On the agronomy and botany of Salak (*Salacca zalacca*)

Promotoren: Prof. dr. ir. P.C. Struik
Hoogleraar in de gewasfysiologie
Prof. dr. ir. M. Flach
Hoogleraar in de tropische plantenteelt

Samenstelling promotiecommissie:
Prof. dr. ir. M. Wessel (Wageningen Universiteit)
Dr. ir. E.W.M. Verheij (Wageningen Universiteit)
Prof. dr. ir. L.J.G. van der Maesen (Wageningen Universiteit)
Dr. ir. J.S. Siemonsma (Wageningen Universiteit)

On the agronomy and botany of Salak

(*Salacca zalacca*)

Sumeru Ashari

Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
Prof. dr. ir. L. Speelman
in het openbaar te verdedigen
op maandag 2 december 2002
des namiddags te half twee in de Aula

Sumeru Ashari (2002)
On the agronomy and botany of salak (*Salacca zalacca*)
PhD Thesis Wageningen University – With ref. –
With summaries in English, Dutch and Indonesian
ISBN: 90-5808-424-8
Subject heading: agronomy, botany, salak, *Salacca zalacca*

Propositions

1. In East Java, salak has been in cultivation for more than hundred years; it is time that research and extension start to contribute to the development of the crop.
This thesis

2. Imperfect pollination is a major cause of low salak yields. The improvement of hand pollination methods should therefore receive priority.
This thesis

3. The pollen source strongly influences the fruit yield of salak, both qualitatively and quantitatively.
This thesis

4. Cultural practices in salak production should be improved in such a way that harvesting can be spread more evenly over the year.

5. The pinnate leaf of a mature salak plant is unique for palms because of its uneven and irregular distribution of the leaflets along the rachis.
This thesis

6. Salak growers rogue plants without knowing their sex. This strongly impedes fruit production.

7. Some scientists have willingly introduced a 9-days working week.

8. Dondong apa salak duku cilik-cilik, gendong apa mundak mlaku timik-timik.
Javanese song

Proprositions with the thesis
On the agronomy and botany of Salak (*Salacca zalacca*)
Sumeru Ashari
Wageningen University
2 December 2002

ABSTRACT

Sumeru Ashari, 2002. On the agronomy and botany of Salak (*Salacca zalacca*). PhD Thesis Wageningen University, 126 pp., English, Dutch and Indonesian Summaries.

Salak is a dioecious, suckering palm, grown for its fruit, mainly in Indonesia. Traditionally, plants are raised from seed and planted in market gardens under the shade of existing trees. Crop care is largely limited to roguing of most male plants, cutting excess suckers and ageing leaves, and hand pollination. Each production centre mainly grows its own favoured variety, but in the 1990s 'Pondoh', originally from Yogyakarta, became popular also elsewhere. Yield varies widely (say 5 - 13 kg per plant per year). A better understanding of the crop can presumably greatly increase yield levels. This fits in with Indonesia's strategy to develop fruit growing with a view to improving nutrition and increasing exports. Salak is one of the fruit crops selected under this strategy. This thesis reports explorative research on the agronomy and botany of the crop.

Agronomy

Intensive pollination of this dioecious species leads to heavy fruit and seed set. Seed shape is determined by the number of seeds per fruit. A correlation between seed shape and sex of the seed as assumed by salak growers in Indonesia is unlikely.

Pollination and pollen quality influence both quality and quantity of the fruits. Choice of pollen depends on the cultivar to be pollinated.

Salak seed is recalcitrant and endosperm plays an important role in germination. Without endosperm the embryo is unable to grow and develop. Storage of salak seed in charcoal can sustain its viability and enhance seedling growth compared to storage in ambient air or even in sawdust.

Germination of salak seeds was retarded when planted in heavy soils. Organic matter is needed to improve the physical properties of the soil, particularly of heavy soils. A higher organic matter content also increased N and P levels in the soil and nutrient levels in the leaves. In the nursery, salak seedlings need 50 - 75% shade and an adequate supply of nitrogen.

During later stages of growth inorganic fertilizer reduced the numbers of split and decaying fruits, thus increasing the numbers of good fruits per bunch.

Botany

In young seedlings, the leaf shape is simple but leaves emerging later are pinnate. The duration of leaf formation from emergence and spear growth until expansion and maturation varies considerably from one leaf to the next.

Leaf area assessment is cumbersome; simple leaf characteristics may be measured to estimate leaf area, but the relationships with leaf area vary, depending on growing conditions.

Suckers are produced from short horizontal stems radiating from the mother stem. Their number needs to be reduced in commercial growing.

In a variety trial, the first inflorescence emerged 23 - 34 months from sowing; after 42 months the percentage of flowering plants ranged from 50 - 84%. The inflorescence bud develops into a spear and splits the base of the subtending leaf to break into the open.

Female and male plants are similar in morphology. The sex should be known at planting, to allow optimal spacing of fruit-bearing plants in an orchard and to include enough pollinator plants from the start. This can be achieved through vegetative propagation, if necessary through tissue culture, or possibly by the genetic markers indicating the sex of seedlings.

Key words: Salak, *Salacca zalacca,* Palmae, dioecious, haustorium, simple leaf, compound leaf, sucker, phyllotaxis, seedling, inflorescence, fruit, hand pollination, farm yard manure, fertilizer, shading, walking palm.

ACKNOWLEDGEMENTS

This dissertation owes quite a bit to the contributions from a number of people. Without their support, assistance and guidance, the work would not have been finished.

First of all I would like to express my sincere thanks to my esteemed promotor Prof. Paul C. Struik, who guided me during the final write-up of the thesis. He has spent his precious time and energy to help me in finalizing the thesis. His encouragement and patience had a significant, positive effect on my work. Thus, working with him was fruitful and has added a lot to my experience and knowledge.

I extend my gratitude to the second promotor Prof. Em. Michiel Flach who encouraged me to undertake this study and who also provided guidance through the actual research and stimulated me by his critical reviews of the draft versions of the chapters. I obtained much benefit from his experience and the many discussions we had together.

I am also grateful to the Wageningen University, which provided financial support during my stay in the Netherlands and for printing of the thesis. I would like to thank all the people in the 'De Nuije, Haarweg 333' and especially the librarians who helped me in finding the information related to my work. I enjoyed the company of the people in the 'Attic' who were my roommates during the last 60 days of finishing the thesis.

My gratitude and appreciation are extended to Dr. E.W.M Verheij. At a time when this study was floundering, he came to Malang to work with me, showing the way to the completion of the thesis. Especially his contribution to the improvement of my English is gratefully acknowledged. He also enlisted the support of Dr. R. Verdooren, whose assistance led to a comprehensive statistical analysis of the leaf area measurements, for which I am greatly indebted. I thank Gon van Laar for excellent final editing and lay-out.

My sincere thanks also go to Prof. Bambang Guritno who as my local supervisor encouraged me and guided me during the work. I am much indebted to the Rector of Brawijaya University, the Dean of the Agricultural Faculty for giving me a study leave in order to finish the work. My gratitude and appreciation are extended to Prof. Tri Susanto (Food Technologist) for his criticism and comments especially on the seed germination aspect; to Prof. Syechfani (Soil Scientist) for his criticism and suggestions on the soil aspects; to Dr. Bernadetha Mitakda for her comments on the English language, the statistics and the biometry aspects; to Mr. Kasman Cadiwirjo MA for his help in the English language; to Mr. Agung Nugroho MS who took the photographs, prepared the diagrams and graphs for the manuscript, and to all students in horticulture who assisted in this study.

To my late father M. Ashari and my father in law Napsir Wirjoadmojo: I am deeply sorry that you do not have the opportunity to see the result of my work. However, I believe that both of you are happy and proud of its completion as a thesis of Wageningen University; you were often telling me stories about the Dutch period in Malang and in Indonesia. To both my mother and my mother in law: I express my appreciation for your patience and support during all these years.

Finally, last but not least, I would like to thank my wife, Endah Sri Handayani and my children, Dadang Meru Utomo, Astri Warih Anjarwi and Yordan Wicaksono Ashari for their patience and understanding during the preparation of this thesis.

CONTENTS

CHAPTER 1: GENERAL INTRODUCTION

Agriculture plays an important role in the Indone
economic crisis the agricultural sector has prove
coffee, clove, banana, mango and salak contribute
and earn foreign currency.

Unfortunately, Indonesian farmers have sever
pieces of land, often not large enough to nour
agricultural technology also needs to be improved.
agricultural commodities, which offer more econor
scale plantations, is also very important. Salak *(Sa*
a horticultural crop that has a potential of contri
However, little is known on the agronomy and
objective of the thesis work was to gather basi
botany of salak.

In the introduction to this thesis some basic
Indonesia is given. This is followed by an intro
production characteristics of Palmae in general
up to a description of salak cultivation in the co
provides details on the research questions and o
the limitations and constraints to the experimenta

For the terminology used in this introduction
the reader is referred to the glossary (Appendix

With compliments

Sumeru Ashari

1.1. Background information

Indonesia had a population of 180 million in 1990 (Anonymous, 1992). The rate of population growth has since then slowed down slowly and in the early nineties it was 1.97% per annum. With a growth rate of 1.9% per year the population is estimated to have reached 215 million in the year 2000.

A great variety of fruits and vegetables thrive in Indonesia. People greatly appreciate this diversity and generally know a lot about varieties, quality, and different food preparations using both green and ripe fruit, health benefits of various fruit, etc. However, statistical data regarding fruit production and consumption are scarce. The fruit production in 1994 was around 8 million tons (Anonymous, 1996). Assuming the same production and a population of 215 million people for the year 2000, this amounts to about 37 kg per person. Because of substantial post-harvest losses the average consumption may be about 30 kg per year. Verheij and Coronel (1991) arrived at the same figure for 1986/87.

Nutritionists recommend a daily intake of 50 - 100 g fresh fruit, that is 18 - 36 kg per year. Because the edible portion is somewhat more than 50% this means that 30 - 60 kg should be available per head. Given the fact that not all fruit is consumed fresh and that consumption is related to purchasing power, it is not surprising that Sunaryono (1990) concludes that most Indonesians consume less than two-thirds of the fruit that the body needs. Thus the indications are that production and consumption are too low to meet nutritional requirements. This situation affects the people's health. The prevalence of vitamin (A, C) and mineral (Fe) deficiencies is high, leading to serious diseases, particularly among children. The symposium on Food and Nutrition in 1989 in Indonesia reported that 1.64% of our youngsters are affected by Xerophthalmia or other eye diseases due to vitamin A deficiency (Wardoyo, 1992).

Most fruit – and especially the best quality fruit – is so expensive that common people are generally only able to buy low-priced fruits such as banana and papaya.

This national health condition became the reason for the Indonesian government to give more attention to the development of horticultural crops (Anonymous, 1990a). This was enhanced by the potential for export of fruit. In the current economic crisis in the country foreign currency earning commodities are very welcome.

Knowledge on most tropical fruits is still scarce. Whereas the yield level of tropical plantation crops such as oil palm, cocoa and coffee, and of leading fruit crops from the temperate zone, such as apple and grape has increased several-fold through sustained research efforts, the contribution of science to the development of tropical fruit crops has so far been very modest (Verheij and Coronel, 1991). Salak also has received little attention from scientists. Because the crop is virtually limited to South-East Asia and Indonesia is by far the largest producer, it is only fitting that research workers in this country do their best to promote development of the crop.

1.2. General characteristics of palms

Botany and ecology

Linnaeus named the palms **Principes**, which means: 'the princes among plants'. Because palms are at home in the tropics and not in Europe, they came late to the attention of taxonomists. In 1753, Linnaeus recognized only 10 species of true palms. However, in Heywood's book on flowering plants, Whitmore (1993) lists 212 palm genera, comprising 2,780 species, distributed over Africa, the Indian Ocean islands, South America and the South-East Asian tropics (the region with the largest diversity: 97 genera and 1,385 species). This large increase in number of species indicates that the work of taxonomists on palms is still far from complete.

Palms grow in a wide range of ecological conditions. Some palms grow in deserts, others in swamps; they are found on limestone (Hodel, 1993; Pritchard, 1993) and even on ultra basic soils (Merlo et al., 1993). More than 75% of the palms are rain forest species and they show a great diversity of habit in the forest understorey. Generally speaking (and as a result of long-term natural selection and evolution) palms with inflorescences in the leaf axils are found in congenial environments, because they have to continuously balance vegetative growth and flowering/fruiting. On the other hand palms in which the terminal bud converts into an inflorescence (ending the life of the palm), can more easily adapt to extreme environments, because adverse conditions just slow down growth, postponing flowering and fruiting. The palms whose growth culminates in a single flowering event are called **hapaxanthic**, the ones, which flower repeatedly while they continue to grow, are **pleonanthic** species.

Palms are economically important because they include major plantation crops (oil-palm, coconut, date-palm, etc.) as well as many lesser crop plants, sources of cane, oil, starch, wax, fibre, sugar and alcohol. Nowadays, the palms have also become increasingly important in ornamental horticulture because of their elegant and predictable shapes (Hodel, 1993).

In spite of the large number of species and the adaptation to a wide range of environments, the diversity of growth habits in palms is limited to 5 architectural models, as defined by Hallé et al (1978) and presented by Tomlinson (1990):

1. Holtum's model: trees with an unbranched axis and a terminal inflorescence, for example *Corypha* and most species of *Metroxylon*. These can be described as *single-stemmed hapaxanthic palms*.
2. Corner's model: trees with an unbranched axis and lateral inflorescences, represented for example by *Areca catechu, Cocos, Elaeis, Roystonea* and *Phoenix canariensis*, which can be described as *single-stemmed pleonanthic palms*.
3. Tomlinson's model: trees with the axis branched exclusively from the base, represented by all *multiple-stemmed palms*. Two subdivisions are recognized: *hapaxanthic* (*Metroxylon* spp., *Eugeissona minor*) and *pleonanthic* (*Bactris gasipaes; Calamus trachycoleus*) palms. The salak palm belongs to the pleonanthic form of this model.
4. Schoute's model: trees with an aerial axis branched exclusively by equal *dichotomy*, i.e. equal division of the shoot apical meristem, represented by non-suckering species of *Hyphaene* and *Vonitra*.
5. Mixed architecture model: combination of Schoute's and Tomlinson's models (*Nannorrhops ritchiana*); Corner's and Tomlinson's models (*Serenoa repens*).

Growth and development

The growth and development of palms can be divided into five stages (Tomlinson, 1990):
1. Embryonic phase: from zygote formation to the dormant embryo in the seed.
2. Seedling phase: from the start of germination until the seed reserves in the haustorium are finished.
3. Establishment phase: the extended period of early development until the terminal bud of the rosette attains its full size.
4. Mature vegetative phase: the period extension of the vegetative axis – the palm trunk – through the formation of leaves of a near-constant size.
5. Reproductive phase: from the appearance of (the) inflorescence(s) until the end of the palm's life.

The different phases are describes in more detail below.

Embryonic and seedling phase

The embryos of palms are very small in relation to the total size of the seed and endosperm and they have a single cotyledon. The cotyledon has two main regions: the distal portion or haustorium remains within the seed and the proximal portion extends to push the shoot and root axis of the seedling into the ground (DeMason, 1984). Tomlinson (1990) divides palms into two groups according to germination types, i.e. remote germination (young plant positioned at some distance from the seed through the extension of the cotyledonary sheath axis) and adjacent germination (cotyledonary sheath axis unextended). The cotyledonary sheath may or may not have a ligule, i.e. a protuberance through which the scale leaves and the first bladed leaf emerge. When a ligule is produced the germination is called ligular, but if not present germination is called non-ligular.

In seedlings of the palm family, the haustorium expands at the expense of the endosperm, absorbing the degradation products from the endosperm. These products may be modified and are eventually transported to the seedling axis. At the end of the germination period the spongy haustorium has completely absorbed the endosperm and fills the seed cavity; at that time the leaves are able to photosynthesize and sustain growth (Hartley, 1988).

Establishment phase

During the establishment phase the young seedling produces ever larger leaves from a growing point which expands till it reaches its ultimate size, reflecting the local growing conditions. At that stage the leaves attain their full size, the rosette of leaves expands no further and the formation of the palm trunk can begin. A suckering palm, such as the salak, also suckers freely during the establishment phase, forming a stool to extend its territorial claim.

Mature vegetative phase

During the mature vegetative phase palms grow in height, but do not spread further. The dimensions of the crown have become more or less constant, because leaf size and number have reached a steady state. The number of leaves is kept fairly constant because for each emerging leaf an old leaf withers. Likewise the root system has reached a steady state, new adventitious roots replacing decaying ones.

Reproductive phase

The main distinction here is that between hapaxanthic (once-flowering) and pleonanthic (continuously flowering) palms, already referred to above. In hapaxanthic palms the reproductive phase comes at the end of the mature vegetative phase; in fact it spells the end of the palm's life. In pleonanthic palms the reproductive phase tends to be reached on completion of the establishment phase and thus coincides with the mature vegetative phase. Whereas in hapaxanthic palms the distinction between a juvenile and an adult stage is not really relevant, pleonanthic palms conform to the notion that the young plant exhibits juvenile traits and that the more complex source-sink relationships in the adult plant may have consequences for crop husbandry.

Palms are either wind-pollinated (**anemophilous**) or animal-pollinated (**zoophilous**) crops. In zoophilous palms precisely timed relations between opening of female and male flowers and 'visiting hours' of successive swarms of pollinating insects have been reported, e.g. for the pejibaye (Mora-Urpi and Solis, 1982; Beach, 1984).

According to Tomlinson (1990) there are three types of sex distribution in palms: dioecy, monoecy, and palms with perfect flowers. Dioecy means a single palm produces one sexual type only; monoecy means that both sexual types are produced but in different flowers (either male or female), while in plants with perfect flowers both pistillate and staminate organs are present in a single flower.

Palms can be very fruitful. Ouvrier (1984) showed that in coconut almost half the energy fixed annually by the palm is going to the fruit; in oil-palm this fraction can even exceed 50% (Corley, 1983).

Leaves: form, number, and longevity

Foliation of palms is special because of the large size and limited number of leaves in a crown. During the seedling and establishment phases the shape and the size of the leaves change gradually, until the form and size of the mature vegetative phase are reached. Before the production of green-bladed leaves, the plumule produces one or more bladeless sheaths or scale leaves. The function of the scale leaves is to help the plumule to break the soil surface.

