming a dense tangled mass. Stem subterete or irregularly angular, ribbed, up to 6 m × 2–3 mm, internodes 6–14 cm long, nodes thickened, sometimes

Mikania cordata (Burm.f.) B.L. Robinson – 1, flowering plant part; 2, flower-head; 3, achene with flower.

with short hairs. Leaves cordate or triangular-ovate, 1–12 cm × 1–6 cm, base cordate or shortly contracted, margin crenate-dentate, sinuate or entire, apex acutely acuminate, subglabrous, glandularly spotted beneath petiole 1–8 cm long. Inflorescence composed of peduncled heads, combined into small dense corymbs, at the top of short, side branches and in the axils of leaves; peduncle of corymbs very variable in length; peduncle of heads up to 6 mm long; heads 6–9 mm × 1.5–2 mm, 4-flowered; involucre of 4 elliptical-oblong bracts; corolla campanulate, 5 mm long, yellowish-white, 5–6-lobed; style with 2 long exserted branches, each 2.5 mm long, white. Fruit a linear-oblongoid, 4-ribbed achene, 2–3 mm long, glandular, black-brown; pappus hairs 3–4 mm long, white to reddish.

M. cordata spreads by seed or by rooting at nodes which are in contact with soil. Flowering occurs throughout the year. Seeds are produced in large numbers and the pappus enables effective wind dispersal over long distances. With its rampant

growth it can rapidly smother young tree crops and other plants, hence the common name 'mile-a-minute'. It can rapidly form a tangled mass to a depth of 0.6–1 m. If undisturbed, it often spreads in massive circular patterns.

This species was long considered to be conspecific with its allies in North America (*M. scandens* (L.) Willd.) and in South America (*M. micrantha* Kunth). Distinctive characters are:

- *M. scandens*: heads 5–6 mm long; involucral bracts lanceolate-oblong, long-acuminate and very acute at apex; corolla purple; achene longer than 2 mm.
- *M. micrantha*: heads 4–5 mm long; involucral bracts oblong-elliptical, shortly acute at apex; corolla white; achene less than 2 mm long.

In Malesia 4 forms of *M. cordata* have been distinguished, mainly based on leaf form, leaf indumentum and leaf margin characteristics. In West Africa 2 varieties have been distinguished, mainly based on peduncle length and length of involucral bracts.

Ecology *M. cordata* is adapted to hot, humid tropical environments with 1500 mm or more annual rainfall and plenty of sunlight, at altitudes ranging from sea-level to 2000 m or more. Hence it is commonly found in young secondary jungle, forest clearings, abandoned ground, secondary regrowth areas, ravines, mountain slopes, roadsides, watercourses, fallow lands, low-lying areas along streams and rivers and open plantations. However, it can also persist with reduced vigour in plantations. Although it may even be found under closed canopies of 4–5 year-old rubber and oil palm, it is markedly etiolated with little vigour. It is rarely found in 5–15 year-old plantations.

Agronomy *M. cordata* can be a devastating weed in crops of tea, coconut, cocoa, rubber, oil palm, coffee, bananas and sugar cane, and can smother leguminous cover crops. Spraying with herbicides can reduce its vigour and spread.

It has been reported as being susceptible to parasitic growth of dodder, *Cuscuta chinensis* Lamk in Sri Lanka and *C. australis* R. Br. in Fiji and Malaysia. It is very palatable to livestock, particularly to sheep. Where present, it is the first species to be eliminated when sheep graze pastures. It is equally acceptable when either grazed or cut and fed as a supplement to other forages. There are no records of it being used for hay or silage. Sheep should not be fed forages where it is the main component. Instances of abortion, death of newborn lambs and of older sheep have been recorded in rubber plantations where it comprised more than 50% of the diet. There is evidence that these problems relate to the high Cu concentrations in *M. cordata*. There is very little information about its productivity. Yields of 4 t/ha of DM have been measured in Mauritius. There are no records of animal production where it was the sole feed, but good animal production levels have consistently occurred in plantations where it has been an appreciable component of the understorey.

Genetic resources and breeding It is unlikely that any germplasm collections of *M. cordata* are being maintained.

Prospects *M. cordata* is an aggressive forage of high acceptability to both large and small ruminants. Further study should be given to its agronomy and to feeding systems using this species so that its potential as forage can be better exploited, while at the same time aiding in the biological control of a serious weed.

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C.P. Chen & Y.K. Chee

Mimosa pudica L.

Sp. Pl.: 518 (1753).

LEGUMINOSAE

$2n = 52$

Synonyms

- var. *tetrandra* (Humb. & Bonpl. ex Willd.) DC.: *Mimosa tetrandra* Humb. & Bonpl. ex Willd. (1806).
- var. *unijuga* (Duchass. & Walp.) Griseb.: *Mimosa unijuga* Duchass. & Walp. (1850).

Vernacular names Sensitive plant (En). Sensitive (Fr). Indonesia: putri malu (Indonesian), bujang kaget (Sundanese), kucingan (Javanese). Malaysia: memalu, malu-malu. Philippines: makahiya (Tagalog), torog-torog (Bikol), Babain (Ilokano). Cambodia: smau bânla, bânkrap. Laos: f'a:z langab, th'üb nhub. Thailand: maiyarep (central), ya-ngap (south). Vietnam: xâú hô', trinh nữ'.

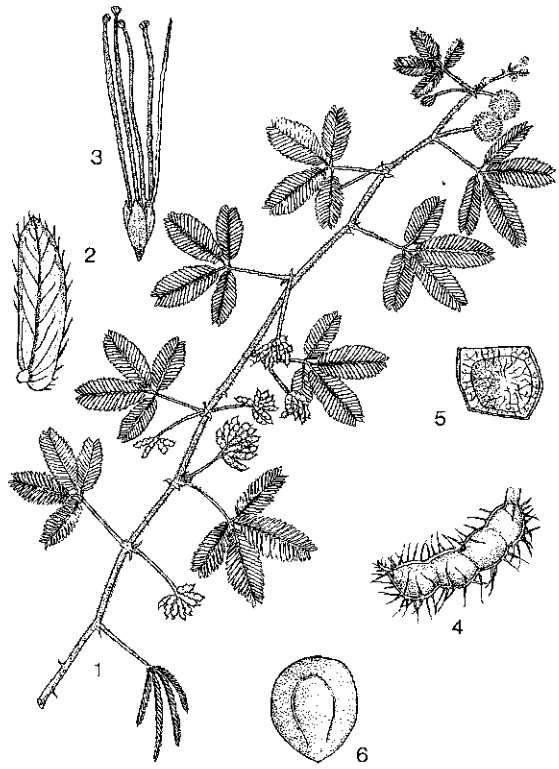
Origin and geographic distribution Probably *M. pudica* originated in South America but is now spread pantropically. It occurs throughout South-East Asia, usually along roadsides and in wastelands.

Uses Young stems and leaves are useful as forage. When the prickles on the stem and the fruits become too hard, they can cause intestinal inflammation in animals. It is often considered as a noxious weed. In areas where other leguminous plants establish with difficulty, *M. pudica* can be of use as a cover crop or green manure. On Java the plants are believed to induce sleep. In Malaysia pounded leaves are applied as a dressing to relieve swellings.

Properties Very little is known about the forage quality of sensitive plant. It is likely that the quality of any sample would vary considerably with the leaf/stem ratio. There are appoximately 110 seeds/g.

Botany Annual or perennial herb, sometimes woody at base, up to 1.5 m tall, often prostrate or straggling. Stem usually sparsely armed with prickles up to 5 mm long, glabrous to densely hispid. Leaves bipinnate, unarmed, sensitive; petiole 1.5–5.5 cm long; rachis very short, giving the 2 pairs of pinnae a subdigitate position; leaflets 10–26 pairs, linear-oblong, 0.6–1.5 cm × 1–3 mm, margins setulose. Inflorescence a globose head, about 1 cm in diameter, 1–5 together per axil; peduncle up to 4 cm long; flowers lilac, pink or blue-purple; calyx about 0.2 mm long, corolla 2 mm long; stamens 4. Pod flattened-oblongoid, 1–1.8 cm × 3–5 mm, several together in a cluster, densely setose, prickly on margins only, consisting of 3–5 one-seeded joints which break away from the persistent sutures. Seed suborbicular to ellipsoidal, flattened, 2.5–3 mm long, light-brown, surface finely granular.

The species flowers throughout the year and it can complete its life cycle in 3 months. Four varieties are distinguished: var. *pudica* (only known from the sterile type specimen, no distinction possible); var. *hispida* Brenan (corolla in bud densely grey puberulous; heads in bud densely bristly; stipules 8–14 mm long); var. *tetrandra* (Humb. & Bonpl. ex Willd.) DC. (corolla in bud densely grey puberulous; heads in bud not or sparsely bristly; stipules 4–8 mm long); var. *unijuga* (Duchass. & Walp.) Griseb. (corolla in bud glabrous; heads in bud not bristly; stipules 4–8 mm long).



Mimosa pudica L. – 1, flowering and fruiting branch; 2, leaflet; 3, flower; 4, fruit; 5, one-seeded segment of fruit; 6, seed.

Ecology Sensitive plant is common in wasteland, disturbed areas and overgrazed sites with moderately to poorly fertile soils. It occurs in the wet tropics and tolerates waterlogging but is not well adapted to the seasonally dry tropics. It is regarded as a weed in dryland field crops, in rainfed wetland rice and in plantation crops where it is reasonably tolerant of shade. It occurs over a wide range of soil types, but iron chlorosis has been noted on coralline soils with a high pH.

Agronomy Sensitive plant is not deliberately sown, but its persistence and spread is aided by its high seed set. It tends to invade pastures of declining soil fertility and is less common where soil fertility is good and pastures are not overgrazed. Sensitive plant has been eliminated from pastures where soil fertility is very poor and grazing pressure is very high. It grows with a wide range of

grasses, including signal grass (*Brachiaria decumbens* Stapf) provided it is not too vigorous. It can hamper the establishment of improved species. Sensitive plant is more readily accepted if it is grazed continuously rather than rotationally. Observations suggest that it can at times stimulate better growth of associated grasses. There are no records of pests and diseases and yield.

Genetic resources and breeding There are no known germplasm collections of sensitive plant.

Prospects Although sensitive plant can provide useful forage, it will continue to be primarily regarded as a weed. While more appropriate management may promote the use of it, it would be preferable to grow species that are more readily accepted by grazing animals or more suited to cut-and-carry feeding systems.

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R.M. Jones & N.O. Aguilar

Neonotonia wightii (Wight & Arnott) Lackey

Phytologia 37: 210 (1977).

LEGUMINOSEAE

$2n = 22$ (diploid), 44.

Synonyms *Notonia wightii* Wight & Arnott (1834), *Glycine javanica* auct. mult., non L. (1753), *G. wightii* (Wight & Arnott) Verdc. (1966).

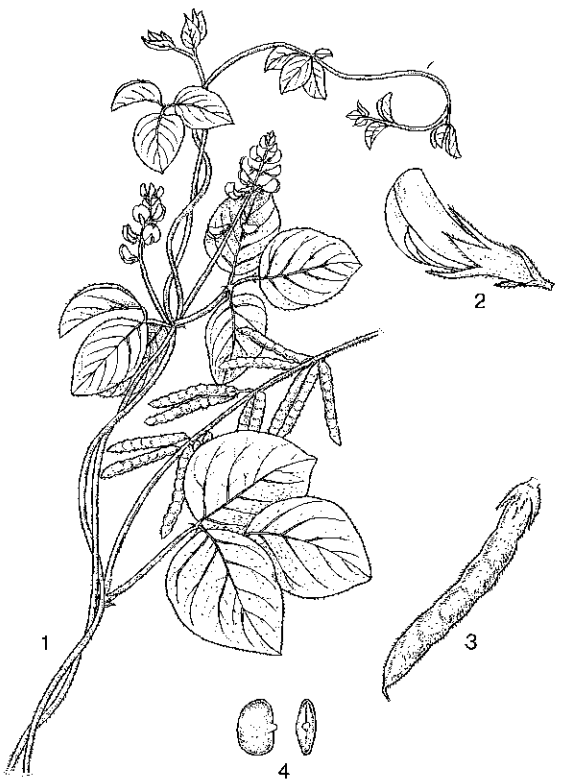
Vernacular names Glycine (En). Brazil: soja perene. Thailand: thua peelenian soibean.

Origin and geographic distribution The natural distribution of glycine ranges from Africa to Asia. It occurs as far south as the wetter parts of southern Africa, in East Africa, Ethiopia, India and mainland Asia and Indonesia. It can currently be found in many humid tropical and subtropical regions of the world since its widespread introduction for use as forage.

Uses Glycine is used as a grazed pasture legume in Australia in the subtropical and tropical high-altitude regions, and for grazing and hay in Brazil. It is used in small areas of Papua New Guinea where it volunteers as a fallow crop in abandoned gardens and is used as a cover crop and for woody weed control in overgrazed pastures.

Properties Nitrogen concentrations ranging from 2–4.2% have been measured in the leaves, with DM digestibilities of between 55–61%. Although oestrogenic substances are present, no toxicity problems have been recorded.

Botany Perennial twining or climbing herb with a woody base, 0.5–4.5 m long. Taproot long, nodulating, rootstock thick and woody. Stems slender and well branched; a dense crown may develop under grazing; stolons in contact with moist soil often root at the nodes. Leaves pinnately trifolio-



Neonotonia wightii (Wight & Arnott) Lackey – 1, flowering and fruiting vines; 2, flower; 3, fruit; 4, seeds.

late; petiole 2–12 cm long; leaflets ovate or elliptical, 1–15 cm × 1–12.5 cm, glabrous to densely velvety on both sides. Racemes axillary, 2–60 cm long, 20–150-flowered; peduncle 2–10 cm long; flower white or violet, 4.5–11 mm long. Pod cylindrical, 1.5–5 cm × 2.5–5 mm, straight or slightly falcate, thinly septate, glabrous to densely hairy, 3–8-seeded. Seed cylindrical, compressed, 2–4 mm × 1.5–3 mm × 1–1.5 mm, reddish-brown.

Three subspecies are recognized: ssp. *wightii* (pod densely hairy, flower 4.5–7.5 mm long), ssp. *pseudojavanica* (Taubert) Lackey (pod glabrous, flower 4.5–7.5 mm long), and ssp. *petitiana* (A. Rich.) Lackey (pod densely hairy, flower 7.5–11 mm long), and within these a number of varieties; the species as a whole is extremely variable, but due to the occurrence of intermediates, the practical value of the botanical subclassifications can be questioned.

Several cultivars have been developed throughout the world, their selection being based on such factors as cold tolerance, maturity, drought tolerance and tolerance to high Mn levels. The cultivars released in Australia are 'Tinaroo', a diploid late-flowering variety with high cold tolerance, 'Cooper', a diploid early-flowering type which tolerates excess moisture and drought stress, 'Clarence', the earliest flowering cultivar and the first variety to start spring growth, and 'Malawi', a tetraploid which is less branched than the other cultivars but adapted to more acid and less fertile soils.

Ecology Glycine is a short-day plant. Optimum day/night temperatures for growth and seed production of glycine are in the range 22–27/16 °C with a base temperature for growth of 13 °C, lower than for most tropical legumes. It has limited frost tolerance, but leaf damage occurs in all cultivars.

It is adapted to dry to humid (800–1800 mm) subtropical or high altitude (up to 3000 m) tropical regions with relatively deep, well drained, usually basalt-derived soils, and prefers a pH above 6.0. It is not adapted to very wet or waterlogged conditions. It is not as drought tolerant as siratro (*Macroptilium atropurpureum* (DC.) Urban), but more so than centro (*Centrosema pubescens* Benth.).

Agronomy Propagation is by seed which, especially if hand harvested, often has a high proportion of hard seed. Mechanical or acid scarification (concentrated sulphuric acid for 25 minutes and then washed) is usually required for successful establishment. Because seedling growth and nodulation are slow, a weed-free seed-bed is favoured for establishment. Sowing rates of 2–6 kg/ha are recommended with the seed inoculated with a suitable strain of *Bradyrhizobium*. Seed should be sown at a depth of less than 2 cm. Where weeds become a problem, high slashing is the best control.

To allow build-up of a soil seed reserve and to enable re-establishment, the pasture should be allowed to seed down in its first year. As with other twining legumes, glycine is susceptible to heavy grazing so it should be leniently grazed and rest periods should be allowed at flowering time if under continuous grazing. Because of its ability to climb, glycine has the potential to become a weed among tree crops, although this is unlikely where it would be regularly cut or grazed.

Glycine combines well with a number of grasses and has been particularly successful with a range of *Panicum* cultivars and with setaria (*Setaria sphacelata* (Schumacher) Stapf & Hubbard ex M.B. Moss).

Under wet conditions, the leaves can be damaged by leaf blight (*Rhizoctonia*), leaf-spot (*Cercospora*) and sclerotinea (*Sclerotinea sclerotiorum*). On the Atherton tableland in Queensland, the webworm (*Oncopera* sp.) can severely damage tops. Control is seldom attempted. Glycine may yield up to 4–5 t/ha of DM per year when sown with a grass and up to 10 t/ha per year if grown alone. Forage is usually grazed directly by animals but where mown for hay, care should be taken not to cut too low as this could damage the crown or low stolons.

Genetic resources and breeding Germplasm is available from ATFGRC (CSIRO, Australia).

Because glycine plants have a short-day photoperiod response, seed production in tropical regions will be limited for some accessions and cultivars. However, material with origins in the high altitudes of tropical Africa should be reproductive in similar environments in Asia and it is this material which would need to be developed for the region.

Prospects In South-East Asia, glycine will be limited to deep, fertile and well-drained soils in tropical high-altitude areas. Such areas are limited and this species is unlikely to be widely used. Currently no selection, breeding or development studies are being carried out.

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B.C. Pengelly & A.K. Benjamin

Ottochloa nodosa (Kunth) Dandy

J. Bot. 69: 55 (1931).

GRAMINEAE

$2n$ = unknown

Synonyms *Panicum nodosum* Kunth (1833), *Hemigymnia multinodis* Stapf (1920), *H. fusca* Ridley (1925).

Vernacular names Slender panic grass (En). Indonesia: suket pring-pringan (Javanese). Malaysia: rumput pait, rumput rawa, rumput sarang buaya. Philippines: banig-usa, kawakawayanan (Tagalog), bariri-magwakat (Han.). Laos: chaax kh'aa. Thailand: ya-laman (central), ya-khui-phaikhon (western).

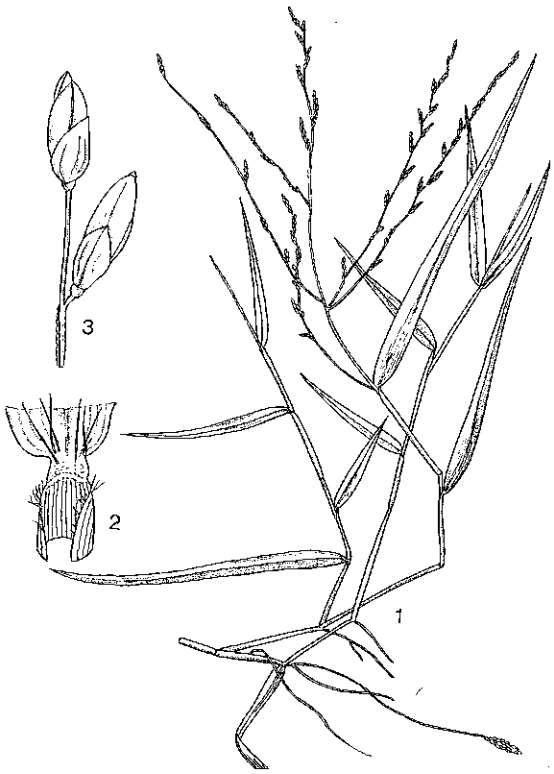
Origin and geographic distribution *O. nodosa* occurs throughout South-East Asia and also in India, Burma and Sri Lanka. It has been introduced to Mexico and parts of Africa and Australia.

Uses *O. nodosa* is used as a forage for cattle and sheep, particularly in rubber and oil-palm plantations in South-East Asia, where it also can become a troublesome weed if ungrazed.

Properties Nitrogen concentrations range typically between 1.1% and 1.3%, with DM digestibilities between 38% and 50%. DM intakes by sheep of 350–400 g/head per day have been measured in Thailand.

Botany Perennial grass with slender, decumbent or scandent culms, more than 1 m tall, rooting at basal nodes. Leaf-sheath shorter than the internode, ciliate at its margins; ligule a shallow fimbriate membrane, about 0.5 mm tall; leaf-blade narrowly lanceolate, up to 15 cm × 12 mm, glabrous or with scattered bulbous-based hairs. Inflorescence of paniculately arranged racemes, up to 30 cm long; lower branches often in a whorl; largest branches with ca. 10 spikelets, grading to solitary spikelets at apex of a branch; spikelets elliptical, 2 mm long, with glumes shorter than the spikelets; lower floret neuter, upper floret hermaphrodite.

The inflorescence is extremely variable in number of branches and spacing of spikelets. In Peninsular Thailand it flowers from September to May.



Ottochloa nodosa (Kunth) Dandy – 1, habit flowering plant part; 2, ligule; 3, spikelets.

Ecology *O. nodosa* occurs from sea-level up to 600 m, mainly in forest, rubber, or oil-palm plantations. It also occurs in rice fields and disturbed habitats.

Agronomy *O. nodosa* spreads naturally, but it can be planted by seeds or rooted culms. It is usually grazed by cattle or sheep but can be cut by hand or mowers and fed to animals. It is moderately palatable but not tolerant of heavy grazing or frequent cutting, so stocking rates should not exceed 1.5 beast/ha and cutting intervals of 8–9 weeks are preferred.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects *O. nodosa* is regarded as a troublesome weed and as a fodder of moderate value, especially in plantations, but more information is needed about its management and utilization.

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C. Manidool

Panicum maximum Jacq.

Ic. pl. rar. 1: 2, t. 13 (1781).
GRAMINEAE
$2n = 18, 32, 36, 48$

Synonyms *Panicum polygamum* Swartz (1788), non Forsskal (1775).

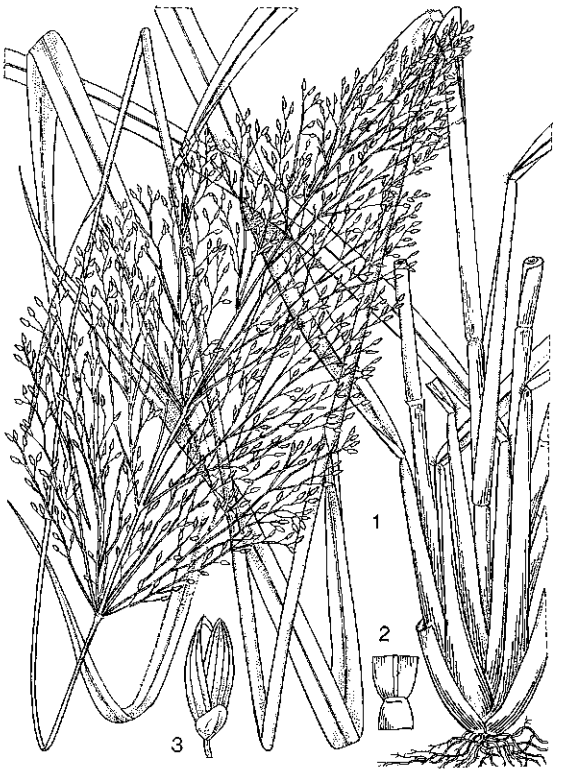
Vernacular names Guinea grass, buffalo grass, green panic grass (En). Herbe de Guinée, panic élevé (Fr). Indonesia: rumput banggala (Indonesian), suket londo (Javanese), rebha luh-buluhan (Madura). Malaysia: rumput kuda, rumput benggala. Thailand: ya-kinni (central). Vietnam: co' kê to.

Origin and geographic distribution Guinea grass is East African in origin, but is now widely cultivated throughout the tropics and subtropics as a forage. It was introduced from Africa into the West Indies before 1756, but for production of bird seed rather than forage. It reached Singapore in 1876 and the Philippines in 1907 and is now widely distributed throughout South-East Asia.

Uses Guinea grass is a palatable and good quality tropical grass used as forage for ruminants in grazed pastures or in cut-and-carry systems. Guinea grass forage is also dried and ground for use in mixtures with legumes as leaf meal, mainly for non-ruminants such as chickens and pigs. It can be conserved as hay or ensiled. It is also used as medicine for heartburn by the Malays under the name 'berita'.

Properties In vitro digestibilities of 64%, 58%, 54% and 50% have been measured in regrowth of ages 2, 4, 6 and 8 weeks. Comparing young leafy with older stemmy herbage, similar trends occur in N concentrations which can fall from over 2% to below 1%, and in metabolizable energy which declines from 11–7 MJ/kg.
There are 1000–2000 seeds/g.

Description An erect or ascending perennial tussock grass, rhizomatous at base or rooting at the lower nodes, glabrous to hairy. Low/medium height forms 1–1.5 m tall, tall forms 2.5–3.0 m or more. Leaf-sheath glabrous; ligule membranous, 4–6 mm long, fringed; leaf-blade linear to narrowly lanceolate, up to 60 cm × 2 cm, usually glabrous except in hairy forms (e.g. cultivar 'Makueni'); midrib pale, vanishing near the tip, other nerves distinct. Inflorescence usually a large, well extended pyramidal panicle up to 40 cm long by 25 cm across with lower primary branches about 20 cm long and arranged in a whorl; spikelets solitary, numerous, narrowly ellipsoidal, 3–4.5 mm long, green or tinged with purple, acute; lower glume 1–2 mm long, thin, clasping, obtuse, 3-nerved; upper glume 3–4.5 mm long, thin, narrowly boat-shaped, 5-nerved, acute; lower florets male, lemma similar to upper glume; upper florets hermaphrodite, lemma tranversely rugose, boat-shaped, pointed, palea fitting inside lemma, both ca. 2 mm long, anthers and stigma purple. Seed production apomictic.



Panicum maximum Jacq. – 1, habit flowering plant; 2, ligule; 3, spikelet.

Growth and development Poor seed produc-

tion, as low as 50 kg/ha in the wet tropics, has discouraged the commercial production of guinea grass seed. Environments with longer daylengths and dry seasons are more conducive to successful seed set. Stems of guinea grass root freely from nodes when in contact with moist soil but, as a result of its erect growth habit, such rooted creeping stolons are rarely seen in the field.

Other botanical information There are many guinea grass cultivars commercially available. Australia is the main producer of guinea grass seed; the forms available include common guinea and colonião and cultivars 'Hamil', 'Riversdale', 'Gatton' and 'Makueni'. Although the selection of these cultivars was primarily done within Australia, they are adapted to the different environments in South-East Asia. The colonião form was selected in Brazil. Variety *trichoglume* Robijns is treated separately in this volume.

Ecology Guinea grass is indigenous to the more fertile soils in Africa where it is often found growing close to the trunks of thorny *Acacia* spp. The grass benefits from the trees because of the N they fix and the shade they provide. Guinea grass thrives best under high rainfall conditions and a minimum annual rainfall of 1100–1300 mm has been suggested. Cultivar 'Hamil' is more tolerant of waterlogged conditions than other cultivars. Guinea grass is adapted to fertile soils or where appropriate fertilizer is applied. Generally it does not thrive on oxisols or ultisols unless they have been heavily limed. Extensive natural areas of vigorous guinea grass in the tropics are usually only found on fertile dark clay soils with a high Ca content, which are rare in South-East Asia.

Guinea grass responds to moderate shading. At about 30% shade its yield exceeds that obtained in full sunlight. Even in 50% shade, it can still maintain about 50% of its normal production. Because of this shade tolerance, it is well suited to agroforestry situations as in rubber and coconut plantations, or to growing with leguminous forage trees such as leucaena (*Leucaena leucocephala* (Lamk) de Wit) which provide partial shade and the essential N.

Propagation and planting Sowing, usually at 2–3 kg/ha of seed into a well-prepared seed-bed, is the best way to establish large areas of guinea grass. A fine soil surface and rolling encourage germination and establishment. Vegetative planting of 2–3 rooted tillers per clump in a triangular planting pattern at 40 cm spacing can expedite establishment, and is suitable for small-scale pasture development, especially when seed is not available. Fertilization immediately before or after planting or sowing can be important because of the slow growth of seedlings in the first month, when they can be easily overwhelmed by agressive weeds, and it is essential in soils which are poor.

Husbandry After establishment, a guinea grass pasture should be allowed to flower and set seed and then be given a light grazing before the seed drops. Guinea grass combines well with herbaceous legumes, but it is not suited to sustained frequent and close grazing. Guinea grass is very responsive to chemical fertilizers, especially N. Dry matter yield responses under cutting are obtained with N applications up to 800 kg/ha per year. However, a more efficient use of N is obtained with 100–300 kg/ha N per year.

Diseases and pests Ergot can be a problem in seed production during wet periods. No major diseases or pests of guinea grass have been documented.

Harvesting Fresh foliage can be grazed directly by animals or can be cut for stall feeding. The N concentration of grazed guinea grass can be 30% higher than in cut material. Although usually fed fresh, guinea grass can be conserved as hay or silage. However, chopping, wilting and the addition of 4% molasses are recommended before silage making.

Yield In Malaysia, annual DM yields range from 16–30 t/ha per year on sedimentary soils, 19–30 t/ha per year on peat soils and 1.5–9 t/ha per year on bris (coastal marine sand) soils when cut at 6–8 weekly intervals. Well managed guinea grass-legume pastures can support cattle at 1000 kg/ha liveweight, gaining 450 kg/ha per year. When fertilized with 300 kg/ha N per year, the animal biomass can be increased to 1400 kg/ha liveweight with an annual gain of 800 kg/ha. Similar liveweight gains to N fertilized guinea grass pastures can be achieved with guinea grass-leucaena pastures. Milk production of 8500 kg/ha milk per year has been recorded on guinea grass with N fertilizer using 2.5 Holstein-Friesian cows per ha yielding 11.3 kg/cow per day. Guinea grass-glycine (*Neonotonia wightii* (Wight & Arnott) Lackey) pastures produced 8220 kg/ha per year using Friesian cows producing 12.7 kg/day, at a slightly lower stocking rate.

Genetic resources Large collections of guinea grass have been assembled by ATFGRC (CSIRO, Australia) and CIAT (Colombia). These have provided a wide range of morphological forms and edaphic adaptations.

Breeding Selection and breeding of guinea

grass for specific ecological conditions has been carried out by a number of research organizations, including CIAT (Colombia) and EMBRAPA (Brazil). Japanese scientists have shown increasing interest in breeding guinea grass for the more difficult climatic conditions prevailing in that country. As a result, cultivar 'Natsukaze' has been registered.

The discovery of a few sexual types of guinea grass in very large populations of this usually apomictic grass has made it possible for plant breeders to develop cultivars suited to different environments. Apomicts like guinea grass have a considerable reservoir of 'fixed' variability which can be released by crossing with sexual types now available. Using crosses between these sexual types and other vigorous lines, a breeding programme to develop guinea grass cultivars tolerant of acid soils was carried out in Colombia and Brazil. This programme has led to the release of cultivar 'Vencedor' by EMBRAPA in 1990. This cultivar thrives in soils with pH < 5, but has also been shown to have better than usual shade and cold tolerance. At the Rubber Research Institute in Malaysia, 'Vencedor' was found to be one of the highest yielding tropical grasses at 55–80% light transmission.

Prospects Guinea grass is unquestionably one of the best tropical grasses and will be increasingly used in South-East Asian pastures. With the trend towards agroforestry, guinea grass will become more important in associations with trees as diverse as rubber and leucaena. More use could be made of it, particularly when mixed with leucaena, for feeding as leaf meal to non-ruminants.

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C.P. Chen & E.M. Hutton

Panicum maximum Jacq. var. trichoglume Robijns

Mem. Inst. Roy. Col. Belge 1(6): 31 (1932).
GRAMINEAE
$2n = 32$

Synonyms *Urochloa maxima* (Jacq.) R. Webster var. *trichoglume* (Robijns) R. Webster (1987).

Vernacular names Green panic, slender guinea grass, fine-leaved guinea grass (En).

Origin and geographic distribution Green panic is native to tropical and subtropical Africa and has been widely distributed, amongst others to India, Japan, Australia, Sumatra, Fiji, and the United States.

Uses Green panic is used in pastures for grazing and for hay or silage making. It can also be grown as ley pasture between two crops, e.g after a paddy rice crop; it is an important grass in sub-humid subtropical regions with summer rainfall.

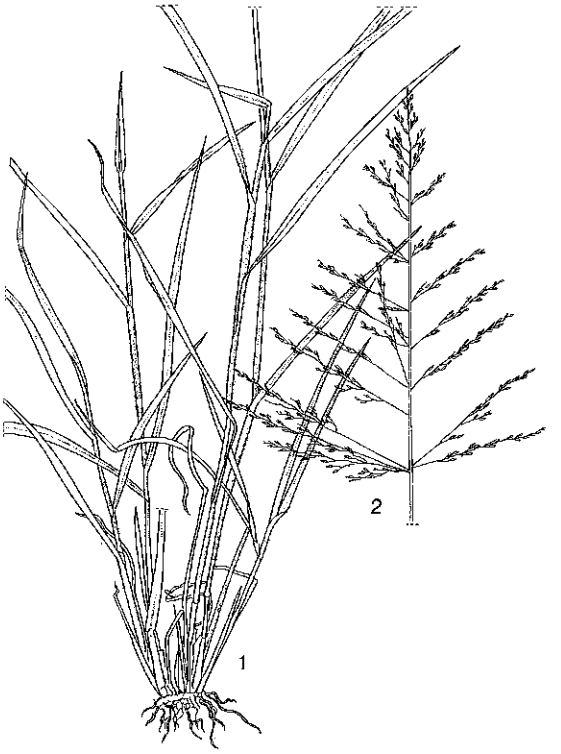
Properties Green panic is a palatable grass with an N concentration of green material between 1.4–3.6% of DM, depending on stage of growth and soil fertility or fertilization rate. Phosphorus concentrations of 0.2–0.4% of DM have been recorded in green material. Dry matter digestibility ranges between 50–65%, depending on age of material and time of year. There are about 2400 caryopses/g.

Botany A bunched, tussock-forming perennial grass with ascending habit, up to 2 m tall; the crown expands by short horizontal stems; root system consists of fine, richly branched, shallow roots. Stem slender, 6–8 noded. Leaves fine and soft; leaf-sheath sparsely hirsute; ligule a ring of downy hairs; leaf-blade velutinous on lower surface. Inflorescence a loose panicle, reaching well above the leaves; spikelets solitary or paired, oblongoid, 2.7–3.5 mm long; glumes puberulent, or strigose to velutinous; lower lemma 5-nerved, hairy; palea of lower floret fully developed, elliptical; upper lemma mucronate, coarsely transversely rugose.

Green panic seed reaches its maximum germination rate after storage for up to 18 months. It has vigorous seedlings, is fast growing and responds quickly after rain. Its flowering period extends throughout the wet season.

In the literature a distinction is not always made between green panic and guinea grass (*Panicum maximum* Jacq.) The only registered cultivar is 'Petrie' from Australia.

Ecology Green panic is adapted to humid (10–12 humid months) and sub-humid (6–9 humid months) subtropical climates with hot wet summers and dry



Panicum maximum Jacq. var. trichoglume Robijns – 1, habit leafy plant; 2, inflorescence.

cool winters, in contrast to guinea grass, which is adapted to humid tropical climates. However, green panic has also shown good performance in northern Sumatra and the Philippines. Optimal annual rainfall is between 560 and 1800 mm. Green panic is moderately drought-tolerant. It does not tolerate flooding for more than two weeks. Optimal temperature for growth is 30°C. It is less frost-tolerant than Rhodes grass (*Chloris gayana* Kunth). Frost kills top growth, but regrowth occurs in spring. Green panic is a quantitative short-day species. It tolerates shade and even grows right up to the trunks of trees and shrubs. Green panic prefers a slightly acid to neutral soil (pH 6.5–7.0), but tolerates acid or alkaline soils (pH 5.0–8.0). It does best on deep, very fertile loams, but also performs well on sandy loams of reasonable fertility. Deep sands are unsuitable. Green panic has an intermediate tolerance of high levels of Mn in the soil.

Propagation and planting Dehulling of the seed increases the percentage and rate of germination because it removes the germination inhibitors in the bracts. Seeds are small and need a well prepared seed-bed. Green panic seed can also be sown into the ashes after burning existing vegetation, as long as there is adequate moisture in the subsoil. It can either be sown on the surface and rolled, or sown 1 cm deep and covered. Seeding rates (2–7 kg) depend on quality of the seed. Sowing beneath a mulch of crop residues improves emergence and decreases the germination of weeds.

Green panic grows well in association with: *Stylosanthes* spp., *Centrosema pubescens* Benth., *Chloris gayana* Kunth, *Medicago sativa* L., annual *Medicago* spp., *Desmodium intortum* (Miller) Urban, *D. uncinatum* (Jacq.) DC. and *Macroptilium atropurpureum* (DC.) Urban.

Husbandry Green panic is sown as a sole crop on fertile soil and it responds well to fertilizer application of N, P and/or S on poor soils. When grown in association with a legume P and S fertilizer will be beneficial on poor soils. Periods of heavy grazing are tolerated. Seed formation once every two years is necessary for long-term persistence. Green panic tolerates an occasional fire. It is suitable for continuous as well as rotational grazing.

Diseases and pests Green panic has no serious diseases or pests.

Harvesting Green panic can be harvested by grazing or cutting to 5 cm above ground level 6 weeks after emergence. For hay, green panic is usually cut at the beginning of the flowering stage.

Yield Dry matter yields ranging from 5 t/ha per year (without fertilizer) to 35 t/ha per year with complete fertilizer have been recorded for green panic. It was one of the highest-yielding grasses tested in northern Sumatra.

Seed yield varies from 30–200 kg/ha. Liveweight gains of 140–180 kg/ha were recorded in south-eastern Queensland. In northern Queensland, Jersey cows and Friesian cows produced respectively 2500 kg and 4200 kg milk per lactation on green panic in association with *Neonotonia wightii* (Wight & Arnott) Lackey 'Tinaroo'. In Hawaii green panic in combination with *Leucaena leucocephala* (Lamk) de Wit produced nearly 10 t milk and 400 kg of beef per ha/year under irrigation.

Genetic resources and breeding Green panic is a pseudogamous apomictic grass with limited sexuality. Germplasm of green panic is held at ATFGRC (CSIRO, Australia). There are no known breeding programmes with green panic.

Prospects Green panic is a useful pasture grass for sub-humid subtropical regions and probably of little prospect in the humid tropics because of the availability of other species.

Literature |1| Cowan, R.T., Byford, I.J.R. &

Stobbs, T.H., 1975. Effects of stocking rates and energy supplementation on milk production from tropical grass-legume pastures. Australian Journal of Experimental Agriculture and Animal Husbandry 15: 740–746. |2| Delaney, N.E., 1975. Green panic is widely accepted. Queensland Agricultural Journal 101: 729–735. |3| Plucknett, D.L. 1970. Productivity of tropical pastures in Hawaii. Proceedings 11th International Grassland Congress, Surfers Paradise, Australia. pp. A38–A49. |4| Silvey, M.W. & Jones, R.M., 1990. Permanent pastures on a brigalow soil: changes in pasture yield and composition during the first five years. Tropical Grasslands 24: 282–290. |5| Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 266–274.

L. 't Mannetje & S.M.M. Kersten

Panicum repens L.

Sp. Pl. ed. 2: 87 (1762).
GRAMINEAE
$2n = 40$

Synonyms *Panicum convolutum* P. Beauv. ex Sprengel (1825).

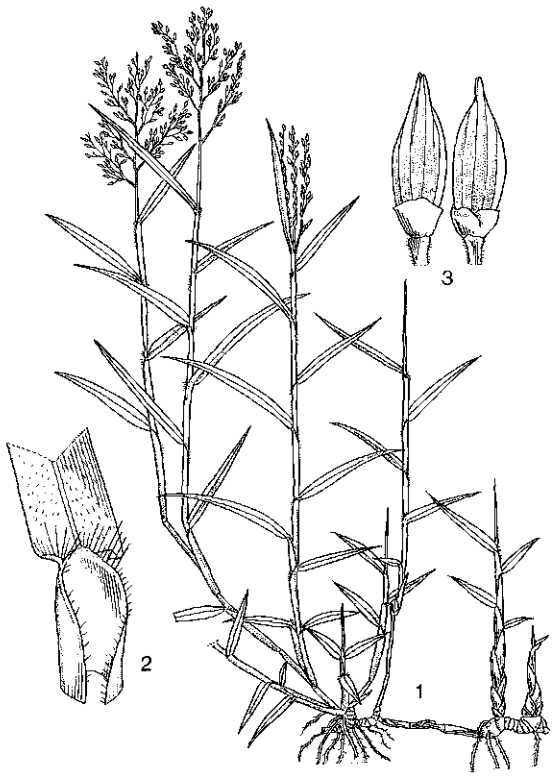
Vernacular names Torpedo grass (Am). Panic rampant (Fr). Indonesia: benda laut (North Sumatra), suket balungen (Javanese), ramput kumaranting (Minang). Malaysia: kerunong padi, metubong, telur ikan. Philippines: luya-luyahan (Tagalog), luy-a-luy-a (Visaya), maralaya (Ilokano). Burma: myet-kha. Cambodia: smau phluk, chhlong. Thailand: ya-chanakat (central), ya-khaemman (northeast), ya-onoi (northern). Vietnam: co' cu'a gà, co' ôńg.

Origin and geographic distribution Torpedo grass is widespread in Indonesia, Malaysia, Thailand and other South-East Asian countries and it also occurs in wetter areas throughout the tropical and subtropical regions of the world.

Uses Torpedo grass is used as a forage for grazing or cutting. It is regarded as an excellent native forage in South-East Asia, being both nutritious and palatable. It is also used to control erosion on sandy soils, but it can be a serious weed in crops. Rhizomes from sandy soils are sometimes dug up and fed to cattle as they are very palatable.

Properties Nitrogen concentrations in torpedo grass range from 0.7% to 3.8%.

Botany A perennial grass with long, sharp pointed rhizomes and often also surface stolons; culms erect or decumbent, up to 120 cm tall, often from a knotty base. Leaf-sheath 4–7 cm long, hairy



Panicum repens L. – 1, habit flowering plant; 2, ligule; 3, spikelet in two views.

at the margins near the throat; leaf-blade linear-acuminate, 7–25 cm × 2–8 mm, flat or rolled when dry, often stiff and pungent, ascending close to the stem; ligule a shallow membrane, 0.5 mm high, fringed with whitish hairs. Inflorescence a narrowly oblong panicle, 5–20 cm long, sparsely to moderately branched, branches usually ascending; spikelets narrowly elliptical, ca. 3 mm long, acute, often tinged with purple; lower glume clasping the base of the spikelet, ⅓ the length of the spikelet; upper glume as long as the spikelet; lower floret male, upper floret bisexual. Caryopsis glossy white.

Flowering starts 3–4 weeks after seedling emergence and continues throughout the year, but seed production is poor. Rhizomes develop so fast that they give a dense sward within 5–6 months.

Ecology Torpedo grass can grow up to 2000 m altitude in the tropics on humid or marshy places, on moist open or partially shaded meadows, in paddy fields, along lagoons, canals and roadsides, and on sandy soils on the coast. It is extrememly tolerant of acid soils. It cannot stand permanently flooded conditions.

Agronomy Torpedo grass is established by seed or rhizomes. A seeding rate of about 10 kg/ha is used in some regions, sowing seed on the soil surface with only a light covering. Ploughing enhances subsequent spread. It is very palatable and extremely tolerant of heavy grazing. Frequent and close cutting or grazing is recommended to maintain plants in a leafy condition. It shows little response to liming in acid peat soils. Irrigated pastures, fertilized with 100 kg/ha of N at each of 5 cuts, have yielded 100 t/ha per year of green matter. On abandoned rice fields it has yielded 60 t/ha per year of green matter. On peat soils, it can yield up to 11 t/ha of DM per year.
As a weed it is difficult to control because of the long-living and deep penetrating rhizomes; it may spread into improved pastures competing with and choking out desirable species.

Genetic resources and breeding Observations suggest that torpedo grass is a variable species, but it is unlikely that any substantial germplasm collections are being maintained.

Prospects Torpedo grass is a useful local forage grass. Selection should aim at obtaining accessions with more leaf, less stem, and less agressive rhizomes.

Literature |1| Bor, N.L., 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, London. p. 330. |2| Manidool, C., 1989. Natural grassland and native grasses of Thailand [in Thai]. Technical Bulletin No 1301–26–32. Division of Animal Nutrition, Department of Livestock Development, Bangkok. p. 22. |3| Manidool, C., Vagama, V. & Poositikul, A., 1985. Digestibility of Panicum repens from organic soils area in Pikulthong village [in Thai]. Annual Report on Animal Production Research. Department of Livestock Development, Bangkok. |4| Mehra, K.L. & Fachrurozi, Z., 1985. Indonesian economic plant resources: forage crops. Lembaga Biologi Nasional – LIPI, Bogor, No 31. p. 31. |5| Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 543–545.

C. Manidool

Paspalum conjugatum Bergius

Act. Helv. Phys. Math. 7: 129, t.8 (1762).
GRAMINEAE
$2n = 20, 40, 80$

Vernacular names Buffalo grass, carabao grass, sour paspalum (En). Indonesia: jampang pahit (Sundanese), paitan (Javanese), klamaran (Madura). Malaysia: rumput kerbau, rumput ala negri. Philippines: kulape (Tagalog), kauat-kauat (Visaya), kalo-kawayan (Ilokano). Thailand: ya-nomnon, ya-hep (southern). Vietnam: cỏ san cặp.

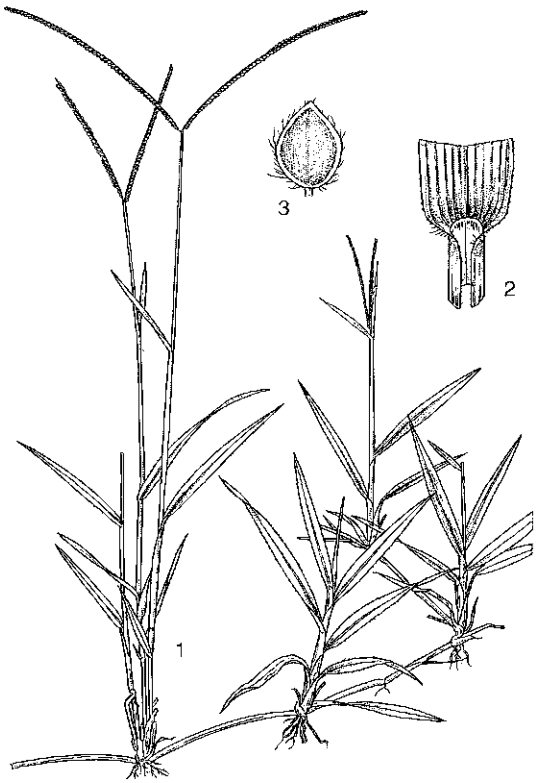
Origin and geographic distribution Originally from the American tropics, *P. conjugatum* is naturalized throughout South-East Asia and in many tropical countries of the world. It is abundant in Indonesia, the Philippines and the Pacific Islands.

Uses *P. conjugatum* is used as a forage for grazing or in cut-and-carry systems, and is rated as very important as a natural pasture grass in coconut plantations. It is occasionally used as a lawn grass and is also regarded as an important weed in rice and plantation crops.
The Iban of Borneo use leaf decoctions in the treatment of wounds and sores, and in the Sepik area of Papua New Guinea crushed spikelets are used for the same purpose.

Properties At the pre-flowering stage, the N concentration in *P. conjugatum* ranges from 1–2.2%. It is stated that only the young stage of the grass is suitable for grazing since the fruits tend to stick in the throats of livestock and choke them. The presence of a haemostatic glucoside, which reduced the time for blood clotting by 50%, has been reported for this species. Wet fruits may become very irritating as they easily stick to one's legs and clothing.

Botany A vigorous, creeping perennial with long stolons, rooting at nodes, with culms ascending to erect, 40–80(–100) cm tall, branching, solid, slightly compressed. Leaf-sheath strongly compressed, usually 30–50 mm long, ciliate on the margins; ligule collar-shaped, about 1 mm long; leaf-blade linear or lanceolate-acuminate, 8–20 cm × 5–12 mm, glabrous to sparsely pubescent. Inflorescence well exserted with two or occasionally three diverging racemes, 7–16 cm long; spikelets solitary, imbricate, flattened ovate, up to 2 mm long, with long hairs on the margins; lower glume absent, upper glume with a fringe of long hairs (1 mm) along its margin. Caryopsis broadly ovoid, plano-convex, about 1 mm long, dark brown.
The germination percentage of *P. conjugatum* seed is usually low. Flowering commences 4–5 weeks after seedling emergence and it continues to flower year round. New shoots develop at every rooted node.

Ecology *P. conjugatum* grows from near sea-level up to 1700 m altitude in open to moderately shaded places. It is adapted to humid climates. It is found under plantation crops and also along



Paspalum conjugatum Bergius – 1, habit flowering plant; 2, ligule; 3, spikelet.

stream banks, roadsides and in disturbed areas on a variety of soils, often growing gregariously.

