BULLETIN 4

A REVIEW OF CROPS AND CROP PERFORMANCE ON SOUTHEAST ASIAN LOWLAND PEATS

SOIL RESEARCH INSTITUTE, BOGOR

A REVIEW OF CROPS AND CROP PERFORMANCE ON SOUTHEAST ASIAN LOWLAND PEATS

P.M. Driessen [x)]
Permadhy Sudewo [xx)]

x) Soil Scientist, Netherlands Technical Cooperation Programme.
xx) Staff, Soil Research Institute, Bogor, Indonesia.

PREFACE

This bulletin has been prepared to give settlers and planners a better insight in the agricultural possibilities of the vast Malesian coastal peat lands. It contains crop data collected in the course of the execution of the Dutch-Indonesian Technical Cooperation Programme ATA 106. This information was gathered in talks with transmigrants in Sumatra and Kalimantan and during visits to farmers and research institutions in Sarawak and Peninsular Malaysia. The field notes were supplemented with other published data and checked for correct nomenclature against Purseglove's "Tropical Crops".

Acknowledgements

The authors are greatly indebted to all farmers and government officials who supplied the information presented in this bulletin. Special thanks are due to Mr S. Mudjio, Extension Officer in the Kempas Jaya Transmigration Project in Indragiri Hilir, Sumatra; to Mr Kueh Hong Siong, Peat Agronomist at Stapok Deep Peat Research Station, Sarawak; to Mr Lim Heng Wee, Head of MARDI's Jalan Kebun Peat Research Station in Kelang, Selangor; and to Mr Soedarso of the Agricultural Extension Service in Pontianak.

Definitions adopted

Peat soil: a soil deeper than 50 cm and with more than 65% organic material (by weight).

Shallow peat: mineral subsoil at 50 to 100 cm from soil surface.

Moderately deep peat: mineral subsoil at 100 to 200 cm from soil surface.

Deep peat: mineral subsoil deeper than 200 cm from soil surface.

Nutrient contents of fertilizers (according to De Geus; 27)

Urea	45%	N
Sulphate of ammonium	21%	N
Superphosphate	16 to 20%	P_2O_5
Double superphosphate	36 to 48%	P_2O_5
Christmas Island Rock Phosphate	36%	P_2O_5
Muriate of potash	50 to 60%	K_2O
Sulphate of potash	48 to 52%	K_2O
Sulphate of potash-magnesia	26 to 30%	K_2O and
	9 to 12%	MgO

LIST OF CROPS

CEREAL CROPS

1. Maize 2. Rice 3. Sorghum

ROOT AND TUBER CROPS

4. Canna 5. Cassava 6. Chinese waterchestnut 7. Black potato 8. Sweet potato 9. Yam 10. Yam bean 11. Winged bean

OIL CROPS

12. Candlenut tree 13. Castor 14. Coconut 15. Groundnut 16. Kayu putih 17. Oil palm 18. Soybean 19. Sunflower

FIBRE CROPS

20. Abaca 21. Agave (sisal) 22. Cotton 23. Kapok 24. Kenaf 25. Ramie 26. Roselle

LATEX CROPS

27. Jelutung 28. Rubber

FRUIT AND NUT CROPS

29. Avocado 30. Banana 31. Breadfruit 32. Cashew nut 33. Chicu 34. Citrus 35. Duku 36. Durian 37. Gandaria 38. Hogplum 39. Jackfruit 40. Jambu 41. Joint fir 42. Kepundung 43. Mango 44. Mangosteen 45. Papaya 46. Passion fruit 47. Pineapple 48. Pomegranate 49. Rambutan 50. Soursop 51. Starfruit

VEGETABLE CROPS

52. Asparagus 53. Beans/pulses 54. Cabbage 55. Cauliflower 56. Celery 57. Chinese cabbage 58. Chinese spinach 59. Cocoyam 60. Egg plant 61. Endive 62. Gourds 63. Jengkol 64. Jungle geranium 65. Kangkung 66. Katuk 67. Leaf mustard cabbage 68. Lettuce 69. Black nightshade 70. Okra 71. Onions 72. Paku 73. Chilli pepper 74. Sweet pepper 75. Petai 76. Radish 77. Tannia 78. Tomato

STIMULANTS

79. Areca nut 80. Betel pepper 81. Coffee 82. Tea 83. Tobacco

SPICES AND FLAVOURS

84. Basil 85. Cinnamon 86. Clove 87. Ginger 88. Kencur 89. Laos (galangal)
90. Lemon grass 91. Marigold 92. Mint 93. Nutmeg 94. Pepper 95. Temu lawak
96. Turmeric

DYES AND TANS

97. Annatto 98. Garden balsam 99. Indian mulberry

PASTURE AND FODDER CROPS

100. Grasses

MISCELLANEOUS CROPS

101. Coral pea tree 102. Horse tamarind 103. Mulberry 104. Pandan 105. Sago
106. Sugar cane 107. Turi (fayotier)

Cereal · crops

1. MAIZE *Zea mays* L. (Gramineae)

Maize, or "jagung", is a common crop on lowland peat where it is planted by settlers as a pioneer crop, immediately after the removal of the forest. It is also grown on reclaimed and stable shallow or moderately deep peats. The grain is a popular staple food and is also used for the production of oil, starch and animal food. Stems and leaves can be used as a stock feed, both fresh and silaged.

Requirements: Maize has high nutrient requirements. Its shallow fibrous root system makes it a good crop for peat areas where nutrients are commonly concentrated in the uppermost layers. Maize is intolerant to waterlogging and requires a finely grained (= well decomposed) surface soil. The soil reaction should preferably be near pH 5.5 or higher (4, 23, 35); Polak (58) and Ehrencron (24) report that maize failed on acid (pH 3.3) forest peat in West Kalimantan, but developed normally after the soil was limed to pH 5.5.

Cultivation: Maize is sown in rows that are 80 to 100 cm apart, with 50 cm between plants (27, 45, 50). The crop is sown in February and/or June, at 3 or 4 seeds per hole; the seedlings are thinned after some 15 days. Ehrencron (24) reports impeded germination on acid ombrogenous peats and states that the leaves of the seedlings had difficulty in unfurling, which is a sign of copper deficiency (34). Liming increased the germination percentage in a number of cases. Farmers in Sumatra obtain good results by raising the seedlings on beds of burnt surface peat; the seedlings are soaked in a copper sulphate solution prior to transplantation (45). This practice improves the yield of cobs but is said to lengthen the growing period from 3 to 4 months. However, transplanting is very rarely applied in other peat areas.

The importance of copper dressings is stressed by many authors (33, 34, 38, 39, 59). Kanapathy found copper dressings increased the average cob weight from 56 to 170-230 gr/cob and grain yields from 1627 to more than 4000 kg of dry grain per hectare. Optimum dressings were in the order of 30 kg $CuSO_4.5H_2O$ per hectare which increased the copper content of the root zone from 7 to 22 p.p.m. After an initial dressing of 30 kg/ha subsequent crops need only a 2 kg/ha booster dressing (4). Low contents of zinc and iron are also known causes of depressed yields (24, 27, 59).

Macronutrients are needed on almost all peats. Kanapathy and Keat (39) calculated that a total harvest of 5000 kg of dry grain per hectare-year removes some 90 kg N, 41 kg P_2O_5, 25 kg K_2O and 11 kg MgO. Another 45 kg N, 36 kg P_2O_5, 110 kg K_2O and 28 kg MgO are contained in the straw.

Cereal crops

Polak and Soepraptohardjo (59) recommend liberal dressings of nitrogen and Edelman (23) reports a beneficial effect of phosphorus. Lim *et al* (47) mention the complete failure of maize on virgin forest peat if not supplied with N and P, and De Geus (27) states that maize on potassium-deficient soils develops weak stalks and produces a poor yield.
Fertilizer recommendations in literature (4, 39, 15, 58) refer to different peat types and maize varieties and are not always in agreement. Recommended dressings are between 40 and 200 kg N, 70 and 90 kg P_2O_5, 70 and 100 kg K_2O, and 30 and 50 kg $CuSO_4.5H_2O$ per hectare.
Acid forest peats need liming to make fertilizers effective. Chew (10) obtained good results with dressings of 10 to 15 tons of ground magnesium limestone (GML) per hectare on peats with an initial pH of 3.5 to 3.7, but Lim *et al* (47) prefer hydrated lime over GML because high magnesium levels induced by GML might depress yields. Ehrencron (24) cured male sterility in maize on acid (pH 3.5) forest peat with dressings of 10 to 16 tons of hydrated lime per hectare.
Grain yields on newly cleared and burnt moderately deep forest peats in Sumatra are initially between 600 and 900 kg/ha but drop to very low values after only a few years. On properly limed and fertilized peats yields of 2,500 to 4,000 kg of dry grain per hectare have been reported (4, 38, 39, 62).
Diseases and pests (birds, borers *(Ostrinia nubilalis* Hubn.*)*, mice, monkeys, wild pigs) do much damage unless rigidly controlled.

2. RICE *Oryza sativa* L. (Gramineae)

Rice, or "padi", is the world's best known swamp grass. *Under dry conditions* it will often grow and produce satisfactorily, even on deep but not too oligotrophic forest peats. *Wet rice on peat* is commonly less successful because of a general failure to set grain. Even the hardy and optimally adapted wild rice varieties occur only on river levees and in marine basins while on true peats rice seems absent altogether.
Shallow (<60 cm) or clayey peats and mucks can be used for wet rice cultivation (4, 15, 17, 19, 22, 30, 67, 74, 76) but despite incidental high yields on such soils there is general agreement that rice production on peat is inferior to that on mineral soils.
Where the peat is not very deep and underlain by fertile non-pyritic mineral sediments it is sometimes tempting to let the organic surface layer desinte-

grate. Coulter (16) states that *under such conditions* "deep drainage, burning the peat and removing and burning the timber are all highly desirable. Adopting this policy would ensure that the present peat areas would be the future padi areas." Unfortunately, the greater part of all shallow or moderately deep peats in S.E.Asia overlies pyritic marine sediments which acidify when exposed to the air and develop toxic levels of aluminium. The aluminium is liberated from clay lattices which desintegrate under such acid conditions.

Requirements: In many respects rice is well adapted to peat swamp conditions because it has a fibrous shallow root system, it can tolerate prolonged inundations and can still grow satisfactorily at pH 3.5, provided that Al and Fe-levels are low (27, 35). Plant nutrients, scarcely available in most peats and concentrated in the uppermost layer of the soil, are effectively taken up and the *vegetative* growth of wet rice on peat is often surprisingly good although deficiency symptoms are common.

However, on other than clayey or very shallow (less than 60 cm) peat soils the *generative* growth of wet rice is disappointing.

Cultivation: Rice is densely sown on seed beds and transplanted after 3 to 4 weeks to a previously prepared sawah, or (upland rice, or "padi gogo") is sown directly in the dry and burnt peat. Wet rice is planted in a 30 x 30 cm grid; dry rice is grown without any particular spacing, although weeding would be much easier if dry rice were sown in rows, e.g. some 35 cm apart. The crop is mature after 4 to 9 months, depending on the variety, the water regime, the environmental conditions and the cultivation methods applied. The nutrient requirements of most traditional rice varieties are not particularly high; nutrient removals are estimated (23, 25) at 10 to 25 kg N, 8 to 12 kg P_2O_5, 5 to 12 kg K_2O, 0.2 to 1 kg CaO and 1 to 4 kg MgO per hectare-crop. Some 50 kg K_2O and 150 kg SiO_2 are contained in the straw. Modern high yielding varieties are more demanding.

Fertilizer recommendations for rice on shallow and/or clayey peats are just as variable as the peat soils are themselves. The vegetative growth of rice can often be improved with a dressing of 30 to 40 kg N/ha directly before transplanting, while phosphorus improves ripening and resistance to drought and diseases ("mentek"; 16, 23). Potassium is particularly needed at flowering time. Burning of the peat increases the levels of plant available NPK and often results in appreciable increases in grain yield. On silicon-poor peats a dressing of H_4SiO_4 might prove beneficial (32) but many coastal peats contain appreciable quantities of silica, particularly so in the peripheral bog areas. Table 1 presents the silica contents of two representative Indonesian peat bogs. All profiles of one sequence were situated within 60 m of each other.

Table 1. Silica contained in the upper 20 cm layers of forest peats from Kalimantan ("P") and Sumatra ("JDP").x)

profile		SiO_2 (kg/ha)	Total ash (kg/ha)	$\frac{100.SiO_2}{\text{total ash}}$
P10	deep central dome peat under mixed sw. forest	5,892	9,070	65%
P11	deep central dome peat cleared 16 years ago; cropped 3 times	1,671	6,570	25%
P5	ditto; cropped 16 times	983	4,340	23%
JDP8	mod. deep fringe peat under mixed sw. forest	14,958	17,500	85%
JDP7	ditto; cleared 2 years ago, never cropped	11,873	17,180	69%
JDP6	ditto; cleared 30 years ago, continuously cropped	4,401	16,000	28%

x) Table presented at the Soils and Rice Symposium, Manila, 20 - 24 September 1977.

The table suggests that silica forms the bulk of the mineral fraction of peats under virgin forest (65 to 85%) but drops to 23 to 28 percent after clearance of the forest and prolonged periods of reduced nutrient cycling. Most oligotrophic lowland peats contain only low quantities of the secondary elements calcium and magnesium and similarly of almost all trace elements. Significant yield increases have been obtained by liming the soil with 10 tons of ground magnesium limestone per hectare (16). This might partly be due to increased levels of calcium and magnesium in the soil solution and/or to depressed aluminium levels (35). Aluminium is extremely toxic to rice and causes visible damage at a concentration of only 14 ppm (22).
Trace elements are rarely available in sufficient quantities and deficiencies of copper, zinc, molybdenum, boron, etc. are to be expected. Recent research (41, 63) suggests that rice is less capable of absorbing copper and zinc if

grown under conditions of prolonged flooding than if it is grown under "low water conditions" where the rice fields frequently dry up. This is in line with the author's opinion (17, 19) that the defective seed formation of wet rice on peat is perhaps caused by a disturbance of oxidative phosphorilation under conditions of low copper (and possibly zinc) availability in the presence of (poly)phenolic lignin degradation products. The latter are abundant in the nearly stagnant low-oxygen waters of deep central peat dome areas. Their fixing capacity is such that dressings of readily soluble copper and zinc sulphates have no effect on the sterility percentage (15) as the metal ions are instantly inactivated by the organic structures (64). There are indications that slow-release copper sources, foliar sprays of a Bordeaux mixture, or incorporation of mineral soil material in the topsoil might help to combat the sterility of wet rice on peat.
Yields of *dry* rice on peat are commonly between 0.5 and 2 tons of dry grain per hectare. On shallow peats and mucks the cultivation of *wet* rice can be very rewarding with reported yields of up to 3.5 tons of dry grain per hectare, but nutrient deficiencies, suboptimal water control, and a multitude of pests and diseases cause the average yield to be nearer to 1 ton of dry grain per hectare.

3. SORGHUM *Sorghum bicolor* Moench (Gramineae)

Sorghum, "cantel" in Java, is widely grown on coastal peat soils, mainly as an animal food (39). The grain is high in proteins and carbohydrates; the leaves are a valuable fodder and can also be used as green manure. Some varieties contain cyanogenic compounds in the milk stage; silaging of the green leaves is a recommendable precaution. The silage can be safely fed to livestock after 2 months.
Requirements: Sorghum is a hardy crop and more tolerant to drought than most other cereals. It has a shallow fibrous root system but requires a well drained soil (root rot!) with a fine tilth. The optimum soil pH is near pH 5.5 but a pH of 4.0 is still not prohibitive. Best results are obtained in areas with a hot climate and much sunshine.
Cultivation: Sorghum is best sown in rows (2 seeds per hole) at a distance of 60 to 80 cm with 10 to 25 cm between the individual plants. Farmers in Sumatra prefer a much wider spacing and intercrop with vegetables. Continuous cropping goes with a marked decrease in yield; a rotation scheme with dry

rice and groundnut produced good results. Sorghum can be harvested after 90 to 180 days depending on the variety grown (4, 39, 62). Burning of the peat is applied where fertilizers are not available or where their use is uneconomic; it was shown to double the uptake of potassium (38) and it increases the availability of phosphorus to which sorghum on peat responds markedly well (36). Nitrogen seems less important - even on limed deep forest peats vegetative growth is generally satisfactory (4) - but dressings of trace elements had a favourable effect (33, 55). Acid peats should be limed for good results (10, 12); sorghum on Malaysian forest peat with an initial pH of 3.5 was highly responsive to liming and performed best at a dressing of 10 tons of ground magnesium limestone per hectare.

The removal of nutrients (at a yield of 2500 kg of dry grain per hectare) is estimated at 20 kg N, 17 kg P_2O_5, 91 kg K_2O, 17 kg CaO and 25 kg MgO (38) which should be replenished if chemical soil fertility is to be maintained.

"Loose head" varieties, common in the humid coastal peat areas, suffer less from mildew and moulds than closed plumes but root rot and bird attacks nevertheless make high yields rare.

The average yield on moderately deep burnt peat in Sumatra is reportedly in the order of 1000 to 1500 kg of dry grain per hectare but with proper care a yield of 1500 to 2500 kg/ha is feasible (13, 33, 62). Kanapathy and Keat (39) obtained a yield of 5000 kg of dry grain per hectare and Andriesse (4) reports that properly fertilized new varieties can produce as much as 6000 kg of dry grain per hectare.

Root and tuber crops

4. EDIBLE CANNA *Canna edulis* Ker. (Cannaceae)

Canna, or "ganyong", is a 2 m high perennial herb indigenous to the Andes. Its rhizomes are edible after baking and can also serve for the production of starch. Tops and rhizomes can be used as a fodder but this is rarely practised in peat areas. The crop is not uncommon on compounds but is always grown in small numbers.
Requirements: The chemical soil requirements of the "Queensland arrowroot" are said to be considerable (31) but plants seen at MARDI's peat research station in Kelang, Malaysia, grew vigorously on moderately acid forest peat which had not been fertilized in years. Proper drainage is essential for good rhizome development.
Cultivation: Seeds or terminal portions of rhizomes are planted in rows, 0.75 to 1.00 m apart. The crop may be harvested after 4 to 12 months. Fertilizer requirements are not known. Masefield (48) reports yields - on mineral soils - of 35 tons of fresh rhizomes and 50 tons of tops per hectare after 12 months. Yields on lowland peat soils are not known. Pests and diseases are rarely serious.

5. CASSAVA / TAPIOCA *Manihot esculenta* Crantz (Euphorbiaceae)

Cassava, or "ubi kayu", is a tall-growing shrub indigenous to Brazil but now widely grown all over the tropics. The crop was introduced in Indonesia in 1810 (43) and quickly became popular as a staple food and a producer of starch for industrial purposes. At present, world production exceeds 90 million tons per year (80).
Not all cassava varieties are suitable for human consumption; some contain toxic cyanogenic glucosides which should first be removed by dissolving in water or by volatilisation. Cassava leaves (2 to 7 tons/ha. yr) are an important vegetable with high contents of protein, vitamins B and C, lipids, carotene, and calcium and other minerals (80).
Tubers can be converted to chips, pellets, pearls or flour for export; some 40% of all animal food manufactured in Europe is based on cassava.
The starch is also used for the production of glucose and dextrin and of solvents such as butanol, ethanol and acetone. In peat areas cassava is grown both in young and old reclamations. It is a true pioneer crop and can be planted in the first year after clearance of the swamp forest.

Requirements: Cassava is an exhaustive crop (36) with high nutrient requirements (9, 11). Its high nutrient absorbing power enables it to be grown on less rich peats but production is only low if such peats are not fertilized. Continuous cultivation of cassava does not lead to greatly reduced yields (33) and even on deep peats cultivation is thought to present prospects (4). Field observations in West Kalimantan suggest that the marked acidity of deep (over 6 metres) oligotrophic forest peat is tolerated after superficial burning of the peat. Cassava is distinctly acid-tolerant but liming of very acid (pH$\leqslant$3.5) peats is essential. Drained and not excessively oligotrophic/acid lowland peat is an almost ideal growing medium for cassava (9, 33, 36, 37) because of the early maturing, easy harvesting and high production of (fertilized) cassava on peat, and the relative freedom from diseases. Unfortunately, the low bearing capacity and high wood content of reclaimed forest peats preclude the use of heavy machinery in many cases.
Cultivation: Cassava is propagated from stem cuttings, 20 to 30 cm long and with 4 to 6 growing buds. The cuttings are planted on shallow ridges, in rows at a distance of 1 to 1.5 m with 1 m between plants, or in a 90 x 90 cm grid.
A very promising technique - known as the Mukibat technique (7) after the Javanese farmer who developed it - involves the grafting or budding of *M. glazovii* Muell. onto a stock of *M. esculenta*. This practice increases the production of tuberous roots; yields of 100 to 150 tons of fresh tubers per hectare are feasible. *M. glazovii* is found in East Java where it was introduced some 50 years ago as a latex producer ("manicoba") but as such was abandoned when *Hevea braziliensis* Muell. became popular. Javanese transmigrants brought the Mukibat technique to the peat swamps where it proved very successful (45); Mukibat cassava was often seen on the market in Tembilahan, Riau.
A similar technique is known in Argentina, where *M. flabellifolia* is grafted on *M. esculenta* resulting in yield increases up to 135%. Sweet varieties of cassava, e.g. "Medan", "Tiga bulan", "Putih", "Jurai" and "Kekabu" (11, 37) are harvested after 8 to 10 months; the bitter varieties "Green twig" and "Berat" are harvested after 10 to 20 months (37, 45). A longer growing period increases the yields of stems, tubers and starch at the cost of leaf production.

Root and tuber crops

Lim *et al* (47) report the failure of *M. esculenta* on virgin peat with a pH of 3.2 but Chew (11, 12) found that a pH of 3.6 was still tolerated. Our observations in Sumatra and Kalimantan confirm reports (47, 56) that production is low at low pH, and marked by many small tubers. Apparently the lower pH limit for satisfactory production lies near pH 4.0. Andriesse (4) mentions a yield increase of 6 tons of fresh tubers per hectare on acid forest peats in Sarawak as a result of liming with 4 tons of GML/ha. Chew (10) obtained the best yields with 7½ tons of GML/ha on Malaysian forest peat with an initial pH of 3.5.

Nutrient requirements of cassava are high; particularly of nitrogen and potassium (23, 33, 66).

The data published by Joseph *et al* (33), Chew (9, 11) and Kanapathy (36, 39) vary widely due to differences in variety, length of the growing time, yields, soil and climate conditions, etc.

The following ranges apply:

Nutrient removal (kg/ha. yield) of cassava on peat

	N	P_2O_5	K_2O	CaO	MgO
tubers	21-75	21-37	55-136	10-15	12.5-16.5
whole plant	85-230	70-163	130-300	65-84	60-100

Research by Kanapathy (36) suggests that P, Ca and Mg are mainly present in the stems while N and K are also high in the tubers. The beneficial effect of the burning of the peat is probably caused not only by the slight increase in pH upon burning but also by increased availability of N and K.