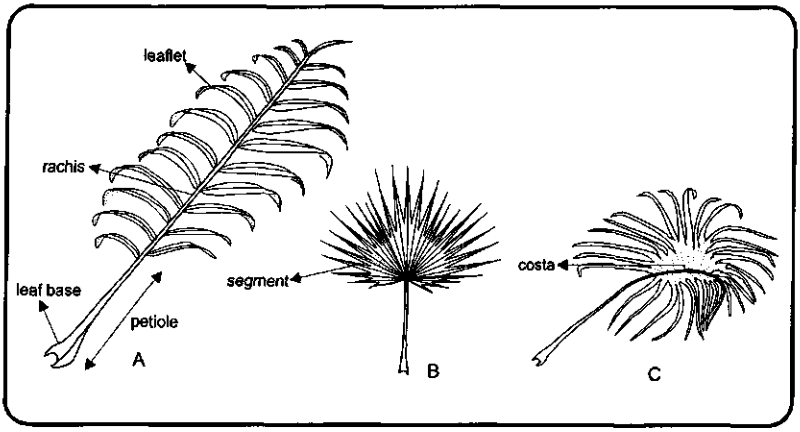

Figure 1.1. Leaf form in palms.
A: pinnate leaf; B: palmate leaf; C: costapalmate leaf.
Redrawn based on Tomlinson (1990); Hickey and King (2000) with modifications.

The first green-bladed leaf following germination is called **'eophyll'**, from the Greek 'eos': dawn or early and 'phyllon' meaning leaf (Tomlinson, 1990). There are two forms of eophyll, i.e. (i) linear or linear lanceolate such as *Phoenix pumila* and *Washingtonia filifera*; and (ii) emarginate or bifid as in *Chrysalidocarpus lutescens* and *Salacca zalacca*.

All palm leaves have a sheath, a petiole and a lamina. The lamina mostly has one of three general shapes: it can be palmate, lacking a rachis; it can be pinnate, where leaflets are borne on the rachis; or it can be costapalmate, an intermediate shape in which palmately arranged leaflets are born on a very short rachis or costa (Bell, 1991). For more details, see Figure 1.1.

The sheath of each leaf clasps the terminal bud, the sheaths of the younger leaves being enclosed in those of the older leaves. The leaf initials in the bud are dome shaped, the older ones completely enfolding the younger ones.

The leaf population in the crown consists of a series of unexposed leaves (Lu) and exposed leaves (Le), the total leaf population in the crown, (n), being:

$$n = Lu + Le$$

In the palm species in which these numbers have been counted, the numbers of unexposed leaves and exposed leaves are usually about equal. In the few instances where this was not the case, there were more unexposed than exposed leaves (Tomlinson, 1990). The production of unexposed leaves and the duration of their functional life are influenced by growing conditions. When growing conditions get worse so that the exposed leaves cannot sustain the terminal bud any more, the terminal meristem will form smaller leaf initials. If there are fewer unexposed than exposed leaves, it will take a relatively short time before the smaller leaves can be exposed to establish a new equilibrium with the poorer growing conditions. In a palm with many unexposed leaves this period to adapt to changed conditions would be excessively long; such a species would be at home only in a fairly constant environment. Hence the fact that Lu and Le tend to be equal, can be interpreted as an attempt to balance flexibility with continuity of growth, corresponding with the observation that 75% of the palm species are at home in the rain forest, where growing conditions tend to be rather steady.

Palm leaves are large and the period from initiation till full exposure is very long. So much is invested in each leaf that it must be able to function for a long time. Corner (1966) offers an equation of leaf-longevity (LL):

$$LL = np \text{ days}$$

in which

LL leaf longevity
n number of unexposed and exposed leaves (Lu + Le)
p the interval between emergence of successive leaves.

In a healthy coconut palm there may be 30 leaves present in the crown, in addition to a similar number in the bud (Child, 1974). On average, the coconut produces 12-14 leaves per year, thus, assuming the interval to be one month, the leaf longevity of a single leaf from primordium to leaf fall is (30 + 30) x 1 = 60 months. Of this 5-year period the leaf is in the making for 2.5 years and functions in the crown for a similar period. A true sago palm growing under optimum ecological conditions produces equal numbers of unexposed and exposed leaves, each 24. The interval between emërgences of successive leaves in a healthy palm is around 30 days. Hence, the leaf longevity from primordial to senescence is 48 months (Flach and Schuiling, 1989), 2 years in the bud and 2 years exposed in the crown.

1.3. Classification of the family Palmae and of the genus *Salacca*

The palms are such a distinct group of plants that they have all been kept together in a single family. Uhl and Dransfield (1987) divide this large family in six sub-families and distinguish several tribes and sub-tribes within most sub-families. Their classification is based on several characters including morphology, anatomy, fossil records, geography, ecology and also describes the evolution and relationships among palms.

As a member of the palm family, the salak palm belongs to the subfamily Calamoideae Griffith, tribe Calameae Drude, subtribe Calaminae Meisner and genus *Salacca* Reinwardt. The closest relative of the genus *Salacca* is *Calamus* Linnaeus, another genus in the same subtribe, which includes nearly all the economically important rattans. Another subtribe, the Metroxylinae Blume, contains the true sago palm (*Metroxylon sago* Rottb.), which nowadays receives increasing attention as a starch crop.

The Calamoideae, which includes the salak palm, comprises 22 genera, the largest being *Calamus*. The subfamily occurs in areas of high rainfall and is especially frequent in swampy regions with the genera *Mauritia* in Latin America, *Metroxylon* in South-East Asia and *Raphia* in Africa. The subfamily can be distinguished by the closely overlapping scales, which cover the ovaries and fruits. The fruits commonly have a fleshy layer, sweet to exceedingly sour. Moreover, this subfamily shows spines, cirri and prickles. The chromosome number (n) is 14 (Whitmore, 1993).

The genera *Calamus* and *Salacca* are two of the eight genera of the subfamily Calamoideae, tribe Calameae and subtribe Calamineae. Calamineae are important in furniture making and as edible fruits. The two genera have some behavioural similarities: branching at the base, mostly dioecious, scaly fruits, 1 - 3 ovules within the ovary, the seed with an edible outer fleshy layer, adjacent-ligular germination (Dransfield, 1979; Manokaran, 1985). Rattan (*Calamus* spp.) is one of Indonesia's more important export commodities.

1.4. Description of the genus *Salacca*

The genus *Salacca* is dioecious, usually acaulescent, spiny and clustered. The stem is partly erect, procumbent and short. The internodes are very short, often with abundant adventitious roots. The suckers grow from a leaf base. The leaves are pinnate or palmate with pinnate venation. The inflorescence is borne at the leaf sheath base. The staminate flower is borne in dyads with two small prophyllar bracteoles; there are stamina, which appear at the mouth of the corolla tube. The pistillate flower is in a dyad with a sterile staminate flower; the form of the calyx is tubular at the base and it contains a trilocular ovary. Seed is basally attached. The sarcotesta or flesh of the fruit is thick, sour or sweet; the endosperm is firm (Dransfield and Mogea, 1986).

So far, about 19 species of *Salacca* have been identified (Mogea, 1986, 1990). They are distributed over southern Yunnan, lower Burma, Thailand, the Malay Peninsula, Sumatera, West-Java, Borneo (Kalimantan) and the southern part of the Philippines (Mogea, 1980). The largest number of species is found in Borneo (about 10 species), in the Malay Peninsula and Sumatera (7 species each) (Mogea, 1986). Out of 19 species, 13 have recently been identified in South-East Asia (see Table 1.1).

Of the species listed in Table 1.1, *S. sumatrana*, *S. zalacca* and *S. wallichiana* are cultivated, the first two mainly in Indonesia (Mogea, 1986; Schuiling and Mogea, 1991), the latter almost exclusively in Thailand (Polprasid, 1991). The leaves of these species are pinnate, but the top part of the leaf is palmate/flabellate. The most distinct character of this group is that the species are dioecious and therefore need pollinator plants to produce fruits. Only one taxon reveals a monoecious character, the Balinese salak from Karangasem, Bali, Indonesia (Moncur and Watson, 1987); it has been named *S. zalacca* var. amboinensis (Becc.) Mogea by Schuiling and Mogea (1991).

S. sumatrana is dioecious and grown in the highlands. The male inflorescence consists of 25 - 40 spadices. The mature palm is much bigger than *S. salacca*. The palm is cultivated in dense stands in the highlands. One in three or one in four are male flowering; artificial pollination is not practised. The colour of the fruit flesh is reddish.

1.5. The cultivated salak in Indonesia

Production centres, area and yield

Two different species of salak in Indonesia produce edible fruits. *S. sumatrana* Becc. is mostly cultivated by farmers in northern Sumatera and *S. zalacca* (Gaertner) Voss is grown elsewhere in Indonesia. The centres of salak production are Sumatera (around Toba lake, Padangsidempuan), West Java (Jakarta, Sumedang, Tasikmalaya), Central Java (Sleman, Yogyakarta), East Java (Bangkalan, Pasuruan, Malang, Bojonegoro, Jombang), North Sulawesi (Pangu, Tagulandang) and Bali (Karangasem) (Sudaryono et al., 1991; Mogea, 1978a); see Figure 1.2.

Data on area and production are scarce and vary, but they indicate rapid

Table 1.1. South-East Asian species of the genus *Salacca* (Haryani, 1994)*.

No	Species	Found in:
1.	*S. magnifica* Mogea	Sarawak (Malaysia) East Kalimantan (Indonesia)
2.	*S. multiflora* Mogea	Malaysia
3.	*S. affinis* Griff.	Sumatera (Indonesia); Malaysia
4.	*S. sumatrana* Becc.	North Sumatera (Indonesia) Tapanuli (Indonesia)
5.	*S. zalacca* (Gaertner) Voss	Sumatera, Java (Indonesia)
6.	*S. glabrescens* Griff.	Malaysia
7.	*S. sarawakensis* Mogea	Sarawak (Malaysia)
8.	*S. dubia* Becc.	South Sumatera (Indonesia)
9.	*S. flabellata* Furtado	Trengganu (Malaysia)
10.	*S. minuta* Mogea	Malaysia
11.	*S. dransfieldiana* Mogea	South Kalimantan (Indonesia)
12.	*S. vermicularis* Becc.	Kalimantan (Indonesia)
13.	*S. wallichiana* Wall. & Mart.	Thailand

*Scientific names according to Ferguson (1986) and Mogea (1986).

expansion of salak growing in Indonesia. Soerojo (1993) reports a doubling of the area, from 10,000 ha in 1986 to 20,000 ha in 1990, the yield level remaining steady at around 6.8 t/ha per annum. In 1992 the production was about 197,000 t, with Java coming first (148,000 t) while Sumatera produced only around 11,000 t (Anonymous, 1996). In East Java the population of salak has also increased sharply. The palm population in 1984 was 3.9 million plants with a production of 48,000 t. In 1987 the population had increased to 6.7 million plants with a production of 110,000 t (Anonymous, 1987).

The fruit production of the varieties per annum per ha varies. The average production of 'Pondoh', mainly grown in kabupaten Sleman of Yogyakarta, is 6.8 t per ha (Sudaryono et al., 1991), while for other varieties in the salak production centres in East Java it is 4.5 t per ha (Ashari, 1993). The difference in the yield level is probably mainly due to the agronomic practices of the gardeners, such as weeding, fertilizing and, the most important one, hand pollination.

Salak cultivation will very likely expand in Indonesia, especially around the large cities where fruit is constantly in high demand. The demand will increase in line with the increase in population, in income per capita, in awareness of need for better nutrition and the development of tourism.

Varieties and cultivars

Salak is an out-crossing crop and commonly propagated from seed. Hence the varieties are ill-defined; they are usually named after the locality where they have come to the fore. There is little information about the way in which growers select seeds for propagation and there are no authoritive descriptions of varieties. As said before, the salak of Bali, also grown in Ambon, is distinct because it is monoecious.

Among the dioecious varieties 'Pondoh' assumes true cultivar traits, because the current expansion originated from a single plant and it is increasingly propagated from suckers rather than seeds. The history of 'Pondoh' has not been clearly documented.

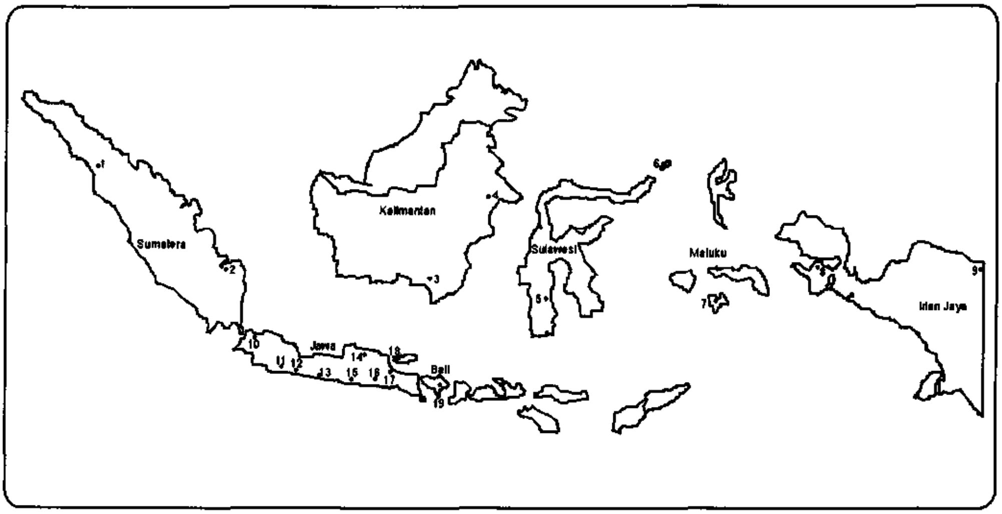

Figure 1.2. The production centres of salak in Indonesia.
1. Padangsidempuan; 2. Palembang; 3.Banjarmasin; 4. Samarinda; 5. Enrekang; 6. Tagulandang; 7. Ambon; 8. Fakfak; 9. Jayapura; 10. Jakarta; 11.Tasikmalaya; 12. Manonjaya; 13. Sleman; 14. Bojonegoro; 15. Jombang; 16. Malang; 17. Pasuruan; 18. Bangkalan; 19. Karangasem.

The delicious taste of the 'Pondoh' fruit was already reported by Ochse in 1931. According to Santoso (1990) a 'Pondoh' plant was given to a farmer by a Dutch tobacco planter before he left for the Netherlands. The farmer, Partomejo, and his son propagated it; in 1954 the son (Muhadiwinarto) had about 1000 plants.

Salak 'Pondoh' was first planted in the villages Soka, Merdikarejo, Candi and Mengunkerto of kecamatan Turi, kabupaten Sleman. Because of its excellent taste, the cultivar has been planted also in other parts of Yogyakarta area such as Tempel, Pakem, Mungkid. The average meteorological data for Sleman are presented in the Appendix 1. Recently the number of 'Pondoh' has increased sharply. The cultivar is not only grown within Yogyakarta area but also elsewhere on Java and on other islands (Purawinata, 1989). However, the number of 'Pondoh' plants in kabupaten Sleman of Yogyakarta is still lower than that of the other varieties combined (Table 1.2).

Most observations in this study refer to 'Pondoh'; where salak from different localities has been compared in the experiments below, the term 'varieties' has been used for the sake of convenience.

The production techniques and cropping system of salak

Salak is usually planted around the house in the home garden, but larger market gardens (one to several hectares) are not uncommon in some villages. Large orchards are found in Bali, because the monoecious variety on that island does not need hand pollination. In Java more than 30% of the production costs is for hand pollination (Ashari, 1993). This high share suggests that crop care is not very intensive and that is indeed the case. The growers usually do not irrigate, apply fertilizer, or control pests and diseases. Senescent leaves are cut and left as mulch. Growers believe that fertilizers affect the soil negatively, cause fruit drop and shorten shelf life of the fruit

Table 1.2. The population of salak palm in kabupaten Sleman in 1992.

Cultivar	Population (plants)	Production (kg/plant/year)
'Pondoh'	423,451	13.3
'Non-Pondoh'	1,418,551	11.8

Sources: Anonymous (1995, in Padmosudarso, 2000).

after harvest. Other cultural operations are weeding and desuckering in young salak gardens; old gardens tend to be so dense that few weeds and suckers grow out.

Salak is commonly intercropped with fruit trees such as rambutan, durian, langsat etc. These trees also provide shade for the salak. It is generally agreed that shade is essential for young salak plants to survive, and when salak is planted short-duration shade plants such as banana or *Sesbania grandiflora* ('turi') are usually interplanted to add to the shade of existing trees. A full-grown salak garden is very dense with extensive mutual shading by the palms. It is not clear whether in this situation shade trees are still important. They may just be a remnant of the mixed crops in the home garden, or their shade may still be welcome in areas with a pronounced dry season, as in East Java.

When a new salak garden is established, salak is still largely grown from seed. The crop is dioecious, thus about half the plants will be male-flowering. In case of direct seeding 4 - 5 seeds are sown in a hole (60 x 60 x 60 cm) dug to incorporate 5 kg of dry mature dung. In other cases, the seedlings are raised in the nursery and planted in the appropriate hole. The spacing is 2 x 2.5 m to 2.5 x 2.5 m; short-term shade trees (banana or turi) are interplanted at the same spacing.

The maintenance of the young plants consists of weeding, fertilizing and cutting of excess suckers and ageing leaves. When the plants are 3 - 4 year some are already flowering. The male plants are rogued leaving only 2 - 20 percent male-flowering plants to supply pollen for hand pollination. In the year after planting fertilization with urea (46% N), TSP (46% P_2O_5) and KCL (52% K_2O), at the rate of 60 - 90 g, 40 - 60 g and 20 - 30 g per plant position, respectively, is recommended; these quantities are to be increased slightly in the following years (Tjahjadi, 1989). However, fertilizer application is the exception rather than the rule.

Constraints for development of the crop

The yield of salak varies much more widely than the average figures of 4.5 ton (Ashari, 1993) to 6.8 ton per ha per annum (Sudaryono et al., 1991). This is also indicated by Padmosudarso (2000) who reports yields per plant ranging from 5 to 13 kg per year. The variation is not only due to differences in dry or wet monsoons, but also to limited crop care by the growers, associated with a poor understanding of the requirements of the crop, e.g. with respect to

- pollination,
- supply of water and nutrients,
- planting density, desuckering and intensity of shade,
- crop protection, etc.

Moreover, the quantity – and perhaps even more so: the quality – of the crop also differs for different varieties.

It is likely that higher and more stable yields could be achieved if research work can clarify crop requirements and if this can be translated into a better choice of varieties and improved growing conditions.

1.6. Research issues and the research programme

From the foregoing description of salak cultivation in Indonesia it is clear that the crop is still grown in a traditional way, based on experience gained by the growers themselves. The contribution of science so far has been quite small.

Botanists have described the plant, but detailed studies are limited to a description of germination and the seedling by Mogea (1978b), the position of the inflorescence buds in *Salacca* by Fisher and Mogea (1980) and the floral biology of the monoecious salak by Machfoedi (1953) and Moncur and Watson (1987). Growth and development have not been studied in quantitative terms (e.g. the rate of leaf production, suckering, emergence of inflorescences and fruit set) and the seasonality of fruit production has not been explained.