Agronomy *P. conjugatum* is propagated from prostate culms, using 2–3 nodes per cutting. Close grazing is required to keep it in palatable stage as palatability declines rapidly after flowering. It is eaten more readily by water buffaloes than by cattle. In a mixture with *Imperata cylindrica* (L.) Raeuschel, it will dominate the latter if the pasture is grazed heavily. Close cutting and heavy grazing are recommended since it is tolerant of defoliation, and because this prevents seed head maturity, resulting in higher quality regrowth. Cut feed can be conserved as hay. Under a coconut plantation without any fertilizer a yield of 19 t/ha of green material has been obtained. Yield increased to 30 t/ha of green material following application of 15–15–15 N:P:K fertilizer at 310 kg/ha.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects Because of the wide distribution of *P. conjugatum*, research on agronomic aspects, such as improving DM yield and seed production, is desirable.

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C. Manidool

Paspalum dilatatum Poiret

Lamk, Tabl. Encycl. 5: 35 (1804).

GRAMINEAE

$2n$ = 40 (sexual, yellow-anthered biotype), 45 (interspecific hybrid), 50 (apomict, common cultivar), 70 (hybrid)

Synonyms *Paspalum platense* Sprengel (1825), *P. ovatum* Trinius (1826), *Digitaria dilatata* (Poiret) Coste (1906).

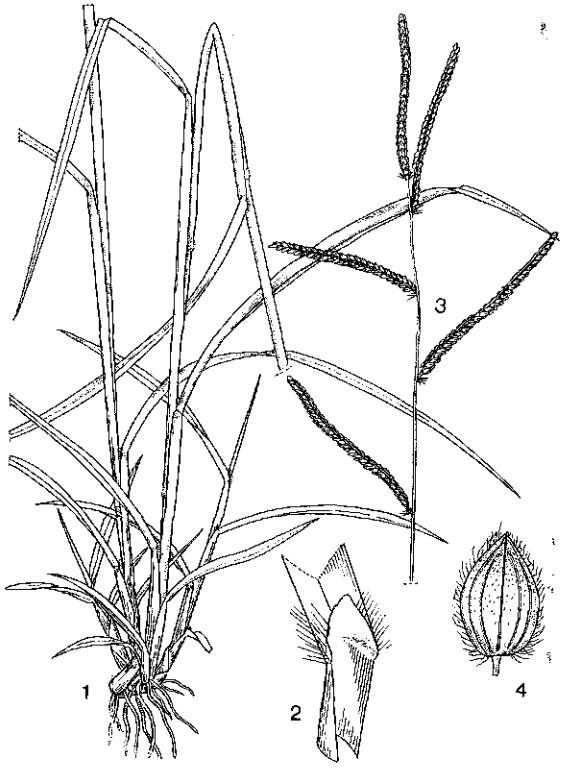
Vernacular names Dallis grass, Australian grass, paspalum (Australia)(En). Paspalum dilaté (Fr). Indonesia: rumput australi. Philippines: lawa-lawa (Tagalog), halanaw (Bikol), sakata (Visaya). Thailand: ya-daenlit. Vietnam: co' san dep.

Origin and geographic distribution Dallis grass is native to the humid subtropics of Brazil, Argentina and Uruguay. Now it is widely distributed in coastal subtropical Australia, the southeastern part of the United States, India, some African countries, Madagascar, Hawaii, Fiji and Malesia.

Uses Dallis grass is used in pastures for grazing, hay and silage-making. It is better suited for grazing than for cutting, because of its tendency to lodge. It can also be sown into the stubble after a rice crop. Dallis grass gives excellent protection against erosion.

Properties Dallis grass is very palatable at early stages of growth, but this decreases rapidly with increasing age. The N concentration of green material ranges from 0.8–3.8% of the DM and the DM digestibility between 50–63%, both depending on plant maturity, soil fertility and environmental conditions. There are 570–750 seeds/g.

Description A leafy, tufted perennial with clustered stems arising from very short, creeping rhizomes, forming a sod under grazing, rooting up to 1.2 m deep. Stem ascending to erect, 50–150 cm tall, rooting at the nodes when in contact with the soil. Leaf-sheath slightly keeled, basal ones often pilose; ligule bluntly triangular, up to 6 mm long; leaf-blade linear, flat, (5–)12–16(–39) cm × 3–13 mm, usually with some up to 6 mm long hairs at the base of the ligule, otherwise glabrous. The inflorescence consists of 3–5(–9) alternate racemes, the lowest 5–13 cm long, the others gradually shorter upwards; spikelets paired, usually imbricate, in rows along one side of a flattened axis, ovate, 3–4 mm long; lower glume absent; upper glume as long as the spikelet, with a fringe of white, ca. 2 mm long hairs along the margin framing the spikelet; lower floret with sterile lemma; upper floret bisexual. Caryopsis suborbicular, plano-convex, up to ca. 2 mm long.



Paspalum dilatatum Poiret – 1, habit leafy plant; 2, ligule; 3, inflorescence; 4, spikelet.

Growth and development Early growth is slow, but once established growth is vigorous and many leaves are produced in a short time. Dallis grass has its fastest growth rate early in the growing season, but growth slows down during midsummer and autumn. During the cool period in subtropical regions and at higher altitudes the plants are dormant. Flowering occurs throughout the growing period and seeds scatter as soon as they are ripe. With declining soil fertility, the vigour of Dallis grass declines and it is then often invaded by *Axonopus affinis* Chase.

Other botanical information *P. dilatatum* can be divided into two varieties, var. *dilatatum* and var. *pauciciliatum* Parodi. The latter has $2n = 40$ chromosomes and is more prostrate. It has slightly smaller and less hairy spikelets, more spikelets per raceme and its lemma and palea have three veins compared with nine in var. *dilatatum*. This variety is better adapted to light and poorly drained soils than common Dallis grass. Important cultivars of var. *dilatatum* are 'Raki' from New Zealand, 'Charu' from Uruguay and 'Natsugumo' from Japan.

Ecology Dallis grass is adapted to permanently humid subtropical climates (10–12 humid months) with over 1000 mm annual rainfall mainly during the warm season. Optimum temperatures for leaf growth, tillering and flowering are 30°C, 27°C and 22.5°C respectively. Seed production is inhibited at temperatures below 13°C. Dallis grass grows on lowlands as well as at altitudes up to 2000 m. It is one of the most frost tolerant subtropical grasses. It is a long-day plant, with an optimal daylength of 14 hours. Dallis grass has little shade tolerance. It requires fertile soils and performs best on alluvial soils or basaltic clays. Optimum pH(H_2O) is between 5.5 and 7.0. Dallis grass does not tolerate salinity.

Propagation and planting Dallis grass seed has some post-harvesting dormancy which can be broken by removal of the glumes. It is usually sown at a seeding rate of 6–10 kg/ha, either broadcast on the surface with a light covering, or drilled to a depth of 1–1.5 cm, preferably just before the start of the rainy season. After a rice crop it can be sown into the stubble without seed-bed preparation. Because Dallis grass is a slow starter, it is often established in mixtures with rapidly growing grasses such as *Chloris gayana* Kunth, which can compete better with weeds. Other species growing

in association with Dallis grass are *Trifolium repens* L., *T. semipilosum* Fresen. and *Vigna parkeri* Baker.

Husbandry Dallis grass tolerates high stocking rates and frequent defoliation, which also prevents it from flowering and consequently ergot infection, which can cause poisoning. It can be grazed continuously or rotationally. Lenient grazing, not shorter than 5–8 cm, results in up to three times more forage than heavy grazing. Dallis grass responds well to fertilization.

Diseases and pests Dallis grass is very susceptible to ergot (*Claviceps paspali*). This fungus infects the inflorescence and excretes a substance which is toxic to cattle and can occasionally cause abortion. Ergot is also the most important factor affecting seed quality. Other diseases are anthracnose (*Colletotrichum graminicola*) and leaf blight (*Helminthosporium micropus*), but these are generally unimportant. Dallis grass pastures are sometimes invaded by white-grubs (*Lepidiota caudata* and *Rhopaea paspali*), which destroy the roots and reduce productivity.

Harvesting For hay or silage making Dallis grass can be cut every 4–6 weeks, preferably before the grass is 30 cm tall and before flowering. Seed is best harvested about 21 days after flowering when inflorescences are brown, but before seed shattering becomes severe.

Yield Total DM yield ranges from 3–15 t/ha, depending on soil fertility or fertilization. High animal production can be obtained from Dallis grass under good management. In southern Australia stocking rates of 25 sheep/ha can be maintained. With irrigation, optimal fertilization and by including winter-growing species, milk yields of 10000 kg/ha per year have been recorded.
Seed yields are variable: 90–500 kg/ha.

Handling after harvest Seed should be dried immediately after harvest at 60°C or spread in a thin layer and dried to 7–10% moisture content.

Genetic resources and breeding A germplasm collection of Dallis grass is held at ATFGRC (CSIRO, Australia). Seed is produced in Australia, the United States and Uruguay. Dallis grass is mainly apomictic by apospory and pseudogamy. The sexual type is less common. Crossing an apomict with a female sexual species gives an interspecific hybrid with $2n = 50$. The first generation reproduces sexually and seed set increases progressively.
Breeding work is being done to increase ergot and anthracnose resistance.

Prospects Due to its palatability, productivity, its ability to combine with *Trifolium repens* and to withstand heavy grazing, Dallis grass is a desirable species, particularly in areas where it is naturalized. However, it requires careful management because of its susceptibility to ergot.

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L. 't Mannetje & S.M.M. Kersten

Paspalum distichum L.

Syst. Nat. ed. 10, 2: 855 (1759).
GRAMINEAE
$2n = 40, 48, 60$

Synonyms *Paspalum paspalodes* Scribner (1894).

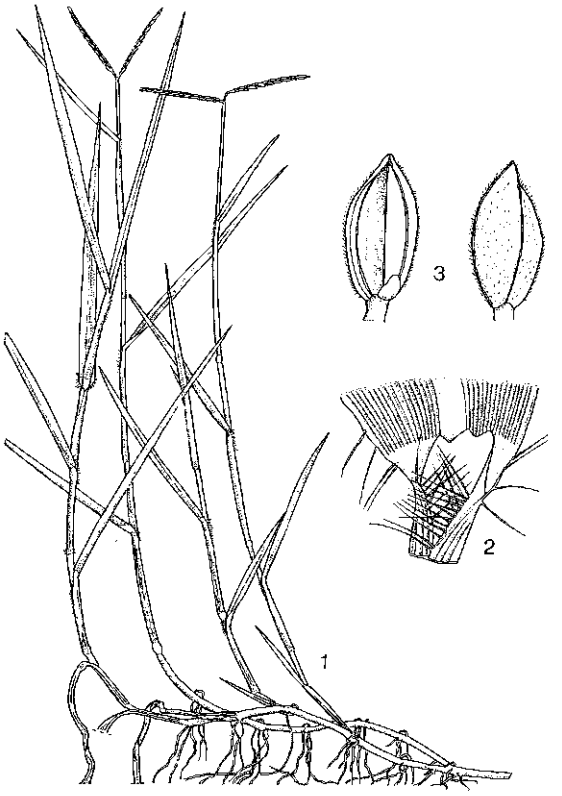
Vernacular names Ginger grass, knot grass, (salt-)water couch grass (En). Indonesia: rumput italia, asinan (Javanese), lamhani (Sundanese). Philippines: malit-kalabaw (Tagalog), bakbaba (Ilokano), gagayut (Wfumo). Thailand: ya-sakat-namkhem (northern). Vietnam: co' san dôi.

Origin and geographic distribution A common weed of the tropics, subtropics and warm temperate regions of unknown origin. In Malesia *P. distichum* probably has been introduced.

Uses Considered as a valuable pasture grass on alluvial flats, *P. distichum* is used as a fodder and is relished by water buffaloes. On stream banks it is useful as a soil binder. In direct-seeded rice it is a serious weed that grows vigorously under favourable conditions.

Properties Nitrogen concentrations of up to 1.5% have been measured, with Ca and P concentrations of 0.22% and 0.14% respectively. It is moderately palatable.

Botany A stoloniferous perennial, sometimes tufted, with leafy stolons rooting at the nodes, and



Paspalum distichum L. – 1, habit flowering plant; 2, ligule; 3, spikelet in two views.

ascending or erect culms 10–60(–100) cm long. Leaf-sheath usually hairy along the margins; ligule truncate or slightly lobed, 0.5–3 mm long; leaf-blade linear, 6–10(–20) cm × 3–5(–9) mm, attenuate-acute, usually with some white hairs at the immediate base of the ligule, otherwise glabrous. Inflorescence composed of 2 subopposite racemes, each 2–8 cm long; spikelets solitary, the upper ones usually imbricate, oblongoid, 3–4 mm long, with acute apex; lower glume often reduced or absent; upper glume pubescent, sometimes leathery. Caryopsis ovoid, plano-convex, ca. 1.5 mm long.

Flowering is throughout the year. Seeds appear to have a period of dormancy; they germinate best at 20–30 °C. From India obligate apomixis has been reported for *P. distichum*.

The species closely resembles *P. vaginatum* Swartz with which it is often confused; *P. vaginatum* does not extend into temperate regions, has at least two strictly opposite racemes in the inflorescence, and its upper glumes are glabrous.

Ecology *P. distichum* occurs in wet marshlands, swamps, in polluted shallow water, along irrigation ditches, etc., up to 1700 m altitude. It can stand high salinity and tolerates waterlogged conditions and periodic flooding in salt swamps and by tidal waters.

Agronomy *P. distichum* can be established by seed or stolons. It requires minimum land preparation and is easily established by placing stolons in holes made in moist soil. The plant remains green throughout the year if growing in water. Light grazing with long rest periods of 80–90 days is recommended since the rooted stolons are sometimes floating. Harrowing of dry surface soils will later help the spreading stolons to root and so form a denser sward. It can be cut and fed to animals, but normally villagers let their animals graze it. Observations suggest that it does not give high DM yields. It can be made into hay but is not suitable for silage.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects *P. distichum* should be included when selecting for species that are tolerant to saline soils.

Literature [1] de Koning, R. & Sosef, M.S.M., 1985. The Malesian species of Paspalum (Gramineae). Blumea 30: 295–297. [2] Manidool, C., 1989. Natural grassland and native grasses of Thailand [in Thai]. Technical Bulletin No 1301–26–32. Division of Animal Nutrition, Department of Livestock Development, Bangkok. pp. 26–32. [3] Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, Rome. pp. 565–568. [4] Soerjani, M., Kostermans, A.J.G.H. & Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta. pp. 460–461.

C. Manidool

Paspalum notatum Flueggé

Gram. monogr., Paspalum: 106 (1810).

GRAMINEAE

$2n = 20$ (sexual), 30, 40 (apomicts)

Vernacular names Bahia grass, Pensacola Bahia grass (En, Am). Indonesia: rumput pencasilan (Timor). Thailand: ya-bahia. Vietnam: co san dâú.

Origin and geographic distribution Bahia grass is indigenous to the Americas, particularly in southern Brazil. It is now widely distributed in the southern United States, Central and South America, and occurs in restricted areas in Austra-

lia, Asia, and Africa, extending into and even beyond the subtropics.

Uses Bahia grass is primarily used as forage for grazing, but also to protect slopes and terraces from soil erosion. It is also used as a lawn grass and provides suitable material for compost or mulch. It is sometimes regarded as a 'weed' grass when it invades pastures of preferred species.

Properties In vitro digestibilities of 65–70% have been measured in young growth, falling to 40–50% in older material. Similar declines have been measured in N concentrations, with old material containing only 0.5% N. Palatability declines markedly once seeding occurs or leaves mature. The digestibility of 6-week-old material in Queensland (Australia), was slightly higher (60%) under 50% shade than it was in full sunlight (55%). There are 300–550 seeds/g.

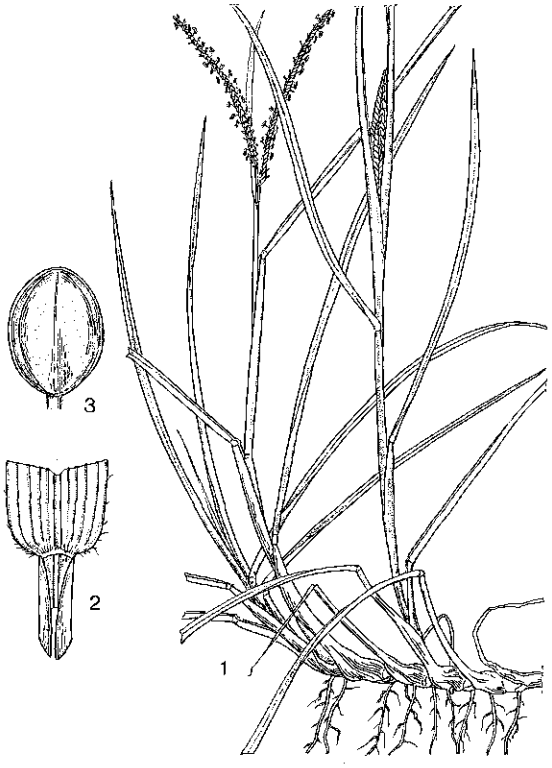
Botany A low-growing creeping perennial with stolons and stout rhizomes. The tough stolons close to the ground have short internodes and root freely from the nodes, forming a dense sod. Culms erect or geniculate, up to 75 cm tall. Leaf-blade linear, 5–20(–50) cm × 2–10 mm, sometimes hairy on margins; ligule membraneous, 0.4 mm tall, hairy from behind. Inflorescence composed of 2 (rarely up to 5) terminal racemes, each 4–12 cm long; spikelets solitary in 2 rows on a narrow rachis and broadly ellipsoid, 2–4 mm long; florets 2, the lower reduced to an empty lemma. Caryopsis ovoid, 3 mm long, flattened on one side, yellowish-green, glossy.

Bahia grass is a polymorphic species in which three varieties have been distinguished: var. *notatum*, $2n = 40$, tetraploid apomict, with short narrow leaves, mainly occurring in southern United States; var. *latiflorum* Doell., $2n = 40$, tetraploid, usually apomict, vigorous, widespread throughout Central and South America; and var. *saureae* Parodi, $2n = 20$, sexual diploid, long narrow leaves, endemic to northern Argentina. There are several cultivars, the best known being 'Pensacola', selected from var. *saureae* in the United States. Other selections have been released as cultivars in the United States, Brazil and Australia, and cultivar 'Tifthi-1' was bred in the United States.

Several studies have been made into the fixation of atmospheric N by micro-organisms, such as *Azotobacter paspali*, in association with Bahia grass. Most reports indicate fixation of only small amounts of N, up to 20 kg/ha per year, but one reported fixation of 90 kg/ha per year.

Ecology Bahia grass is a vigorous aggressive grass that spreads vegetatively and by seed. Viable seed is spread through dissemination in faeces. It prefers sub-humid to humid subtropical climates with annual rainfall ranging from 800 to 2000 mm. The optimum temperature ranges for growth (25–30°C maximum and 20°C mean) are slightly lower than those of grasses best suited to the lowland humid tropics. Top growth is killed by frost but established plants can tolerate temperatures down to −10°C. It is very tolerant of shade and 35% higher yield has been measured under 50% shade than in full sunlight. It is best suited to sandy or light-textured soils but can grow on a wide range of soil types. It has good drought tolerance and has also been known to survive 36 days of flooding, and has some salt tolerance.

Agronomy Bahia grass can be established from seed or vegetatively, from pieces of rhizomes or stolons planted closely at spacings of 15–25 cm. Hand-harvested seed has a high proportion of hard-seededness so the germination percentage is initially low, but improves progressively with up to 3 years of storage. Hammer milling of seed or treatment with sulphuric acid also improves germination.



Paspalum notatum Flueggé – 1, habit flowering plant; 2, ligule; 3, spikelet.

Sowing rates of 2–5 kg/ha are recommended. For optimum establishment, seed is sown into a fully prepared seed-bed to a depth of less than 1 cm, followed by rolling.

Bahia grass is very persistent and competitive and, given very fertile soil, can be reasonably productive. Frequent defoliation close to ground level is not only tolerated but is desirable to keep the sward leafy and acceptable to animals. It is more difficult to maintain legumes with Bahia grass than with most tropical grasses, partly because it is so competitive and partly because Bahia grass pastures have to be closely and regularly grazed. Good results have been achieved with prostrate legumes, especially with white clover (*Trifolium repens* L.) in the subtropics, but also with *Vigna parkeri* Baker and perennial *Arachis* spp.

Cultivars differ in their susceptibility to a stinging nematode (*Belonolaimus longicaudatus*), but Bahia grass is resistent to root-knot nematodes and has been used in rotation with crops susceptible to these nematodes to reduce populations. Seed yields can be reduced by Paspalum ergot (*Claviceps paspali*), although 'Pensacola' is resistant.

Herbage yields of Bahia grass are not particularly high. Yields of 3–8 t/ha of DM can be expected given moderate fertility and a suitable climate, with extreme yields ranging from 1 to 20 t/ha, the latter from heavily fertilized and irrigated swards. In the United States, Bahia grass pastures fertilized with N, usually 100–200 kg/ha, produce 400–600 kg/ha of liveweight gain per year and can carry about 5 head per hectare. In comparative studies, gains per head are usually slightly lower than recorded from pastures of *Cynodon* spp. Bahia grass is usually harvested by grazing animals. It is not suited for making hay or silage as yields are low when it is in a young leafy stage and as quality is poor if it is left for a longer growth period to achieve higher yields. It is a heavy seeder and seed yields of 100–350 kg/ha have been reported.

Genetic resources and breeding A major collection is maintained by the USDA at Tifton, Georgia. Hybrid lines of Bahia grass have been produced in the United States, but there are no current breeding programmes.

Prospects The potential for Bahia grass is South-East Asia has yet to be assessed. Although not ideally adapted to the lowland tropics, it has potential for use in plantation crops because of its tolerance to moderate shade. Where it is well adapted, the benefits of its persistence and competitiveness must be balanced against its tendency to have lower yield, quality and acceptability.

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B.B. Baki, I.B. Ipor & C.P. Chen

Paspalum plicatulum Michaux

Fl. Bor. Amer. 1: 45 (1803).

GRAMINEAE

$2n = 20$ (diploid), 30, 40, 60

Synonyms *Paspalum undulatum* Poiret (1804), *Panicum plicatulum* (Michaux) Kuntze (1898).

Vernacular names Plicatulum, brown seed paspalum, brown top paspalum (En, Am). Herbe à cheval (Fr). Thailand: ya-phlikhathiulum.

Origin and geographic distribution Plicatulum occurs naturally in South and Central America. It is distributed throughout the world from Africa (Kenya, Ivory Coast) to Australia, the United States, Oceania (Fiji) and South-East Asia (including the Philippines, Thailand, Indonesia, Malaysia and China).

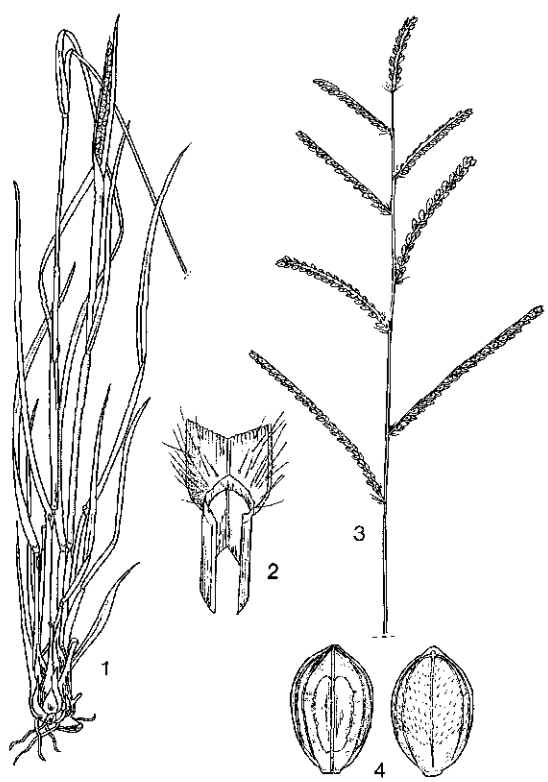
Uses Plicatulum is used as a pasture grass for grazing and silage or hay making, as an understorey in coconut plantations and in ley pastures after harvesting a paddy rice crop.

Properties Nitrogen concentration ranges from 0.8–2.0% of the DM and DM digestibility from 39–50% of whole plant material and 50–70% of green leaves. Plicatulum is a palatable grass with a high nutritive value at the young leafy stage of

growth. 'Hartley' maintains a high nutritive value after frosting, in contrast to 'Rodds Bay'. There are 750–1200 seeds/g.

Description A tufted, decumbent perennial, growing to a height of 1.2 m, sometimes with a short rhizome. Leaf-sheath keeled, usually glabrous; ligule membranous, 1–3 mm tall; leaf-blade folded at the base, linear 10–50(–85) cm × 3–7(–10) mm, often slightly hairy on the upper surface towards the base, in the tropics often hairy on both surfaces. Inflorescence a panicle composed of (5–)10–13(–19) racemes 2–10 cm long; spikelets in pairs (one of the pair sometimes undeveloped), obovoid-ellipsoidal, 2–3 mm × 1.5–2 mm; lower glumes absent; lower lemma with short transverse wrinkles just inside the slightly raised margin. Caryopsis as large as the spikelet, dark-brown, shiny.

Growth and development Plicatulum has a slow seedling growth, but rapid growth rate once established. It is a short-day plant, with a critical photoperiod of 13 hours and a short flowering period at the end of the wet season. Seed is ready for harvesting 21 days after panicle emergence. Seedlings have a juvenile period of 50–60 days in which they will not flower.



Paspalum plicatulum Michaux – 1, habit flowering plant; 2, ligule; 3, inflorescence; 4, two views of a spikelet.

Other botanical information Three cultivars have been released in Queensland, Australia, viz. 'Rodds Bay', with narrower leaves than the other two cultivars; 'Hartley', more prostrate growing and leaves with wavy margins towards the base; 'Bryan' is intermediate to these two cultivars and is the hairiest one.

Ecology Plicatulum is adapted to tropical and subtropical climates with over 750 mm of annual rainfall. Plicatulum survives dry seasons of 5–6 months. 'Rodd's Bay' has the best drought tolerance. Temporary waterlogging is also tolerated. Plicatulum does not grow at temperatures below 10°C and top growth is killed by frost, although regrowth occurs in spring. Optimal temperature for germination and growth is between 20–35°C. The grass can grow on a wide range of soils; it is very tolerant of low pH and of high Al concentrations. Plicatulum is tolerant of fire, but it is not adapted to shade.

Propagation and planting Plicatulum is propagated normally by seed, but can also be planted vegetatively. The seed can remain dormant for several months after maturity. This is caused by permeability restrictions imposed by the lemma and the palea. Dormancy can be broken by chilling at 7°C for 30 days. Full land preparation to a fine seed-bed is necessary and the recommended seeding rate is 2–3 kg/ha. The seed can be broadcast on the surface and covered by rolling, or drilled to a depth of 1–1.5 cm. Plicatulum can be grown in association with *Macroptilium atropurpureum* (DC.) Urban, *Stylosanthes* spp., *Desmodium intortum* (Miller) Urban and *Trifolium repens* L.

Husbandry Plicatulum responds well to N fertilizer, but it can also grow and persist on poor soils. Plicatulum can be grazed continuously or rotationally.

Diseases and pests Plicatulum is very resistant to ergot and no other diseases or pests are known to affect it.

Yield Dry matter yield varies from 8.5–24 t/ha per year. With irrigation and complete fertilizer (NPK) and cutting intervals of five weeks, DM yield per cut of 2.5 t/ha can be obtained.
In Fiji DM yield under coconut was 9.5 t/ha per year, while in Malaysia the yield under oil palm was negligible. Seed harvest yields 200–300 kg/ha. Annual liveweight gains of beef cattle of up to 250–300 kg/ha have been measured in the sub-

humid subtropics in Queensland.

Genetic resources and breeding Plicatulum is an aposporous apomict ($2n = 40$), or sexual ($2n = 20$). A germplasm collection of plicatulum is maintained at ATFGRC (CSIRO, Australia). Seed is also produced in Queensland. There are no known breeding programmes with plicatulum.

Prospects Plicatulum has good prospects for use in open pastures in subtropical and tropical regions of South-East Asia because of its persistence even on infertile soils and its ability to combine with legumes.

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L. 't Mannetje & S.M.M. Kersten

Paspalum scrobiculatum L.

Mant. Pl. 1: 29 (1767).

GRAMINEAE

$2n = 20, 40, 60$

Synonyms

- var. *auriculatum*: *P. auriculatum* Presl (1830), *P. zollingeri* Steudel (1853);
- var. *bispicatum*: *P. commersonii* Lamk (1791), *P. cartilagineum* Presl (1830);
- var. *horneri*: *P. horneri* Henrard (1935);
- var. *lanceolatum*: *P. lamprocaryon* K. Schum. (1895).

Vernacular names

- var. *scrobiculatum*: kodo or kodra millet (En). Indonesia: rebu bawang, rumput kinangan (Java), suket krisik (Madura).
- var. *bispicatum*: koda grass, scrobic (En). Indonesia: jaringan, rumput ketih belalang (Indonesian), kumpai batu (Kalimantan). Malaysia: pala belang, rumput tulo santadok. Philippines: sabung-sabungan (Tagalog), bias-biasin (Visaya), tat-awwa (Bontok). Cambodia: smau 'ânnchien. Thailand: ya-sakhorbik (central). Vietnam: co' san tru'ńg, co' tru'ńg.

Origin and geographic distribution *P. scrobiculatum* occurs throughout the Old World tropics and is occasionally cultivated elsewhere. In India it is often also cultivated. In South-East Asia it is a common grass.

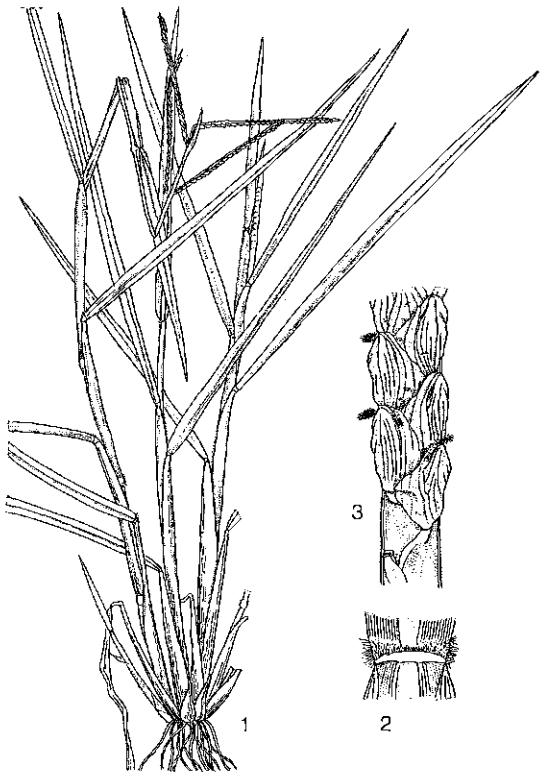
Uses *P. scrobiculatum* provides useful forage but is also regarded as a weed of annual and plantation crops. Occasionally it is used as compost or mulch. In India it is cultivated for the grain.

Properties Nitrogen concentrations of 1–5% during the growing season and below 0.5% in standover seed have been measured. It is a very palatable grass except when it is frosted. The cultivars grown for grain in India are said to contain compounds in the grain which are toxic to man and to animals. The fungi *Sorosporium paspali* and *Uredo paspali-scrobiculari* are almost invariably present in the outer husks of the grain and are thought to be responsible for its toxicity. In Australia it has not been toxic to grazing animals. There are 300–600 seeds/g.

Botany A tufted perennial, not stoloniferous, with ascending to erect, sometimes branching culms up to 135 cm tall. Leaf-sheath glabrous or hairy at the margins; ligule collar-shaped, up to 1.8 mm long; leaf-blade linear, up to 53 cm × 2.5 cm, flat or folded length-wise, narrowed towards the base, hirsute at base, along the margins and above the ligule. Inflorescence composed of 1–14 alternate or subopposite racemes each up to 15 cm long; peduncle 0.5–2 mm in diameter; rachis flat, straight to slightly zigzag, winged,; spikelets solitary, imbricate or not, usually suborbicular, 2–3 mm long; lower glume usually absent; upper glume 5–13-nerved, sterile lemma 5–9-nerved. Caryopsis obovoid to ovoid, ca. 2 mm long.

P. scrobiculatum is a polymorphic species, possibly an aggregate swarm of apomicts. Although the variability is quite continuous, at present 5 varieties are distinguished with the following characteristics:

- var. *scrobiculatum*: culms 8–20(–55) cm long; cauline leaf-sheaths hairy at margins, rarely glabrous; leaf-blades (4–)7–20(–30) cm × (3–)5–7(–9) mm; peduncle 0.5–1 mm in diameter; racemes 1–2, alternate or subopposite, 1.5–7 cm long; spikelet 2.5–3.3 mm × 2.1–2.6 mm; upper glume with 7, 9 11 or 13 nearves; sterile lemma with 7 or 9 nerves. Distributed from India throughout Malesia to the Pacific. Its occurrence in Africa and elsewhere is uncertain.
- var. *auriculatum* (Presl) Merrill: culms up to 135 cm long; cauline leaf-sheaths glabrous; leaf-blades 20–40(–53) cm × 10–16(–19) mm; pedun-



Paspalum scrobiculatum L. – 1, habit flowering plant; 2, ligule; 3, part of raceme.

cle 1–1.9 mm in diameter; racemes 3–8, alternate, 8–15.5 cm long; upper glume 7-nerved; sterile lemma with 7 or 9 nerves. Distributed from India throughout Malesia. Its occurrance in the rest of the world is uncertain.

- var. *bispicatum* Hackel: culms 8–70(–130) cm long; cauline leaf-sheaths glabrous or hirsute; leaf-blades 10–25(–42) cm × 4–9(–15) cm; peduncle 0.5–1.4 mm in diameter; racemes (1–)(2–6(–14), alternate, 1.5–9(–11) cm long; spikelet 1.8–2.6 mm × 1.5–2.2 mm; upper glume and sterile lemma 5 or 7 nerved. Distributed in tropical Africa, Asia (including Malesia), the Pacific and Australia.
- var. *horneri* (Henrard) Koning & Sosef: culms 15–80 cm long; cauline leaf-sheaths hirsute; leaf-blades 3–6 mm wide; racemes 1–4, alternate or subopposite; spikelets 1.7–2.5 mm × 1.2–1.9 mm; upper glume 5-nerved; sterile lemma 5 or 7-nerved. Distribution is disjunct: in Assam and in Malesia only.
- var. *lanceolatum* Koning & Sosef: cauline leaf-sheaths enveloping the nodes; leaf-blades 7–21 cm × 12–27 mm; racemes 2–4; spikelets 2–2.7 mm long. Distributed only in tropical Africa.

P. scrobiculatum flowers freely, and in Malaysia it produces seed during 3–4 months per year. The seeds fall as they mature.

P. orbiculare Forster f. much resembles *P. scrobiculatum*, especially var. *bispicatum*. Its spikelets are usually broadly obovate with 3 or 5 discolorous nerves in the upper glumes and sterile lemmas. In var. *bispicatum* the spikelets are usually suborbicular and the nerves are 5 or 7, concolorous. In Australia cultivar 'Paltridge' of *P. scrobiculatum* was released in 1966, but it is now rarely cultivated.

Ecology In Indonesia and Malaysia, *P. scrobiculatum* is found mostly in open, wet cultivated areas, up to 1200 m altitude, and in upland and tidal rice fields. It is commonly found on disturbed sites and is a weed in cropping land. It is well adapted to waterlogged soils and can tolerate flooding, but has only limited drought tolerance. The optimum temperature for growth is 25–27°C. It is a sun-loving plant although it can tolerate and flourish with only 30–50% sunlight, as found in young rubber and oil palm plantations or black pepper farms. It is not as salt tolerant as the closely related *P. vaginatum* Swartz. It can tolerate poor soil fertility if there is little competition, but prefers very fertile soils and responds well to fertilizer application.

Agronomy *P. scrobiculatum* can be propagated by seed or by rooted tillers. Newly ripened seeds are dormant and mechanical or acid scarification is desirable to reduce dormancy. It needs a very fine seed-bed which is usually prepared by ploughing, disking and harrowing. It is usually sown through a cereal drill in rows 1.3 m apart on a well-prepared seed-bed.

P. scrobiculatum is susceptible to a root-knot nematode (*Meloidogyne incognita*) and can be attacked by the *Paspalum* ergot (*Claviceps paspali*).

It is a very palatable and highly digestible grass during the wet season and retains these characteristics later into maturity than most other grasses. Consequently it could be used intensively during the dry season when the nutritive value of other species is generally lower. Strategic intermittent or rotational grazing helps to allow sufficient seeding for regeneration. Experience in Australia suggests that it will not persist in permanent pastures, where it is replaced by other perennial grasses.

It is usually harvested by grazing animals but is occasionally cut and fed as green fodder. Although

usually not as persistent as other perennial tropical grasses, results from experiments with both sheep and cattle suggest that it can result in good animal production.

Genetic resources and breeding There is considerable variation within *P. scrobiculatum* and closely related *Paspalum* species which might even belong to the same species complex. It is unlikely that any of the existing germplasm collections adequately document this variability. There are no breeding programmes on *P. scrobiculatum*.

Prospects The present opportunistic use of *P. scrobiculatum* will continue. Studies on the variability within this species and on its agronomic requirements are necessary to determine its potential as a forage species. Australian experience suggests it may be more suited for use as a short-term forage rather than as a long-lived grass in permanent pastures.

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B.B. Baki & I.B. Ipor

Pennisetum clandestinum Hochst. ex Chiov.

Ann. Ist. Bot. Roma 8: 41, fig. 5 (2) (1903).
GRAMINEAE
$2n = 36$

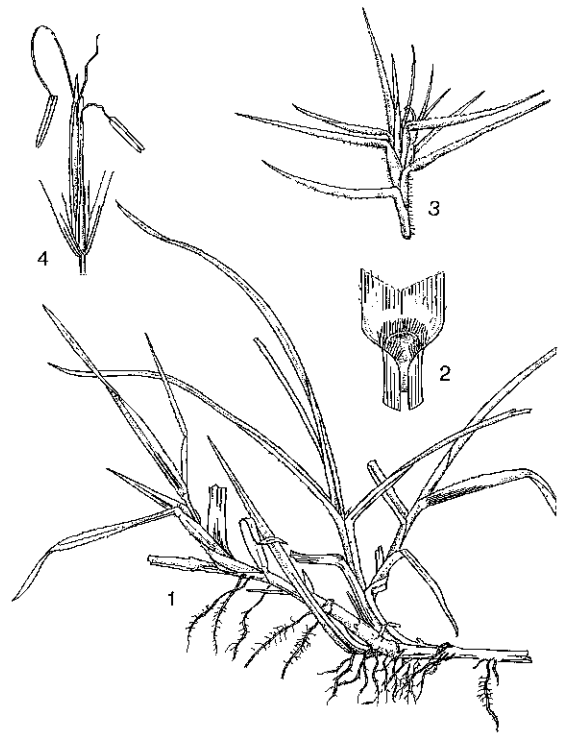
Vernacular names Kikuyu grass (En). Thailand: ya-khikhuyu.

Origin and geographic distribution Kikuyu grass occurs naturally across the elevated plateaux of East and Central Africa, and has been distributed to other continents and islands with (sub)-tropical, humid climates, between latitudes 0°–35°. In South-East Asia, kikuyu grass is restricted to elevated areas (> 1900 m) mainly in Papua New Guinea and the Philippines.

Uses Kikuyu grass is used for many purposes including lawns and recreational areas, pasture for ruminants under intensive grazing and to prevent soil erosion. It is potentially a weed on arable land and in irrigation channels.

Properties Nitrogen concentrations range from 1.8–4.3% depending on age and fertilizer application. Digestibility of DM varies from 73% (young leaf) to 50% (mature or frosted material). With advancing maturity the rate of decline in nutritive value of kikuyu herbage is slower than that of other tropical grasses. As kikuyu grass is adapted to very fertile soils, the concentrations of P, K and S are normally adequate for animal growth. On the other hand Na levels are often low (0.02–0.05%), indicating potential deficiencies for very productive lactating ruminants. There are approximately 400 seeds/g.

Description A perennial, stoloniferous and rhizomatous grass with short culms, 8–15 cm tall, arising from long, prostrate runners, multi-



Pennisetum clandestinum Hochst. ex Chiov. – 1, habit of basal plant part; 2, ligule; 3, inflorescence; 4, spikelet.

branched and rooting at the nodes. Roots proliferate densely in upper 0–15 cm of soil, from older rhizomes/stolons, becoming less dense towards the growing point; in friable soils, roots can penetrate to 3 m. Leaves arise alternately from multibranched stolons; leaf-sheath 1–2 cm long, pale green, eventually turning brown on older stolons, densely hairy; ligule a rim of short hairs; leaf-blade linear, 1–15 cm × 1–5 mm, tightly folded when young, flattened when older with sparingly hairy midrib. Inflorescence reduced to a cluster of 2–4 short spikelets each with fine bristles carried close to lateral runners, concealed within the uppermost sheath; spikelets consist of two florets, pale or translucent, one of which is usually fertile; stamens exserted on slender filaments for a short time, often asynchronously with the stigma. Caryopsis develops near stem at ground level, dark brown, ovoid, 2.5 mm long, pointed.

Growth and development In established swards, kikuyu grass growth is cyclical, dependent on temperature, moisture and fertility. Flowering is indeterminate, being stimulated by defoliation or heavy grazing. After germination and emergence of primary tillers, kikuyu grass seedlings develop a prostrate growth habit as stolons grow radially.

Other botanical information Early collections of ecotypes in East Africa were distinguished by differences in leaf type and flowering behaviour. Some strains are female fertile (apomictic through aposporic embryos) others are open-pollinated. Several cultivars have been released in Australia. 'Whittet', a robust, upright form, was selected in New South Wales from seed introduced from Kenya. 'Breakwell' a densely tillered, prostrate strain, was derived from a naturalized stand at Grafton. 'Crofts' is fine-leafed with a degree of cold tolerance. 'Noonan' seeds prolifically and is tolerant of the disease 'kikuyu yellows'.

Ecology Kikuyu grass occurs naturally on the margins of forests on the highland plateaux of Ethiopia, Kenya and Central Africa (1950–3000 m) receiving 1000–1600 mm rainfall per annum. In Kenya at elevations of 2250 m, mean minimum and maximum temperatures range from 2–8°C and 16–22°C, respectively. Optimum growth for kikuyu grass is attained at 25/20°C (day/night temperatures). The grass withstands short duration frosts, but tissue is killed below −2°C. The present geographical distribution of the grass coincides with mesothermal humid climates, frequently where rain forest was the original vegetation. At higher latitudes (25°–35°) kikuyu grass naturalizes at sealevel. Kikuyu grass is sensitive to water supply; with increasing evaporative demand from 2–5 mm/day growth is reduced and ceases at a water potential of −100 kPa. Kikuyu grass is adapted to free-draining lateritic red loam soils of moderate or good fertility, often with low pH(H_2O) (< 5), and is tolerant of high Al and Mn levels.

Propagation and planting Kikuyu grass establishes vegetatively and from seed. In vegetative propagation, rooted stolons can be dug or ploughed out mechanically, spread out and pressed in to the ground. Kikuyu grass seed (1–2 kg/ha) is either broadcast or drilled into a prepared seed-bed, usually with companion legumes. Once introduced to a locality, kikuyu grass usually spreads naturally because it offers strong competition with other species or because ingested seed is dispersed in dung by cattle.

Husbandry After sowing, kikuyu grass forms a dominant sward within 3–9 months, aided by fertilizer application (N and P) and mowing to reduce weeds. It responds vigorously to N fertilizer, yielding 15–30 kg of DM per kg N applied during active growth under a cutting regime, although the response will vary with soil fertility. It responds to P and K if these are in short supply. To improve feeding value and to maintain legumes, the grass needs and responds to intensive grazing which can be either continuous or rotational. In arable land or irrigation channels it is a weed, and intensive control by hand or with herbicides is necessary.

Diseases and pests In Australia, the major disease is 'kikuyu yellows' caused by a soilborne pathogen *Verrucalvus flavofaciens*; symptoms are patches of yellow, chlorotic leaves appearing in summer. Larvae of various moths or scarab beetles (*Rhopea magnicornies*) cause temporary damage to kikuyu grass pastures.

Harvesting Being prostrate, kikuyu grass is suited to grazing, rather than for use as cut-and-carry forage. Repeated mowing to promote flowering is needed for seed production. Seed is harvested by removing all material to ground level, threshing and sieving.

Yield Dry matter yields of kikuyu grass vary from 9–30 t/ha, indicating a potential for high carrying capacities and animal production by dairy or beef cattle. Stocking rates of 1.5–3.0 dairy cows/ha have been achieved in Australia with high rates of fertilizer, although productivity per head was moderate (9.0–16.6 kg milk/day).

Genetic resources Although kikuyu grass shows variation in leaf morphology and flowering behaviour in the wild, original clonal introduc-

tions have resulted in uniform pastures in many countries. Germplasm collections are available in Australia (New South Wales Agriculture & Fisheries, Grafton) and ILCA (Ethiopia).

Breeding Improvement in kikuyu disease resistance and cold tolerance has been mainly achieved by selection within natural variation of existing collections. Suitable breeding methods are not available for this species.

Prospects Kikuyu pastures in South-East Asia are restricted to certain highland areas in New Guinea and the Philippines at present. Widespread soil erosion on steep, cultivated land and degraded catchments in South-East Asia, could be reduced if permanent pastures were established. Kikuyu grass could have an important role for land stabilization and improved animal nutrition in some of these situations.

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P.T. Mears

Pennisetum polystachion (L.) Schultes

Syst. Veg. Mant. 2: 146 (1824).
GRAMINEAE
$2n$ = 32, 36, 45, 53, 54, 56, 78

Synonyms *Panicum polystachion* L. (1759), *Pennisetum setosum* (Swartz) L. Rich. (1805), *P. atrichum* Stapf & Hubbard (1933), *P. subangustum* (Schum.) Stapf & Hubbard (1933).

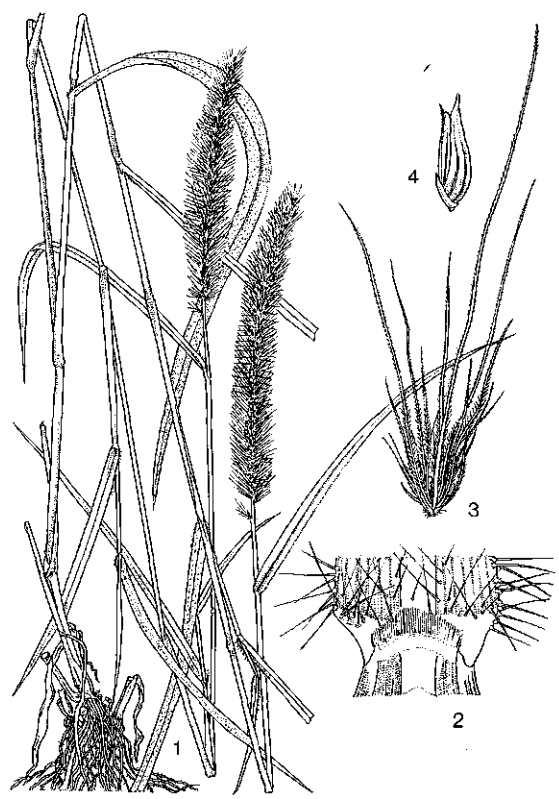
Vernacular names Feather pennisetum (En). Malaysia: rumput ekor kucing, rumput berus kucing. Philippines: ikug-kuting (Tagalog). Laos: hnhaaz khachoon. Thailand: ya-khachonchop. Vietnam: co' duôi voi nho'.

Origin and geographic distribution *P. polystachion* is a native of tropical Africa and India but is widely introduced and distributed in Indonesia, Malaysia, Thailand, Fiji, Australia and generally throughout the tropics, but rarely beyond 23°N and 23°S.

Uses *P. polystachion* is grazed and also cut for use as a fresh fodder or as hay. It is useful for controlling soil erosion, especially on sloping land. It is considered a weed in Thailand, Fiji and parts of Malaysia. The fully mature culms make good paper pulp.

Properties Nitrogen concentrations in *P. polystachion*, before or at early flowering, are 1.8–2.8%, declining to 0.8% in older material. Similarly, P concentrations fall from 0.5–0.2%. Experiments in Thailand showed a DM digestibility of 60–70% and a DM intake by sheep of 363–536 g/head per day. After flowering, nutritive value and acceptability to animals decrease rapidly.