It seems impossible to provide universally applicable fertilizer recommendations for cassava on peat. Kanapathy and Keat (39) recommend 150 kg N, 120 kg P_2O_5, 200 kg K_2O, 35 kg copper sulphate and up to 11 tons of GML per hectare of moderately deep peat, but Chew (10) found lower optima and suggests a basal dressing of 65 kg N, 55 kg P_2O_5, 120 kg K_2O, 17 kg copper sulphate, 17 kg manganese sulphate, 17 kg magnesium sulphate, 8 kg zinc sulphate, 600 gr sodium molybdate, 600 gr borax and up to 7 tons of GML per hectare, followed after 3 to 4 months by a top dressing of 75 kg N and 80 kg K_2O per hectare. Increases of 60 percent and more in both tuber weight and starch production have been obtained with liming and fertilization.

Tuber yields on Indonesian forest peats - where fertilizers are rarely used - are among the lowest in Asia. The average yield lies probably between 6 and 8 tons per hectare-yield. The average tuber yield in Asia is estimated at

8.14 tons/ha and yields in Malaysia average some 16 tons per hectare (80). Chew (11) reports sustained yields of 14 to 15.5 tons of tubers per hectare on acid forest peat; Kanapathy obtained 17 tons/ha on non-fertilized peat (copper sulphate applied!) and 23 tons per hectare with fertilization. Andriesse (4) mentions yields of 18 to 36 tons per hectare on moderately deep (28% ash) peat in Sarawak.
Top yields, obtained with heavy liming and fertilization, are much higher: Joseph *et al* (33) report 49 tons of fresh tubers (Black Twig) per hectare, and Kanapathy (38) obtained 54 tons after only 9 months. With a computed *potential* yield of 97 tons of fresh tubers per hectare (26) there seems room for even higher scores. The Mukibat technique opens the way to tuber yields which exceed all existing records.
Diseases are rarely serious; wild pigs are a haggard in many peat swamp areas. Cassava tubers are rarely exported as such; they are converted to chips, flour, pearls or pellets which have a lower moisture content and are less perishable. Pellets have a 1.75 times higher bulk density than chips and are cheaper to transport but pelleting - a complex process involving gelatinization of starch and successive breakdown into simple sugars which serve as binders - requires specialized knowledge and equipment beyond the means of the common farmer. Cassava products for export should meet the standards set by the main importers (Europe and U.S.A.) but these conditions are not very severe:

	Standards to be met by cassava products for export (after 53)	Average composition of dried cassava (data by Flach, 26)
moisture	less than 14%	14%
starch	more than 62%	81.18%
fibre	less than 7%	1.81% x)
ash	less than 3%	1.63%
sand	less than 3%	--
rest	less than 3%	1.38%

x) higher in old tubers

It is to be expected that the demand for cassava products will further increase in the years to come. Commercial cassava growing in areas of tropical lowland peat has prospects, provided that the farmers are properly guided and introduced to modern varieties and cultivation practices.

Root and tuber crops

6. CHINESE WATER CHESTNUT *Heleocharis tuberosa* Schult. (Cyperaceae)

The chinese water chestnut, or "tikê", is a 0.9 to 1.25 m high sedge with onion-like leaves which are used for making mats. The crop forms tubers with a brownish black skin and white flesh that is edible when crushed and fried in oil. Tikê performed well in pot tests with inundated forest peat at Stapok Deep Peat Research Station in Sarawak. Although the crop is of minor importance, its cultivation on a small scale might be attractive in areas with prolonged inundation and/or brackish peats.

7. BLACK POTATO *Coleus parviflorus* Benth.(Labiatae)

Black potato, or "gembili", originates from Africa. It is grown in the coastal peat swamps of Sumatra and Kalimantan but never over large areas. The small brown tubers are eaten as a vegetable.
Requirements: The crop has low chemical requirements but prefers a loose and well aerated surface soil. It thrives in the hot and humid swamp climate.
Cultivation: Black potato is multiplied by planting rhizomes or suckers in a 40 x 40 cm grid, either on shallow beds or *in situ* in the drained and burnt surface soil. The rhizomes can be lifted after some 5 months.
Response to lime and fertilizers is not known. Yield estimates provided by farmers in Indragiri, Riau, ran as high as 10 tons of fresh rhizomes per hectare but gembili is always grown in small numbers and these estimates may be highly inaccurate.

8. SWEET POTATO *Ipomoea batatas* Poir (Convulvulaceae)

Sweet potato is a perennial herb, locally called "ketella" or "ubi jalar", and is one of the pioneer crops on recently cleared forest peat. The leaves and boiled tubers are used as a vegetable; the flour for baking cookies. High yielding non-edible varieties are grown for the production of starch and alcohol (55).
Requirements: Sweet potato will even grow on acid peats of moderate chemical fertility (8, 50) but a well aerated surface soil is essential. Droughts or floods cause a sharp drop in tuber yield and should be avoided whenever possible.

Cultivation: The crop can be multiplied by means of 30 to 60 cm long apical stem cuttings planted on shallow beds of burnt peat. Sweet potato is grown in a 50 x 50 cm grid or in rows at a distance of 90 to 100 cm with 25 to 50 cm between the individual plants (10, 50). The tubers can be lifted after 3 to 6 months (typically after 120 to 135 days; 4, 8, 10, 50) when the sap of cut-through tubers dries rapidly to a white crust (8). Prolonged monocropping causes a comparatively small reduction in yield (33). Liming is not always necessary but dressings of 5 to 10 tons of ground magnesium limestone per hectare improve yields on acid (pH 3.5) peats (10, 12). Sweet potato responds well to fertilizers, especially to potassium which greatly improves tuber weights (8, 12). High N-levels increase leaf growth at the cost of tuber production (50). Fertilizer recommendations for sweet potato on peat are in the order of 25 to 50 kg N, 30 kg P_2O_5, 60 to 120 kg K_2O, 17 kg copper sulphate, 11 kg manganese sulphate and 5 kg borax per hectare (8, 10). Pests sometimes reduce yields by as much as 75 percent (4). Wild pigs, cutworm *(Prodenia litura)*, weevil *(Cyclas formicarius* Fab.*)* and borers *(Terastia anastomosalis, Omphisa sp.)* are particularly harmful (4, 8). Tuber yields depend greatly on the variety and the growing period. Most edible varieties yield lower (10 to 15 tons of fresh tubers per hectare) than less tasty varieties such as "Large White" and "Serdang" which can produce as much as 20 to 24 tons of fresh tubers per hectare (4, 8, 10, 13, 33). In very dry years yields may drop to 3 to 5 tons/ha if the soil's moisture retention capacity is insufficient.

9. YAM *Dioscorea spp.* (Dioscoreaceae)

Yam, or "uwi", is a climbing perennial and very common on tropical lowland peat, - even on newly cleared land (75) - but it is not often mentioned in literature as growing on peat. Its tubers are edible after washing/cooking to remove toxic alkaloids. Yams in Sumatra *(D. alata)* were reportedly free of toxins. The plant is mainly grown on compounds or is planted as a pioneer crop on newly cleared land.

Requirements: Like most starch producing root crops yams exhaust the chemical fertility of the soil; the need for potassium is partioularly high. The plant grows vigorously in the hot and humid swamps but requires a well drained root zone (72) although Joseph *et al* (33) mention good results under conditions of suboptimal drainage.

Cultivation: Tubers or divisions with 2 or 3 buds are planted *in situ*, commonly along drainage ditches or garden fences or on 20 cm high ridges at a 1 x 1 m spacing. The species grown in many Sumatran peat areas ripens in 8 to 10 months; the tubers are lifted when the first leaves turn yellow. Introduction trials with Mexican yams - producers of steroidal compounds for birth control pills - on deep peat in Sarawak are still under way and look very promising.
Yams are grown in a fairly extensive way and fertilizers are rarely used although the crop would greatly benefit from dressings of nitrogen and potassium. Staking is reported to increase tuber yields with 50 to 100% (72) but is not always practised. Diseases are rarely serious. The main pests are wild pigs and - on compounds - chickens. Quantitative yield data could not be obtained; the results are generally described as "satisfactory". Yields on mineral soils are reportedly in the order of 10 to 15 tons per hectare.

10. YAM BEAN *Pachyrrhizus erosus* Urb. (Leguminosae)

The Yam Bean or "bangkuang" is a climbing herb from Central America. Its leaves, pods and seeds are poisonous but the young tubers can be eaten raw.
Requirements: Yam beans seem to have moderately high requirements with regard to the chemical soil fertility and prefer a loose and well drained soil. The climatic conditions in S.E.Asian lowland peat areas are apparently suitable for yam bean growing.
Cultivation: Yam beans are propagated by seed and sown on ridges or small mounds. In Sumatra, the crop was seen on burnt peat in a 1 x 1 m grid. The tubers are lifted after 8 to 10 months. Growth on peat seems to be somewhat slower than on mineral soils where the tubers can be harvested after 6 months. As a rule the crop is grown without much care and fertilizers are not applied. For high yields a pre-planting application of 300 to 400 kg of a compound (12-24-12) fertilizer is recommended. The average tuber size can be increased by nipping off the inflorescences. Leaf yellowing is a common disorder. Yields on peat are not impressive although Joseph *et al* (33) report a Malaysian variety to produce 6.6 tons of fresh roots per hectare.

Root and tuber crops

11. WINGED BEAN *Psophocarpus tetragonalobus* A.D.C. (Leguminosae)

(See also "Beans/pulses" in the section on Vegetable Crops).

Winged bean or "kecipir" produces edible tuberous roots which can be harvested after some 8 months. In Indonesian peat areas the roots are not harvested and the plant is grown for the seeds only.

Oil crops

12. CANDLENUT TREE *Aleurites molluccana* Willd (Euphorbiaceae)

The candlenut tree, or "kemiri", is a tall tree (up to 40 m) with extremely hard seeds which contain 17 percent "Tung" oil. The oil is less suited for consumption but is locally used as a lamp oil or pomade.
Requirements: Kemiri is obviously not very demanding. Vigorous growth was recorded on 1 m deep peat with groundwater at -70 cm. The warm and humid climate of most coastal peat swamps suit the tree well.
Cultivation: Kemiri is propagated by seed. The seedlings are transplanted when 12 months old and the crop will bear fruits after only 3 years. No special care seems to be needed. Javanese transmigrants rated the growth and production of kemiri on peat as satisfactory, but the fruits are rather small. Response to lime and fertilizers is not known; reliable yield data could not be obtained.

13. CASTOR *Ricinus communis* L. (Euphorbiaceae)

Castor, or"jarak", is a perennial herb from Africa which is successfully grown on Malaysian lowland peat (4, 38) but absent or rare in the peat areas of Indonesia. The young fruits can be eaten as a vegetable but the crop is almost exclusively grown for the ripe seeds which contain 40 to 65 percent of a heavy (0.96 g /cc) and valuable oil. The seeds contain a toxic protein; their consumption is dangerous.
Requirements: Castor requires a well aerated and fertile soil (50) and does not tolerate shallow groundwater. The climate of most coastal peat swamp areas seems less than ideal for castor growing because heavy rains during flowering and ripening depress yields.
Cultivation: Castor is propagated by seed. Data on optimum plant densities are not known but a 1 x 1 m grid will probably be satisfactory. The plant is mature after 6 to 7 months and grows well on fertilized peat but lodges easily. The quantity of nutrients removed with 2000 kg seeds and 1330 kg seed hulls (high yielding American hybrid; 27) is in order of 80 kg N, 18 kg P_2O_5, 32 kg CaO and 10 kg MgO, but seed yields - and hence the quantities of nutrients removed from the field - are commonly much lower in tropical peat swamp areas. Kanapathy (38) obtained highly variable results on forest peat in Peninsular Malaysia and Andriesse (4) reports that the best variety in a test on deep peat in Sarawak produced 690 kg dry seeds

per hectare, with an oil content of 44.68 percent. In recent experiments on limed and fertilized deep peat in Sarawak a high yielding American hybrid gave as much as 2 tons of dry seeds per hectare while a variety from Thailand produced more than 750 kg/ha.

14. COCONUT *Cocos nucifera* L. (Palmae)

The cultivation of coconut, or "kelapa", on peat is a practice of long standing. As early as 1903 coconut was the main crop on peat in Indragiri, Sumatra, (56) and in 1922 Tembilahan was a major copra market. Cooke (14) reports that coconut was widely grown on forest peat in Malaya in 1930. Subsidence of the land resulting in tree fall and deterioration of the soil's drainage status limits production unless precautions are taken. In 1940 the importance of Tembilahan as a copra market had strongly declined because of these problems.

Requirements: Shallow clayey lowland peat is an excellent growing medium for coconut but deep peats are less suitable because of their chemical infertility and the strong subsidence after drainage. Young palms on deep peat do sometimes remarkably well but stands tend to be irregular. Cooke (14) reports poor yields on 120 cm of peat with 83 percent loss on ignition, and Polak (56) states that coconut growing on peats deeper than one metre should be discouraged because many palms develop yellow foliage and produce poor yields. Our observations suggest that stagnant *shallow* water is the main cause of yellowing and retarded growth, whereas on *deeply drained* peat lodging is a problem during the first years after drainage when initial subsidence is still high. The palms need a sunny place; the crowns of mature palms should not overshadow each other.

Cultivation: Six to ten months old seedlings are planted in a 5 x 5 "depa" (8.5 x 8.5 m) grid; plant densities are typically close to 140 trees per hectare (27, 45, 46). The seedlings are planted in 40 to 60 cm deep holes and are loosely covered with topsoil to account for shrinkage of the peat. Once the young palms are firmly established, farmers in Indragiri and West Kalimantan dig a shallow pit adjacent to the planting hole and push the tree sidewards until it leans under a small angle, with the thickened base of the stem touching the walls and bottom of the new pit. Subsequently developing adventitious roots give the tree a firmer footing and keep the topheavy production palms from toppling over despite considerable subsidence of the peat. Extremely leaning and even fallen palms will rise again, but such plantations rarely reach 15 years of age (58) instead of the normal 30 to 40 years.

Dwarf varieties with fruits at a height of only 3 metres, are probably less susceptible to tree fall. Dwarf coconuts from Japan performed well in introduction trials on deep peat in Sarawak, in spite of their relatively high requirements and little tolerance to acidity.

Although coconut oil contains only low amounts of plant nutrients (25), copra production for export will rapidly exhaust the peat's natural fertility. Nutrient removal (at a plant density of 125 to 150 trees per hectare) is estimated at 47 to 66 kg N, 24 to 30 kg P_2O_5, 76 to 137 kg K_2O, 16 to 26 kg CaO and 27 to 40 kg MgO per hectare (27, 28, 56). Potassium, and sodium (23), are of particular importance to bearing palms (38); excessive K-dressings might induce magnesium deficiency, accentuated by the commonly acid soil reaction. Liming of the peat at a rate of 1 to 2½ kg of ground magnesium limestone per tree is recommendable on acid peat.

Vegetative growth is often improved with dressings of nitrogen and phosphorus but fertilizer recommendations will strongly depend on the quality and decomposition of the peat, the water regime, the age and plant density of the palms, etc. Green manure is reportedly not successful (56); it was never seen in coconut groves on peats in Indonesia. Macro-fertilizers are spread on the soil in a ring around the tree. Trace elements are given in various ways:

Copper is commonly given as a copper sulphate solution. In Indragiri one litre of a 1 : 100 solution is poured on the soil in a ring around the stem and Polak (56) observed that yellowing was successfully cured by pouring a 1 : 20 copper sulphate solution directly in the head of the tree at the rate of "one Coke bottle per tree".

Zinc deficiency is cured by burying dry batteries or a mixture of dry batteries, copper sulphate and sea salt, wrapped in a cloth. On estates, copper and zinc solutions are given in less colourful but equally effective ways; Fe- and Mn-deficiencies are reportedly cured by injecting dilute sulphate solutions (27).

Coconut is often intercropped with catch crops such as coffee or (in Malaysia) cocoa. Pineapple is less popular as an intercrop because it is believed to hinder the development of the palms on non-fertilized peats.

Oil crops

Coconut on peat starts to produce after 5 to 8 years and is in full production around the 15th year. Palms on shallow peat produce for longer periods, with 30 to 40 nuts per tree per year versus 20 to 30 nuts on deeper peat. Smallholder copra yields are typically between 450 and 900 kg per hectare, with maxima up to 1½ tons per hectare (46). The average oil content of the copra is 64 percent.

15. GROUNDNUT *Arachis hypogaea* L. (Leguminosae)

Groundnut, or "kacang tanah" is a popular crop in most reclaimed peat areas. The seeds contain up to 60% oil and some 200 grams of protein per kilo of shelled nuts (30); the cake is also used for consumption, often after grinding into flour or after a complex process of controlled moulding. Cake and leaves are also fed to livestock.

Requirements: Groundnut requires a well drained soil, preferably with a friable top layer which allows easy penetration of the pegs in the soil and easy harvesting. Extreme acidity is not well tolerated; the optimum pH lies between pH 4.6 and 5.5. The crop requires a continuous moisture supply, and thrives where rainfall is high and evenly distributed (as is the case in most coastal peat swamps).

Cultivation: Groundnut is sown at two seeds per hole on raised beds of some 40 cm high. The plants are grown in rows, 30 to 50 cm apart with 15 to 20 cm between plants, but planting in a 40 x 40 cm grid is not uncommon. The average plant density amounts to 60,000 to 80,000 plants per hectare. Short season varieties which can be harvested after 3 to 4 months are most popular in the peat swamps. Inoculation of the seeds with *rhizobium* is reported to increase nodule development and yield (27) but was never seen. Crop rotation, e.g. with sorghum, maize or dry rice is essential for sustained production. The cropping pattern should not include tobacco, tomato, soybean or sweet potato, as this might increase the incidence of nematode damage.

Farmers in the Teluk Kiambang transmigration area in Sumatra report however that on newly reclaimed fields the second crop is commonly better than the first one. This is probably accounted for by the very low pH value of virgin forest peats and by the relative absence of N-fixing bacteria. Lim *et al* (47) report the complete failure of groundnut on non-fertilized virgin peat with an initial pH of 3.2 and recommend liming with hydrated limestone. They warn against the use of ground magnesium limestone (GML) because too much magnesium would reduce yields, but others (10, 12) report groundnut on acid peat (pH 3.75) to be highly responsive to GML dressings of 4 tons per hectare.

Like most leguminous crops, groundnut has high phosphorus requirements (27), although P-removal is limited to only 3 kg/ton unshelled nuts. Potassium removal is higher (13 kg K/ton; 25) but the plant's need for potassium is often camouflaged by burning of the peat prior to planting. A small N-dressing (150 kg/ha) at planting time, when *rhizobium* activity is still low, is recommended. Calcium is of importance because it influences the number of kernels formed. (The strong antagonism between magnesium and calcium may be responsible for the unsatisfactory results obtained with GML by Lim *et al*; 47).

In a number of cases, sprays of copper sulphate had a favourable effect on groundnut production, possibly because its fungistatic effects help reduce Leaf Spot (55). Joseph *et al* (33) report the complete failure of groundnut on acid peat in Selangor if not supplied with copper but this report is not confirmed by results on comparable forest peat in Sumatra.

Small quantities of sulphur (in ammonium sulphate), boron, molybdenum and cobalt, e.g. as a seed treatment, did increase yields in a number of instances.

Pests and diseases are often serious. Nematodes, bacterial wilt (*Pseudomonas solanaceum*), Leaf Spot (*Cercospora personata*) and insects pose problems and strict rotation of crops should be observed at all times. Yields on limed/burnt and fertilized peats (NPK) vary from 1250 to 2,000 kg of dry pods per hectare (4, 10, 27, 47, 62), equivalent to some 900 to 1,400 kg dry seeds. Yields in transmigration projects on moderately deep peat in Sumatra and Kalimantan were commonly nearer to 500 kg/ha whereas top yields of 3.5 tons of fresh nuts per hectare, as reported by Joseph *et al* (33), were never obtained by smallholders in Indonesia.

16. KAYU PUTIH (Myrtaceae)

More than one tree species is indicated with the name "kayu putih" ("cajeput"). Most common on (shallow) peat soils is *Melaleuca leucadendra* L. or "gelam" which grows wild in the swamps of South Kalimantan and South

Sumatra, predominantly in areas with (potential) acid sulphate soils (18). Its wood and bark are used as a raw material for the paper industry but the tree is best known for its "kayu putih oil" which is extracted by distillation of the leaves.
A recently introduced *Eucalyptus* species (*E. globulus* Labill.?) proved very successful on moderately deep peat in Indragiri, Sumatra, despite acid groundwater at a depth of only -40 cm. The crop grew vigorously and flowered after only 18 months although neither lime nor fertilizers were used. *Eucalyptus* is considered superior to *Melaleuca* because its oil (0.1 percent of the fresh leaf weight) contains 85 percent of the active compound "cineole" versus only 65 percent in gelam oil (31). Reliable production figures are not yet available.

17. OIL PALM *Elaeis guineensis* Jacq (Palmae)

Oil palm, or "kelapa sawit", is a common crop in transmigration projects on shallow or moderately deep peats in Sumatra and Kalimantan where the palms are planted on compounds. The pericarp of the fruit contains 40 to 55 percent oil and the nut 50 to 60 percent. The cake is used in animal foods.
Requirements: Oil palm has a shallow root system (23) and tolerates soil acidity to some extent (35, 56) which makes it an attractive crop for areas with shallow and moderately deep peats (15). On deeper peats the trees lean after only a few years (33). The water table should not be too shallow (a depth of 75 cm below soil surface proved adequate) but the palms can tolerate temporary flooding. Chemical soil requirements are considerable (25) although the oil contains only negligible quantities of nutrients and elements contained in the kernels could possibly be returned to the field via stable manure. The hot and humid climate of coastal peat swamp areas suits the crop well.
Cultivation: Oil palm seedlings are raised on beds and transplanted to a 9 x 8 m grid, equivalent to some 140 trees per hectare, after 16 to 18 months. Production starts 3 to 4 years after planting and can continue for several decades. Oil palm on moderately deep peat failed in a number of cases after a few years of normal development (15, 56) probably because of starvation. In particular phosphorus and potassium are needed. Nutrient removal at a production of 20 tons of fresh fruit bunches per hectare is equivalent to 60 -73 kg N, 25-50 kg P_2O_5, 110-120 kg K_2O, 34-37 kg MgO and 27 kg CaO. Fertil-

izer recommendations - on mineral soils; 27 - are accordingly high: 50-100 kg N, 75 kg P_2O_5 (as Christmas Island Rock Phosphate, CIRP, once per 5 years supplemented with an extra 250 kg of CIRP/ha), 50-100 kg K_2O and 50 kg MgO. High potassium dressings may induce magnesium deficiency (chlorosis of the leaves) and require extra dressings of Kieserite of up to 3 kg/palm. Factory wastes should be returned to the field where possible. The fertilizers are worked into the topsoil in a ring around each tree; fertilizers with an alkaline reaction are to be preferred (28).
Copper deficiency is widespread in oil palm plantations on peat (33, 38, 40). It causes the younger fronds to turn yellow ("peat yellows") with some of the older ones becoming yellow and - later - brownish. Kanapathy *et al* (40) report that yellow fronds on deep peat contained 2.5 to 3 ppm copper versus 4.2 ppm present in healthy green fronds. Bronzing could be corrected with a dressing of 30 to 50 kg copper sulphate per hectare, supplemented where needed with an extra 200 to 300 grams per palm. Dressings of 15 g copper sulphate per palm at planting time, followed by dressings of 30 g/palm after one year and 60 g/palm after two years, will prevent yellowing in most cases.
Boron, zinc and molybdenum are needed as well (27, 33, 68). Boron deficiency ("hook leaf") can be corrected with a dressing of 40 g borax per palm. "Anthracnose" is a serious disorder in places, associated with necrosis and stunted growth. On properly fertilized peats, which can be limed if too acid, ($pH < 4.0$; 23) yields were in the order of 7 to 8 tons f.f.b. per hectare (4) corresponding with 2000 to 2500 kg oil. "Wild" varieties on less fertile peats yield much lower, e.g. 500 kg oil/ha.