The number of agronomic studies on salak in Indonesia is increasing rapidly. These studies describe salak cultivation in different regions with emphasis on the expanding areas (Lahiya, 1984; Sudaryono et al., 1991), on 'Pondoh' (Santoso, 1990; Siswandono, 1989), and on the suitability of soils (Padmosudarso, 2000). Several reports compare the fruit of different varieties (Haryani, 1994; Sarwono and Maryanti, 1990;) and the start of selection and hybridization work (Purnomo and Sudaryono, 1994; Purnomo and Dzanuri, 1996); in this context the report on vegetative propagation through air layering by Kasijadi et al. (1999) is also important. The tolerance of salak seed to drying, chilling and attack by fungi was investigated by Purwanto et al. (1988). Nutrient levels in the leaves have been determined by Kusumainderawati et al. (1992) and fertilizer recommendations are given by Tjahjadi (1989) and Sholeh et al. (1994). Baswarsiati et al. (1991) and Bawarsiati and Rosmahani (1992) have observed pollinating insects on salak. The economics of salak growing and export potential have also been subject of studies (Ashari, 1993; Kasijadi, 1996; Purawinata, 1989).

These studies are all recent and – in as far they are based on experimental work – the results are tentative, requiring continuation of the experiments or verification.

Thus topics for research work abound, both regarding the botany and the agronomy of the crop. For this thesis research objectives were chosen so that the experimental work fitted in the research programme of the Agricultural Faculty of Brawijaya University. For a perennial crop such as salak long-term experiments are needed to resolve most of the agronomic issues. One long-term experiment, a variety trial, could be accomodated at the research farm of the University. For most other experimental work the cultivar Pondoh was used, because it is gaining prominence. These other experiments were of short duration, mainly because thesis work of undergraduate students is limited to 6 months.

The variety trial led to a comparison of methods to measure or estimate leaf area, also in order to facilitate calculation of LAI in future experimental work.

The seed lends itself to short-duration trials. Salak seed is recalcitrant, and it was attempted to prolong seed viability by storage in different media. A trial in which germination was studied after removal of different portions of the endosperm is botanical in nature rather than agronomic, but in most of the experimental work aspects of botany and agronomy were combined.

Environmental factors – soils, nutrient supply, and shade level – were also included in the study, but these had to be limited to observing the growth of seedlings for a short period only.

To help resolve problems in existing salak gardens, two experiments were designed to study pollination, a crucial factor in determining yield; another experiment, putting the belief held by growers that fertilizers have adverse effects on yield to the test, was also conducted in an old salak garden.

Aspects of botany which were studied, mainly in 'Pondoh', include:

- the germination process in treatments where the endosperm was kept intact or partly removed;
- duration of growth stages of individual leaves, and the phyllochron and changing leaf shape and size in seedlings;
- numbers of unexposed leaves (in the terminal bud) and exposed leaves;
- phyllotaxis and position of leaf and flower buds;
- suckering;
- importance of pollination intensity and pollen source;
- fruit shape and size in relation to number of seeds per fruit.

1.7. Outline of the thesis

From November 1989 till January 1994 a series of field experiments was conducted to clarify agronomic aspects of salak growing. Most of the experiments were conducted with 'Pondoh'. These experiments are reported in Chapters 2 - 5.

Chapter 2 describes the only long-term experiment, a variety trial which was continued till the end of the juvenile phase. The problems encountered with leaf area measurements in this trial led to another experiment in which different ways to estimate leaf area are compared. This experiment is also reported in Chapter 2.

Chapter 3 is devoted to pollination experiments; the effects of more intensive pollination and the effectiveness of a range of pollinator varieties on two female-flowering varieties were studied in mature salak gardens.

Chapter 4 deals with the salak seed. Germination after removal of different portions of the endosperm was studied, as well as the effect of seed storage in different media and for different periods of time on germination.

In Chapter 5 experiments with potted plants are described. The seedlings were grown in soils collected from four salak centres. The soils were compared to Jatikerto soil where the salak cv. Pondoh is to be introduced.

Whereas the field experiments were designed to clarify aspects of the agronomy of the crop, they also yielded much information on growth and development of salak. Moreover, alongside some of the experiments, additional 'Pondoh' plants were raised for botanical observations. In Chapter 6 all this information is combined with published data in order to outline a model of the growth and development of salak.

The findings in the various experiments are further discussed in Chapter 7.

1.8. Limitations of and constraints to the experimental work

As the salak palm is a perennial, long-term agronomic research is needed. Treatments applied in one year may still have an effect on the plant in the following year(s). This study does comprise one long-term experiment, but it is limited to the juvenile phase and the onset of flowering. Nearly all other experiments covered periods of up to 6 months only, which in some cases – e.g. plant nutrition studies – is far too short to arrive at practical recommendations for growers. Nevertheless several experiments of this nature are reported in this thesis, because even within the short period of time the palms responded to the treatments. The 8-month duration of the pollination experiments reported here was about adequate, but ideally the experiments should have been repeated in successive years, which in this case was not possible.

The contribution of students to this study was substantial; several of them devoted their BSc thesis to salak research work; these theses are listed separately under References. However, student thesis work is limited to 6 months, and this is one reason for the short duration of experiments.

The spiny nature of salak also is a serious handicap for experimental work. Observations and records requiring close contact with the plants – e.g. determining phyllotaxis, bud positions in the axils, or leaf area measurements – are painful. Getting to grips with salak means getting hurt!

CHAPTER 2: VEGETATIVE AND GENERATIVE GROWTH

This chapter describes observational and methodological experiments in which the development over time of the number of leaves, the leaf area, the suckering, flowering and sex expression are quantified.

2.1. Variety trial: seedling and establishment phases

Introduction

The growth of plants in general consists of a vegetative and a generative stage. Vegetative growth is initiated by germination of the seed. Flower initiation marks the transition from vegetative to reproductive development in crop plants (Goldsworthy, 1984). Each crop, however, has a different timing with respect to onset and ending of these growth stages.

In palms, however, the vegetative phase is divided further into four phases, i.e. the embryonic phase, the seedling phase, the establishment phase and the mature vegetative phase (Tomlinson, 1990).

According to Mogea (1978b) the seedling phase – from germination till the moment that growth no longer depends on reserves in the seed, i.e. the heterotrophic growth phase – lasts 100 to 109 days in salak. However, the length of this period may range much wider if effects of genotype and growing conditions are taken into account.

During the establishment phase the palm seedling stakes out its territorial claim by forming a full complement of expanded leaves; salak also suckers freely during this phase.

The seedling and the establishment phases together make up the juvenile period, which is said to last 3 - 4 years in the salak palm (Santoso, 1990) and comes to an end when the first flowers are initiated. The length of this period may also depend on cultivar and growing conditions.

The mode of suckering of the sago palm, a plant which belongs to the same subtribe as salak, has been studied by Flach (1983). He concluded that suckers inhibited the growth of the mother trunk, and thus could delay the harvest.

Information on the early growth of salak is scanty. When a variety trial was planted at Jatikerto research farm this offered an opportunity to observe for a number of varieties such parameters as rate of leaf production, changes in shape and size of the leaves as the palms get established, the onset of suckering and the numbers and disposition of the suckers, etc., until the emergence of the first inflorescence, indicating the end of the establishment phase.

The early growth and suckering of salak have not yet been investigated. In the experiment described here, leaf growth and suckering of different seedling progenies were studied over a period of about 2½ years after sowing.

Materials and methods

The experiment was conducted at the Research Station of Brawijaya University at Jatikerto. Climatic data for Jatikerto are presented in Appendix 2.

Experimental design

Seven varieties grown from seed were used in the experiment, namely 'Kersikan' (black and yellow); 'Suwaru' (black and yellow); 'Kacuk' (black); 'Bali' (black); and 'Pondoh' (black). 'Black' and 'Yellow' refer to the colour of the fruit skin; growers use the terms 'Budeng' and 'Gading', respectively, and consider the colour a stable distinguishing trait. More than 200 seeds of each variety were sown in polythene pots on November 19, 1989, in order to obtain at least 100 seedlings per variety, except for 'Pondoh' which was sown on February 5, 1990. All references to age of the plants in this report are in relation to these dates of sowing. After the first simple leaf had matured, 90 good seedlings of each variety were planted in a complete randomized block design in three replicates, each plot consisting of a single row of 30 plants, spaced 50 cm apart. The inter-row spacing was 2 m. Surplus seedlings were planted as guard row plants around the experimental field. To provide shade *Sesbania grandiflora* was sown in the experimental field. At the time the salak varieties were planted out, the shade trees were about 1 m high, and spaced 2 x 1 m in rows alternating with the salak rows. When the salak rows became overcrowded, half the plants were grubbed to increase the spacing to 1 m. Further thinning to provide adequate space was effected by removing most male-flowering and some female-flowering plants after flowering set in, 30 months from sowing. As a consequence, at the end of the experiment the total number of plants in the experiment ranged from 22 to 25 for the different varieties.

Agronomy

Individual plants were fertilized with 500 g cattle manure, 20 g urea, 20 g TSP (triple super phosphate) and 20 g KCl. These quantities were provided every 6 months, in October and April, i.e. before the beginning and towards the end of the wet season.

Data collection and analysis

In the young seedlings the rate of growth of simple leaves was measured by recording the number of days from leaf emergence, that is when the new spear has a length of 1 cm, until:

- the spear attains its ultimate length,
- the spear begins to unfold,
- the leaf is mature (indicated by the colour change from pale to dark green).

Later, when compound leaves were formed, these were measured in the same way. The method of measurement of leaf development is illustrated in Figure 2.1; Figure 2.2 shows simple and compound leaves of the palm.

Sixteen months ('Black Pondoh': 13 months) after sowing the number of simple and compound leaves per plant and their leaf areas were measured. The leaf area was determined by multiplying the maximum leaflet length, the maximum leaflet width, number of leaflets on both sides of the rachis with a shape factor. The shape factor was derived by tracing the contour of all leaflets of the sampled leaves on a piece of paper and cutting the tracing out. The weight of the cuttings was divided by the weight of total paper and multiplied by the original paper area (Evans, 1972). The samples consisted of 4 simple leaves (the third oldest) and 4 compound leaves (the second mature leaf from the top) per plot.

When the plants were 19 and 33 months ('Black Pondoh': 16 and 30 months) the number of suckers per plant was recorded.

A complete random block design additive model was used to analyse the collected data according to Steel and Torrie (1980).

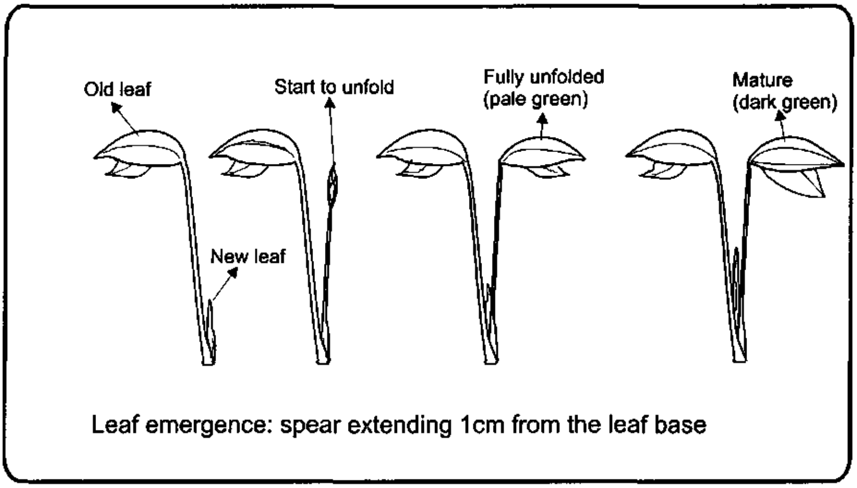

Figure 2.1. Method of measurement of leaf growth stages.

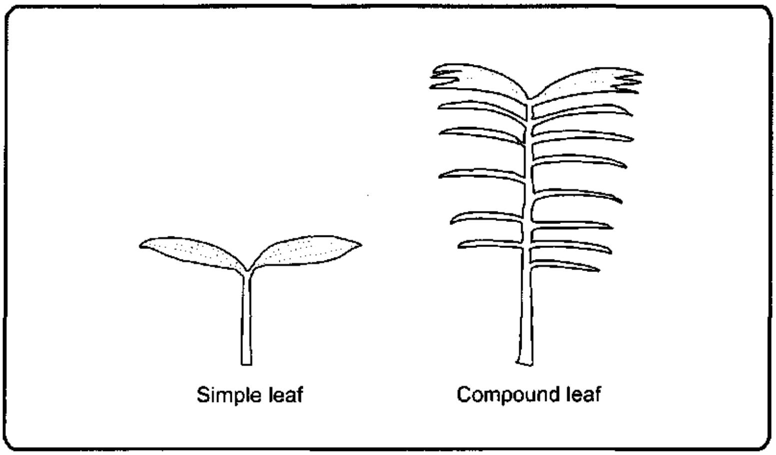

Figure 2.2. Simple and compound leaves of the salak palm.
Note the erratic positions of the leaflets along the rachis and the variation in leaflet size in the compound leaf.

Results

Leaf numbers per plant. Sixteen months after sowing the number of simple leaves varied from 4 to 7 and of compound leaves from 3 to 7 while total leaf numbers ranged from 8 to 12 as shown in Table 2.1. It is clear from Table 2.1 that small numbers of simple leaves tended to be compensated by larger numbers of compound leaves. One reason is that the definition of 'simple' and 'compound' leaf does not take into account the actual gradual change in leaf form: splitting-off of a single leaflet in the fifth leaf, for instance, shifts this leaf from the simple to the compound category. 'Yellow Kersikan' which had the largest number of simple leaves, had the smallest number of compound leaves. 'Black Pondoh' showed the largest number of compound leaves even though the plants were 3 months younger than the others. 'Black Pondoh' also had the largest total number of leaves.

With 12 leaves in 13 months, 'Black Pondoh' produced almost one leaf per month. In the other varieties the average interval between the emergence of successive leaves was approximately 45 - 50 days. The data on total number are calculated as the sum of the averages and thus not statistically analysed.

Leaf area. The shape factors of simple and compound leaves differed. The average value for the simple leaf was 0.6 while that for the compound leaf was 0.7. The shape factors for the simple leaves were not significantly different for the varieties, but those for the compound leaves were (see Table 2.2).

Table 2.3 shows large differences in leaf size between varieties, mainly because the leaves of 'Black Bali' and 'Black Pondoh' were so small. In fact 'Black Bali' grew very weakly; its compound leaves were even smaller than the simple leaves. Perhaps the seeds of this variety were too old; the results of Chapter 4.2 (see below) showed that with increasing duration of storage not only the germination percentage was reduced, but also the growth rate of the remaining seedlings. The small leaf size of 'Black Pondoh' is in agreement with its high rate of leaf production. For the remaining varieties the differences in leaf size were small in comparison with the differences in

Table 2.1. Mean numbers of simple and compound leaves per plant (for 'Black Pondoh' after 13 months, for the others after 16 months).

Variety	Simple leaf	Compound leaf	Total
1. 'Black Pondoh'	4.75 b	7.25 b	12.00
2. 'Black Suwaru'	6.00 c	5.00 ab	11.00
3. 'Yellow Suwaru'	6.50 de	3.75 a	10.25
4. 'Black Kersikan'	6.25 cd	4.75 ab	11.00
5. 'Yellow Kersikan'	6.75 e	3.00 a	9.75
6. 'Black Kacuk'	4.00 a	5.50 ab	9.50
7. 'Black Bali'	4.50 b	4.00 a	8.50

Means in the columns for simple and compound leaves followed by the same letter are not significantly different at P = 0.05.

Table 2.2. Leaf area measurements: shape factors for simple and compound leaves.

Variety	Shape factor	
	Simple leaf	Compound leaf
1. 'Black Pondoh'	0.60 a	0.65 a
2. 'Black Suwaru'	0.64 a	0.69 ab
3. 'Yellow Suwaru'	0.62 a	0.77 b
4. 'Black Kersikan'	0.67 a	0.72 ab
5. 'Yellow Kersikan'	0.64 a	0.73 ab
6. 'Black Kacuk'	0.60 a	0.65 a
7. 'Black Bali'	0.57 a	0.73 ab
Averages	0.62	0.71

Means in a column followed by the same letter are not significantly different at P =0.05.

Table 2.3. Average size of simple and compound leaves and estimated leaf area per plant 16 months ('Black Pondoh': 13 months) after sowing.

Variety	Area per leaf (cm²)		Estimated leaf area per plant (m²)
	Simple leaf	Compound leaf	
1. 'Black Pondoh'	155 a	813 b	0.66
2. 'Black Suwaru'	252 c	980 bc	0.64
3. 'Yellow Suwaru'	230 b	1112 bc	0.57
4. 'Black Kersikan'	241 bc	1144 c	0.69
5. 'Yellow Kersikan'	254 c	1079 bc	0.50
6. 'Black Kacuk'	273 d	992 bc	0.65
7. 'Black Bali'	167 a	156 a	0.14

Means in a column followed by the same letter are not significantly different at P = 0.05.

leaf number in Table 2.1. Consequently the variation in estimated leaf area per plant was substantial. Remarkably 'Black Kersikan' ranked highest, whereas 'Yellow Kersikan', at home in the same area, ranked lowest.

Data on estimated leaf area were calculated by multiplying the values on area per leaf with the values on leaf number in Table 2.1 and thus not statistically analysed.

Leaf growth. The duration of the sequence of growth stages of simple and compound leaves of the seven salak varieties examined was very much the same; there were no significant differences. The emerging leaf extended as a spear leaf during 32 - 35 days for both simple and compound leaves. The simple leaf started to unfold between day 40 and 43, and the compound leaves between 51 and 54 days after emergence. Hence, having attained its maximum length, the leaf does not unfold until after on average 8 days in simple leaves and nearly 20 days in compound leaves.

Leaf maturity of the simple leaf occurred at day 48 - 50 after emergence, while that of the compound leaves took place between day 65 and 67 (Table 2.4). Thus the simple leaves on average took about a week to unfold and mature, the compound leaves nearly 2 weeks.

The average interval between the emergence of successive leaves, calculated above at 45 - 50 days, is about equal to the period from emergence to maturation of simple leaves (48 - 50 days) and much shorter than the 65 - 67 days it takes a

Table 2.4. Number of days from emergence till attainment of successive leaf growth stages.

Variety	Max. spear length		Start to unfold		Leaf maturity	
	Simple leaf	Compound leaf	Simple leaf	Compound leaf	Simple leaf	Compound leaf
1. 'Black Pondoh'	33.6	33.4	41.7	52.5	48.7	65.5
2. 'Black Suwaru'	34.3	32.9	42.7	54.1	49.8	67.3
3. 'Yellow Suwaru'	32.6	35.3	40.7	53.1	47.7	66.0
4. 'Black Kersikan'	33.3	32.2	41.4	51.9	48.5	65.0
5. 'Yellow Kersikan'	33.6	32.3	41.5	52.4	48.6	65.2
6. 'Black Kacuk'	33.2	33.2	42.1	53.8	49.2	66.9
7. 'Black Bali'	35.2	34.4	43.3	54.1	50.4	67.1

Table 2.5. Mean number of suckers per plant 19 and 33 months ('Black Pondoh' 16 and 30 months) after sowing (transformed data based on $\sqrt{(x + ½)}$ according to Steel and Torrie (1980).