Botany An annual or perennial tufted or spreading grass, 0.5–3 m tall with culms erect or geniculate, simple or branched. Leaf-blade linear, 10–50 cm × 5–18 mm, drooping, glabrous to soft hairy above. Inflorescence a cylindrical panicle, 5–25 cm × 13–26 mm, purple or brownish; spikelets sessile, 3–5 mm long, each enclosed by up to 30 cm long involucral bristles, two-flowered, only the



Pennisetum polystachion (L.) Schultes – 1, flowering plant; 2, ligule; 3, spikelet with bristles; 4, spikelet without bristles.

upper floret fertile; bristles scabrous to densely ciliate, 20–50 per spikelet.

In northern latitudes (Thailand) it flowers in October and in southern latitudes (Fiji) in April. Seedlings grow vigorously early in the rainy season. There are conflicting reports about seed dormancy. Some say that seeds may have a dormancy period of 3–6 months and others indicate there is no dormancy. One report mentions that the germination percentage of *P. polystachion* seed was 6–8% after one year of storage, improving to 14–22% after two years. It is a prolific seeder.

P. polystachion is a polymorphic species, very variable in colour, stiffness and length of the bristles. In fact it is a complex species, formerly subdivided into the species mentioned under synonyms, which are now joined by a continuous pattern of variation. Sometimes the complex is subdivided into 3 subspecies (without clearly separating characteristics):

- ssp. *polystachion*: annual plant; involucral bristles 6–45, ciliate; $2n = 32, 36, 45, 54$.
- ssp. *setosum* (Swartz) Brunken: perennial plant; involucral bristles up to 50, densely to sparsely ciliate; $2n = 53, 54, 56, 78$.
- ssp. *atrichum* (Stapf & Hubbard) Brunken: perennial plant; involucral bristles up to 30, scabrous; $2n = 36$.

P. polystachion resembles *P. pedicellatum* Trin. and *P. purpureum* Schumach., but it can be distinguished by the lower lemmas which are often three-lobed, the upper florets which disjoint readily and rachises with decurrent wings on the ridge below the pedicels.

Ecology *P. polystachion* is a short-day plant and mainly adapted to the lowland tropics, although it can be found at altitudes up to 2400 m. It grows well in high rainfall areas, but can also tolerate short dry periods. Its optimal temperature for growth is 32–35°C with a minimum of 12°C. It is adapted to a wide range of soil types, from light sandy soils to waterlogged clay soils, but it will not stand prolonged flooding. It often occurs on old farmland and other disturbed places. *P. polystachion* tolerates acid (pH(H_2O) 4.5) as well as alkaline soils. It is tolerant of shade and poor soil fertility, and is favoured by regular burning.

Agronomy *P. polystachion* is best established by broadcasting seed on cultivated land, sowing at 3.5–4.5 kg/ha. It is usually not fertilized, but either chemical fertilizer or farmyard manure is sometimes applied in Fiji and India. There are no reports of any major diseases or serious pests. When used as forage, *P. polystachion* should be grazed or cut before flowering. When used as cut-and-carry forage, it can be cut 2–3 times a year. Cut forage can be fed fresh or conserved as hay, although the succulent stems are slow to dry. If it is prevented from flowering, *P. polystachion* will stay green well into the dry season. When subjected to sustained heavy grazing it will not persist and will be replaced by prostrate species. Legumes can be grown with *P. polystachion*, although fertilization with P may be required. When grown with a suitable legume in Fiji, *P. polystachion* was eaten more readily by cattle. Shade-tolerant legumes such as *Desmodium heterophyllum* (Willd.) DC., *Desmodium heterocarpon* (L.) DC. ssp. *ovalifolium* (Prain) Ohashi, and *Centrosema pubescens* Benth. can be grown with *P. polystachion*. Also *Macroptilium atropurpureum* (DC.) Urban and *Stylosanthes guianensis* (Aublet) Swartz have been successfully introduced into *P. polystachion* pastures after burning and with the use of P fertilizer. For pulp making, it should be cut after the seeds are fully ripe since pulp quality is best at this stage.

In Fiji, *P. polystachion* yielded 11–13 t/ha per year of DM when fertilized with N. Steers grazing unfertilized *P. polystachion* in Fiji produced liveweight gains of only 110–80 kg per beast per year within a stocking rate range of 1–3 beasts/ha. Seed yields of up to 420 kg/ha have been obtained in India. Seeds can be viviparous in very wet weather.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained and there are no breeding programmes with *P. polystachion*.

Prospects *P. polystachion*'s ability to adapt, persist, give high yields, and combine with a range of legumes make this a very useful grass. Research is needed into its general agronomy, the best management regime to obtain the highest animal production, and how to conserve it as hay or silage.

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B.B. Baki, C. Manidool & C.P. Chen

Pennisetum purpureum Schumach.

Beskr. Guin. Pl.: 44 (1827).
GRAMINEAE
$2n = 28, 56, 27$

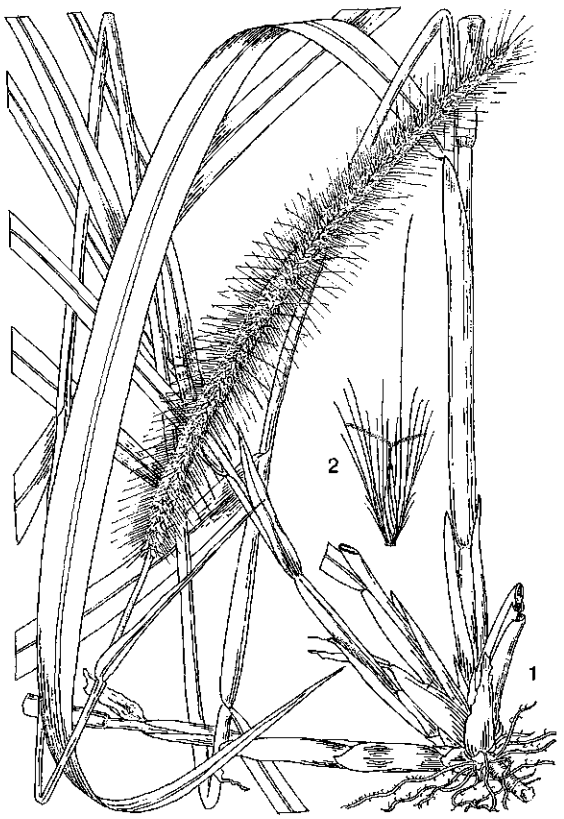
Vernacular names Elephant grass, napier grass (En). Herbe d'éléphant (Fr). Indonesia: rumput gajah. Malaysia: rumput gajah. Philippines: buntot-pusa (Tagalog), handalawi (Bokil), lagoli (Bagobo). Thailand: ya-nepia. Vietnam: co' duôi voi.

Origin and geographic distribution Of tropical African origin, this grass has been introduced to all tropical regions of the world and is naturalized throughout South-East Asia where annual rainfall exceeds 1000 mm and there is no long dry season.

Uses The main use of elephant grass is as a forage for ruminants. As a naturalized species in humid regions of South-East Asia, it is collected by farmers by cutting the whole plant, which is offered to ruminants, mainly buffaloes and cattle, which are either tethered or confined in stalls. It can also be used to provide mulch.

Properties The feeding value is influenced mainly by the ratio of leaf to stem and by age. Nitrogen concentrations of regularly harvested forage are usually in the range of 2–4%. Young leaves may have a digestibility of 70%, but this value declines rapidly with age to less than 55%. Stems are of low digestibility, except when very young.

Description A tall, robust, deep-rooting, erect perennial, with short rhizomes. Stem up to 7 m tall and 3 cm in diameter, up to 20-noded. The plant forms clumps to 1 m across. Leaf-sheath glabrous to short bristly; leaf-blade linear with broad base and acute tip, up to 120 cm × 5 cm, glabrous to hairy at the base, with a prominent midrib along the lower surface. Inflorescence a dense spike-like panicle, up to 30 cm tall and 30 mm wide, not including the 16–40 mm long bristles on the spikelets; spikelets 5–7 mm long, solitary or in clusters of up to five, of which usually only one is fertile; the lower floret is male or void, the upper bisexual and fertile, sometimes male. There is little or no seed formation.



Pennisetum purpureum Schumach. – 1, habit of flowering plant; 2, spikelet surrounded by bristles.

Growth and development Elephant grass is an obligate quantitative short-day plant, with a critical photoperiod between 13 and 12 hours. However, viability of pollen is poor and this may be the main cause of the typically poor seed set. In addition, seedlings are weak and grow slowly, so that the grass is usually propagated vegetatively. Under favourable conditions, vegetative material is fast-growing and the plant can reach a height of several metres within two months.

Other botanical information There are numerous cultivar names in various countries and three subspecies have been proposed in northern Africa, but there has been no similar subdivision

for South-East Asia. In Florida (United States), a dwarf cultivar 'Mott' of high feed value has been developed.

Ecology Elephant grass is adapted to a humid warm environment. However, it can exhibit remarkable drought-tolerance and can survive light frost. For acceptable agronomic performance, the species requires a deep soil of at least moderate fertility, although it will survive at much reduced productivity on all kinds of soils. It does not tolerate sustained flooding. In its naturalized state, the grass is found mainly along forest edges.

Propagation and planting Vegetative propagation is either by dividing clumps of roots and stubble, or by stem cuttings consisting of at least three nodes, two of which are buried. This can be done by hand or with a sugar-cane planter. Row width ranges from 50–200 cm, the greater distances being preferred in drier regions. Distance within rows varies from 50–100 cm. Intercropping with cassava and banana is often practised in home gardens.

Husbandry For high yields and persistence, elephant grass planted as a crop requires a regular water supply and a rich supply of nutrients. The latter applies particularly when the crop is cut frequently. Nutrient removal per t DM is: N 10–30 kg, P 2–3 kg, K 30–50 kg, Ca 3–6 kg, Mg and S 2–3 kg. With annual DM yields between 20 and 40 t/ha, very large quantities are thus extracted from the soil. If they are not replenished, yield soon drops and weeds will invade. Although elephant grass is not often grown with legumes, it combines well with, for instance, *Centrosema pubescens* Benth. and it can be interspaced with the shrub legume *Leucaena leucocephala* (Lamk) de Wit.

Diseases and pests The most common disease is a blight caused by *Helminthosporium sacchari*. The best control measure is to use a resistant cultivar. No major pests have been recorded.

Harvesting Elephant grass can be harvested year-round. It is usually offered fresh to animals, but it can also be conserved as silage. However, preservation is often poor and losses of DM and crude protein can be very large. Best results are obtained by chopping the material, mixing it with molasses, and compressing and covering it to exclude air.

Yield Annual DM yields that can be expected in farm practice may range from 2–10 t/ha for unfertilized or slightly fertilized stands and from 6–40 t/ha from grass well fertilized with N and given a basic dressing of P.

Cattle liveweight gains of 1 kg/animal per day during the growing season and of 120 kg/animal and 480 kg/ha per year over 3 years were recorded on N fertilized dwarf elephant grass ('Mott') in Florida, United States.

Genetic resources Because of clonal propagation, planted stands of *P. purpureum* are often uniform. However, the species contains much variation in the extent of hairiness of stem nodes and leaf-sheaths, and the size, colour and density of the panicle. There are also differences in stem thickness and height and leaf size between forms of the grass, but these are greatly influenced by the fertility of the soil and by rates of fertilizers.

Breeding *P. purpureum* × *P. americanum* (L.) Leeke hybrids have been developed in many countries. They produce larger plants with more tillering and larger total production. However, this also means that more mineral nutrients are required. The hybrid is sterile and therefore must be vegetatively propagated.

Prospects Elephant grass is widely grown in tropical regions and, with adequate use of fertilizers, large increases in yield can be expected. By harvesting at a young stage of growth or by using dwarf cultivars, forage of high feeding value can be obtained. An advantage of this species is its versatility. It can be grown on a large or small scale; it lends itself to mechanization but is also suitable for smallholder agriculture.

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L. 't Mannetje

Pueraria phaseoloides (Roxb.) Benth.

Journ. Linn. Soc. 9: 125 (1865).
LEGUMINOSAE
$2n = 22, 24$

Synonyms *Dolichos phaseoloides* Roxb. (1832), *Pueraria javanica* (Benth.) Benth. (1865), *P. phaseoloides* Roxb. var. *javanica* (Benth.) Baker (1876).

Vernacular names Tropical kudzu, puero (Australia) (En). Indonesia: krandang (Javanese), foea banga (Ternate). Malaysia: kudzu tropika. Philip-

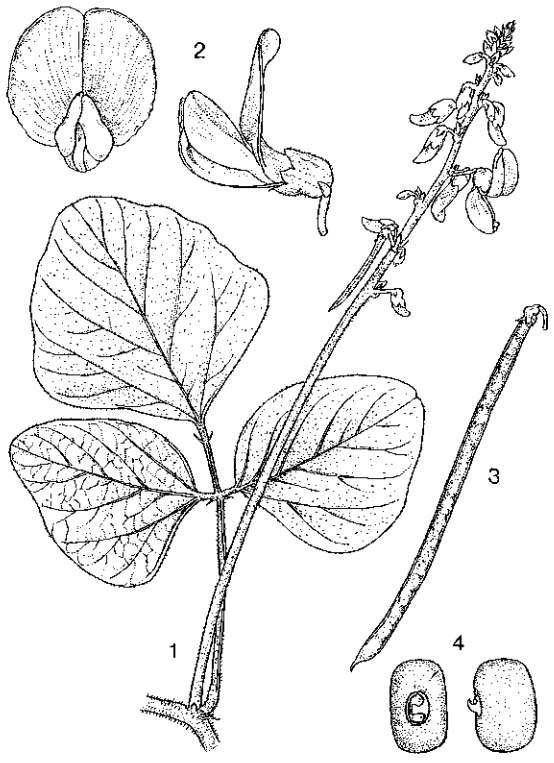
pines: singkamasaso (Tagalog), bahay (Bikol), vaay (Ivatan). Laos: pièd, s'üak pièd. Thailand: thua sian paa (Ang Thong). Vietnam: dâu ma, dâu dai, dâu rùng.

Origin and geographic distribution Tropical kudzu is indigenous to the lowlands of East and South-East Asia where it is widely cultivated as a cover crop. It has been introduced to other tropical regions and is now naturalized in many areas including the wet tropics of Australia and the Americas.

Uses Tropical kudzu is especially important as a component of grazed and ungrazed cover crop mixtures in rubber and oil-palm plantations in South-East Asia, Africa and tropical America. It is used as a pasture legume in South-East Asia, tropical America and Australia. Its ability to smother weeds makes it a useful pioneer legume in combination with other more permanent species. It has been planted on sloping sites to reduce soil erosion. In mixtures with other cover crops, it has been used as green manure by periodic incorporation into the soil. The tuberous roots are edible. Strong fibres from the stem are used for rope making. In Malesia the plant is used in traditional medicine to cure boils and ulcers.

Properties Tropical kudzu is a very palatable legume, although its wet season palatability is reported to be low in tropical America. Nutrient concentrations typically range from 2–4% N, 30–40% crude fibre, 0.15–0.45% P and 0.4–1.6% Ca. Seed weight is 80–90 seeds per g.

Description Deep-rooting perennial herb with climbing or twining, hairy stems. Roots subtuberous. Main stems ca. 6 mm diameter, extending 4.5–10 m, rooting at nodes if in contact with moist soil, lateral stems branching from nodes; young shoots densely covered with brown hairs. Leaves large, trifoliolate, borne on hairy petioles 2–13 cm long; leaflets triangular or ovate, 2–20 cm × 2–15 cm, thin, base broadly cuneate or subrhomboidal and very shallowly lobed, apex acuminate, laterals oblique usually 6–7 cm long and wide, thinly hairy on upper surface, greyish-green and densely pubescent on lower surface; stipules small, lanceolate, ciliate with long brown hairs. Flowers small, mauve to deep purple, borne in scattered pairs on axillary racemes 15–30 cm long; peduncle about 13 cm long; bracteoles lanceolate, 1–3 mm long; calyx campanulate, 6 mm long, hairy, upper teeth broad, lateral ones triangular, the lower lanceolate and all terminating in a bristle; standard orbicular, 1–2 cm diameter, spurred, greenish on outside and white on the inner side with a mauve violet central blotch. Pod straight or slightly curved, terete or compressed cylindrical, 4–11 cm × 3–5 mm, thinly clothed with stiff appressed hairs, black when mature and containing 10–20 seeds. Seed oblong to squarish with rounded corners, about 3 mm × 2 mm, brown to brownish-black.



Pueraria phaseoloides (Roxb.) Benth. – 1, flowering branch; 2, flower, frontal and side view; 3, fruit; 4, seeds.

Growth and development Seedlings of tropical kudzu are only moderately vigorous and may only grow slowly for the first 3 or 4 months. Nevertheless, seedling vigour is superior to other cover crop species such as *Centrosema pubescens* Benth. (centro) and *Calopogonium mucunoides* Desv. (calopo). Once established, it is very vigorous and quickly smothers weeds. It can form a tangled mat of vegetation 60–75 cm deep, and climb trees and fences.

Other botanical information Sometimes 2 botanical varieties are distinguished within *P. phaseoloides:* var. *phaseoloides* and var. *javanica.* In this view, var. *javanica* is a more robust plant with larger flowers and pods. There is no registered Australian cultivar; seed may be traded, but without cultivar name.

Ecology Tropical kudzu is only suited to the humid tropics with an annual rainfall in excess of 1500 mm. It has a temperature optimum of 32/24°C (day/night) and dry matter yields are reduced by 35% with a change in temperature regime to 26/15°C. Few reports are available on photoperiod responses. In Puerto Rico (lat. 18°N), flowering and seed set occur in the short daylength period from January to March, suggesting that it may be a short-day plant. Tropical kudzu has been ranked highly as being shade-tolerant in comparison with other legume species. Under a 50% shade regime in coconut plantations in the Solomon Islands, it was the most productive legume and it even suppressed the accompanying grasses. This characteristic makes it suitable in integrated livestock/plantation production systems. Under a more than 50% shade regime, tropical kudzu gives way to centro or desmodium (*Desmodium heterocarpon* (L.) DC. ssp. *ovalifolium* (Prain) Ohashi).

Tropical kudzu is tolerant of waterlogged sites. It prefers heavy soils and is well adapted to acid soils. It is particularly susceptible to Mg and S deficiencies and has moderate to low Ca and P requirements, but it responds to fertilizer application.

Propagation and planting Tropical kudzu is usually planted by seed. It has a high proportion of hard seed and germination can be increased by using either hot water, acid or mechanical scarification. Commercial suppliers often sell scarified seed which is obtained by abrading the seed-coats in a hexagonal drum, lined with sandpaper, rotating at 7.5 rpm for 24 hours.

Tropical kudzu will usually nodulate with native cowpea rhizobia but inoculation with the appropriate strain of *Bradyrhizobium*, such as RRIM 768 in Malaysia, is recommended when planting in new areas. Seed is usually broadcast or drilled in rows 1 m apart. It can also be established by oversowing into an existing pasture if the pasture is disked or burnt beforehand. It can be propagated vegetatively, one recommendation being to plant two rooted cuttings, 0.7–1 m long, at each point on a 1–2 m grid.

Standard cover crop mixtures include a 5:4:1 ratio of calopo, centro and tropical kudzu or a 4:1 mixture of centro and tropical kudzu. Seeding rates for these mixtures are 2–5 kg/ha in the inter-row areas between rubber or oil palm trees.

Husbandry Tropical kudzu responds well to added P; linear responses to at least 50 kg/ha of P have been obtained on infertile soil.

Tropical kudzu is very palatable, much more so than calopo, and this can lead to selective grazing and poor persistence. Grazing experiments in Malaysia have shown that under continuous grazing at stocking rates of 2, 4 and 6 local cattle per ha, the proportion of tropical kudzu was significantly reduced with increased stocking even after one year of grazing while the effect of stocking rate on centro was only evident after three years grazing. Farmers using grass-legume mixtures have also reported excellent growth of tropical kudzu in the first two years, which thereafter rapidly declined under grazing. The lack of persistence of tropical kudzu is probably also influenced by soil physical characteristics and related to the poor development of rooted stolons on some soils.

When planted under palm and tree crops on former high forest land, some initial control of natural regrowth of forest plants is necessary to establish tropical kudzu. During the subsequent two years, tropical kudzu has to be cutlassed or beaten down to a height of 30 cm. Rings around trees are cleanweeded to prevent tropical kudzu from climbing the trees.

Diseases and pests Tropical kudzu is remarkably free from diseases, but leaf-eating caterpillars can damage ungrazed swards and pod-borers reduce seed production.

Harvesting Usually tropical kudzu is directly grazed in mixed pastures but can be cut for hay, silage or for stall feeding as fresh forage.

Yield Annual DM yields of up to 10 t/ha from tropical kudzu swards have been recorded in cutting experiments, with some $\frac{2}{3}$–$\frac{3}{4}$ of the yield from the wet season and $\frac{1}{3}$–$\frac{1}{4}$ from the dry season. DM yields of up to 23 t/ha have been measured in tropical kudzu-grass swards, 40% of this being tropical kudzu. In tropical America, tropical kudzu-grass pastures have produced live weight gains of 313 kg/ha per year (with *Andropogon gayanus* Kunth) and 542 kg/ha per year (with *Panicum maximum* Jacq.)

Genetic resources and breeding The largest germplasm collection is maintained by CIAT (Colombia) and a smaller collection is held at ATFGRC (CSIRO, Australia). There are no known breeding programmes with this species.

Prospects Tropical kudzu is widely grown throughout the humid tropics, especially in plantation crops. Its main features as a forage legume are its vigorous initial growth on fertile soil and its high palatability. Improvements in this species should primarily be aimed at improving its persistence under grazing.

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R.A. Halim

Saccharum spontaneum L.

Mant. pl. alt.: 183 (1771).
GRAMINEAE
$2n$ varies from 48 to 128

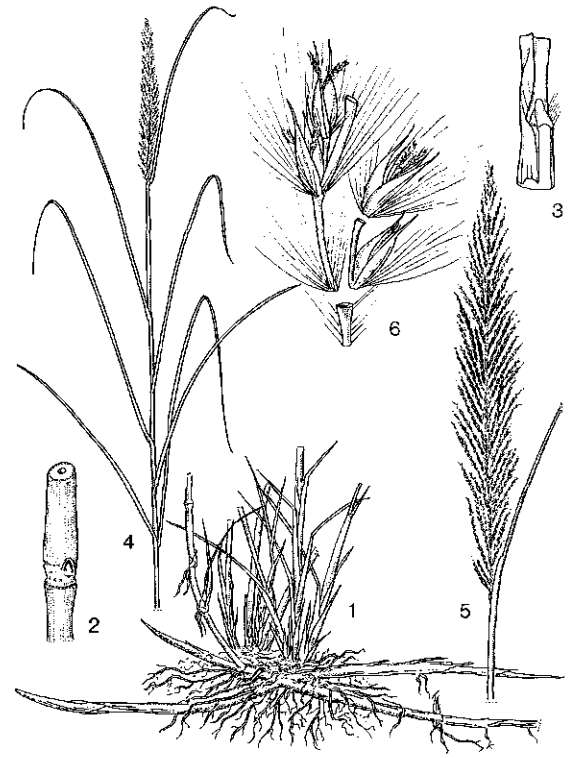
Vernacular names Indonesia: glagah (Javanese), tatebu (Timor). Papua New Guinea: pit-pit. Philippines: talahib (Tagalog), tigbau (Bikol), sidda (Ilokano). Cambodia: 'âm'pëu préi. Laos: ph'ông, lau. Thailand: phong, lao. Vietnam: co' lách.

Origin and geographic distribution *S. spontaneum* originates from and is widely distributed in the warmer regions of the Old World, including South-East Asia.

Uses It is used by villagers as a fodder for cattle, buffaloes and, in some places, elephants. It is also used to prevent erosion of sandy soils. The foliage is used for thatching and the plant is used as an ornamental and to produce paper pulp.

Properties Nitrogen concentrations ranging from 0.5–1.4% have been measured in India and Thailand. It is relished by water buffaloes and elephants but is less attractive to cattle. In the Philippines it is claimed that N-fixing bacteria live in symbiosis with *S. spontaneum*.

Botany Rhizomatous perennial, with culms 1–4 m tall or more, waxy below the nodes. Leaf-sheath tight, 20 cm or more long, overlapping, striate, often purplish, glabrous; ligule obtuse or triangular, about 2 mm long, shortly ciliate; leaf-blade linear-acuminate, 50–90 cm × 5–15(–40) mm, glabrous, margins scaberulous. Inflorescence a panicle, 20–60 cm long, axis hirsute; racemes 3–15 cm long, usually much longer than the supporting branches; spikelets paired, one sessile, one pedicelled, similar, lanceolate, 3–7 mm long, the callus bearded with silky white hairs 2–3 times as long as the spikelet; glumes ciliate on the margins above. Caryopsis about 1.5 mm long.



Saccharum spontaneum L. – 1, base of plant; 2, culm node; 3, ligule; 4, flowering culm; 5, panicle; 6, part of raceme with (partly separated) spikelets.

S. spontaneum is a polymorphic species of which its many forms are commonly grouped into two subspecies:

- ssp. *spontaneum*: leaf-blade narrowed to the midrib towards its base; ligule ca. triangular; mainly in tropical and warm temperate Asia;
- ssp. *aegyptiacum* (Willd.) Hack.: leaf-blade not narrowed at base; ligule crescent-shaped; mainly in Africa and the Middle East.

Seeds germinate poorly, but once germinated the seedlings resist harsh conditions and soon develop a strong root system. Large tussocks will form when grown on river banks or ditches, thereby colonizing large areas. It flowers towards the end of the rainy season.

Ecology *S. spontaneum* grows from near sea-

level up to 1700 m altitude. It prefers a high rainfall environment, usually in excess of 1500 mm per year, and is adapted to a wide range of soils, from alluvial soils on river banks to sandy soils of old mines.

Agronomy *S. spontaneum* is easily propagated by division of rhizomes. The spikelets bear long silky hairs and are easily and effectively dispersed by wind. It is tolerant of heavy grazing. Regular grazing or cutting is required to keep plants in a leafy state so that they maintain their palatability. Burning also helps the plants to produce new shoots for grazing. It is normally grazed by village cattle and water buffaloes, but young leaves can also be cut and fed to the livestock. It is expected to give fairly high yields. Young leaves can also be made into hay for the dry season as is done with sugar cane tops. In Thailand it is reported to be a host for a downy mildew fungus that badly affects maize plants.

Genetic resources and breeding It has been thought that *S. spontaneum* can cross naturally with sugar cane to produce a hybrid known as *S. sinense* Roxb. which is almost completely sterile. *S. spontaneum* is a very variable species but it is unlikely that any germplasm collections are being maintained.

Prospects For forage purposes, cultivars with better palatibility and nutritive status are required. *S. spontaneum* has good prospects for use in controlling soil erosion and reclaiming mine waste.

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C. Manidool

Sesbania grandiflora (L.) Poiret

Lamk, Encycl. Méth. Bot. 7: 127 (1806) ('*Sesban*').
LEGUMINOSAE
$2n = 24$

Synonyms *Robinia grandiflora* L. (1753), *Aeschynomene grandiflora* (L.) L. (1763), *Agati grandiflora* (L.) Desv. (1813).

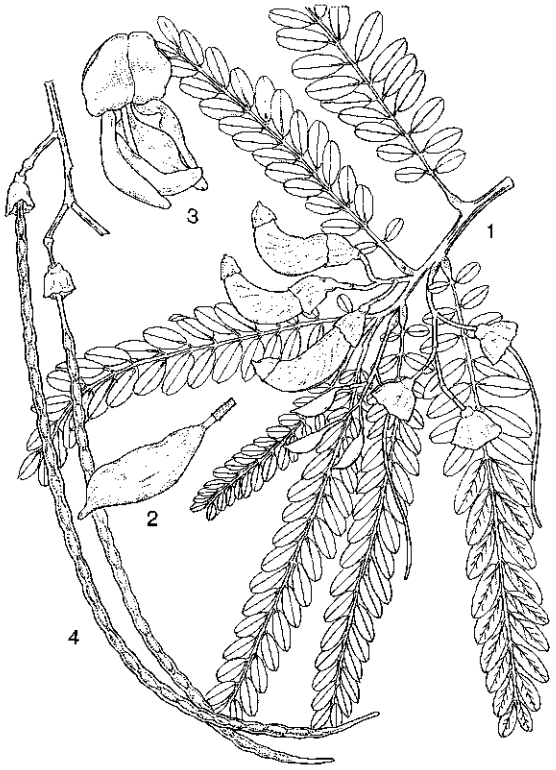
Vernacular names Agati sesbania, West-Indian pea (En). Fagotier (Fr). Indonesia: turi (Sundanese), toroy (Maduranese), tuwi (Balinese). Malaysia: sesban, kacang turi (Peninsular), petai belalang (Sabah). Philippines: pan (Tagalog), gauai-gauai (Visaya), katuday (Ilokano). Cambodia: 'ângkiëdèi. Laos: kh'ê: kha:w. Thailand: khae, khae-ban. Vietnam: so dũa.

Origin and geographic distribution The exact country of origin of *S. grandiflora* is not known (India or Indonesia have been suggested) but it is considered native to many South-East Asian countries. It is widely distributed through the tropics from southern Mexico to South America and has been planted in southern Florida and Hawaii. It has been cultivated for at least 140 years in West Africa and more recently in East Africa.

Uses The leaves and fruits are used as forage and green manure. The tree can be used as an ornamental, a shade tree, a windbreak, a living fence, a live support for crops like pepper and vanilla, and for the reforestation of eroded areas. In South-East Asia it has long been used for fuelwood. The young leaves, flowers and tender pods are used as a vegetable for salads, curries and soups. The tree is used as a pulp source for the paper industry, especially in East Java. The light wood is used in floating fishing nets. The extracts from leaves, flowers, bark and roots are known for their traditional medicinal uses (e.g. the root is a well known medicine for malaria). The bark, when cut or damaged, exudes a clear gum which has some potential in the food and non-food industries.

Properties Many reports indicate that *S. grandiflora* is a very palatable fodder with a high feeding value for ruminants. The N concentration of the seeds is up to 6.5 % and it ranges from 3.0–5.5 % in the foliage. This makes it a very suitable supplement for poor quality roughages. The DM digestibility of foliage ranges between 65 % and 73 %; it generally has a low crude fibre content (5–18 %) and a relatively high P concentration (0.30–0.45 %). The information on anti-nutritional factors is limited and although the foliage contains saponins and tannins it has no known toxic reaction to ruminants. However, caution should be used in feeding it to monogastric animals as it has caused mortality in chickens. *S. grandiflora* has 14–20 seeds/g. The wood is white and soft and not durable. Its low specific gravity of 0.42 kg/dm^3 makes it also a poor fuelwood.

Description A loosely branching tree, up to 15 m tall and about 30 cm in diameter. Roots are nor-



Sesbania grandiflora (L.) Poiret – 1, flowering branch; 2, flower bud; 3, flower; 4, fruits.

mally heavily nodulated with large nodules. The tree can develop floating roots and aerenchyma tissue. Stems tomentose, unarmed. Leaf pinnately compound, up to 30 cm long, including a petiole of 7–15 mm long; the rachis slightly pubescent or glabrous; leaflets 20–50, in pairs opposite to alternate on the same leaf, oblong to elliptical, 12–44 mm × 5–15 mm, rounded to obtuse to slightly emarginate at the apex, slightly asymmetrical at the base, glabrous or sparsely pubescent on both surfaces; stipels filiform, 0.75–1 mm long, pubescent, persistent; stipules broadly lanceolate, 8 mm long, early deciduous. Raceme axillary, 2–4 flowered, rachis up to 65 mm long; peduncle 15–35 mm long, tomentose; pedicels 15–18 mm long, pubescent; bracts lanceolate, 3–6 mm long, early deciduous; bracteoles broadly lanceolate, 4–6 mm long, deciduous; flower white, yellowish, rose-pink or red; calyx 15–22 mm long, closed in young buds, splitting or breaking in various ways at anthesis, the basal part persistent in fruit; standard up to 10.5 cm × 6 cm, no appendages at the claw; wings up to 10.5 cm × 3 cm without a basal tooth; keel up to 10.5 cm × 4.5 cm with basal tooth; staminal tube 10–12 cm long, curved for most of its length; ovary and style glabrous. Pod linear to slightly falcate, 20–60 cm × 6–9 mm with broad sutures, 15–50 seeded, septa 7.5–10 mm apart, glabrous, hanging vertically, indehiscent. Seed subreniform, 6.5 mm × 5 mm × 2.5–3 mm, dark brown.

Growth and development One of the characteristics of *S. grandiflora* is its rapid early growth, reaching heights of up to 2 m in 12 weeks, 4–5 m in one year and about 8 m in 3 years. It is able to produce ripe pods nine months after planting. *S. grandiflora* seeds lose their viability after about one year when stored at ambient conditions. It improves soil fertility, although the ability to fix N may be suppressed by nematodes or high acidity of the soil. It has responded to the inoculation of soil with Vesicular-Arbuscular Mycorrhizal (VAM) fungi (*Glomus fasciculatum* and *Glomus mossaeae*). This treatment could facilitate the introduction of this species to P-deficient soils. The tree has a lifespan of about 20 years. It is not wind resistant.

Other botanical information A closely related species, *Sesbania formosa* (F. Mueller) N. Burbridge, is native to northern Australia.

Ecology *S. grandiflora* is only suitable for the lowland tropics, up to 800 m above sea-level, as it is frost-sensitive and cannot tolerate cool temperatures over an extended period. Although it has been successfully grown in arid areas with only 800 mm annual rainfall it is best adapted to places with an annual rainfall between 2000–4000 mm. It can be grown in a wide range of soils including those that are poor and waterlogged. It tolerates saline and alkaline soils and has also some tolerance to acidic soils down to pH(H_2O) 4.5. *S. grandiflora* is able to tolerate flooding over long periods.

Propagation and planting *S. grandiflora* is easily propagated by direct seeding. Although scarification might have some positive effects the seeds usually germinate promptly without any treatment. Seedlings nodulate on most soils without inoculation. Because of its rapid early growth, it can compete very well with weeds. Vegetative propagation by cuttings is possible but seldom practised. Occasionally seedlings raised in polythene bags or other containers are used, to ensure a better establishment. *S. grandiflora* is often planted as individual trees or in rows (spaced 1–2 m apart) along fence lines, field borders and the bunds of rice paddies.

For wood production it can be planted very densely. Over 3000 stems per ha have been used in Australia and India.

Husbandry The foliage of *S. grandiflora* is generally used in a cut-and-carry system. It is usually fed fresh as a supplement to other roughages, but it can also be dried. Although there are several reports that it is browsed, the reaction to and recovery of bushes after direct grazing has not been studied. Fertilizers are rarely used and therefore their effects are not well known.

Diseases and pests Little information is available on the occurrence and importance of diseases and pests in *S. grandiflora*. Reports on the fungus *Pseudocercospora sesbaniae* (grey leaf-spot) are only from India, as is the occurrence of the sesbania mosaic virus. The stem-borer *Azygophleps scalaris* has caused some damage in India. Larvae of the insect *Bruchophagus mellipes* infest and damage seeds. Susceptibility to nematodes has been reported.

Harvesting *S. grandiflora* does not tolerate frequent, complete defoliation; this will cause high mortality rates. Initially the side branches of a tree may be cut, leaving the main growing point untouched. After the tree has reached a height of 3 m or more, the leader can be cut back to heights above 1.5 m.

Yield Forage yields of *S. grandiflora* depend very much on soil fertility and the management imposed. When side branches are lopped periodically a tree can yield up to 27 kg of fresh green leaves per year.

Wood yields of 20–25 m^3/ha per year are commonly achieved in Indonesia. For green manure, yields of 55 t/ha green material have been obtained in Java in 6–7 months.

Genetic resources Small germplasm collections are available at the University of Hawaii (Waimanalo, United States), ILCA (Ethiopia) and ATFGRC (CSIRO, Australia).

Breeding No breeding work is being carried out.

Prospects This species is widely grown in the tropics and has potential for wider use, although prospects for improvement as a livestock fodder are limited. The research needs are: to collect germplasm of *S. grandiflora*, to document diseases and pests, to quantify the yield of forage from border plantings and fences, and to study the anti-nutritional factors that affect ruminants and monogastric animals.

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J.H. Heering & R.C. Gutteridge

Sesbania sesban (L.) Merrill

Philipp. J. Sci., Bot. 7: 235 (1912).

LEGUMINOSAE

$2n = 12$

Synonyms *Aeschynomene sesban* L. (1753), *Sesbania aegyptiaca* Poiret (1806) (as '*Sesban aegyptiacus*').

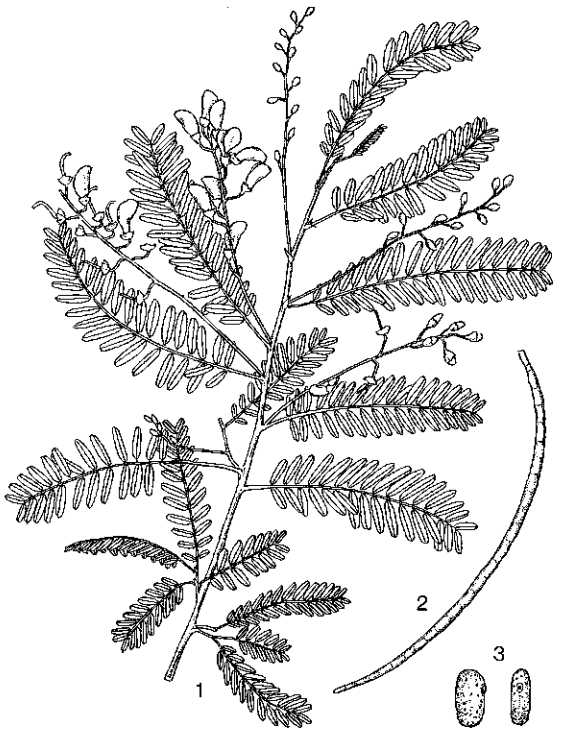
Vernacular names Sesban (En). Indonesia: jayanti (Sundanese), janti (Javanese), puri. Philippines: katuray (Tagalog, Bikol), katodai (Ilokano). Burma: yay-tha-kyee (Burmese), yethugyi. Cambodia: snaô kôôk. Laos: sapao lom. Thailand: sami (central), saphaolom (northern). Vietnam: dien-dien.

Origin and geographic distribution The exact origin of *S. sesban* is unknown, but it is widely distributed and cultivated throughout tropical Africa and tropical Asia. It has been introduced into tropical America.

Uses The leaves and young twigs of sesban are used as fodder for ruminants. The thick branches and stems serve as fuelwood or are used as construction material. Sesban is frequently used to improve soil fertility, either through direct N fixation or through the incorporation of foliage as a green manure to the soil. Sesban can be grown to provide shade (e.g. in coffee, cocoa, turmeric), and as a live support (e.g. in pepper and betel vine) or windbreak for other crops (e.g. banana). Sesban is also used by humans for food from the edible leaves and flowers, for fibre from the bark, for traditional medicines from leaves and flowers, and for gum from the seeds and bark.

Properties The N concentration of sesban leaves ranges between 3.0 and 4.5% of DM. In vitro DM digestibility often exceeds 65% because of a relatively low fibre content. Anti-nutritional factors such as polyphenolic compounds may sometimes have an adverse effect on the digestibility of sesban, but their role is not clearly understood. In view of reported negative effects of sesban in monogastric animals, especially poultry, it is less suitable to be used in diets for these animals. Phosphorus concentrations in the edible portion are generally adequate for animal nutrition. Sesban has 55–80 seeds/g.

Description Shrub or short-lived tree up to 8 m tall. Stem up to 12 cm in diameter, usually pubescent, sometimes becoming glabrous. Leaves, including a short petiole, 2–18 cm long, pinnately compound; leaflets in 6–27 pairs, linear oblong, up to 26 mm × 5 mm, glabrous or almost so above, sometimes pubescent beneath, often pilose at the margins; stipules narrowly triangular, up to 7 mm long, pubescent. Racemes 2–20 flowered, up to 20 cm long, glabrous or sparsely pilose; peduncle up to 5 cm long; pedicels 4–12 mm long, glabrous; bracts and bracteoles linear lanceolate, 3–5 mm long, subglabrous or pilose, very early caducous; calyx up to 6.5 mm long, the tube glabrous, the teeth broadly triangular with an acuminate point 0.5–1 mm long, marginally pubescent; standard ovate, 11–20 mm × 13–21 mm, cordate at the base, yellow and commonly speckled or flecked with violet-purple, claw up to 4 mm long, appendages with acuminate free tips 2–5 mm long; wings 15–19 mm × 4.5–7 mm including a claw of 4–6 mm, yellow, with a broad tooth or short hook at the base; keel 11–21 mm × 6.5–9 mm, including a claw of 6–9 mm, yellow or creamish, basal tooth acute at 0–20 degrees to the claw; staminal tube (9–)12–13(–17) mm long; ovary glabrous or rarely somewhat pilose; style glabrous, 5 mm long. Pod subcylindrical, straight or slightly curved, up to 20–30 cm × 2–5 mm, straw-coloured, often with a brown blotch over each septum or reddish-brown, 10–50 seeded, glabrous; septa 4–8 mm apart. Seed subcylindrical, 3–4.5 mm × 2 mm × 2 mm, olive-green or brown, usually mottled.



Sesbania sesban (L.) Merrill – 1, flowering branch; 2, fruit; 3, seeds.

Growth and development Sesban germinates and grows rapidly; plants can reach a height of 1.5–2 m in 10–12 weeks after sowing under favourable conditions. It usually flowers and produces ripe pods within the first year after planting. The flowers are mostly visited and pollinated by members of the *Hymenoptera*.

Other botanical information *S. sesban* is subdivided into two subspecies, ssp. *sesban* and ssp. *punctata* (DC.) J.B. Gillett, of which the latter occurs only in West Africa from Senegal to the Sudan. The main difference is the length of the staminal tube: 15–17 mm in ssp. *punctata* and 9–13 mm in ssp. *sesban*. The specimens in South-East Asia belong to ssp. *sesban*.

Based on flower colour and hairiness, ssp. *sesban* has been further divided into 4 botanical varieties, which are, however, without much practical value because the distinguishing characters are weak and unstable.

Ecology Sesban grows in areas with a semi-arid to sub-humid climate, with a rainfall between 500 and 2000 mm per year. In East Africa it grows up to an altitude of 2300 m as it can withstand cool temperatures, but not frost. It grows in a wide range of soil types ranging from loose sandy soils to heavy clays. It tolerates saline (1.0% salt concentration in seedling stage to 1.4% at maturity), alkaline (pH(H_2O) < 10) and acidic soils as well as waterlogging and flooding. However, sesban cannot withstand waterlogging immediately after germination or in the early stages of seedling development. Although sesban tolerates low P

levels, the application of P has a positive effect on its growth and nodulation.

Propagation and planting Sesban is propagated by seeds. Scarification of the seeds, using hot water or acid, improves germination. The seeds are sown in a well prepared soil. The planting distance depends on the purpose: as a fence, planting is in rows with a spacing up to 1–2 m; as an alley crop, rows (single or double) are planted 2–10 m apart with a spacing of 25–50 cm between plants; as a fodderbank, rows are 1–2 m apart and plants 25–50 cm apart. Seedlings will normally form root nodules with native rhizobia within 3–4 weeks after planting. Where the effective rhizobia are absent and effective nodulation does not take place, inoculation with an appropriate *Bradyrhizobium* strain is necessary. Sesban has rapid early growth and therefore overcomes weed competition easily and usually requires little maintenance. If necessary, the selective herbicide fluazifop can be used post-emergence at 2 kg of active ingredient/ha to control grass weeds. Vegetative propagation using stem cuttings is possible but rarely practised.

Husbandry Sesban is normally used by cutting the foliage and carrying it to the animals for fodder or to neighbouring fields for green manure. Natural stands of sesban are known to be browsed by ruminants. Limited experience with the effects of direct grazing by cattle have shown that stems are quite brittle and are easily broken but regrowth below the break is rapid. Direct grazing by goats, however, resulted in over 80% plant mortality because of ringbarking 8–20 cm above ground level. Although it responds to fertilizers, especially P and farmyard manure, their application is not a common practice.

Diseases and pests In general the reduction in yield caused by diseases and pests is not large and very few reports are available from South-East Asia. Larvae of the *Azygophleps scalaris* are reported to tunnel in the stem. Seeds can be infested with larvae of *Bruchophagus mellipes* (*Hymenoptera*) which reduce the seed yield. Nematodes can reduce the growth of the plants. In East Africa, larvae of a leaf-feeding beetle *Mesoplatys ochroptera* can completely defoliate and kill sesban. In Australia, larvae of the moth *Orgyia australis* have caused leaf rolling and drop of young leaves. In cool moist conditions in south-eastern Queensland, lesions of the fungus *Botrytis cinerea* girdled the stem resulting in death of leaf and stem above the lesion.

Harvesting Sesban can be cut after it reaches 1–2 m height. Leaving the first cutting until it is > 4 m tall may even be detrimental. Cutting frequency depends on use, soil type and climate but can be as much as 5 times per year. A cutting height of 75–100 cm is best. Too low (< 50 cm) and too frequent cutting decreases the lifespan of plants. In order to increase longevity, it is advisable to leave some foliage on the plant when harvesting. Although usually fed fresh as a supplement, sesban can also be dried.

Yield The fodder yields of sesban depend on soil type, soil fertility and moisture, climate and on management factors, such as planting distance, cutting height and frequency. Under favourable conditions DM yields of 20 t/ha per year have been obtained. The edible fraction (leaves and young twigs) ranges from 30–60% depending on the growing conditions and cutting frequency. In a subtropical environment DM yields of 5 t/ha over 6 months have been obtained at a cutting height of 100 cm and cutting frequency of 8 weeks.
Seed production depends on growing conditions but can be as much as 1–2 t/ha.

Genetic resources Sesban is the most widely collected species of the genus *Sesbania* Adanson, but only few accessions are of Asian origin; most were collected in Africa. Germplasm collections are available at ILCA (Ethiopia), ATFGRC (CSIRO, Australia) and the University of Hawaii (Waimanalo, United States).

Breeding No breeding programmes have been started.

Prospects It is only recently that sesban has received international attention as fodder. Research priorities are to collect germplasm, especially in South-East Asia, to establish proper management systems for alley cropping, to investigate the role of anti-nutritional factors in animal feeding and to develop a proper feeding strategy. The outcome of this research will determine further use of sesban.

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J.H. Heering & R.C. Gutteridge

Setaria sphacelata (Schumach.) Stapf & Hubbard ex M.B. Moss

Kew Bull. 1929: 195 (1929).

GRAMINEAE

$2n = 18$ (diploid), 36, 45, 54, 72, 90 (decaploid)

Synonyms

- var. *sphacelata*: *Panicum sphacelatum* Schumacher (1827);
- var. *sericea* (Stapf) W.D. Clayton: *Setaria anceps* Stapf (1930);
- var. *splendida* (Stapf) W.D. Clayton: *Setaria splendida* Stapf (1930).

Vernacular names General: setaria (En).

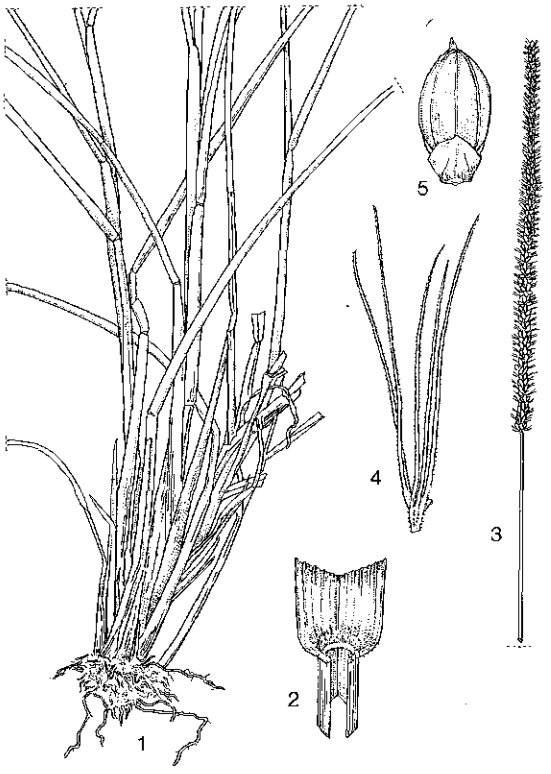
- var. *splendida*: splendida, broadleafed setaria (En). Malaysia: sekoi. Philippines: bunga-bunga. Thailand: ya taiwan. Vietnam: co duôi chó, co ro'm.

Origin and geographic distribution *Setaria* originates from and is widely distributed in tropical and subtropical Africa. It also occurs in Yemen. The species was first brought into cultivation as a pasture plant in Kenya and has since been widely planted throughout the tropics and subtropics, especially in Africa, Asia and Australia. It has become naturalized in many of the countries to which it was introduced. In South-East Asia it is widely planted in Malaysia and Indonesia but is of only minor importance in Thailand.

Uses Setaria is an important forage and is used under grazing and in cut-and-carry systems. The botanical variety *splendida* is reported to be one of the more commonly used species for cut-and-carry systems in Indonesia and Malaysia.