18. SOYBEAN *Glycine max* Merr. (Leguminosae)

Soybean, or "kacang kedelai", is a potentially valuable crop for remote lowland peat areas because soybean seeds can easily be stored and transported and fetch a good price which eliminates the marketing and transport problems associated with so many other crops. Soybean is widely grown in peat areas; the oil containing seeds are eaten boiled or roasted, or are converted to tempe or tahu. The oil is used in margarine, soap, candles, etc.
Requirements: Soybean requires a well drained and fertile soil but grows also on less rich peats provided that the peat is not too acid ($pH \geq 5.0$).

Excessive moisture during ripening results in poor yields.
Cultivation: Soybean is sown directly in the peat, preferably after liming and fertilizer application. The plants are grown in rows, 30 to 45 cm apart with 10 to 15 cm between plants. Chew (10) reports that soybean on Malaysian forest peat with an initial pH of 3.50 to 3.75 performed considerably better after a dressing of 10 tons of ground magnesium limestone (GML) per hectare. De Geus (27) recommends liming with GML to pH 6.0 as this improves root growth and N-fixation and covers the plant's need for magnesium at the same time. In Indonesian peat areas burning of the peat is common practice and lime and fertilizers are not used although urea is sometimes given during early growth. Data from Malaysia suggest that a basal dressing of 75 kg N, 35 kg P_2O_5 and 70 kg K_2O per hectare is satisfactory on most deep forest peats. Yields in Sarawak increased after application of 20 kg of copper sulphate per hectare (4) and similar results have been obtained on peats in Florida (55). A dressing of 50 kg zinc sulphate per hectare did not increase yields on Sarawak peats but De Geus (27) reports a beneficial effect of dressings of Zn and B on certain mineral soils. Pests and diseases are problematic in most lowland peat areas. Bean fly (*Agromyza phaseoli*) and bacterial blight (*Pseudomonas glycinea* Coerper) are widespread.
Soybean is harvested after 3 to 4 months. Yields on unlimed burnt peats are in the order of 150 to 200 kg of dry seeds per hectare. Chew (10) reports yields of 160 kg dry seeds on unlimed forest peat versus 500 to 1000 kg/ha on plots which received lime and fertilizers, and Andriesse (4) mentions a yield of 869 kg of dry seeds per hectare on limed and fertilized lowland peat in Sarawak.

19. SUNFLOWER *Helianthus annuus* L. (Compositae)

Sunflower, "bunga matahari", is mainly grown as an ornamental plant on compounds. Kanapathy (38) mentions trials on peat in Peninsular Malaysia and Andriesse (4) reports that 4 varieties were tested on deep peat in Sarawak. The seeds contain 25-35 percent pale yellow "salad oil"; the press cake is a good animal food. The seeds are fed to poultry.
Requirements: Sunflower is less suited to the wet tropics. The crop is not very demanding with regard to chemical soil fertility but requires a well drained soil and will not tolerate severe acidity.

Oil crops

Cultivation: Sunflower is sown directly in the burnt surface peat to a density of 40,000 to 60,000 plants per hectare. Farmers in Indragiri harvest the seeds after 3 to 4 months. Responses to lime and fertilizers are not known. Kanapathy (34) found that the growth of sunflower on peat improved considerably after the application of copper sulphate. Transmigrants in Sumatra consider the seed yields obtained on burnt shallow forest peat "satisfactory". Andriesse (4) reports that the highest yield obtained on (deep) peat in Sarawak was 470 kg seed per hectare (with 29.5 percent oil) which is low in comparison to yields on mineral soils (900 to 1350 kg/ha; 27).

Fibre crops

20. ABACA *Musa textilis* Nee. (Musaceae)

Abaca, or "Manila hemp", is a potential crop for peat areas. It occurs in the Rasau Jaya Transmigration Area in West Kalimantan where it performs well on shallow (less than 1 metre) clayey peat. Abaca produces a strong fibre that is highly resistant to salt water and it is used for making durable ropes. World production amounted to 75,000 tons of fibre in 1968 (27).
Requirements: Abaca thrives in a warm and humid climate with an evenly distributed rainfall of 2,000 mm per annum or more. The average temperature should be higher than 21°C; the optimum temperature lies between 27 and 29°C (6). Abaca is very sensitive to waterlogging and requires a permeable and well drained soil although its root system is only shallow. The high quantities of green matter removed (54 to 84 tons/ha/annum; 27) cause the crop's nutrient requirements to be high. Extreme acidity is not tolerated.
Cultivation: Abaca is propagated by seed, or by planting root heads ("corms") or suckers. On estates, plant densities are commonly between 1,700 and 2,500 plants per hectare. Cutting starts 18 to 24 months after planting, when blossoms appear. The plant can become more than 20 years old but stands are commonly replaced after 12 to 15 years. Abaca is more demanding than the common banana; it needs nitrogen and potassium in particular. Berger (6) estimates the annual nutrient removal at 280 kg N, 30 kg P, 517 kg K and 124 kg Ca per ha-year, but these very high figures are substantially lower if, after extraction of the fibres, the waste is brought back to the field. Acid peats need to be limed, preferably to pH 5-5.5. Fibres make up some 1.5 to 3 percent of the total stalk weight. Fibre production is highest between the fourth and the eighth year after planting and is reportedly in the order of 2 to 5 tons of dry fibre per hectare-year (6).

21. AGAVE *Agave spp.* (Amaryllidaceae)

Agave, or "sisal", was once widely grown in Indonesia (23) but the acreage decreased in the sixties because of a disease to which *A. cantala* Roxb. had little resistance (6). *Agave sisalana* Perrine which produces a stronger but coarser fibre is less common; its flower stem is reportedly (50) edible. Sisal is not common on peat, probably because its nutrient

requirements which are normally low (6, 23, 25, 27) increase dramatically when the leaves are regularly harvested for the production of fibres.
Requirements: Agave does not require a very fertile soil but needs a well aerated root zone of 30 to 40 cm. It performs optimally on light, moisture-retaining soils in a climate with 1250 to 1750 mm rain and without a distinct dry period (27); *A. cantala* can be grown in areas with 2500 mm of rain per year and tolerates wetter conditions than *A. sisalana*. Soil pH should preferably be near pH 7. Waterlogging causes root damage and cannot be tolerated. Ten-year old sisal at MARDI's Jalan Kebun Peat Research Station grew vigorously on moderately acid (pH$>$5.5) peat without fertilization.
Cultivation: Agave is propagated by suckers which are raised in a nursery (80,000 plants per hectare) and subsequently transplanted to a density of 4,000 to 6,000 plants per hectare. Although sisal fibres contain only negligible quantities of nutrients (25) fertilization is necessary where large quantities of green matter are removed. Even if wastes are returned to the field (40 to 50 tons per hectare; 23, 27) fertilizers need to be given to prevent depletion of the soil's nutrient reserves.
The removal of nutrients is estimated at 40 kg N, 14 kg P_2O_5, 70 to 90 kg K_2O, 70 to 110 kg CaO and 35 to 50 kg MgO per ton of fibre (6, 27). Berger (6) estimates that the return of 50 tons of waste adds 60 to 300 kg N, 23 to 115 kg P_2O_5, 50 to 60 kg K_2O, 265 to 1720 kg CaO and 83 to 1330 kg MgO per hectare but recommends an additional dressing (on mineral soil!) of 50 to 100 kg N, 60 to 120 kg P_2O_5 and 150 to 300 kg K_2O per hectare. Soils with a low calcium content (peats!) need 2 to 5 tons of dolomitic lime per hectare to prevent chlorotic mottle and deterioration of the root system. High levels of calcium (or nitrogen, which is of paramount importance for leaf growth and fibre production) may induce potassium deficiency and "banding" or "leaf foot" disease in low-potassium soils.
The crop is sensitive furthermore to low boron levels; on peat soils a dressing of 5 to 10 kg borax per hectare might be needed. Sisal leaves can be harvested from the third or fourth year after planting. They contain 2 to 5 percent fibres. With proper fertilization yields of 3.5 tons of fibre per hectare can be obtained; without the use of fertilizers the expected yields are much lower, e.g. 1 ton per hectare-year.

Fibre crops

22. COTTON *Gossipium obtusifolium* Roxb. (Malvaceae)

Cotton, or "kapas", is rare in lowland peat areas. Some interesting experiments were seen on shallow peat near Teluk Kiambang, Sumatra. The experiments were discontinued in 1975 despite reasonable yields. Cotton seed contains 13 to 18 percent edible oil; the whole seed may be fed to cattle just as the press cake or meal. Cotton wool is a raw material for the production of textiles.

Requirements: Cotton has a tap root and requires a deeply drained soil. Its nutrient requirements are not excessively high. Climate-wise lowland peat swamps are less than ideal for cotton growing because the even rainfall distribution is associated with low quality floss.

Cultivation: Cotton is best sown in rows but the plants seen on peat were randomly spaced. Nutrient removal is low with an estimated 10 kg K_2O and 2 kg P_2O_5 per ton of fibre (25). Response to lime or fertilizers is still unknown for cotton on peat. In the experiment seen the first cottonbolls could be picked after some 5 months.

23. KAPOK *Eriodendron anfractuosum* DC. (Bombacaceae)

Kapok originated in the American tropics. It is a common tree in most transmigration areas on peat in the coastal swamps of Sumatra and Kalimantan. Its seeds are surrounded by a fine floss which is used for stuffing cushions, etc. Half-ripe seeds are reportedly edible (50). The seeds contain 22 to 25 percent oil which can be used for lubrication and soap manufacture.

Requirements: Kapok has low soil requirements and grows vigorously on shallow or moderately deep peats but the tree is never seen on deep formations. It thrives in the hot and humid coastal swamp areas but rainfall is perhaps too high for the production of high quality floss.

Cultivation: Kapok is propagated from stem cuttings or - more commonly in peat areas - by seed. On mineral soils, 80 to 100 trees are planted per hectare, commonly in a 10 x 12 m grid (50), but kapok grown on peat is more commonly planted in small numbers along the boundaries of fields or compounds. The trees start to produce after 5 or 6 years which is reportedly slower than on most mineral soils. Response to lime or fertilizers is not known. Yield estimates - though admittedly not very reliable - are in the order of 10 to 20 kg dry floss per tree.

Fibre crops

24. KENAF *Hibiscus cannabinus* L. (Malvaceae)

Several species of *Hibiscus* and related genera were seen on Malesian lowland peat. They all grew vigorously and seemed relatively free from pests and diseases.

Kenaf was seen in transmigration areas in Sumatra and was probably imported from Java. It has a stronger fibre than jute. Kenaf seeds contain some 20 percent oil (cooking); the cake is used in animal foods (6).

Requirements: Kenaf has lower requirements than jute but will not tolerate waterlogging.

Cultivation: The crop is sown in lines, 30 cm apart and with 5 to 7 cm between plants. The stalks can be harvested after 120 to 140 days when the plants flower. Nitrogen is very important for fibre production (27). Data on fertilizer requirements and stalk/fibre yields are not available for kenaf on peat. For mineral soils the recommended dressings vary between 33 and 66 kg N, 40 and 60 kg P_2O_5 and 44 and 66 kg K_2O per hectare (6). The dry stalks consist of 16 percent of fibres which are extracted by retting in water for 10 to 20 days. Fibre yields on mineral soils are between 900 and 2000 kg dry fibres per hectare and they depend on the environmental conditions, the variety grown and the length of the growing period.

25. RAMIE *Boehmeria nivea* Gaud (Urticaceae)

Ramie, or "rami", is a perennial half-shrub (from eastern Asia) with a life cycle of 6 to 12 years. Its glossy fibres can be used for making fabrics and ropes but ramie grown on peat is almost exclusively planted as an ornamental plant on compounds. The young leaves are high in vitamin A1 and protein and can be eaten as a vegetable. The variety "tenacissima" is hardy and well suited to humid tropical conditions (6).

Requirements: Ramie grows vigorously on most peats and has apparently only moderate nutrient requirements when grown as an ornamental plant or a vegetable. However, the crop needs considerable quantities of NPK and trace elements if grown for the production of fibre. It was very productive on calcareous peats in Florida (15) but failed on acid forest peat in Malaysia unless burnt plant remains were added to the soil. Sodium chloride is toxic to ramie at low concentration (27) and peat soils a short distance from the shore might be less suitable for ramie production. The continuously high temperature and high air humidity of coastal peat swamps are excellent for ramie growing.

Cultivation: Ramie is propagated by seed or by planting rhizome cuttings (6, 55). Ramie is best grown in rows, 90 cm apart with 60 cm between the individual plants. The crop can be cut 3 to 6 times per year. Replanting is needed after 7 to 10 years. The annual removal of green matter is considerable and is associated with an accordingly high removal of plant nutrients from the field. Estimates run as high as 190 to 240 kg N, 70 to 90 kg P_2O_5, and 270 to 340 kg K_2O per hectare (6, 27). These high values can be reduced by returning the decortication wastes to the field. Fertilizer recommendations are in the order of 150 to 300 kg N, 35 to 60 kg P_2O_5 and 45 to 100 kg K_2O per hectare, supplemented with 6 to 8 tons of stable manure or 10 tons of decortication waste. Trace elements had no effect in a number of experiments (15, 34) and seem less important. The better growth of ramie after the burning of the peat may partly be due to a slight rise in pH of the surface layer. Ramie yields on peat are not known. De Geus(27) estimates the annual green matter production of ramie on mineral soils at 10 to 15 tons of fresh leaves and a similar quantity of stalks. The stalks contain 12 to 15 percent of crude, not yet degummed fibre ("China grass") which brings the estimated crude fibre production to some 1000 to 2000 kg/ha-yr. The crop can be grown commercially where hand labour required for stripping and degumming is cheaply available.

26. ROSELLE *Hibiscus sabdariffa* L. (Malvaceae)

Roselle is an annual herb and is related to the "perambos", a popular ornamental plant on peat in transmigration areas of Sumatra and Kalimantan. Roselle fibres resemble those of kenaf. The crop is grown as a substitute for jute because of its higher level of production (27). The seeds contain 17 percent oil. The leaves, seeds and calyx can be eaten.

Requirements: Roselle has moderate nutrient requirements (50) but needs a well-aerated moisture retaining soil and will not tolerate stagnant groundwater. It can stand a warmer climate than kenaf but prefers an evenly distributed rainfall of 1500 to 2000 mm/year. The crop performed well on moderately deep forest peat in Malaysia but the experiments were discontinued after a few years.

Cultivation: Roselle is photosensitive and is best sown in the first half of August (50). The seedlings need 7 to 8 months to come to maturity but the best quality fibres are obtained when the crop is harvested after some 4 months.

Roselle responds well to dressings of phosphorus (23) and nitrogen, but high N dressings increase its sensitivity to *phytophthora* and moulds (27). Berger (6) recommends a dressing of 80 kg N, 36 to 54 kg P_2O_5 and 75 to 100 kg K_2O per hectare for roselle on mineral soils but higher dressings might be needed on peat soils.

Fibre yields are normally between 1600 and 2500 kg per hectare; maximum yields are close to 3500 kg fibre per hectare.

Latex crops

27. JELUTUNG *Dyera costulata* Hook (Apocynaceae)

Jelutung, also called "pantung", is a large tree indigenous to the Malesian peat swamp forest. Its latex is collected for the production of chewing gum. Most of the production is concentrated in Sabah.
Requirements: Jelutung grows vigorously in the hot and humid coastal peat swamps and needs no deep drainage. Van Wijk (78) states that the trees grow optimally on 1.5 to 2 m deep peat but they can also survive on deep, extremely acid "padang" peat (2). They do not occur in all swamps but seem confined to certain areas without any obvious reason. High soil iron contents are said to make the latex granular and of an inferior quality.
Cultivation: Cuttings from 3-year old saplings - collected in the forest - are made to sprout in water after which the stumps are planted in shallow holes. Van Wijk (78) recommends cutting parallel lines in the swamp forest at intervals of 5 to 15 metres in which the stumps are planted to a density of 125 to 250 stumps per hectare. After 2 to 3 years the lines are widened in order to provide more light to the young trees. This method has advantages over the traditional practice of clear felling of the forest because it ensures the continuation of nutrient cycling and prevents chemical exhaustion and excessive desintegration of the peat. The trees are tapped like rubber trees but in central forest areas slaughter tapping is deplorably frequent. Yield data could not be obtained.

28. RUBBER *Hevea brasiliensis* Muell. (Euphorbiaceae)

Rubber, or "karet", on peat is a typical smallholder crop and is grown in a traditional manner. Estates on peat, established in the first decades of the century, were not ultimately successful because after a period of vigorous growth the trees started to lean and seldom became older than 15 years (30).
Requirements: Rubber has low chemical requirements and grows well on soils of moderate fertility. It thrives on newly reclaimed, still relatively rich, and deeply drained peats but needs a firm footing. Coulter (15) recommends that rubber can be grown on peats shallower than 90 cm. Rubber trees on 8 m thick peat in Riau leaned heavily but were still in production after 15 years.
Cultivation: Estates make use of selected clones or use both seeds and

budding but smallholders on peat multiply their rubber solely by means of seeds. The seedlings are planted in an 8 x 8 m grid. It is probably worthwhile to replace gradually the original swamp forest with rubber trees (in order not to interrupt the important process of nutrient cycling) and/or to maintain a ground cover. Rubber trees on peat are slow to mature; tapping starts reportedly in the eighth year when the trees have a diameter of some 20 cm. Leaning and treefall are problematic on almost all peats but this seems not to affect the production of latex (4, 27, 30, 56). Weeding - suboptimal in most cases - is necessary in order to reduce competition from the undergrowth.

The latex contains only negligible quantities of nutrients. At a production of 1,100 to 1,300 kg latex per hectare the annual removal amounts to 3-10 kg N, 5-12 kg P_2O_5, 2-14 kg K_2O, 0.1 kg CaO and 3 kg MgO per hectare (39, 56). Rubber on peat responds well to fertilization, particularly to dressings of nitrogen and phosphorus. Nitrogen dressings promote vegetative growth but increase the danger of wind damage and treefall, particularly so at wide spacings. Phosphorus is most needed during early growth (27); it is often supplied as Christmas Island Rock Phosphate (CIRP) which gives good results at about half the price (per unit P_2O_5) of superphosphate.

Pests and diseases are relatively rare; Van Heurn (30) mentions a "root disease" (root rot?) in rubber plantations along Sumatra's east coast, possibly associated with inadequate drainage after some years of subsidence of the peat.

The latex production of smallholder rubber on peat is not commonly higher than 500 to 900 kg/ha-yr but yields of 1,200 to 1,400 kg latex/ha are feasible with proper cultivation and tapping techniques.

Rubber gives less problems on mineral soils than on peat soils. However, smallholder rubber on peat has some attractive aspects as it provides a steady source of income without high investments in fertilizers or manpower. Rubber is a highly price-elastic commodity and the crop should preferably be grown complementary to other crops which ensure some income in times when rubber prices are low.

Fruit and nut crops

29. AVOCADO *Persea gratissima* Gaertn. (Lauraceae)

The avocado, or "apokat", originates from Central America but is now found throughout the tropics. Good growth was seen on shallow lowland peat in Sumatra and Kalimantan. Avocado fruits are very high in protein and minerals, and fruits from selected varieties contain up to 30% oil (27) which can be used in cosmetics.
Requirements: Avocado on peat accepts low nutrient conditions but grows much better if manured. pH-values should preferably be between pH 5.5 and 6.5 (27) but field observations suggest that values around pH 4.0 are not prohibitive. Avocado requires a continuously high soil moisture content but it is sensitive to waterlogging.
Cultivation: Shallow, well drained lowland peat soils seem well suited for avocado growing. Avocado can be grown from seed but grafting trees with a suitable clone and planting at a 6 x 12 m spacing (equivalent to 140 trees per hectare) results in higher production. The trees start bearing after 5 to 6 years. Fertilizer recommendations for avocado on peat are not available; experience on mineral soils suggests dressings of some 110 to 170 kg N, 15 to 60 kg P_2O_5 and 40 to 120 kg K_2O per hectare-year, depending on the fertility status of the soil and the development stage of the crop. These macro-nutrients ought to be supplemented with foliar sprays of Zn, Mn and Fe where needed. Exact fruit yields of avocado on peat are not known; yields are reportedly very variable. The perishable nature of the fruits precludes their transportation to other than local markets.

30. BANANA *Musa spp.* (Musaceae)

Banana, or "pisang", is widely grown in areas with tropical lowland peat. It is one of the pioneer crops in young reclamations where it is planted in the 3rd year after clearance and drainage of the plot, when initial subsidence has slowed down. It is also grown in older schemes, even on moderately deep peats, but rarely (if ever) on a commercial basis.
Requirements: Banana needs a fertile and well drained soil for rapid growth, but can still be grown on peat soils of moderate chemical fertility, provided that the soil pH is not lower than 4.0. The crop needs a humid climate and thrives in lowland swamp conditions, if adequate drainage is provided.

Cultivation: Banana is propagated by suckers which are planted in rows or in a grid at an initial density of 600 to 800 plants per hectare. On deep peat the plants remain small and form only a few suckers (65, 68) if not fertilized. Polak (56) recommends artificial compaction of the surface peat as a means to increase production, but at present this practice is not or only rarely applied.

Banana removes considerable quantities of nutrients, even if pseudostems, leaves and roots are left behind. The estimated removal of nutrients at a production of 10 tons of fresh fruit bunches per hectare amounts to 25 kg N, 12 kg P_2O_5 and 45-90 kg K_2O per hectare (25, 27); fertilizer dressings of 30 to 50 g N, 7 to 12 g P_2O_5 and 60 to 100 g K_2O per tree are adequate in most cases.

Banana plants on peat often exhibit serious copper deficiency (27, 45). Farmers in Sumatra prevent this with 200 ml of a 1 : 100 copper sulphate solution poured on the soil in a ring around the pseudostem.

The first harvest of banana on peat can be expected after 8 to 12 months. On limed and fertilized peat suitable varieties produce one bunch of 12 to 20 kg per tree, equivalent to 8 to 12 tons of fresh fruit bunches per hectare.

31. BREADFRUIT *Artocarpus spp.* (Moraceae)

Breadfruit is a native of the Pacific region and a common crop in all tropical lowland areas. Two species widely grown on peat are *A. altilis* Fosberg ("kluwih") and *A. champeden* Spreng ("cempedak") which has hairy leaves. Sliced and dried the fruits can be eaten like bread (hence the name) but they are more commonly eaten fresh in sayur asam, or fried with flour. Roasted seeds are also edible.

Requirements: The crop grows well on almost all peats and has obviously only moderate nutrient requirements. Excellent growth was seen on moderately deep peat with groundwater at 50 cm below the soil surface.

Cultivation: Breadfruit is propagated by seed or, in the case of seedless trees, by cuttings. The first fruits can be harvested after some 5 to 7 years; fruits damaged by insects were frequently seen. Data on fertilizer needs or fruit yields could not be obtained.