Variety	Number of suckers	
	19 months	33 months
1. 'Black Pondoh'	1.0 b	3.9 bc
2. 'Black Suwaru'	2.1 c	4.7 c
3. 'Yellow Suwaru'	1.3 bc	3.0 bc
4. 'Black Kersikan'	2.2 c	3.9 bc
4. 'Yellow Kersikan'	2.2 c	4.0 c
6. 'Black Kacuk'	2.1 c	4.0 c
7. 'Black Bali'	0.0 a	0.0 a

Means in a column followed by the same letter are not significantly different at P=0.05.

compound leaf to grow out. This implies that a new leaf emerges before the previous leaf has turned green, as was indeed the case in the field.

Suckering. At the age of 15 months, the palms started suckering, except 'Black Bali'; the stunted plants of this variety did not produce suckers at all. The average number of suckers per plant 19 and 33 months after sowing is presented in Table 2.5.

Discussion

The pattern of leaf growth of the seedlings was the same for all varieties: following the formation of 4 - 7 simple leaves, 3 - 7 compound leaves were formed with increasingly more leaflets. Every new leaf tended to be larger than its predecessor and after 16 months the average leaf area per plant ranged from 0.50 to 0.69 m^2 for the different varieties. The main exception was 'Black Bali' which grew very poorly. 'Black Pondoh' was also exceptional because of its small leaves, but this was compensated by an equally exceptional rate of leaf production.

The duration of the growth stages of individual leaves – spear extension, spear rest, unfolding and maturation – was very similar for all varieties, but differed for the two leaf forms: simple leaves took 48 - 50 days to grow out, compound leaves 65 - 67 days. Because leaf shape (and size) change in fact gradually, it is likely that the duration of the growth stages also increases gradually rather than abruptly as suggested by these figures.

'Black Pondoh' seedlings produced a total of 12 leaves in 13 months time, whereas seedlings of other varieties made 9.5 to 11 leaves in 16 months time. This works out to a 33 day interval between the appearance of successive 'Black Pondoh' leaves, against 45 - 50 days for the other varieties. These average figures may hide a gradual increase in the phyllochron, perhaps in keeping with the increasing time required for individual leaves to grow out. The calculated rate of leaf production of 'Black Pondoh' is similar to that of bearing coconut (1 leaf per month, Child, 1974), but much lower than in oil palm (2 leaves per month, Hartley, 1988). Since the phyllochron determines potential yield (each leaf axil holds a single inflorescence bud), it is important to verify the phyllochron in bearing palms of different salak varieties.

Nineteen months after sowing most plants had formed two suckers; only the 'Yellow Suwaru' plants lagged behind. After 33 months this variety still had the lowest number of suckers (3 per plant on average), the highest number being found in 'Black Suwaru' (4.7 suckers per plant). Thus suckering starts early, long before the end of the juvenile phase. The sago palm which belongs to the same tribe as salak, suckers in the first year after planting and second order suckers may also be formed (Flach, 1983). Unchecked suckering appears to slow down the growth of the main trunk; therefore farmers practise desuckering (Flach and Schuiling, 1989). In salak suckering causes problems in cultivation as well as in artificial pollination; there is a need to establish the optimum number of suckers per palm, also in relation to yield.

Conclusions

1. Salak seedlings show a gradual transition in leaf form. The first 4 - 7 leaves are simple. Later leaves are compound, near the leaf tip several leaflets remain united.
2. 'Black Bali' seedlings remained stunted; perhaps the seed was too old.
3. Sixteen months after sowing the mean leaf area per plant ranged from 0.50 to 0.69 m^2 for the different varieties. There was not much difference in mean leaf size of either the simple or the compound leaves, with the exception of the rather small leaves of 'Black Pondoh'. In all varieties the duration of the growth stages of an individual leaf was similar, the average period from emergence to maturity being 48 - 50 days for simple leaves and 65 - 67 days for compound leaves.
4. 'Black Pondoh' plants produced 12 leaves in 13 months, the other varieties 9.5 - 11 leaves in 16 months, leading to a calculated phyllochron of 33 days and 45 - 50 days, respectively. These average numbers of days, like the numbers of days in the previous conclusion, may hide a gradual increase in duration as the leaves become larger. Because of its importance for potential yield, the phyllochron should be measured in bearing salak varieties too.
5. Suckering starts early: most 19-month-old plants had 2 suckers, after 33 months the average was nearly 4 suckers. There may be scope to select for limited suckering, because 'Yellow Suwaru' had fewer suckers than other varieties, after 33 months as well as after 19 months.

2.2. Variety trial: onset of flowering and dioecy

Introduction

Vegetative and generative growth of plants should be balanced. The vegetative parts: leaves, stem and roots, should be adequate to support the generative parts, consisting of inflorescences, fruits and seeds. The age at which plants complete their juvenile phase, i.e. the period from germination until first initiation of flowers, differs between species and even within a species.

The kind of planting material also influences this period. If seeds are used, especially in perennial crops, the time needed by the plant to bear flowers is much longer than if asexual parts such as stems, rhizomes or leaves are used; in the latter case the propagule may already have progressed to flowering but it still has to complete its organs (branches, leaves, etc.) before it becomes capable of bearing flowers.

Salak is mostly propagated from seed. The plant requires 3 - 4 years from sowing till flowering (Tohir, 1983; Tjahjadi, 1989; Schuiling and Mogea, 1991). Well-sized suckers will flower after 2 - 3 years. Environmental factors such as temperature, humidity and nutrients also influence the start of the generative phase. Few aspects of the generative phase of the salak palm have been studied. This report concerns the onset of flowering in a variety trial, to determine the length of the juvenile phase and the ratio of female : male flowering plants.

Materials and methods

This experiment is a continuation of the one described in Chapter 2.1; hence the layout and the varieties are the same. Only 'Black Bali' had to be excluded because it grew so poorly that it could not be expected to flower. The first plant flowered in March 1992, 28 months after sowing. The number of plants, which had come into flowering, was recorded monthly from 34 to 42 months ('Black Pondoh': 31 - 39 months) after sowing, separately for male and female flowering plants. At the age of 33 months the salak stand became so crowded that getting into the row became problematic. Therefore, plants were desuckered after 33 months, leaving only the two smallest suckers and thereby facilitating observations.

Results

The number of flowering plants. The plant that flowered after 28 months was male, as were most of the plants which came into bloom in the following months. These male flowering plants were removed after recording their sex to relieve the congestion in the rows.

After 34 months, when monthly recording started, 2 or more plants had come into bloom in all varieties (except in the younger 'Black Pondoh' plants), 'Yellow Kersikan' having 7 plants with inflorescences (Table 2.6). The numbers increased gradually, in some varieties ('Yellow Suwaru', 'Black Kersikan') with a sudden leap in one month. When the experiment was terminated, after 3½ years, the percentage of adult plants ranged from 83 for 'Black Kacuk' to 50 for 'Black Suwaru', 'Black Pondoh' scoring 25%.

Looking at the monthly increase in number of plants which have issued inflorescences for the experiment as a whole, Table 2.6 suggests a strong seasonal influence. From October to January, i.e. from the end of the dry season till well into the wet season, many plants produce their first inflorescence, against hardly any during the next 2 wet months, February and March. There is an upsurge again in April, i.e. the transition from wet to dry season. In May, however, only 2 of the remaining 55 juvenile plants attained adulthood i.e one plant each for 'Yellow Kersikan' and 'Black Kacuk'.

For the individual varieties the period of little or no gain in numbers of plants with inflorescences ranged from 2 months (February - March) for 'Black Pondoh', 'Yellow Suwaru', Black Kersikan' and 'Black Kacuk' to 5 months (January - May) for 'Black Suwaru' and 'Yellow Kersikan'.

The proportion of female and male plants. In Table 2.7 the proportions of female and male flowering plants at the end of the experiment are presented. These figures, however, refer only to the 62% plants which had flowered, the rest did not flower yet. The data were therefore not analysed statistically.

According to the data presented in Table 2.7, the ratio of female and male plants varied widely, even in varieties where more than 60% of the plants had already flowered. Only 'Yellow Kersikan' and 'Black Kacuk' produced about equal numbers of female and male plants, but the number of female trees of 'Black Kersikan' was 3 times

Table 2.6. Monthly number of plants showing inflorescence(s), cumulative ('Black Pondoh': plants 3 months younger than indicated).

Variety		Month, age								
		Sep. 34	Oct. 35	Nov. 36	Dec. 37	Jan. 38	Feb. 39	Mar. 40	Apr. 41	May 42
1.'Black Pondoh'	(24) *	-	-	3	3	4	4	4	6	6
2.'Black Suwaru'	(22)	2	3	6	9	11	11	11	11	11
3.'Yellow Suwaru'	(25)	3	11	13	15	16	16	16	17	17
4.'Black Kersikan'	(22)	2	3	3	12	13	13	13	17	17
5.'Yellow Kersikan'	(23)	7	9	11	14	14	15	15	15	16
6.'Black Kacuk'	(23)	2	6	8	8	14	14	14	18	19
Total	(139)	16	32	44	61	72	73	73	84	86
Increase/month			+16	+ 12	+ 17	+11	+ 1	+ 0	+11	+ 2

*Figures between brackets are the number of plants observed.

Table 2.7. The number of female and male flowering plants and the sex ratio 42 months ('Black Pondoh': 39 months) after sowing.

Variety		Number of flowering plants		Sex ratio Female : male
		Female	Male	
1. 'Black Pondoh'	(24)*	1	5	0.2
2. 'Black Suwaru'	(22)	7	4	1.7
3. 'Yellow Suwaru'	(25)	10	7	1.4
4. 'Black Kersikan'	(22)	13	4	3.2
5. 'Yellow Kersikan'	(23)	8	8	1.0
6. 'Black Kacuk'	(23)	10	9	1.1
Total	(139)	49	37	1.4

* Figures between brackets are the number of plants observed.

that of the male ones. Taking all varieties together, however, the numbers of female and male plants did not differ much.

The number of plants involved in this study is too small to draw firm conclusions.

Discussion

Salak grown from seed started to flower at the age of 28 months; at 34 months some flowering plants were found in all varieties. The palms grown by farmers on Java island are pollinated by hand. When pollen is not readily available, the farmers get it from other gardens, even in other villages. This use of different pollen sources may cause variation in flowering time of the progeny as has been shown for pea seedlings by Khvostova (1983). Genetic control of precocious flowering has been demonstrated in *Pinus* (Smidtling, 1981).

The seasonality in the emergence of the first inflorescence is of much interest, but hard to interpret because the records do not cover a full year and the number of plants per variety is low. It takes about one month for the inflorescence to reach anthesis and a further 6 months for the fruit to ripen. Hence the inflorescences emerging from October to January should yield fruit in May - August, the April inflorescences in November. These periods fit fairly well with the main harvest season in East Java, which runs from December to January, and the second smaller crop which is harvested in June - July.

Thus it appears that flowering that makes an end to the juvenile phase is subject to the same seasonal influences as flowering in older palms.

The sex ratio in dioecious species is expected to be 1:1 at the zygote stage. Carrol and Mulcahy (1993) report that a deviating sex ratio is governed mostly by factors operating after fertilization, such as sex-linked mortality. Early identification of female and male plants is important for the growers. Female plants cannot be distinguished morphologically from male plants by vegetative markers. Genetic markers which find expression in young seedlings and which are linked to the sex chromosomes could possibly be used to reveal the sex while the seedlings are still in the nursery. This could include the mere presence of the Y chromosome.

A curious segregation of the sexes has been reported from Java island (Moncur, 1988). Seeds from fruits containing 2 or 3 seeds are always used for planting; it is assumed that they produce female plants. Those from single-seeded fruits allegedly produce male trees. Experimental verification of this unlikely notion is time-consuming, unless genetic markers or observations on Y chromosomes could be used.

Another possibility is vegetative propagation using suckers of known sex. Suckers are rarely used by Indonesian farmers, except for 'Pondoh' in Sleman. Recently, however, farmers in Gondanglegi have also started to propagate salak vegetatively, following advice of the local Agricultural Department and horticultural staff of Brawijaya University in Malang.

Conclusions

1. Seedlings of salak varieties, originated from seeds, came into bloom when they were 28 - 34 months old. Progress was slow: after 42 months the percentage of plants, which had flowered, ranged from 50 to 84.
2. The periods of the year during which many juvenile plants came into bloom

corresponded fairly well with the main flowering periods in older orchards.

3. The sex ratio of the flowering plants in the experiment was 1.4 female against 1 male; for some varieties the sex ratios were more extreme, but the numbers of flowering plants were quite small. Female and male plants can only be distinguished when they flower. In order to control the sex of planting material, vegetative propagation by suckers of known sex is recommended.

2.3. Estimating the leaf area

Introduction

The arrangement of the leaflets along the rachis of a salak leaf is unlike that in other palms. There is no apparent system in the positions: the leaflets are neither opposite nor alternating and over varying distances along the rachis there may be no leaflet or only a leaflet on one side. The impression is of some – often quite a few – missing leaflets, here and there along the rachis. Near the rachis basis there are some smaller leaflets, sometimes including very small ones. Normally at the leaf tip several leaflets remain united, but it is not obvious how many leaflets make up these two blades.

Leaf area measurements in palms are difficult because of the very large size of the leaves. The method used in the experiment described in Chapter 2.1 is not unusual for palms (Flach and Schuiling, 1989), but it is designed for mature palms where leaf shape and size are more or less constant. Its use in young seedlings, where leaf shape and size range widely, is of doubtful value. The irregular size and distribution of the leaflets on a salak leaf, so different from other palms, further complicates the matter. Therefore an experiment was conducted in which a number of leaf characteristics were measured in order to work out a suitable – preferably non-destructive – method to estimate leaf area in salak.

Materials and methods

The methods were compared on 30 'Pondoh' leaves from a 3-year-old salak garden in Junrejo, near Malang in January 2000. The shade trees had lost the competition with the salak and some of the older leaves suffered from sunburn; pests had damaged some others. Therefore the youngest mature leaf was chosen in 30 palms. To avoid complications through drying of the leaves, they were measured immediately after cutting. The leaflets were stripped from the rachis and the following data were collected:

- diameter of the petiole 1 cm below the lowest leaflet,
- rachis length,
- length and width of the largest leaflet (excluding the pair at the tip),
- number of leaflets (including the pair at the tip).

Corner (1966) suggested that the final length of the spear leaf might serve as an indicator of the area of the leaf in palms in general. Because it was difficult to reach the basis of the petiole in the spiny salak crown, rachis length was measured instead of leaf length. Verheij (1972) related the leaf area of 4-year-old apple trees to the square of the diameter of the tree trunk; he found that the estimate could be improved by seeking the optimal power to which the trunk diameter should be raised. Perhaps the area of a palm leaf can likewise be estimated on the basis of the diameter of the petiole.

Flach and Schuiling (1989) estimated leaf area of sago, closely related to salak, by multiplying length and width of the largest leaflet with the number of leaflets on the rachis. This method was used in Chapter 2.1, and hence it is included in the study.

To obtain a direct estimate of leaf area the stripped leaflets were placed on graph paper marked with a square centimeter grid. The number of grid points covered by the leaflets gives a mathematically correct estimate of area (Bleasdale,1973); the accuracy can be improved by shifting the leaflets somewhat and repeating the count. However, this method proved to be so time-consuming that only a single count was made per leaf. Before the grid count the leaflets were passed over a calibrated electric leaf area meter. On the supposition that it would give the best estimate of leaf area, this method served as control.

The analysis compares four methods (using a total of seven variables):

Method C1: Leaf area measured by the photo-electric meter (control);

Method C2: Leaf area estimated by counting grid points covered by the leaflets (alternative control);

Method A : Petiole diameter x rachis length x number of leaflets;

Method B : (length x width) largest leaflet x number of leaflets.

Multiple regressions were conducted to determine the correlations between the measured leaf attributes, followed by automatic stepwise selection of the most powerful predictors to obtain the regression equations which best relate each of the tested methods to the control. The analysis was repeated after transformation of the data into their natural logarithms.

Results

Mean values and their standard deviation. The mean values and standard deviations for the seven variables are listed in Table 2.8. The table shows that the average leaf area was about 0.75 m^2, the results of the two control methods agreeing fairly well. Methods A and B obviously require some adjustment to estimate leaf area; moreover the values of their standard deviations were about 2 to 3 times higher than those for the leaf area meter method. The average leaf consists of 50 leaflets and the rachis is nearly 2 m long. The petiole diameter is quite small and therefore must be measured accurately to serve as a meaningful estimator of leaf area.

The relationship between variables. Scatter diagrams were made relating the values obtained by control method C1 with those of each of the other three methods, in order to visualize the relationship (Figure 2.3). A linear regression function was fitted to each diagram, as shown in the figures and explained below.

Figure 2.3 shows the close correlation between both control methods; the relation between C1 and method A was less well defined and that between C1 and B was weakest.

Table 2.8. Mean value, standard deviation and coefficient of variation for the measured and derived variables.