Properties Nitrogen concentrations vary from over 3% in very young growth to under 1% in old growth. It is difficult to compare nutrient concentrations in different cultivars, as they flower at different times. Setaria has a higher moisture content than some other tropical grasses. In Australia accessions have been shown to differ quite widely in digestibility and a range of chemical components, especially Na. Setaria is a species which accumulates oxalate, especially when heavily fertilized with N. This is normally not a problem with ruminants, such as cattle, provided they have been allowed to become used to setaria, but it is a problem with horses, which develop a condition known as big-head (*Osteodystrophia fibrosa*). There are 1200–1900 seeds/g.

Description A tufted, or more rarely rhizomatous, perennial with more or less erect stems to 3 m tall. Young tillers are strongly flattened in commercial cultivars, with leaf-sheath prominently keeled and often red-pigmented, sometimes hairy. Culms vary in number of internodes and diameter, depending on variety and cultivar, few and narrow in 'Nandi', up to 17 and 6–12 mm in diameter in var. *splendida*; nodes hairless; the culms occasionally branching when grown in fertile soils to give multiple inflorescences. Leaf-blade 10–70 cm × 11–12 mm in var. *sericea*, up to 20 mm wide in var. *splendida*, hairless or with a few long hairs close to the junction with the sheath. Inflorescence an elongated cylindrical spike-like panicle 10–50 cm long, the spikelets borne in groups of 2 or 3 on short



Setaria sphacelata (Schumach.) Stapf & Hubbard ex M.B. Moss – 1, habit; 2, ligule; 3, inflorescence; 4, bristles; 5, spikelet.

branches, each spikelet subtended by 5–15 stiff bristles varying in length and colour; spikelets 2.5–3 mm long, flat on the side of the lower glume, convex on the other, the lower glume about $\frac{1}{3}$, the upper $\frac{2}{3}$ the length of the spikelet; lower floret male or sterile, the upper floret bisexual, the palea and lemma hardened and enclosing the caryopsis when ripe.

Growth and development Var. *splendida* is near-sterile, but seed of other varieties germinates reasonably readily in good conditions and establishes without difficulty. If the initial stand has a low plant density, setaria has the capacity to thicken up if allowed to produce a seed crop. Flowering is variable within most cultivars, with plants and tillers within a plant poorly synchronized. Furthermore, a single inflorescence takes from 1–7 weeks to complete flowering. Thus the earliest-formed spikelets may be ripe and shedding when the latest ones have only just flowered. This poor synchrony, together with abscission of the spikelet soon after ripening, is a major contributory factor to low seed production in this species. In subtropical climates, setaria generally produces two seed crops a year.

Other botanical information The mainly African *S. sphacelata* is a polyploid complex, running from diploid to decaploid, with the different ploidy levels crossing freely without showing clearly different morphological characters. For convenience only, the enormous variability of the complex species has been divided into 5 botanical varieties which, however, intergrade completely and do not represent discrete entities. Only two varieties are in commercial use:

- var. *sericea*: culms 4–10-noded, 3–6 mm in diameter, up to 2 m tall; basal leaf-sheaths conspicuously flabellate; leaf-blades 3–10 mm wide, glabrous; panicle 7–25 cm long; bristles fulvous.
- var. *splendida*: culms 6–16-noded, 6–12 mm in diameter, very stout, up to 3 m tall; basal leaf-sheaths often flabellate; leaf-blades 10–17 mm wide, glabrous; panicle 20–50 cm long; bristles fulvous.

Cultivars of var. *sericea* include 'Nandi', a diploid, and 'Narok', 'Kazungula' and 'Solander', tetraploids. 'Narok' was selected for its cool-season productivity and winter-greenness in frost-prone subtropical environments, but seed production is poor, owing to the low percentage of tillers bearing inflorescences, especially in older seed production stands. This was partially remedied with the release of 'Solander', which is similar to 'Narok' in winter-greenness and yield but has much higher seed production, associated with higher tiller fertility. 'Kazungula' produces more seed than other cultivars, but becomes extremely stemmy when mature. Hybridization between var. *splendida* and var. *sericea* and selection in Australia led to the release of the seed-producing cultivar 'Splenda', which has yielded well in trials throughout South-East Asia and the South Pacific.

Ecology In natural grasslands at moderate to high altitudes in East Africa, setaria can constitute a considerable proportion of the herbage but is rarely dominant. Setaria grows at higher altitudes in the tropics than other panicoid pasture grass species, and this has been associated with evolutionary physiological adaptation to sub-zero night temperatures. Varieties and cultivars differ in their adaptation and yield, although all require a relatively moist environment and have low drought tolerance. In general, setaria cultivars have some tolerance of intermittent waterlogging. 'Kazungula' is considered to be one of the better adapted forages for the lowland wet tropics receiving at least 1200 mm annual rainfall. In Malaysia it has been commonly recommended as an improved forage for sowing in smallholdings and commercial enterprises since the early 1970s. 'Kazungula' can tolerate brief periods of moisture stress and is suited to well-drained soils of lower fertility. The variety *splendida* is also well adapted to the humid lowland tropics. 'Nandi', 'Narok' and 'Solander' are better adapted to the subtropics or elevated tropics receiving more than 1000 mm of annual rainfall.

Propagation and planting Most cultivars and varieties are sown by seed, except for var. *splendida*, which needs to be vegetatively planted. This has to some extent limited the usefulness of var. *splendida* in Malaysia and Indonesia. For vegetative planting, plants should be topped to a height of about 15 cm, split into pieces of 2–3 tillers, and planted without allowing them to dry out. Successful establishment usually exceeds 90%, providing the soil remains moist following planting. Setaria seed should be sown at a rate of at least 2 kg/ha. Establishment is most successful in a fully-cultivated seed-bed. Setaria may be sown with a companion legume, such as *Centrosema pubescens* Benth. or *Neonotonia wightii* (Wight & Arnott) Lackey, and may produce a stable pasture mixture, although var. *splendida* and 'Kazungula' compete aggressively with legumes and are less suitable for mixed pastures.

Husbandry Setaria should be grown on a relatively fertile soil or fertilized, particularly with N,

if it is to yield to its potential. It responds well to applied N and yields exceeding 30 kg dry matter per kg of N applied have been reported. It also has a high requirement for K. It is tolerant of continuous grazing and high grazing pressures, although the latter would have an adverse effect on most associate legumes. In subtropical Australia, well-fertilized setaria pastures sustained continuous stocking rates of up to 6 steers per hectare. Similar stocking rates could be anticipated in tropical regions without a pronounced dry/cool season.

Diseases and pests The leaf disease caused by *Pyricularia grisea* is noted in Australia but is not a serious problem. Inflorescence diseases caused by *Sphacelotheca* sp. and *Fusarium nivale* can be serious in Zaire and setaria bunt, caused by *Tilletia echinosperma*, can devastate seed crops in Kenya. It is considered that there is little likelihood of transmitting this disease in seed, as it is spread from inflorescence to inflorescence in the field. Seed crops in Australia may also be adversely affected by caterpillars.

Harvesting Setaria is both grazed and fed as cut-and-carry forage and can also be made into hay or silage. Thicker stemmed cultivars, such as 'Kazungula' or 'Splenda' are less satisfactory for hay than finer stemmed cultivars such as 'Nandi'.

Yield Annual DM yields of as high as 31 t/ha have been recorded for var. *splendida* in Indonesia and 19 t/ha under regular defoliation in Malaysia. Trials in Malaysia gave higher DM yields for 'Kazungula' than 'Narok' or 'Nandi', and 'Nandi' also yielded poorly in trials at Khon Kaen, Thailand. In Australia, dairy cows grazing var. *splendida* have produced more milk than cows grazing cultivars of other setaria varieties. In beef-production studies var. *splendida* and 'Narok' produced high levels of animal weight gain, although differences between cultivars are most pronounced during the subtropical cool season.

Genetic resources Setaria is an extremely diverse species which in Africa naturally covers a wide latitudinal and altitudinal range. The existence of various intra-specific taxa, at least some of which can be inter-hybridized, is an indication of its morphological diversity. Germplasm resources are held by ATFGRC (CSIRO, Australia) and a smaller collection by CIAT (Columbia).

Breeding Hybridization between ecotypes may be carried out without difficulty. Being a cross-pollinated species, combining inflorescences in a bag when at anthesis results in a high proportion of hybrid seed. However, the existence of an extensive polyploid series is a barrier to gene transfer. Although hybrids can be produced between tetraploids and hexaploids, and between hexaploids and octaploids, they are likely to be unstable as they have an odd number of genomes.

Prospects Setaria has been shown to be a successful species in Malaysia and Indonesia, and it can be expected that its usefulness will extend to pasture developments elsewhere in the region. The relatively reliable establishment of setaria when sown by seed is a point in its favour. The new cultivar 'Splenda' is likely to take over from 'Kazungula', especially in flood-prone and high rainfall environments.

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J.B. Hacker

Sorghum × *almum* Parodi

Rev. Argent. Agron. 10: 361 (1943).
GRAMINEAE
$2n = 40$ (tetraploid)

Vernacular names Columbus grass (En). Pasto colon, sorgo negro (Sp). Philippines: batag (Tagalog), gau (Ifugao). Thailand: ya-sokum.

Origin and geographic distribution This species, first noted in Argentina, is considered to be a natural hybrid between *S. halepense* (L.) Pers. (Johnson grass) and *S. bicolor* (L.) Moench (grain sorghum). It has been introduced into some South-East Asian countries, notably Thailand, but is

only used to a very limited extent.

Uses Used as a forage for grazing by cattle, or less commonly for hay or silage, Columbus grass has now largely been replaced by the man-made hybrid cultivar 'Silk'. Columbus grass is mostly grown in pure stands.

Properties Herbage of Columbus grass is of reasonably high quality and N concentrations in leaves can be over 3% if stands are adequately fertilized, although concentrations decrease as plants mature. It is palatable to cattle. Young herbage can accumulate dangerously high levels of HCN which may lead to prussic acid poisoning in livestock. Unlike its putative Johnson grass parent, it can be eradicated without difficulty when so desired.

Botany Densely tufted perennial to about 3 m tall, producing short, thick, ascending terminal rhizomes. Leaf-blade flat, 30–100 cm × 15–40 mm. Inflorescence an open panicle 20–60 cm long, the lowermost branches in whorls of 4–9; spikelets in short fragile racemes, paired, the lower one 5–6.5 mm long, mostly with an awn about 1 cm long; glumes brown or black, completely covering the caryopsis at maturity.

Columbus grass may be distinguished from the widespread weed species *S. halepense* by its short ascending terminal rhizomes and its 5–6.5 mm long sessile spikelets. *S. halepense* has some rhizomes which arise from side buds and elongated and sessile spikelets 4.5–5mm long. Columbus grass cultivars are 'Crooble' and 'Nunbank' (Australia), 'de Soto' (United States) and 'Rietondale' (South Africa).

Sorgum × almum Parodi – 1, base of plant; 2, culm- and leaf- part; 3, inflorescence; 4, sessile spikelet; 5, pedicelled spikelet; 6, caryopsis.

Ecology Columbus grass is well adapted to heavy clay soils and areas receiving 500–800 mm rainfall. It can tolerate drought and some salinity. Stands are not killed by mild frosts. It is intolerant of waterlogged soils.

Agronomy Columbus grass is a reliable seed producer and is sown by seed, either broadcast at 20 kg/ha, or, preferably, drilled in rows 1 m apart at 5–7 kg/ha. Seedlings are vigorous and the species normally establishes without difficulty. Forage yields tend to be best in the season of sowing, and, although in exceptional circumstances it may persist for five years or more, mostly stands are ploughed out after the third year. Columbus grass seeds profusely and, as there is little loss from shedding, seed yields are high.

Columbus grass is commonly grown on more fertile soils and only low levels of N fertilization are required. On less fertile soils, the species responds well to applied N.

Colombus grass is susceptible to leaf blight (*Helminthosporium turcicum*) and leaf rusts (*Puccinia* spp.).

Columbus grass is normally grazed, and topping to a height of 30–40 cm after grazing has been recommended. Stands of Columbus grass should not be grazed within 3 months of sowing nor should young regrowth be grazed, so as to avoid the risk of prussic acid poisoning. For hay or silage, stands should be cut at early flowering stage.

Dry matter yields as high as 19 t/ha per year have been recorded from two cuts. In farm practice, 4–10 t/ha per year can be expected, depending on rainfall and fertility. On an annual basis, liveweight gains of cattle of up to 0.5 kg/head per day can be expected, while weight gains of 1.3 kg/head per day have been recorded over shorter periods.

Genetic resources and breeding Due to its probable hybrid origin and the large diversity of one of the parents, there is potential for extensive variation within *S.* × *almum* which may be exploited by the plant breeder. Columbus grass is

predominantly cross-pollinating. It may be hybridized with Johnson grass, also a tetraploid, and with the diploids *S. bicolor* and *S.* × *drummondii* (Steud.) Millsp. & Chase. A limited germplasm collection is held by ATFGRC (CSIRO, Australia).

Prospects Columbus grass is used only to a very limited extent in South-East Asia and it is not anticipated that its usefulness will increase as better perennial sorghums are available.

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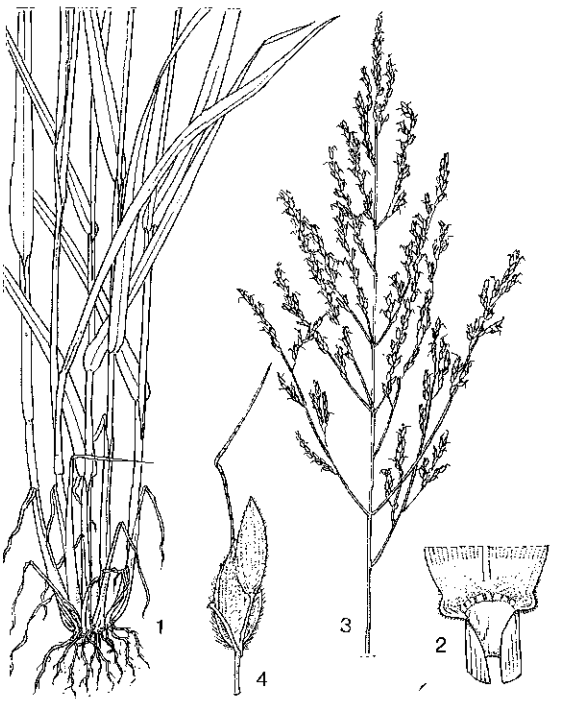
J.B. Hacker



Sorghum, cultivar 'Silk' – 1, habit; 2, ligule; 3, inflorescence; 4, pair of spikelets.

Sorghum, artificial perennial hybrids

GRAMINEAE

$2n = 20, 40$

Vernacular names General: artificial perennial hybrids are usually known by their cultivar names, e.g., 'Silk', 'Krish'. Philippines: batag (Tagalog), batad (Bikol), bukakau (Ilokano). Laos: lüay, khauz f'angx. Thailand: ya khao fang.

Origin and geographic distribution Being man-made hybrids, these are confined to areas where they have purposefully been sown or have since become naturalized. They have only been grown to a limited extent in South-East Asia, but 'Silk' is widely grown in subtropical Australia.

Uses Perennial sorghum hybrids are grown as short-duration perennial forages for grazing by cattle, but can be used for cut-and-carry forage or for hay and silage.

Properties Foliage is very palatable to livestock and 'Silk' has greater in vitro digestibility than *S.* × *almum* Parodi ('Crooble'). Total free sugars in the stem averaged about 20%. In common with other sorghum species, young herbage can accumulate dangerously high levels of HCN which may lead to prussic acid poisoning in livestock. There are 120–160 seeds/g.

Botany Erect perennials with numerous tillers and stems to 4 m tall, with or without a few short rhizomes. Leaf-blade 25–40 mm wide, glabrous except for a few hairs close to the membranous ligule. Inflorescence a large open pyramidal panicle with secondary and tertiary branches, the branches sometimes drooping; spikelets in short, fragile racemes, paired, the lower one sessile and bisexual, with rigid shiny glumes which may be straw-coloured, reddish-brown or black, depending on cultivar, and which tightly enclose the caryopsis when ripe, the upper pedicelled and male; lemmas often awned.

'Krish' is a hybrid between *S. halepense* (L.) Pers. and *S. roxburghii* Stapf; it has not been utilized commercially to any great extent. 'Silk' is a hybrid between 'Krish' and *S. arundinaceum* (Desv.) Stapf. In the subtropics, 'Silk' may easily be established in spring and shows rapid early growth, early tillering and an ability to compete with weeds. In contrast, 'Krish' has poor seedling vigour and growth in spring is also slow; however, it outyields other sorghums provided it is not defoliated before 10 weeks of growth. 'Krish' flowers much later than 'Silk', which is later flowering than *S.* × *almum* cultivar 'Crooble'. 'Krish' has been used as a source of resistance to sugar-cane

mosaic virus in the breeding of grain sorghum (*S. bicolor* (L.) Moench). One of the merits of 'Krish' and 'Silk' is that, unlike the weed-parent *S. halepense*, they can be eradicated without difficulty and hence do not pose a problem to any subsequent crop. However, this does not necessarily apply to other hybrid combinations.

Ecology Perennial sorghums are well-adapted to high temperatures and are well suited to areas receiving from 500–800 mm annual rainfall to periods of moisture stress. In Queensland, Australia, 'Silk' is widely grown on clay soils, and has replaced *S.* × *almum* as a sown forage in these situations.

Agronomy Perennial sorghum pastures may be established by seed into a cultivated seed-bed, either by broadcasting at 20–25 kg/ha or drilled in 1 m rows at 5–7 kg/ha. Perennial sorghum is usually sown in pure stands but can be sown with other grasses with or without legumes. Initally the mixtures grow more slowly, but they are more persistent. The sorghum then provides early grazing and contributes to the suppression of weeds. Perennial sorghums are compatible with cool season forages such as lucerne (*Medicago sativa* L.), annual *Medicago* spp. or oats (*Avena sativa* L.) and warm season legumes such as *Neonotonia wightii* (Wight & Arnott) Lackey or *Lablab purpureus* (L.) Sweet. Young plants or young regrowth should not be grazed owing to risk of prussic acid poisoning. Perennial sorghums are normally grazed, although they are suitable for cut-and-carry systems of management or for hay or silage if not allowed to become too coarse. A recovery period in spring may be necessary to ensure persistence if pastures have been heavily grazed during the cool season. In trials in Australia which led to its release, 'Silk' consistently outyielded *S.* × *almum* 'Crooble' by 24–78%. 'Krish' outyields other forage sorghums late in the growing season. Under continuous grazing in sub-humid Queensland, Australia, steers grazing at stocking rates of 1.5–3 steers/ha averaged liveweight gains of 150 kg/head per year. 'Krish' shows a high degree of resistance to rust and blight, also to sugar-cane mosaic virus.

Genetic resources and breeding Breeder's seed of hybrid cultivars and stocks of parental species are held by ATFGRC (CSIRO, Australia). The perennial hybrid sorghums are cross-pollinating plants which show a considerable degree of intravarietal genetic diversity. Many perennial hybrid combinations have been produced experimentally and the wide range in variability in the genus allows the possibility of new improved cultivars. In Australia the difficulty in distinguishing between seeds of 'Silk' and the noxious weed *S. halepense* has led to efforts to produce a cultivar with tan-coloured seeds by selection within 'Silk'.

Prospects The perennial sorghums have potential in sub-humid regions where yearly cultivation for sowing annual forages is undesirable and where permanent pastures are not required. In more humid regions, over a period of several years, annual forages are higher yielding when yields are averaged over the lifespan of the perennial forages.

Literature |1| Ferraris, R. & Silvey, M.W., 1988. Sward productivity and seasonal animal production from perennial forage sorghums grazed at four stocking rates. CSIRO, Australia. Division of Tropical Crops and Pastures, Technical Memorandum No 56. 22 pp. |2| Oram, R.N., 1990. Register of Australian herbage plant cultivars. CSIRO, Australia. pp. 66–68.

J.B. Hacker

Sorghum × drummondii (Steud.) Millsp. & Chase

Publ. Field Columb. Mus. Bot. 3: 21 (1903); Flora of Trop. E. Africa. Gram. (3): 726 (1982).

GRAMINEAE

$2n = 20$ (counts of 40 are also reported, but require confirmation)

Synonyms *Sorghum sudanense* (Piper) Stapf (1917), *S. bicolor* (L.) Moench ssp. *drummondii* (Steud.) de Wet (1978).

Vernacular names Sudan grass (En). Pasto Sudan (Sp). Philippines: batag (Tagalog), bukakau (Ilokano), layagah (Sulu). Thailand: ya-sudan.

Origin and geographic distribution What is known commercially as Sudan grass is a segregate from a natural hybrid between *S. bicolor* (L.) Moench and *S. arundinaceum* (Desv.) Stapf. This hybrid combination is responsible for several other 'species' which are, however, unstable, and revert to one or other of their parental types. They have all been included in the binomial *S.* × *drummondii* in the Flora of Tropical East Africa. The hybrid originated in the region from southern Egypt to the Sudan, but has rarely been collected there. It was introduced to the United States in 1909 and rapidly became popular as a forage, later being evaluated and sown in other regions with warm and dry growing season.

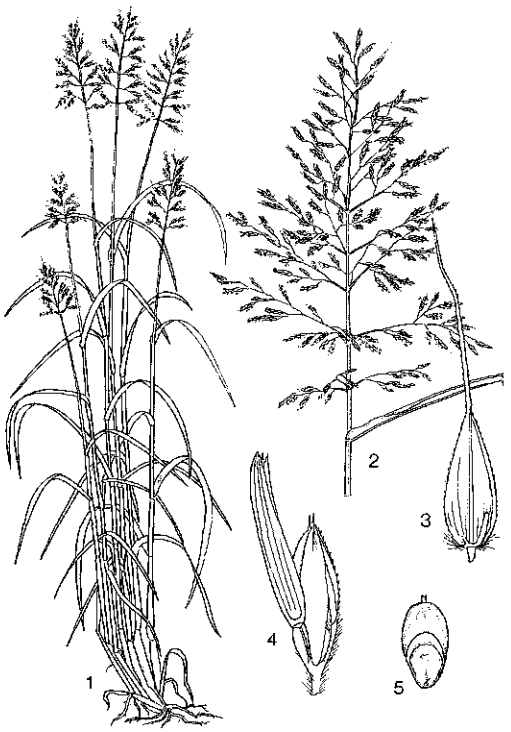
Uses Sudan grass is used as an annual forage for ruminants, but more commonly as a parent in a

wide range of inter-specific F_1 hybrids in which *S. bicolor*, grain sorghum, is the alternative parent. Examples of such hybrids are 'Sudax', 'Zulu' and 'Bantu'. In Thailand, sorghum × sudan hybrids are utilized as fresh cut-and-carry forages or as hay for dairy cattle or water buffaloes.

Properties Nitrogen concentrations can be as high as 3%, although levels fall with increasing maturity. Sudan grass is very palatable to livestock so the level of utilization is high and cattle are reported to consume 80% of the forage at panicle emergence. In common with other sorghum species, young herbage can accumulate quite high levels of HCN which may lead to prussic acid poisoning in livestock. This is rarely a serious problem, except where high levels of N fertilizer have been applied or where the grass is wilted. Prussic acid poisoning is considered to be less of a problem with Sudan grass than it is with either fodder sorghum or sorghum-Sudan hybrids. There are 90–120 seeds/g.

Botany Annual with erect stems to 3 m tall, 3–9 mm thick. Leaf-blade lanceolate, 30–60 cm × 8–15 mm. Inflorescence an open pyramidal panicle with secondary and sometimes tertiary branches which end in short fragile racemes, which do not readily break up at maturity; spikelets paired; sessile spikelet 6–7 mm long; glumes loosely hairy, shiny and almost hairless when mature; upper lemma with an awn up to 16 mm long; pedicelled spikelet about as long as the sessile spikelet, but narrower. Caryopsis variable, enclosed by the glumes.

Seedlings emerge 5–6 days after sowing. Flowering in Sudan grass is to some extent photoperiod-sensitive, but in the tropics it flowers freely. As the racemes do not break up easily, seed production of Sudan grass is easier than it is with many tropical grasses, even though flowering within individual plants is poorly synchronized. A number of 'cultivars' which are marketed as Sudan grass are, in fact, hybrids with other species. There are relatively few cultivars available within *S.* × *drummondii* as such, but considerable numbers of open-pollinated and F_1 hybrids have been developed. Examples, and their parentage, are: 'Tift' (Sudan grass × 'Leoti' sweet sorghum) × Sudan grass; 'Piper' ('Tift' × Sudan grass); 'Greenleaf' ('Leoti' sweet sorghum × Sudan grass); 'Lahoma' (Sudan grass × 'Leoti' sweet sorghum); 'Sucro'-(perennial) (*S.* × *almum* × perennial sweet Sudan grass); 'Sudax'(F_1) (male sterile grain sorghum × Sudan grass); 'Zulu'(F_1) (male sterile grain sorghum × 'Greenleaf') (see above); 'Bantu'(F_1) (male sterile grain sorghum × 'Piper') (see above).



Sorghum × *drummondii (Steud.) Millsp. & Chase – 1, habit flowering plant; 2, inflorescence; 3, long-awned spikelet; 4, pedicelled and sessile spikelet; 5, caryopsis.*

Ecology Sudan grass is not adapted to the humid tropics, but is suited to warm conditions with low humidity and an average annual rainfall of 600–900 mm. It is intolerant of waterlogging but has reasonable tolerance of salinity.

Agronomy Sudan grass should be sown in a well-prepared seed-bed, either broadcast or preferably drilled in rows 25–50 cm apart (wider in drier climates) and not deeper than 2.5 cm, at seeding rates of 8–12 kg/ha when drilled and 12–16 when broadcast. Higher rates have been recommended in more humid areas. It is normally grown as a pure crop, although companion legumes such as *Glycine max* (L.) Merrill and *Vigna unguiculata* (L.) Walp. have been used. It responds well to irrigation in dry climates. Relatively low levels of fertilizer are normally used, but it responds to N, P and K fertilizers where these nutrients are deficient in the soil. Cultivars differ in resistance to leaf diseases. These diseases are of greater concern where the crop is grown under conditions of higher humidity and rainfall than it is normally suited to.

Sudan grass may be grazed, chopped and fed directly, or made into hay or silage. As stems are thin, compared with the perennial sorghum species, it dries quickly, which is an advantage when haymaking. Yields of green fodder average 20–40 t/ha but may be twice as high with optimal fertilizer use. Milk production may be low if sulphur is limited in Sudan grass forage.

Genetic resources and breeding Genetic resources within *S.* × *drummondii* are limited, but there is a considerable genetic resource associated with closely related species with which it can be hybridized. Limited germplasm is maintained under the binomial *S. sudanense* at ATFGRC (CSIRO, Australia). More extensive collections of *S.* × *drummondii* and related hybrids are held by the USDA (Fort Collins, Colorado and Beltsville, Maryland) and ICRISAT (India).

Prospects In a number of countries, commercial companies have a major interest in production of F_1 hybrid forages, and it can be anticipated that there will be a continuing flow of new hybrid cultivars with improved characteristics. As with existing cultivars, these are likely to be better adapted to the less humid parts of South-East Asia.

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J.B. Hacker

Stenotaphrum secundatum (Walter) O. Kuntze

Revis. gen. pl. 2: 794 (1891), ('*secundum*').
GRAMINEAE
$2n$ = 18, 27 (triploid), 36 (tetraploid), 54 and 72

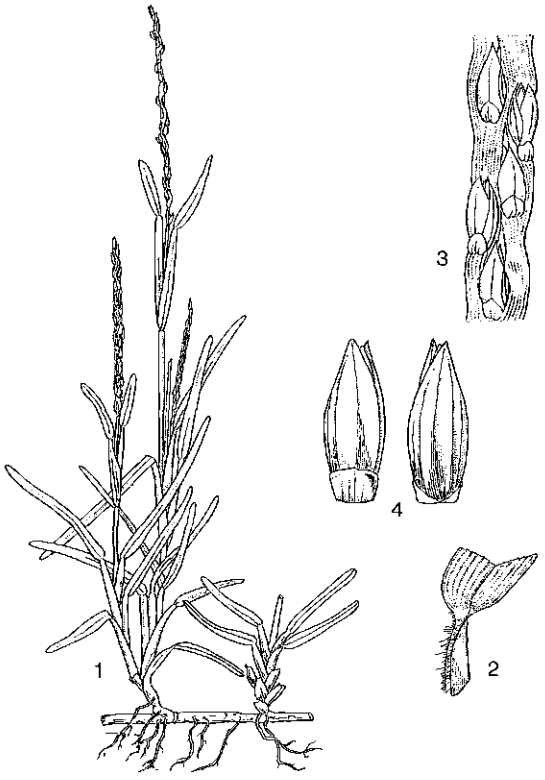
Vernacular names St. Augustine grass, crab grass, buffalo grass (En). Gros chiendent (Fr). Vietnam: co'quai chèo.

Origin and geographic distribution Although its natural distribution is on the shores of the Atlantic Ocean, St. Augustine grass is now found quite extensively in Australia and the Pacific, too, always in coastal areas. In cultivation it occasionally occurs outside its natural range.

Uses St. Augustine grass is used for grazing in open areas, but is also showing considerable promise for use under plantation crops. It is also a popular lawn grass and is used for soil conservation.

Properties The quality of St. Augustine grass declines throughout the growing season, with N concentrations between 2.6% and 2.0%. Digestibilities of crude protein decline from 53% to 31% and DM digestibilities from 60% to 50%. It is palatable when young, but palatability of old material is low.

Botany A stoloniferous perennial with upright or ascending stems, often much branched, 10–50 cm tall. Leaf-sheath tightly compressed and keeled; ligule a ring of hairs, 0.5 mm high; leaf-blade oblong-linear, 3–15 cm × 4–10 mm, plicate when young, obtuse, glabrous, slightly bluish. Inflorescence terminal or axillary, 5–10 cm × 5–10 mm, composed of 10–20 racemes each 0.5–1



Stenotaphrum secundatum (Walter) O. Kuntze – 1, flowering plant; 2, ligule; 3, detail of inflorescence; 4, spikelet in two views.

cm long and bearing 1–3 spikelets; main axis thick, corky, flat on one surface, deeply hollowed out on the other, each cavity containing a raceme, borne alternately on either side of a wavy midrib; spikelets sessile, lanceolate, up to 5 mm long; lower glume 1–2 mm long, nerveless; upper glume 4–5 cm long, 5–7-nerved; lower floret neuter, upper floret bisexual. Caryopsis oblongoid to obovoid, about 2 mm long.

A form with abnormally slender inflorescences occurs in South Africa and Brazil (called 'Natal-Plata deme' by Sauer); a form with almost strobiloid inflorescences is a sterile triploid and occurs in South Africa, Australia and the Pacific islands (called 'Cape deme' by Sauer).

The species only flowers occasionally in the wet tropics, hence seed production is very poor. The most popular cultivar for lawns, 'Roselawn', is used in several countries.

Ecology St. Augustine grass is primarily a coastal pioneer. It occurs at altitudes from sea-level up to 800 m, and could well grow at higher elevations than this as it is one of the more cold- and frost-tolerant tropical and warm temperate grasses. It grows in relatively humid areas, preferring fertile soils, although it is also well-adapted to organic sandy soils in Florida (United States) and to alkaline soils. In Puerto Rico it grows well on soils rich in lime and on sandy soils on sloping hillsides. It responds to fertilization on poorer soils. It tolerates short-term flooding and salt spray, but it does not persist where there is a prolonged dry season and on soils with a shallow water table. St. Augustine grass is shade-loving and produces higher yields under shade intensities of as low as 40% sunlight than in full sunlight. Its productivity is maintained with 40% full sunlight.

Agronomy St. Augustine grass is propagated by planting sections of rooted stolons, preferably early in the wet season. The sections can be planted about 30 cm apart in rows 60–70 cm apart, or else scattered on the soil surface and disked in. One ha of grass will provide sufficient cuttings to plant 10 ha. The stolons grow quickly, although it may still take 5–6 months to form a complete cover. Sward formation is faster under light to moderate shade than in the open. Once established, the dense swards resist weed invasion. Because of its low growth habit, St. Augustine grass is usually grazed, although it can be cut for hay or silage. It should be closely grazed, and grazing every 12–14 days to a height of 5 cm or less has been suggested. When used as a lawn, it should be regularly and closely mown. In one study, St. Augustine grass yielded 5.5 t/ha of DM per year in full sunlight, as measured over 6 harvests. Corresponding yields under 70%, 50%, 40% and 20% sunlight were 3.5, 4.0, 4.9 and 1.9 t/ha. At 40% light transmission St. Augustine grass can attain its maximum yield and can outyield signal grass (*Brachiaria decumbens* Stapf).

Nitrogen-fertilized pastures of St. Augustine grass have produced over 1000 kg/ha of liveweight gain per year in the United States. St. Augustine grass–siratro (*Macroptilium atropurpureum* (DC.) Urban) pastures beneath a sparse coconut plantation in Vanuatu gave annual liveweight gains of 275–400 kg/ha. However, only 1–2 head/ha could be sustained during the growing season under a denser stand of coconuts at a 9 m spacing.

Genetic resources and breeding Evaluation of a range of accessions of St. Augustine grass is being carried out in South-East Asia by ACIAR.

Prospects With the recent emphasis on development of farm systems involving the integration of livestock and plantations in South-East Asia and elsewhere in the tropics, further research on the shade-tolerant St. Augustine grass is warranted. Improving its productivity and seed production would be priority objectives.

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C.P. Chen

Stylosanthes capitata Vogel

Linnaea 12: 70 (1838).

LEGUMINOSAE

$2n = 40$

Origin and geographic distribution *S. capitata* originates in South America where it occurs naturally in sub-humid and dryland areas in north-eastern Venezuela and, mainly, in central-west, south-east and north-eastern Brazil. One cultivar

and several experimental lines have spread to other tropical regions for testing, including South-East Asia.

Uses The main use of *S. capitata* is as forage in permanent pastures grazed by ruminants.

Properties *S. capitata* provides a palatable forage of moderate to high quality, with N concentrations ranging from 2–3.0%, and DM digestibility 55–60%. Phosphorus concentrations in the herbage are moderate to low (0.09–0.18%). There are 400–450 seeds/g.

Description A perennial herb or sub-shrub, semi-erect to erect, with a strong taproot. Stems many-branched, lignified at the base; under competition ascending up to 1 m; indumentum varying from glabrous to densely pilose, or with scattered bristles. Leaves 3-foliolate; stipules oblong, 16–20 mm long (including teeth) and 6–8 mm wide, with 2–3 pairs of veins; petiole 2–6 mm long, densely villous; rachis up to 3.5 mm long; leaflets broad-elliptical, oblong or sometimes obovate, 15–40 mm × 5–15 mm, apically acute, mostly densely villous on both surfaces, with 8–12 pairs of conspicuous veins. Inflorescence a capitate spike, terminal or axillary, cylindrical-ovoid, up to 7 cm × 15–20 mm, many-flowered; often several inflorescences in dense clusters; bracts 1-foliate, oblong, 9–13 mm long, with 3–5 pairs of veins, and variable pilosity; flowers papilionaceous, small, with obovoid standard 4–6 mm long, sulphur-yellow; axis rudiment and 2 inner bracteoles present. Pod 2-articulated, 5–7 mm × 2–2.5 mm, reticulately nerved; both articles usually fertile, the upper one glabrous and with a straight to uncinate beak about 1 mm long. Seed colour varying from yellow, sometimes slightly mottled, to almost black.

Stylosanthes capitata Vogel – 1, habit flowering and fruiting branch; 2, fruit with axis rudiment.

Growth and development Initial growth of *S. capitata* is slow. Flowering and seed setting occur mainly during the end of the rainy season and extend into the dry. Being a very prolific seeder, *S. capitata* regenerates through seedling recruitment. If plants are allowed to set seed in the year of establishment, more than 1 t of seeds in pods per ha can be produced. The species tends to behave like an annual and plants seldom live longer than 2–3 years.

Other botanical information To date, *S. capitata* has become a commercial pasture legume only in Colombia, South America, where a blend of five similar ecotypes was released as 'Capica'. The objective of blending was to broaden the genetic base of the cultivar and to decrease the risk of anthracnose susceptibility.

Ecology *S. capitata* is best adapted to tropical savanna ecosystems with a sub-humid to humid climate characterized by relatively high rainfall (1000–2500 mm/year) during a growing season of 6–9 months. The species requires light-textured, well-drained, acid soils, and has a good tolerance of toxic levels of soil Al and Mn. It grows well on soils of poor fertility, including low available P. Savanna ecosystems with such soils are common in tropical America; their South-East Asian equivalents would be *Imperata cylindrica* (L.) Raeuschel grasslands in somewhat drier areas with ultisols as the predominant soil type.

Agronomy *S. capitata* is drilled in rows or broadcast, preferably with a grass, at a rate of 2–3 kg/ha. Germination of fresh seed is poor because of a high degree of hard-seededness; this can be overcome by mechanical or acid scarification, or by hot-water treatment. Successful *S. capitata* associations have been obtained with *Andropogon gayanus* Kunth (gamba grass), *Brachiaria decumbens* Stapf (signal grass) and *Brachiaria dictyo-*

neura (Fig. & De Not.) Stapf. Although the legume nodulates with native rhizobia, inoculation of seed with a *Bradyrhizobium* strain of known effectiveness is recommended.

Fertilization with P and K enhances establishment, and despite its low soil-fertility requirements, *S. capitata* responds to maintenance fertilization with these nutrients. It persists well in association with a strongly competitive grass such as *Andropogon gayanus*, even under fairly uncontrolled grazing, but the use of intermittent grazing systems is suggested.

S. capitata has proved to be very tolerant of anthracnose (*Colletotrichum gloeosporioides*), the major disease affecting *Stylosanthes* spp. There are, however, regional differences, depending on anthracnose-strain virulence. A common pest is the pod-borer *Stegasta bosqueella*; it can drastically decrease seed yield.

In pure legume stands, DM yields of 1–3 t/ha every 12 weeks are obtained during the rainy season. Dry-season yields can be very low, as plants will eventually shed their leaves completely under severe drought. Nevertheless, year-round animal production can be improved due to the presence of *S. capitata* in a pasture. For example, in a mixture with *A. gayanus*, liveweight gains of 150 kg/steer per year have been measured compared with 110 kg/steer per year in *A. gayanus* alone.

Genetic resources and breeding The species has been widely collected and there is a large, very variable collection available at CIAT (Colombia). A *S. capitata* breeding programme, aimed at adapting 'Capica' to the higher anthracnose-stress conditions of central Brazil is now being concluded.

Prospects Because of such characteristics as outstanding adaptation to acid and poor soils, disease resistance, long-term persistence through seedling recruitment as a result of high seed production, and good forage quality, *S. capitata* is an important pasture legume for low-input production systems on marginal soils in tropical savanna regions. Efforts to improve its dry-season performance seem to be justified.

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R. Schultze-Kraft

Stylosanthes guianensis (Aublet) Swartz

Svenska Vet. Akad. Handl. 10: 301 (1789).

LEGUMINOSAE

$2n = 20$

Synonyms *Trifolium guianense* Aublet (1775).

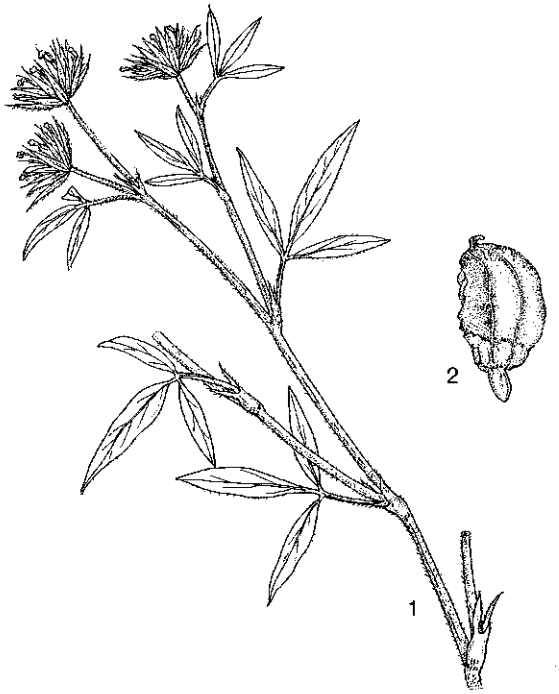
Vernacular names Stylo, Brazilian lucerne (En). Luzerne du Brésil, luzerne tropicale (Fr). Thailand: thua-satailo.

Origin and geographic distribution The natural distribution of stylo ranges from northern Argentina into Mexico. The variety *guianensis*, which is of particular interest to South-East Asia, has its centre of origin in Brazil and is naturally distributed to Paraguay, Bolivia, Peru, Colombia, Venezuela, Guyana and Central America. During the 20th Century it has been introduced all over the tropical world and is now widely naturalized in most tropical countries.

Uses Stylo is used as a cover crop in plantations, as a green manure crop and as a fallow crop in shifting cultivation, but it is best known as a pasture legume for humid tropical regions.

Properties Nitrogen concentrations range from 1.5–3.0%. Dry matter digestibility of young plant material lies between 60% and 70%, but with increasing age and lignification this may be reduced to below 40%. Because stylo is able to grow on poor soil, its P concentration is often as low as 0.06%, but with P fertilization it can increase to over 0.30% of DM. Stylo can grow adequately on soils with a low phosphate availability, in which case animals feeding on the plant need to be supplemented with P for their normal requirements. Although stylo is readily eaten by cattle and sheep, its palatability is not very high, which protects it from being overgrazed. As with many other tropical legumes, young growth of stylo is less palatable than young growth of grasses.

Description A perennial herb or sub-shrub, semi-erect to erect, with a strong taproot and small round root nodules. Stem much branched, herbaceous or lignified at the base, to 1 m tall, indumentum varying from nearly glabrous to densely pilose, often with bristles and viscid. Leaves trifoliolate; petiole 1–12 mm, rachis 0.5–1.5 mm long; stipules 2–15 mm, adnate to the petiole, teeth 2–10 mm long; leaflets elliptical to lanceolate, 5–45 mm × 2–20 mm, not more than 8 times longer than wide, indumentum varying as on stems. Inflorescence a loosely capitate spike, terminal or axillary, with more than 4 flowers. Flower subtended by an outer bract with 3–7 mm long sheath, a 2.5–5.5



Stylosanthes guianensis (Aublet) Swartz – 1, habit flowering and fruiting branch; 2, fruit.

mm long outer bracteole and a 2–4.5 mm long inner bracteole; calyx tube 4–8 mm long, lobes 3–5 mm; standard 4–8 mm × 3–5 mm, yellow to orange, often with black stripes, wings and keel 3.5–5 mm long. Pod usually 1-jointed, the article ovoid, 2–3 mm × 1.5–2.5 mm, glabrous or rarely with very short pubescence, indistinctly veined, with a minute beak, strongly inflexed. Seeds pale brown or purple.

Growth and development Stylo plants have a juvenile phase during which floral initiation does not take place. Stylo is a copious seed producer, but more than 70% may be hardseeded. Hardseededness breaks down naturally under hot conditions and can also be broken by dry or wet heat before sowing.

As it fixes atmospheric N, stylo contributes to increased soil fertility, although it has been compared unfavourably with other legumes in this respect. It nodulates freely with cowpea rhizobia and does not require inoculation.

Other botanical information In *S. guianensis* 7 varieties are distinguished by morphological and ecological characteristics. Only var. *guianensis* is important for South-East Asia and the information given here refers mainly to this variety. Another variety adapted for humid tropical regions is var. *gracilis* (Kunth) J. Vogel (syn. *S. gracilis* Kunth), but this has no agronomic value. Several cultivars of var. *guianensis* have been developed in Australia and South America. The cultivars released in Australia are : 'Schofield', adapted to hot humid climates; 'Cook', similar to 'Schofield' but earlier flowering, more branched and better adapted to lower temperatures; 'Endeavour' intermediate between cultivars 'Schofield' and 'Cook'; 'Graham', the earliest flowering cultivar and better adapted to subtropical conditions. 'Pucallpa', released in Peru specifically for the humid tropics and soils with a low pH. This cultivar is also widely used in tropical China as 'Pi Hua Dou 184'. Var. *intermedia* (Vogel) Hassler 'Oxley' (known as fine stem stylo) is adapted to subtropical sub-humid regions with 700–1000 mm annual rainfall and is frost-tolerant.

The name *S. guianensis* is sometimes erroneously spelled *S. guyanensis*.

Ecology Stylo is adapted to hot, humid climates, and is neither frost nor drought tolerant. It grows on all soil types, but is particularly well adapted to poor acid soils with high Al and Mn contents.

Stylo is a short-day plant with a critical photoperiod of between 12–14 hours, depending on cultivar. However, some cultivars have been reported to require exposure to long days prior to short days before flowering is initiated. Cultivars with a critical photoperiod about 12 hours will only flower sporadically at the equator because of daylength requirements.

Propagation and planting Stylo is propagated by seed. Hot water treatment (10 minutes at 80°C) to break hardseededness improves germination rates. Seeding rate is 2–6 kg/ha. When sown together with grasses a good seed-bed preparation is desirable, but when sown into an existing pasture, little or no seed-bed preparation is necessary although establishment will be slower. Stylo can also be grown in a pure stand as a green manure, cover or fodder crop. It is suitable for small- and large-scale agriculture.

Husbandry Stylo can be used by continuous or rotational grazing or cutting. It responds to improved soil fertility, particularly P, but can grow on infertile soil.

It is sometimes sown as a pioneer species in a mixture of legume species. In this role, it provides forage early in the life of the pasture, but is not expected to persist in the long term.

Diseases and pests Stylo is susceptible to anthracnose disease, caused by the fungi *Colletotrichum gloeosporioides* and *C. dematium*, the former

being the more important one. The disease was first reported from Brazil, but has now spread throughout the world by transport of infected seed. Symptoms of the infection are black lesions on the leaves and stems, which eventually lead to the death of the plants. Although the fungi can be controlled chemically, this is not an economic proposition, except for valuable seed crops. The approach being followed in Australia and Colombia is to select resistant cultivars. It has been reported by CIAT (Colombia), that stylo is more resistant to the disease in humid than in seasonally dry tropical regions, because of the presence of microorganisms antagonistic to the fungi.

Harvesting Stylo is harvested by grazing animals or it is mown for stall feeding or artificial drying. When mown, care should be taken not to cut woody stems too low, otherwise regrowth will be adversely affected. Although usually consumed fresh, the forage can also be artificially dried. Hay making or ensiling are not commonly practised in the humid tropics.

Yield In pure stands stylo can produce DM up to 10 t/ha and its contribution in mixed pastures can amount to 2–6 t/ha, depending on soil fertility and moisture level.

Cattle liveweight gains of 140 kg/animal and 400 kg/ha were recorded in Peninsular Malaysia in the third year of continuous grazing of a guinea grass (*Panicum maximum* Jacq.) pasture containing 18% stylo and 7% centro (*Centrosema pubescens* Benth.).

Genetic resources Stylo is well represented in South-East Asia and seed is on sale. Germplasm collections are available at ATFGRC (CSIRO, Australia) and CIAT (Colombia).

Breeding Plant breeding programmes are in progress in Queensland, Australia, for anthracnose resistance within var. *intermedia*. The available natural variation within the species allows selection for adapted cultivars to a wide range of environmental conditions. Plant collections in South America also offer scope for further cultivar development and improvement.

Prospects It is unlikely that much effort will be put into improving the adaptation or yield of *S. guianensis*, because there are other species of *Stylosanthes* that can take its place.

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L. 't Mannetje

Stylosanthes hamata (L.) Taub.

Verh. Bot. Ver. Brandenb. 32: 22 (1890).

LEGUMINOSAE

$2n = 20, 40$

Synonyms *Hedysarum hamatum* L. (1759), *Stylosanthes procumbens* Swartz (1788).

Vernacular names Caribbean stylo (En). Laos: hnha:z liaz ngu:. Thailand: thua-hamata.

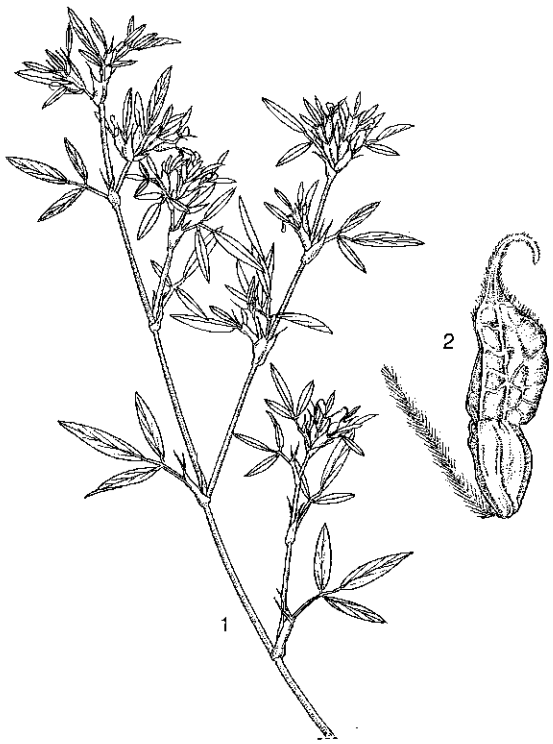
Origin and geographic distribution *S. hamata* is indigenous to the drier habitats of the Caribbean Islands, southern Florida, Central America and South America. In South America it is recorded from Colombia, Venezuela and Brazil (Ceara, Pernambuco and Bahia). Tetraploid as well as diploid races occur in Central and South America but tetraploids have not been recorded in the Caribbean Islands or Florida.