Fruit and nut crops

32. CASHEW NUT *Anacardium occidentale* L. (Anacardiaceae)

Cashew, or "jambu monyet", is a medium-sized tree indigenous to South America. It is an extremely hardy tree, common on peat (57) but rarely grown on a commercial basis. The young leaves and the fruits are edible, the roasted oily seeds are used in confectionary and as a dessert.
Requirements: Cashew has low nutrient requirements (27, 57) but needs a deeply drained soil. Cashew on 75 cm of acid forest peat was seen to grow vigorously with little attention from the farmer. The tree grows in almost any tropical climate but too much rain can depress fruit formation. It performs best at an altitude of less than 350 m above sea level (50).
Cultivation: Cashew is sown *in situ* in the peat because young seedlings do not often survive transplantation. The tree bears fruits after 4 to 5 years and is productive for "several decades". It is common in compounds where it is planted together with other fruit trees.
The trees have obvious acidity-tolerance and lime or fertilizers are rarely applied. Reliable yield data for cashew on peat are not available. Javanese transmigrants in Sumatra and Kalimantan described its performance as "paling bagus" (excellent) but experiments on deep peat in Malaysia gave only moderate results with low yields and occasional lodging.

33. CHICU *Manilkara achras* Fosberg (Sapotaceae)

Chicu, or "sawo", is a medium-sized fruit tree from Guatemala which is grown throughout the Malesian region. The egg-shaped fruits are eaten fresh. The latex is used in chewing gum which (according to Heyne; 31) is "indispensable to the Yankee to promote the flow of saliva *after* a hurriedly taken meal".
Requirements: Chicu is not very demanding and grows well on most shallow or moderately deep forest peats. Good drainage is essential.
Cultivation: The tree is propagated by seed or cuttings and bears fruits after 4 to 6 years. Sawo on moderately deep peat in Sarawak and Sumatra performed satisfactorily without the use of lime or fertilizers but the fruits were rather small. Mature, 20 years old trees on peat in Indragiri produced an estimated 500 fruits per year. If grown for its latex, chicu is tapped like rubber and produces 1.5 to 2.5 kg latex per tree each year.

Fruit and nut crops

34. CITRUS *Citrus spp.* (Rutaceae)

Many species/varieties of citrus, or "jeruk", are grown on tropical lowland peat and the multitude of local names often causes misunderstandings if one interviews settlers on the requirements and performance of a certain species. Very common are the lime,("jeruk nipis", *Citrus aurantifolia* Swing.), the "jeruk peres" (*C. amblicarpa* Ochse) and the "jeruk purut" (*C. hystrix* DC.). Sweet oranges ("jeruk manis," *C. sinensis* Osbeck.) and mandarins ("jeruk keprok," *C. reticulata* Blance) are less common and are rare in young peat reclamations. Pummelos ("jeruk Bali", *C. grandis* Osbeck) were seen only once on peat.
Requirements: Citrus has low chemical requirements but sweet oranges and mandarins seem to require shallow eutrophic/mesotrophic and not too acid peat. The optimum soil pH is around pH 5.5. Waterlogging is not well tolerated.
Cultivation: The low quality species "nipis", "peres" and "purut" are propagated by seed. Trees of these species can grow for more than 30 years. They produce from the 4th year onwards. The more demanding "keprok" and "manis" are grafted and bear fruits from the 5th till the 15th year. Smallholder citrus on peat is rarely manured and trees seen in areas with deep peats were commonly deficient in N, P, K and a score of trace elements. Chlorosis and necrotic spots suggested a need for zinc, iron, manganese and molybdenum, but the symptoms were often blurred by the occurrence of pests and diseases. Trees on shallow peat, mainly "manis" and "keprok", are usually better cared for. Reliable yield indications could not be obtained because most farmers have only a few trees. Oranges sold on local markets are produced on the mineral river levees where citrus growing is more intensive and yields are much higher. Citrus yields on peat were nonetheless rated "satisfactory" by most of the farmers interviewed.

35. DUKU *Lansium domesticum* Corr (Meliaceae)

Duku is one of the less important fruit trees in coastal peat swamp areas. Its fruits are eaten fresh. Javanese transmigrants were of the opinion that it grows slower and produces less on peat than on fertile Javanese mineral soils. If not too deep/oligotrophic, peat seems a suitable growing medium for duku but specific crop requirements are as yet unknown.

Duku is propagated by seed. Fruit production starts after 10 to 15 years.

36. DURIAN *Durio zibethinus* Murr. (Bombacaceae)

Durian, with its penetrant smell, is a popular fruit throughout the Malesian region. The ripe fruit is eaten fresh and the unripe pericarp can be used as a vegetable. Roasted seeds are considered edible as well.
In many Mixed Swamp Forests, even on deep peat, "durian burung" (*Durio carinatus*) with smaller and non-edible fruits is one of the main residents.
Requirements: Durian grows well on most shallow or moderately deep peats with the water table at 75 cm below soil surface or deeper.
Nutrient requirements seem not excessively high but durian was never seen on deep oligotrophic peat.
Cultivation: In peat areas durian is propagated by seed. The tree bears fruits only after 8 to 10 years which is reportedly later than on mineral soils. Responses to lime and fertilizers are not known. Pests and diseases are rarely serious although foot rot (*Phytophthora*) seems to occur in places. Fruit yields are variable; a young tree produces 5 to 10 fruits in its first years of production but fully mature trees can bear as many as 50 fruits.

37. GANDARIA *Bouea macrophylla* Griff. (Anacardiaceae)

Gandaria, or "kalangkala", is a fruit tree of minor importance in (Indonesian) peat areas. It grows vigorously on most shallow and moderately deep peats and can reach a height of 10 to 15 metres. The tree is propagated by seed or cuttings and produces fruits after some 5 years. Mature trees bear thousands of small fruits each year. Response to lime or fertilizers is not known. Pests and diseases are reportedly never serious.

38. HOGPLUM *Spondias cytherea* Sonn. (Anacardiaceae)

Hogplum, or "kedondong", is a 10 to 25 m high tree with oval acid fruits that can be eaten fresh, or mashed and sweetened. The tree is not uncommon on compounds but its fruits are not in great demand.
Requirements: Hogplum grows well on most shallow or moderately deep peats

with the water table at a depth of 60 to 75 cm below soil surface.
Cultivation: The tree is propagated by seed and bears fruits after only 4 years. Hogplum produces hundreds of fruits per year and remains productive for more than 20 years. On (non-fertilized) moderately deep forest peat the fruits have the size of an egg and are reportedly inferior to those from trees on mineral soils.

39. JACKFRUIT *Artocarpus heterophyllus* Lam. (Moraceae)

Jackfruit, or "nangka", is one of the commonest fruit trees in peat areas. It grows vigorously on shallow or moderately deep peats. Ripe and unripe fruits can be eaten, as well as the seeds.
Requirements: Jackfruit has obviously low chemical requirements but the tree needs a permeable, well drained soil. Shallow peats are to be preferred otherwise treefall becomes a problem (45).
Cultivation: In peat areas, jackfruit is propagated by seed. The tree is common on compounds where it is planted in a 4 x 4 m grid (wider spacings are common), usually together with other fruit trees. It bears fruit after 3 years. Sewandono (65) reports that jackfruit on shallow peat over pyritic (potentially acid) marine sediments in Bengkalis, Sumatra, died after only a few years; possibly the tree is sensitive to high aluminium levels. Response to lime and fertilizers is not known and reliable yield data are absent. Farmers in Sumatra estimated the average monthly production at 2 to 3 fruits per tree, or higher if unripe fruits are harvested.

40. JAMBU (Myrtaceae, Anacardiaceae)

The local name "jambu" refers to a number of medium-sized fruit trees in different botanical *taxa*. Common in peat areas are the "jambu air" (*Eugenia aquea* Würmf.), the "jambu bol" (Malay Apple, *Eugenia malaccensis* L.), the "jambu semarang" (*Eugenia javanica* Lam.), the "jambu biji" (Guava, *Psidium guajava* L.) and the "jambu monyet" (Cashew, *Anacardium occidentale* L.). The latter bears tasty fruits but is more commonly grown for its oily seeds (see also 32). Jambu trees are common on compounds where they are grown in small numbers for the farmer's own consumption or for the local market.

Requirements: All jambus are hardy trees with low soil requirements. They grow vigorously under peat swamp conditions, even on moderately deep and shallow-drained central dome peats.
Cultivation: Most jambus are propagated by seed; j. air and j. semarang more commonly by stem cuttings. Guava often grows spontaneously, the seeds being disseminated by birds or bats. Jambu air and j. biji bear fruits after 3 to 5 years; j. bol and j. semarang after 6 to 8 years. The fruits are often infested with worms which are difficult to control.
Farmers in Sumatra rated the fruit production of all species "satisfactory" although yields are lower than on (fertile Javanese) mineral soils. Response to lime and fertilizers is unknown; trials with guava are reportedly under way (13).

41. JOINT FIR *Gnetum gnemon* L. (Gnetaceae)

The joint fir, or "melinjo", is a moderately high cone-shaped tree. Its young leaves are sometimes eaten as a vegetable; the crushed seeds are fried in oil ("emping"). Melinjo is rare on peat. A few trees were seen on shallow well decomposed peat in Indragiri, Sumatra, and at MARDI's Jalan Kebun Peat Research Station in Kelang, Malaysia, where the trees grew vigorously on limed and fertilized moderately deep peat. Some lodging may occur after 6 or 7 years. Data on lime and fertilizer requirements are not yet available.

42. KEPUNDUNG *Baccauria racemosa* Muell. (Euphorbiaceae)

Kepundung is one of the bigger fruit trees but is of little importance. It is multiplied by seed. Kepundung on peat becomes productive in the eighth year. Mature trees produce thousands of small fruits per year. Response to lime and fertilizers is not known; pests and diseases are reportedly never serious.

43. MANGO *Mangifera spp.* (Anacardiaceae)

Mango, or "mangga" (*M. indica* L.), is uncommon in coastal peat areas, probably because the crop needs some three months with less than 60 mm of

rain for proper fruit formation. The related *M. foetida* Lour ("bacang",or horse mango), *M. odorata* Griff. ("keweni"), and *M. caesia* Jacq ("kemang") are widely grown but their fruits are less popular because they are acid (kemang), fibrous (keweni) or cause itching lips (bacang). Young *M. indica* fruits and leaves can be used as a vegetable; ripe fruits are eaten fresh.
Requirements: Soil requirements are low (27) but good drainage is essential. Soil pH should preferably be near pH 5.5, but mangos were also seen on (shallow) acid peats.
Cultivation: Mangos are propagated by seed or by grafting. They are planted to a density of 200 trees/ha, most commonly in a 6 x 9 m grid, and start to produce fruits after 5 to 8 years. Liming with ground magnesium limestone improved the growth of mango on a number of forest peats, just as dressings of 125 kg N/ha. Too much nitrogen is said to increase the incidence of "soft nose" (27). Copper, zinc and manganese may be deficient on deep peat. Anthracnose (*Coletotrichum gloeosporioides*) is cured with copper compounds.
Fruit production is highly irregular with "off" and "on" years. In Sumatra mangga produced up to 300 kg of fresh fruits per tree in old peat reclamations.

44. MANGOSTEEN *Garcinia mangostana* L. (Guttiferae)

Mangosteen, or "manggis", is a tall tree and a native of the Malesian region; many *Garcinia* species occur in the natural peat swamp forests of Sumatra and Kalimantan (2) and are referred to as "manggis hutan" by the local population. *G. mangostana* is common on compounds but is never grown on a commercial basis. Its delicious fruits are best eaten fresh.
Requirements: Mangosteen thrives in the hot and humid tropical peat swamps. The tree was never seen on acid deep peat. Good drainage seems essential.
Cultivation: Mangosteen is propagated by seed; the seedlings are transplanted when 2 years old. Trees on moderately deep peat in Sumatra became productive after some 8 years which is reportedly earlier than on mineral soils in Java. Their production was estimated at 300 to 400 fruits per tree. Data on response to lime or fertilizers could not be obtained.

Fruit and nut crops

45. PAPAYA *Carica papaya* L. (Caricaceae)

Papaya is one of the traditional crops on peat where it usually grows to a height of 3 to 4 m (8 to 10 m on mineral soil). Its fruits are eaten fresh; the unripe fruits and bitter leaves can serve as a vegetable. The leaves contain papain which makes tough meat tender.
Requirements: Papaya has a tap root and requires a deeply drained but moisture retaining soil. Stagnant shallow groundwater increases the incidence of root rot. The crop prefers a rich and only slightly acid soil (50) but grows also on moderately deep (burnt) peat of low pH.
Cultivation: Papaya is propagated by seed. The seedlings are transplanted to a 3 x 3 m grid; root damage incurred in transplantation is often lethal. Papaya bears fruits after 8 to 10 months (12 months on mineral soils; 27) and remains productive for several years. Being top-heavy, papaya on newly reclaimed peats is in danger of toppling over.
Liming and manuring (3) are necessary for high yields; the rapid vegetative growth of the crop is associated with a high need for nitrogen. Phosphorus and potassium seem to be required less. Papaya growers on peat near Pontianak obtained good production by fertilizing the crop with peat ash and fish meal, supplemented with dressings of urea and pig manure. Fruit flies (*Dacus sp.*) cause deformation of the fruits and are a major pest.
Farmers in Indonesian peat areas estimate the production of papaya at 15 to 20 fruits per plant-year. At a density of 1000 plants per hectare and an average fruit weight of 1 kg, this corresponds with 15 to 20 tons of fresh fruits per hectare-year, similar to yields on mineral soils in Hawaii (27). However, papaya-on-peat is a typical smallholder crop and is usually grown in a very extensive way as an intercrop with pineapple, cassava, sweet potato, vegetables, etc. This reduces the yields to 3 to 4 tons of fresh fruits per hectare. Transport and marketing of the perishable fruits is a problem in many peat areas; prospects for commercial papaya growing do not seem promising.

46. PASSION FRUIT *Passiflora spp.* (Passifloraceae)

Passion fruit is a perennial climber from Brazil and rare on Malaysian lowland peat. At least one *Passiflora* species grows wild in the coastal swamps where it occurs even on deep, acid and chemically exhausted peats.

Requirements: The cultivated *Passiflora edulis* L. needs a fertile, well drained but moisture retaining soil. It grows best at some altitude but can also be cultivated at sea level.
Cultivation : The crop is propagated by seed or rooted stem cuttings which are planted along bamboo frames, e.g. in a 2 x 4 m grid. The plants bear fruits after 15 months and live for 5 to 6 years. Trials with various varieties on deep peat in Sarawak were very successful. The yields obtained so far are still rather low due to too wide spacing and damage by fruit flies (3 tons of fresh fruits per hectare).

47. PINEAPPLE *Ananas comosus* Merr. (Bromeliaceae)

Pineapple, or "nanas", is by far the commonest crop on peat. It was introduced to the Malesian region by the Portuguese, in the 16th century. Canning of pineapple started in 1888, initially by European investors and later also by local entrepreneurs. Since 1938 pineapple has been the sole crop on deep peat in Malaysia (3, 75). In 1965 the Malaysian government set up a small growers cannery which resulted in a spectacular rise in acreage. At present some 25,000 hectares of Malaysian deep peat are under pineapple (38); in Indonesia the acreage is even larger.
The varieties "Singapore Spanish" and "Selangor Green" are popular canning varieties; "Mauritius" and "Sarawak" ("Smooth Cayenne") are mainly for consumption as fresh fruit. Pineapple in Indonesia is almost exclusively produced for local consumption.
Requirements: Pineapple has low nutrient requirements. Its shallow root system and its tolerance to soil acidity (27, 35, 54, 69) make it a suitable crop for almost any peat although it grows and produces best on a well drained (water table at 60 to 90 cm below soil surface; 54) and moderately acid (pH 4.5 - 5.0; 69) fertile soil.
Cultivation: Pineapple is one of the "pioneer crops" planted immediately after removal of the natural forest vegetation, usually in combination with cassava, sweet potato, cocoyam, and vegetables. It is also grown as an intercrop with rubber or coconut but rarely the latter because of an assumed negative effect on the growth of the palms.
Cultivated pineapple varieties are self-incompatible and therefore usually seedless. Pineapple is multiplied by means of basal slips. Crowns can be used as well but are less popular because they are slow to come to maturity.

Ratoon crops rely mainly on suckers; such crops produce smaller fruits and yield considerably lower than the plant crops (20).

On estates, pineapple is planted in double rows at a distance of 1.25 m with 1.80 m wide harvesting paths at 200 m intervals. The optimum spacing between plants is approximately 60 cm, which brings the total plant density to some 15,000 plants per hectare. Higher initial plant densities (30,000 plants/ha) favour early yields; lower densities as applied in many Indonesian transmigration areas, are associated with excessive vegetative growth, slow fruiting and increased average fruit sizes. Too wide spacings lead to sunburn and toppling over of the plants (20). Before planting the slips are best dipped in a Bordeaux mixture.

Weeding is rarely needed on newly cleared forest peats but should be done monthly in older reclamations until the vegetation cover is closed (after 6 to 8 months).

On pineapple estates in Malaysia flowers are induced artificially after 11 months by means of a small dose of acetylene (from calcium carbide) or α-naphtalene acetic acid (69, 75), repeated every 3 months. The fruits can be harvested some 6 months after flower induction when the bottom 2 or 3 rows of eyes have turned yellow. The crop is inspected every 5 to 7 days.

Although pineapple survives on most forest peats without much attention, dressings of NPK and trace elements are often needed for satisfactory results. The nutrient removal per ton of fresh fruits is estimated at 1 kg N, 0.6 kg P_2O_5, 2 to 5 kg K_2O, 0.3 kg CaO and 0.2 kg MgO (25, 27). Wee (75) reports that 40 percent of all smallholders in Malaysia never fertilize their pineapple; this percentage is certainly much higher in Indonesia.

Nitrogen dressings improve the vegetative growth of pineapple (54); nitrogen should not be given within 3 months from harvesting. Phosphorus improves flowering but seems not always needed. Potassium increases the sugar content of the fruits (20, 27).

Recommended NPK-dressings are in the order of 45 to 80 kg N, 45 to 80 kg P_2O_5, and 80 to 120 kg K_2O per hectare (4, 10, 20); Kanapathy (38) suggests much higher dressings of N and K_2O (280 kg/ha and 225 kg/ha resp.). Excess calcium causes stunted growth and partly chlorotic plants and liming of the peat is generally disadvised (10, 68, 69). Trace elements are needed on most deep peats, particularly copper ("green die back disease"), zinc ("crooked neck"), manganese and boron. Chew (10) recommends a basal dressing of 17 kg copper sulphate, 17 kg magnesium sulphate, 17 kg zinc sulphate, 8 kg manganese sulphate and 1 kg borax per hectare to prevent micro-element deficiencies.

Pineapple is relatively unaffected by diseases but mealy bug (*Dysmicoccus brevipes*), monkeys, pigs and rats can cause considerable damage.

On estates, where high plant densities, high yielding varieties, fertilizers and pesticides are used, yields can be in the order of 40 to 50 tons of fresh fruits per hectare for the plant crop and 30 tons/ha for the first ratoon crop (33) but smallholders in Riau produce - without any inputs - only 5 to 8 tons of fresh fruits per hectare.

Processing: Not all pineapple varieties are suited for canning. The ideal fruit has shallow eyes, a rectangular or slightly oval shape, a small core, and a golden yellow colour. It has a diameter of 10 to 13 cm and few air cells (20). The Smooth Cayenne varieties grown by smallholders in Indonesia, are less suited for canning but are popular because of their low requirements. A cannery must rely on a minimum 600 hectares of pineapple crop to operate economically. At a return for canned fruit of US$ 27.00/ton, estates would receive a cash *gross* return (ex-farm) of some US$ 800.00 to 1,250.00 per hectare. The high costs of freight and canning, the uncertain market situation, and the present excess production capacity of established industries make the prospects seem rather dubious for new entrants into the canned pineapple market (77).

48. POMEGRANATE *Punica granatum* L. (Punicaceae)

The pomegranate, or "delima", is a 2 to 4 m high shrub from the Middle East. Its fruits contain juicy pulp which is used in beverages. The bark is used as a medicine against (tape)worms. Chinese farmers near Pontianak grow delima on their compounds because they consider it effective against bad luck.

Requirements: The tropical lowland peat swamps seem not well suited for delima cultivation. The plants seen had only few fruits, probably because the climate was too humid.

Cultivation: Delima is propagated from 40 cm long woody cuttings. The latter root readily and produce fruits after some 3 years. Growth of this unimportant crop is often less than impressive.

Fruit and nut crops

49. RAMBUTAN *Nephelium lappaceum* L. (Sapindaceae)

Rambutan is a medium-sized tree. It grows vigorously on shallow and moderately deep peat. The fruits have sweet and juicy arils and are produced for the farmer's own consumption and for sale at the local market. At least one "wild" rambutan species is a native of the swamp forests of Central Kalimantan; its small, bright red and very acid fruits are considered edible by the local Dayak population.
Requirements: Rambutan seems not very demanding but requires a well drained soil. It was seen on mesotrophic moderately deep forest peat where it grew well without the use of fertilizers or lime.
Cultivation: Rambutan is propagated by seed, grafting or stem cuttings. Seedlings become mature after 6 years; trees propagated by cuttings produce earlier, viz. after 3 to 4 years. Rambutan trees are commonly planted in a 7 x 7 m grid. Coulter (16) makes mention of trials on a small scale on forest peat in Malaysia but to the author's knowledge fertilizer recommendations are as yet not available.
The first harvest rarely exceeds 300 fruits per tree but fully mature trees of a high yielding variety can produce 5,000 to 7,000 fruits per year. Yields obtained by smallholders in Sumatra are reportedly equivalent to 6.2 to 7.7 tons of fresh fruit per hectare (46).

50. SOURSOP *Anona muricata* L. (Anonaceae)

Soursop, or "nangka belanda", is a medium-sized tree from the Antillas (50). Its fruits are eaten fresh; soursop juice is a popular beverage.
Requirements: Soursop grows vigorously on almost all well drained shallow or moderately deep lowland peat soils (13, 62). Waterlogging causes canker (50) and cannot be tolerated.
Cultivation: The trees are multiplied by seed and become productive after 4 to 5 years. Farmers in Indragiri harvest "several tens of fruits" per tree each year.
The related *A. squamosa* L. (Custard apple or "sirikaya") was seen on 2 m deep peat near Pontianak (West Kalimantan) where it grew vigorously and produced fruits within 2 years after sowing.

51. STAR FRUIT *Averrhoa spp.* (Oxalidaceae)

Star fruit, or "belimbing", is a small tree and a native of the Malesian region. Commercial plantations exist on peat in Malaysia but in Indonesia the tree is solely grown on compounds and always in small numbers. The fruits of *A. carambola* L., or "belimbing manis", are eaten fresh, those of *A. bilimbi* L. ("belimbing wuluh") are boiled and used as a vegetable.
Requirements: The trees grow vigorously on shallow and moderately deep coastal peats without the use of lime and fertilizers but produce much better fruits if manured.
Cultivation: Star fruit is multiplied by seed or stem cuttings which are planted to a density of 650 trees per hectare. Fruit flies (*Dacus sp.*) and the tedious harvest (each fruit has to be ripe) limit the success of this otherwise attractive crop.
In its first productive year a healthy tree produces some 50 kg of fresh fruits; fully mature trees produce up to 125 kg fruits per year.
Fertilizer recommendations are not available.

Vegetable crops

52. ASPARAGUS *Asparagus officinalis* L. (Liliaceae)

Asparagus is a perennial herbaceous plant. Its immature shoots are an expensive vegetable. The crop requires a light, fertile and deeply drained soil. Experiments on peat in Sarawak were not very successful (4), reportedly because of damage by pests and diseases.