Variables		Mean	Standard deviation	Unit	Coefficient of variation
Petiole diameter,	d	1.37	0.28	cm	0.204
Rachis length,	h	177.6	27.7	cm	0.156
Largest leaflet, width,	w	5.1	0.4	cm	0.078
Largest leaflet, length,	l	53.3	6.0	cm	0.113
Number of leaflets,	n	49.9	9.4		0.188
C1: Area meter		7236	1748	cm^2	0.242
C2: Grid count		7579	1579	cm^2	0.208
A: d x h x n		12982	2975	cm^2	0.229
B: w x l x n		13853	4145	cm^2	0.299

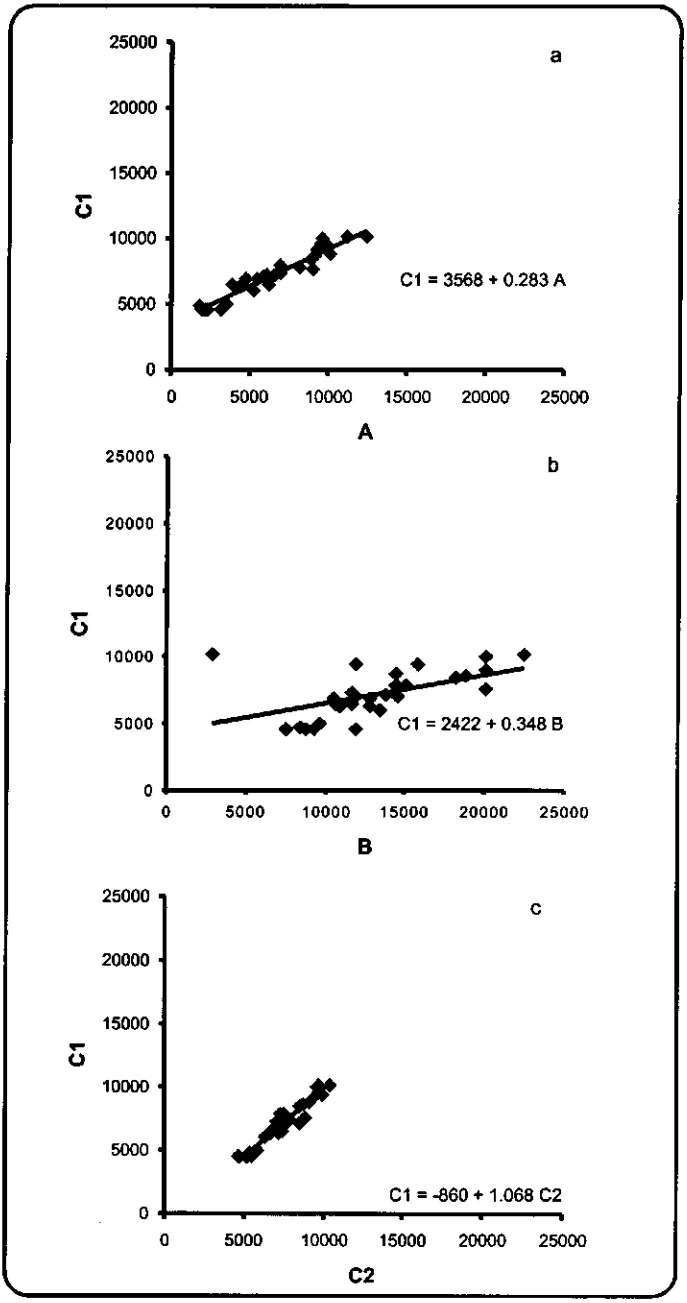

Figure 2.3. Scatter diagrams for the values for C1 against those for each of the other methods; in each diagram the fitted line represents the linear regression.
a is for C1 - A, b for C1 - B and c for C1 - C2; n = 30.

A multiple regression analysis with automatic stepwise selection of the most powerful predictors was carried out to relate method C1 to methods A and B, respectively. First, the matrix of single correlations between C1, the parameters used to calculate A and B, and A is presented in Table 2.9. Correlations between leaf attributes were generally close to one, as shown in Table 2.9; only correlations involving length and – in particular – width of the largest leaflet were below 0.7. In fact most correlations were highly significant, except those involving width of the largest leaflet. This parameter, therefore, should not be applied as predictor to estimate leaf area of salak.

Table 2.10 shows how stepwise removal of predictors affected the multiple regression of C1 - A. Including petiole diameter and number of leaflets in the multiple regression slightly improved the fraction of the variation in leaf area accounted for; including rachis length made virtually no difference (the standard error of the estimate even became slightly larger). Evidently, the straight regression of C1 on A was almost as good as the multiple regressions, 92.5% of the variation in leaf area being accounted for by method A on its own.

The same analyses as shown in Tables 2.9 and 2.10 for the regression of C1 on A were carried out for C1 on B and for C2 on A and C2 on B. It was found that the regressions with C2 were only slightly less well-defined than those with C1, but using method B to estimate leaf area was clearly inferior to using method A. This is shown by the regression equations and the goodness-of-fit in Table 2.11, which also includes these data for the regression of C1 on C2.

According to Table 2.11 agreement between the two control methods C1 and C2 was only marginally better than that between method A and C1. However, the relationship as indicated by the equations was very different; the small constant and a coefficient close to one suggest that C2 was almost equal C1. Therefore the ratio between C1 and C2 was also calculated; it is indeed close to unity. In Figure 2.3, lines have been fitted according to the regression equations in Table 2.11.

Analysis of transformed data. Leaf area may be better correlated with the cross sectional area of the petiole than with the diameter; this would mean a regression on the square of the petiole diameter. This brings up the question to what power the petiole diameter – and/or other variables – has to be raised to obtain the best possible estimate of leaf area. In other words: find the optimum values for p, q and r in the equation:

$$Y = s \cdot K^p \cdot L^q \cdot M^r,$$

where K, L and M stand for petiole diameter and any of the other leaf attributes measured.

The equation can be rewritten in a linear form by converting the data into their natural logarithms:

$$\ln Y = \ln s + p\ln K + q\ln L + r\ln M,$$

after which regression can proceed as above.

The best results were obtained by regression of the logarithms of C1 on those of petiole diameter, rachis length and number of leaflets, i.e. the variables included in method A. Table 2.12 gives the outcome. Table 2.12 shows that the coefficients improved and the standard error became smaller when more predictors were included in the model. However, the highest value for R^2 (0.920) is not higher than in the corresponding model in Table 2.11 ($R^2 = 0.925$).

Table 2.9. Matrix of single correlations between leaf attributes, C1 and A; significances of the correlations.

	C1	d	h	l	w	n	A
Pearson correlation							
C1	1.000	0.899	0.875	0.617	0.171	0.867	0.962
petiole diameter, d	0.899	1.000	0.796	0.625	0.241	0.741	0.888
rachis height, h	0.875	0.796	1.000	0.657	0.077	0.821	0.913
leaflet length, l	0.617	0.625	0.657	1.000	0.594	0.489	0.634
leaflet width, w	0.171	0.241	0.077	0.594	1.000	0.009	0.128
leaflets, n	0.867	0.741	0.821	0.489	0.009	1.000	0.937
A	0.962	0.888	0.913	0.634	0.128	0.937	1.000
Significance(1-tailed)							
C1	1.000	0.000	0.000	0.000	0.184	0.000	0.000
petiole diameter, d	0.000	1.000	0.000	0.000	0.100	0.000	0.000
rachis height, h	0.000	0.000	1.000	0.000	0.343	0.000	0.000
leaflet length, l	0.000	0.000	0.000	1.000	0.000	0.003	0.000
leaflet width, w	0.184	0.100	0.343	0.000	1.000	0.481	0.251
leaflets, n	0.000	0.000	0.000	0.003	0.481	1.000	0.000
A	0.000	0.000	0.000	0.000	0.251	0.000	1.000

Table 2.10. Coefficients of determination (R^2), multiple correlation (R), and the estimate of the standard deviation (S) for a decreasing series of predictors of C1.

Predictors:	R^2	R	S
A + petiole d + rachis h + leaflets n	0.938	0.968	470.2
A + petiole d + leaflets n	0.937	0.968	462.4
A	0.925	0.962	487.0

Table 2.11. Regression equations, coefficients of determination and correlation, and estimates of the standard deviation for both C1 and C2 on A and B, as well as C1 on C2.

Regression equation	R^2	R	S
C1 = 3568 + 0.283 A	0.925	0.962	487.0
C2 = 4351 + 0.249 A	0.878	0.937	561.9
C1 = 2422 + 0.348 B	0.679	0.824	1007.5
C2 = 3450 + 0.298 B	0.612	0.782	1000.8
C1 = – 860 + 1.068 C2	0.931	0.965	466.0
C1 = 0.959 C2*			490.4

* linear regression through the origin, ratio C1/C2.

Table 2.12. Coefficients of determination (R^2) and correlation (R), and the estimate of the standard deviation (S) for 3 regression models.

Model	Predictor(s)	R^2	R	S
1	*ln*(petiole d)	0.829	0.911	0.1063
2	*ln*(petiole d), *ln*(leaflets,n)	0.903	0.950	0.0816
3	*ln*(petiole d), *ln*(leaflets,n), *ln*(rachis h)	0.920	0.959	0.0756

Table 2.13. Values of the coefficients in the regression equations for the three models presented in Table 2.12, their standard error, and the significance of their contribution to the correlation.

Model	Coefficients	Std error	Significance
1. (constant)	8.573	0.031	0.000
ln(petiole d)	0.989	0.085	0.000
2. (constant)	6.743	0.405	0.000
ln(petiole d)	0.701	0.091	0.000
ln(leaflets,n)	0.491	0.109	0.000
3. (constant)	5.205	0.759	0.000
ln(petiole d)	0.551	0.106	0.000
ln(leaflets,n)	0.320	0.125	0.016
ln(rachis h)	0.435	0.187	0.028

Table 2.13 lists the coefficients for the equations, that is the calculated optimum power to which each variable has to be raised, and statistical information.

In Model 1 in Table 2.13, the coefficient for *ln*(petiole d) is almost unity, which means that the optimum power for raising the petiole diameter is very close to one. Hence, the supposition that the optimum power would be close to 2, is not confirmed. In Model 3 the coefficients for both *ln*(petiole d) and *ln*(rachis h) are about one half, corresponding to the square root of petiole diameter and rachis length. Whereas the square of petiole diameter is proportional to cross sectional area and therefore should be linked with the mechanical strength and perhaps the transport capacity of the petiole, no biological explanations can be given for relationships based on the square root of either petiole diameter or rachis length.

Discussion

Leaf area measurements in palms are complicated by the large leaf size and in the case of salak also by the irregular leaf shape and the long spines. On the other hand the leaves of a mature palm adapted to its environment should all be about the same size, greatly facilitating the step from area of a leaf to leaf area of the crop.

It is generally accepted that the ultimate length of the spear leaf gives a prediction of the size of a palm leaf; after all the fully extended spear contains the folded leaflets which only have to unfold to expose the leaf area. It therefore comes as a surprise that rachis length is not such a good estimator of leaf area in salak; in most multiple regressions it does not augment the coefficient of determination as much as other predictors.

The petiole diameter is only a slightly better predictor of leaf area, although petiole dimensions must ensure adequate mechanical strength and transport capacity for the leaf. One would expect these functions to be correlated more closely with petiole cross sectional area than with petiole diameter, but in a model with petiole diameter as the sole predictor of leaf area, the best correlation was obtained by raising it to a power which was almost one.

Measuring the rachis instead of the spear, and the petiole diameter just below the leaflets instead of near the petiole base, may have made a difference, but it is hard to see how this could have affected the relationship with leaf area. In salak the petiole diameter is very small in relation to leaf size; perhaps the correlation with leaf area could have been improved by greater accuracy of measurement (use a nonius to read to 0.1 mm, duplicate measurement).

The number of leaflets proved an important predictor in multiple regressions, in spite of the extreme variations in leaflet size in salak.

The combination of rachis length, petiole diameter, and number of leaflets in method A gave an acceptable estimate of leaf area in comparison with both controls (methods C1 and C2). In fact Method A resulted in leaf area estimates which were almost as good as those obtained by Method C2, the grid count. However, the large value of the constants in the regression equations shows that A is not simply proportional to C1 or C2. It follows that the equations are only valid for the sampled leaves; they cannot be used for much smaller or larger leaves in younger or older gardens. Consequently in another garden – and also in the case of other varieties – the appropriate equation has to be established anew by sampling leaves according to Method A and a control method.

Method B gave the poorest estimates of leaf area and the regression equations on C1 and C2 show that like Method A its validity is limited to the plants from which the sample was taken. Length and particularly width of the largest leaflet were by far the poorest predictors of leaf area, so that the effectiveness of the method depends largely on the predictive value of the number of leaflets. The idea that the dimensions of the largest leaflet are indicative of the area of the other leaflets stems from palms with a much more rigid regulation of size and placement of leaflets along the rachis; it is not surprising that it is not really suited to salak, as salak has many missing leaflets.

Method B was used to estimate leaf area in the variety trial (Chapter 2.1). In the light of the present findings these estimates are of doubtful value, the more so since a simple ratio (the 'shape factor') was assumed between the values according to Method B and the control method. The plants were 16 months old, so leaf size ranged from the smallest simple leaf to a fair-sized compound leaf. Fortunately the shape factors were determined separately for each variety and for simple leaves as well as compound leaves. So there is no reason to discard the findings altogether; they may still be indicative of the leaf area per plant and the differences between varieties.

Both control methods, the photo-electric measurement and the grid count, are based on the same principle, so it is not surprising that the results are in close agreement. The grid count was very laborious and prone to counting errors, but with more practice the efficiency could probably be improved a lot. On the other hand, the homogeneous structure of the leaf blades suggests that another control method, based on the ratio between the weight of discs of known area punched out of the leaflets and the total weight of the leaflets, might be much simpler and quite accurate.

The control methods are destructive, whereas Methods A and B are meant to be non-destructive. This may indeed be the case in young salak stands, but mature plantations are so dense and prickly that measuring in-situ becomes impractical. However, growers occasionally cut ageing leaves in mature stands, and if these are still intact they can be used for sampling.

Conclusions

1. Four methods for measuring leaf area produced significantly different results. Estimates of the leaf area by counting the number of grid points covered by the

leaflets corresponded closely with those of the electric leaf area meter. However, this method is time consuming.

2. Method A, defined by the product of rachis length, petiole diameter and number of leaflets, produced acceptable results, not much inferior to the grid count, but it is only valid for the sampled population. The petiole diameter is small, requiring precision in measurement; the leaf area estimate could not be improved by using the cross sectional area instead of the diameter or by raising the petiole diameter to any other power.
3. Method B, based on the dimensions of the largest leaflet and the number of leaflets, was inferior to Method A because length and width of the largest leaflet were very poor predictors of leaf area.
4. Methods A and B were meant to be non-destructive, but it is virtually impossible to take the required measurements without cutting the leaves.
5. A full appraisal of the four methods requires a wider range of leaf sizes than was included in the sample.

CHAPTER 3: POLLEN

3.1. Yield per spadix as determined by intensity of pollination

Introduction

The productivity of the salak palm varies according to climatic conditions, soils and method of cultivation. Sarwono and Maryanti (1990) reported a production of 6 - 7 kg fruit per tree per year. The productivity per plant in East Java was reportedly higher, i.e. around 16 kg (Sudaryono et al., 1991). It is likely that the differences in production are also partly due to the genetic background of the varieties and the intensity of pollination (Purseglove, 1972).

Pollination usually precedes the production of fruit (Swamy and Krishnamurthy, 1980) as fruit growth is associated with seed set and production. In exceptional cases, however, formation of seeds is not needed for the fruit to grow out (parthenocarpy); in these cases pollination is not essential to harvest fruits. Parthenocarpic fruit growth has not been observed in salak. As the species is dioecious the fruits can only be produced through cross-pollination. This requires an adequate proportion of male-flowering plants, synchrony of anthesis of staminate and pistillate inflorescences and an effective vector – whether wind, insects, or man – for transmission of the pollen.

Pollination by wind or insects is inadequate for good fruit set in salak (Baswarsiati et al., 1991; Baswarsiati and Rosmahani, 1992). Growers pollinate by hand, which is very time consuming. Ashari (1993) estimated that hand pollination accounts for about 30% of the production cost. Only the Balinese salak does not require artificial pollination, as this type is monoecious.

The pistillate flower of salak consists of an ovary covered by hairs, containing three ovules, a short style and three lobed, almost sessile stigmata, one for each ovule (Moncur, 1988; Tomlinson, 1990). When all stigmata are successfully pollinated by hand, the developing fruits are triple-seeded.

Based on this information it is postulated that the number of pollinated stigmata of the pistillate flowers determines fruit development of salak. This was tested in an experiment in which one or two stigmata of a pistillate flower were excised and the treated spadices were bagged.

Materials and methods

The trial was conducted in a salak garden of Mr. Adi Pranowo in desa Suwaru, approximately 30 km southeast of Malang, from June to October 1991, that is during the dry season. The salak was grown rainfed in a garden around the house. The orchard was well maintained. According to the owner the age of the palm stools was over 100 years. The treatments were:

1. All three stigmata hand-pollinated.
2. Two stigmata hand-pollinated.
3. One stigma hand-pollinated.
4. Unpollinated.

The pistillate flower is a dyad (Uhl and Dransfield, 1987) (Figure 3.1). The sterile staminate flowers were removed before the stigmata became receptive. In the second and third treatment, stigmata were cut with a sharp razor using a magnifying glass (Figure 3.2), when the bracts enclosing the spadix had opened up, indicating that the stigmata were becoming receptive. In all treatments the pistillate flowers were covered with thin paper soon after being pollinated by hand and before natural pollination by wind or insects could take place (unpollinated control). Palms with 3 spadices in the inflorescence were selected at random and one spadix was allocated for each of the treatments 1, 2, and 3. On average there were 20 flowers in a spadix and all flowers were treated. Different palms were selected for the 4th treatment. The treatments were replicated on five palms/inflorescences. The pollen came from trees in the same garden. Mature pollen, sticky when touched, was used. The male flowers were tapped above the emasculated pistillate flowers.

Fruit set, diameter, length, fresh weight and seed numbers per fruit were measured. The collected data were analysed using a complete randomized block design additive model according to Steel and Torrie (1980).

Results

Fruit set and seed set. As expected, when all stigmata were intact, fruit set was much better than when 1 or 2 stigmata had been removed (Table 3.1). Differences in receptivity of the flowers – within and between spadices – may explain why intensive pollination resulted in no more than 75% fruit set and why removal of two stigmata led to a significantly higher fruit set than removal of a single stigma. Moreover, because of the sharp drop in fruit set – from 75 to about 30% – for flowers with excised stigmata, an adverse effect of the excision on pistils cannot be ruled out. Moreover, the physical damages during the excision work could be the cause of the drop of fruits.

Unpollinated flowers produced no fruit. The pollination treatments affected both the fruit set and the fruit number per bunch in a similar way. The number of seeds per fruit was close to the maximum for intact flowers and dropped to half as much for flowers with a single intact stigma.

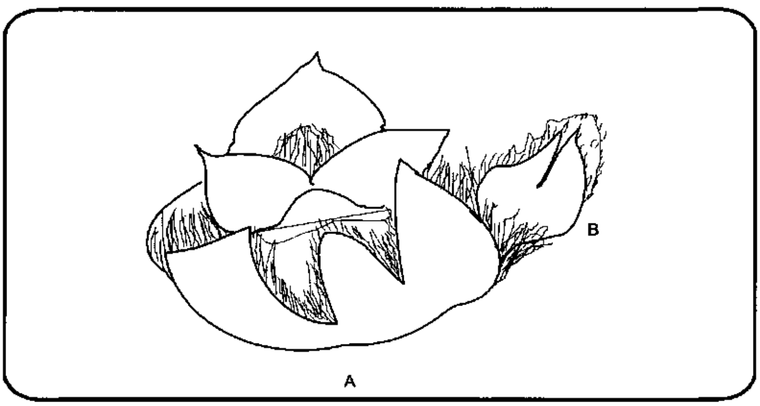

Figure 3.1. Dyad of pistillate flower and sterile staminate flower with bracteoles.
A: pistillate; B: staminate.
Redrawn based on Uhl and Dransfield (1987).