Uses The tetraploid Caribbean stylo cultivars 'Verano' and 'Amiga' are widely used as a pasture legume in northern Australia, Thailand, India, Nigeria and other West African countries. It can also be cut and fed fresh or used to make hay. Diploid *S. hamata* accessions have so far not been used as sown pasture legumes.

Properties The N and P concentrations of whole plants of Caribbean stylo sampled at flowering averaged 1.8% and 0.08%, respectively. The DM digestibility and DM intake of young plant material grown under irrigation with P fertilizer averaged 80% and 73 g/kg $Lw^{0.75}$ when fed to sheep. The N and P concentrations and in vitro digestibility (IVD) of leaf and stem fractions generally differ from each other and decline during the growing season. In green leaves, the mean N concentration falls from 3.9% to 2.7%, P concentration from 0.37% to 0.16% and IVD from 72% to 66%. In stems, the corresponding changes were 2.0% to 1.0% N, 0.34% to 0.06% P and 57% to 33% IVD. However, P levels will vary with soil P status. The IVD of inflorescence and seed is 69% and 60% respectively.

There are about 270 seeds/g with pods and 450 seeds/g without pods.

Description The tetraploid is a short-lived perennial herb, usually with an erect habit but sometimes prostrate, 0.5 m or more tall, with much branched stems; internodes 2–8 cm long, line of ascending whitish indumentum changing sides on successive internodes, glabrous elsewhere. Leaves trifoliolate; leaflets narrowly elliptical-lanceolate, central leaflet 16–26 mm × 3–6 mm, acute at base and tip, mucronate, sparsely hairy above and below, central vein prominent below, 4–6 pairs lateral whitish veins, margins entire or minutely denticulate at base of whitish hairs; petioles 3–6 mm long, grooved with 2 lines of hairs; stipules bidentate, adnate to the base of the petiole with hairs on the sheath and teeth; sheath about 6 mm long. Inflorescence axillary or terminal, indeterminate, with 8–14 flowers; terminal inflorescence with 2–3 alternate spikes; outer bracts trifoliate, broader than stipules but venation and pilosity similar; inner bracts unifoliate, evenly sericeous; corolla tube 3 mm long; standard petal 4–5 mm wide, yellow with reddish mark; wings and keel petals yellow; axis rudiment 4–5 mm long in first flower of the spike, 1–2 mm in the next flower, minute or absent in upper flowers; there are two inner bracteoles. Fruit a loment, usually with two fertile articles, upper article 6–7 mm long including distally recurved beak 3–4 mm long, body with prominent nerve on each side, reticulate, minute hairs on edges; lower article 3.5 mm long with dense white hairs. Seeds 2.5 mm × 1.5 mm, tan to dark maroon, mottled.



Stylosanthes hamata (L.) Taub. – 1, habit flowering and fruiting branch; 2, fruit with axis rudiment.

Growth and development Embryo dormancy of tetraploid *S. hamata* is high with up to 50% in July at the end of the wet season in Queensland, Australia and has disappeared by October. Hard-seededness (> 97%) occurs where the mean temperature during seed formation is above 24°C but is less at lower temperature (64% at 21°C and 30% at 20/16°C). Seed germinates freely following early summer rain and the seedlings are able to withstand considerable water stress. It flowers 9–10 weeks after germination, and plants will flower within 6 weeks of the start of the season. Seed ripens over a period of 15–16 days after flowering. It largely behaves as an annual except in the second year when the survival rate of first-year plants can be as high as 93%. It avoids long dry seasons as predominantly hard seed which rapidly breaks down when the maximum diurnal soil temperatures reach 50–55°C just before the onset of the wet season.

The tetraploid *S. hamata* lines have an indeterminate flowering response to short days.

Other botanical information Strictly *S. hamata* refers to the diploid species and the tetraploids may be a separate species. There is genetic evidence that the tetraploids have evolved as an allotetraploid combination of *S. hamata* ($2n = 20$) and *S. humilis* Kunth ($2n = 20$); both diploid species are sympatric or nearly so with the tetraploids.

Because the tetraploid *S. hamata* ($2n = 40$) is largely sympatrical with its diploid progenitors *S. hamata* and *S. humilis*, it is advantageous to distinguish between them. The tetraploid and diploid *S. hamata* have similarities in the presence of a fine line of indumentum on one side of each internode, the presence of an axis rudiment, the loment often with two fertile articles and the absence of bristles on stems. The tetraploid differs from the diploid in its short-lived perenniality, the axis rudiment present in the lower flowers only, the presence of a long terminal bristle on the tips of the stipules and bracts, and in its darker coloured and longer seed. Although the tetraploid *S. hamata* is superficially similar to *S. humilis*, the latter differs

from the tetraploid in having abundant bristles on stems, stipules and bracts; stipules forming a fused sheath around the stem; the loment with only one fertile article; no axis rudiment and is an obligate annual.

Cultivars 'Verano' and 'Amiga' were released in Queensland in 1973 and 1988 respectively. Although both cultivars are morphologically similar, they differ in that 'Amiga' gives 40–50% higher seed yields and appears better adapted to high altitude (> 300 m) environments than 'Verano'.

Ecology Tetraploid Caribbean stylo is suited to semi-arid to sub-humid tropical regions with short variable growing seasons and an annual rainfall of 500–2000 mm. It is poorly adapted to subtropical environments. It grows on a wide variety of soil types ranging from sands to clay loams, but not on heavy clays. It is particularly well adapted to infertile, moderately acid and sandy surface soils with very low P levels. This adaptation is enhanced by its efficiency in extracting less available forms of soil P. The diploid Caribbean stylo occurs on neutral to slightly alkaline soils and is less adapted to acid conditions.

Propagation and planting Caribbean stylo is propagated by seed. Hard-seededness can be broken by mechanical scarification or hot water treatment to improve germination. Seeding rate is usually 2–3 kg/ha. In drier regions it should be sown with *S. scabra* Vog. cultivars 'Seca' and/or 'Siran' at 1 kg/ha and in the wetter areas other legumes such as *Aeschynomene americana* L. 'Glen' and *Stylosanthes guianensis* (Aublet) Swartz 'Cook' could be included in the mixture. In semi-arid environments the seed can be surface sown onto existing pasture following burning. When sown together with improved grasses, usually in more humid environments, a well prepared seed-bed is desirable. The tetraploid cultivars nodulate freely with the native cowpea rhizobia and do not require inoculation. Caribbean stylo pastures require early grazing soon after establishment to reduce the competition from grasses as Caribbean stylo is less palatable than the young growth of grasses.

Husbandry Caribbean stylo can be utilized by continuous or rotational grazing or cutting. Because it can grow at very low P levels, it may be necessary to apply 10 to 20 kg/ha of P at establishment and periodically thereafter to maintain soil P at 8 mg/kg so that the P concentration in the herbage reaches a level of above 0.12% during the growing season to insure adequate animal nutrition. Alternatively, grazing animals can be directly supplemented with P to meet their dietary requirements.

Diseases and pests Caribbean stylo is largely resistant to anthracnose disease caused by the fungi *Colletotrichum gloeosporioides* and *C. dematium* (see *S. guianensis*). There is some variation in anthracnose resistance between naturally occurring genotypes of Caribbean stylo; 'Verano' and 'Amiga' show a high field resistance to anthracnose. Web blight (*Rhizoctonia solani*) can damage vegetative growth of Caribbean stylo during the wet season in Queensland and head blight (*Botrytis cinerea*) can cause yield losses in seed crops. The latter fungus causes extensive blossom blighting and apical dieback. Under wet conditions conducive to disease development a grey-coloured mould grows over the inflorescences. There are no important insect pests of Caribbean stylo.

Harvesting Caribbean stylo is usually harvested by grazing animals but can be cut for stall feeding as green feed or to make hay. Caribbean stylo paddocks that are cut may need resting from cutting every third or fourth year to allow seed reserves to build up.

Yield In pure stands, Caribbean stylo can produce up to 10 t/ha of DM in high rainfall environments with adequate fertilizer. Its contribution in mixed pastures usually ranges from 1–7 t/ha depending on soil fertility, moisture level and the competition from grasses. Heavy grazing encourages legume dominance in mixed Caribbean stylo-grass pastures. Tetrapolid *S. hamata* lines have a high seed potential from 1750–2000 kg/ha. Actual machine harvester yields can reach 1000 kg/ha. Annual liveweight gains of 140 to 160 kg/head have been recorded from Caribbean stylo-shrubby stylo pastures on lightly fertilized poor soils in northern Queensland.

Genetic resources Germplasm collections are maintained by ATFGRC (CSIRO, Australia) and CIAT (Colombia).

Breeding Plant breeding programmes are in progress in Queensland, Australia, to develop cultivars with greater anthracnose resistance than 'Verano' and 'Amiga'. Accessions with low disease damage could have potential as parents for a breeding programme to improve anthracnose resistance and in studies of the genetics of anthracnose resistance.

Prospects The wide range of adaptation and productivity of Caribbean stylos will encourage further plant improvement programmes through plant breeding and the selection of naturally

occurring genotypes. Besides resistance to anthracnose, other desirable objectives are increased seed yield and colonizing ability. It is well suited to the drier parts of South-East Asia.

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L.A. Edye & A. Topark-Ngarm

Stylosanthes humilis Kunth – 1, 2, habit of flowering and fruiting branches; 3, flower; 4, fruit.

Stylosanthes humilis Kunth

Nov. gen. sp. 6: 506, t. 594 (1824).

LEGUMINOSAE

$2n = 20$

Synonyms *S. figueroae* Mohl. (1957).

Vernacular names Townsville stylo, Townsville lucerne (En). Philippines: magsaysay-lucerne (Tagalog). Thailand: thua-satailo.

Origin and geographic distribution Townsville stylo is widespread in Brazil and also occurs in Venezuela, Colombia, Central America, Mexico and Cuba. It is adventive to Queensland (Australia) and is naturalized in Malaysia, Indonesia and Thailand.

Uses Townsville stylo is a forage particularly useful in heavily grazed areas in the semi-arid to subhumid tropical and lower latitude subtropical regions with a marked dry season.

Properties The N and P concentrations of whole plants range from 3.0–1.6% and 0.20–0.04% respectively. The DM digestibility of young plant material lies between 60% and 70%, but with increasing age it is reduced to 40%. Seed has a DM digestibility of ca. 62%. There are 275–300 seeds/g with pods and 400–500 seeds/g without pods.

Description A herbaceous, usually erect but sometimes prostrate annual, 0.5 m tall, branched, usually with short white hairs along one side of the stem and often with scattered short bristles on the stem and nodes. Leaves trifoliolate; leaflets lanceolate or sometimes elliptical, acute, both surfaces nearly glabrous, with 3–6 pairs of conspicuous veins; terminal leaflet up to 15 mm × 3.5 mm; petioles 3–5 mm long, shortly hairy and often with scattered bristles; stipules bidentate, adnate to base of petiole with bristles on both sheath and teeth. Inflorescence consists of several short, ovoid, crowded spikes with 5–15 flowers in each spike; spikes hirsute without axis rudiment; flower with one inner and one outer bracteole; calyx tube 4–5 mm long, lobes 1.5 mm long; corolla bright yellow; standard 3–4 mm × 3–4 mm. Fruit a loment, 1.5–2.5 mm broad, reticulately nerved; only the upper articulation fertile, 1.5–2.5 mm long, with beak 4–10 mm long; beak 1.5–3 times the length of the upper articulation and strongly uncinate to coiled. Seed yellowish-brown.

Growth and development Embryo dormancy is high with up to 94% in July in northern Australia at the end of the wet season, but is short lived and has disappeared by October. Hard-seededness can be as high as 100% in July but it breaks down rapidly to 1–6% by December when maximum diurnal soil temperatures are 50–55°C under field

conditions. Hard-seed breakdown occurs to a lesser extent when the soil surface is moist as the temperatures do not rise above 40°C. It germinates freely following early summer rain and the seedlings are able to withstand considerable water stress and then grow rapidly during the vegetative and early reproductive stage if the soil moisture is adequate. It has a short-day flowering response with a critical photoperiod of 12–14 hours. It nodulates freely with the cowpea type rhizobia and does not require inoculation. Once Townsville stylo plants become established the major influences on growth are water, nutrition and amount of competition from associated grasses. Flowering is genetically controlled with shorter critical photoperiod flowering being dominant. Flowering occurs over 8–10 weeks and seed ripens over a similar time interval. It avoids long dry seasons as predominantly hard-seed.

Other botanical information Collections of Townsville stylo can be divided into two major groups. One includes adventive populations from Australia, Colombia, Dominican Republic, Ivory Coast, Kenya, the Philippines, Tanzania, the United States, as well as collections from Brazil of supposedly indigenous material. The second group includes collections from Venezuela, Costa Rica, Nicaragua and Mexico. The evidence suggests that Townsville stylo is not native to Brazil and that it first occurred around ports in north-eastern Brazil in the late 19th Century about the same time as its first recorded occurrence in Australia.

The cultivars released in Queensland, Australia during the late 1960's were the common naturalized type, 'Paterson' (early flowering), 'Lawson' (mid season flowering) and 'Gordon' (late flowering). All the Australian naturalized populations and cultivars proved highly susceptible to the fungal disease anthracnose when it was accidentally introduced into Australia ca. 1973.

Ecology Townsville stylo's adaptation in Australia to a wide latitudinal range (12–28°S) with annual rainfall ranging from 600–1500 mm is due to ecotypic variation in critical photoperiod. Rainfall and latitude delineate ecotypic occurrences; ecotypes with a long critical photoperiod are restricted to drier or higher latitude regions whilst those with a shorter critical photoperiod are adapted to higher rainfall regions at lower latitudes. Although it will persist in regions with as little as 600 mm annual rainfall, it is not sufficiently productive to enhance animal production below 800 mm rainfall. It occurs on infertile sandy to clay loam soils with a pH(H_2O) range of 5 to 6.5. It is unsuited to heavier textured and more fertile soils, including cracking clays and soils derived from basalt or other igneous rocks, and also saline coastal soils.

Townsville stylo is sensitive to shading when grown in mixtures with taller grasses.

Propagation and planting Townsville stylo is propagated by seed. Hard-seededness can be broken by mechanical scarification or hot water or dry heat treatment. Seeding rate is 2–3 kg/ha. In semi-arid environments, seed can be surface sown onto existing pastures following burning just prior to the expected start of the wet season.

Husbandry In Thailand, the anthracnose-resistant cultivar 'Khon Kaen' was released in 1984 because it showed greater productivity and persistence than *S. hamata* (L.) Taub. 'Verano' under extremely heavy grazing, because of its prostrate growth habit. It is oversown onto communal grazing lands which are subjected to very heavy continuous grazing. Townsville stylo was widely used for pasture improvement in northern Australia during 1960–1974 but, since the advent of anthracnose it is of little importance as it has been superseded by the anthracnose-resistant cultivars of *S. hamata*, 'Verano' and 'Amiga', and of *S. scabra* Vogel 'Seca' and 'Siran'.

Diseases and pests Townsville stylo is susceptible to anthracnose disease caused by the fungi *Colletotrichum gloeosporioides* and *C. dematium* (see S. *guianensis*). There is some variation in anthracnose resistance between naturally occurring genotypes of Townsville stylo (e.g. 'Khon Kaen'). Blight (*Sclerotium rolfsii*) and bacterial wilt (*Pseudomonas solanacearum*) have been recorded on Townsville stylo in Australia. There are no known important insect pests.

Harvesting Although usually consumed fresh by grazing animals, Townsville stylo can be cut and fed when grown or made into hay towards the end of the growing season. Prior to the advent of anthracnose, feeding of Townsville stylo hay during the dry season was commonly practised in northern Australia to encourage seed dispersal by cattle.

Yield Townsville stylo has a high seed yield potential up to 1250 kg/ha and actual machine harvested yields of 600 kg/ha. Yields of dry matter can range from 1–6 t/ha.

Genetic resources Major germplasm collections are held by ATFGRC (CSIRO, Australia) and CIAT (Columbia).

Breeding There are no plant breeding programmes in progress.

Prospects It is unlikely that any effort will be put into improving adaptation and yield of *S. humilis* because there are other *Stylosanthes* species that can take its place.

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L.A. Edye & A. Topark-Ngarm

Stylosanthes macrocephala M.B. Ferreira & N.M. Sousa Costa

An. Soc. Bot. Brazil 28 Congr. Nac. Bot.: 87 (1978).

LEGUMINOSAE

$2n = 20$?

Origin and geographic distribution *S. macrocephala* originates in South America; its natural distribution is restricted to sub-humid and dryland areas of central and eastern Brazil. Experimental lines have spread for testing to other tropical regions, including South-East Asia.

Uses The main use of *S. macrocephala* is as forage in permanent pastures grazed by ruminants.

Properties In many regards, *S. macrocephala* is similar to *S. capitata* Vogel. Its nutritive value, however, is higher: in 6-week-old regrowth, N concentrations in leaves range from 2.2%–3.5% (stems: 1.4–1.8%), and leaf DM digestibility from 66%–75% (stems: 46–61%); P concentrations are moderate to low, 0.17–0.25% in leaves and 0.13–0.25% in stems. There are about 500 seeds (dehulled pods)/g.

Botany A perennial, fine-stemmed, many-branched, and taprooted subshrub, prostrate to semi-erect, 20–80 cm tall; stems and branches hairy-bristly. Leaves 3-foliolate; stipules obovate, 14–16 mm × 5–6 mm, with pointed teeth, pubescent to glabrous or bristly, with 11–13 pairs of veins; petiole 1–2 mm long, villous; leaflets lanceolate, 20–55 mm × 10–19 mm, pubescent or glabrous, with 7–10 pairs of veins. Inflorescence a capitate spike, terminal or axillary, ovoid to almost spherical, 14–18 mm × 10–15 mm, with 10–30 flowers; often several inflorescences in a cluster; bracts imbricate, 1-foliate, elliptical-ovate, 10–12 mm × 8–9 mm, pubescent, with 11–15 veins, reddish; flowers papilionaceous, small, with obovoid standard 4–6 mm long, yellow, striated; axis rudiment and 2 inner bracteoles present. Fruit 2-articulated, reticulately nerved; both articles usually fertile; the upper one glabrous, 3–4 mm × 2.5–3 mm, with a short, straight to uncinate beak; lower article villous and smaller. Seed yellow-brown, sometimes slightly mottled, to black.

Stylosanthes macrocephala M.B. Ferreira & N.M. Sousa Costa – 1, habit of flowering and fruiting branch; 2, fruit with axis rudiment.

Like *S. capitata*, *S. macrocephala* persists through extensive seedling recruitment. It is a prolific seeder. Cultivar 'Pioneiro' has been released in Brazil for use in the Cerrados savanna region.

Prior to its relatively recent description, *S. macro-*

cephala has sometimes been referred to as *S. capitata* or *S. bracteata* Vogel.

Ecology *S. macrocephala* has essentially the same climatic and soil adaptation as *S. capitata*. That is, good adaptation to savanna environments, mainly in terms of tolerance of the prevailing acid, low-fertility oxisols and ultisols.

Agronomy The agronomy of *S. macrocephala* is similar to that of *S. capitata*. Newly harvested seed may have to be treated to reduce hard-seededness. Although *S. macrocephala* nodulates effectively with native rhizobia, inoculation with an effective strain of *Bradyrhizobium* is recommended. Although tolerant of low fertility, productivity is enhanced by fertilization. It is somewhat less productive than *S. capitata*, during both the rainy and dry seasons. Seed set and seedling recruitment are essential for long-term persistence. *S. macrocephala* is, in general, more anthracnose-tolerant than any other *Stylosanthes* species. In Colombia, it can be seriously affected by *Rhizoctonia* foliar blight.

Genetic resources and breeding A large and quite variable *S. macrocephala* collection is held at CIAT (Colombia). At present there is no breeding programme for *S. macrocephala*.

Prospects Unless more productive cultivars with better dry-season performance become available, the potential role of *S. macrocephala* for pasture development in its particular ecological niche will most likely be limited, as *S. capitata* is an equally well-adapted but more productive species.

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R. Schultze-Kraft

Stylosanthes scabra Vogel

Linnaea 12: 69 (1838).
LEGUMINOSAE
$2n = 40$

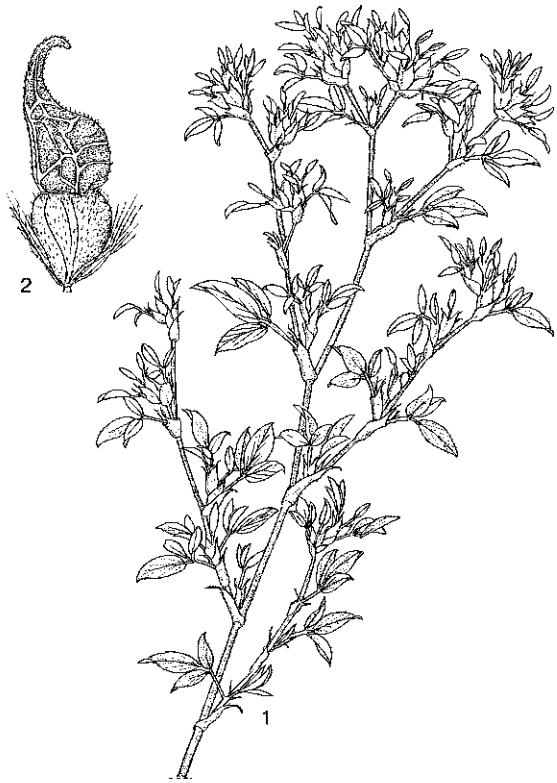
Vernacular names Shrubby stylo (En).

Origin and geographic distribution Shrubby stylo is widespread in Brazil, but also occurs in Bolivia, Colombia and Venezuela. It is also cultivated in other tropical regions besides South America, e.g. in Australia and India.

Uses Shrubby stylo is mainly used as a pasture legume for semi-arid to humid tropical regions with an average annual rainfall of 500–2000 mm. In the State of Maharashtra, India, it is cut and fed green to dairy cattle.

Properties The N and P concentrations of whole plants sampled at flowering averaged 1.7% N (range 1.1–2.2%) and 0.07% P (range 0.07–0.11%). The N and P concentrations and in vitro digestibility (IVD) of leaf and stem fractions generally differ from each other and decline during the growing season. In leaves, the mean N concentration falls from 3% to 1.5%, P concentration from 0.3% to 0.1%, and IVD from 70% to 50%. In stems, the corresponding changes were 1.5% to 0.5% N, 0.3% to 0.03% P and 60% to 30% IVD. Shrubby stylo has a high proportion of stem which increases from 20% in the early growth stage to 75% at the end of the growing season. In grazed pastures, stem contents of 80–96% have been recorded. There are 400–550 hulled seeds, and 600–800 dehulled seeds per g.

Description A perennial subshrub, erect to suberect to 2 m tall with a strong taproot with small round root nodules and penetrating deeply to depths up to 4 m. Stems with variable branching, covered by short or long hairs with bristles, usually viscose, pale green to dark blue-green, brown or red. Leaves trifoliolate; leaflets elliptical to oblong-laceolate, apex obtuse to mucronate, hairy on both surfaces with 4–7 prominent veins thickening terminally, pale green to dark green or dark blue-green; terminal leaflet 20–33 mm × 4–12 mm, length/breadth ratio 2 to 5; petiole up to 10 mm long, canaliculate above, scabrous with dense short hairs, the rachis 4–5 mm long; stipules obovate, 15–25 mm long including teeth, bristly-hairy. Inflorescence obovoid to ellipsoid, generally longer than wide, 10–30 mm long, several-flowered, each flower surrounded by a bract and 3 bracteoles; bracts unifoliolate, the blade about 4 mm long, the sheath 3.5–6.5 mm long with long teeth; outer bracteole 1, 2–4.5 mm long, bifid and ciliate at apex; axis rudiment 4–5 mm long; inner bracteoles 2, 2–4 mm long, ciliate at apex; calyx tube 3–6.5 mm long, lobes 1.5–3.5 mm long; standard suborbiculate, ca. 7 mm long. Fruit a loment with usually two fertile articles about 2.5 mm broad, reticulately nerved; upper articulation 2–4 mm long, shortly hairy, the lower 2–3 mm long, evenly pilose throughout; beak uncinate, with short



Stylosanthes scabra Vogel – 1, habit of flowering and fruiting branch; 2, fruit.

hairs, 1–2 mm long, ½ to ⅓ as long as the upper articulation. Seed asymmetrically reniform, small (< 2 mm long), pale to light brown, radical end prominent.

Growth and development Shrubby stylo appears to have a juvenile phase during which floral initiation does not take place, followed by a short-day flowering response; the critical photoperiod lies between 11.5–12.5 hours, depending on the accession. Seed yields stay at a peak for a long period but vary with the accession and season; 70–90% of the seed may be hard-seeded.

Other botanical information *S. scabra* is part of a species complex in which the species cannot be separated satisfactorily. Besides *S. scabra*, the complex comprises *S. tuberculata* Blake, *S. nervosa* Macbr., *S. fruticosa* (Retzius) Mohlenbrock, and *S. suffruticosa* Mohlenbrock. If, after a badly needed taxonomic revision, the whole complex is reduced to one taxon, the correct name will be *S. fruticosa* for reasons of priority.

Although shrubby stylo is very variable, most plants can be readily classified into morphological-agronomic groups that reflect geographical and climatic ecotypes. In Brazil the species is very widespread and two major forms have been recognized. One, often described as *S.* aff. *scabra* or *S.* aff. *hamata* by some authors, has thin stems with long, narrow leaflets, length/breadth ratio 4 to 5, with dark blue-green stems and leaves, and produces seed all year; this form mainly occurs in the coastal states of Maranhïo, Pernambuco Bahia and Rio de Janeiro. The other major form, which is more readily accepted as *S. scabra*, has thick woody stems and can be grouped into coastal types and continental types. The coastal types are tall robust subshrubs, leaflets elliptical and a length/breadth ratio of 2.0 to 2.7. The continental types are shorter in growth habit and more densely branched, leaflets lanceolate or elliptical, length/breadth ratio 2.3 to 3.9. The continental types mainly occur in the states of Goiás, Minas Gerais, Matto Grosso, Matto Grosso do Sul, Piauí and São Paulo.

The shrubby stylos from Colombia and Venezuela are morphologically different from the Brazilian material but more closely resemble the continental types than the coastal types of Brazil by their short growth habit and dense branching. The geographical plant groups reflect the climatic and edaphic differences between the regions.

The cultivars released in Australia are: 'Seca', an anthracnose-resistant cultivar which is widely adapted in Queensland; 'Fitzroy', an early flowering and leafy cultivar which is very susceptible to anthracnose and is no longer used; and 'Siran', bred to provide a multigenic resistance to anthracnose.

Ecology Shrubby stylo is very drought resistant and can survive long dry periods. It is adapted to tropical and subtropical environments with an average annual rainfall of 500–2000 mm and can tolerate light frost to −3°C; heavy frosts can kill the crowns. It grows on a wide range of soil types, but is particularly well adapted to infertile, moderately acid, sandy surfaced soils with very low P levels. This adaptation is enhanced by its efficiency in extracting less available forms of soil P. Shrubby stylo can grow on heavier textured soils than most other stylos, but is not suited to heavy black basaltic clays.

Propagation and planting Shrubby stylo is propagated by seed. Hard-seededness can be broken by mechanical scarification to improve germination. Under field conditions, substantial softening of hard seed occurs when the maximum diurnal soil temperatures reach 50–55°C and is largely restricted to the late dry and pre-wet period

in the tropics and to late spring and summer in the subtropics. Seeding rate is 1–2.5 kg/ha with the lower figure for drier regions. In semi-arid environments, the seed can be surface sown onto existing pasture following a burn; in humid environments when sown together with improved grasses, a well prepared seed-bed is desirable. Shrubby stylo nodulates freely with cowpea type rhizobia and does not require inoculation. In drier regions it should be sown with *S. hamata* (L.) Taub. cultivars 'Verano' or 'Amiga'. In wetter areas it should be sown with other legumes such as *Aeschynomene americana* L. cultivars 'Glenn' or 'Lee' and *S. guianensis* (Aublet) Swartz cultivar 'Cook' could be included in the mixture.

Husbandry Shrubby stylo is used by continuous or rotational grazing or cutting. Because it can grow at very low P levels, it may be necessary to apply 10–20 kg/ha of P as superphosphate or alternatively, directly supplement the grazing animals with P to meet their dietary requirements. Although it is readily eaten by cattle and sheep, it is not very palatable. As with most *Stylosanthes* species, young growth of shrubby stylo is less palatable than young growth of grasses. This assists in seedling establishment and regeneration of shrubby stylo and enables long-term persistence.

Diseases and pests Shrubby stylo is susceptible to anthracnose disease caused by the fungi *Colletotrichum gloeosporioides* and *C. dematium*; the cultivars 'Seca' and 'Siran' are resistant to anthracnose. Blight (*Sclerotium rolfsii*) has been recorded on shrubby stylo in Thailand. Two important stemborers damage shrubby stylo: *Caloptilia* sp. in Brazil and Colombia, and *Platyomopsis pedicornis* in Queensland, Australia. *Calotilia* sp. is the major pest of *Stylosanthes* in South America. The larvae tunnel through lower stems, considerably weakening susceptible accessions which usually die within 2 years. Field screening has identified accessions that are resistant to stem-borer. Isolated occurrences of *Platyomopsis* have been recorded in Queensland but it is not a serious pest; the larvae hollowed the taproot and lower main stem and killed the infested plants. Termites have been recorded on shrubby stylo in Queensland and they can kill older plants.

Harvesting Shrubby stylo is harvested by grazing animals or it is cut for stall feeding. When mown, care should be taken not to cut the woody stems too low, otherwise regrowth will be adversely affected and some plants will die. In semi-arid environments, forage can be made into hay towards the end of the growing season.

Yield In pure stands, shrubby stylo can produce DM up to 10 t/ha in areas of high rainfall, and its contribution in mixed pastures can amount to 2–7 t/ha depending on soil fertility and moisture levels. Annual liveweight gains of cattle of 140–160 kg/head have been recorded from shrubby stylo pastures on lightly fertilized poor soils in northern Queensland (Australia).
Seed yields of up to 620 kg/ha have been recorded.

Genetic resources Germplasm collections are maintained at ATFGRC (CSIRO, Australia) and CIAT (Colombia).

Breeding Plant breeding programmes are in progress in Queensland, Australia. Cultivar 'Siran', a composite of 3 lines, was released in August 1990; it incorporates a multigenic resistance to anthracnose derived from crosses and selections of the anthracnose-resistant accessions Q 10042 × CPI 93116 (Line 1), an early flowering selection of 'Seca' (Line 4), and CPI 55860 × Q 10042 (Line 8). Lines 1, 4 and 8 have been named 'Jecuipe', 'Recife' and 'Feira' respectively for plant cultivar rights registration. Current research has shown that partial resistance to anthracnose is stable, heritable and improvable through breeding. Future plant breeding objectives will aim at combining both major gene and partial resistance genes against anthracnose in new cultivars.

Prospects The extreme drought resistance and wide range of adaptation of shrubby stylo will encourage further plant improvement programmes through plant breeding and the selection of naturally occurring genotypes. Besides resistance to anthracnose, other desirable objectives for plant improvement include increased frost resistance and higher nutritive value.

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L.A. Edye & A. Topark-Ngarm

Themeda triandra Forssk.

Fl. Aegypt.-Arab.: 178 (1775).
GRAMINEAE
$2n$ = 20, 30, 40, 50, 60, 70, 80

Synonyms *Themeda imberbis* (Retzius) Cooke (1908), *T. australis* (R. Br.) Stapf (in part) (1919).

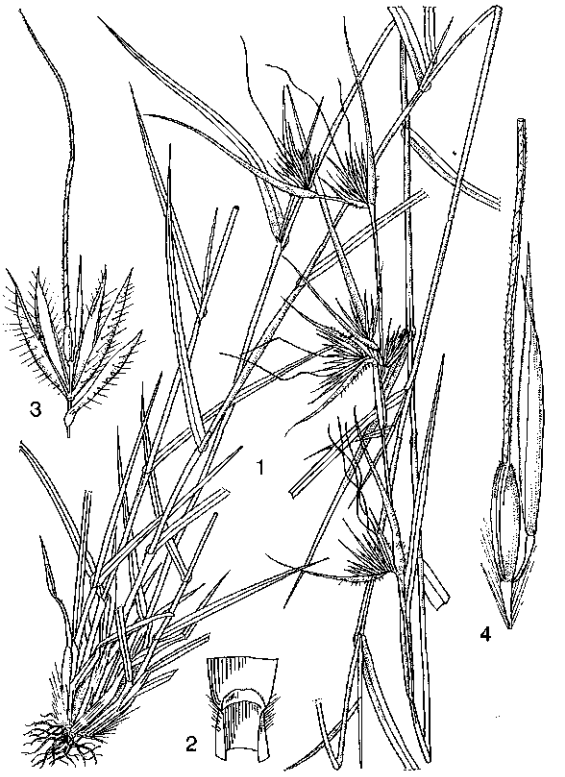
Vernacular names Red oat grass, kangaroo grass (En). Indonesia: merakan lanang (Javanese). Philippines: bagokbok (Tagalog), samsamon (Ilokano), ipatpatey (Bontok). Cambodia: sbö':w. Laos: hnaaz fèèk. Thailand: ya-faek. Vietnam: co' bông cao ru'ng khôp, co'tam hung.

Origin and geographic distribution The natural distribution of red oat grass is pantropical/subtropical with extension into the temperate zone as a summer growing grass. It is most likely of Gondwanan origin with a predominant distribution in Australia, South-East Asia, India and Africa.

Uses Red oat grass is used as part of the naturally occurring savanna pastures for domestic livestock production and wildlife.

Properties In native pastures the N concentration of red oat grass ranges from 2.7% in green material from the early flush of the growing season to 0.5% in dry forage by the end of the dry season. Digestibility varies from about 60% to 35%.

Botany A tufted leafy perennial, growing up to 1.5 m tall, erect, culms usually unbranched but quite variable in morphology, smooth, often becoming golden at maturity, nodes hairless. Leaves both basal and on the culms; leaf-sheath keeled, coarsely striate, hairless below but becoming quite short-hairy towards the ligule, the margins translucent; ligule short and membranous, later splitting into a broad rim of short hairs with some longer, marginal hairs; leaf-blade 15–50 cm × 2–5 mm, green or sometimes bluish, folded with a more or less hairy clasping base, becoming more or less flat towards the acutely pointed tip, flexuous, smooth or slightly rough down the margins. Inflorescence a loose, narrow spathate usually reddish-coloured panicle, the flexuous peduncled racemes slightly nodding; panicle branches slender and smooth, often quite widely separated along the axis and bearing clusters of one to several racemes (spikelet clusters), each at first enclosed by, and later subtended by a strongly keeled, sheath-like spathe; spikelet clusters are composed of a sessile, fertile awned spikelet surrounded by an involucre of 2 pairs of sessile and 1 pair of pedicellate male or sterile (often reduced) spikelets; florets 2 in the fertile spikelet, the lower sterile and reduced to a lemma, the upper bisexual,



Themeda triandra Forssk. – 1, flowering plant; 2, ligule; 3, group of spikelets; 4, two spikelets.

1 in the involucral and pedicellate spikelets which are male, sterile or reduced to a lemma; fertile spikelet sessile and awned, about 8 mm long including the dark brown, sharply pointed, densely and stiffly hairy barbed callus; awn up to 7 cm long, puberulous, twisted and geniculate, hygroscopically active so that the seed can bore itself into the ground. Caryopsis lanceolate, channelled on one side.

The fruits ('seeds') of red oat grass fall individually to the ground. They probably have similar seed dormancy and germination control mechanisms to speargrass *Heteropogon contortus* (L.) Beauv. ex Roemer & Schultes and other *Andropogoneae*. Flower initiation is obligately to facultatively short-day in the tropics, short-day to day-neutral in the subtropics and long-day in the temperate zone. There is some evidence of a cold stratification response in materials occurring in subalpine areas, these forms also being polyploid. The reproductive system is also likely to be obligately to facultatively apomictic as in the majority of *Andropogoneae*.

The species is very polymorphic, and based on the

hairiness of the inflorescence parts, has been subdivided repeatedly in the literature. Without clear correlations with geographic distribution, these subdivisions are of little value.

Ecology Red oat grass is a typical andropogonoid grass of the tropical and subtropical savannas which are characterized by a marked seasonality of warm wet, and cooler dry seasons. It is a savanna grass in seasonally wet/dry climates of moderate rainfall. However, it also occurs in quite arid environments along drainage lines and run-on areas. It is relatively drought-tolerant, with its main range of distribution being within 500–1200 mm of annual rainfall. It has been recorded at above 3000 m in the Himalayas. However, an interesting departure from this is its adaptation to growing during the warm season of the temperate zone provided there is moisture at that time. In the subtropics red oat grass will produce green growth in the cool season if there is some out-of-season rainfall, which is atypical of andropogonoid grasses. However, it is sensitive to continued intensive grazing and this unseasonal growth places it at greater risk from overgrazing when almost everything else is senesced and dormant. It has been shown to be particularly sensitive to heavy grazing when the growing points are elongating late in the growing season. Like *Heteropogon contortus*, red oat grass responds to dry-season burning, but being more sensitive to grazing, it will predominate in areas which are burnt and not significantly grazed, e.g. some road and railway exclosures. It grows on a wide range of soil types except heavy clays.

Agronomy The wide variety of growth forms and habitats of red oat grass makes generalizing somewhat hazardous. Its intolerance of prolonged heavy grazing is sometimes belied by areas which have survived many years of close grazing or mowing where the species has developed a prostrate growth form. *Heteropogon contortus* often replaces red oat grass following sustained grazing and dry-season burning.

As red oat grass is susceptible to prolonged heavy grazing pressure, it requires very careful control of grazing when used in conjunction with management practices such as oversowing legumes or provision of feed supplements such as mineral licks, urea/molasses, and other externally supplied feeds. These practices usually lead to increased grazing pressure, especially early in the growing season when red oat grass is more susceptible to defoliation than is *Heteropogon contortus*. This appears to be becasue of the interactive effect of defoliation with the different pattern of synchrony of growing points in these two species at the start of the growing season.

No diseases and pests of any consequence have been recorded.

The annual yield depends very much on the amount and favourable distribution of rainfall occurring during the warm season. The normal savanna environment means that growth and quality are seasonal so that there is a fluctuating amount of biomass and level of feed quality on offer for livestock grazing. Production is likely to range between 0.5–5 t/ha of DM, depending on conditions.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects In production systems where a stable alternative can be established, either naturally as with replacement by *Heteropogon contortus*, or by conversion to planted pastures, there could be little disadvantage in losing red oat grass. However, where there are no viable and acceptable alternatives or where there is the need to preserve its particular type of ecosystem, as in some national park systems, it may be important to maintain it, which requires careful management of livestock or wildlife.

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J.C. Tothill

Thysanolaena latifolia (Roxb. ex Hornem.) Honda

Journ. Fac. Sci. Tokyo, Sect. 3. Bot. 3: 312 (1930).
GRAMINEAE
$2n = 24$

Synonyms *Melica latifolia* Roxb. ex Hornem. (1819), *Agrostis maxima* Roxb. (1820), *Thysanolaena maxima* (Roxb.) Kuntze (1891).

Vernacular names Tiger grass (En). Indonesia: awis (Sundanese), menjalin wuwu (Javanese), lantebung (Makasar). Malaysia: buloh teberau, rumput buloh. Philippines: tambu (Tagalog), gatbo (Bikol), buybuy (Ilokano). Laos: kh'èèm kh'ôông. Thailand: tongkong, laolaeng (northern), ya-yung (southern). Vietnam: dót, dông trung hòa tha'o.

Origin and geographic distribution Tiger grass occurs from India to Indo-China and China and throughout Malesia. It is also occasionally cultivated outside this region.

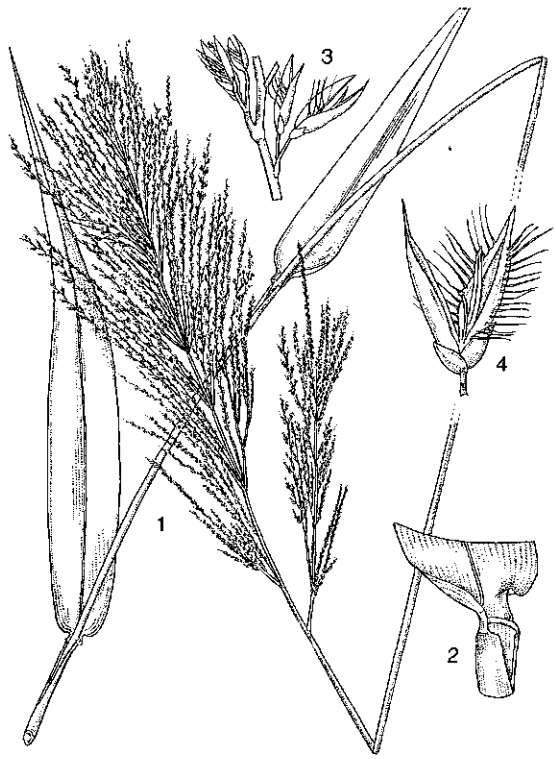
Uses Young leaves and stem tips are used to feed cattle and buffaloes. Its large inflorescences are used in making brooms. The grass is occasionally planted for ornamental purposes and as a hedge.

Properties One leaf sample in Thailand had a N concentration of 1.2%. The in vitro DM digestibility of leaves ranged from 40% to 60%.

Botany A strongly tufted, very robust perennial grass with erect or slightly spreading solid bamboo-like culms up to 3.5 m tall. Leaf-sheath hairy along outer margin; ligule a scarious membrane, 1–2 mm long; leaf-blade lanceolate-acuminate, 30–65 cm × 3–7.5 cm, base broad and rounded or subcordate, margins scaberulous, conspicuously glaucous beneath. Inflorescence a terminal huge and drooping panicle, up to 140 cm long, well exserted, branches divided and subdivided into many branchlets; spikelets awnless, short pedicelled, falling with part of the pedicel, often in pairs on a common peduncle, 2-flowered; lower glumes clasping. Caryopsis subglobose to ovoid, 0.6 mm long, reddish-brown.
In light shade seedlings grow slowly at first, but are then able to compete with other low-growing plants. It flowers throughout the year at lower altitudes.

Ecology Tiger grass grows from 150–2000 m altitude in valleys and on lightly shaded slopes, in ravines and on river banks. It tends to grow in association with trees (often bamboo forests), solitarily or in small groups, and not in full sunlight.

Agronomy Tiger grass can be propagated by rhizomes, rooted culms or seeds. It is cultivated for broom making, but not primarily for forage. Weeding is required at the early stage of establishment.



Thysanolaena latifolia (Roxb. ex Hornem.) Honda – 1, flowering culm; 2, ligule; 3, part of inflorescence branch; 4, spikelet.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects More attention should be given to this species as a source of feed for cattle in highland areas.

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Vol. 4. Natural Resources Management Center and University of the Philippines. Manila. p. 127.

C. Manidool

Trifolium repens L.

Sp. Pl.: 767 (1753).

LEGUMINOSAE

$2n = 32$ (tetraploid), but 16, 28, 48 and 64 occur as well

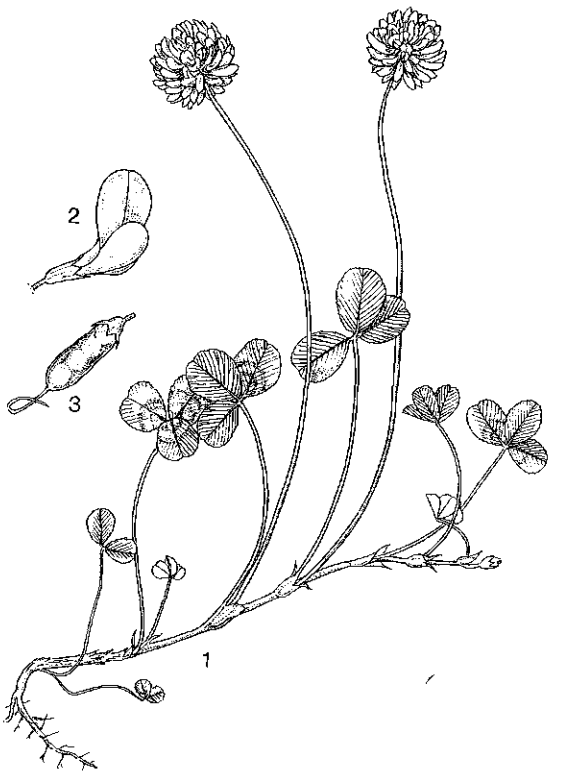
Vernacular names White clover, Dutch clover (En). Trèfle blanc (Fr). Indonesia: semanggi landa (Javanese). Thailand: thua clover.

Origin and geographic distribution The likely centre of origin is the Mediterranean region but white clover is indigenous to the whole of Europe, Central Asia west of Lake Baikal, and to small areas in Morocco and Tunisia. It is naturalized in many countries, particularly in North America, China, Australia and in higher latitudes of South America. Although of most importance in mild temperate and Mediterranean climates, white clover is naturalized in the higher rainfall subtropics and in the elevated tropical areas such as the highlands of Papua New Guinea.

Uses In the tropics and subtropics, white clover is used as a forage legume in grazed pastures. It is also an important species for pasture hay and silage in temperate regions. The flowers are considered as an important source of honey.

Properties White clover is one of the best quality temperate legumes and is better in quality than any tropical legume. Nitrogen percentages in foliage range from 3.5–5% and DM digestibilities range from 60–80%. Cultivars adapted to warmer climates tend to have higher glycoside levels, but not high enough to affect animal production. There are 1400–1800 seeds/g.

Botany A perennial herb which, particularly in subtropical areas, can also persist as an annual. The primary taproot seldom persists for more than one year (subtropics) or two years (temperate areas). The prostrate succulent stolons which develop shallow adventitious roots are short-lived, usually for less than one year. Leaves trifoliolate, long-petioled (1–30 cm); leaflets elliptical to obovate to heart-shaped, 0.5–4 cm × 1–1.5 cm, margin denticulate, glabrous, frequently with white or light green markings that are often crescent shaped; petiole length and leaflet size vary markedly with cultivar and decrease with increasing grazing pressure. Peduncle 2–30 cm long, glabrous; inflorescence umbellate, globose, 1.5–3.5 cm in diameter, with up to 40 white or light pink flowers, reflexed after fertilization; calyx 3–5 mm, corolla 4–13 mm long. Pod linear-oblongoid, 4–5 mm long, with 3–4 seeds. Seed ovoid to reniform, ca. 1.5 mm long, usually pale yellow, occasionally reddish-brown.



Trifolium repens L. – 1, flowering plant part; 2, flower; 3, fruit.

White clover is a very variable species, and mainly based on flower colour and size of flowers and leaflets, numerous botanical varieties have been distinguished. No satisfying classification exists. There are numerous cultivars of white clover, for description purposes roughly classified based on size into small, intermediate and large types. Two widely used ones in the subtropics are 'Haifa' and 'Louisiana S1', both being heavier seeders in the subtropics than 'Ladino' or 'Grassland Huia'.

In temperate areas white clover grows actively during summer. In contrast, in the subtropics it grows in the cooler months with a peak late in spring if there is adequate moisture. There is considerable stolon death over late summer and early autumn. This death is associated with high minimum and maximum temperatures and also with moisture stress during dry periods, with rot-

ting of roots and stolons in wet conditions, and with competition from warm season grasses. Growth from late autumn onwards is then from surviving stolons and from seedlings which emerge until early spring. Soil seed reserves can reach 10000 seeds/m^2 in good white clover pastures in the subtropics, whereas poor pastures may have less than 1000 seeds/m^2.

Ecology White clover does not grow well on drought-susceptible soils with low soil moisture storage or on waterlogged soils, particularly where waterlogging coincides with high temperatures. White clover requires high levels of fertility, with a pH(H_2O) of over 5.0 and preferably 5.5., and available soil P levels of over 20 mg/kg. It is susceptible to high levels of available soil Mn and Al.

Agronomy Although hand-harvested seed of white clover is hard-seeded, commercial seed usually has low levels of hard seed. Under favourable conditions it can be established by broadcasting into closely grazed pastures, but there is more prospect of success with sowing into rough cultivation or a fully prepared seed-bed. Seed should be inoculated with an appropriate *Rhizobium* strain before sowing if it is sown in an area where it has not been grown before. White clover based pastures should be well grazed, especially during the summer period when the companion grasses are growing quickly and the clover is growing under adverse temperature conditions. Bloat (tympanitis) can be a problem in spring when clover growth is vigorous and there is little grass in the pasture. Probably the most important diseases are those associated with weak pathogens such as *Pythium middletonii* which attack stolons and roots during wet and hot conditions during summer. Rust pustules on leaves caused by *Uromyces* spp. can be more conspicuous but are much less serious. Pests of white clover in the subtropics are usually of minor importance. Total annual DM yields range from < 1 to > 7 t/ha. Peak DM yields on offer in well grazed pastures seldom exceed 1 t/ha and are more often under 0.5 t/ha. However, as white clover is selectively grazed such yields substantially improve animal production. Good clover growth results in increased soil nitrogen status.