53. BEANS/PULSES (Leguminosae)

Pulses make attractive crops for lowland peat areas because of their high nutritional value and their comparatively low requirements. Most species seem well adapted to the conditions prevailing in coastal swamp areas; several "wild" bean species were recorded on lowland forest peats in Sumatra. The most common species cultivated include "kacang benguk" (Velvet Bean, *Mucuna utilis* Wall), "kacang gude" (Pigeon Pea, *Cajanus cajan* Mill sp.), "kacang hijau" (Green Gram, *Vigna aureus* Hepper), "kacang kedelai" (Soybean, *Glycine max* Merr.), French Bean, (*Phaseolus vulgaris* L.), "kacang panjang", or Yardlong Bean, and "kacang tunggak" or Cow Pea (both types of *Vigna unguiculata* Walp.), "kacang pedang" (Sword Bean, *Canavalia gladiata* Jacq.), "kacang tanah" (Groundnut, *Arachis hypogaea* L.), "kara" (Bonavist Bean, *Lablab niger*), "kecipir" (Winged Bean, *Psophocarpus tetragonalobus* A.D.C.), "kacang Bogor" (Bambara groundnut, *Voandzeia subterranea* Thou) and "kratok" (Lima Bean, *Phaseolus lunatus* L.). Stands recorded in Indonesian peat areas were often poor because of pests and diseases and because of inadequate cultivation practices. Species with low requirements such as Velvet Bean and Winged Bean perform best, but such valuable species as Green Gram, Groundnut and Soybean produce often less and need inoculation with *Rhizobium* and measures to control pests and diseases. With the exception of Groundnut and Soybean - which are discussed in the section on Oil Crops - pulses on peat are almost exclusively grown for local consumption, either fresh or after being converted to tauge. Some species, e.g. Lima Bean, contain poisonous hydrocyanic compounds and can only be consumed after boiling. *Requirements:* Most species do not need a chemically rich soil but a loose and well aerated rooting zone of 40 cm or more is essential for satisfactory growth and production. A period of continuous rainfall or high temperature seems to affect the yields of at least some species because of imperfect fertilization and consequent failing pod formation.

Vegetable crops

Cultivation: Beans and peas are commonly sown with three seeds per 3 to 4 cm deep hole. Pole beans such as Velvet Bean and Winged Bean are grown in rows at 1 metre intervals and with 70 to 100 cm between plants. Dwarf beans and peas are more densely spaced, e.g. in a 50 x 50 cm grid. Most species mature in 3 to 4 months; fresh pods - e.g. of Yardlong Bean - can be harvested after some two months. In Indonesian peat areas where fertilizers are not commonly used - and also in Malaysia (34) - repeated burning of the peat is practised. Yields obtained this way are rarely high, and the second crop may be poor. Most leguminous crops need much P_2O_5 (36) and they benefit also from a dressing of 50 kg N/ha during early growth when *rhizobium*-activity is still low. The application of copper is required in places (39, 55) but in practice copper is rarely used. If properly grown and fertilized, pulses on peat perform satisfactorily. Chew and Yeong(12) report that yields of French Bean increased from 3 tons of fresh pods/ha on unlimed plots to 10 tons/ha on plots which received 18.75 tons of ground magnesium limestone per hectare, and Joseph *et al* (33) obtained as much as 11 tons of fresh French Bean per hectare (after only 80 days) and 20 tons of Yardlong Bean. Andriesse (4) reports Cow Pea yields of 5,500 kg of fresh pods per hectare, equivalent to 1,200 kg of dry seeds, on deep peat in Sarawak. Green Gram performs less well; yields on limed and fertilized deep peat in Sarawak did not exceed 600 kg/ha. Yields on moderately deep (1.0 m) peat in Indragiri Hilir, obtained without fertilizers and lime, were much lower: 1 to 2 tons of fresh Yardlong Bean per hectare, 2 to 3 tons of French Bean and 500 kilos of dry Cow Pea per hectare.

Pests and diseases are problematic in almost all peat areas. Bacterial Wilt ("penyakit layu"), pod borers, *(Maruca testulalis)*, Bean fly *(Agromyza phaseoli)* and Bean Rust *(Uromyces sp.)* are particularly harmful.

54/55. CABBAGE/CAULIFLOWER *Brassica oleracea* L. (Cruciferae)

Cabbage *(Brassica oleracea* cv *capitata)* and cauliflower *(B. oleracea* cv *botrytis)* are not yet grown on Indonesian peats but are among the most promising vegetable crops on peats in Peninsular Malaysia. Recently introduced tropical varieties such as the Japanese "KK" and "Eiyu"-cabbages and the "American tropical" cauliflower, are commercially grown on moderately deep forest peats near major population centres where horticulture benefits from a good infrastructure and a ready market.

Vegetable crops

Requirements: Both crops have shallow root systems and need a fertile, not too acid (pH 5.5) and well drained but moisture retaining soil. Plants should be protected against excessive sun or rain which damage the cauliflower curds. The crops are easily damaged by insects, and pest control is a necessary condition for success.
Cultivation: Both cabbage and cauliflower are sown on a finely grained bed and transplanted to ridges or shallow beds of burnt (or limed) and fertilized peat after some 4 weeks when the seedlings have 4 to 5 leaves. Imported seeds are recommended for good results. The crops are best planted in rows, 60 cm apart with 30 to 45 cm between the individual plants. Cabbage heads can be harvested 70 to 80 days after transplanting; cauliflower curds after 50 to 55 days because of a tendency of the flower heads to branch when left to grow longer. Covering the curds with leaves (a few weeks before harvesting) improves the colour and market value. Both crops respond well to liberal dressings (e.g. 500 kg/ha) of NPK-compounds incorporated in the soil prior to transplanting. Farmers in Malaysia add a fungicide and - sometimes - trace elements. Liming with ground magnesium limestone prevents the occurrence of "chlorotic mottle", a magnesium deficiency symptom. Dressings of 10 to 15 kg borax per hectare may be needed on boron-poor peats where cauliflower heads would otherwise rot; 1 to 2 kg sodium molybdate per hectare improved production in a number of instances. Much damage can be caused by caterpillars, particularly those of the Diamond-back moth *(Plutella maculipennis)*, a common pest to crucifers. They are effectively controlled with sprays of Malathion or a bacterial type pesticide containing *Bacillus thuringiensis*. Experimental gardens in Malaysia produced as many as 20,000 heads of cabbage per hectare, with a weight between 1.5 and 3 kg per head. Farmers on deep peat in Selangor report yields of 40 picols of cauliflower curds per acre, equivalent to some 6 tons per hectare.

56. CELERY *Apium graveolens* L. (Umbelliferae)

Adapted varieties of celery ("seledri" or "daun sop")thrive on tropical lowland peats, particularly in the first years after clearance of the forest vegetation when the soil's natural fertility is still high (56). The crop requires a rich, moisture retaining soil of moderate acidity (pH 5.0 to 6.8) and grows best on shaded beds of fertile topsoil.

Celery is multiplied by seed or by planting root cuttings on a mixture of peat and chicken manure. Copper dressings did improve the growth of celery in a number of instances. Polak (55) recommends importing seeds from temperate regions for good results. Yield data is not available.

57. CHINESE CABBAGE *Brassica chinensis* cv *pekinensis* (Cruciferae)

Suitable varieties of chinese cabbage ("petsai"), e.g. the variety "Tropicana" seen at MARDI's Peat Research Station in Kelang, Malaysia, grow vigorously under tropical peat swamp conditions. The crop was never seen in the coastal swamp areas of Indonesia but will undoubtedly be introduced in the future. Its fresh leaves are a popular vegetable and a major ingredient in many dishes.

Requirements: The crop has a shallow root system and requires a fertile and well drained surface soil. It is relatively tolerant to heavy rainfall.

Cultivation: Chinese cabbage is multiplied by seed which is best imported (31, 51). The seedlings are transplanted to shallow ridges of burnt or limed and fertilized peat after some 3 weeks, when the young plants have 3 or 4 leaves. A suitable spacing is 30 x 30 cm. A dressing of compound NPK-fertilizer followed by a top dressing of ammonium sulphate after 2 weeks ensures vigorous growth in most cases.

Chinese cabbage on limed and fertilized moderately deep peat in Malaysia could be harvested 27 days after transplanting and produced 900 to 1200 grams of marketable leaves per plant. Caterpillar damage can be prevented with sprays of Malathion or a bacterial type pesticide.

58. CHINESE SPINACH *Amaranthus hybridus* L. (Amaranthaceae)

Chinese spinach, or "bayam", is an annual herb. It can reach a height of 1 to 2 metres but is commonly harvested when 20 cm high. The leaves of the green varieties are among the most popular vegetables in lowland peat areas.

Requirements: Bayam grows vigorously on all peats, both in shade and in direct sunlight. Few crops are less demanding; it can even tolerate shallow acid groundwater.

Cultivation: Bayam is densely sown after superficial burning of the peat. The leaves are harvested after some 50 days; the plants are mature after 3 months. Fertilizers are rarely used but dressings of a compound NPK fertilizer should increase yields. Farmers on deep peat near Pontianak obtained high yields with a mixture of fish refuse and peat ash, supplemented with topdressings of urea. Reliable yield data is not easy to obtain; one literature source (46) estimates the equivalent yield at 2 tons of fresh green material per hectare, but this value seems very conservative.

59. COCOYAM *Colocasia esculenta* Schott (Araceae)

Cocoyam, or "keladi", is a perennial plant, 30 to 150 cm high, and with edible corms, stems and leaves. The latter are sometimes used as a substitute for soap (50). The crop is very common on lowland peat (14, 15, 79) especially in young reclamations where it is planted along fields and drainage ditches. "Keladi berwarna" *(Caladium bicolor)* is grown and used in a similar fashion but is less common.

Requirements: Cocoyam has moderate nutrient requirements. It prefers a well aerated soil of pH 5 or higher. Good drainage is essential.

Cultivation: The crop is multiplied by planting suckers in rows, 90 cm apart and with 30 to 45 cm between the individual plants (10, 50). The crop can be harvested after 8 to 9 months, depending on the variety grown and the application of lime and fertilizers.

In experiments on acid (pH 3.5 to 3.75) forest peat in Malaysia best results were obtained with dressings of 5 to 10 tons of ground magnesium limestone per hectare. Chew (10) recommends a basal fertilizer dressing of 50 kg N, 165 kg P_2O_5 and 135 kg K_2O per hectare, and reports yields of 2.5 (unlimed) to 8.75 tons of fresh corms per hectare. Pests ana diseases are reportedly rarely serious.

60. EGGPLANT *Solanum melongena* L. (Solanaceae)

Eggplant, or "terong" ("brinjal" in Malaysia), is one of the commonest vegetables in peat swamp areas. The varieties "bulat", with spherical fruits, and "panjang" or "panjang putih" (elongated fruits) are particularly popular but many other varieties with fruit sizes between 1½ and 20 cm are grown as well.

Requirements: Eggplant prefers a fertile,well aerated soil. It grows also on less fertile (deep) peats that are not too acid, but the fact that burning of the peat prior to planting is often necessary for reasonable growth indicates a general need for fertilizers and lime. The crop is tolerant to varying climatic conditions.

Cultivation: Eggplant is sown on seed beds and transplanted after one month to a 60 x 60 cm grid or to rows at a distance of 90 cm with 60 cm between plants. Fruits can be harvested from the 3rd till the 8th month after transplantation. Eggplant on acid peat responds well to liming and fertilization. Chew and Yeong (12) obtained the highest yields with a dressing of 12.5 tons of ground magnesium limestone per hectare. Moderate dressings of NPK and trace elements often result in doubled yields. Polak (55) mentions the beneficial effect of copper and Kanapathy (38) found dressings of copper(sulphate) and boron (borax) to be essential on Malaysian forest peats where yields were reduced to only 10 percent without these elements. Eggplant yields in Indragiri where lime and fertilizers are not commonly applied, are as low as 1.5 to 4.7 tons of fresh fruits per hectare (46). Joseph *et al* (33) report a yield of 18 tons of fresh fruits per hectare and Chew and Yeong (12) a maximum of 20 tons on limed and fertilized forest peat versus 6.0 tons/ha on untreated peat.

61. ENDIVE *Cichorium endivia* L. (Compositae)

Endive, "andewi" in Indonesia, is not popular in the peat swamps of S.E. ASIA, although it can be grown even in lowland areas (50). The reason for its little popularity might lie in the often defective seed formation of endive in the tropics, which necessitates import of seeds from temperate regions.

Requirements: Endive is a rapid grower with a small root system. It needs a loose, well drained and fertile surface soil. Acid peats must be limed to pH 4.5 or higher.

Cultivation: Endive is densely sown on a finely grained seed bed and is transplanted to a 30 x 30 cm grid after 3 weeks when the seedlings have 3 to 4 leaves. After 3 to 3½ months the plants can be harvested. If the outer leaves are tied together after 2½ months, the plant develops a white heart with tender leaves.

The crop responds well to compound NPK fertilizers and lime but experience with this crop is still fragmentary. Pests and diseases are rarely serious. Reliable yield data could not be obtained for endive on lowland peat.

Vegetable crops

62. GOURDS (Cucurbitaceae)

Cucurbits are among the crops best adapted to the hot and humid conditions prevailing in coastal peat swamps; spontaneous growth of "wild" species was often seen. As early as 1931 Cooke (14) reports that pumpkins ("labu kuning", *Cucurbita maxima* Duch.) are widely grown by Javanese settlers colonizing the fringe areas of peat domes in Malaya. Banjarese farmers grew the calcium-loving water melon ("semangka", *Colocynthis citrullus* O.Ktze) on newly reclaimed forest peat in South Kalimantan (79) but the crop is rare in other peat areas. The unripe fruits of many species, e.g. luffas ("belustru", *Luffa cylindrica* L., and "gambas", *L. acutangula* Roxb.), wax gourds ("bligo", *Benincasa cerifera* Standl.), bitter gourds ("pare pahit", *Momordica charantia* L.) and pumpkins are eaten as vegetables. The fruits of water melons, sweet melons ("belewah", *Cucumis melo* L,) and cucumbers ("ketimun", *Cucumis sativa* L.) are more commonly harvested ripe. Roasted and salted seeds of bligo are popular as "kwaci".
Requirements: Most cucurbits perform well on lowland peat provided that the water table is not too shallow. They are not very demanding, although some species prefer a higher pH and base saturation than commonly found in tropical forest peats.
Cultivation: The crop is sown *in situ* on burnt peat or on shallow beds (34). Creeping species such as pumpkin, water melon, sweet melon, wax gourd and bottle gourd are planted in a 3 x 3 m grid; cucumbers and luffas are more commonly planted in rows at a distance of 1 m and with 50 to 75 cm between plants. Climbing species such as luffa, bitter cucumber and wax gourd are grown along poles or racks.
The first fruits are commonly harvested after 2 to 4 months; fruit production may continue for 3 to 6 months depending on the species grown. Diseases are rarely serious except for a feared "leaf disease", e.g. in gambas. However, fruitflies, *(Dacus cucurbitae)*, mice and luaks *(Paradoxurus sp.)* can cause considerable damage. Cucurbits are rarely limed or fertilized but the peat is commonly burnt prior to planting. De Geus (27) recommends a basal dressing of 100 kg N./ha to cover the high need for nitrogen of most species. Experiments in Malaysia (12) resulted in doubled luffa yields (from 12.4 to 26.0 tons/ha) on fields which received the equivalent of 18.75 tons of ground magnesium limestone per hectare.

Similar high yields have been reported by Joseph *et al* (33) who obtained 15 tons of fresh luffa per hectare and 25 tons of cucumbers, and by Kanapathy (34) who mentions "high" (40 tons/ha is reportedly normal) yields of bitter gourds on burnt peat and 12 tons of water melon per hectare.
Farmers in Indonesian peat areas described the performance of cucurbits as "satisfactory" although their yields are comparatively low. Transport and marketing of the perishable fruits are often problematic and the need to increase production is not often felt.

63. JENGKOL *Pithecolobium lobatum* Benth. (Leguminosae)

Jengkol is a 10 to 20 m high leguminous tree and is common on compounds where it is grown alone or in small numbers. Its seeds are boiled and eaten as a vegetable. Too much jengkol is said to cause "jengkolan", a disorder of the kidneys.
Requirements: Jengkol has low soil requirements and grows vigorously on shallow and moderately deep lowland peat.
Cultivation: The tree is propagated by seed and produces pods after 7 to 8 years. Response to lime and fertilizers is not known; pests and diseases are reportedly rarely serious. Farmers in Indragiri, Sumatra, estimated the production of a mature tree at some 400 pods per year.

64. JUNGLE GERANIUM *Ixora coccinea* L. (Rubiaceae)

Jungle geranium, or "soka", is an ornamental shrub on compounds. Its fruits are eaten as a vegetable.
Soka has low soil requirements. It is propagated by seed and is mature after some 5 months. The yield reportedly exceeds demand.

65. KANGKUNG *Ipomoea aquatica* Poir. (Convulvulaceae)

Kangkung is a perennial creeper found in all lowland peat swamps. The young stems and leaves are popular as a vegetable and are also used as an animal feed.
Requirements: Kangkung grows vigorously on almost any peat and has very low requirements. It is tolerant to soil acidity and waterlogging - it prefers a wet environment - and is not very specific with regard to the climate.

Cultivation: Stem cuttings are planted on shallow beds or directly in the untilled soil. The crop is closed after only 2 to 3 months and can be harvested for several years but the stand is best replaced after one year (50). Lime and fertilizers are seldom used in the Indonesian peat swamps but elsewhere (42) a dressing of 150 to 200 kg ammonium sulphate per hectare gave good results. Tindall (72) recommends a compound NPK-fertilizer several days before planting supplemented with occasional N-dressings to stimulate growth. Farmers near Pontianak have good results with a mixture of peat ash and fish refuse. The crop is relatively free from pests and diseases. Yields in Indragiri are reportedly equivalent to 2.6 tons of fresh green matter per hectare-cutting (46); yields of more than 40 tons of marketable tips per hectare-year are common in Taiwan.

66. KATUK *Sauropus androgynus* Merr. (Euphorbiaceae)

Katuk is a common vegetable in peat areas where it is grown on compounds. The leaves are used in soups and are said to contain a drug which stimulates lactation. The crop has obviously low requirements as it grows well on most lowland peats without much attention. It is propagated from stem cuttings which are planted in rows along fences or on shallow ridges. The leaves can be harvested after some 3 months and can be picked for a period of almost 2 years. Data on fertilizer dressings, pests, diseases and yields are not available for katuk on peat.

67. LEAF MUSTARD CABBAGE *Brassica juncea* Czern and Coss (Cruciferae)

Leaf mustard cabbage, or "sawi", is a popular vegetable in most lowland peat areas of tropical Asia. Near Pontianak (West Kalimantan) 3 varieties are grown, viz. "sawi hijau", "s. putih" with white stems, and "s. kriting", a variety with curled leaves. The leaves are eaten fresh or boiled, or (s. hijau) are brine-treated. The pungent oil-containing seeds are used as a condiment.

Requirements: Sawi requires a fertile, well aerated soil with good water holding properties. Fertilized lowland peats are well suited for sawi growing but prolonged periods of heavy rainfall are often associated with losses because of rot to which s. kriting is particularly sensitive.

Cultivation: The crop is propagated by seed. The densely spaced seedlings are transplanted to 20 cm high beds when 20 to 25 days old. A 20 x 20 cm spacing is adequate. The leaves can be harvested some 45 to 55 days after transplanting. Chinese vegetable growers use elongated beds of some 10 x 1 m which they fertilize with a mixture of peat ash and fish refuse (2 kg/bed). Top dressings of urea (1:200 watery solution) are applied every 2 weeks. Diseases are rarely serious; caterpillars (e.g. of *Plutella maculipennis*) are a common pest. They can be controlled with sprays of Supracide AC or with a bacterial type pesticide. Farmers near Pontianak report yields of 30 kg of marketable leaves per bed (equivalent to some 15 tons/ha) with top yields close to 50 kg/bed.

68. LETTUCE *Lactuca sativa* L. (Compositae)

Lettuce, or "selada", is a common horticultural crop on peat in temperate regions. Trials on tropical peat soils in Sarawak gave disappointing results because of heavy damage by pests and diseases (4), but lettuce on moderately deep limed and fertilized peats in Peninsular Malaysia grows very well although it forms no head. It is now referred to as a local variety.

Requirements: Lettuce grows best in fertile (burnt) peat. It needs adequate manuring and watering. Quick bolting is a problem in the hot lowland peat swamps.

Cultivation: Lettuce is sown on beds and transplanted to a 30 x 30 cm grid after 3 to 4 weeks. It can be harvested after 2 to 4 months (27, 50). The crop responds well to nitrogen and potassium; a pre-planting application of 300 kg 15-15-15 compound NPK fertilizer per hectare, followed after 2 weeks by an additional 100 kg of ammonium sulphate is recommended. Dressings of copper and molybdenum improved growth on some very exhausted peats. Liming is needed in almost all cases. Early sprays of a fungicide are recommended to control "damping off". Reliable yield data for lettuce on lowland peats could not be obtained.

69. BLACK NIGHTSHADE *Solanum nigrum* L. (Solanaceae)

Black nightshade, or "ranti", is a strongly branched annual herb of 10 to 150 cm height. It occurs wild all over the region and has been long known

as a vegetable (leaves, young stems and fruits with rice and in soups and stews). It became very popular in Malaysia where it is now grown commercially on moderately deep forest peats.
Requirements: The crop has low nutrient requirements but growth is particularly vigorous if the peat is limed and fertilized with a compound NPK-fertilizer. Direct sunlight or light shade are preferred. A well aerated surface soil is essential.
Cultivation: Black nightshade is multiplied by seed. The seedlings are transplanted to a 30 x 30 cm grid on shallow beds of burnt peat. The plants can be cut after 5 to 6 weeks; ratoon cropping is possible with heavy fertilization. Pests and diseases are rare. The promotion of this crop in Indonesian peat areas would add a valuable vegetable to the diet of the inhabitants of remote swamp areas where vegetables are often scarce.

70. OKRA *Hibiscus esculentus* L. (Malvaceae)

Okra, or "kopi arab", is an annual herb, 1½ to 2 m high and indigenous to central Africa. It became a popular vegetable throughout the tropics but is almost unknown in Indonesia (50). The pods are edible and used in soups and stews. The roasted seeds can reportedly be used as a substitute for coffee.
Requirements: Okra has low chemical soil requirements but needs a deeply drained soil. Experiments in Malaysia made clear that okra grows vigorously on moderately acid tropical lowland peat. A well decomposed (fine grained) seed bed is recommended.
Cultivation: Okra is sown directly in the field, commonly with 3 or 4 seeds in 3 cm deep holes and in a 50 x 50 cm grid. The seedlings cannot be transplanted without considerable damage. Although there are short season and long season varieties, most okras are mature after 8 to 10 weeks. Fertilizer requirements are low but insufficient levels of boron and copper proved lethal to okra on deep oligotrophic peats in Malaysia. Kanapathy (34, 38) recommends a basal dressing of 30 kg copper sulphate per hectare, later supplemented with a similar dressing where needed. When satisfactory, soil copper contents are maintained at a sufficiently high level by booster applications at a rate of 10 kg/ha-5 yrs. Borers can be harmful; they are best controlled by spraying a 0.05% solution of Endosulfan. Nematodes *(Meloidogyne sp.)* become a problem if the crop is

repeatedly grown on one field. Joseph *et al* (33) report a yield of 15 tons of fresh fruits per hectare using a local Malaysian variety on moderately deep forest peat.