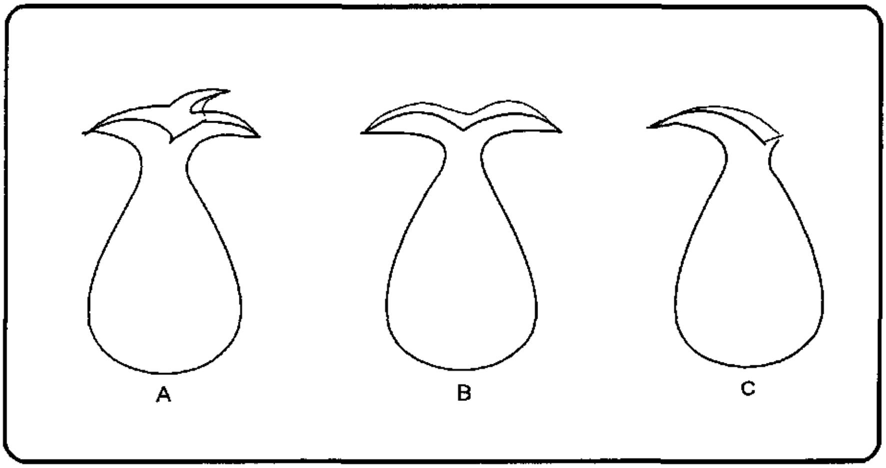

Figure 3.2. Florets of pistillate flowers showing the way the stigmata were cut. Pollinated stigmata: A: three; B: two; C: one.

Table 3.1. Percentage fruit set, and mean numbers of fruits per bunch and seeds per fruit.

Hand-pollinated stigmata	Fruit set (%)	Fruits/bunch	Seeds/fruit
3	74.9 c	14.9 c	2.85 c
2	27.3 a	5.5 b	2.22 b
1	31.9 b	6.4 b	1.41 a
0	-	0 a	-

Values followed by the same letter are not significantly different at LSD 5%.

Number of seeds per fruit. The fruits from flowers with three pollinated stigmata were mostly triple-seeded with a small number of double-seeded and single-seeded ones. Two pollinated stigmata produced 9.5% single-seeded fruits; 59.3% double-seeded fruits and 31.3% triple-seeded fruits. One pollinated stigma produced 70.1% single-seeded fruit; 18.5% double-seeded fruits and 11.5% triple-seeded fruits (see Figure 3.3).

Differences in the number of seeds per fruit were associated with differences in the shape of the fruit and, in particular, of the seed. When there were three seeds per fruit, the seed shape was trigonous (terminology after Mogea, 1978b), in fruits with two seeds the seeds were flattened on the side facing the other seed, and seeds of single-seeded fruit were round (see Plate 1A-C). The shape of triple-seeded fruits was nearly globular, double-seeded fruits were oblong/lanceolate and single-seeded fruits were globular but smaller than the triple-seeded ones (see also Plate 13).

Fruit size. Four weeks after pollination, the diameter of the fruit was more than 5 mm; after 20 weeks it was about 25 - 30 mm (Figure 3.4). Fruit diameter growth was apparently enhanced by the intensity of pollination. The growth rates of the fruit were 1.46, 1.33 and 1.21 mm per week for treatments 1, 2 and 3, respectively.

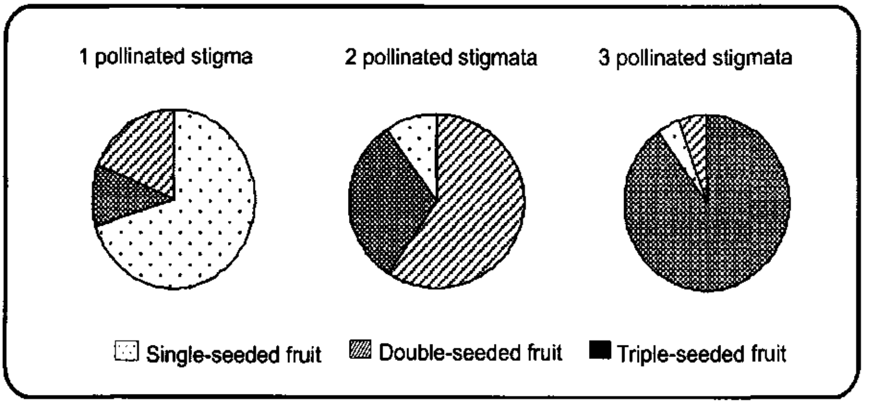

Figure 3.3. The proportions of fruit with 1, 2 or 3 seeds in each pollination treatment.

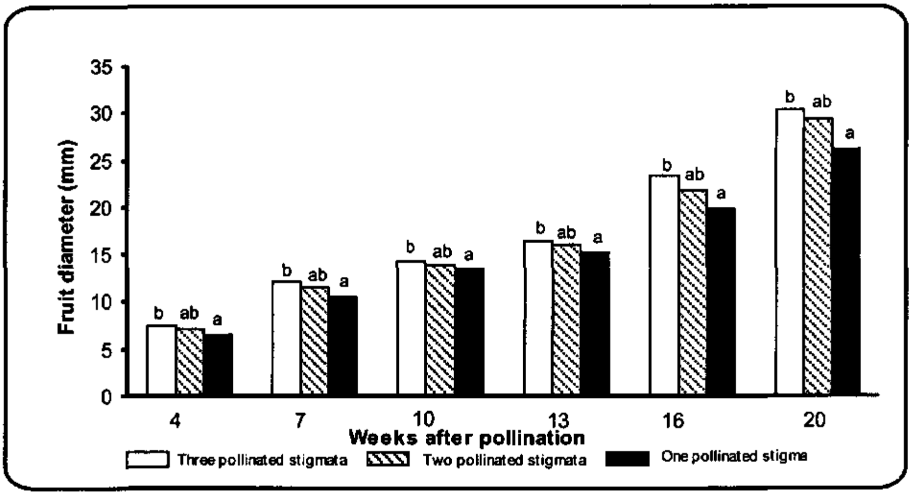

Figure 3.4. Increase in fruit diameter from 4 to 20 weeks after pollination.
* Bars topped by the same letter for a given week do not differ significantly at LSD 5%.

When all stigmata were pollinated, the fruits produced were longer than when only two or one were pollinated (Figure 3.5). Twenty weeks after hand-pollination the fruit length exceeded 30 mm. The rates of growth for fruitlets with 3, 2 and 1 pollinated stigma(ta) were 1.69, 1.51 and 1.38 mm per week, respectively.

As was the case with fruit diameter and length, the fresh weight of fruit with three pollinated stigmata was higher than that of fruits with either two or one pollinated stigma (Figure 3.6). In Plate 13 the shape and size of immature fruit is shown 20 weeks after pollination for the three pollination treatments.

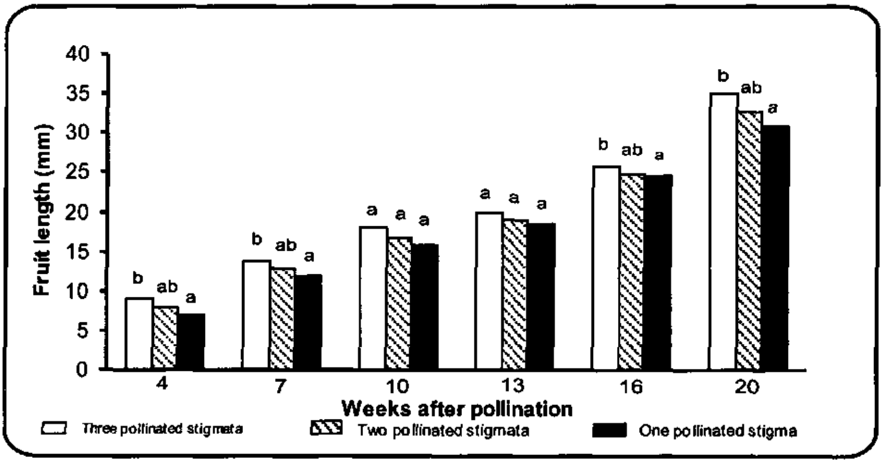

Figure 3.5. Increase in fruit length from 4 to 20 weeks after pollination.
* Bars topped by the same letter for a given week do not differ significantly at LSD 5%.

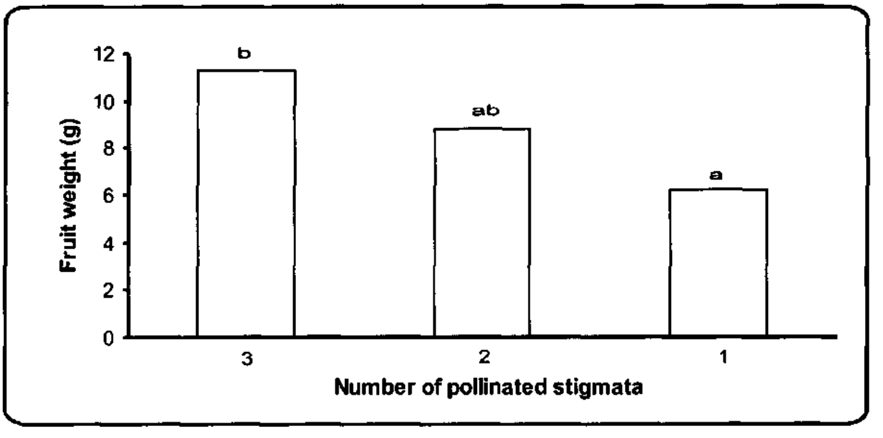

Figure 3.6. Fresh fruit weight, 20 weeks after pollination.
* Bars topped by the same letter are not significantly different at LSD 5%

Discussion

The results show that pollination is necessary for fruit set; there is no evidence of parthenocarpy. Intensive pollination leads to high fruit set (75% of flowers) and seed set (90% 3-seeded fruit). This indicates that:

- nearly all ovules are functional;
- the plants have enough energy to sustain fruit set of nearly all flowers in a spadix.

Moreover, there is no indication of competition between the fruits in a bunch: pollination of all stigmata resulted in much larger fruit, even though the number of fruit was more than twice as high as in the other pollination treatments; the experiment was conducted during the main cropping season, and – apart from the treated inflorescence – the plants were bearing normally.

It follows that intensive pollination is necessary to realize the fruit bearing capacity of the palm. The position of the spadices – close to the ground and sheltered by the dense canopy of large leaves – makes wind pollination less effective. The sticky pollen points to pollination by insects. It has been suggested that a *Nodocnemis* weevil is involved in pollination in Indonesia, and in Australia large numbers of curculionid beetles have been found on the flowers, carrying pollen from palm to palm.

In an observation on pollination of *Crysophila albida*, Henderson (1984) reported that this species is cantharophylous. During 36 hours prior to anthesis, a number of insects (curculionids, nitidulids, scarab beetles, *Trigona* bees and canopid flies) visited the flowers both during the day and at night. The inflorescence appeared to be a major food source for these natural pollinators. A study by Beach (1984) of pollination in the pejibaye palm (*Bactris gasipaes*) reveals precisely timed relations between flower opening and invasion of the spadices by successive swarms of insects (tiny weevils and scarab beetles, followed by drosophilid flies and *Trigona* bees). Megachilidae and Halictidae are pollen-gathering bees and *Sabal etonia* is predominantly bee-pollinated (Zona, 1987). Other palms which are reported to be insect pollinated are *Socrata exorrhiza* and *Iriartea ventricosa* (Henderson, 1985). However, natural pollination in salak is generally inadequate for a good crop and growers in Indonesia practice hand pollination.

The results show that the number of seeds is strongly correlated with the number of stigma lobes pollinated. Also the shape of the seeds is largely determined by the number of seeds per fruit. A correlation between seed shape and sex of the seedling as assumed by salak growers in Indonesia is, therefore, most unlikely.

The pollen tube grows down through the stylar canal to reach the ovule. The floral vascular system in palms is complex because it involves relatively large numbers of vascular bundles (Tomlinson, 1990). This may be the reason that some pollen tubes enter other ovules than the one associated with the stigma lobe on which they germinated. This may also be the reason that some flowers with a single stigma lobe produced triple-seeded fruits.

Conclusions

1. The experiment showed no evidence of parthenocarpy; unpollinated, pistillate flowers did not produce fruits.
2. Intensive pollination leads to heavy fruit set (75% of flowers) and seed set (90% 3-seeded fruit). Hence nearly all ovules appear to be functional and imperfect pollination can easily become yield-limiting. In a good orchard there needs be no competition between fruits in a bunch. The best treatment more than doubled the number of fruits per bunch and nevertheless the fruit grew to a larger size than in the other treatments.
3. The smaller fruit size resulting from flowers with excised stigmas can be attributed to the smaller number of seeds per fruit.
4. Pollinating 2 or 1 stigma lobes gave a large majority of respectively double- and single-seeded fruits, but both treatments also produced 3-seeded fruits.
5. The seed shape correlates with number of seeds per fruit. In fruits with three seeds, the seed shape is trigonous, when there are two seeds the seed is flattened on one side, and in case of a single seed the shape is globular.

3.2. Pollen sources in relation to fruit yield

Introduction

Artificial or hand pollination is required for salak in Indonesia. Natural pollination by wind or insects is inadequate (Baswarsiati et al., 1991; Baswarsiati and Rosmahani, 1992) to carry pollen from male-flowering to female-flowering plants.

Competition for pollination (CFP) has been reported to limit the production of avocado in Israel (Ish-am and Eisikowitch, 1998). When oranges, mustards and avocados flowered at the same time, the nectar-foraging bees were more attracted to visit flowers of orange and mustard rather than avocado flowers. Nectar-sugar content is supposed to be one of the parameters responsible for genetic variability in flower attractiveness to bees in the genus *Citrullus* (Wolf et al., 1999). The CFP is likely to occur in salak production, since most Indonesian salak gardens are surrounded by many plants of the same species and also fruit trees grown as shade plants, such as rambutan, durian, banana, or even coconut.

By roguing and replanting the proportion of male plants in orchards is reduced to 2 - 20% (Tjahjadi, 1989; Schuiling and Mogea, 1991). The farmers collect pollen from other orchards in case of shortage of pollen. Lack of male flowers is usually due to untimely anthesis of the male plants or too low a percentage of male plants. Cross-pollination using different pollen sources may affect plant productivity. Salak growers in kabupaten Sleman, Yogyakarta, believe that if 'Pondoh' flowers are pollinated by other varieties, e.g. 'Jawa', they will produce larger, better tasting fruits than when they are pollinated by the 'Pondoh'. Use of pollen of other varieties and indiscriminate propagation by seed could be the reason that several types of 'Pondoh' are distinguished: Black, Yellow and Red (Santoso, 1990). However, Siswandono (1989) did not find an effect of pollen types on the productivity of 'Pondoh'.

Pollinators had a significant effect on the inheritance of precocious flowering in beans (Khvostova, 1983) as well as in *Pinus* (Schmidtling, 1981). Where the previously described experiment (Chapter 3.1) showed the importance of intensive pollination, the current experiments were designed to study the effect of different pollen sources on productivity and fruit quality.

Materials and methods

The trials were conducted in orchards in two locations. The first experiment was done in desa Cepoko, kecamatan Berbek, kabupaten Nganjuk. The altitude is about 100 m above sea level, soil type latosol, average daily temperature about 28 °C, rainfall 2000 mm per year. The second was conducted in desa Kacuk near Malang (about 350 m a.s.l; the average temperature about 23 °C, rainfall 2017 mm per year). The trials were laid out in May 1993, that is early in the dry season; the fruit was harvested in December (early in the rainy season) and the observations were completed in January 1994.

The pistillate flower used in the first experiment was 'Nganjuk' pollinated with 5 different pollen types, i.e. 'Nganjuk' (Nga), 'Suwaru' (Su), 'Kacuk' (Ka), 'Pasuruan' (Pas) and 'Pondoh' (Pon). The second experiment used 'Kacuk' as pistillate flower, pollinated with the same varieties and in addition with 'Bangkalan' (Ba). The treatments thus were (Table 3.2):

Table 3.2. Treatments and lay-out of experiments.

Nganjuk	Malang
1. Nga x Nga 2. Nga x Su 3. Nga x Ka 4. Nga x Pas 5. Nga x Pon	1. Ka x Ka 2. Ka x Su 3. Ka x Pas 4. Ka x Nga 5. Ka x Pon 6. Ka x Ba
Each treatment consisted of 4 inflorescences (one spadix per plant) and was replicated 5 times, resulting in a total of 100 pollinated spadices	Each treatment consisted of 5 inflorescences (one spadix per plant), replicated 5 times, resulting in a total of 150 pollinated spadices

Both experiments were arranged in a randomized block design. The variables observed were number of fruits per bunch, fruit weight per bunch, fruit size (length and diameter), fresh weight per fruit, ratio between edible and non-edible part (based on weight), fruit longevity and chemical fruit composition (sugars, total acid and tannin).

For each treatment samples of 10 fruits were measured and put into open paper boxes which were stored at room temperature (20 - 25 °C). Fruit longevity was defined as the number of days from picking until 50% of the fruit showed symptoms of decay.

The analysis of reducing sugars was done on other fruit samples, using Soxhlet solution reagent (Lane-Eynon volumetric method). The procedures of total acid and tannin followed those of Sudarmadji et al. (1984) and Ranganna (1977). Each analysis was replicated three times.

The data were analysed using a complete random design model, and regression and correlation analysis according to Steel and Torrie (1980).

Results

The differences in number of fruits per bunch were extreme, the best pollinator, 'Pondoh', setting 4x as many fruits as the poorest pollinator, 'Kacuk'. Self-pollination gave intermediate fruit set. The weight per bunch also varied greatly, but larger weight per fruit compensated to some extent for low fruit number per bunch, so that the differences were less extreme in weight per bunch (Table 3.3).

Table 3.3. Mean number of fruit and weight of fruit per bunch.

Treatments: Female Male	Number of fruits per bunch	Fruit weight per bunch (g)
Nga x Nga	17.5 b	490.6 b
Nga x Su	14.0 b	670.0 c
Nga x Ka	5.8 a	331.3 a
Nga x Pas	18.3 b	868.8 e
Nga x Pon	24.0 c	793.8 d
Average	15.9	630.9

Values in a column followed by the same letter are not significantly different at Duncan's Multiple Range Test 5%.

Table 3.4. Mean weight per fruit, size and longevity of fruit samples from different crosses.

Treatments Female Male	Fresh weight (g)	Length (cm)	Diameter (cm)	Longevity (days)
Nga x Nga	35.5 a	4.8 a	4.2 a	16.2 b
Nga x Su	59.4 bc	7.2 d	4.9 bc	11.8 a
Nga x Ka	57.9 b	6.2 bc	4.7 b	15.6 b
Nga x Pas	62.1 c	6.6 c	5.2 c	9.6 a
Nga x Pon	37.9 a	6.0 b	4.0 a	27.4 c
Average	50.6	6.2	4.6	16.1

Values in a column followed by the same letter are not significantly different at Duncan's Multiple Range Test 5%.

Table 3.5. Edible : non-edible ratio, reducing sugar, total acid and tannin content of fruit samples from different crosses.