Genetic resources and breeding Germplasm collections are held in many countries. An important collection is held by DSIR Grasslands Division, Palmerston North, New Zealand. The main breeding programme to improve white clover for use in the subtropics has been carried out in Florida, United States, leading to the release of cultivar 'Osceola'. There is some evidence that *T. repens* is an amphidiploid and its related diploid species are thought to be *T. nigrescens* Viv., a self-incompatible Mediterranean annual, and *T. occidentale* Coombe, a self-compatible perennial indigenous to southern England, south-western France and Spain.

Prospects While breeding and selection may improve the persistence and productivity of white clover in tropical highlands and subtropical areas where it is adapted, it is unlikely that breeding will substantially increase its area of adaption.

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R.M. Jones & S.M.M. Kersten

Trifolium semipilosum Fresen.

Flora 22: 52 (1839).
LEGUMINOSAE
$2n = 16$

Vernacular names Kenya white clover, Kenya clover (En).

Origin and geographic distribution *T. semipilosum* occurs naturally in the humid and equatorial high altitude areas of Kenya, Uganda, Tanzania, Yemen and Ethiopia. Now it is cultivated elsewhere in the high altitude tropics and in the subtropics and sometimes it is naturalized locally.

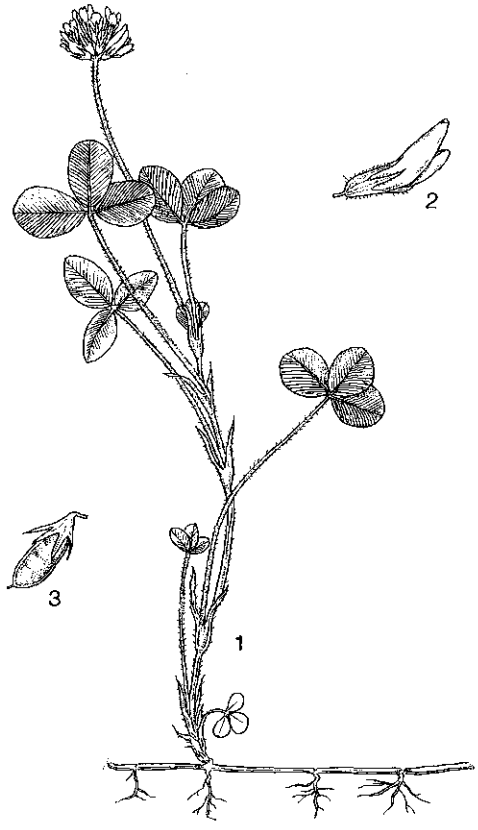
Uses Kenya white clover is mainly used for grazing ruminants, although it is also fed to pigs, chickens and ducks in Papua New Guinea.

Properties The N concentration and digestibility of Kenya white clover leaves and stems are only slightly lower than white clover (*Trifolium*

repens L.) and higher than for almost all tropical legumes. Nitrogen concentrations range from 2–5% and P concentrations from 0.2–0.5%. Sodium percentages are often below 0.1%. There are 700–900 seeds/g.

Botany A perennial herb, initially with a crown and taproot, with prostrate pilose stems radiating from this, which root at the nodes if in contact with moist soil. Leaf trifoliolate with pilose petiole much longer than the leaflets; leaflets cuneate-obovate to elliptical or orbicular, 0.4–2 cm × 0.4–1.1 cm, glabrous above and pilose on the margins, midrib and usually on the lower half of the two lateral leaflets; petiole length varies with grazing pressure, from 2–20 cm. Inflorescence globose, 5–40 flowered, about 2 cm across; flowers white to pale pink; calyx 4–6 mm long, corolla 8–10 mm long. Pods oblongoid, 5–6 mm long with 2–6 seeds. Seed irregularly discoid, ca. 1.5 mm across, dull yellow, light brown or olive green to black.

The primary taproot usually only lives for 1–2 years and the prostrate stems then persist through continuing development of nodal roots.



Trifolium semipilosum Fresen. – 1, flowering plant; 2, flower; 3, fruit.

Two varieties are distinguished:

- var. *semipilosum* (synonyms var. *microphyllum* Chiov. and var. *kilimanjaricum* Baker), with leaflets twice as long as broad and silky pilose underneath; pods pilose at least at apex.
- var. *glabrescens* Gillett, with leaflets about as long as broad, glabrescent underneath and glabrous pods.

Var. *glabrescens* naturally occurs in rather more humid areas than var. *semipilosum*, often in association with *Pennisetum clandestinum* Hochst. ex Chiov.

Cultivar 'Safari' is described as being var. *glabrescens*.

Ecology Kenya white clover grows in the low altitude subtropics and elevated tropics (1000–3000 m). In its natural habitat in East Africa, annual rainfall is 550–1400 mm. Temperature requirements for growth are intermediate between those of most tropical legumes and white clover. It grows very well in Papua New Guinea at sites with a diurnal temperature range of 10–20°C and at elevations as low as 1300 m, provided the soil is fertile. It can flower and set seed on the equator and also at latitudes in excess of 30°. In the subtropics, flowering occurs mainly during the cooler months. Plants of 'Safari' can resist moderate frosting but top growth is killed by heavy frosts. It grows at pH range of 5–7.5 with greater tolerance of low Ca and high Al and Mn than white clover. It requires levels of available soil P > 20 mg/kg. It cannot tolerate very dry or waterlogged sites. In Papua New Guinea it grows very well in abandoned gardens and along roadsides.

Agronomy Seed of 'Safari' can be very hard-seeded, particularly when hand-harvested, and scarification is usually required. Seed should be inoculated with the appropriate rhizobium inoculum (e.g. CB782). Although it can be established by surface broadcasting into undisturbed swards, it is best established into a seed-bed. In the subtropics, it is best to sow in autumn when temperatures are falling yet soil moisture is often favourable. First year pastures often go through a period when growth is poor and leaves pucker and turn yellow, orange or red. The reasons for this are not clear, although sometimes ascribed to 'rugose leaf curl', but the plants often or usually grow out of the condition. However, new plants arising from seedling recruitment in an established sward can also be affected.

The main disease described for 'Safari' has been

rugose leaf curl. This was initially ascribed to a virus and then to a *Rickettsia*-like organism. However, the symptoms on young stands may not necessarily be caused by that disease. Slugs can severely defoliate swards of 'Safari' during sustained periods of wet weather, and weevils can damage swards by damaging or severing larger roots. Rotting of roots and stolons by *Pythium* spp. has been recorded during hot, moist conditions.

'Safari' combines well with a wide range of tussock and stoloniferous grasses in mixed pastures. Although 'Safari' stems can grow upwards from the soil surface, 'Safari' pastures should be well grazed, particularly when the grasses are growing actively. This ensures that stolons remain close to the ground and continue to develop new nodal roots to make up for the death of older roots. 'Safari' swards can develop high reserves of soil seed, of over 10000 seeds/m^2, but recruitment of new seedlings is not reliable. 'Safari' can spread through seed dispersed in faeces. Given levels of above 10–20% legume in the sward, 'Safari' pastures can give high production of milk or liveweight gain.

Genetic resources and breeding Germplasm collections are held by ATFGRC (CSIRO, Australia) and ILCA (Ethiopia). Attempts to cross 'Safari' with *T. repens* have been unsuccessful. Some plants in Ethiopia and Kenya look like intermediates between *T. semipilosum* and *T. burchellianum* Ser., and var. *glabrescens* might be originally a natural hybrid of these 2 species.

Prospects It is highly unlikely that the zone of adaptation will be extended beyond the wetter subtropics and elevated tropics. Even within this zone, the main limitation of 'Safari' is its unreliability of successful establishment and persistence, which is partly related to the condition described as rugose leaf curl. Although it is showing considerable promise in Papua New Guinea highlands, this unreliability will continue to limit its use in many areas unless the problems can be defined and solutions found.

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R.M. Jones & A.K. Benjamin

Tripsacum andersonii J.R. Gray

Phytologia 33: 204 (1976).

GRAMINEAE

$2n = 64$

Vernacular names Guatemala grass (En). Malaysia: rumput jelai, rumput jagung. Thailand: ya-kuatemala.

Origin and geographic distribution Guatemala grass is native to Central America and northern South America (from Mexico to Peru). It is now widely cultivated throughout the tropics including South-East Asia.

Uses Green foliage of Guatemala grass is widely used as cut fodder. In Sri Lanka, it has been used as a soil cover in tea plantations. In Malaysia, it has been planted extensively in rubber and oil palm estates for control of erosion, for mulching and as a soil conditioner in drained swamps. It can be a weed in cultivated areas.

Properties Regrowth harvested at 4, 6, 10 and 12 weeks had N concentrations of 2.2, 2.1, 1.3 and 0.8%. Digestible crude protein percentages at the same growth stages were 9.8%, 9.1%, 5.0% and 2.2% as assessed by using cattle. Six-week-old regrowth from plants grown on 'acid sulphate' soil contained 1.5% N, 0.14% P, 2.6% K, 0.13% Ca and 0.11% Mg.

Botany Robust perennial grass, forming large mats up to 5 m across of tangled stolons and rhizomes, from which erect to decumbent flowering culms are produced; stolons and culms up to 5 cm in diameter, flowering culms 2–3 m tall. Lower leaf-sheaths shortly pubescent near the base, upper ones glabrous; ligule a membraneous ridge, slightly hairy behind; leaf-blade sessile, linear-lanceolate, up to 120 cm × 5–10 cm, shortly tomentose

Tripsacum andersonii J.R. Gray – 1, habit; 2, ligule; 3, inflorescence; 4, male spikelet; 5, female spikelet.

above, glabrous below. Inflorescences terminal and axillary, composed of 3–7 branches (terminal) and 1–4 branches (axillary); branches subdigitately arranged on a short primary axis and each raceme consists of several basal fruitcases (pistillate spikelets) with numerous staminate spikelets on a continuous rachis above them; pistillate spikelets 6–10 mm long, sunken in cavities of the indurated rachis and covered by the outer glume, disarticulating individually at maturity; staminate spikelets paired at each rachis node (one sessile, one shortly pedicelled), 6–10 mm long, with coriaceous 10–15-nerved glumes.

In Central America *T. andersonii* is often confused with *T. latifolium* Hitchcock ($2n = 36$), *T. laxum* Nash ($2n = 36$), and *T. maizar* Hernandez & Randolph ($2n = 36, 72$). *T. laxum* and *T. maizar* bear 10–50 racemes per terminal inflorescence and the male section of each raceme is typically pendent. *T. latifolium* has sessile, 4–6 mm long, staminate spikelets. *T. andersonii* is very sterile.

Ecology Although known for its excellent performance in lowland conditions, vigorous growth in suitable sites at higher altitudes (about 1800 m) has also been observed. Good growth can also be maintained when planted in plantations with about 50% shade. It is adapted to a wide range of soil types including ultisols, oxisols, peats, acid sulphate soils and Bris soils (coastal marine sands) with a pH(H_2O) range of 2.7–4.5. Guatemala grass is adapted to inundated and marshy conditions. It has remarkable tolerance to shallow water tables, but poor tolerance to soil moisture stress.

Agronomy Guatemala grass is planted vegetatively, either through splitting the rooted tillers from clumps, by rhizomes or through stem cuttings containing 3 nodes. There are no known commercial suppliers of seed in South-East Asia.

Green foliage is cut by hand for pen feeding rather than being conserved for hay. The vigorous growth of Guatemala grass has been demonstrated in its annual DM yields, at a 6-week cutting interval with maintenance fertilization of 200 kg/ha of N, 40 kg/ha of P and 100 kg/ha of K per year, of 23 t/ha on a sedimentary soil, 21 t on a peat soil, 24 t on an acid sulphate soil and 2 t on a Bris soil. The low production on the Bris soil is attributed to water stress and high soil temperatures. It outyielded 20 other grass species on acid sulphate soil. While only 30% of plants died over a 3-year cutting experiment, mortality might have been higher if plants had been subjected to more frequent defoliation. Adequate soil moisture (either from rainfall or irrigation) and fertilizer are the two important factors involved in maintaining productive Guatemala grass. In view of its declining quality with increasing age of regrowth, supplementation with a leguminous shrub such as *Leucaena leucocephala* (Lamk) de Wit may best exploit its high yield potential to optimize animal production. No serious disease or pest problems have been noted so far.

Genetic resources and breeding It is unlikely that any substantial germplasm collections are being maintained and there are no known breeding programmes. *T. andersonii* behaves cytologically as if its genome consists of a triploid *Tripsacum* L. genome (54 chromosomes) and a haploid *Zea* L. genome (10 chromosomes). Cytogenetic studies indicate that *T. andersonii* originated as a hybrid between a species of *Tripsacum* ($2n = 36$) and a species of *Zea* ($2n = 20$). The *Tripsacum* parent probably was *T. latifolium* of Central America and the *Zea* parent either *Z. mays* L. ssp. *mays* (domesticated maize) or *Z. mays* L. ssp. *mexicana* (Schrad.) Iltis (annual teosinte).

T. andersonii is remarkably uniform morphologi-

cally, indicating that the species had a single hybrid origin. Its wide distribution in Central and South America suggests a rather ancient origin.

Prospects Under high rainfall tropical environments, Guatemala grass is a proven species for erosion control, soil conditioning and mulching, and it is also a high-yielding forage species. If combined with legumes in a feeding system, its utilization for animal production could be further improved.

Literature |1| Aminah, A. & Wong, C. C., 1991. Dry matter productivity and chemical composition of some promising grasses grown on acid sulphate soil. In: Recent innovation in the animal and animal products industry. 14th Malaysian Society for Animal Production (MSAP) Conference, Genting Highlands, Malaysia, May 8–9, 1991. MSAP and The Federation of Livestock Farmers Association of Malaysia (FLFAM), Kuala Lumpur. pp. 92–96. |2| Devendra, C., 1979. Malaysian feedingstuffs. MARDI, Kuala Lumpur, Malaysia. 145 pp. |3| de Wet, J.M.J., Fletcher, G.B., Hilu, K.W. & Harlan, J.R., 1983. Origin of Tripsacum andersonii (Gramineae). American Journal of Botany 70: 706–711. |4| de Wet, J.M.J., Gray, J.R. & Harlan, J.R., 1976. Systematics of Tripsacum (Gramineae). Phytologia 33: 203–227. |5| Wong, C.C., Chen, C.P. & Ajit, S.S., 1982. A report on pasture and fodder introduction in MARDI. MARDI Report No 76. MARDI, Kuala Lumpur. 35 pp. |6| Wycherley, P.R. & Ahmad Azli, M.Y., 1974. Grasses in Malaysian plantations. Rubber Research Institute of Malaysia. Rajiv Printers, Kuala Lumpur. pp. 58–59.

C.P. Chen

Urochloa mosambicensis (Hack.) Dandy

J. Bot. 69: 54 (1931).

GRAMINEAE

$2n = 28, 30, 42$

Synonyms *Panicum mosambicense* Hack. (1888).

Vernacular names Sabi grass (En). Thailand: ya sabee.

Origin and geographic distribution Sabi grass originated in the drier (400–800 mm annual rainfall), frost-free regions of southern and eastern Africa. It has been introduced into many countries including Australia, India, Sri Lanka, Burma, Thailand, Indonesia, Fiji and Hawaii. It is used commercially and is now naturalized in northern Australia.

Uses Sabi grass is mainly used as a forage for ruminants but can also be used for reseeding denuded areas.

Properties Chemical composition and nutritive value of Sabi grass depend on soil fertility but young green leaves typically contain up to 2.5% N, 0.2% P and are 65–70% digestible. In the late wet season equivalent values are 1.2%, 0.15% and 55–60% respectively. Dry leaves and stems are much lower in quality and typical values are 0.5% N and 0.05% P. Sabi grass is palatable. There are 600–1000 seeds/g.

Botany A creeping, perennial grass of variable size and growth habit usually with short stolons or often tufted. Culms smooth, more or less erect, up to 150 cm tall, 5 mm in diameter, often branching at the nodes, and sometimes rooting at lower nodes; nodes prominent, densely covered with short, silky hairs. Leaf-sheaths close, covered with erect, white, tubercle-based hairs particularly in their upper part, shorter than the internodes; ligule a rim of short (1 mm) hairs. Leaf-blade broadly linear to narrowly lanceolate, 2–30 cm ×

Urochloa mosambicensis (Hack.) Dandy – 1, habit; 2, inflorescence; 3, spikelets.

3–20 mm, pale to bright green, hirsute on both surfaces; midrib prominent, often purplish, apex tapering to a fine point. Inflorescence composed of 3–15 racemes (3–90 mm long) on a simple common axis up to 15 cm long but often much less; spikelets are borne on the lower side of the rachis only, 3–5 mm × 1.5–3 mm; lower glume ovate-lanceolate, 3-nerved, with a single bristle 1–2 mm long; lower lemma with a conspicuous fringe of bristles 1–1.5 mm long. Caryopsis light buff or cream.

Seeds of Sabi grass germinate early in the wet season and vegetative growth continues until soil water is exhausted. Flowering commences 3–4 weeks after the start of the wet season and continues until growth ceases. Seed matures in 3–4 weeks. Leaves live for 5–25 weeks depending mainly on water supply. Plants are often short-lived (3–4 years) but new plants are formed from seedling recruitment. Cultivar 'Nixon' has been developed in Australia from material introduced from Zimbabwe.

Sabi grass is closely related to and much resembles *Urochloa oligotricha* (Fig. & De Not.) Henrard which has a 5-nerved lower glume, but intermediates occur. Both species also resemble the South African *Urochloa stolonifera* (Goossens) Chippend. which is smaller and with its spikelets untidily arranged.

Ecology Sabi grass is commonly grown in areas with 500–1200 mm annual rainfall with a pronounced warm season and a dry season of 5 to 9 months. It has poor frost tolerance and rapidly hays off when soil moisture is exhausted. In its natural habitat in Africa of wooded grassland and deciduous bushland, it occurs up to 1400 m altitude. Flower initiation occurs over a range of daylengths but it is earlier at 12 hours than 9 or 15 hours. Sabi grass is adapted to a wide range of soils but will not tolerate permanently flooded or waterlogged conditions. In Africa it is a common roadside weed and often grows in disturbed or overgrazed areas.

Agronomy Although Sabi grass can be propagated vegetatively it is normally established from seed. Freshly harvested seed is dormant but dormancy breaks down after 9 to 12 months storage. Hammer milling to destroy the hard lemma can increase germination. Sabi grass can be readily established under a variety of sowing conditions, but is best established by sowing on or near the soil surface of a well cultivated seed-bed during the early wet season. Oversowing into undisturbed pasture is often a complete failure, or takes several years to develop into a pasture. Seeding rates range from 1–5 kg/ha.

There are no important diseases or pests of Sabi grass.

Sabi grass can be used by continuous or rotational grazing, or by cutting for feeding as fresh material or for making hay. It will stand close defoliation. Sabi grass responds to N and P and is aggressive at high fertility. It combines well with legumes and is a common associate grass for *Stylosanthes* spp. Sabi grass produces 1–8 t/ha of DM per year depending on seasonal conditions, soil fertility and associate species.

Genetic resources and breeding There is wide variation in Sabi grass for morphological and agronomic characteristics. The collection held at ATFGRC (CSIRO, Australia) mainly came from South Africa.

There are no active breeding programmes and improvement will depend on selection from natural populations. Important objectives to date have been adaptability to a range of environments, yield and quality.

Prospects Sabi grass is an effective colonizing, palatable, and grazing-tolerant forage of reasonable quality suited for sowing in the drier regions of South-East Asia. It is recommended for use in the 'Three Strata Forage System' in drier areas of Indonesia.

Literature |1| Bogdan, A.V., 1977. Tropical pasture and fodder plants. Longman, New York. pp. 295–296. |2| Burt, R.L., Williams, W.T., Gillard, P. & Pengelly, B.C., 1980. Variation within and between some perennial Urochloa species. Australian Journal of Botany 28: 343–356. |3| Clayton, W.D. & Renvoize, S.A., 1982. Urochloa. In: Polhill, R.M. (Editor): Flora of tropical East Africa. Gramineae. A.A. Balkema, Rotterdam. Part 3. pp. 600–607. |4| Devendra, C. (Editor), 1990. Shrubs and tree fodders for farm animals. Proceedings of a workshop held in Denpasar, Indonesia, 24–29 July 1989. IDRC, Ottawa, Canada. 349 pp. |5| McIvor, J.G., 1985. The growth of Urochloa accessions in grazed swards with Stylosanthes near Townsville, north Queensland. Australian Journal of Experimental Agriculture 25: 61–69. |6| Oram, R.N., 1990. Register of Australian herbage plant cultivars. CSIRO, Australia. pp. 87–88. |7| Whiteman, P.C. & Gillard, P., 1971. Species of Urochloa as pasture plants. Herbage Abstracts 41: 351–357.

J.G. McIvor

Vigna parkeri Baker

Journ. Bot. 20: 69 (1882).
LEGUMINOSAE
$2n = 22$

Synonyms *Dolichos maranguënsis* Taub. (1892), *Vigna maranguënsis* (Taub.) Harms (1915), *V. gracilis* sensu auctt., non (Guill. & Perr.) Hook.f.

Vernacular names Creeping vigna, (Papua New Guinea) (En). Philippines: balatong (Bontok), bulligan (Ifugao).

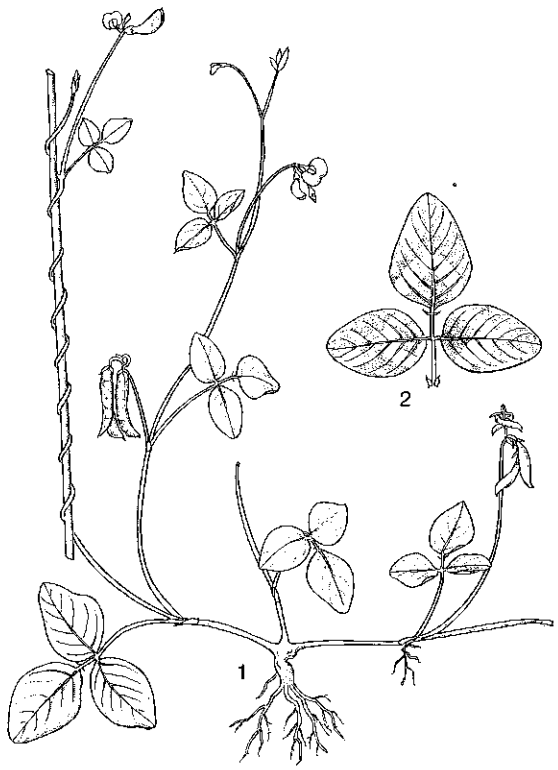
Origin and geographic distribution Creeping vigna is native to tropical East and Central Africa, but has been recorded most frequently in Kenya, Uganda and Tanzania. It is being sown in the humid subtropics in Australia and Florida (United States) and has become naturalized in the highlands of Papua New Guinea.

Uses While the main use of creeping vigna is as a pasture legume, it is also proving useful in Papua New Guinea as a protein supplement for pigs, and as a green manure and cover crop in shifting cultivation.

Properties Creeping vigna provides quality forage. In one report, leaves comprised 65% of the top growth and had a N concentration of 4.1% and DM digestibility of 61%, while stems had a N concentration of 2% and DM digestibility of 55%. It is generally readily eaten by cattle but there is some doubt about its acceptance by goats.

Botany A perennial twining or prostrate stoloniferous herb. Stolons remain appressed to the soil surface, while the primary axis, and laterals developing from stolon nodes, have a twining habit. Taproot slender, freely nodulating; nodal roots at first fibrous becoming small taproots as new crowns develop. Stems slender, sparsely to densely covered with mostly spreading hairs. Leaves trifoliolate; leaflets round, ovate to ovate-lanceolate, 1–9 cm × 1–5 cm, rounded to acuminate at the apex and rounded to subacute at the base, pubescent on both faces, margins entire and densely ciliate; petiole 1–8.5 cm long; stipules lanceolate, up to 8 mm long, bilobed at the base, persistent. Inflorescence axillary, with 2–5(–10) flowers per raceme; peduncle 2–13 cm long; flowers blue, yellow or white, occurring in alternate pairs inserted on either side of a glandular node; standard oblate, 5–8(–12) mm × 5–8(–10) mm, glabrous. Pod linear-oblong, compressed, mostly 1–2(–3) cm × 4.5–5.5 mm, 2–5-seeded. Seed oblong-ovoid, 3–4 mm × 2–3 mm × 2 mm, grey-to-brown/black mottled.

Three subspecies have beeen distinguished: ssp. *parkeri* (flowers blue or rose, leaflets ovate, only on Madagascar); ssp. *acutifolia* Verdc. (flowers mainly yellow, leaflets elliptical or ovate, in Kenya, Tanzania, Mozambique); and ssp. *maranguënsis* (Taub.) Verdc. (flowers mainly blue or purple, leaflets round, in East and Central Africa). The occurrence of many intermediate forms makes the subdivision unpractical.



Vigna parkeri Baker – 1, flowering and fruiting plant part; 2, leaf.

One introduction of creeping vigna which became naturalized in parts of south-east Queensland has been released as cultivar 'Shaw' and is now being planted in other parts of the humid subtropics and the tropical highlands. It appears that only one form (of ssp. *maranguënsis*) was introduced from Africa into Papua New Guinea at Aiyura in the Eastern Highlands about 1958, from where it has spread to the Southern Highlands, Western Highlands and Enga Provinces.

The ecotype from Papua New Guinea and 'Shaw' are distinguishable by the more acuminate, often paler leaflets and the stronger twining tendency in the former. Both have blue flowers and a pale crescent on the leaflets of some plants. In south-

eastern Queensland, latitude 26°S, some types flower throughout the growing season, while others, including the Papua New Guinea ecotype and 'Shaw' do not flower until about May. The Papua New Guinea ecotype flowers throughout the year in its naturalized habitat in the highlands between 5° and 7°15'S.

Ecology In general, creeping vigna has similar environmental requirements as greenleaf desmodium (*Desmodium intortum* (Miller) Urban). The Papua New Guinea ecotype and 'Shaw', both of which have uncertain origins, are adapted to moist soils in the high altitude tropics and low altitude subtropics where annual rainfall exceeds 1100 mm per year. They appear to grow best at cooler temperatures, and when cut by frost, mostly recover from crowns. They are tolerant of poorly fertile, acid soils (down to pH(H_2O) 5.0), and although both are also tolerant of low available soil P, have responded to applied P. They cannot withstand prolonged dry periods, but in the event of stand loss through drought, they can regenerate from the often high levels of soil seed, measured at 50 seeds/m^2 under close grazing to over 1000 seeds/m^2 under lenient grazing. Both possess moderate shade tolerance. It can spread through dense grasses such as *Pennisetum clandestinum* Hochst. ex Chiov. by stolons, sometimes at over 1 m/year. It may be spread over considerable distances through ingested seed being voided in the dung.

Agronomy High levels of hard seed have been recorded and, where immediate germination is required, seed may need to be scarified. This can be achieved using mild abrasion or hot water (preliminary results suggest 10 minutes at 70°C). Seed is best sown at 2 kg/ha into a clean, well prepared seed-bed. It may be sown on the surface or at shallow depth. Subsequent rolling improves establishment. Native cowpea rhizobia give effective nodulation. Renovation of old stands can be achieved through limited cultivation, using soil seed reserves. Where seed is unavailable or more rapid establishment is required, creeping vigna may be established from rooted stolons.

Creeping vigna is adapted to both lenient and heavy grazing. However, to achieve maximum benefit as a forage and for N fixation, stands should be maintained between 20 and 50 cm. In low-fertility soils, nutrient deficiencies should be corrected, paying special attention to P and Mo.

In Papua New Guinea, no major disease or pest problems have been recorded. A fungus (*Sclerotium rolfsii*) and a root-knot nematode (*Meloidogyne javanica*) have caused some damage in 'Shaw' swards in Queensland, but had no lasting effect. Two other fungi, *Rhizoctonia solani* and *Colletotrichum truncatum* have been isolated from leaf and stem lesions in seed crops of 'Shaw', but can be largely controlled by avoiding accumulation of a bulk of mature top growth.

Creeping vigna is usually grazed since its prostrate, low twining growth habit does not readily lend itself to a cut-and-carry system. High quality hay can be made from creeping vigna, but weather conditions in its preferred habitats are rarely ideal for hay-making. Improved utilization by cattle of grasses such as *Pennisetum clandestinum, Axonopus affinis* A. Chase and even *Imperata cylindrica* (L.) Raeuschel has been observed where they are associated with this legume.

No yield data are available from South-East Asia, but in Queensland, autumn presentation DM yields of 1650 kg/ha of 'Shaw' were obtained from a grass/legume pasture stocked at 1.5 beast/ha.

Genetic resources and breeding A limited range of germplasm material is held at ATFGRC (CSIRO, Australia). The species is only adapted to humid highland areas in South-East Asia and has not attracted and does not warrant breeding work, at least not until wild types have been fully exploited.

Prospects Creeping vigna is a useful species, especially in acid soil areas where sward-forming grasses are common and in which pastures are subjected to heavy grazing. At this stage, its potential has only been partly realized. Evaluation of existing collections in tropical highland and subtropical lowland areas in South-East Asia is required.

Literature [1] Cook, B.G. & Jones, R.M., 1987. Persistent new legumes for intensive grazing. 1. Shaw creeping vigna. Queensland Agricultural Journal 113: 89–91. **2** Gillett, J.B., Polhill, R.M. & Verdcourt, B. 1971. Papilionoideae (2). In: Milne-Redhead, E. & Polhill, R.M. (Editors): Flora of tropical East Africa. Leguminosae 4 – Papilionoideae 2. Crown Agents for Oversea Governments and Administrations, London. pp. 635–637. **3** Jones, R.M. & Clements, R.J. 1987. Persistence and productivity of Centrosema virginianum and Vigna parkeri cv. Shaw under grazing on the coastal lowlands of South-East Queensland. Tropical Grasslands 21: 55–64. **4** Oram, R.N., 1990. Register of Australian herbage plant cultivars. CSIRO, Australia. pp. 269–270. [5] Pentney, C.J., Whiteman, P.C., & Sivasupiramaniam, S. 1984. Studies on the germination, phenology and Rhizobium requirements of Vigna parkeri. Tropical Grasslands 18: 66–74. [6] Verdcourt, B. 1979. A

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B.G. Cook & A.K. Benjamin

Zoysia matrella (L.) Merrill

Philip. J. Sc. 7: 230 (1912).

GRAMINEAE

$2n = 20, 40$

Synonyms *Agrostis matrella* L. (1771), *Zoysia pungens* Willd. (1801), *Z. tenuifolia* Willd. ex Thiele (1834).

Vernacular names Manila grass, Siglap grass, Korean grass (En). Mascarene grass (Am). Chiendent gazon (Fr). Indonesia: jukut kakawatan hijau (Sundanese), rebha sekem-sekeman (Madura), burikit (Ceram). Malaysia: rumput siglap. Philippines: damong-alat, barit-baritan (Tagalog), malakuwerdas (Pangasinan). Singapore: Siglap grass. Thailand: ya-nuannoi. Vietnam: cỏng cỏng.

Origin and geographic distribution Manila grass occurs naturally along the coasts of the Indian Ocean, the Chinese Sea to the Ryukyu Islands, and particularly in all South-East Asian countries. Now it is extensively cultivated (also inland) pantropically.

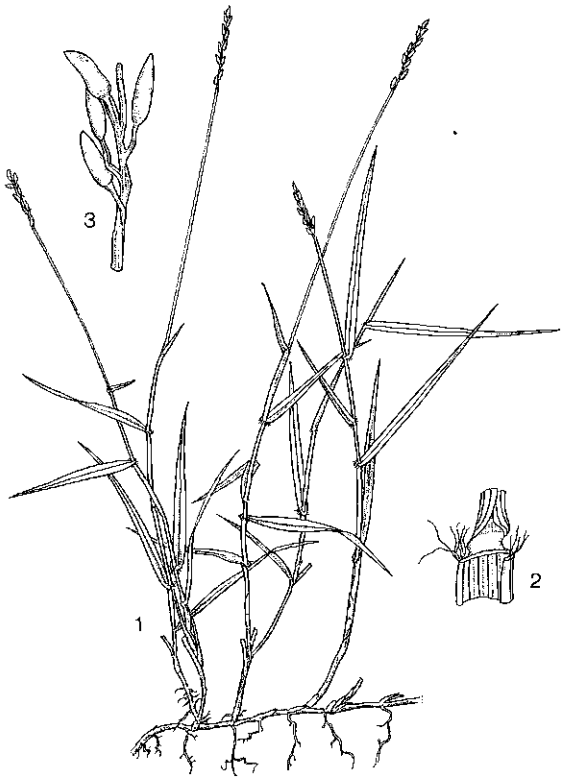
Uses Manila grass is used as forage on sandy soils in coastal areas where other grasses are not adapted. It is a good sand-binder and is cultivated for lawns.

Botany A mat-forming perennial, often stoloniferous, rarely rhizomatous, up to 35 cm high. Stolons to 45 cm long. Leaf-sheath hairy at the throat; ligule membranous and finely hairy, ca. 0.25 mm long; leaf-blade lanceolate, up to 8 cm × 3 mm when expanded, erectopatent to patent, base more or less cordately contracted into a short pseudopetiole. Inflorescence a terminal, spike-like raceme, up to 4 cm long, rachis somewhat wavy; pedicels 0–3 mm long; spikelets ovoid-oblongoid, 2–3.8 mm × 1 mm; lower glume usually absent, upper glume 5-nerved; palea absent. Caryopsis with a straight truncate base.

Seedling growth is slow but after 5–8 weeks strong new shoots send out tough rhizomes leading to the formation of a turf mat. There is considerable variation in growth habit, rhizome development and the shape of spikelets.

Two varieties are distinquished:

- var. *matrella*: leaf-blade 1.5–2.6 mm wide, more or less spreading; peduncle exserted from the uppermost sheath at anthesis, the raceme distinctly exserted above the foliage, up to 4.2 cm long; distribution as above.
- var. *pacifica* Goudswaard: leaf-blade 0.7–1 mm wide, usually erect; peduncle, even in fruit, not or hardly exserted from the uppermost sheath, the raceme therefore not or little exserted above the foliage, up to 1.5 cm long; distribution: Taiwan to the Ryukyu Islands and Loo Choo Island, Marianes, Solomons and in the Moluccas.



Zoysia matrella (L.) Merrill – 1, habit flowering plant; 2, ligule; 3, part of inflorescence.

Ecology *Z. matrella* can grow up to 300 m altitude, but is primarily adapted to very sandy soils on coastal areas. It is often found covering the ground under coconut plantations on sandy coastal soils.

Agronomy It is easily established by rhizomes. Frequent grazing is required to stimulate the growth of young leaves, which are palatable to stock. It is low yielding and not suited to cutting for forage. When used as a lawn grass it is frequently mown to keep it weed-free and green.

Genetic resources and breeding It is unlikely that substantial germplasm collections are being maintained.

Prospects The forage yield from this species will inevitably be very low and thus research is not warranted.

Literature [1] Gilliland, H.B., Holttum, R.E. & Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Vol. 3. Government Printing Office, Singapore. pp. 109–111. [2] Goudswaard, P.C., 1980. The genus Zoysia (Gramineae) in Malesia. Blumea 26: 169–175. [3] Häfliger, E. & Scholz, H., 1981. Grass weeds 2. Ciba-Geigy Ltd., Basel, Switzerland. p. 137. [4] Mehra, K.L. & Fachrurozi, Z., 1985. Indonesian economic plant resources: forage crops. Lembaga Biologi Nasional – LIPI, Bogor, No 31. p. 51.

C. Manidool

3 Minor forages

In this tentative list the species name is followed by its botanical family name, and synonyms are given in the following, indented lines. The list contains species which the major historical handbooks on economically useful plants of South-East Asia have noted as primarily being used for forage. In the Prosea books species of minor importance within a commodity group are normally described briefly. In this volume it was decided not to do this because theoretically all non-poisonous plant species might be considered to be forages. Nevertheless, it was thought useful to present this list of 'minor forage species' as compiled in the Prosea documentation system, realizing that the list in no way claims to be complete.

Acroceras crassiapiculatum (Merrill) Alston – Gramineae
    Panicum crassiapiculatum Merrill
Acroceras rigidula Steudel var. *rigidula* – Gramineae
    Agrostis infirma Buse
Acroceras tonkinense (Belanse) Bor – Gramineae
    Acroceras sparsum Stapf
Acroceras zizanioides (Kunth) Dandy – Gramineae
    Panicum oryzoides Swartz
    Acroceras oryzoides (Swartz) Stapf
Alloteropsis ciminica (L.) Stapf – Gramineae
    Coridochloa cimicina Nees
Alloteropsis semialata (R. Br.) Hitchc. – Gramineae
    Coridochloa semialata Nees
Alysicarpus rugosus (Willd.) DC. – Leguminosae
    Hedysarum rugosum Willd.
    Alysicarpus wallichii Wight & Arnott
Apluda mutica L. – Gramineae
    Apluda varia Hackel
Arthraxon castratus Bor – Gramineae
    Arthraxon pilipes Backer
Arthraxon hispidus (Thunberg ex Murray) Makino – Gramineae
Arthraxon hispidus (Thunberg ex Murray) Makino var. *robustior* Welzen – Gramineae
    Arthraxon typicus Koord.
Arthraxon microphyllus Hochst. – Gramineae
Arundinella holcoides (Kunth) Trinius – Gramineae
    Arundinella agrostoides Trinius
Arundinella nepalensis Trinius – Gramineae
Arundinella pumila (Hochst.) Steudel – Gramineae
    Arundinella tenella Nees & Wight

Arundinella setosa Trinius – Gramineae
Asthenochloa tenera Buse – Gramineae
Avena fatua L. – Gramineae
Avena sativa L. – Gramineae
Avena sterilis L. – Gramineae
Bauhinia hirsuta Weinmann – Leguminosae
Bothriochloa bladhii (Retzius) S.T. Blake – Gramineae
    Amphilophis glabra Stapf
    Andropogon intermedius R. Br.
    Amphilophis intermedia Stapf
Bothriochloa modesta (Backer) Backer & Henrard – Gramineae
    Andropogon modestus Backer
Brachiaria eruciformis (J.E. Smith) Griseb. – Gramineae
    Panicum eruciforme J.E. Smith
Brachiaria ramosa (L.) Stapf – Gramineae
    Panicum ramosum L.
Brachiaria reptans (L.) C. Gardner & C.E. Hubbard – Gramineae
    Panicum reptans L.
    Urochloa reptans (L.) Stapf
Brachiaria villosa (Lamk) A. Camus – Gramineae
    Panicum coccospermum Steudel
Brachypodium sylvaticum P. Beauv. – Gramineae
Briza minor L. – Gramineae
Bromus catharticus Vahl – Gramineae
    Bromus unioloides Kunth
Bromus insignis Buse – Gramineae
Calamagrostis australis Buse – Gramineae
Capillipedium assimile (Steudel) Camus – Gramineae
    Andropogon parviflorus Backer, non Roxburgh
Carex baccans Nees – Cyperaceae
Carex remota L. ssp. *alta* (Boott) Kuek. – Cyperaceae
Cenchrus inflexus R. Br. – Gramineae
Ceratonia siliqua L. – Leguminosae
Chloris inflata Link – Gramineae
    Chloris barbata auct., non Swartz
Chloris pumilio R. Br. – Gramineae
    Chloris divaricata R. Br. (misapplied to *Chloris pumilio* R. Br.)
Chloris truncata R. Br. – Gramineae
Chloris virgata Swartz – Gramineae
Chrysopogon subtilis (Steudel) Miquel – Gramineae
    Andropogon subtilis Steudel
Coelachne infirma Buse – Gramineae
    Coelachne pulchella auct., non R. Br.
Commelina diffusa Burm.f. – Commelinaceae
    Commelina nudiflora L.
Cyperus brevifolius (Rottb.) Hassk. – Cyperaceae
    Kyllinga brevifolia Rottb.
Cyperus castaneus Willd. – Cyperaceae
Cyperus compressus L. – Cyperaceae

Cyperus haspan L. – Cyperaceae
Cyperus iria L.
Cyperus kyllingia Endl. – Cyperaceae
Kyllinga monocephala Rottb.
Cytisus palmensis (Christ) Hutch. – Leguminosae
Dactylis glomerata L. – Gramineae
Dactyloctenium verticillatum Backer – Gramineae
Dichanthium caricosum (L.) Camus – Gramineae
Andropogon caricosus L.
Diectomis fastigiata (Swartz) Kunth – Gramineae
Andropogon fastigiatus Swartz
Digitaria abludens (Roemer & Schultes) Veldk. – Gramineae
Digitaria pedicellaris Prain
Digitaria eminens (Steudel) Backer – Gramineae
Digitaria junghuhniana (Steudel) Henrard – Gramineae
Digitaria perrottetii Backer
Digitaria longiflora (Retzius) Pers. – Gramineae
Digitaria ternata (A. Richard) Stapf – Gramineae
Digitaria ropalotricha Buse
Digitaria violascens Link – Gramineae
Digitaria pertenuis Buse
Dinebra retroflexa (Vahl) Panz. – Gramineae
Dinebra arabica Jacq.
Drymaria cordata (L.) Willd. ex Roemer & Schultes – Caryophyllaceae
Drymaria hirsuta Bartling – Caryophyllaceae
Echinochloa stagnina (Retzius) Beauv. – Gramineae
Panicum stagninum Retzius
Ectrosia leporina R. Br. – Gramineae
Enteropogon dolichostachyus (Lagasca) Keng – Gramineae
Chloris digitata Steudel
Epipremnum pinnatum (L.) Engl. – Araceae
Rhaphidophora merrillii Engl.
Eragrostis atrovirens (Desf.) Trinius ex Steudel – Gramineae
Eragrostis elegantula Steudel
Eragrostis bahiensis Schultes – Gramineae
Eragrostis elongata (Willd.) Jacq. – Gramineae
Eragrostis brownii Nees ex Hook. & Arnott
Eragrostis interrupta (R. Br.) Beauv. – Gramineae
Eragrostis japonica (Thunberg ex Murray) Trinius – Gramineae
Eragrostis megastachya (Koeler) Link – Gramineae
Eragrostis cilianensis (All.) Link ex Vign.
Eragrostis nigra Nees ex Steudel – Gramineae
Eragrostis pilosa (L.) Beauv. – Gramineae
Eremochloa ciliaris (L.) Merrill – Gramineae
Eremochloa horneri Buse
Eremochloa malayana Ridley
Eriachne obtusa R. Br. – Gramineae
Eriachne pallescens R. Br. – Gramineae
Eriachne tincta Nees – Gramineae

Eriachne triseta Nees ex Steudel – Gramineae
Eriochloa nubica (Steudel) Hackel & Stapf ex Thell. – Gramineae
Eriochloa decumbens F.M. Bailey
Eriochloa procera (Retzius) C.E. Hubbard – Gramineae
Eriochloa ramosa (Retzius) O. Kuntze
Eriochloa subglabra (Nash) Hitchc. – Gramineae
Euchlaena mexicana Schrader – Gramineae
Eulalia fimbriata (Hackel) O. Kuntze – Gramineae
Pollinia fimbriata Hackel
Eulalia fulva (R. Br.) O. Kuntze – Gramineae
Pollinia fulva (R. Br.) Benth.
Eulalia quadrinervis (Hackel) O. Kuntze – Gramineae
Pollinia quadrinervis Hackel
Eulalia trispicata (Schultes) Henrard – Gramineae
Pollinia argentea (Brongn.) Trinius
Eustachys tenera (Presl) Camus – Gramineae
Chloris tenera Scribner
Festuca leptopogon Stapf – Gramineae
Festuca nubigena Jungh. – Gramineae
Ficus globosa Blume – Moraceae
Ficus hirta Vahl – Moraceae
Fimbristylis annua (All.) Roemer & Schultes – Cyperaceae
Fimbristylis miliacea (L.) Vahl – Cyperaceae
Garnotia stricta Brongn. – Gramineae
Hackechloa granularis (L.) O. Kuntze – Gramineae
Manisuris granularis L.f.
Helictotrichon virescens (Steudel) Henrard – Gramineae
Avena junghuhnii Buse
Hemarthria vaginata Buse – Gramineae
Rottboellia vaginata (Buse) Backer
Heteropogon triticeus (R. Br.) Stapf – Gramineae
Andropogon triticeus R. Br.
Hierochloe horsfieldii (Kunth) Maxim. – Gramineae
Holcus lanatus L. – Gramineae
Homalomena aromatica (Roxburgh) Schott – Araceae
Homalomena cordata Schott – Araceae
Homalomena philippinensis Engl.
Hydrilla verticillata (L.f.) Royle – Hydrocharitaceae
Hymenachne amplexicaulis (Rudge) Nees – Gramineae
Hymenachne myurus Beauv.
Hymenachne aurita (Nees) Backer – Gramineae
Panicum auritum Presl
Hymenachne interrupta (Willd.) Buse – Gramineae
Hyparrhenia filipendula (Hochst.) Stapf – Gramineae
Andropogon filipendulus Hochst.
Ichnanthus pallens (Swartz) Munro – Gramineae
Ichnanthus vicinus (F.M. Bailey) Merrill (misapplied to *Ichnanthus pallens* (Swartz) Munro)
Indigofera cordifolia K. Heyne ex Roth – Leguminosae

Indigofera glandulosa Wendl. – Leguminosae
Psoralea leichhardtii F. v. Muell.
Isachne albens Trinius – Gramineae
Isachne beneckei Hackel – Gramineae
Isachne globosa (Thunberg ex Murray) O. Kuntze – Gramineae
Isachne miliacea Roth ex Roemer & Schultes – Gramineae
Isachne myosotis Nees – Gramineae
Isachne pangerangensis Zollinger & Moritzi – Gramineae
Isachne rigida Nees ex Miquel
Ischaemum arundinaceum F.v.Mueller ex Benth. – Gramineae
Ischaemum digitatum Brongn. – Gramineae
Ischaemum laxum R. Br. – Gramineae
Leersia hexandra Swartz – Gramineae
Lemna minor L. – Lemnaceae
Leptaspis banksii R. Br. – Gramineae
Leptaspis cochleata Thwaites – Gramineae
Leptochloa filiformis (Lamk) Beauv. – Gramineae
Leptochloa polystachya (R. Br.) Benth. (misapplied to *Leptochloa filiformis* (Lamk) Beauv.)
Leptochloa malabarica (L.) Veldk. – Gramineae
Diplachne polystachya (Forsskal) Backer
Diplachne fusca (L.) Beauv. ex Roemer & Schultes
Panicum malabaricum (L.) Merrill
Leptochloa tectoneticola (Backer) Jansen – Gramineae
Diplachne tectoneticola Backer
Lepturus repens (Forster) R. Br. – Gramineae
Monerma repens Beauv.
Lespedeza thunbergii (DC.) Nakai – Leguminosae
Lespedeza sieboldi Miquel
Ligustrum lucidum Aiton – Oleaceae
Lindernia ciliata (Colsm.) Pennell – Scrophulariaceae
Bonnaya ciliata Burkill
Bonnaya serrata Burkill
Lolium multiflorum Lamk – Gramineae
Lolium italicum A. Braun
Lolium perenne L. – Gramineae
Lolium temulentum L. – Gramineae
Lophatherum gracile Brongn. – Gramineae
Macaranga hosei King ex Hook.f. – Euphorbiaceae
Mapania kurzii Clarke – Cyperaceae
Melinis minutiflora Beauv. – Gramineae
Microchloa indica (L.f.) Beauv. – Gramineae
Microlaena stipoides (Labill.) R. Br. – Gramineae
Mnesithea glandulosa (Trinius) Koning & Sosef – Gramineae
Coelorrhachis glandulosa Stapf
Rottboellia glandulosa Trinius
Mnesithea laevis (Retzius) Kunth – Gramineae
Mnesithea mollicoma (Hance) Camus – Gramineae
Mnesithea pubescens Ridley

Mnesithea rottboellioides (R. Br.) Koning & Sosef – Gramineae
Rottboellia ophiuroides Benth.
Morus alba L. – Moraceae
Muehlenbergia huegelii Trinius – Gramineae
Myriostachya wightiana (Nees) Hook.f. – Gramineae
Najas indica (Willd.) Chamisso – Najadaceae
Najas falciculata A. Braun
Najas minor Allioni – Najadaceae
Nertera depressa Banks & Soland. – Rubiaceae
Ophiurus exaltatus (L.) O. Kuntze – Gramineae
Oplismenus burmanni (Retzius) Beauv. – Gramineae
Hoplismenus burmani P. Beauv.
Oplismenus compositus (L.) Beauv. – Gramineae
Hoplismenus compositus P. Beauv.
Oplismenus undulatifolius (Ard.) Beauv. – Gramineae
Hoplismenus undulatifolius P. Beauv.
Opuntia cochenillifera Miller – Cactaceae
Nopalea coccinellifera (Miller) Salm-Dyck
Opuntia monacantha Haw. – Cactaceae
Oryza fatua Koenig ex Trinius – Gramineae
Oryza granulata Nees & Arnott ex Steudel – Gramineae
Oryza meyeriana (Zollinger & Moritzi) Baillon – Gramineae
Oryza minuta Presl – Gramineae
Oryza latifolia Desv.
Oryza ridleyi Hook.f. – Gramineae
Panicum ambiguum Trinius – Gramineae
Urochloa paspaloides Presl
Panicum brevifolium L. – Gramineae
Panicum caudiglume Hackel – Gramineae
Panicum luzonense Presl – Gramineae
Panicum tuberculatum Presl (misapplied to *Panicum luzonense* Presl)
Panicum notatum Retzius – Gramineae
Panicum miliare Lamk
Panicum montanum Roxburgh
Panicum paludosum Roxburgh – Gramineae
Panicum sarmentosum Roxburgh – Gramineae
Panicum trichoides Swartz – Gramineae
Panicum trypheron Schultes – Gramineae
Panicum walense Mez – Gramineae
Panicum humile Nees ex Steudel
Paspalidium flavidum (Retzius) Camus – Gramineae
Panicum flavidum Retzius
Paspalidium geminatum (Forsskal) Stapf – Gramineae
Panicum geminatum Forsskal
Paspalidium punctatum (Burm.f.) Camus – Gramineae
Panicum mucronatum Roth ex Roemer & Schultes
Paspalum orbiculare Forster f. – Gramineae
Paspalum vaginatum Swartz – Gramineae
Pennisetum alopecuroides (L.) Sprengel – Gramineae

Pennisetum compressum R. Br.
Perotis indica (L.) Kuntze – Gramineae
Phalaris arundinacea L. – Gramineae
Pisonia umbellifera (J. & G. Forster) Seemann – Nyctaginaceae
Pisonia excelsa Blume
Pistia stratiotes L. – Araceae
Planchonella longepetiolata (King & Prain) H.J. Lam – Sapotaceae
Planchonella pohlmanniana Burkill – Sapotaceae
Pluchea lanceolata (DC.) C.B. Clarke – Compositae
Poa annua L. – Gramineae
Poa trivialis L. – Gramineae
Pollinia clavigera Backer ex Heyne – Gramineae
Pollinia dispar Nees ex Steudel – Gramineae
Pollinia grata Hackel – Gramineae
Pollinia nuda Trinius – Gramineae
Pollinia spectabilis Trinius – Gramineae
Polypogon monspeliensis (L.) Desv. – Gramineae
Polytoca bracteata R. Br. – Gramineae
Polytoca macrophylla Benth. – Gramineae
Polytrias amaura (Buse) Kuntze – Gramineae
Eulalia praemorsa (Nees) Hackel (misapplied to *Polytrias amaura* (Buse) Kuntze)
Pseudochinolaena polystachya (Kunth) Stapf – Gramineae
Panicum uncinatum Raddi
Pseudopogonatherum contortum (Brongn.) Camus – Gramineae
Pollinia contorta Backer
Pseudoraphis spinescens (R. Br.) Vickery – Gramineae
Chamaeraphis aspera Nees
Pseudosorghum zollingeri (Steudel) Camus – Gramineae
Andropogon zollingeri Steudel
Rhagodia hastata R. Br. – Chenopodiaceae
Rhagodia parabolica R. Br. – Chenopodiaceae
Richardsonia brasiliensis Gomez – Rubiaceae
Rottboellia exaltata L.f. – Gramineae
Rytidosperma pilosa (R. Br.) Connor & Edgar – Gramineae
Danthonia pilosa R. Br.
Saccolepis angusta (Trinius) Stapf – Gramineae
Saccolepis indica (L.) A. Chase – Gramineae
Hymenachne indica Buse
Saccolepis myosuroides (R. Br.) Chase ex Camus – Gramineae
Saraca dives Pierre – Leguminosae
Schismatoglottis rupestris Zollinger & Moritzi – Araceae
Schismatoglottis latifolia Miquel
Schizachyrium brevifolium (Swartz) Nees ex Buse – Gramineae
Andropogon brevifolius Swartz
Schizachyrium sanguineum (Retzius) Alston – Gramineae
Andropogon sanguineus Merrill
Schizachyrium semiberbe Nees – Gramineae
Scirpus erectus Poiret – Cyperaceae

Sclerachne punctata R. Br. – Gramineae
Scrotochloa urceolata (Roxburgh) Judziewicz – Gramineae
Leptaspis urceolata R. Br.
Semecarpus kurzii Engl. – Anacardiaceae
Setaria barbata (Lamk) Kunth – Gramineae
Panicum barbatum Lamk
Setaria clivalis (Ridley) Veldk. – Gramineae
Panicum chamaeraphoides Hackel
Setaria geniculata (Lamk) Beauv. – Gramineae
Setaria glauca (L.) Beauv. – Gramineae
Panicum lutescens Weigel
Setaria palmifolia (Koenig) Stapf – Gramineae
Panicum palmifolium Koenig
Setaria verticillata (L.) Beauv. – Gramineae
Panicum verticillatum L.
Setaria viridis (L.) Beauv. – Gramineae
Panicum viride L.
Sorghum affine Camus – Gramineae
Sorghum halepense (L.) Pers. – Gramineae
Andropogon halepensis Brot.
Andropogon halepensis Brot. var. *propinquus* (Kunth) Merrill (misapplied to *Sorghum halepense* (L.) Pers.)
Sorghum nitidum (Vahl) Pers. – Gramineae
Andropogon amboinicus Merrill
Sorghum plumosum (R. Br.) Beauv. – Gramineae
Andropogon plumosus Backer, non Kunth
Sorghum sudanense (Piper) Stapf – Gramineae
Spergula arvensis L. – Caryophyllaceae
Sporobolus diandrus (Retzius) Beauv. – Gramineae
Sporobolus humilus Presl – Gramineae
Sporobolus tremulus (Willd.) Kunth
Sporobolus pulchellus R. Br. – Gramineae
Sporobolus virginicus (L.) Kunth – Gramineae
Streblochaete longiaristum (Richard) Pilger – Gramineae
Koordersiochloa javanica Merrill
Symphytum asperum Lepechin – Boraginaceae
Symphytum asperrimum J. Donn
Thelepogon elegans Roth ex Roemer & Schultes – Gramineae
Themeda arguens (L.) Hackel – Gramineae
Themeda gigantea (Cav.) Hackel – Gramineae
Themeda villosa Durand & Jackson (misapplied to *Themeda gigantea* (Cav.) Hackel)
Thuarea involuta (Forster) R. Br. ex Roemer & Schultes – Gramineae
Thuarea sarmentosa Pers.
Trema aspera Blume – Ulmaceae
Tricholaena rosea Nees – Gramineae
Trifolium incarnatum L. – Leguminosae
Tripogon exiguus Buse – Gramineae
Tripsacum latifolium Hitchc. – Gramineae

Vigna trilobata (L.) Verdc. – Leguminosae
Dolichos trilobatus L.
Phaseolus trilobatus (L.) Schreb.
Wallichia densiflora (Martius) Martius – Palmae

4 Forages with other primary use

In this tentative list the commodity group of primary use is given in parentheses and synonyms are given in the following, indented lines. The list contains species which have been noted in the major historical handbooks on economically useful plants of South-East Asia as having a secundary use as forage. It is not a list of all species that are used as forage.