71. ONIONS *Allium spp.* (Liliaceae)

Onions, or "bawang", are not very common on tropical lowland peat soils but can be grown with success if properly cultivated. Shallot ("bawang merah", *A. cepa* var *aggregatum*), "bawang daun" (*A. fistulosum* L.) and "kucai" (*A. ampeloprasum* L.) give good results, particularly so on burnt newly cleared forest peats.
Requirements: Both onions and leeks require a loose, well drained and fertile soil with a pH between 4.5 and 7.0. Burning or liming of the peat is a condition for good growth. Shallow groundwater can not be tolerated.
Cultivation: Onions are multiplied by seed bulbs which are preferred over seeds because the latter loose their viability after only a short time. Bawang daun forms no bulbs. The young seedlings are transplanted to rows, 25 cm apart and with 10 to 15 cm between the individual plants, or to a 20 x 20 cm grid. Weeds will overgrow the crop unless rigidly controlled. Weeding is best done by hand; a pre-emergence application of 50 kg calcium cyanamide per hectare is reportedly effective on mineral soils but burnt peats should not need this precaution. Manure or - as seen near Pontianak- a mixture of peat ash and fish refuse will provide good results. High nitrogen dressings stimulate leaf growth at lower bulb weights and might be uneconomic. Copper improves the storage of bulbs (55). Leaf blotches (purple blotch, caused by *Alternaria porri* Cif) were frequently seen, particularly so on peats that had not been burnt. Most onions can be harvested after some 3 months. Reliable yield data could not be obtained. Farmers in Sumatra report "fair" yields. Onions were very productive in West Kalimantan but failed in Sarawak because of rot, wilt and fungi.

72. PAKU *Pleopeltis longistema* Moore (Polypodiaceae)

Paku is a fern, abundantly present in coastal peat swamps. Its newly unfurled leaves have a reddish-yellow colour and are an important vegetable in remote settlements. According to Ochse (50), young leaves of the equally common tree-fern *Stenochlaena palustris* Bedd. are also edible.

Vegetable crops

73. CHILLI PEPPER *Capsicum frutescens* L. (Solanaceae)

Chilli pepper, or "cabe rawit", is a perennial herb from tropical America. It became a popular vegetable throughout the tropics. The small red, yellow, or white fruits are high in vitamin C. Their pungency is caused by "capsicin".

Requirements: Chilli pepper has low nutrient requirements. It was seen on 6 m deep formations of acid forest peat in Kalimantan, where few other crops would grow. The crop is acidity-tolerant but needs a well aerated root zone. Heavy rainfall is associated with poor yields.

Cultivation: Chilli pepper is sown on beds of repeatedly burnt peat and is transplanted after 4 to 5 weeks to a 75 x 75 cm grid. The crop is mature after 3 to 4 months and can be harvested at intervals of 10 to 14 days for a period of approximately one year. De Geus (27) recommends NPK-dressings of 60 to 200 kg N, 40 to 100 kg P_2O_5, and 80 to 120 kg K_2O per hectare for chillies on mineral soils. On moderately deep forest peat in Malaysia repeated burning of the surface soil was sufficient for good results (34) but a second crop yield is much lower because of chemical exhaustion of the root zone and increased damage by *Colletopsichum capsici*, mozaic virus and white mites (4, 33).

Dressings of 30 kg copper sulphate and 1 kg borax per hectare were beneficial on a number of deep peats (38, 55). Liming with 1.65 tons of hydrated lime per hectare did promote healthy growth (12) but did not improve yields. However, liming might help to combat "blossom end rot", a common disorder of peppers on calcium-deficient soils.

The yield data obtained are highly variable. A Malaysian variety produced as much as 10 tons of fresh chillies/ha on fertilized, moderately deep forest peat in Selangor (13, 33) but subsequent crops are commonly less productive with 3.2 to 6.4 tons of fresh fruits per hectare. Farmers in Indonesia estimate the average yield on burnt, non-fertilized deep peat at 800 to 1000 kg of fresh chillies per hectare (46), but chillies on burnt and fertilized peat near Pontianak were certainly much more productive.

74. SWEET PEPPER *Capsicum annuum* L. (Solanaceae)

Sweet pepper, or "cabe minang", is an annual herb from tropical America and a popular vegetable in S.E. Asian peat areas.

Requirements: Sweet pepper has low chemical requirements and grows on almost any peat soil provided that the surface layer is loose and well aerated. Waterlogging causes root rot and the shedding of leaves and fruits, and thus should be avoided. Too heavy rainfall can cause fruit rot.
Cultivation: Sweet pepper is sown on beds. The seedlings are transplanted after one month to a spacing of 50 x 50 cm. Where the water table is shallow, the plants are best grown on beds or ridges. The fruits are harvested from the 4th till the 12th month. Experiments in Malaysia resulted in a yield of 2.6 tons of fresh fruits per hectare (13, 33); transmigrants in Sumatra report a maximum of 2 tons per hectare, but the average yield is probably much lower. Excessive fruit dropping is a common disorder.

75. PETAI *Parkia speciosa* Hort. (Leguminosae)

Petai is a tall leguminous tree reaching a height of 25 m. The boiled seeds are an ingredient of many vegetable dishes. Petai is found on compounds on shallow or moderately deep peat.
Requirements: The crop prefers a permeable and well drained soil (50) but vigorous growth was also recorded on moderately deep acid forest peat with groundwater at 40 cm below soil surface. The warm and humid climate of Malesian coastal peat swamps is apparently well suited for the cultivation of petai.
Cultivation: Petai is propagated by seed and becomes productive after 5 to 8 years. Response to lime or fertilizers is not known. Pests and diseases are reportedly never serious. Transmigrants in Sumatra claim "fair" yields but accurate data could not be obtained.

76. RADISH *Raphanus sativus* L. (Cruciferae)

Radish, or "lobak", is grown for its edible roots and leaves. The crop performs best at some altitude but can also be grown in lowland areas. It is not rare in market gardens on lowland peat but was never seen in transmigration areas. "Chinese radish" (*R. sativus* cv *longipinnatus*) with tubers of up to 25 cm length and a diameter of 5 to 6 cm, is a popular and very productive variety in the peat swamps of Malaysia and West Kalimantan.
Requirements: Radish requires a light, well aerated and moisture retaining soil. It needs fertilizers and lime for good growth; animal manure gives

good results but dressings of a compound NPK fertilizer, followed by top-dressings of nitrogen are also adequate.
Cultivation: Radish is sown in rows, 30 cm apart with 5 to 20 cm between plants, depending on the variety grown. The crop is mature after 4 to 5 weeks. Seeds can be produced in the tropics but Ochse (50) recommends to import seeds from temperate regions for maximum viability.
Flea beetles (*Phyllotreta sp.*) can be harmful, especially during early growth of the crop, but they are easily controlled with Deodrex or Malathion. Joseph *et al* (33) report successful trials in which a Malaysian variety produced 20 tons of fresh roots per hectare on NPK-fertilized, moderately deep, limed forest peat.

77. TANNIA *Xanthosoma sagittifolium* Schott (Araceae)

Tannia, or "bentul", is grown for its "cormels" and for its stems and leaves. The main corm is commonly discarded. The plants are grown in small numbers on compounds and along fields.
Requirements: Bentul is not very demanding and grows on most moderately deep and well drained peat soils, preferably in direct sunlight or light shade.
Cultivation: Tannia is multiplied by planting 10 cm long stem divisions, either in rows or in a 2 x 1 m grid. The crop can be harvested after 5 to 6 months but is commonly left to grow for 9 to 10 months. Wild pigs dig for the tubers and are a pest in many peat areas. Farmers described the performance of tannia as "satisfactory"; yields are probably in the order of 15 tons of fresh corms per hectare-crop.

78. TOMATO *Lycopersicon esculentum* Mill. (Solanaceae)

Tomato, or "tomat" is grown on coastal lowland peat but the results are not impressive. Better varieties and management practices would result in much higher yields but transport of the perishable fruits is often a problem and unless the crop is grown for canning or for the production of juice, ketchup or sauce (16) the market is limited.
Requirements: Tomato needs a fertile and deeply drained (75 cm) soil, slightly acid to neutral in reaction. The crop can be grown at low altitudes

but performs better in a cooler climate. Burning of the peat is beneficial (38) but the use of fertilizers is essential for sustained high yields.
Cultivation: Tomato is sown on a seedbed and transplanted after 4 to 6 weeks to a shallow bed of thoroughly burnt (38) peat, e.g. in a 40 x 50 cm grid. Varieties taller than 40 cm are best planted along stakes. The crop bears fruit after 3 to 4 months. Picking continues for 12 to 14 weeks (27) but in transmigration areas of peat in Sumatra the plants were allowed to produce (few) fruits for a period of 6 months or more. Monthly pruning (nipping off excess buds) is recommended. Tomato needs considerable quantities of NPK and does not prosper when deficient in boron (33, 38) or copper (34, 55). Calcium deficiency leads to "blossom end rot", and the beneficial effects of 1 to 4 tons of hydrated lime per hectare (12, 27, 68) might partly be caused by increased levels of calcium in the surface soil. De Geus (27) estimates the fertilizer requirements of tomato at 320 kg N, 60 kg P_2O_5 and 440 kg K_2O/per 60 tons of fresh fruits. Such high yields were never seen in transmigration projects on Indonesian lowland peat where tomato is grown in an extensive way. It is recommended to supply copper sulphate (e.g. 15 kg/ha) and borax (5 kg/ha) to tomatoes on oligotrophic peat and to lime soils with a pH of less than 4.5 as a precaution against "slime disease" (23). Trials with tomato in Sarawak (4) incurred serious damage by pests and diseases.
Bacterial Wilt (*Pseudomonas solanacearum* E.F.Sm.) used to be curbed by grafting tomato on eggplant, but recently developed resistant tomato lines eliminate this laborious practice. Tomato stands in glasshouses on peat in the Netherlands produced an average 12.5 kg of fresh fruits per m^2 in 1974 (29) which corresponds with an average net yield of some 80 tons of fresh fruits per hectare. Top yields obtained in Florida are close to 100 tons of fresh fruits per hectare. Farmers in Indragiri to whom tomato is a relatively unimportant crop, estimate the yields obtained on non-fertilized burnt peat at some 500 gr/plant. Tomato growers in Malaysia report average yields of 7 to 12 tons of fresh fruits per hectare on burnt and fertilized lowland peat.

Stimulants

79. ARECA "NUT" *Areca catechu* L. (Palmae)

Areca, or "pinang", grows well on tropical forest peat (14). The palms are grown in small numbers near homesteads to cover the farmer's need for betel nuts. Betel chewing is believed to prevent tooth decay.
Requirements: Soil conditions in areas with drained and settled forest peats seem to suit areca well but little is known about the crop's specific requirements. Nutrient deficiencies were never apparent and pests and diseases seem rare. Although top-heavy the trees rarely lean.
Cultivation: Areca is propagated by seed. De Geus (27) reports that the crop is common on mineral soils in India where dense stands of 2,000 trees per hectare occur. Under those conditions the annual nutrient removal is estimated at 65 to 90 kg N, 20 to 35 kg P_2O_5, and 65 to 90 kg K_2O per hectare. The fertilizer dressings recommended amount to approximately twice these quantities, preferably administered in split applications. Areca in peat areas depends on decomposing organic matter for its nutrient supply. The first harvest can be expected after 5 to 7 years. The cultivation of areca on peat is rather limited; accurate yield data could not be obtained.

80. BETEL PEPPER *Piper betle* L. (Piperaceae)

Betel pepper, or "sirih", is a climbing herb, indigenous to the Malesian region. Its pungent leaves contain essential oils and are chewed together with areca nut *(Areca catechu)*, lime and (sometimes) tobacco and spices. Sirih is not uncommon on compounds where it is grown in small numbers for the farmer's own use.
Requirements: The crop requires a permeable and fertile soil with good drainage. It grows vigorously on most shallow and moderately deep peats both in direct sunlight and in light shade.
Cultivation: Betel pepper is propagated by 40 to 50 cm long apical stem cuttings which need to be supported by sticks or trees. The crop is grown in a 1 x 1½ m grid or, more commonly, without any particular spacing. Leaves from young vines can be picked after 12 to 18 months, preferably during the early morning hours. The plants are reportedly productive for more than 10 years.
Sirih on peat is rarely fertilized but since it is commonly planted near homesteads most planting sites will probably have an above average fertility

status. Liming does not appear to be required. Pests and diseases are rare or absent. Yield data could not be obtained for sirih on peat.

81. COFFEE *Coffea spp.* (Rubiaceae)

Coffee, or "kopi", is grown in almost all peat areas. "Liberica" (*C. liberica* Bull.) and "Robusta" (*C. canephora* Pierre) trees grow vigorously on most shallow peats but healthy and highly productive 10 year-old coffee trees were also seen on moderately deep low fertility peats. Liberica coffee has a stronger flavour than robusta. It is not grown in Indonesian peat areas but the crop is popular in Malaysia/Sarawak.
Requirements: Robusta and liberica are well adapted to the high temperatures and humidity of lowland peat swamps. Coffee prefers a deeply drained soil but the plants develop a horizontal root system on shallowly drained peats (56, 66) provided that the surface soil is friable and well aerated. The optimum soil reaction is near pH 5.5 but coffee could still survive on very acid topogenous peat in East Java (56). There are reports, however, of attempts to improve the drainage of shallow coastal peats - over vast areas underlain by pyritic marine clays - after some years of peat decomposition and subsidence, which caused considerable damage to the crop because of increased soil acidity and sulphide accumulation. High producing varieties are demanding with regard to the chemical fertility of the soil but some can apparently still grow and produce satisfactorily on less fertile peats.
Cultivation: Coffee seedlings are transplanted to a 3 x 3 m grid when 30 to 50 cm high. Plant densities of 1,000 to 1,500 trees per hectare are common. The trees come into bearing after 3 to 4 years. Coffee trees in older reclamations are often grown under *Leucaena glauca* or *Cocos nucifera* but in young reclamations coffee was seen to produce satisfactorily in full sunlight. The beneficial effects of shade trees seem less than obvious. On chemically poor peats shade trees compete with the coffee by taking up precious nutrients but on shallow peat they might root in the underlying clay and actually enrich the surface peat. Their main effect might be that they protect the surface soil from direct solar radiation and therewith reduce peat decomposition and increase the lifespan of the coffee garden. Coffee on peat flowers earlier than trees on mineral soil (66), possibly because soluble humic substances include compounds which are chemically

related with auxin-type phytohormones. The fertilizer requirements of coffee depend on the species grown. The nutrient removal per 1000 kg dry beans is estimated at 35 kg N, 7 kg P_2O_5 and 50 kg K_2O (27). Nitrogen and phosphorus are important for the vegetative development of the tree, potassium in particular is needed during the generative phase. Quarterly dressings of 6 to 10 g N and 18 to 25 g K_2O per tree, supplemented once a year with 18 g P_2O_5, are adequate in most cases.
Trace elements are needed as well, and copper in particular (4, 34, 40). Farmers in Sumatra increase the yield of berries by pouring 200 ml of a 1:100 copper sulphate-solution on the soil in a ring around the tree. Foliar sprays of a Bordeaux mixture are also effective. Chlorosis of the leaves is widespread; it can be caused by low levels of available magnesium, boron, zinc, manganese or iron,often associated with inadequate drainage. Liming improved yields on peat in Sarawak (4) but is not always economic. Rust can be a problem but it never causes complete defoliation. Pruning is important because bearing is largely confined to the young wood. After picking,the berries are sun-dried for 1 to 2 weeks and hulled. The first few yields of coffee on peat are often very promising but the size of the berries is likely to decrease after only a few years because of chemical exhaustion of the soil. Robusta yields on peat are typically between 500 and 1000 kg dry berries per hectare but considerably higher yields have been obtained on limed and fertilized peat. Liberica does particularly well on peat; yields of 6500 kg berries per hectare, equivalent to 600 kg dry beans, are not uncommon.

82. TEA *Camellia sinensis* O.K. (Theaceae)

Tea, or "teh", is very rare in Indonesian peat areas, but the crop was tested on forest peat in Malaysia (13). Experiments on shallow peat near Pontianak are soon to be started. Tea can grow and is productive on well drained moderately deep lowland peat soils, but it is considered inferior to highland tea and the prospects for tea on peat are not favourable.

83. TOBACCO *Nicotiana tabacum* L. (Solanaceae)

Tobacco, or "tembakau", is a long standing crop on peat soils where it is grown with varying success. Van Heurn (30) reports that tobacco on shallow peats along Sumatra's east coast produced poorly and he considers peat a less suitable growing medium for the crop. Wichmann (76) however, states that at the beginning of this century "many peats were transformed to tobacco fields" and today "tembakau jawa" (Kentucky) is grown by transmigrants in Sumatra where the crop performs well on shallow and moderately deep peat soils. Andriesse (4) reports satisfactory yields of Virginia tobacco on peats in Malaysia; the good results are attributed to the use of fertilizers and to the low availability of nitrogen contained in the peat (33). Mohr (49) mentions peak yields on newly reclaimed lowland peats but considers such soils less suitable for tobacco growing because of the danger of "slime disease" in wet periods and of stunted growth during dry spells.

Requirements: The general impression is that tobacco can be grown on burnt shallow or moderately deep coastal peats if the soils are well drained. "Wet feet" are disastrous (27). The optimal soil pH lies near 5.5.

Cultivation: Tobacco is sown on a fine tilthed seed bed and transplanted after 6 to 8 weeks. Farmers in Indragiri suggested a 0.6 x 1 m spacing; tobacco seen on compounds was nearly always grown in rows along drainage ditches or fences. The crop can be harvested after 6 to 8 months. Continuous cropping might increase the incidence of pests and diseases (33) and the second crop is nearly always less productive than the first. Tobacco is nitrogen-sensitive, but requires high quantities of potassium. Ferwerda (25) estimates the removal of potassium at 120 kg K_2O per ton of dry leaves and the removal of P_2O_5 at some 14 kg/ton. Edelman (23) recommends fertilization with 2 to 3 grams ammonium sulphate, 5 to 6 grams double superphosphate and 2 grams potassium sulphate per plant for tobacco on fertile volcanic soil in Deli. At a plant density of 5,500 to 7,500 plants per hectare this corresponds with 2.3 to 4.7 kg N, 9.9 to 16.2 kg P_2O_5, and 5.5 to 7.5 kg K_2O per hectare. On peat soils much higher dressings will be required, e.g. 30 kg N (27), 30 kg P_2O_5 and 70 to 100 kg K_2O per hectare, but reliable recommendations are not yet available.
A dressing of magnesium sulphate might improve the quality of the tobacco leaves (white ash) and a dressing of 5 kg borax/ha may be needed to prevent distortion of the buds ("top disease") on low-boron peats. The use of muriate should be avoided because chloride lowers the quality of the leaves.

Heavy damage can be caused by nematodes ("root knot"), bacterial wilt and insects ("hama ulat"). Tobacco should not be grown in rotation with tomato in order to reduce the incidence of mozaic virus (23). On newly cleared peats, yields are often very high (49) but they decrease sharply in the following years. Yields obtained with Virginia tobacco on shallow forest peat in Malaysia were in the order of 1 ton of flue cured leaves per hectare (4, 33).

Spices and flavours

84. BASIL *Ocimum canum* Sims. (Labiatae)

Basil, or "kemangi", is a strongly branched annual herb, 25 to 100 cm high. It appears on compounds, always in small numbers. The aromatic leaves contain essential oils and are used in a powdered form as a condiment.
Requirements: Basil has clearly low requirements; it was actually seen in areas of deep peat.
Cultivation: Basil is propagated by seed and is mature after 12 weeks but the leaves can be harvested from 2 months after transplanting onwards. The crop is usually grown in ratoon. Response to lime or fertilizers is not known. Pests and diseases are reportedly never serious.

85. CINNAMON *Cinnamomum spp.* (Lauraceae)

Cinnamon, or "kayu manis", is a medium-sized tree. Its bark contains cinnamonaldehyde and is used as a spice or condiment. Bark oil and leaf oil, obtained through a distillation process, possess the same flavour. The tree is rare on peat but a number of 10 year-old trees on shallow forest peat in Malaysia (MARDI station) were perfectly healthy and grew vigorously.
Requirements: Cinnamon can be grown successfully on lowland peats but the soil must be well drained and not excessively acid. Waterlogging is reportedly associated with root canker and should be avoided. The crop seems satisfied with a moderately fertile soil and performs best in light shade.
Cultivation: Cinnamon is propagated by seed. In order to produce long straight shoots, the seedlings are best transplanted in clumps, 2 to 3 metres apart. If spaced at 5 x 5 metres, as at Mardi's Jalan Kebun Station, the trees produce few straight shoots. The shoots can be cut after 2 to 3 years when they have a length of 150 to 250 cm. The bark is peeled off and left to ferment after which the outer skin is scraped off. Fertilizer requirements for cinnamon on peat are not known but moderate liming and fertilization seem adequate. Pests and diseases are reportedly rare or absent. Yield data are not available.
Experiments with *C. zeylanicum* Breyn. and *C. burmanii* Bl. on moderately deep and/or mesotrophic peats seem worthwhile because the product can be easily harvested, stored and transported which is an advantage in remote swamp areas.

Spices and flavours

86. CLOVE *Eugenia caryophyllus* Bullock and Harrison (Myrtaceae)

Cloves, or "cengkeh", are the dried flower buds of a medium-sized tree from the Moluccas. Clove trees are now grown throughout the Malesian region but are rare in coastal peat areas. Cloves are an important spice and an ingredient of "kretek" cigarettes; clove oil is used in cosmetics and as a flavouring.
Experiments on *shallow* peat in Teluk Kiambang, Riau, looked very promising but trees on well drained deep peat died after a few years of good growth. Clove seeds are sown in a nursery; the seedlings are transplanted to a 6 x 6 m grid after some 15 months. The trees come into production after 6 years. Response to lime and fertilizers or accurate yield data is not known for clove trees on peat; further experiments are needed.

87. GINGER *Zingiber officinale* Rosc. (Zingiberaceae)

Ginger, or "ja(h)e", is a common crop on compounds. The rhizomes are used as a seasoning in many dishes and for making drinks, medicine, ginger bread, etc. Ochse (50) states that ginger can be preserved by soaking the fresh rhizomes in limey water for 24 hours after which they are boiled three times in fresh water and once in a concentrated sugar solution.
Requirements: Zingiberaceae are well represented in the natural vegetation of the peat swamps. Common ginger is unknown in a wild state. It grows best in direct sunlight. The soft nature of the peat favours rhizome development (44) but the soil should be drained to a depth of 50 cm or deeper to avoid rhizome rot. Transmigrants in Sumatra and Kalimantan plant ginger along shallow ditches to ensure proper drainage. Ginger prefers a fertile soil (50) but can still grow and produce on moderately fertile peat, preferably after burning. Acidity of the soil - if not too extreme - is tolerated.
Cultivation: Ginger is propagated by planting rhizomes or divisions of rhizomes on 15 cm high ridges at a rate of 30,000 plants per hectare (44). Farmers in Sumatra and Kalimantan plant ginger *in situ* in the burnt topsoil and use a 50 x 50 cm or 75 x 75 cm grid. Denser spacings, e.g. 30 x 20 cm, are probably better. The rhizomes can be lifted after 5 to 10 months; ginger on mineral soils is harvested after only 5 months (50). Liming is not essential; Chew and Yeong (12) found that yields did not increase with 3.75 tons of hydrated lime per hectare. Potassium is important for rhizome

formation and potassium requirements of ginger are high. Andriesse (4) states that 390 kilos of K_2O per hectare increased yields whereas N dressings of more than 40 kg N per hectare had no effect. Leaf spot *(Colletotrichum zingiberis)* and bacterial wilt *(Pseudomonas solanacearum)* are sometimes problematic. Rhizome rot (by *Pythium spp.*) can be serious (10 to 25 percent of all rhizomes affected) if the growing medium is too wet but the problem is said to be less on burnt peats. Yields on burnt peat are in the order of 5 to 8 tons of fresh rhizomes per hectare; fertilized moderately deep peats produced 15 to 25 tons of green ginger per hectare (27, 33, 68). Top yields obtained in experiments on shallow peat in Sarawak were as high as 34 tons of fresh rhizomes per hectare after 7 months (4).