Treatments Female Male	Edible: non-edible ratio	Reducing sugar (%)	Total acid (%)	Tannin (%)
Nga x Nga	1.3 : 1	2.72 ± 0.38	0.42 ± 0.06	0.82 ± 0.09
Nga x Su	2.1 : 1	2.60 ± 0.41	0.43 ± 0.06	0.41 ± 0.04
Nga x Ka	1.7 : 1	2.96 ± 0.58	0.25 ± 0.03	1.23 ± 0.21
Nga x Pas	1.8 : 1	3.96 ± 0.39	0.82 ± 0.11	0.82 ± 0.12
Nga x Pon	1.4 : 1	4.94 ± 0.84	0.52 ± 0.06	0.65 ± 0.07
Average:	1.7 : 1	3.43	0.48	0.78

±: Standard deviation

Differences in weight are of course strongly reflected in fruit length and diameter, but the figures (Table 3.4) show that shape was also affected by pollinator. Fruit length varied much more than diameter; whereas selfed 'Nganjuk' fruit was squat, fruit from crosses with 'Suwaru' was slender, the length exceeding the diameter by about 50%. Fruit longevity appeared to depend on fruit size rather than on pollinator; as a rule, the smaller the weight or diameter the longer the fruit could be kept.

Fruit quality as shown by edible : non-edible ratio, reducing sugar, acid and tannin content was also affected by pollen types (Table 3.5). The pollen of 'Suwaru', 'Kacuk' and 'Pasuruan' increased the edible portion on average by about 15% compared with self-pollination. The pollen of 'Pondoh' increased sugar content by 81% compared with self-pollination. 'Pasuruan' also scored well for reducing sugar and both varieties also were high in total acids. 'Kacuk' pollen gave fruit with low acid and high tannin content.

With 'Kacuk' as the female parent, the pollinators again gave significantly different numbers of fruits per bunch, but in this experiment the extreme effects were found in weight per bunch rather than in number of fruit (Table 3.6). 'Bangkalan' pollen gave the best yield, almost 4x as much as 'Nganjuk', the least effective pollinator.

Fruit fresh weight, fruit length, fruit diameter and fruit longevity were affected by pollen sources (Table 3.7). Being less numerous, the fruit was generally much bigger than in the first experiment. Average weight of fruit from the cross with 'Nganjuk' was only 37.3 g, but in the other treatments it ranged from 74 to 95 g, about twice as much as in the first experiment. Fruit length again varied more than diameter, the pollinators 'Suwaru' and 'Bangkalan' producing relatively slender fruits. Longevity was between 12 and 15 days, except for the small fruit of the 'Nganjuk' cross which lasted 24 days.

Table 3.6. Mean number of fruits and weight of fruit per bunch from different crosses.

Treatments: Female Male	Number of fruits per bunch	Fruit weight per bunch (g)
Ka x Ka	8.8 b	803.8 c
Ka x Su	7.8 b	761.4 c
Ka x Pas	6.0 a	504.0 b
Ka x Nga	7.0 ab	231.6 a
Ka x Pon	7.0 ab	525.0 b
Ka x Ba	8.8 b	838.0 c
Average	7.6	610.6

Values in a column followed by the same letter are not significantly different at Duncan's Multiple Range Test 5%.

Table 3.7. Mean weight, size and longevity of sampled fruit from different crosses.

Treatments Female Male	Fruit fresh weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit longevity (days)
Ka x Ka	82.2 c	6.2 b	5.3 c	12.1 a
Ka x Su	94.7 d	7.1 c	4.9 b	15.0 b
Ka x Pas	83.1 c	6.1 b	5.3 c	15.0 b
Ka x Nga	37.3 a	4.5 a	3.8 a	24.3 c
Ka x Pon	74.1 b	6.5 b	5.2 c	12.2 a
Ka x Ba	86.3 c	8.1 d	5.8 d	15.0 b
Average	76.3	6.4	5.1	15.6

Values in a column followed by the same letter are not significantly different at Duncan's Multiple Range Test 5%.

The pollinators affected the edible portion as a fraction of total fruit weight (Table 3.8) but to a smaller extent than in the previous experiment; in all treatments the edible portion amounted to about two-thirds.

Pollen types also affected the contents of sugar, total acid and tannin (Table 3.8). The pollen of 'Pondoh', 'Pasuruan' and 'Bangkalan' increased the sugar content by 4 to 29% as compared to self-pollinated 'Kacuk' and for these three crosses the tannin content was almost twice as high.

Comparison of selfing and the reciprocal crosses. For 'Nganjuk' and 'Kacuk' self-pollination and the reciprocal crosses can be compared by combining the results of the two experiments. Unfortunately, judged by the fruit weight per bunch, 'Kacuk' was the worst pollinator for 'Nganjuk' and 'Nganjuk' for 'Kacuk'. So in Table 3.9 the yield is better when the varieties were selfed than when they were crossed. The yield of 'Nganjuk' x 'Nganjuk' is based on good fruit set, that of 'Kacuk' x 'Kacuk' on high weight per fruit. In the crosses 'Kacuk' pollen indeed failed because of poor fruit set, but 'Nganjuk' pollen failed both with respect to fruit set and weight per fruit, resulting in the lowest yield.

Interior fruit quality in Table 3.9 appeared to depend on the female parent rather than the pollen source. Fruit on 'Kacuk' plants had a higher sugar content, that on

'Nganjuk' plants a higher tannin content. The main indication of a positive effect of crossing is the enhanced edible portion. The highest edible portion was found in the fruit of 'Kacuk' x 'Nganjuk' (69%), while that of 'Nganjuk' x 'Nganjuk' fruits was lowest (57%).

Résumé of results of both experiments. In Table 3.10 the results in the two localities are compared. Yield (fruit weight per bunch) was similar in both localities, but in Nganjuk fruit set was much better, whereas in Malang the fruit grew much larger and became sweeter.

Table 3.8. Edible : non-edible ratio, reducing sugar, total acid and tannin in fruit samples from different crosses.

Treatments Female Male	Edible : non-edible ratio	Reducing sugar (%)	Total acid (%)	Tannin (%)
Ka x Ka	1.7 : 1	4.8 ± 0.51	0.35 ± 0.05	0.39 ± 0.05
Ka x Su	1.6 : 1	3.3 ± 0.38	0.31 ± 0.04	0.39 ± 0.04
Ka x Pas	2.0 : 1	6.2 ± 0.91	0.53 ± 0.09	0.79 ± 0.11
Ka x Nga	2.2 : 1	4.7 ± 0.49	0.35 ± 0.05	0.39 ± 0.07
Ka x Pon	1.6 : 1	5.0 ± 0.52	0.35 ± 0.07	0.83 ± 0.12
Ka x Ba	2.0 : 1	5.5 ± 0.61	0.48 ± 0.08	0.79 ± 0.08
Average	1.9 : 1	4.9	0.39	0.59

±: Standard deviation.

Table 3.9. Comparison of findings for self-pollination of 'Nganjuk' and 'Kacuk' and the reciprocal crosses.

Treatments Female Male	Weight per bunch (g)	Fruits per bunch	Weight per fruit (g)	Edible weight (g)	Sugar (%)	Acid (%)	Tannin (%)
Nga x Nga	491	17	35.5	20.1	2.72	0.42	0.82
Nga x Ka	331	6	57.9	36.5	2.96	0.25	1.23
Ka x Nga	232	7	37.3	25.6	4.70	0.35	0.39
Ka x Ka	804	9	82.2	53.8	4.80	0.35	0.39

Table 3.10. Comparison of yield and of fruit characters in the two locations; means for all crosses.

Variables	Nganjuk	Malang
Fruit weight per bunch (g)	631	611
Fruit numbers per bunch	15.9	7.6
Fruit length (cm)	6.2	6.4
Fruit diameter (cm)	4.6	5.1
Fruit longevity (days)	16.1	15.6
Edible : non-edible portion	1.7 : 1	1.9 : 1
Reducing sugar (%)	3.43	4.90
Acid (%)	0.48	0.39
Tannin (%)	0.78	0.59

Discussion

In both locations the pollen source strongly influenced fruit production, qualitatively as well as quantitatively. Pollinators 'Pondoh' and 'Pasuruan' gave the highest yield of 'Nganjuk' plants, pollinator 'Bangkalan' was best for 'Kacuk'. Pollinator 'Suwaru' gave higher than average yields in both experiments.

The effects of pollinators on yield have been tested in many fruit crops. Cross-pollination tends to improve yield and is necessary for cultivars which are self-incompatible. The results show that both 'Nganjuk' and 'Kacuk' are self-compatible, but these two varieties happened to show a high degree of cross-incompatibility: both 'Nganjuk' x 'Kacuk' and 'Kacuk' x 'Nganjuk' yielded very little in comparison with the other crosses, selfing of both varieties included. Salak is dioecious and usually propagated from seed, so that the genotype of pollen of a 'variety' must be extremely variable. Hence it is not surprising that varieties are self-compatible; however, the poor yield of the reciprocal crosses of 'Nganjuk' and 'Kacuk' indicates that incompatibility factors do occur in salak.

The effect of pollinators on yield can best be measured by recording the percentage of flowers which set fruit and the number of seeds per fruit. Percentage fruit set shows to what extent the potential number of fruit is achieved; the number of seed per fruit has a strong bearing on fruit size, as was shown for salak in Section 3.1. Unfortunately these data were not recorded in these experiments. This makes it difficult to offer an explanation for the striking differences in yield of different crosses. However, it was noticed that 'Nganjuk' spadices usually contained 20 - 25 female flowers, whereas in 'Kacuk' the number was generally lower than 20. This implies that the differences in percentage fruit set were smaller than the recorded differences in number of fruit per bunch.

Where many fruit quality attributes are affected by fruit size, a proper comparison of pollinators involves:

- recording percentage fruit set, the main factor determining yield, and
- grading of the fruit in 2 or more size classes and recording number of seeds per fruit and other quality attributes in samples of each class, to clarify pollinator effects on fruit quality.

Such an experimental procedure would allow a more comprehensive comparison of the effects of pollinators on yield and quality. The influence of pollen on maternal tissue (i.e. outside embryo and endosperm) is called metaxenia (Abercrombie et al., 1961).

The results in Malang agree with those of the experiment reported in Section 3.2 in that fruit size was not affected by the number of fruits per bunch. In the trial in Nganjuk, however, the tendency towards smaller fruit size at larger numbers of fruits (up to 24) indicates that competition between fruits in a bunch does occur.

Shelf life of the fruit appeared to depend on fruit size rather than on the pollinator. This is fairly common; for several fruit crops it has been shown that small fruit can be stored longer. The edible portion did vary with the pollen source, but not much nor consistently in both locations. In the first experiment the edible portion tended to be higher for larger fruits, as might be expected, but in the second experiment the treatment with small fruit had the greatest edible portion. The non-edible portion consists mainly of the seeds, the only other component being the scaly fruit skin. Thus records of seed numbers per fruit could also have assisted in the interpretation of these findings.

The sugar, acid and tannin contents of the fruit also varied considerably for different treatments. Pollinator 'Suwaru' gave lower than average concentrations of all three constituents in both experiments, whereas pollinator 'Pasuruan' consistently gave higher than average levels, sugar in particular. Comparison of all four combinations of 'Nganjuk' and 'Kacuk', however, pointed to a much larger role for the female parent than the pollinator in determining chemical composition. No relations could be discerned between chemical composition and other attributes of the fruit, such as fruit size, edible portion and shelf life.

The results show clearly that choosing the right pollinator can substantially improve yield, as expressed by numbers and weight of fruit per bunch. There are indications that metaxenia plays a role as well, because pollinators also appear to influence other fruit attributes, such as size, shape, and chemical constituents of the flesh.

Fruit longevity seemed indeed to be correlated with fruit size, but there was no evidence in the data of correlation of either edible portion, or chemical constituents with fruit size. So metaxenia cannot be ruled out. Moreover, botanically the edible flesh of salak is a sarcotesta, i.e. a part of the seed, not of the fruit. The flesh grows from the integument(s) of the ovule and thus consists of maternal tissue, but as part of the seed it may be more prone to paternal influences than fruit tissues.

Conclusions

1. Pollen source strongly influenced yield, qualitatively (longevity, chemical constituents of the flesh) as well as quantitatively (numbers and weight of fruit per bunch, edible:non-edible ratio).
2. Two varieties were selfed and the pollen proved compatible, but the poor yield of the reciprocal crosses is evidence that incompatibility factors play a role in salak.
3. Metaxenia cannot be ruled out, but it is more likely that good pollinators simply increase the numbers of seeds per fruit, resulting in larger fruit size. The effects of pollinators on fruit shape, edible portion, shelf-life and chemical composition may therefore be just indirect, i.e. a consequence of better seed set making the fruit grow larger.

CHAPTER 4: SEED

4.1. Seed germination

Introduction

Germination is a process of growth of the embryo by utilizing reserves in the seed. The process involves a drastic reversal of the metabolism in storage tissues. Seeds of angiosperms store reserves either in the embryo, in the endosperm, or more likely, in the aleuron layer, the perisperm, which lies in between the embryo and the seed coat. However, in seeds of monocotyledonous plants the endosperm is important as storage tissue.

Apart from providing nutrients for the embryo, the endosperm also provides nutrients for tissues surrounding the embryo. During germination and before leaves are capable of photosynthesis, growth and development of the embryo depend entirely on the metabolites from this storage organ. In palm seeds stored reserves are present in the cotyledon of the small embryo and in the massive, hard endosperm. During germination, the distal part of the cotyledon enlarges to form an haustorium, digesting the endosperm (Copeland, 1976). The major functions of the haustorium are absorption and storage of the nutrients during germination (De Mason, 1985). Most plants within the Palmae family have haustoria.

Studies on the development of the embryo of coconut and other palms have been reported (Child, 1974; Tomlinson, 1990). In *Phoenix dactylifera* exhaustion of the endosperm takes 10 weeks (De Mason, 1985). Little is known about germination in the salak palm. Mogea (1978b) reported that 105 days after sowing the cotyledon had decayed and the first bladed leaf had matured, the second leaf being in the spear stage. The aim of the work reported here is to investigate the growth and development of the embryo during germination and to clarify the function of the endosperm and haustorium in supporting the embryo's growth and development.

Materials and methods

The seeds used in the experiment came from a grower in kabupaten Sleman, Yogyakarta. Fully mature fruits of 'Pondoh' were picked. After the seed kernels (or "stones") were extracted they were washed thoroughly in tap water. Four treatments were applied by excising parts of the endosperm (Figure 4.1):

1. All endosperm excised, leaving only the embryo,
2. Half of the endosperm excised by a longitudinal cut glancing the embryo,
3. Half of the endosperm excised by a transverse cut,
4. Control, endosperm left intact.

There were 25 seeds per treatment per replication, of which some were used for the destructive measurements for the chemical analysis. The embryos with and without endosperm were then sown in sand. The sand was washed, air-dried and sieved to <2 mm. It was put into boiling water for 30 minutes, and then spread on trays, 60 x 40 x 15 cm. The trays were placed in a growth chamber to study germination under constant, controlled conditions.

The following records were collected:

- percentage germination;
- fresh weight gain of the embryos over a period of 12 days.

In the treatment with complete endosperm additional observations and analyses were made 0, 2, 4, 8, 11 and 18 weeks after sowing, in order to:

- measure the growth in diameter of the haustorium in transverse and longitudinal directions (corresponding to the planes used for halving the endosperm in treatments 2 and 3);
- measure the losses and gains in dry weight of endosperm, haustorium and root plus shoot;
- analyse the starch, sugar, lipid and N-total content in the dry matter of endosperm, haustorium, and root plus shoot.

About 0.2 g of dry matter was used to analyse starch content, 1 g for reducing sugars, 2 g for fat and 1 g for protein. Each analysis was replicated three times. These procedures for the analyses followed those of Sudarmadji et al. (1984) and Ranganna (1977). The starch content was analysed by direct acid hydrolysis, reducing sugars were determined using Soxhlet solution reagent (Lane-Eynon volumetric method), lipids by Soxhlet extraction using petroleum as a solvent, N-total was measured by using the Kjeldahl method.

The data were analysed using a complete random design model and regression analysis according to Steel and Torrie (1980).

Results

Germination. As expected, germination was influenced by the presence of endosperm. The embryos without endosperm did not germinate but those with full endosperm all did. Cutting half of the endosperm transversely did not reduce germination substantially, but longitudinal excision lowered germination to 87% of the embryos (Table 4.1).

Embryo growth and development. The embryos without endosperm showed activity on the 6th day after sowing, fresh weight increasing from 72 to 87 mg, but this weight decreased on the 9th day and the embryos had died on the 12th day (Table 4.2). The weights of embryos with half of the endosperm cut transversely and with intact endosperm were similar and increased progressively, but the rate of weight gain of the embryos in which the endosperm had been cut longitudinally lagged behind and

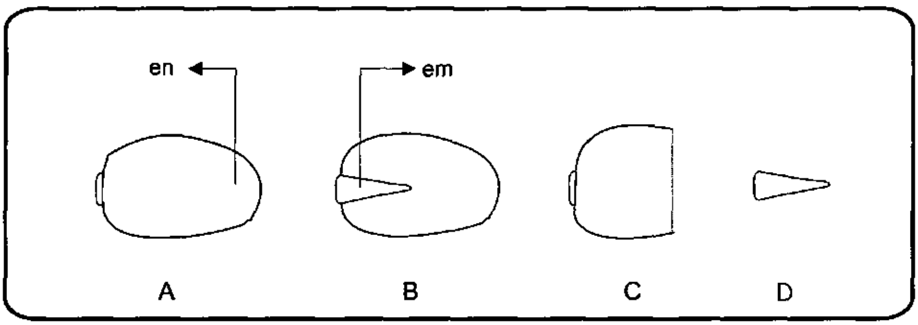

Figure 4.1. The treatments of seed kernels.
Embryo with A: full endosperm; B: 50% endosperm (longitudinal cut glancing the embryo); C: 50% endosperm (transverse cut); D: without endosperm; em: embryo; en: endosperm.

Table 4.1. Germination percentage of the salak seed, with and without its endosperm, analysis of data transformed to √% (Steel and Torrie, 1980).

Treatments	Germination (%)
No endosperm	0.0 a
Endosperm halved longitudinally	87.2 b
Endosperm halved transversely	97.5 c
Endosperm intact	100.0 c

Means in a column followed by the same letter are not significantly different at P = 0.05.

Table 4.2. Fresh weight of embryos (mg).

Treatments	Days after sowing			
	3	6	9	12
No endosperm	72 a	87 a	67 a	-*
Endosperm halved longitudinally	65 a	73 a	110 ab	126 a
Endosperm halved transversely	62 a	73 a	130 b	358 b
Endosperm intact	58 a	64 a	120 b	343 b

Means within a column followed by the same letter are not significantly different at P = 0.05.

* On the 12th day the embryos without endosperm had died.

became very small towards day 12. Eventually the transversely cut endosperm also reduced the growth rate; as shown in Plate 5 this resulted in large differences in size of seedlings 77 days after sowing. The embryos with full endosperm produced normal seedlings, but those with half the endosperm produced weak seedlings.