Abelmoschus esculentus (L.) Moench (vegetables)
    Hibiscus esculentus L.
Acacia farnesiana (L.) Willd. (essentail-oil plants)
Acacia mearnsii De Wild. (dye and tannin-producing plants)
    Acacia decurrens auct. non Willd.
Acacia nilotica (L.) Willd. ex Del. (dye and tannin-producing plants)
    Acacia arabica (Lamk) Willd.
Acacia tomentosa (Roxburgh) Willd. (auxiliary plants in agriculture and forestry)
Acanthus ilicifolius L. (medicinal and poisonous plants)
    Acanthus volubilis Wallich
Adenostemma lavenia (L.) Kuntze (medicinal and poisonous plants)
Aganope heptaphylla (L.) Polhill (vegetables)
    Derris heptaphylla Merrill
Ailanthus altissima (Miller) Swingle (medicinal and poisonous plants)
    Ailanthus glandulosa Desf.
    Ailanthus vilmoriniana Dode
Albizia procera (Roxburgh) Benth. (timber trees)
Alphitonia excelsa Reisseck ex Endlicher (timber trees)
Amaranthus spinosus L. (medicinal and poisonous plants)
Amaranthus viridis L. (vegetables)
    Amaranthus gracilis Desf.
Amorphophallus paeoniifolius (Dennst.) Nicolson (plants mainly producing carbohydrates)
    Amorphophallus campanulatus Blume
Amorphophallus variabilis Blume (plants mainly producing carbohydrates)
Andropogon nardus L. (essentail-oil plants)
    Cymbopogon citratus Stapf (misapplied to *Andropogon nardus* L.)
    Andropogon nardus L. var. *tortilis* (Presl) Merrill (misapplied to *Andropogon nardus* L.)
Annona muricata L. (edible fruits and nuts)
Annona squamosa L. (edible fruits and nuts)
Anthocephalus chinensis (Lamk) A. Rich. ex Walp. (timber trees)
    Anthocephalus cadamba (Roxburgh) Miquel

Anthocephalus indicus Richard
Neolamarckia cadamba (Roxburgh) Bosser
Antidesma bunius (L.) Sprengel (edible fruits and nuts)
Antidesma dallachyanum Baillon
Antidesma rumphii Tulasne
Apium graveolens L. (vegetables)
Arachis hypogaea L. (pulses)
Areca triandra Roxburgh (stimulants)
Areca borneensis Beccari
Artabotrys suaveolens Blume (ornamental plants)
Artocarpus altilis (Parkinson) Fosberg (edible fruits and nuts)
Artocarpus communis J.R. & G. Forster
Artocarpus camansi Blanco
Artocarpus integer (Thunberg) Merrill (edible fruits and nuts)
Artocarpus champeden (Loureiro) Stokes
Azadirachta indica Adr. Jussieu (medicinal and poisonous plants)
Melia indica Brandis
Azolla pinnata R. Br. (lower plants)
Bambusa bambos Backer (bamboos)
Beta vulgaris L. (vegetables)
Bidens pilosa L. var. *radiata* Schultz-Bip. (medicinal and poisonous plants)
Bidens pilosus L. var. *albus* Schultz-Bip.
Boerhavia diffusa L. (medicinal and poisonous plants)
Bombax ceiba L. (timber trees)
Gossampinus heptaphylla Bakh.
Bombax malabaricum DC.
Bombax valetonii Hochr. (timber trees)
Bombax insigne Wallich
Bombax larutense Ridley
Borassus flabellifer L. (plants mainly producing carbohydrates)
Brassica juncea (L.) Czernova (vegetables)
Brassica rugosa Prain
Brassica integrifolia (West) Rupr.
Bridelia retusa (L.) Sprengel (timber trees)
Brugmansia candida (Pers.) Safford (ornamental plants)
Pseudodatura arborea van Zyp
Brugmansia suaveolens Humb. & Bonpl. (ornamental plants)
Pseudodatura suaveolens van Zyp
Datura suaveolens Humb. & Bonpl.
Bruguiera gymnorhiza (L.) Savigny (dye and tannin-producing plants)
Bruguiera conjugata Merrill
Butea monosperma (Lamk) Taubert (dye and tannin-producing plants)
Butea superba Roxburgh (medicinal and poisonous plants)
Caesalpinia crista L. (medicinal and poisonous plants)
Caesalpinia nuga (L.) W.T. Aiton
Caesalpinia digyna Rottler (dye and tannin-producing plants)
Cajanus cajan (L.) Millsp. (pulses)
Cytisus cajan L.
Cajanus indicus Spreng.

Canarium sylvestre Gaertner (plants producing exudates)
Canavalia maritima (Aublet) du Petit-Thouars (auxiliary plants in agriculture and forestry)
Canavalia rosea (Swartz) DC.
Canna edulis Ker (plants mainly producing carbohydrates)
Cannabis sativa L. (medicinal and poisonous plants)
Careya arborea Roxburgh (timber trees)
Carthamus tinctorius L. (vegetable oils and fats)
Carum carvi L. (spices and condiments)
Cassia mimosoides L. (auxiliary plants in agriculture and forestry)
Cassia siamea Lamk (timber trees)
Ceiba pentandra (L.) Gaertner (fibre plants)
Cicer arietinum L. (pulses)
Citrullus lanatus (Thunberg) Matsum. & Nakai ssp. *vulgaris* (Schrader) Fursa (vegetables)
Citrullus vulgaris Schrader ex Ecklon & Zeyher
Citrus limon (L.) Burm.f. (edible fruits and nuts)
Claoxylon indicum (Reinw. ex Blume) Hassk. (spices and condiments)
Claoxylon polot Merrill
Cleome gynandra L. (vegetables)
Gynandropsis gynandra (L.) Merrill
Cocos nucifera L. (vegetable oils and fats)
Coix lachryma-jobi L. (cereals)
Colocasia esculenta (L.) Schott (plants mainly producing carbohydrates)
Combretum quadrangulare Kurz (medicinal and poisonous plants)
Commelina benghalensis L. (vegetables)
Corchorus olitorius L. (fibre plants)
Cordia dichotoma Forster f. (medicinal and poisonous plants)
Cordia obliqua Willd.
Coriandrum sativum L. (spices and condiments)
Corypha utan Lamk (fibre plants)
Corypha elata Roxburgh
Crotalaria alata Buch.-Ham. & Roxburgh ex D. Don (auxiliary plants in agriculture and forestry)
Crotalaria anagyroides Kunth (auxiliary plants in agriculture and forestry)
Crotalaria ferruginea Graham ex Benth. (auxiliary plants in agriculture and forestry)
Crotalaria zanzibarica Benth. (auxiliary plants in agriculture and forestry)
Crotalaria usaramoensis Baker f.
Cucurbita pepo L. (vegetables)
Cyamopsis tetragonoloba (L.) Taubert (auxiliary plants in agriculture and forestry)
Cyamopsis psoralioides DC.
Cyanotis cristata (L.) D. Don (vegetables)
Cyathea amboinensis (v.A.v.R.) Merrill (lower plants)
Alsophila amboinensis v.A.v.R.
Cyperus cyperoides (L.) O. Kuntze (medicinal and poisonous plants)
Mariscus sieberianus Nees ex Clarke
Cyperus elatus L. (fibre plants)

Cyperus pilosus Vahl (auxiliary plants in agriculture and forestry)
Cyperus rotundus L. (plants mainly producing carbohydrates)
Cyrtococcum accrescens (Trinius) Stapf (auxiliary plants in agriculture and forestry)
Cyrtococcum oxyphyllum (Steudel) Stapf (auxiliary plants in agriculture and forestry)
Panicum pilipes Nees & Arnott ex Buse
Cyrtococcum trigonum (Retzius) Camus (auxiliary plants in agriculture and forestry)
Panicum trigonum Retzius
Desmodium tortuosum (Swartz) DC. (auxiliary plants in agriculture and forestry)
Desmodium purpureum (Miller) Fawc. & Rendle
Digitaria didactyla Willd. (ornamental plants)
Dimeria ornithopoda Trinius (ornamental plants)
Echinochloa frumentacea (Roxburgh) Link (cereals)
Eichhornia crassipes (Martius) Solms (auxiliary plants in agriculture and forestry)
Pontederia crassipes Mart.
Eichhornia speciosa Kunth
Elaeis guineensis N.J. Jacquin (vegetable oils and fats)
Elephantopus scaber L. (medicinal and poisonous plants)
Eleusine indica (L.) Gaertner f. *coracana* (L.) Hook.f. ex Backer (cereals)
Eleusine coracana Gaertner
Enhalus acoroides (L.f.) L.C. Richard ex Steudel (fibre plants)
Eragrostis tef (Zuccagni) Trotter (cereals)
Erianthus arundinaceus (Retzius) Jeswiet (fibre plants)
Saccharum arundinaceum Retzius
Erythrina subumbrans (Hassk.) Merrill (auxiliary plants in agriculture and forestry)
Erythrina lithosperma Miquel
Fagopyrum esculentum Moench (cereals)
Ficus altissima Blume (fibre plants)
Ficus benghalensis L. (timber trees)
Ficus indica L.
Ficus grossularioides Burm.f. (vegetables)
Ficus alba Reinw. ex Blume
Ficus hispida L. (medicinal and poisonous plants)
Ficus padana Burm.f. (plants producing exudates)
Ficus toxicaria L.
Ficus religiosa L. (medicinal and poisonous plants)
Ficus superba (Miquel) Miquel (vegetables)
Ficus variegata Blume (plants producing exudates)
Fimbristylis dichotoma (L.) Vahl (auxiliary plants in agriculture and forestry)
Fimbristylis diphylla Vahl
Firmiana colorata (Roxburgh) R. Br. (fibre plants)
Erythropsis colorata (Roxburgh) Burkill
Galinsoga parviflora Cav. (vegetables)
Garuga floribunda Decaisne (timber trees)
Garuga abilo Merrill

Glycine max (L.) Merrill (pulses)
Gossypium arboreum L. var. *obtusifolium* (Roxburgh) Roberty (fibre plants)
Gossypium nangking Meyen
Gossypium obtusifolium Roxburgh
Gossypium hirsutum L. (fibre plants)
Guazuma ulmifolia Lamk var. *tomentosa* K. Schumann (fibre plants)
Guizotia abyssinica (L.f.) Cass. (vegetable oils and fats)
Helianthus annuus L. (vegetable oils and fats)
Hevea brasiliensis (Willd. ex A. Jussieu) Muell. Arg. (plants producing exudates)
Hibiscus cannabinus L. (fibre plants)
Hibiscus sabdariffa L. (vegetables)
Hibiscus tiliaceus L. (fibre plants)
Homalomena alba Hassk. (medicinal and poisonous plants)
Homalomena javanica Alderw.
Hydnocarpus castanea Hook.f. & Thomson (timber trees)
Hydnocarpus heterophylla Blume (vegetable oils and fats)
Taraktogenos heterophylla Slooten
Hydnocarpus kurzii (King) Warb. (vegetable oils and fats)
Taraktogenos kurzii King
Hydnocarpus polypetala (Slooten) Sleumer (vegetable oils and fats)
Taraktogenos polypetala Slooten
Hygrorhiza aristata (Retzius) Nees ex Wight & Arnott (cereals)
Hymenodictyon orixense (Roxburgh) Mabberly (timber trees)
Hymenodictyon excelsum Wallich
Hymenodictyon timoriense Klotsch ex Walp.
Imperata conferta (Presl) Ohwi (fibre plants)
Imperata contracta Hitchc.
Imperata exaltata Brongn. (misapplied to *Imperata conferta* (Presl) Ohwi)
Indigofera spicata Forssk. var. *spicata* (auxiliary plants in agriculture and forestry)
Indigofera hendecaphylla Jacq.
Inocarpus fagiferus (Parkinson) Fosberg (ornamental plants)
Inocarpus edulis J.R. & G. Forster
Ipomoea aquatica Forssk. (vegetables)
Ipomoea reptans Poiret
Ipomoea batatas (L.) Lamk (plants mainly producing carbohydrates)
Ipomoea pes-caprae (L.) Sweet (medicinal and poisonous plants)
Justicia procumbens L. (medicinal and poisonous plants)
Rostellaria procumbens (L.) Nees
Kydia calycina Roxburgh (fibre plants)
Lablab purpureus (L.) Sweet (pulses)
Dolichos lablab L.
Lablab niger Medikus
Lactuca indica L. (vegetables)
Lagerstroemia indica L. (ornamental plants)
Lannea coromandelica (Houtt.) Merrill (ornamental plants)
Lannea grandis (Dennst.) Engl.
Lantana camara L. (medicinal and poisonous plants)

Lantana aculeata L.
Leucas lavandulifolia J.E. Smith (medicinal and poisonous plants)
Leucas linifolia (Roth) Sprengel
Limnocharis flava (L.) Buchenau (vegetables)
Litchi chinensis Sonn. (edible fruits and nuts)
Nephelium litchi Cambess.
Litchi philippinensis Radlk.
Euphoria didyma Blanco
Litsea garciae Vidal (edible fruits and nuts)
Litsea sebifera (Blume) Blume
Litsea glutinosa (Loureiro) C.B. Robinson (timber trees)
Litsea chinensis Lamk
Lycopersicon esculentum Miller (vegetables)
Solanum lycopersicum L.
Macaranga gigantea (H.G. Reichenbach & Zollinger) Muell. Arg. (timber trees)
Macaranga incisa Gage
Maclura cochinchinensis (Loureiro) Corner (dye and tannin-producing plants)
Cudrania javanensis Trécul
Cudrania pubescens Trécul
Macrotyloma uniflorum (Lamk) Verdc. (pulses)
Dolichos uniflorus Lamk
Dolichos biflorus auct. mult., non L.
Mangifera indica L. (edible fruits and nuts)
Manihot esculenta Crantz (plants mainly producing carbohydrates)
Manihot utilissima Pohl
Melastoma malabathricum L. (medicinal and poisonous plants)
Melastoma polyanthum Blume (medicinal and poisonous plants)
Melastoma malabathricum L. f. *polyanthum* L.
Melastoma sanguineum Sims (medicinal and poisonous plants)
Melastoma decemfidum Roxburgh
Merremia hederacea (Burm.f.) H. Hallier (medicinal and poisonous plants)
Metroxylon sagu Rottboel (plants mainly producing carbohydrates)
Metroxylon rumphii (Willdenow) Martius
Metroxylon squarrosum Beccari
Mimosa invisa Martius ex Colla (auxiliary plants in agriculture and forestry)
Miscanthus japonicus Andersson (fibre plants)
Mollugo pentaphylla L. (medicinal and poisonous plants)
Monochoria hastata (L.) Solms (vegetables)
Monochoria vaginalis (Burm.f.) Presl (vegetables)
Moringa oleifera Lamk (spices and condiments)
Mucuna pruriens (L.) DC. cv. group Utilis (auxiliary plants in agriculture and forestry)
Mucuna aterrima (Piper & Tracy) Merrill
Mucuna cochinchinensis (Loureiro) A. Chev.
Mucuna deeringiana (Bort.) Merrill
Murdannia nudiflora (L.) Brenan (vegetables)
Aneilema nudiflorum R. Br.
Musa × *paradisiaca* L. (Musa AAB group) (edible fruits and nuts)
Musa paradisiaca L. var. *sapientum* Kuntze

Musa sapientum L. var. *paradisiaca* Baker
Neyraudia reynaudiana (Kunth) Keng ex Hitchc. (ornamental plants)
Neyraudia madagascariensis Hook.f. var. *zollingeri* Hook.f.
Triraphis madagascariensis Hook.f. ex Prain
Nymphoides spp. (vegetables)
Limnanthemum spp.
Oldenlandia corymbosa L. (medicinal and poisonous plants)
Opuntia elatior Miller (ornamental plants)
Opuntia nigricans Haw.
Oryza sativa L. (cereals)
Pandanus affinis Kurz (medicinal and poisonous plants)
Pandanus aurantiacus Ridley
Pandanus helicopus Kurz (fibre plants)
Pandanus johorensis Martelli
Panicum miliaceum L. (cereals)
Paraserianthes falcataria (L.) Nielsen (auxiliary plants in agriculture and forestry)
Albizia falcata sensu Backer
Parkinsonia aculeata L. (ornamental plants)
Passiflora foetida L. (auxiliary plants in agriculture and forestry)
Peltophorum pterocarpum (DC.) Backer ex Heyne (dye and tannin-producing plants)
Pennisetum americanum (L.) K. Schum. ex Leeke (cereals)
Pennisetum glaucum R. Br.
Pennisetum macrostachyum (Brongn.) Trinius (ornamental plants)
Pennisetum villosum R. Br. ex Fresen. (ornamental plants)
Perilla frutescens (L.) Britton (vegetable oils and fats)
Perilla ocimoides L.
Phaseolus coccineus L. (pulses)
Phaseolus multiflorus Lamk
Phaseolus lunatus L. (pulses)
Phragmites australis (Cav.) Steudel (fibre plants)
Phragmites vulgaris (Lamk) Crepin
Phragmites karka (Retzius) Trinius ex Steudel (fibre plants)
Phragmites communis Trinius (misappplied to *Phragmites karka* (Retzius) Trinius ex Steudel)
Phyllodium pulchellum (L.) Desv. (medicinal and poisonous plants)
Desmodium pulchellum (L.) Benth.
Phytelephas macrocarpa Ruiz & Pavon (ornamental plants)
Pimpinella anisum L. (medicinal and poisonous plants)
Plantago major L. (medicinal and poisonous plants)
Pogonatherum crinitum (Thunberg ex Murray) Trinius ex Kunth (auxiliary plants in agriculture and forestry)
Pogonatherum paniceum (Lamk) Hackel
Pongamia pinnata (L.) Pierre (medicinal and poisonous plants)
Portulaca oleracea L. (vegetables)
Premna serratifolia L. (timber trees)
Premna integrifolia L.
Premna foetida Reinw. ex Blume

Prosopis juliflora (Swartz) DC. (auxiliary plants in agriculture and forestry)
Prosopis spicigera L. (auxiliary plants in agriculture and forestry)
Pseuderanthemum racemosum (Roxburgh) Radlk. (vegetables)
Pteridium aquilinum Kuhn (lower plants)
Pueraria lobata (Willd.) Ohwi (plants mainly producing carbohydrates)
    Pueraria triloba (Loureiro) Backer
    Pueraria hirsuta (Thunberg) Schneider
Putranjiva roxburghii Wallich (medicinal and poisonous plants)
Quercus robur L. (timber trees)
Ricinus communis L. (vegetable oils and fats)
Rivina humilis L. (medicinal and poisonous plants)
Saccharum officinarum L. (plants mainly producing carbohydrates)
Saccharum ravennae (L.) Murray (fibre plants)
Sagittaria sagittifolia L. (plants mainly producing carbohydrates)
    Sagittaria sagittaefolia L.
Samanea saman (Jacq.) Merrill (ornamental plants)
    Enterolobium saman (Jacq.) Prain
Santalum acuminatum (R. Br.) A. DC. (essential-oil plants)
    Eucarya acuminata (R. Br.) Sprague & Summerhayes
Sapium discolor (Champ. ex Benth.) Muell.Arg. (timber trees)
Schismatoglottis calyptrata (Roxburgh) Zollinger & Moritzi (vegetables)
Schleichera oleosa (Loureiro) Oken (vegetable oils and fats)
Scoparia dulcis L. (medicinal and poisonous plants)
Sechium edule (Jacq.) Swartz (vegetables)
Sesamum orientale L. (vegetable oils and fats)
    Sesamum indicum L.
Sesamum radiatum Schumacher (vegetable oils and fats)
Sesbania bispinosa (Jacq.) W.F. Wight (fibre plants)
    Sesbania aculeata (Willd.) Pers.
Sesbania javanica Miquel (ornamental plants)
    Sesbania roxburghii Merrill
Sesuvium portulacastrum (L.) L. (vegetables)
Setaria italica (L.) Beauv. (cereals)
    Panicum viride L. var. *italica* L.
Shorea roxburghii G. Don (timber trees)
    Shorea cochinchinensis Pierre
Shorea siamensis Miquel (timber trees)
    Pentacme siamensis (Miquel) Kurz
Sida cordifolia L. (medicinal and poisonous plants)
Sida rhombifolia L. (medicinal and poisonous plants)
Smithia sensitiva Aiton (medicinal and poisonous plants)
Sonchus oleraceus L. (vegetables)
Sonchus wightianus DC. (vegetables)
    Sonchus arvensis L. (misapplied to *Sonchus wightianus* DC.)
Sophora tomentosa L. (medicinal and poisonous plants)
Sorghum bicolor (L.) Moench (cereals)
    Andropogon sorghum Brot.
    Sorghum vulgare Pers.
Sparganophorus sparganophora (L.) C. Jeffrey (auxiliary plants in agriculture

and forestry)
Sparganophorus vaillantii Gaertner
Sphaeranthus africanus L. (medicinal and poisonous plants)
Sporobolus indicus (L.) R. Br. (fibre plants)
Sporobolus berteroanus Hitchc. & Chase
Stachytarpheta jamaicensis (L.) Vahl (medicinal and poisonous plants)
Streblus asper (Retzius) Loureiro (medicinal and poisonous plants)
Syagrus oleracea (Martius) Beccari (timber trees)
Tamarindus indica L. (edible fruits and nuts)
Tephrosia purpurea (L.) Pers. (auxiliary plants in agriculture and forestry)
Theobroma cacao L. (vegetable oils and fats)
Theobroma pentagona Bernoulli
Tragus racemosus Aiton ex Hook.f. (auxiliary plants in agriculture and forestry)
Trema orientalis (L.) Blume (auxiliary plants in agriculture and forestry)
Tridax procumbens L. (auxiliary plants in agriculture and forestry)
Trigonella foenum-graecum L. (spices and condiments)
Triumfetta bartramia L. (fibre plants)
Triumfetta rhomboidea Jacq.
Turnera ulmifolia L. (medicinal and poisonous plants)
Typhonium trilobatum (L.) Schott (plants mainly producing carbohydrates)
Urena lobata L. (fibre plants)
Vallisneria spiralis L. (vegetables)
Vernonia cinerea (L) Less. (medicinal and poisonous plants)
Vetiveria zizanoides (L.) Nash (essentail-oil plants)
Andropogon zizanioides Urban
Vigna aconitifolia (Jacq.) Marechal (pulses)
Phaseolus aconitifolius Jacq.
Vigna radiata (L.) Wilczek (pulses)
Phaseolus radiatus L.
Phaseolus aureus Roxburgh
Vigna umbellata (Thunberg) Ohwi & Ohashi (pulses)
Phaseolus calcaratus Roxburgh
Vigna unguiculata (L.) Walp. (pulses)
Dolichos unguiculatus L.
Dolichos sinensis L.
Vigna sinensis (L.) Hassk.
Wollastonia biflora (L.) DC. (medicinal and poisonous plants)
Wedelia biflora DC.
Wollastonia moluccana (Blume) DC. (medicinal and poisonous plants)
Wedelia moluccana Boerl.
Zea mays L. (cereals)
Ziziphus mauritiana Lamk (edible fruits and nuts)
Ziziphus jujuba (L.) Gaertner (non Miller; often cited as Lamk)
Ziziphus xylopyrus (Retzius) Willd. (edible fruits and nuts)

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Acronyms of organizations

- ACIAR: Australian Centre for International Agricultural Research (Canberra, Australia)
- ARFSN: Asian Rice Farming Systems Network (IRRI, Los Baños, the Philippines)
- ATFGRC: Australian Tropical Forage Genetic Resource Centre (CSIRO, Brisbane, Australia)
- BIOTROP: South-East Asian Regional Centre for Tropical Biology (Bogor, Indonesia)
- CATIE: Centro Agronómico Tropical de Investigación y Enseñanza [Centre for Tropical Agricultural Research and Training] (Turrialba, Costa Rica).
- CENARGEN: Centro Nacional de Recursos Genéticos [National Centre for Genetic Resources] (Brasília, Brazil)
- CIAT: Centro Internacional de Agricultura Tropical [International Center for Tropical Agriculture] (Cali, Columbia)
- CNPGC: Centro Nacional de Pesquisa de Gado de Corte [National Centre for Beef Cattle Research] (Campo Grande, Brazil)
- CSIRO: Commonwealth Scientific and Industrial Research Organization (Canberra, Australia)
- DSIR: Department of Scientific and Industrial Research (Palmerston-North, New Zealand)
- EMBRAPA: Empresa Brasileira de Pesquisa Agropecuária [Brazilian Centre for Animal Production Research] (Brasília, Brazil)
- FAO: Food and Agriculture Organization of the United Nations (Rome, Italy)
- FFTC: Food and Fertilizer Technology Center for the Asian and Pacific Region (Taipei, Taiwan)
- FLFAM: Federation of Livestock Farmers Association of Malaysia (Kuala Lumpur, Malaysia)
- HITAHR: Hawaiian Institute of Tropical Agriculture and Human Resources (University of Hawaii, Honolulu, United States)
- IBPGR: International Board of Plant Genetic Resources (Rome, Italy)
- ICA: Instituto Columbiano Agropecuario [Colombian Institute for Animal Production Research] (Bogotá, Columbia)
- ICARDA: International Center for Agricultural Research in the Dry Areas (Aleppo, Syria)
- ICRAF: International Council for Research in Agroforestry (Nairobi, Kenya)
- ICRISAT: International Crops Research Institute for the Semi-Arid Tropics (Hyderabad, India)
- IDRC: International Development Research Centre (Ottawa, Canada)
- ILCA: International Livestock Center for Africa (Addis Ababa, Ethiopia)
- IPB: Institute of Plant Breeding (University of the Philippines, Los Baños)

- IRRI: International Rice Research Institute (Los Baños, the Philippines)
- LBN: Lembaga Biologi Nasional [National Biological Institute] (Bogor, Indonesia)
- LIPI: Lembaga Ilmu Pengetahuan Indonesia [Indonesian Institute of Sciences] (Jakarta, Indonesia)
- MARDI: Malaysian Agricultural and Development Institute (Serdang, Malaysia)
- MSAP: Malaysian Society for Animal Production (Kuala Lumpur, Malaysia)
- NFTA: Nitrogen Fixing Tree Association (Waimanolo, Hawaii, United States)
- PORIM: Palm Oil Research Institute of Malaysia (Kuala Lumpur, Malaysia)
- QDPI: Queensland Department of Primary Industries (Australia)
- UNESCO: United Nations Educational, Scientific, and Cultural Organization (Paris, France)
- USDA: United States Department of Agriculture (Washington, D.C., United States)

Glossary

abaxial: on the side facing away from the axis or stem (dorsal)

abscission: the natural detachment of leaves, branches, flowers or fruits

accession: in germplasm collections: plant material of a particular collection, usually indicated with a number

accessory buds: those additional to the axillary and normal buds; more than one bud in an axil

accrescent: increasing in size with age

achene: a small dry indehiscent one-seeded fruit that does not split open

actinomorphic: radially symmetrical; applied to flowers that can be bisected in more than one vertical plane

aculeate: furnished with prickles; prickly

acuminate: ending in a narrowed, tapering point with concave sides

acute: sharp; ending in a point with straight or slightly convex sides

adaxial: on the side facing the axis (ventral)

adnate: united with another part; with unlike parts fused, e.g., ovary and calyx tube

adpressed (appressed): lying flat for the whole length of the organ

adventitious: not in the usual place, e.g. roots on stems, or buds produced in other than terminal or axillary positions on stems

aerenchyma: a spongy tissue having large thin-walled cells and large intercellular spaces, serving for aeration or floating tissue

agosporic: a type of apomixis in which a diploid gametophyte is produced from the sporophyte without spore formation

agrostology: that part of botany dealing with grasses; graminology

albumen: the nutritive material stored within the seed, and in many cases surrounding the embryo (endosperm)

allopolyploid (alloploid): a polyploid with more than two sets of chromosomes, derived from different species; allotriploid with three sets, allotetraploid with four sets, etc.

alternate: leaves, etc., inserted at different levels along the stem, as distinct from opposite or whorled

amphicarpic: amphicarpous; posessing two kinds of fruit, differing in character or time of ripening

amplexicaul: stem-clasping, when the petiole-leaf, or stipule, is dilated at the base, and embraces the stem

anastomosis: cross connection of branches; in botany: union of one vein with another, the connection forming a reticulation

androecium: the male element; the stamens as a unit of the flower

androgynophore: a column on which stamens and carpels are borne

annual: a plant that completes its life cycle in one year

annulate: ring-shaped

annulus: a ring or a ring-like part

anther: the part of the stamen containing the pollen

anthesis: the time the flower is expanded, or, more strictly, the time when pollination takes place

antrorse: directed upwards (opposed to retrorse)

apetalous: without petals or with a single perianth

apex: the growing point of a stem or root

apical: at the point of any structure

apices: plural of apex

apiculate: ending abruptly in a short point

apomict: an organism reproducing by apomixis

apomixis: reproduction by seed formed without sexual fusion (apomictic)

aposporic: with suppression of spore-formation, the prothallus developing direct from the asexual generation

appendage: a part added to another; attached secondary or subsidiary part, sometimes projecting or hanging

applanate: flattened out or horizontally expanded

appressed (adpressed): lying flat for the whole length of the organ

arachnoid: like a cobweb

areole: irregular squares or angular spaces marked out on a surface, e.g. of a fruit; a small cell or cavity

aril: an expansion of the funicle enveloping the seed, arising from the placenta; sometimes occurring as a pulpy cover (arillus)
arillode: a false aril, a coat of the seed not arising from the placenta
arilloid: like an aril
article: a segment of a constricted pod or fruit, as in *Desmodium*
articulate: jointed, or with places where separation takes place naturally
articulation: a joint, popularly applied to nodes of grasses
ascending: curving or sloping upwards
asynchronous: not synchronous, not existing or occurring at the same time
attenuate: gradually tapering
auricle: a small lobe or ear, an appendage to the leaf
awn: a bristle-like appendage, especially occurring on the glumes of grasses
axil: the upper angle between the leaf and the stem
axillary: arising from the axil
axis: the main or central line of development of a plant or organ
barb: a hooked hair at the base of spikelets in some grasses
bark: the tissue external to the vascular cambium collectively, being the secondary phloem, cortex and periderm
beaked: used of fruits which end in a long point
bearded: awned; having tufts of hairs
bidentate: having two teeth; doubly dentate, as when the marginal teeth are also toothed
bidenticulate: minutely bidentate
biennial: a plant which flowers, fruits and dies in its second year or season
bifid: cleft into two parts at the tip
biotype: a population or race in which all the individuals have the same genetic constitution
binate: consisting of two members
bipinnate: when the primary divisions (pinnae) of a pinnate leaf are themselves pinnate
bisexual: having both sexes present and functional in the same flower
blade: the expanded part of a leaf or petal
bole: the main trunk of a tree, with a distinct stem
bract: a reduced leaf subtending a flower, flower stalk or (a part of an) inflorescence
bracteole: a secondary bract on the pedicel or close under the flower
bristle: a stiff hair or a hair-like stiff slender body
bullate: surface much blistered or puckered
bunch grass: grass growing in clusters
caducous: falling off early
callus: small hard outgrowth at the base of spikelets in some grasses
calyx: the outer envelope of the flower, consisting of sepals, free or united
campanulate: bell-shaped
canaliculate: channelled, with a longitudinal groove
canopy: the uppermost leafy layer of a tree or a forest
capitate: headed, like the head of a pin in some stigmas, or collected into compact head-like clusters as in some inflorescences
capitellate: diminutive of capitate
capsule: a dry dehiscent fruit composed of two or more carpels and either splitting when ripe into valves, or opening by slits or pores
carinal: relating to the keel in aestivation (the manner in which the parts of a flower are folded up before expansion) when the carina (keel) includes the other parts of the flower
carpel: one of the foliar units of a compound pistil or ovary; a simple pistil has only one carpel
cartilaginous: hard and tough
caruncle: an outgrowth of a seed near the hilum
caryopsis: the fruit of a grass, in which the outer layer (testa) of the seed proper is fused to the ovary wall
cauline: belonging to the stem or arising from it
chalaza: basal part of the ovule or seed where it is attached to the funiculus and the point at which vascular tissues enter and spread into the ovule
chalazal: pertaining to the chalaza
chartaceous: papery
ciliate: with a fringe of hairs along the edge
clavate: club-shaped or thickened towards the end
claw: the narrow part of a petal or sepal
cleft: cut halfway down
cleistogamous: pollination and fertilization taking place within the unopened flowers
clone: a group of plants originating by vegetative propagation from a single plant and therefore of the same genotype
coenocarpium: the collective fruit of an entire inflorescence, e.g. as a pineapple or fig
compatibility: in floral biology: capable of cross- or self-fertilization; in plant propagation: stock–scion combinations resulting in a lasting union
compound: of two or more similar parts in one organ, as in a compound leaf or compound fruit
concave: hollow
confluent: blended into one, passing by degrees one into the other
conical: having the shape of a cone (cone-shaped)

conjugate: coupled
connate: united or joined
connivent: having a gradually inward direction, as in many petals (convergent)
convex: having a more or less rounded surface
cordate: heart-shaped, as seen at the base of a deeply-notched leaf, etc.
cordiform: heart-shaped
coriaceous: of leathery texture
corolla: the inner envelope of the flower of free or united petals
corymb: indeterminate flat- or convex-topped inflorescence in which the branches or pedicels start from different points, but attain approximately the same level, with the outer flowers opening first (a modified panicle)
corymbose: flowers arranged to resemble a corymb
cotyledon: seed leaf, the primary leaf. Dicotylous embryos have two cotyledons and monocotylous embryos have one
cover crop: a crop planted to prevent soil erosion and to provide humus and/or fodder
crenate: the margin notched with blunt or rounded teeth
crenulate: crenate (scalloped), but the teeth themselves small
cross-pollination: placement of pollen from one flower on the stigma of a flower of another plant which is not of the same clone
cross-protection: protection of crop plants against infection by a virulent form of a virus by prior inoculation with an innocuous form of that virus
crown: corona; a short rootstock with leaves; the base of a tufted, herbaceous, perennial grass; the aerial expanse of a tree, not including the trunk
culm: the stem of grasses and sedges
cultivar (cv., cvs): an agricultural or horticultural variety that has originated and persisted under cultivation, as distinct from a botanical variety. A cultivar name should always be written with an initial capital letter and given single quotation marks (e.g. sabi grass 'Nixon')
cuneate: wedge-shaped; triangular, with the narrow end at the point of attachment, as the bases of leaves or petals
cusp: a sharp, rigid point
cuspidate: abruptly tipped with a sharp rigid point
cyme: a determinate inflorescence, often flat-topped, in which the central flowers open first
cymose: flowers in a cyme-like inflorescence that may or may not be a true cyme
cymule: a diminutive, usually few-flowered cyme or portion of one
cystolith: mineral concretions, usually of calcium carbonate on a cellulose stalk
deciduous: finally falling off; a perennial plant that sheds its leaves more or less simultaneously, being leafless for a while
decumbent: reclining or lying on the ground, but with the summit ascending
decurrent: extending down and adnate to the stem, as occurs in some leaves
decussate (of leaves): arranged in opposite pairs on the stem, with each pair perpendicular to the preceding pair
dehiscent: opening spontaneously when ripe, e.g., capsules, legume pods *deltoid:* shaped like an equilateral triangle
dentate: margin prominently toothed with the pointed teeth directed outwards
denticulate: minutely toothed
determinate: of inflorescences: when the terminal or central flower of an inflorescence opens first and the prolongation of the axis is arrested. Of shoot growth: when extension growth takes the form of a flush, i.e. only the previously formed leaf primordia unfold
dicotyledon: angiosperm with two cotyledons or seed-leaves
digestibility: the percentage of a foodstuff taken into the digestive tract that is absorbed into the body
digitate: a compound leaf whose leaflets diverge from the same point like the fingers of a hand
dimorphic: of two forms, as may occur with branches, etc.
dioecious: with unisexual flowers and with the staminate and pistillate flowers on different plants (dioecy)
diploid: with two sets (genomes) of chromosomes, as occurs in somatic or body cells; usually written $2n$, having twice the basic chromosome number of the haploid germ cells
discoid: resembling a disk or discus, being flat and circular
disk: a fleshy or elevated development of the receptacle within the calyx, or corolla or stamens, often lobed and nectariferous
distal: situated farthest from the place of attachment
distichous: regularly arranged in two opposite rows on either side of the stem
DM: dry matter
dormancy: a term used to denote the inability of a resting plant or plant part (e.g. the seed, or in tree crops usually the buds) to grow or to leaf out even under favourable environmental conditions

dorsal: back; referring to the back or outer surface of a part or organ (abaxial)
ear: the spike of a grass
eccentric: one-sided, out of the centre
ecotype: a biotype resulting from selection in a particular habitat
ellipsoid(al): a solid object which is elliptical in section
elliptic(al): shaped like an ellipse
emarginate: having a notch at the end; indented with an acute sinus
emasculate: to remove the anthers from a bud or flower before the pollen is shed
embryo: the rudimentary plant within a seed, developed from a zygote (sexual) or from other nuclei in the embryo sac or cells of the nucellus or integuments (apomictic)
endocarp: the innermost layer of the pericarp or fruit wall
entire (botany): with an even margin
epicalyx: an involucre of bracts below the flower, resembling an extra calyx
epicotyl: the young stem above the cotyledons
epigeal: above ground; in epigeal germination the cotyledons are raised above the ground
erect: directed towards summit, not decumbent
erectopatent: between spreading and erect
evergreen: bearing foliage all year long; a plant that changes its leaves gradually
exsert, exserted: protruded beyond, as stamens beyond the tube of the corolla
extra-axillary: beyond or outside the axil
extrorse: an anther which dehisces outwardly towards the perianth
falcate: sickle-shaped
fascicle: a cluster of flowers, leaves, etc., arising from the same point
ferruginous: rust-coloured
fertile (botany): bearing pollen which fecundates the ovules; said of pollen-bearing anthers or of seed-bearing fruits
fertilization: union of the gametes (egg and sperm) to form a zygote
fibrous: having much woody fibre
fig: the fleshy multiple fruit derived from the inflorescence of *Ficus* spp. (syconium)
filament: thread; the stalk supporting the anther
filiform: slender; threadlike
fimbriate: fringed
flabellate: fan-shaped, dilated in a wedge shape, sometimes plaited (folded)
flaky: lamelliform, in the shape of a plate or scale
flexuose, flexuous: zigzag; bent alternately in opposite directions
floccose: covered with dense hairs that fall away in tufts, locks or flocci
floret: a small flower, one of a cluster as in grasses or *Compositae*
flush: a brief period of rapid shoot growth, with unfolding of the leaf primordia which had accumulated during the previous quiescent period
fodder: something fed to domesticated animals, especially coarse, dried food from plants (hay, straw, leaves)
foliolate (2-, 3-, 4- etc.): with 2-, 3-, 4- leaflets
follicle: a dry, unicarpellate fruit, dehiscing by the ventral suture to which the seeds are attached
forage: grassland and fodder plants suitable as feed for herbivores, usually with lower nutrient concentration and digestibility than concentrates such as grain
foveola: a small pit
fruit: the ripened ovary with adnate parts
fulvous: yellow, tawny
funicle (funiculus): the little cord which attaches the ovule or seed to the placenta
funnelform: salver-shaped, as the corolla of *Asystasia gangetica* (L.) T. Anderson
fusiform: spindle-shaped; tapering towards each end from a swollen middle
gene: the unit of inheritance located on the chromosome
geniculate: abruptly bent so as to resemble the knee-joint
genome: a set of chromosomes as contained within the gamete and corresponding to the haploid chromosome number of the species
genotype: the genetic make-up of an organism comprising the sum total of its genes, both dominant and recessive; a group of organisms with the same genetic make-up
germplasm: the genetic material that provides the physical basis of heredity; also a collection of genotypes of an organism
glabrate: destitute of pubescence or any roughness
glabrescent: becoming glabrous or nearly so
glabrous: devoid of hairs
glandular: having or bearing secreting organs or glands
glaucous: pale bluish-green, or with a whitish bloom which rubs off
globose: spherical or nearly so
glumes: the chaffy or membranous two-ranked members of the inflorescence of grasses and similar plants; lower glume and upper glume, two sterile bracts at the base of a grass spikelet
granulose (granular): composed of or covered with grain-like tiny particles

gynoecium: the female part or pistil of a flower, consisting, when complete, of one or more ovaries with their styles and stigmas

gynophore: a stalk supporting the gynoecium formed by elongation of the receptacle

habit: external appearance or way of growth of a plant

habitat: the kind of locality in which a plant grows

haploid: having a single set (genome) of chromosomes in a cell or an individual, corresponding to the chromosome number (n) in a gamete

hard-seededness: impermeability of the seed-coat, which avoids quick germination

harvest index: the total harvestable produce as a fraction of the total biomass produced by the crop in a given year

herb: any vascular plant which is not woody

herbaceous: not woody

heritability: the proportion of variability that results from genetic causes; also that proportion of the variation of a population that is transmitted to progeny

hermaphrodite: bisexual; in flowers, with stamens and pistil in the same flower

heterogamous: with two or more kinds or forms of flowers

heterozygote: an organism with different genes at corresponding loci of homologous chromosomes; consequently producing unlike gametes

heterozygous: the condition in which homologous chromosomes of an individual possess different alleles at corresponding loci

hilum: the scar left on a seed indicating its point of attachment

hirsute: hairy, with long, tolerably distinct hairs

hispid: covered with long rigid hairs or bristles

hispidulous: minutely hispid

homomorphous: uniform in shape

homozygote: an individual whose homologous chromosomes carry identical genes at corresponding loci

homozygous: possessing identical genes at corresponding loci on homologous chromosomes

hull: see husk

husk: the outer covering of certain fruits or seeds

hyaline: almost transparant

hybrid: the first generation offspring of a cross between two individuals differing in one or more genes

hybridization: the crossing of individuals of unlike genetic constitution

hygroscopic: susceptible to extending or shrinking on application or removal of water or vapour

hypanthium: a cup-like receptacle usually derived from the fusion of the floral envelopes and androecium on which are seemingly borne the calyx, corolla and stamens

hypocotyl: the young stem below the cotyledons

hypogeal: below ground; in hypogeal germination the cotyledons remain below ground within the testa

imbricate: overlapping like tiles; in a flower bud when one sepal or petal is wholly external and one wholly internal and the others overlapping at the edges only

imparipinnate: pinnate with an odd terminal leaflet

impressed: marked with slight depressions

incised: cut deeply

incompatibility: in floral biology: not capable of cross- or self-fertilization; in plant propagation: no stock–scion combinations resulting in a lasting union

indehiscent: not opening when ripe

indented: forced inward to form a depression

indeterminate: of inflorescences: a sequence in which the terminal flowers are the last to open, so that the floral axis may be prolonged indefinitely by the terminal meristem. Of shoot growth: when the shoot apex forms and unfolds leaves during extension growth, so that shoot growth can continue indefinitely

indumentum: any covering, as hairiness

inferior ovary: situated below the sepals, petals and stamens

inflexed: turned abruptly or bent inward

inflorescence: the arrangement and mode of development of the flowers on the floral axis

infructescence: a ripened inflorescence in the fruiting stage

inoculum: material used for inoculation, e.g. rhizobia in soil to promote the growth of certain *Leguminosae*

internode: the portion of the stem between two nodes

in vitro: outside the living body and in an artificial environment

involucral: belonging to an involucre

involucre: a ring of bracts surrounding several flowers or their supports, as in the heads of *Compositae* or the umbels in *Umbelliferae*

involute: having the edges of the leaves rolled inwards

isozymes: multiple distinct molecular forms of an enzyme that differ in net electrical charge; important to the investigation of the molecular basis for cellular differentiation and morphoge-

nesis, and increasingly used to clarify genotypic relationships

isthmus: a narrowed connection between two parts

IVD: in vitro digestibility

IVOMD: in vitro organic matter digestibility

jugate: connected or yoked together; e.g. in leaves 1–n jugate: with 1–n pairs of leaflets

juvenile phase (stage): the period between germination and the first signs of flowering, during which vegetative processes preclude flower initiation even under the most favourable conditions

keel (carina): a ridge like the keel of a boat; the two anterior and united petals of a papilionaceous corolla; the principal nerve of a sepal or glume

keeled (carinate): having a keel or carina

kernel: the nucellus of an ovule or of a seed, that is, the whole body within the coats

knee: an abrupt bend in a stem or tree-trunk

labyrinthine seed: seed with the testa filling the crevices between the transverse lobes and folds of the cotyledons which closely adhere together

lacerate(d): torn, or irregularly cleft

lamina: see blade

lanceolate: lance-shaped; much longer than broad, being widest at the base and tapering to the apex

lateral: fixed on or near the side of an organ

latex: a juice, usually white and sometimes sticky, which exudes from broken surfaces of some plants

lax: loose, distant

leaflet: one part of a compound leaf

lemma: the lower of the two membranous bracts enclosing the flower in grasses; the lower of the two glumes which surround each floret in the spikelet of grasses

lenticel: lenticular masses of loose cells protruding through fissures in the periderm on stems, fruits and roots; they usually arise beneath individual stomata and their main function is gaseous exchange

lenticular: shaped like a doubly convex lens

lignification: the thickening or hardening of the cell-wall by secondary deposits

ligulate: with or possessing a ligule

ligule: a membranous outgrowth on the upper surface of a grass leaf at the junction of the sheath and the blade. It may be presented by a ridge or by a line of hairs; an elongated flattened strap-shaped structure

limb: the expanded part of a tubular corolla, as distinct from the tube or throat; the lamina of a leaf or of a petal

lobe: any division of an organ or specially rounded division

lobed: of leaves: divided, but not into separate leaflets

locular: divided by internal partitions into compartments as in anthers and ovaries

loment: lomentum; a legume or pod which is contracted between the seeds, falling apart at the constrictions into one-seeded joints when mature