88. KENCUR *Kaemferia galanga* L. (Zingiberaceae)

Kencur is a low perennial herb. It is used to add relish to certain dishes or as a tonic ("beras kencur"). It is commonly planted in small numbers. Kencur is said to exhaust the soil (50) but it grows well on most (burnt) peats provided that the water table is within 40 to 60 cm of the surface of the soil. Rhizomes or divisions of rhizomes are planted in a 20 x 30 cm to 40 x 40 cm grid on shallow beds or directly in the burnt topsoil. The crop can be harvested after 6 months.
Diseases are rare but insect damage to the leaves and rhizomes was frequently recorded. Response to lime and fertilizers is not known. Reliable yield data could not be obtained.

89. LAOS *Alpinia galanga* SW. (Zingiberaceae)

Laos, or "lengkuas", is a perennial herb with branched rhizomes which are used in condiments and medicine. Young shoots and flower buds can be eaten as a vegetable. Laos is very common in transmigration areas in the peat swamps of Sumatra and Kalimantan.
Requirements: Laos requires a moist but well aerated soil and thrives on shallow and moderately deep peats, both in the shade and in full sunlight. Transmigrants plant laos along shallow drainage ditches to prevent rhizome rot.

Cultivation: Rhizomes are planted on shallow beds or directly in the burnt peat, in rows or in a 1 x 0.5 m grid. The crop can be harvested after 3 to 4 months but longer growing periods (up to 3 years) are not uncommon. Pests and diseases are rarely serious; fertilizers are not used. The yields were generally described as "satisfactory".

90. LEMON GRASS *Cymbopogon citratus* Stapf. (Gramineae)

Lemon grass, or "serai", is grown in all coastal peat swamps but almost always on a small scale. The grass contains a volatile oil that can be extracted by steam distillation. More commonly the leaves are used for flavouring cakes and dishes.

Requirements: Lemon grass has low nutrient requirements (50); it was even seen on oligotrophic deep peat albeit with clear symptoms of potassium and phosphorus deficiency. It prefers direct sunlight. The crop is apparently acidity-tolerant and survives on leached and temporarily waterlogged peats on which little else will grow.

Cultivation: Small tussocks of lemon grass are planted in rows at a distance of approximately one metre. Cutting starts after 4 to 8 months and can be continued for several years. Andriesse (4) mentions experiments in Sarawak which confirm the crop's need for potassium: a dressing of 160 kg K_2O per hectare increased yields. Nitrogen and phosphorus dressings exceeding 60 kg N and 40 kg P_2O_5 per hectare had no effect. Chlorosis of the leaves is effectively cured with sprays of a ferro-sulphate solution. Nematodes may pose problems. One experiment in Sarawak resulted in 42 tons of fresh grass per hectare with an oil content of 0.52 percent, another experiment gave 31 tons/ha with 0.62% oil. The highest oil production was obtained by cutting every two months (4).

91. MARIGOLD *Tagetes erecta* L. (Compositae)

Marigold, or "kenikir", is a fine-leaved composite, 100 to 200 cm in height. It is grown in small numbers; its leaves are used as a condiment. The plant has obviously low soil requirements; it grows even on deep peats. Kenikir is sown directly in the burnt surface soil and can be harvested from 2 months onward. Response to lime and fertilizers is not known; pests and diseases are rare. The crop is said to be useful in the control of nematodes as exudes from its roots seem to bring the nematode population down.

92. MINT *Mentha spp.* (Labiatae)

Mentha javanica Bl. is mainly grown on mineral soils but to a small extent also on peat (in Malaysia). *M. piperata* (peppermint) and *M. spicata* (spearmint) are reportedly grown with good results on (calcareous) peats in Florida (55). The leaves contain essential oil which is used as a flavour in the food industry; they are also used to give relish to certain dishes and are effective in controlling *Sitophyllus oryzae* in stored grain (27). *M. javanica* performs best at altitudes between 150 and 1200 m above sea level (50). Mint is propagated by means of stem cuttings. Data on fertilizer requirements and yields is not available. Mint at Stapok Deep Peat Research Station in Sarawak declined after some time despite the use of fertilizers. Beds are best replanted after 2 to 3 years.

93. NUTMEG *Myristica fragrans* Houtt. (Myristicaceae)

Nutmeg, or "pala", is a 15 m high tree found in the Moluccas. The seed and dried arel are valuable spices. Although several *Myristica* species occur in the natural peat swamp forests of Sumatra and Kalimantan (2), *M. fragrans* is not grown on peat. The crop was seen only once in a trial on shallow peat near Teluk Kiambang, Riau.
Nutmeg needs a loose, well aerated and fertile soil. It grows and produces optimally in lowland areas with an even rainfall distribution. Seedlings are transplanted to an 8 x 8 m grid when 2 months old and start to produce (on mineral soils) after 7 or 8 years. Nutmeg on peat showed excellent growth during the first two years; the trials are being continued.

94. PEPPER *Piper nigrum* L. (Piperaceae)

Pepper, or "merica", is a climbing perennial herb. It occurs on peat in Malaysia (40) and was also seen in Sumatra where it grew vigorously on shallow peat over pyritic marine clay. The seeds/fruits are among the commonest condiments; their pungency is due to the resin chavicine. The fruits contain 5 to 8 percent of the alkaloid piperine.

Requirements: Pepper has predominantly a shallow root system and is very demanding with regard to the physical and chemical conditions of the surface soil. The latter should be friable and well aerated, rich in nutrients and not too acid (27, 50). Stagnant water is a known cause of foot rot (31). From the climatic point of view coastal swamp lands, with their evenly distributed rainfall of 2000 to 2500 mm/year, are well suited for the cultivation of pepper.

Cultivation: Pepper is propagated by cuttings. In Sumatra, 3 top cuttings are planted per hole in a 2 x 2 m grid; stakes (or suitable trees) are needed to support the vines which become productive after 2 or 3 years. The success of pepper cultivation on mineral soils depends largely on the supply of manure which cannot be replaced entirely by inorganic fertilizers. The situation is different on peat. De Geus (27) quotes De Waart, who made a thorough study of pepper cultivation in S.E. Asia, and estimates the annual nutrient removal by 1725 vines of the "Kuching"-variety at 250 kg N, 31 kg P_2O_5, 225 kg K_2O, 67 kg CaO and 22 kg MgO per hectare. Farmers on (shallow) peat in Indragiri, Sumatra, report a marked response to dressings of nitrogen (ammonium sulphate) mixed with peat ash. The ash might satisfy the crop's high need for potassium and offset the acid reaction of ammonium sulphate. Shallow peat soils over pyritic marine sediments should be carefully managed, as high contents of aluminium (and magnesium) in the root zone are toxic to pepper (40). Pepper gardens on deep peat in Sarawak suffered from yellowing and leaf dropping; nematodes are a possible cause. De Waart reports that pepper in Sarawak produced some 1.5 kg of *black* pepper per vine which corresponds with a yield of 3750 kg/ha. Kanapathy *et al* (40) consider a yield of less than 1.8 kg of *white* pepper to be low; high yielding plants on peat produce 3 kg/vine or more. These reports and the excellent growth of pepper recorded on shallow peat in Sumatra make a study of the possibilities of pepper cultivation on peat soils recommendable.

95. TEMU LAWAK *Curcuma xanthorrhiza* Roxb. (Zingiberaceae)

Temu lawak is a perennial herb which can reach a height of 2 metres. Its rhizomes have a pungent smell and a bitter taste and are used in home-made medicine and in drinks.

Requirements: The crop needs a loose, well drained and fertile soil and performs best in full sun.
Cultivation: Temu lawak is multiplied by planting rhizomes or divisions thereof on beds or along fences and drainage ditches. The rhizomes can be harvested after 9 months. The crop is of secondary importance. Specific information on fertilizer response, pests, diseases or yields could not be obtained.

96. TURMERIC *Curcuma domestica* Val. (Zingiberaceae)

Turmeric, or "kunyit", is a perennial herb. Its powdered bright yellow rhizomes are used as a dyestuff or as a condiment, especially in curry powder. Turmeric is common on compounds where it is grown in small numbers for the farmer's own use.
Requirements: The crop has low chemical requirements and grows well on burnt (non-fertilized) shallow and moderately deep peats. It requires a loose and well drained soil; the watertable should preferably be deeper than 50 cm.
Cultivation: Turmeric is propagated by planting rhizomes or divisions of rhizomes in 10 cm deep planting holes, either directly in the burnt surface peat or on 20 cm high beds, and commonly in a 30 x 100 cm pattern. The rhizomes can be harvested after 4 to 9 months. Yields obtained on peat, in Sumatra, were described as "satisfactory" but would probably be considerably higher if fertilizers were used. On fertile, well drained peats a yield of 15 tons of fresh rhizomes may be expected.

Dyes and tans

97. ANNATTO *Bixa orellana* L. (Bixaceae)

Annatto, or "kasumba keling", is a shrub from tropical America. It attains a height of up to 10 metres but is typically between 2 and 5 metres high with a diameter not exceeding 30 cm. Its seeds contain a reddish pigment, "bixin", (52) which was already known in Europe (for colouring butter) more than a century ago. At present it is used in cosmetics, medicine and foodstuffs (21). Bixin is bleached by direct sunlight and can be removed with alcohol.

Requirements: Annatto thrives in areas less than 2,000 m above sea level. It requires a well drained soil with a steady moisture regime but it is not very demanding with regard to soil fertility. The crop performs best in direct sunlight. Annatto in Malaysia appears very promising, even on deep peat, but the crop is not grown in Indonesian peat areas.

Cultivation: The cultivation of annatto on peat has been very limited so far and not much is known about specific measures to be taken.

Annatto responded well to lime and compound fertilizers on deep acid forest peat in Peninsular Malaysia and Sarawak. Ohler (52) reports that tree spacings vary between 2 x 2 m on poor soils and 7 x 7 m on chemically and physically rich soils; the typical plant density varies between 200 and 600 trees per hectare. The crop is harvested twice a year, the first time 18 months after planting. On mineral soils maximum seed yields are obtained after 3 to 5 years. Yields vary between 1 and 3 kg per tree, or between 600 and 2,000 kg per hectare (52). High yielding varieties from Irian contained 3.4 to 5.3% bixin in their seeds.

98. GARDEN BALSAM *Impatiens balsamina* L. (Geraniaceae)

Garden balsam, or "pacar kuku", occurs in gardens and near homesteads where it grows vigorously without any care. Its leaves are said to be edible but the plant is mainly grown for its reddish pigment which is popular as a substitute for nail polish. Garden balsam is also used as a medicine to depress fever. The plants are multiplied by means of stem cuttings.

Dyes and tans

99. INDIAN MULBERRY *Morinda citrifolia* L. (Rubiaceae)

The Indian mulberry, or "mengkudu", is a medium-sized tree and not uncommon in transmigration areas on peat in Sumatra and Kalimantan. The bitter fruits are mainly used in medicine. The roots contain a stable non-fading dyestuff that is traditionally used for the making of "batik".
Requirements: Mengkudu has low soil requirements. It grew vigorously on shallow (75 cm) Sumatran forest peat with the water table at a depth of 50 cm or more.
Cultivation: Mengkudu on peat is propagated by seed and produces abundant fruits after only 3 years. Neither liming nor fertilizers seem necessary. Pests and diseases are reportedly never serious.

100. GRASSES (Gramineae)

Pasture land is extensive in temperate peat areas but extremely rare in tropical swamps, probably because of a lack of suitable swamp grasses. Certain species, such as *Eriochloa subglabra* Hitchcock, which proved a success in the wet coastal area of Puerto Rico (27), have low nutrient requirements and tolerate waterlogging but their performance under the adverse conditions of the tropical peat swamps (stagnant acid and oligotrophic low-oxygen water with a high organic matter content) is still to be studied. Valuable experiments have been done in Malaysia (4, 16, 33), where Guinea grass ("rumput banggala", *Panicum maximum* Jacq) and Napier grass (*Pennisetum purpureum* Schuhm.) were tested on acid forest peat in a bid to replace local low protein grasses. Silaged maize or sorghum, and oil cake are valuable supplements to the swamp grass diet. Animal husbandry in peat swamp areas is presently limited to poultry and goats; cows and buffaloes are considered too heavy for the loose forest peats and hogs are unpopular on religious grounds and probably also because wild pigs are abundant in most swamps. Chinese farmers near Pontianak keep hogs for the production of meat and manure.

Requirements: Most grasses have only moderate nutrient requirements but dressings of NPK and trace elements are needed on all oligotrophic peats (33, 55). Acid peats should be limed with ground (magnesium) limestone (GML), preferably to pH 5.0. Soil drainage should be kept as shallow as tolerated by the crop in order to reduce subsidence of the land.

Cultivation: Grasses are propagated by seed, cuttings or suckers. Once the crop is established it is cut at regular intervals (e.g. every two months) depending on the environmental conditions and the variety grown. Lime and nitrogen fertilizers are particularly effective in boosting grass yields.

Napier grass on deep peat was shown to respond well to potassium fertilizers. Sprays of iron sulphate after each cutting are necessary to prevent chlorosis in grasses on deep (iron-poor) forest peats. Yields of Napier grass on deep peat in Sarawak went up from 36 tons of fresh herbage per cutting to 60 tons per cutting by increasing the GML dressing from 4 to 6 tons. Guinea grass on mineral soil produced 40 tons of dry matter per hectare when given 1.800 kg N, versus 25 tons without nitrogen. Joseph *et al.*(33) report Guinea grass on Malaysian forest peat to produce 19.3 tons of dry grass per hectare but yields were lower in the second year of the experiment.

Miscellaneous

101. CORAL PEA TREE *Adenanthera sp.* (Leguminosae)

The coral pea tree is a tall tree with bright red oil-containing (35% oil) seeds. Its timber can be used for construction purposes; the tree is commonly grown as a shade tree.
Adenanthera grew vigorously on deep (6 m) forest peat at Stapok Deep Peat Research Station in Sarawak and did not lean even after 10 years.
Its nutrient requirements are apparently low; the trees did not receive fertilizers for several years but nutrient cycling kept them thriving and in perfect health where the main crop (coconut) perished.
The tree apparently will tolerate shallow groundwater. Pests or diseases were not recorded.

102. HORSE TAMARIND *Leucaena glauca* Benth. (Leguminosae)

The horse tamarind, locally known as "lamtoro" or "petai cina", is a leguminous tree with a maximum height of 10 meters. It is mainly planted as a shade tree but young pods, leaves and roasted seeds can be eaten as a vegetable. The leaves can be used as stock feed but might cause loss of hair to non-ruminants (70).
Requirements: The tree prefers a loose humous soil and thrives on shallow and moderately deep forest peats with groundwater at -50 cm. Its chemical requirements do not seem very high.
Cultivation: Lamtoro can be propagated by stem cuttings or seed. The trees are rarely planted in any particular pattern but grow semi-wild or along fences. Harvest may begin after only two years. Pests and diseases are not serious; fertilizers are rarely used. Lamtoro's performance was generally described as "excellent".

103. MULBERRY *Morus alba* L. (Moraceae)

Mulberry, ("murbei" in Indonesia), is a small tree planted for silkworm (*Bombyx mori*) rearing. The fresh fruits are edible; young plants can be eaten as a vegetable. Mulberry was never seen in Indonesian peat areas but experiments on Malaysian forest peat (13, 33) were very successful with leaf yields that are reportedly the highest in the world.

Requirements: Mulberry grows well in lowlands but seems even better suited to the higher belts (70) although the fruits tend to be less sweet there (50). The tree is not very demanding but needs a well drained soil.
Cultivation: Mulberry is propagated by hard wood cuttings. Regular pruning is said to be beneficial. Data on optimum plant spacings and response to fertilizers are not available. Liming increased yields on deep acid forest peat in Malaysia. Joseph *et al.*(33) report leaf yields of 7.5 tons of dry leaves per hectare-year.

104. PANDAN *Pandanus spp.* (Pandanaceae)

Many *Pandanus* species, e.g. *P. andersonii, P. atrocarpus, P. brevifolius,* are natives of the peat swamps of S.E. Asia (2) but only few species are useful.
Pandanus odoratissimus L.f. is grown in small numbers on compounds; its leaves are used for mats and baskets. Extracts of pandan leaves are added to snacks as a flavour and food colouring.
Pandans are propagated by means of root cuttings. *P. tectorius* is mature after 6 months and the leaves can be harvested for several years. The performance of pandan on peat was rated "fair".

105. SAGO *Metroxylon spp.* (Palmae)

Sago, or "sagu", is a native of the lowlands of parts of S.E. Asia (26). It was described as early as 1750 AD by Rumphius, whose name is remembered in the thorny *M. rumphii* Mart. This palm crosses readily with the smooth sheathed *M. sagu* Rottb. Semi-wild sago stands cover vast areas in the coastal plains of Irian and are also found in Sarawak (71), mainly in the Third Division. It is the third largest export commodity there, with a production of more than 27,000 tons of flour in 1974.
Sago produces a high quality starch that remains viscous over a wide temperature range. It is in demand as a raw material for the food industry (pudding, confectionary, custard powder, sauces) and as an animal food (rasped and dried sago for pigs). It is also applied in the textile industry and for the making of adhesives, dextrine and paper coatings (1). Sago leaves are a suitable material for making roofs (50).
Requirements: Sago can grow on acid (pH 3.7 to 3.9) undrained peats (1,33)

but performs poorly under such conditions (Flach; pers. comm.). The best stands occur on humous clayey (freshwater; 5) swamp soils which are regularly flooded with chemically rich water. Permanent inundation is a disadvantage (26). Palms on peat produce more shoots than those on mineral soils but mature slowly (1, 71). They produce more dry matter in direct sunlight than in shade. Sago is potentially a good crop on shallow and moderately deep peats which cannot be used for other crops because of inadequate water control.

Cultivation: Sago is propagated by suckers which are planted 9 or 10 m apart (1) in shallow holes. The trees are cut during or directly after flowering which takes place after 8 to 10 years on mineral soils and after 12 to 15 years on peat soils. A denser spacing (e.g. 6 x 6 m) and earlier harvest (lower starch production per tree) may be economically attractive. In virgin swamps clearing prior to planting is best done progressively by poisoning the large trees and subsequently removing the undergrowth (26) because this reduces clearing costs.

Starch contents are highest immediately before flowering or when the inflorescence is still young. The flour accumulates from the base of the palm upwards; the bottom log (0-150 cm, diameter 35 to 60 cm) contains less flour than the second log.

Most sago grows semi-wild without any weeding, pruning or liming being done. The nutrient removal by a stand of 130 palms per hectare is estimated at 80 kg N, 30 kg P_2O_5, 160 kg K_2O, 100 kg CaO and 40 kg MgO (1). Fertilization is commonly restricted to the nutrients supplied by flood water, which explains the poor growth of sago on oligotrophic forest peats. However, the extensive way in which sago is grown and the fact that harvests are not peaked but spread over the year, enable one man to tend 5 hectares. Barrau (5) estimates that the average family in Oceania must spend some 10 days per month in the sago groves in order to satisfy its needs.

Transport of the raw material (40 to 60 tons/ha.yr) is the main problem in peat swamp areas where the brownish peat water lowers the quality of the flour if extracted on the spot. The semi-wild palms can be harvested at a rate of 40 to 75 stems per hectare-year (1, 5, 26) and contain 125 to 180 kg flour each. Sterile palms (bud removed by man) accumulate up to 450 kg of crude starch (water content 35 to 40 percent) in their trunks. Cultivated palms *can* contain up to 250 kg flour per tree and may be harvested at a rate of 75 to 125 trunks per hectare-year. The trunks consist for 60 percent of water. Bark, fibre, etc. make up another 21 percent of the trunk weight; the rest (19 percent) consists of flour (1).

106. SUGAR CANE *Saccharum officinarum* L. (Gramineae)

Sugar cane, or "tebu", is a common crop on peat. A number of sugar estates were established on shallow peat soils during the first half of this century (56, 73, 76) but at present the crop is almost exclusively grown in transmigration areas where (Javanese) settlers plant cane for chewing.

Requirements: The green matter production of sugar cane on peat is commonly satisfactory if the peat is not too acid (23). The crop needs a well drained soil despite the presence of aerenchym cells. If grown commercially it removes considerable quantities of nutrients (25). Sugar cane prefers a temperature of 25 to 28^{o}C without extremes of heat or cold (27) but needs a dry period with much sunshine for sufficient assimilation of sugar.

Cultivation: Sugar cane is propagated by cuttings which are planted in rows or-on compounds-without any particular spacing. Cane on peat is slow to come to maturity but it can be harvested after 10 to 12 months. Fertilizers improve vegetative growth; particularly phosphorus is needed (23,36) but potassium, copper and zinc (39, 55) are also important. Soils with a pH of less than 4.5 should be limed and it is generally recommendable to use alkaline fertilizers and to return the carbonatation residue (which contains 65 percent $CaCO_3$) to the field (23). The quantities of nutrients removed per crop depend on a multitude of factors; estimates for sugar cane on mineral soils vary from 65 to 190 kg N, 52 to 139 kg P_2O_5, 82 to 656 kg K_2O, 21 to 58 kg CaO, 22 to 69 kg MgO, 79 to 261 kg SO_3,530 to 1130 kg SiO_2 and 21 to 33 kg Fe_2O_3 (23, 27).

On deep peat in Sarawak 20 to 30 tons of cane were produced per hectare; accurate information on the sugar content could not be obtained.

Saccharum edule Hassk., or "tebu telor", is also grown on peat. The young inflorescences are eaten as a vegetable. Its cultivation is similar to that of *S. officinarum.*

Miscellaneous

107. TURI *Sesbania grandiflora* Pers.(Leguminosae)

Turi is a tall (12 m) leguminous tree, widely planted as a shade tree. It seems less common on peat than on mineral soils. Its white flowers are edible and the young leaves are believed to stimulate milk production of breast-feeding mothers.

Requirements: The nutrient requirements of turi are obviously not very high but the tree needs a deeply drained soil. Farmers in Sumatra report that many trees died when subsidence of the land caused the water table to become shallower than 50 cm.

Cultivation: Turi is multiplied by sowing 2 or 3 seeds per hole in a 5 x 5 m grid (50). Trees on well drained soils (or on ridges) grow rapidly and flower after only 3 years but on the whole the performance of turi on peat is less than impressive. Data on fertilizer needs, pests and diseases, etc., could not be obtained.