Malesia: the bio-geographical region including Malaysia, Indonesia, the Philippines, Singapore, Brunei and Papua New Guinea

margin: the edge or boundary line of a body

marginate: furnished with a margin of distinct character

mass selection: a system of breeding in which seed from individuals selected on the basis of phenotype is used to grow the next generation

membranous: thin and semi-transparant, like a fine membrane

meristem: undifferentiated tissue of the growing point whose cells are capable of dividing and developing into various organs and tissues

merous: (4–,5–,etc.) with 4, 5, etc. parts or numbers of sepals, petals etc.

midrib: the main vein of a leaf which is a continuation of the petiole

monocotyledon: angiosperms having a single cotyledon or seed-leaf

monoecious: with unisexual flowers, but male and female flowers borne on the same plant

monogastric: having a stomach with only one compartment (e.g. swine, chicks)

monopodial: of a primary axis which continues its original line of growth from the same apical meristem to produce successive lateral branches

morphotype: a special form of a plant species, usually only slightly differing from the normal habit

mucro: a sharp terminal point

mucronate: ending abruptly in a short stiff point

mucronulate: diminutive of mucronate

muricate: rough, with short and hard tubercular excrescences

mycorrhiza: a symbiotic association of roots with a fungal mycelium which may form a layer outside the root (ectotrophic) or within the outer root tissue (endotrophic)

nectar: a sweet fluid exuded from various parts of the plant (e.g. from the flower to attract pollinators)

nematode: small elongated cylindrical worm-like micro-organism, free-living in soil or water, or parasitic in animals or plants

nerve: a strand of strengthening and/or conducting tissue running through a leaf, which starts from the midrib and diverges or branches throughout the blade
neuter: sexless, neither male nor female; having neither functional stamens nor pistils
node: the point on the stem or branch at which a leaf or lateral is borne
nodulation: formation of root-nodules
nucellus: the nutritive tissue in an ovule
ob-: the inverse or opposite condition (obtriangular, obcordate, etc.)
oblanceolate: reverse of lanceolate
oblate: flattened at the poles
obligate: necessary, essential; the reverse of facultative
oblique: slanting; of unequal sides
oblong: longer than broad, with the sides parallel or almost so
oblongoid: a solid object which is oblong in section
obovate: reverse of ovate
obovoid: a solid object which is obovate in section
obtuse: blunt or rounded at the end
opaque: neither shining nor transparent
opposite: of leaves and branches when two are borne at the same node on opposite sides of the stem
orbicular: flat with a more or less circular outline
orthotropic: having a more or less vertical direction of growth
ovary: that part of the pistil, usually the enlarged base, which contains the ovules and eventually becomes the fruit
ovate: egg-shaped; a flat surface which is scarcely twice as long as broad with the widest portion below the middle
ovoid: a solid object which is egg-shaped (ovate) in section
ovule: the immature seeds in the ovary before fertilization
palea: the upper of two membranous bracts enclosing the flower in grasses
palmate: lobed or divided like the palm of the hand
panicle: an indeterminate branched racemose inflorescence
paniculate: resembling a panicle
papilionaceous: a butterfly-shaped corolla, as in *Papilionaceae*
papillae: soft superficial glands or protuberances
papillose: covered with minute nipple-like protuberances
pappus: the various tufts of hairs on achenes or fruits; the limb of the calyx of *Compositae* florets
papyraceous: papery, like paper
paripinnate: a pinnate leaf without the odd terminal leaflet
parthenocarpy: the production of fruit without true fertilization
patent: spreading
pedicel: stalk of each individual flower of an inflorescence
pedicellate: borne on a pedicel
peduncle: the stalk of an inflorescence or partial inflorescence
pellucid: translucent
peltate: shield-shaped, as a leaf attached by its lower surface to a stalk instead of by its margin
pendent: hanging down from its support
pendulous: drooping; hanging down
pentamerous: having five parts in a flower-whorl
perennial: a plant living for several years and usually flowering each year
perfect flower: a flower possessing both male and female organs
perianth: the floral leaves as a whole, including sepals and petals if both are present
petal: a member of the inner series of perianth segments which are often brightly coloured
petiolar: borne on, or pertaining to a a petiole
petiolate: having a petiole
petiole: the stalk of a leaf
petiolule: the stalk of a leaflet
phenology: the complex annual course of flushing, quiescence, flowering, fruiting and leaf fall in a given environment
phenotype: the physical or external appearance of an organism as distinguished from its genetic constitution (genotype); a group of organisms with similar physical or external make-up
photoperiod: length of day favouring optimum functioning of an organism
phyllotaxy: the arrangement of leaves or floral parts on their axis
physiological varieties (races): pathogens of the same species which are structurally similar, but which differ in physiological and pathological characteristics
pilose: hairy with rather long soft hairs
pilosity: hairiness
pinna (plural pinnae): a primary division or leaflet of a pinnate leaf
pinnate: a compound leaf with the leaflets arranged along each side of a common rachis
pinnatifid: with the margin pinnately cleft
pistil: the female part of a flower (gynoecium) of one or more carpels, consisting, when complete, of one or more ovaries, styles and stigmas

pistillate: a unisexual flower with pistil, but no stamens
pistillode: a sterile, often reduced pistil
placenta: the part of the ovary to which the ovules are attached
plano-convex: flat on one side and convex on the other
plagiotropic: having an oblique or horizontal direction of growth
plumose: featherlike with fine hairs, as on the sides of some bristles
plumule: the primary bud of an embryo or germinating seed
pod: a dry and many-seeded dehiscent fruit, a legume or silique
pollen: spores or grains borne by the anthers containing the male element (gametophyte)
pollination: the transfer of pollen from the dehiscing anther to the receptive stigma
polyembryony: the production of two or more embryos within an ovule
polygamous: with unisexual and bisexual flowers in the same plant
polymorphic: polymorphous, with several or various forms; variable as to habit
polyphenol: a polyhydroxy phenol
posterior: next to or towards the main axis
precocious: exceptionally early in development; flowering and fruiting at an early age
prickle: a sharp, relatively stout outgrowth from the outer layers
primordial: first in order of appearance
procumbent: lying along the ground
prolific: fruitful, producing offspring
prop roots: aerial roots
prostrate: lying flat on the ground
protandrous: stamens shedding pollen before the stigma is receptive
proximal: the part nearest the axis (as opposed to distal)
pseudogamy: parthenogenetic fruiting, as pollination without impregnation of ovules
pseudopetiole: a structure resembling a petiole, but not being one
puberulent: covered with soft fine hairs
puberulous: minutely pubescent
pubescent: covered with soft short hairs
pulvinule: the swollen base of a petiolule
pulvinus: the swollen base of the petiole
punctate: marked with dots or translucent glands
p.v.: see physiological varieties (races)
pyriform: resembling a pear in shape
quadrangular: four-cornered
quadrate: approximately square or cubical
raceme: an unbranched elongated indeterminate inflorescence with stalked flowers opening from the base upwards
racemose: raceme-like
rachis (plural: rachides): the principal axis of an inflorescence or a compound leaf
radical: arising from the root, or its crown
radicle: the first root of an embryo or germinating seed
receptacle: the flat, concave or convex part of the stem from which the parts of the flower arise
recurved: bent or curved downward or backward
reflexed: abruptly bent or turned downward or backward
reniform: kidney-shaped
resupinate: upside down, or apparently so
reticulate: netted, as when the smallest veins of a leaf are connected together
retrorse: turned or directed backward or downward (opposed to antrorse)
rhizobia: the organisms forming root-nodules in *Leguminosae*
rhizoid: root-like
rhizome: an underground stem which is distinguished from a root by the presence of nodes with buds and leaves or scales
rhombic: shaped like an equilateral oblique-angled figure
rhomboid (botany): quadrangular, with the lateral angles obtuse
root-nodules: small swellings on roots of leguminous and other plants, containing nitrogen-fixing bacteria (rhizobia)
rootstock: see rhizome
rosette: a cluster of leaves or other organs in a circular form
rotund: rounded in outline, somewhat orbicular, but slightly inclined towards oblong
rudimentary: of organs which are imperfectly developed and nonfunctional
rugose: wrinkled
rugulose: somewhat wrinkled
ruminant: an animal that chews again what has been swallowed (e.g. sheep, cows, camels, goats)
runner: a specialized stem that develops from a leaf axil at the crown of a plant, grows horizontally along the ground, and forms a new plant at one of the nodes, usually at or near the tip (as in strawberry)
scabrid: rough to the touch
scabridulous: slightly rough
scabrous: see scabrid
scalariform: having markings suggestive of a ladder

scale: reduced leaf, usually sessile, thin and dry, and seldom green
scandent: climbing
scarification (seed): scarifying, to cut or soften the wall of a hard seed to hasten germination
scrub: vegetation whose growth is stunted because of lack of water coupled with strong transpiration
scurfy: bearing small scales on the surface (lepidote; scaly)
seed: the reproductive unit formed from a fertilized ovule, consisting of embryo and seed-coat, and, in some cases, also endosperm
self-sterile: failure to complete fertilization and obtain seed after self-pollination
self-pollination: pollination with pollen from the same flower or from other flowers of plants of the same clone
self-compatible: see self-fertile
self-fertile: capable of fertilization and setting seed after self-pollination
semi-: half, incomplete (e.g. semi-inferior ovary)
sepal: a member of the outer series of perianth segments
septate: divided by a partition
septum (plural septa): a partition or cross-wall
seriate: serial, disposed in series of rows
sericeous: silky
serrate: toothed like a saw, with regular pointed teeth pointing forwards
sessile: without a stalk
seta(e): a bristle-like body
setose: bristle-pointed; terminating gradually in a fine, sharp point
setulose: resembling a fine bristle
sheath: a tubular structure surrounding an organ or part, as the lower part of the leaf clasping the stem in grasses
shoot: a young growing branch or twig
shrub: a woody plant which branches from the base, all branches being equivalent
silique: a dry and many-seeded dehiscent fruit splitting into 2 valves with a false partition
simple (botany): not compound, as in leaves with a single blade
sod (turf): the upper stratum of soil bound by grass and plant roots into a thick mat
spathate: furnished with a spathe
spathe: a large bract enclosing a flower cluster
spathulate: spoon-shaped
spicate: spike-like
spiciform: spike-like
spike: a simple indeterminate inflorescence with sessile flowers along a single axis
spikelet: a secondary spike, one of the units comprising the inflorescence in grasses, consisting of one or more florets on a thin axis, subtended by a common pair of glumes
spine: a short stiff straight sharp-pointed hard structure
spinescent: ending in a spine or sharp point
spinose: having spines (spinous)
spinulose: with small spines
stamen: one of the male reproductive organs of a flower; a unit of the androecium
staminate: a flower bearing stamens but no pistil
staminode: an abortive or rudimentary stamen without a perfect anther
standard (flower part): the fifth or posterior petal of a papilionaceous corolla
stellate: star-shaped, as of hairs with radiating branches
sterile: failing to complete fertilization and produce seed as a result of defective pollen or ovules; not producing seed capable of germination; lacking functional sexual organs (sterility)
stigma: the portion of the pistil which receives the pollen
stilt roots: the oblique adventitious roots of the mangrove and similar forms
stipe: the stalk supporting a carpel or gynoecium
stipel (stipella): a minute stipule on a partial petiole of compound leaves
stipitate: having a stipe or special stalk
stipulate: with or bearing stipules
stipule: a scale-like or leaf-like appendage at the base of a leaf petiole
stolon: a trailing stem usually above the ground which is capable of producing roots and shoots at its nodes
stoloniferous: bearing a stolon or stolons
straggling: divaricate, extremely divergent
striate: marked with fine longitudinal parallel lines, as grooves or ridges
style: the part of the pistil connecting the ovary with the stigma
sub-: somewhat or slightly (e.g. subacute)
subglobose: nearly globular
subulate: awl-shaped
subverticillate: in imperfect or irregular whorls
succulent: juicy, fleshy
sucker: a shoot, usually originating from adventitious buds on the roots or basal stem parts, which does not fit in the architectural model, but is capable of repeating the model
suffrutescent: obscurely shrubby
sulcate: grooved or furrowed

superior (ovary): an ovary with the perianth inserted below or around its base, the ovary being attached at its base only
sutural: relating to a suture
suture: the line of junction of two carpels; the line or mark of splitting open
sympodial: of a stem in which the growing point either terminates in an inflorescence or dies, growth being continued by a subtending lateral growing point
syncarpous: of an ovary composed of two or more united carpels
synchronous: happening, existing or arising at the same time
taproot: the primary descending root, forming a direct continuation of the radicle
taxon (plural taxa): a term applied to any taxonomic unit irrespective of its classification level
TDN: total digestible nutrients
tendril: a thread-like climbing organ formed from the whole or part of a stem, leaf or petiole
tepal: a segment of a perianth, sepal or petal
terete: cylindrical; circular in transverse section
terminal: borne at the end or apex
terrestrial: on or in the ground
testa: the outer coat of the seed
tetrafoliolate: with four leaflets
tetraploid: having four times the basic number of chromosomes, usually written $4n$
thorn: a woody sharp-pointed structure formed from a modified branch
thyrse: a compound inflorescence composed of a panicle (indeterminate axis) with the secondary and ultimate axes cymose (determinate)
thyrsiform: shaped like a thyrse
thyrsoid: like a thyrse
tomentose: densely covered with short soft hairs
torus: receptacle
trailing: prostrate, but not rooting
tree: a perennial woody plant with an evident persistent trunk
trifoliate: three-leaved
trifoliolate: with three leaflets
triploid: having three times the basic number of chromosomes, usually written $3n$
tripping (flowers): to help in pollinating
triquetrous: three-edged, with three salient angles
truncate: cut off more or less squarely at the end
trunk: the main stem of a tree (as opposed to the roots and branches)
tubercle: a small tuberlike excrescence
tuberculate: covered with warty protuberances
tuberiform: resembling a tuber
tuberous: producing tubers or resembling a tuber
tufted: growing in tufts (caespitose)
tunicated: provided with a dry papery covering round a bulb or corm
tussock: a tuft of grass or grass-like plants
umbilicus: see hilum
unarmed: destitue of prickles or other armature; pointless
uncinate: hooked
uncinulate: diminutive of uncinate
undershrub: any low shrub; partially herbaceous shrub, the ends of the branches perishing during the winter
undulate: wavy, said for instance of a leaf margin if the waves run in a plane at right angles to the plane of the leaf blade
unifoliolate: with one leaflet only, but in origin a compound leaf
unisexual: of one sex, having stamens or pistils only
valve: a piece into which a capsule naturally separates at maturity
variety: botanical variety which is a subdivision of a species; an agricultural or horticultural variety is referred to as a cultivar
vein: a strand of vascular tissue in a flat organ, such as a leaf
velutinous: see velvety
velvety: with a coating of fine soft hairs; the same as tomentose but denser so that the surface resembles (and feels like) velvet
venation: the arrangement of the veins in a leaf
ventral: faces central axis (adaxial), opposed to dorsal
versatile (botany): turning freely on its support, as many anthers on their filaments
villose (villous): with long weak hairs
vine: a plant having a stem that is too slender to hold itself erect and therefore supports itself by climbing over an object
viny: trailing or climbing
violaceous: violet-coloured
viscid: sticky
viviparous: germinating or sprouting from seed or bud while attached to the parent plant
warty: covered with firm roundish excrescences
whorl: more than two organs of the same kind arising at the same level
wing: any membraneous expansion attached to an organ; a lateral petal of a papilionaceous corolla
xerophytic: relating to a plant structurally adapted for life and growth with a limited water supply

Sources of illustrations

All illustrations have been redrawn and adapted by Mrs. P. Verheij-Hayes, using the following sources:

Aeschynomene americana: Skerman, P.J., Cameron, D.G. & Riveros, F., 1988. Tropical forage legumes. FAO, United Nations, Rome, Italy. p. 207, Fig. 35 (leafy branch); Koorders, S.H., 1926. Exkursionsflora von Java. Band 4, Atlas. Gustav Fischer Verlag, Jena, Deutschland. Lieferung 7(1). p. 960, Fig. 1252 (flowering and fruiting branch).

Aeschynomene falcata: original drawing by P. Verheij-Hayes, Prosea, Wageningen.

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Alysicarpus vaginalis: Ohashi, H., 1977. Leguminosae. In: Hui-lin Li et al. (Editors): Flora of Taiwan. Epoch Publishing Company, Taipei. Vol. 3. p. 171, Pl. 516.

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Arachis glabrata: drawing provided by the Queensland Herbarium, Meiers Road, Indooroopilly, Q 4068, Australia.

Arachis pintoi: drawing provided by the Queensland Herbarium, Meiers Road, Indooroopilly, Q 4068, Australia.

Arundinaria pusilla: Camus, E.G. & A., 1923. In: Lecomte, M.H. & Gagnepain, F. (Editors): Flore générale de l'Indo-Chine. Vol. 7. p. 586, Fig. 45 (leafy twig, apex of inflorescence); habit of plant with rhizome: drawing provided by the author.

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Axonopus compressus: Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. Aquarelle (without page number).

Bothriochloa pertusa: Matthew, K.M., 1982. Illustrations on the flora of the Tamilnadu Carnatic. The Rapinat Herbarium, Tiruchirapalli, India. Pl. 816 (flowering plant, ligule); Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, United Nations, Rome, Italy. p. 231, Fig. 15.14 (inflorescence, sessile and pedicelled spikelet).

Brachiaria brizantha: Clayton, W.D., 1972. Gramineae. In: Hepper, F.N. (Editor): Flora of West Tropical Africa. 2nd ed. Crown Agents for Oversea Governments and Administrations. London. Vol. 3(2). p. 441, Fig. 442.

Brachiaria decumbens: leafy branches: drawing provided by CIAT; Ibrahim, K.M. & Kabuya, C.M.S., 1987. An illustrated manual of Kenya grasses. FAO, United Nations, Rome, Italy. p. 330, Pl. 47 (inflorescence).

Brachiaria dictyoneura: leafy branch: drawing provided by CIAT; Ibrahim, K.M. & Kabuya, C.M.S., 1987. An illustrated manual of Kenya grasses. FAO, United Nations, Rome, Italy. p. 332, Pl. 49 (inflorescence).

Brachiaria distachya: Gilliland, H.B., Holttum, R.E., Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Government Printing Office, Singapore. Vol. 3. p. 177, Fig. 36 (leafy branch); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 14 (inflorescence, spikelet).

Brachiaria humidicola: leafy plant part: drawing provided by CIAT; Ibrahim, K.M. & Kabuya, C.M.S., 1987. An illustrated manual of Kenya grasses. FAO, United Nations, Rome, Italy. p. 334, Pl. 51 (inflorescence).

Brachiaria mutica: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 393, Fig. 4.180.

Brachiaria ruziziensis: habit: drawing provided by CIAT; original drawing by P. Verheij-Hayes, after Reekmans 11040 (WAG) (inflorescence).

Brachiaria subquadripara: drawing provided by CIAT.

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Centotheca latifolia: Bor, N.L., 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, Oxford, U.K. p. 458, Fig. 50.

Centrosema acutifolium: drawing provided by CIAT.

Centrosema macrocarpum: drawing provided by CIAT.

Centrosema pascuorum: drawing provided by the author.

Centrosema pubescens: Botton, H. & Hallé, N, 1958. Les plantes de couverture. Guide pratique de reconnaissance et d'utilisation des Légumineuses en Côte d'Ivoire 2. Journal d'Agriculture tropicale et de botanique appliquée 5. p. 127, Pl. 31.

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Chloris gayana: Häfliger, E. & Scholz, H., 1981. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 2. p. 48 (ligule, spikelets); aquarelle (without page number) (leafy plant parts); original drawing by P. Verheij-Hayes after Pawek 7199 (WAG) (inflorescence).

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Cynodon dactylon: Häfliger, E. & Scholz, H., 1981. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 2. Aquarelle (without page number) (flowering plant); p. 53 (ligule, spikelet).

Cynodon nlemfuensis: original drawing by P. Verheij-Hayes, Prosea, Wageningen, from Tanner 5417 (WAG) (flowering plant); Ibrahim, K.M. & Kabuya, C.M.S., 1987. An illustrated manual of Kenya grasses. FAO, United Nations, Rome, Italy. p. 388, Fig. 105 (spikelet).

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Desmodium hetercarpon ssp. *ovalifolium:* original drawing by P. Verheij-Hayes, Prosea, Wageningen, from living material.

Desmodium heterophyllum: Backer, C.A. & van Slooten, D.F., 1924. Geïllustreerd handbook der Javaansche theeonkruiden en hunne beteekenis voor de cultuur [Illustrated handbook of the Javanese weeds in tea and their agricultural significance]. Algemeen proefstation voor thee, Batavia. p. 142, Fig. 142 (flowering and fruiting branch); Ohashi, H., 1973. The Asiatic species of Desmodium and its allied genera (Leguminosae). Ginkgoana 1: 231, Fig. 67(6) (fruit, seeds).

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Echinochloa crus-galli: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 419, Fig. 4.193.

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Eragrostis unioloides: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 427, Fig. 4.197.

Ficus subcordata: drawing (fruiting branch) and photograph (habit) provided by the author.

Flemingia macrophylla: Westphal, E. & Jansen, P.C.M. (Editors), 1989. Plant Resources of South-East Asia. A selection. Pudoc, Wageningen: p. 129.

Gliricidia sepium: Westphal, E. & Jansen, P.C.M. (Editors), 1989. Plant Resources of South-East Asia. A selection. Pudoc, Wageningen: p. 137.

Heteropogon contortus: Bor, N.L., 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, Oxford, U.K. p. 164, Fig. 6 (habit flowering plant); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel.

Vol. 1. p. 61 (ligule); Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, United Nations, Rome, Italy. p. 447, Fig. 15.78 (two pairs of heterogamous spikelets).

Hymenachne acutigluma: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 433, Fig. 4.200.

Imperata cylindrica: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 435, Fig. 4.201 (habit, seeds); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 63 (ligule, inflorescence, spikelet).

Ischaemum ciliare: Chien-Chang Hsu, 1978. Gramineae. In: Hui-lin Li et al. (Editors): Flora of Taiwan. Epoch Publishing Company, Taipei. Vol. 5. p. 669, Pl. 1472 (habit flowering plant); Gilliland, H.B., Holttum, R.E., Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Government Printing Office, Singapore. Vol. 3. Opposite p. 263, Pl. 20 (habit stoloniferous part); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 64 (ligule, spikelet).

Ischaemum magnum: Wycherley, P.R. & Ahmad Azli, M.Y., 1974. Grasses of Malayan plantations. p. 40, Pl. 8.

Ischaemum muticum: Gilliland, H.B., Holttum, R.E., Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Government Printing Office, Singapore. Vol. 3. p. 256, Fig. 56 (leafy branch); Chien-Chang Hsu, 1974. Taiwan grasses. Taiwan Provincial Education Association, Taipei, Taiwan. p. 716, Fig. 253 (flowering branch); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 65 (ligule, pair of spikelets).

Ischaemum rugosum: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 441, Fig. 4.204.

Ischaemum timorense: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 443, Fig. 4.205 (flowering plant part, pair of spikelets, caryopsis in two views); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 67 (ligule).

Leptochloa chinensis: Häfliger, E. & Scholz, H., 1981. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 2. Aquarelle (without page number) (flowering plants), p. 94 (ligule, spikelet).

Leucaena leucocephala: Westphal, E. & Jansen, P.C.M. (Editors), 1989. Plant Resources of South-East Asia. A selection. Pudoc, Wageningen. p. 173.

Lotononis bainesii: Verdcourt, B., 1979. A manual of New Guinea legumes. Botany Bulletin No 11. Office of Forests, Division of Botany, Lae, Papua New Guinea. p. 586, Fig. 148.

Macroptilium atropurpureum: drawing provided by the Department of Field Crops and Grassland Science, Wageningen Agricultural University.

Macroptilium lathyroides: Verdcourt, B., 1979. A manual of New Guinea legumes. Botany Bulletin No 11. Office of Forests, Division of Botany, Lae, Papua New Guinea. p. 506, Fig. 126.

Macroptilium longepedunculatum: drawing provided by the Department of Field Crops and Grassland Science, Wageningen Agricultural University.

Macrotyloma axillare: Verdcourt, B., 1979. A manual of New Guinea legumes. Botany Bulletin No 11. Office of Forests, Division of Botany, Lae, Papua New Guinea. p. 531, Fig. 129.

Medicago sativa: Verdcourt, B., 1979. A manual of New Guinea legumes. Botany Bulletin No 11. Office of Forests, Division of Botany, Lae, Papua New Guinea. p. 566, Fig. 143.

Microstegium ciliatum: Gilliland, H.B., Holttum, R.E., Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Government Printing Office, Singapore. Vol. 3. p. 248, Fig. 54.

Mikania cordata: Holm, L.G., Plucknett, D.L., Pancho, J.V. & Herberger, J.P., 1977. The world's worst weeds: distribution and biology. The East-West Center, University of Hawaii Press, Honolulu, Hawaii, United States. p. 321, Fig. 133.

Mimosa pudica: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 331, Fig. 4.150.

Neonotonia wightii: Legel, S., 1983. Tropical forage legumes and grasses. Part 1. Legumes. p. 35 (flowering and fruiting plant); Milne-Redhead, E. & Polhill, R.M. (Editors), 1971. Flora of Tropical East Africa – Leguminosae 4 – Papilionoideae 2. Crown Agents for Oversea Governments and Administrations. p. 531, Fig. 79 (flower, fruit, seeds).

Ottochloa nodosa: Chien-Chang Hsu, 1974. Taiwan grasses. Taiwan Provincial Education Association, Taipei, Taiwan. p. 548, Fig. 168 (flowering branch, branchlet with two spikelets); Chien-Chang Hsu, 1978. Gramineae. In: Hui-lin Li et-

al. (Editors): Flora of Taiwan. Epoch Publishing Company, Taipei. Vol. 5. p. 567, Pl. 1434 (ligule).

Panicum maximum: Bor, N.L., 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, Oxford, U.K. p. 328, Fig. 37.

Panicum maximum var. *trichoglume*: Humphreys, L.R., 1980. A guide to better pastures for the tropics and sub-tropics. 4th ed. Wright Stephenson & Co., Ermington, Sydney. p. 36.

Panicum repens: Holm, L.G., Plucknett, D.L., Pancho, J.V. & Herberger, J.P., 1977. The world's worst weeds: distribution and biology. The East-West Center, University of Hawaii Press, Honolulu, Hawaii, United States. p. 354, Fig. 148.

Paspalum conjugatum: Hitchcock, A.S., 1950. Manual of the grasses of the United States. 2nd ed. revised by A. Chase. United States Department of Agriculture, Miscellaneous Publication No 200, Washington. p. 614, Fig. 892 (flowering plant); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 95 (ligule, spikelet).

Paspalum dilatatum: Holm, L.G., Plucknett, D.L., Pancho, J.V. & Herberger, J.P., 1977. The world's worst weeds: distribution and biology. The East-West Center, University of Hawaii Press, Honolulu, Hawaii, United States. p. 359, Fig. 151 (plant habit, ligule); Häfliger, E. & Scholz, H., 1981. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 2. p. 96 (inflorescence, spikelet).

Paspalum distichum: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 461, Fig. 4.214.

Paspalum notatum: Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. Aquarelle (without numbered page) (flowering plant); p. 102 (ligule, spikelet).

Paspalum plicatulum: Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, United Nations, Rome, Italy. p. 580, Fig. 15.121 (habit); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 104 (ligule, inflorescence, spikelets).

Paspalum scrobiculatum: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 457, Fig. 4.212.

Pennisetum clandestinum: Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, United Nations, Rome, Italy. p. 605, Fig. 15.126 (habit); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 112 (ligule, inflorescence, spikelet).

Pennisetum polystachion: Soerjani, M., Kostermans, A.J.G.H., Tjitrosoepomo, G. (Editors), 1987. Weeds of rice in Indonesia. Balai Pustaka, Jakarta, Indonesia. p. 467, Fig. 4.217.

Pennisetum purpureum: Westphal, E. & Jansen, P.C.M. (Editors), 1989. Plant Resources of South-East Asia. A selection. Pudoc, Wageningen. p. 221.

Pueraria phaseoloides: Botton, H. & Hallé, N, 1958. Les plantes de couverture. Guide pratique de reconnaissance et d'utilisation des Légumineuses en Côte d'Ivoire 2. Journal d'Agriculture tropicale et de botanique appliquée 5: 105, Fig. 28.

Saccharum spontaneum: Gilliland, H.B., Holttum, R.E., Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Government Printing Office, Singapore. Vol. 3. p. 225, Fig. 49 (base of plant, flowering culm, culm node, panicle, branch with spikelets); Matthew, K.M., 1982. Illustrations on the flora of the Tamilnadu Carnatic. The Rapinat Herbarium, Tiruchirapalli, India. Pl. 928 (ligule).

Sesbania grandiflora: Sachet, M.H., 1987. The littoral species of Sesbania (Leguminosae) in the South Pacific islands and its relations. Bulletin du Muséum National D'Histoire Naturelle, 4e série, section B, Adansonia. Vol. 9. p. 11, Pl. 3.

Sesbania sesban: Havard-Duclos, B., 1967. Les plantes fourragères tropicales. Techniques Agricoles et Productions Tropicales, Collection dirigée par René Coste, 10. G.-P. Maisonneuve & Larose, Paris. p. 185, Fig. 70 (flowering branch); Busson, F., 1965. Plantes alimentaires de l'Ouest africain. Ministère de la Coopération et al., Paris. p. 244, Fig. 95 (fruit, seeds).

Setaria sphacelata: drawing provided by the author (leafy plant part); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 131 (ligule, spikelet, bristle); Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, United Nations, Rome, Italy. p. 663. Fig. 15.140 (inflorescence).

Sorghum × *almum*: Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, United Nations, Rome, Italy. p. 671, Fig. 15.142.

Sorghum, artificial perennial hybrids: drawing provided by the Department of Field Crops and Grassland Science, Wageningen Agricultural University.

Sorghum × *drummondii*: Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, United Nations, Rome, Italy. p. 691, Fig. 15.146; inflorescence: diapositive of the editors.

Stenotaphrum secundatum: Skerman, P.J. & Riveros, F., 1990. Tropical grasses. FAO, United Nations, Rome, Italy. p. 712, Fig. 15.152 (flowering plant, portion of spike); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 137 (ligule, spikelets).

Stylosanthes capitata: original drawing by P. Verheij-Hayes, Prosea, Wageningen, from Irwin et al. 14908 (WAG) (habit); Mohlenbrock, R.H., 1963. Further considerations in Stylosanthes (Leguminosae). Rhodora 65: 250, Fig. 1 (fruit).

Stylosanthes guianensis: Westphal, E. & Jansen, P.C.M. (Editors), 1989. Plant Resources of South-East Asia. A selection. Pudoc, Wageningen. p. 256 (flowering branch); Mohlenbrock, R.H., 1963. Further considerations in Stylosanthes (Leguminosae). Rhodora 65: 254, Fig. 19 (fruit).

Stylosanthes hamata: original drawing by P. Verheij-Hayes, Prosea, Wageningen, from Burt s.n. (habit); Mohlenbrock, R.H., 1963. Further considerations in Stylosanthes (Leguminosae). Rhodora 65: 254, Fig. 16 (fruit).

Stylosanthes humilis: Verdcourt, B., 1979. A manual of New Guinea legumes. Botany Bulletin No 11. Office of Forests, Division of Botany, Lae, Papua New Guinea. p. 374, Fig. 87 (flowering branches, flower); Mohlenbrock, R.H., 1963. Further considerations in Stylosanthes (Leguminosae). Rhodora 65: 257, Fig. 30 (fruit).

Stylosanthes macrocephala: original drawing by P. Verheij-Hayes, Prosea, Wageningen, from Irwin et al. 31823 (WAG) (habit); Sousa Costa, N.M. & Ferreira, M.B., 1984. Species of Stylosanthes. In: Stace, H.M. & Edye, L.A. (Editors): The biology and agronomy of Stylosanthes. Academic Press, Sydney. p. 31, Fig. 3 (fruit).

Stylosanthes scabra: original drawing by P. Verheij-Hayes, Prosea, Wageningen, from Belem 3886 (WAG) (habit); Mohlenbrock, R.H., 1963. Further considerations in Stylosanthes (Leguminosae). Rhodora 65: 251, Fig. 6 (fruit).

Themeda triandra: Bor, N.L., 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, Oxford, U.K. p. 253, Fig. 27.

Thysanolaena latifolia: Chien-Chang Hsu, 1978. Gramineae. In: Hui-lin Li et al. (Editors): Flora of Taiwan. Epoch Publishing Company, Taipei. Vol. 5. p. 396, Pl. 1374 (flowering branch); Chien-Chang Hsu, 1974. Taiwan grasses. Taiwan Provincial Education Association, Taipei, Taiwan. p. 238, Fig. 13 (ligule, part of inflorescence branch); Gilliland, H.B., Holttum, R.E., Bor, N.L., 1971. Grasses of Malaya. In: Burkill, H.M. (Editor): Flora of Malaya. Government Printing Office, Singapore. Vol. 3. p. 46, Fig. 1 (spikelet).

Trifolium repens: Zohary, M. & Heller, D., 1984. The genus Trifolium. The Israel Academy of Sciences and Humanities. p. 169, Pl. 52.

Trifolium semipilosum: Zohary, M. & Heller, D., 1984. The genus Trifolium. The Israel Academy of Sciences and Humanities. p. 178, Pl. 54.

Tripsacum andersonii: Wycherley, P.R. & Ahmad Azli, N.Y., 1974. Grasses of Malayan plantations. (plant habit); Matthew, K.M., 1982. Illustrations on the flora of the Tamilnadu Carnatic. The Rapinat Herbarium, Tiruchirapalli, India. p. 952, Pl. 952 (ligule, inflorescence); Häfliger, E. & Scholz, H., 1980. Grass weeds. Documenta, Ciba-Geigy, Basel. Vol. 1. p. 141 (spikelets).

Urochloa mosambicensis: Chippendall, L.K.A., 1955. A guide to the identification of grasses in South Africa. In: Meredith, D. (Editor): The grasses and pastures of South Africa. Part 1. Central News Agency. p. 383, Fig. 327 (leafy plant part, inflorescence); Tothill, J.C. & Hacker, J.B., 1983. The grasses of southern Queensland. University of Queensland Press, Brisbane, Australia. p. 426 (spikelets).

Vigna parkeri: drawing provided by the Department of Field Crops and Grassland Science, Wageningen Agricultural University.

Zoysia matrella: Chien-Chang Hsu, 1978. Gramineae. In: Hui-lin Li et al. (Editors): Flora of Taiwan. Epoch Publishing Company, Taipei. Vol. 5. p. 509, Pl. 1414 (flowering plant part); Chien-Chang Hsu, 1974. Taiwan grasses. Taiwan Provincial Education Association, Taipei, Taiwan. p. 450, Fig. 120 (ligule, part of inflorescence).

Index of scientific plant names

Page numbers printed in bold refer to main treatment.

Index of vernacular plant names

Page numbers printed in bold refer to main treatment.

The Prosea Foundation
(Plant Resources of South-East Asia)

Name, location, legal status, and structure

- Prosea is a Foundation under Indonesian law, with an international charter, domiciled in Bogor. It is an autonomous, non-profit, international agency, governed by a Board of Trustees. It seeks linkages with existing regional and international organizations;
- Prosea is an international programme focusing on the documentation of information on plant resources of South-East Asia;
- Prosea consists of a Network Office at Bogor (Indonesia) coordinating 6 Country Offices in South-East Asia, and a Publication Office in Wageningen (the Netherlands).

Participating institutions

- Forest Research Institute of Malaysia (FRIM), Karung Berkunci 201, Jalan FRI Kepong, 52109 Kuala Lumpur, Malaysia;
- Indonesian Institute of Sciences (LIPI), Widya Graha, Jalan Gatot Subroto 10, Jakarta 12710, Indonesia;
- Institute of Ecology & Biological Resources (IEBR), Nghia Do, Tu Liem, Hanoi, Vietnam;
- Papua New Guinea University of Technology (UNITECH), Private Mail Bag, Lae, Papua New Guinea;
- Philippine Council for Agriculture, Forestry and Natural Resources Research & Development (PCARRD), Los Baños, Laguna, the Philippines;
- Thailand Institute of Scientific & Technological Research (TISTR), 196 Phahonyothin Road, Bang Khen, Bangkok 10900, Thailand;
- Wageningen Agricultural University (WAU), Costerweg 50, 6701 BH Wageningen, the Netherlands.

Objectives

- to document and make available the existing wealth of information on the plant resources of South-East Asia for education, extension work, research and industry;
- to make operational a computerized data bank on the plant resources of South-East Asia;
- to publish the results in the form of an illustrated, multi-volume handbook in English;
- to promote the dissemination of the information gathered.

Target groups

- those professionally concerned with plant resources in South-East Asia and working in education, extension work, research and commercial production (direct users);
- those in South-East Asia depending directly on plant resources, obtaining relevant information through extension (indirect users).

Activities

- the establishment and operation of data bases;
- the publication of books;
- the sponsorship, support and organization of training courses;
- research into topics relevant to Prosea's purpose;
- the publication and disseminaton of reports and the research results.

Implementation

The programme period has been tentatively divided into 3 phases:
- preliminary phase (1985–1986): publication of 'Plant Resources of South-East Asia, Proposal for a Handbook' (1986);
- preparatory phase (1987–1990): establishing cooperation with South-East Asia through internationalization, documentation, consultation and publication; reaching agreement on the scientific, organizational and financial structure of Prosea;
- implementation phase (1991–1995): compiling, editing and publishing of the handbook; making operational the computerized data bank with the texts and additional information; promoting the dissemination of the information obtained.

Documentation

A documentation system has been developed for information storage and retrieval called SAPRIS (South-East Asian Plant Resources Information System). It consists of 6 data bases:
- BASELIST: primarily a checklist of more than 6200 plant species;
- CATALOG: references to general literature on plant resources;
- PREPHASE: references to literature from South-East Asia;
- ORGANYM: references to institutions and their research activities;
- PERSONYM: references to specialists;
- TEXTFILE: the published handbook volumes and additional information.

Publication

The handbook in blue cover (hardbound) is distributed by Pudoc, the low-price edition in green cover (paperback) by Prosea only in the developing countries of South-East Asia and the Pacific, the bibliographies by Prosea and the miscellaneous publications by Pudoc.

The handbook
- No 1. Pulses. L.J.G. van der Maesen and Sadikin Somaatmadja (Editors). Pudoc, Wageningen. 1989/ESCAP CGPRT Centre, Bogor. 1990 (out of print)/ Prosea, Bogor. 1992.
- No 2. Edible fruits and nuts. E.W.M. Verheij and R.E. Coronel (Editors). Pudoc, Wageningen. 1991/Prosea, Bogor. 1992.
- No 3. Dye and tannin-producing plants. R.H.M.J. Lemmens and N. Wulijarni-Soetjipto (Editors). Pudoc, Wageningen. 1991/Prosea, Bogor. 1992.
- No 4. Forages. L. 't Mannetje and R.M. Jones (Editors). Pudoc, Wageningen. 1992/Prosea, Bogor. 1992.
- No 5 (1). Timber trees. Major commercial timbers. I. Soerianegara and R. H. M. J. Lemmens (Editors). (expected publication date 1993).
- No 6. Rattans. J. Dransfield and N. Manokaran (Editors). (expected publication date 1993).
- No 7. Bamboos. S. Dransfield and E. A. Widjaja (Editors). (expected publication date 1993).
- No. 8. Vegetables. J. S. Siemonsma and K. Piluek (Editors). (expected publication date 1992/1993).

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- Bibliography 1: Pulses. Edition 1. N. Wulijarni-Soetjipto and J.S. Siemonsma (Editors). Prosea, Bogor. 1990.
- Bibliography 2: Edible fruits and nuts. Edition 1. N. Wulijarni-Soetjipto and L. S. Anema (Editors). Prosea, Bogor/Pudoc, Wageningen. 1992.
- Bibliography 3: Dye and tannin-producing plants. Edition 1. N. Wulijarni-Soetjipto and J.S. Siemonsma (Editors). Prosea, Bogor/Pudoc, Wageningen. 1991.

Miscellaneous
- A Selection. E. Westphal and P.C.M. Jansen (Editors). Pudoc, Wageningen. 1989.
- Basic list of species and commodity grouping. Version 1. R.H.M.J. Lemmens, P.C.M. Jansen, J.S. Siemonsma, F.M. Stavast (Editors). Prosea Project, Wageningen. 1989. (out of print).
- Basic list of species and commodity grouping. Final version. P.C.M. Jansen, R.H.M.J. Lemmens, L.P.A. Oyen, J.S. Siemonsma, F.M. Stavast and J.L.C.H. van Valkenburg (Editors). Pudoc, Wageningen. 1991.
- Proceedings of the First PROSEA International Symposium, May 22–25, 1989, Jakarta, Indonesia. J.S. Siemonsma and N. Wulijarni-Soetjipto (Editors). Pudoc, Wageningen. 1989. (out of print).

In brief, Prosea is

- an international programme, focused on plant resources of South-East Asia;
- interdisciplinary, covering the fields of agriculture, forestry, horticulture and botany;
- a research programme, making knowledge available for education and extension;
- ecologically focused on promoting plant resources for sustainable tropical land-use systems;

- committed to conservation of biodiversity;
- committed to rural development through diversification of resources and application of farmers' knowledge.

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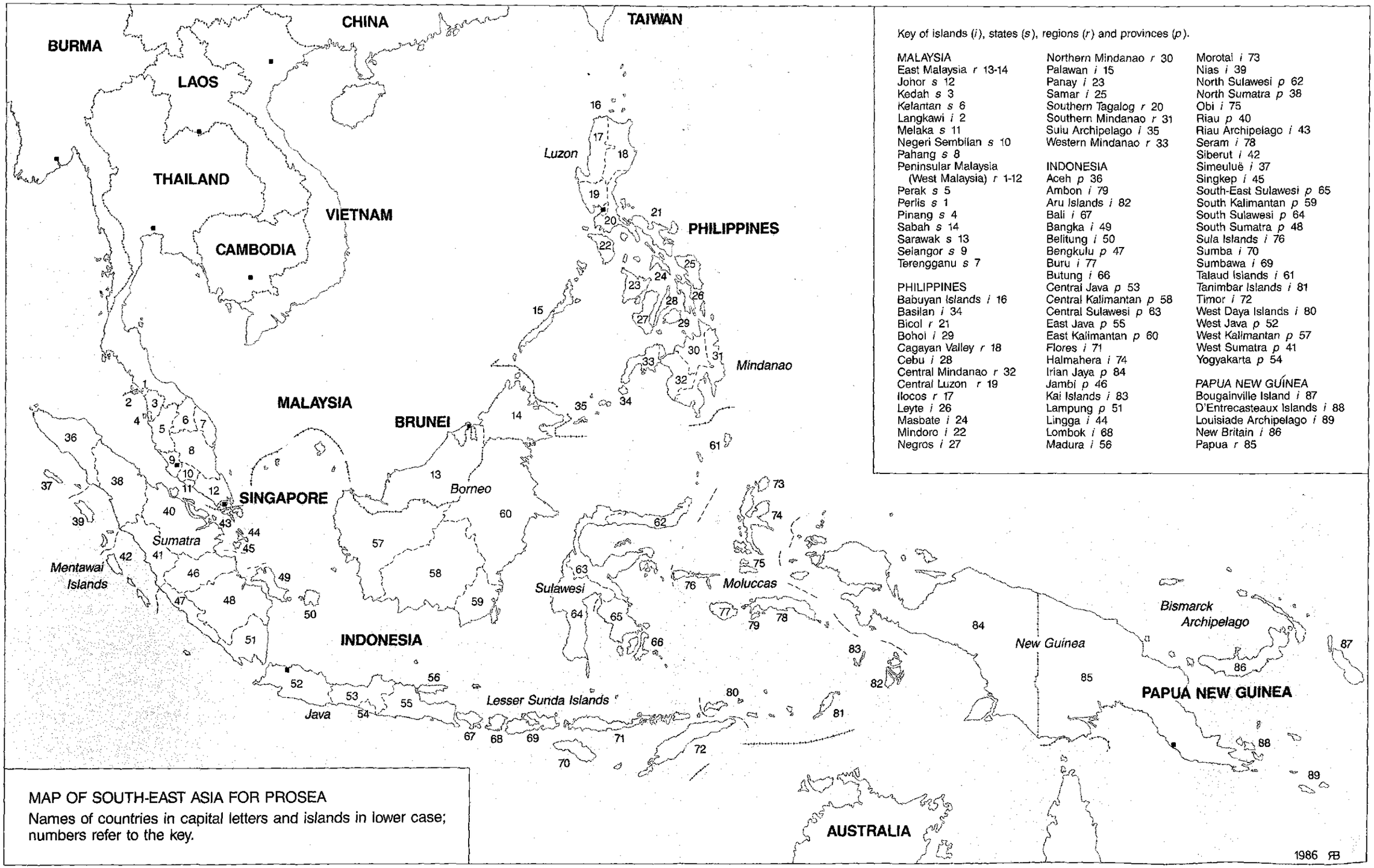

Key of islands (*i*), states (*s*), regions (*r*) and provinces (*p*).

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MAP OF SOUTH-EAST ASIA FOR PROSEA

Names of countries in capital letters and islands in lower case; numbers refer to the key.

1986 YB