REFERENCES

1. Ahmed, M.I. and E.S. Sim, 1975. Utilization of peat soils for sago palm cultivation in Sarawak. 3rd ASEAN Soil Conf., Kuala Lumpur.
2. Anderson, J.A.R., 1976. Observations on the ecology of five peat swamp forests in Sumatra and Kalimantan. In: Bull. No. 3, Soil Res. Inst., Bogor, Indonesia.
3. Andriesse, J.P., 1964. The use of Sarawak peat for agriculture. Research Circular No. 4, Dept. Agric. Sarawak.
4. Andriesse, J.P., 1974. Tropical lowland peats in S.E. Asia. Comm. No. 63. Royal Trop. Inst., Amsterdam.
5. Barrau, J., 1959. The sago palms and other food plants of marsh dwellers in the South Pacific islands. Econ. Bot. 13; 151-162.
6. Berger, J., 1969. The world's major fibre crops, their cultivation and manuring. Publ. No. 6. Centre d'ètude de l'azote, Zürich.
7. Bruijn, G.H. de, and T.S. Dharmaputra, 1974. The Mukibat system, a high-yielding method of cassava production in Indonesia. Neth. Agr. J., Vol 22, 2; 89-100.
8. Chew, W.Y., 1970. Effects of length of growing season and NPK fertilizers on the yield of five varieties of sweet potatoes (*Ipomoea batatas*) on peat. Mal. Agr. J., No. 47; 453-463.
9. Chew, W.Y., 1970. Varieties and NPK fertilizers for tapioca (*Manihot utilissima* Pohl) on peat. Mal. Agr. J., No. 47; 483-491.
10. Chew, W.Y., 1971. Yield and growth responses of some leguminous and root crops on acid peat to magnesium lime. Mal. Agr. J., No. 48, 2; 142-158.
11. Chew, W.Y., 1974. Yields of some varieties of tapioca (*Manihot utilissima* Pohl) grown on Malaysian peat as affected by different planting methods, plant densities, fertilizers and growth periods. Mal. Agr. J., No. 49, 3; 393-402.
12. Chew, W.Y. and N.H. Yeong, 1974. An observation on the yield of some vegetables grown on Malaysian peat. Mal. Agr. J., No. 49, 4; 433-436.
13. Chew, W.Y. and V.J. Samuel, 1975. The Peat Research Station, Jalan Kebun, Selangor. In: Field tour guide book of the 3rd ASEAN Soil Conf., Kuala Lumpur.

14. Cooke, F.C., 1930. Coconuts on peat. Mal. Agr. J., No. 18; 587-595.

15. Coulter, J.K., 1950. Peat formation in Malaya. Mal. Agr. J., No. 33; 63-81.

16. Coulter, J.K., 1957. Development of the peat soils of Malaya. Mal. Agr. J., No. 40; 188-199.

17. Driessen, P.M., 1977. Peat Soils. Their occurrence, properties, reclamation and suitability for rice cultivation. (in press) Soils and Rice Symp., Manila.

18. Driessen, P.M. and M. Soepraptohardjo, 1974. Soils for agricultural expansion in Indonesia. Bull. No. 1, Soil Res. Inst., Bogor.

19. Driessen. P.M. and H. Suhardjo, 1976. On the defective grain formation of sawah rice on peat. In: Bull. No. 3, Soil Res. Inst., Bogor.

20. Dunsmore, J.R., 1957. The pineapple in Malaya (*Ananas comosus* Merr.). Mal. Agr. J., No. 40; 159-187.

21. Dupaigne, P., 1974. Les colorants rouges d'origine naturel. IFAC, Paris.

22. Dijk, J.W. van, 1937. Einiges über die bodenkundliche Beschaffenheit der Moorsumpfböden in der Residentur Süd-und Ost-Borneo bezüglich ihrer Berieselung für den Reisbau. Komm. Int. Bodenk. Ges., Teil B, Verh. 6, Zürich.

23. Edelman, C.H., 1947. Studiën over de bodemkunde van Nederlandsch Indië. Publ. Nr 24, L.E.B., Wageningen.

24. Ehrencron, V.K.R., 1949. Orienterende potproeven met zuur bosveen van Borneo. Med. Alg. Proefst. Landb., Nr 90, Buitenzorg.

25. Ferwerda, J.D., 1970. Soil fertility in the tropics as affected by land-use. Proc. Potass. Symp.

26. Flach, M., 1973. The sago palm; a potential competitor to root crops. Proc. 3rd Int. Root Crop Conf.

27. Geus, J.G. de, 1967. Fertilizer guide for tropical and subtropical farming. Centre d'ètude de l'azote, Zürich.

28. Godin, V.J. and P.C. Spensley, 1971. Crop and product digests, No. 1; Oils and oil seeds. Trop. Prod. Inst., London.

29. Groenewegen, J.H., 1975. Productie-top stooktomaten nog steeds niet bereikt. Groenten en Fruit; 684-685.

30. Heurn, Jhr F.C. Van, 1922. De gronden van het cultuurgebied van Sumatra's Ooskust en hunne vruchtbaarheid voor cultuurgewassen. Thesis, Delft.

31. Heyne, K., 1951. De nuttige planten van Indonesië. Veenman, Wageningen.
32. Ishizuka, Y. and A. Tanaka, 1956. Nutrio-physiological and edaphological studies on rice culture on peat soil, especially the mineral-soil dressing on peat soil. Hokkaido Nat. Agr. Exp. Sta. Res. Bull. 69; 86-102.
33. Joseph, K.T., W.Y. Chew and T.H. Tay, 1974. Potential of peat for agriculture. MARDI Rep. No. 16, Malaysia.
34. Kanapathy, K., 1972. Copper requirement and residual effect with maize on a peat soil. Mal. Agr. J., No. 48, 3; 249-263.
35. Kanapathy, K., 1973. Acidity, acid sulphate soils and liming of padi fields. Mal. Agr. J., No. 49; 154-165.
36. Kanapathy, K., 1974. Fertilizer experiments on shallow peat under continuous cropping with tapioca. Mal. Agr. J., No. 49, 4; 403-412.
37. Kanapathy, K., 1974. Time of harvesting different varieties of tapioca on peat. Mal. Agr. J., No. 49, 4; 469-479.
38. Kanapathy, K., 1975. Factors in the utilization of peat soils in Peninsular Malaysia. 3rd ASEAN Soil Conf., Kuala Lumpur.
39. Kanapathy, K. and A.K. Goh, 1970. Growing maize, sorghum and tapioca on peat soil. Proc. Conf. Crop Diversif. in Malaysia; 25-35.
40. Kanapathy, K., S.H. Tan and T.E. Cheah, 1974. Available micronutrients in some Peninsular Malaysian soils as indicated by the oil palm. Mal. Agr. J., No. 49, 3; 357-364.
41. Kausar, M.A., F.M. Chaudry and A. Rashid, 1976. Micronutrient availability to cereals from calcareous soils, I. Plant and Soil, No. 45; 397-410.
42. Knott, J.E. and J.R. Deanon, 1967. Vegetable production in Southeast Asia. Univ. Philippines, Los Baños.
43. Koch, L., 1946. Stelselmatige planteninvoer. Landbouw 19, No. 4; 167-174.
44. Lee, S.A., 1974. Effect of rhizome size and fungicide treatment on the sprouting and early growth of ginger. Mal. Agr. J., No. 49, 4; 480-491.
45. Lembaga Penelitian Tanah, 1974. Laporan survey dan pemetaan tanah daerah S. Enok, Delta S. Ketih. LPT No. 3, 1975. Bogor, Indonesia.
46. Lembaga Penelitian Tanah, 1975. Laporan survey dan pemetaan tanah daerah Bunut-K. Kampar, Riau. Buku I, LPT, Bogor, Indonesia.

47. Lim, C.K., Y.K. Chin and E.W. Bolle-Jones, 1973. Crop indicators of nutrient status in peat soil. Mal. Agr. J., No. 49; 198-208.

48. Masefield, G.B., 1965. A handbook of tropical agriculture. Oxford University Press, London.

49. Mohr, E.C. Jul., 1908. Ueber Moorbildungen in den Tropen. Bull. Dept. Agr. Indes-Nêerl., XVII.

50. Ochse, J.J., 1931. Indische groenten. Dept. Land. Nijverh. en Handel. Buitenzorg.

51. Ochse, J.J., (bew. W. de Jong), 1941. Tropische groenten. Balai Poestaka, Batavia.

52. Ohler, J.G., 1968. Annatto *(Bixa orellana* L.). Review Article. Trop. Abstr., Vol. 24, No. 7.

53. Ong, K.H., 1974. Investigations into pelleting of tapioca *(Manihot utilissima* Pohl) as single product. Mal. Agr. J., No. 49, 4; 442-454.

54. Parbery, D.B. and R.M. Venkatachalam, 1964. Chemical analysis of South Malayan peat soil. J. Trop. Geogr., No. 18; 125-133.

55. Polak, B., 1946. Over veenonderzoek in Nederlandsch Indië. Natuurwetensch. Tijdschr. Ned. Indië, No. 124, 4; 63-73.

56. Polak, B., 1948. Waarnemingen betreffende het gedrag van cultuurgewassen op veen. Landbouw XX, nrs 6 en 7.

57. Polak, B., 1949. De Rawa Lakbok, een eutroof laagveen op Java. Med. Alg. Proefst. Landb., Nr 85; 1-60. Buitenzorg.

58. Polak, B., 1975. Character and occurrence of peat deposits in the Malaysian tropics. In: Modern Quaternary Research in S.E. Asia; 71-83. Balkema, Rotterdam.

59. Polak, B. and M. Supraptohardjo, 1951. Pot and field experiments with maize on acid forest peat from Borneo. Contr. Gen. Agr. Res. Sta., No. 125; 1-17. Bogor, Indonesia.

60. Protzman, C.M., 1947. The new jute production industry of Brazil. Landbouw IXX, 5; 237-238.

61. PUTL/TRANSKOP, 1972. Transmigrasi dalam persawahan pasang surut. PUTL-P4S, Jakarta.

62. PUTL/P4S, 1974. Rawa-rawa dan pasang surut. PUTL, Jakarta.

63. Rahmatullah, F.M. Chaudry and A. Rashid, 1976. Micronutrient availability to cereals from calcareous soils, II. Plant and Soil, No. 45; 411-420.

64. Sapek, B., 1976. Study of the copper sorption kinetics of peat-muck soils. Proc. 5th Int. Peat Conf., Poznan, Poland.

65. Sewandono, M., 1938. Het veengebied van Bengkalis (Sumatra). Tectona 31; 99-135.

66. Snoep, W., 1932. Verschijnselen in een koffie-aanplant op veengrond. De Bergcultures, 6.

67. Staff. Dept. Agr., 1975. Monograph on soils and agriculture (in) Malaysia. Min. Agr. Rural Dev., Kuala Lumpur.

68. Tay, T.H., 1969. The distribution, characteristics, uses and potential of peat in West Malaysia. J. Trop. Geogr. No 29; 58-63.

69. Tay, T.H. and Y.C. Wee, 1972. Liming of peat soils and its effect on pineapple. Malaysian Pineapple No 2; 53-59.

70. Terra, G.J.A., 1966. Tropical Vegetables. Communication 54 e, Royal Tropical Institute, Amsterdam.

71. Tie, Y.L. and C.P. Lim, 1976. Peat soils for sago growing in Sarawak. Sago Sem.; Kuching, Sarawak.

72. Tindall, H.D., 1968. Commercial vegetable growing. Oxford Tropical Handbooks. London.

73. Veen, R. van der, 1938. Veengrond op een koffieland. De Bergcultures 12; 345-347.

74. Voort, M. van der, 1942. Veen en veencultuur in de Anaïvlakte op Sumatra's westkust. Landbouw XVIII; 189-202.

75. Wee, Y.C., 1970. The development of pineapple cultivation in West Malaysia. J. Trop. Geogr., No 30; 68-75.

76. Wichmann, C.E.A., 1910. De veenen in den Indischen archipel. Versl. Gew. Verg. Wis- en Natuurk. Afd. Kon. Acad. Wetensch., Amsterdam.

77. Winnen, E., 1977. Prospects of the cultivation of cassava, coconut and pineapple in general and on peat soils in particular. ILACO Int. Memo (mimeographed).

78. Wijk, C.L. van, 1950. Enkele aantekeningen over de verjonging van djelutung (*Dyera lowii* Hook). Tectona 40; 167-173.

79. Wijk, C.L. van, 1951. Soil survey of the tidal swamps of South Borneo in connection with the agricultural possibilities. Contr. Gen. Agr. Res. Sta., No 123; 1-49.

80. Yeoh, H.H. and W.Y. Chew, 1974. Research in tapioca - A brief review. Mal. Agr. J., No 49,3; 332-343.

INDEX x)

Abaca 20
Adenanthera sp. 101
Agave 21
Agave cantala Roxb. 21
Agave sisalana Perrine 21
Aleurites moluccana Willd 12
Allium ampeloprasum L. 71
Allium cepa L. 71
Allium fistulosum L. 71
Alpinia galanga Sw. 89
Amaranthus hybridus L. 58
Anacardium occidentale L. 32, 40
Ananas comosus Merr. 47
Andewi 61
Angled luffa 62
Annatto 97
Anona muricata L. 50
Anona squamosa L. 50
Apium graveolens L. 56
Apokat 29
Arachis hypogaea L. 15
Areca catechu L. 71
Areca nut 71
Artocarpus altilis Fosberg 31
Artocarpus champeden Spreng. 31
Artocarpus heterophyllus Lam. 39
Asparagus officinalis L. 52
Averrhoa bilimbi L. 51
Averrhoa carambola L. 51
Avocado 29
Bacang 43
Baccauria racemosa Muell. 42
Bambara Groundnut 53
Banana 30
Bangkuang 10
Basil 84
Bawang daun 71
Bawang merah 71
Bayam 58
Belewah 62
Belimbing manis 51
Belimbing wuluh 51
Belustru 62
Benincasa cerifera Savi 62
Bentul 77
Betel pepper 80
Bilimbi 51
Bitter gourd 62
Bixa orellana L. 97
Black nightshade 69
Black potato 7
Bligo 62
Blumkol 55
Boehmeria nivea Gaud 25
Bonavist bean 53
Bottle gourd 62
Bouea macrophylla Griff. 37
Brassica chinensis L. 57
Brassica juncea Czern and Coss 67
Brassica oleracea L. 54/55
Breadfruit 31
Brinjal 60
Bunga matahari 19
Cabbage 54
Cabe minang 74

x) Numbers refer to LIST OF CROPS (pages 1 and 2); they are not page numbers!

Cabe rawit 73
Cajanus cajan Millsp. 53
Cajeput 16
Caladium bicolor Vent. 59
Camellia sinensis O.K. 82
Canavalia gladiata Jacq. 53
Candlenut tree 12
Canna edulis Ker. 4
Cantel 3
Capsicum annuum L. 74
Capsicum frutescens L. 73
Carica papaya L. 45
Cashew nut 32, 40
Cassava 5
Castor 13
Cauliflower 55
Celery 56
Cempedak 31
Cengkeh 86
Chicu 33
Chilli pepper 73
Chinese cabbage 57
Chinese spinach 58
Chinese waterchestnut 6
Cichorium endivia L. 61
Cinnamon 85
Cinnamomum burmanii Bl. 85
Cinnamomum zeylanicum Breyn. 85
Citrus amblicarpa Ochse 34
Citrus aurantifolia Swing. 34
Citrus grandis Osbeck 34
Citrus hystrix D.C. 34
Citrus reticulata Blanco 34
Citrus sinensis Osbeck 34
Clove tree 86
Coconut 14
Cocos nucifera L. 14
Cocoyam 59
Coffee 81
Coffea canephora Pierre 81
Coffea liberica Bull. 81
Coleus parviflorus Benth. 7
Colocasia esculenta Schott. 59
Colocynthis citrullus O. Ktze 62
Coral pea tree 101
Cotton 22
Cow pea 53
Cucumber 62
Cucumis melo L. 62
Cucumis sativus L. 62
Cucurbita maxima Duch. 62
Curcuma domestica Val. 96
Curcuma xanthorrhiza Roxb. 95
Custard apple 50
Cymbopogon citratus Stapf. 90
Daun sop 56
Delima 48
Dioscorea sp. 9
Duku 35
Durian 36
Durio carinatus 36
Durio zibethinus Murr. 36
Dyera costulata Hook. 27
Edible canna 4
Eggplant 60
Elaeis guineensis L. 17
Endive 61
Eriochloa subglabra Hitchcock 100
Eriodendron anfractuosum D.C. 23
Eucalypt 16
Eucalyptus sp. 16
Eugenia aquea Würmf. 40
Eugenia caryophyllus Bullock and Harrison 86

Eugenia javanica Lamk. 40
Eugenia malaccensis L. 40
Fayotier 107
French bean 53
Galangal 89
Gambas 62
Gandaria 37
Ganyong 4
Garcinia mangostana L. 44
Garden balsam 98
Gelam 16
Gembili 7
Ginger 87
Glycine max Merr. 18
Gnetum gnemon L. 41
Gossipium obtusifolium Roxb. 22
Green gram 53
Groundnut 15
Guava 40
Guinea grass 100
Helianthus annuus L. 19
Heliocharis tuberosa Schult. 6
Hevea brasiliensis Muell. 28
Hibiscus cannabinus L. 24
Hibiscus esculentus L. 70
Hibiscus sabdariffa L. 26
Hogplum 38
Horse mango 43
Horse tamarind 102
Impatiens balsamina L. 98
Indian mulberry 99
Ipomoea aquatica Poir. 65
Ipomoea batatas Poir. 8
Ixora coccinea L. 64
Jackfruit 39
Jagung 1
Ja(h)e 87
Jambu 40
Jambu air 40
Jambu biji 40
Jambu bol 40
Jambu monyet 32, 40
Jambu semarang 40
Jarak 13
Jelutung 27
Jengkol 63
Jeruk bali 34
Jeruk keprok 34
Jeruk manis 34
Jeruk nipis 34
Jeruk peres 34
Jeruk purut 34
Joint fir 41
Jungle geranium 64
Kacang benguk 53
Kacang bogor 53
Kacang gude 53
Kacang hijau 53
Kacang kedelai 18, 53
Kacang panjang 53
Kacang pedang 53
Kacang tanah 15, 53
Kacang tunggak 53
Kalangkala 37
Kangkung 65
Kapas 22
Kapok 23
Kara 53
Karet 28
Kasumba keling 97
Katuk 66
Kayu manis 85
Kayu putih 16
Kecipir 11, 53

Kedelai 18, 53
Kedondong 38
Keladi 59
Keladi berwarna 59
Kelapa 14
Kelapa sawit 17
Kemang 43
Kemangi 84
Kemiri 12
Kenaf 24
Kencur 88
Kenikir 91
Kepundung 42
Ketela 8
Ketimun 62
Keweni 43
Kluwih 31
Kol 54
Kopi 81
Kopi arab 70
Kucai 71
Kunyit 96
Kratok 53
Lablab niger Savi. 53
Labu air 62
Labu kuning 62
Lactuca sativa L. 68
Lagenaria siceraria Stand. 62
Lamtoro 102
Lansium domesticum Corr. 35
Laos 89
Leaf mustard cabbage 67
Leek 71
Lemon grass 90
Lengkuas 89
Lettuce 68
Leucaena glauca Benth. 102
Lima bean 53
Lime 34
Lobak 76
Luffa acutangula Roxb. 62
Luffa cylindrica L. 62
Lycopersicon esculentum Mill. 78
Maize 1
Malay apple 40
Mandarin 34
Mangga 43
Manggis 44
Mangifera caesia Jacq. 43
Mangifera foetida Lour. 43
Mangifera indica L. 43
Mangifera odorata Griff. 43
Mango 43
Mangosteen 44
Manicoba 5
Manihot esculenta Crantz 5
Manihot flabellifolia 5
Manihot glazovii Muell-Arg. 5
Manila hemp 20
Manilkara achras Fosberg 33
Marigold 91
Melaleuca leucadendra L. 16
Melinjo 41
Mengkudu 99
Mentha spp. 92
Merica 94
Metroxylon rumphii Mart 105
Metroxylon sagu Rottb. 105
Mint 92
Momordica charantia L. 62
Morinda citrifolia L. 99
Morus alba L. 103
Mucuna utilis Wall. 53
Mulberry 103

Murbai 103
Musa spp. 30
Musa textilis Née 20
Myristica fragrans Houtt. 93
Nanas 47
Nangka 39
Nangka belanda 50
Napier grass 100
Nephelium lappaceum L. 49
Nicotiana tabacum L. 83
Nutmeg 93
Ocimum canum Sims. 84
Oil palm 17
Okra 70
Oryza sativa L. 2
Pacar kuku 98
Pachyrrhizus erosus Urb. 10
Padi 2
Paku 72
Pala 93
Pandan 104
Pandanus spp. 104
Panicum maximum Jacq. 100
Pantung 27
Papaya 45
Pare pahit 62
Parkia speciosa Hort. 75
Passiflora edulis Sims. 46
Passion fruit 46
Pennisetum purpureum Schuhm. 100
Pepper 94
Persea gratissima Gaertn. 29
Petai 75
Petai cina 102
Petsai 57
Phaseolus lunatus L. 53
Phaseolus vulgaris L. 53
Pigeon pea 53
Pinang 71
Pineapple 47
Piper betle L. 80
Piper nigrum L. 94
Pisang 30
Pithecolobium lobatum Benth. 63
Pleopeltis longistema Moore 72
Pomegranate 48
Psidium guajava L. 40
Psophocarpus tetragonolobus ADC 11, 53
Pummelo 34
Pumpkin 62
Punica granatum L. 48
Queensland arrowroot 4
Rambutan 49
Rami 25
Ramie 25
Ranti 69
Raphanus sativus L. 76
Rice 2
Ricinus communis L. 13
Roselle 26
Rubber 28
Rumput banggala 100
Saccharum edule Hassk. 106
Saccharum officinarum L. 106
Sago (palm) 105
Sagu 105
Sauropus androgynus Merr. 66
Sawi 67
Sawo 33
Selada 68
Seledri 56
Semangka 62
Serai 90

Sesbania grandiflora Pers. 107
Shallot 71
Sirih 80
Sirikaya 50
Sisal 21
Smooth luffa 62
Soka 64
Solanum melongena L. 60
Solanum nigrum L. 69
Sorghum 3
Sorghum bicolor Moench 3
Soursop 50
Soybean 18
Spondias cytherea Sonn. 38
Starfruit 51
Stenochlaena palustris Bedd. 72
Sugar cane 106
Sunflower 19
Sweet melon 62
Sweet orange 34
Sweet pepper 74
Sweet potato 8
Sword bean 53
Tagetes erecta L. 91
Tannia 77
Tapioca 5
Tea 82
Tebu 106
Tebu telor 106
Teh 82
Tembakau 83
Temu lawak 95
Terong 60
Tikê 6
Tobacco 83
Tomat 78
Tomato 78
Treefern 72
Turi 107
Turmeric 96
Ubi jalar 8
Ubi kayu 5
U(w)i 9
Velvet bean 53
Vigna aureus Hepper 53
Vigna unguiculata Walp. 53
Voandzeia subterranea Thou 53
Water melon 62
Wax gourd 62
Winged bean 11, 53
Xanthosoma sagittifolium Schott. 77
Yam 9
Yam bean 10
Yardlong bean 53
Zea mays L. 1
Zingiber officinale Rosc. 87