The cotyledon embedded in the endosperm grew steadily and became a haustorium. Approximately 12 days after sowing, the embryo started to develop. At approximately 19 days it showed shoot growth as well as root growth. After 40 days, the first bladed leaf appeared. It started to unfold at day 77 (Plate 5) and reached maturity about 126 days after sowing.

Dry weight losses and gains

The dry weight of root and shoot increased gradually as shown by a quadratic regression in Figure 4.2 (R^2 = 0.991**). Also the haustorium showed a quadratic function up to 18 weeks after sowing (R^2 = 0.966**). Meanwhile, the endosperm dry weight decreased rapidly, especially in the phase before the root, shoot and haustorium started to grow (R^2 = 0.820*), following a quadratic function. The seedling as a whole lost weight up to 11 weeks after sowing; by that time nearly 2/3 of the initial weight had been lost. The turning point – photosynthesis of the new leaf compensating respiration losses of the seedling – must have occurred shortly thereafter, because at 18 weeks the weight loss had been more than compensated by large gains in dry weight of haustorium and root plus shoot.

Chemical composition of endosperm. Owing to the limited number of embryos with intact endosperm for sampling, the chemical contents of haustorium and root and shoot were only measured 8, 11 and 18 weeks after sowing. At the time of sowing, the main

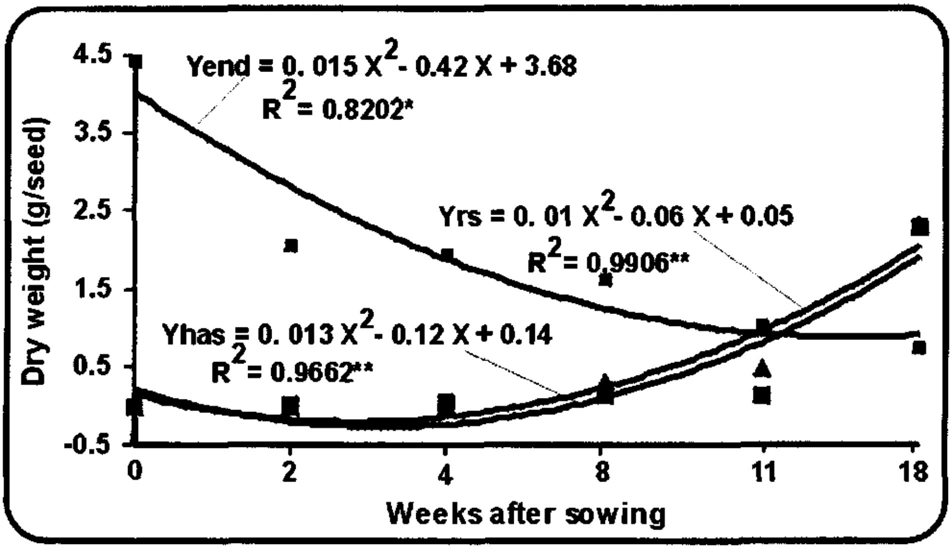

Figure 4.2. Dry weight losses and gains of endosperm, haustorium, root and shoot.

constituent of the endosperm was starch (95% of dry weight) followed by N-total, fat and sugar, respectively (Table 4.3). During germination the starch is converted into sugars and translocated to the haustorium and root and shoot, where it provides both energy and building material for the biosynthesis of the other constituents. The sugar content in the endosperm was relatively constant, whereas lipids and N-total initially increased sharply, but levelled off (lipids) or declined (N-total) towards week 18. After 18 weeks the starch in the endosperm was almost depleted.

The quantity of starch, fats and N-total in haustorium and root and shoot increased sharply towards week 18, contrasting with the changes in the endosperm. The weight of reducing sugars in haustorium and root and shoot rose less spectacularly, presumably because the sugars were metabolized as they became available. Until some time between weeks 11 and 18 the gain in weight of the constituents in haustorium and root and shoot did not compensate for the losses in the endosperm; this was due to the loss of dry matter by respiration, providing the energy for biosynthesis.

The growth of the haustorium. The growth of the haustorium made up for the decline of the endosperm. By week 18 the haustorium almost completely occupied the space where the endosperm had been (Table 4.4). When the first bladed leaf was fully mature, the haustorium was crisp and already depleted.

Discussion

The endosperm is essential for germination of the seed; without endosperm, the embryo is unable to grow out. However the excised embryos did show enlargement a few days after sowing. This suggests potential for raising embryos in-vitro for collection and conservation in breeding programmes. Embryos of palms such as coconut and palmyra have also been raised in artificial media to induce germination and to make long distance transport easier (Child, 1974; Kovoor, 1983). Rillo and Paloma (1991) cultured coconut embryos in artificial media under aseptic conditions; after long distance transport the germination percentage was between 42.7% and 72.6%.

The process of haustorium growth in salak seed is not fully understood. Tomlinson (1960) suggested that the surface of the cotyledon in germinating palm seeds secretes enzymes which convert the inert materials of the endosperm into soluble substances which pass through the haustorium and nourish the seedling. The question of the origin of the enzymes in palm seeds is somewhat controversial. Some believe that the enzymes originate from the endosperm while others hold the view that they come from the cotyledon or the haustorium and diffuse into the endosperm.

The development of the salak embryo is similar to that reported by Child (1974) in the coconut. In coconut, the embryo enlarges and differentiates, the apex into the plumule and the cotyledon into the haustorium. The globular form of the enlarging haustorium in this study suggests that the digestion of the endosperm proceeds at the same pace in all directions.

Identification of the enzymes which attack the endosperm is also very difficult. However, since the main constituent of the endosperm was starch, it is likely that amylase enzymes are predominant, followed by other enzymes such as saccharase,

Table 4.3. The changing quantities (in mg) of chemical constituents in the main organs during germination.

Organ	Weeks after sowing					
	0	2	4	8	11	18
Endosperm:						
- starch	4162	1279	1083	678	425	303
- sugars	0.05	0.15	0.16	0.15	0.14	0.14
- lipid	0.09	0.17	0.33	0.67	1.13	1.27
- N-total	0.31	1.38	1.61	2.69	2.63	1.70
Haustorium:						
- starch	-	-	-	56	54	869
- sugars	-	-	-	0.01	0.01	0.43
- lipid	-	-	-	0.02	0.11	2.25
- N-total	-	-	-	0.05	0.13	3.79
Root and Shoot:						
- starch	-	-	-	72	166	1033
- sugars	-	-	-	0.01	0.04	0.21
- lipid	-	-	-	0.02	0.11	1.82
- N-total	-	-	-	0.11	0.22	2.26

Table 4.4. The growth of the haustorium in two directions (% of the corresponding endosperm diameters).

Growth directions	Weeks after sowing					
	0	2	4	8	11	18
Transverse	0	14.7	22.2	60.8	70.6	96.0
Longitudinal	0	13.4	28.9	67.2	73.9	97.7

lipase and proteinase. In coconuts these enzymes are also active in the haustorium (Nagarajan and Pandalai, 1963).

Increasing nutrient contents within the root and shoot at week 11 and 18 indicated that there was a deposition of substances in these organs, resulting in seedling growth. The consecutive stages of germination consist of water absorption, embryo growth, haustorium development, initiation and growth of root and leaves and depletion of the endosperm. Germination is completed when the first leaf matures; by that time dry weight of the seedling surpasses the initial dry weight of the seed kernel, showing that photosynthesis sustains growth.

The leaf became mature at the same time that the haustorium, having reached its maximum size, became depleted, indicating that the seedling had consumed all the endosperm. When transferring seedlings to the field, the seed must remain attached to it if the first leaf has not yet matured; at a later stage the seed can be taken away.

Mogea (1978b) reported that 105 days after sowing the cotyledon had decayed and the first bladed leaf had matured, followed by the appearance of the second folded leaf. In this study leaf maturation as well as the exhaustion of the cotyledon occurred after 126 days. The difference may be due to the fact that the seeds in this study were placed in a growth chamber; lack of natural light resulted in etiolated seedlings.

Conclusions

1. The endosperm is essential for the germination of the embryo and the further development of the seedling.
2. Before being used by the embryo, the endosperm was digested by the developing haustorium. The growth of the haustorium is initiated in the cotyledon or at its surface. It is assumed that certain enzymes are secreted to hydrolyse the endosperm which consists largely of starch. The haustorium grew in all directions, assuming a globular form.
3. The haustorium starts decaying when the first bladed leaf matures. This marks the end of the germination phase, because at this stage the dry weight lost in respiration during germination, is compensated by photosynthesis.

4.2. Seed storage

Introduction

Seeds are commonly divided into two groups according to their viability after storage, related to water status. The first group, orthodox seed, is able to germinate after being stored with low water content, and at low temperatures. Seed of the second group called recalcitrant, is killed when the moisture content drops below some relatively high critical value (12 - 31%) (Chin and Pritchard, 1988). Most recalcitrant seeds are sensitive to chilling, have a tiny embryo compared to total seed size and are short-lived (King and Roberts, 1980).

In Indonesia salak is commonly propagated from seed. A large number of seeds have been sent to other places, sometimes far away. This long distance transport is reported to have reduced the seed viability sharply; the germination percentage became very low.

Schuiling and Mogea (1991) reported that salak seeds lose their viability quickly in storage. Fifty percent of the seeds did not germinate after one week in storage, and germination was zero when stored for 2 weeks. This seems to be caused by a loss of moisture, which results in the death of the embryo. Purwanto et al. (1988) reported that if the water content decreases to 24.9% the seeds no longer germinate. The aim of the work reported here was to find a method for storing seeds over longer periods, minimizing the adverse effects on germination percentage.

Materials and methods

The trial was done in the laboratory of the Agronomy Department, Brawijaya University Malang, from May to August 1991. The seeds used in the experiment were from 'Pondoh' of the black type. The fruits were obtained from a farmer in kabupaten Sleman, Yogyakarta. Fully mature fruits as shown by the easy shedding of hair from the base of the fruit, and of equal size, were chosen. The fruits were kept in the refrigerator at about 15 °C.

The treatments consisted of two factors, i.e. storage medium and duration of storage. The seed kernels were stored in (1) ambient air, (2) sawdust and (3) charcoal. Both sawdust and charcoal media were air-dried, crushed and sieved to 2 mm. They were then sprayed with fungicide ('Benlate' 2 ml/l water) and insecticide ('Furadan 2G': 2 g/l water). Storage trays were made of cardboard, dimensions 9 x 14 x 9 cm. The trays were left in ambient air for three days to allow the media to attain equilibrium humidity with that in the storage room. The moisture content of the media before storing the seeds was 7% for sawdust and 13% for charcoal. The seeds were extracted, washed thoroughly, dipped into a fungicide solution of 'Benlate' 2 ml/l water for 2 minutes, and put in the media.

The trays with seed were stored at room temperature (1) for 28 days; (2) for 21 days; (3) for 14 days; (4) for 7 days. The control treatment (0 days) was sown immediately. For germination measurement each treatment combination consisted of 6 seeds and 3 replications, while 3 seeds and 3 replications were used for fresh and dry weight observation of seeds after storage.

After storage the seeds were planted in a mixture of soil and sand in equal parts. The mixture was prepared by putting it into an oven at 80 °C for three days. It was then put into polybags of 10 cm in diameter and 15 cm in height. In each polybag a single seed was planted, buried at 1 cm depth. The bags were kept in a glasshouse. Natural light was used with a temperature ranging from 23 - 29 °C and a relative humidity between 75 - 85%. The seeds were watered daily during the first week and once every three days thereafter. After planting the variables observed were germination rate, germination percentage, time of emergence of rudimentary root and of the scale leaf and number of leaves and leaf area per plant. Germination rate was calculated according to the formula by Copeland (1976):

$$GS = \frac{A_1T_1 + A_2T_2 + \ldots\ldots A_xT_x}{(100)\,(A_1 + A_2 + \ \ldots\ldots A_x)}$$

in which

GS	germination rate (in days)
A	number of seeds germinating
T	time corresponding to A
X	number of days to final count.

Germination percentage was determined by dividing the number of germinating seeds by the number of seed sown. Germination was defined to occur when the cotyledonary sheath grew up to about two mm length from the seed (see Plate 4).

The collected data were analysed using a complete randomized design model according to Steel and Torrie (1980).

Results

Seed water content. There was no interaction between medium and storage period on seed moisture; therefore the effects of both factors are presented separately in Table 4.5. Averaged over the range of storage periods, the water content of seeds differred significantly for the media, although the differences were small in absolute terms. Seed stored in ambient air lost most moisture; seed in charcoal retained more moisture than that in sawdust. The initial moisture content of the seed was high, about 60%. Averaged over the storage media, nearly half the moisture was lost within 28 days, by far the greatest loss occurring during the first 7 days of storage.

Germination rate. The effects of storage duration were highly significant for all three media (Table 4.6). In general, storage in air retarded germination more as the storage period was extended. The seeds stored in air for 28 days did not germinate at all. The seeds stored in charcoal germinated faster than seeds stored in sawdust.

Germination. Germination was best when the seeds were sown directly after extraction from the fruit (Figure 4.3). Whereas the viability of seed stored in sawdust and charcoal only dropped after 3 and 4 weeks of storage, only about 60% of seeds stored for one week in ambient air germinated and seed stored for 4 weeks did not germinate at all. Charcoal proved a better medium than sawdust for storage during 3 and 4 weeks, although for seed stored 4 weeks the difference was not significant.

Table 4.5. Mean water content of seed stored in different media for 0 - 4 weeks, analysis of data after transformation to the arc.sin √% (Steel and Torrie, 1980).

Treatments	Water content (%)
Media :	
Ambient air	39.0 a
Sawdust	43.3 b
Charcoal	45.3 c
Period of storage (days) :	
0	60.4 e
7	43.5 d
14	39.6 c
21	35.9 b
28	33.3 a

Means in a column followed by the same letter are not significantly different at Duncan's Multiple Range Test 5%.

Table 4.6. The germination rate of the seeds after storage in different media and for different periods of time, in days.

Storage period (days)	Ambient air	Sawdust	Charcoal
0	11.5 a	11.5 a	11.5 a
7	16.9 b	15.0 b	13.5 b
14	18.4 bc	16.5 bc	16.0 c
21	20.4 c	18.0 c	16.4 c
28	-	19.2 c	17.5 c

Means in a column followed by the same letter are not significantly different at Duncan's Multiple Range Test 5%.

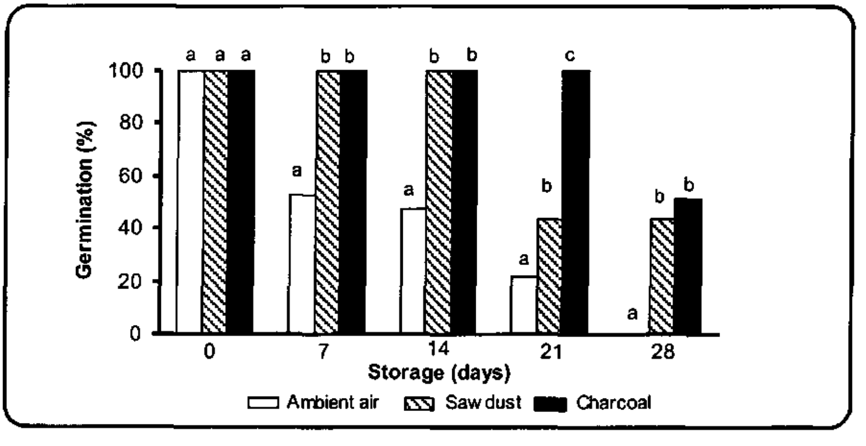

Figure 4.3. The germination percentage after different storage periods of seeds in ambient air, sawdust or charcoal, data transformed to √% (Steel and Torrie, 1980).

Columns bearing the same letter are not significantly different at P = 0.05.

Table 4.7. Emergence of rudimentary roots, in days after sowing; analysis of data transformed to $\sqrt{(x + ½)}$ (Steel and Torrie, 1980).

Storage period (days)	Rudimentary root emergence (days)		
	Ambient air	Sawdust	Charcoal
0	20.3 a	19.7 a	20.3 a
7	27.3 b	25.0 b	24.3 b
14	29.7 b	27.3 bc	26.7 bc
21	30.3 b	28.3 c	28.0 cd
28	-	29.7 c	29.0 d

Means in a column followed by the same letter are not significantly different at Duncan's Multiple Range Test 5%.

Emergence of the rudimentary roots. The rudimentary root emerged earlier when seeds were sown directly (Table 4.7). The time needed was approximately 20 days. When the seeds had been stored longer, it took longer for the roots to be formed. The delay in emergence of the rudimentary root of seeds stored for 21 days was approximately 10 days for ambient air and 8 - 9 days for sawdust and charcoal; the differences between these two media were small.

Emergence of the scale leaf. Like the rudimentary root, the scale leaf emerged faster when the seeds were directly sown than after storage. The seeds without storage showed growth of the scale leaf around 32 days after sowing, but when the seeds had been stored for 7 to 28 days, the growth of the scale leaf was delayed, in particular after storage in air (Figure 4.4). The growth of the scale leaf after seed storage in both sawdust and charcoal was similar.

Leaf numbers and area. The number of leaves and the leaf area per plant for seedlings which had been growing for 100 days are presented in Table 4.8. The majority of the seeds which had been sown without storage grew into plants with 2 leaves within 100 days. One week storage in ambient air sufficed to limit growth to a single leaf, but 1 week storage in sawdust still gave a fair proportion of seedlings with 2 leaves and in charcoal there were some plants with 2 leaves even after 2 weeks of seed storage.

From the leaf areas in Table 4.8 it is clear that prolonged storage had adverse effects. Moreover, the single leaf of seedlings remained smaller if the seeds had been stored longer, particularly after storage in ambient air. In treatment combinations in which the seedlings had more than one leaf on average, the mean area per leaf worked out to about 50 cm^2. That was considerably smaller than leaf size of the best treatment combinations with only single-leafed plants (63 - 64 cm^2). This suggests that in plants with more than 1 leaf the higher rate of leaf production had limited the size of the first leaf.

Discussion

The results show that storage for 1 week or longer had adverse effects on all measured variables. After 2 weeks of storage in sawdust and charcoal all seeds still germinated, but the rate of growth and development was reduced after a storage period of 1 week, in these treatments as well, as evidenced by retarded germination (perhaps due to the time required to rehydrate the seeds before germination could start), and delayed emergence of the rudimentary root and the ligule. This reduced rate of growth persisted; it was still noticeable after 100 days in the number of leaves and leaf area per plant. This effect was similar to that of removal of half the endosperm in the previous experiment (Chapter 4.1).

Inter alia it is interesting to note that the rate of growth of the seeds planted without storage was much better than in Chapter 4.1. For the seeds in the growth chamber it took 126 days before the first bladed leaf had matured. Under the favourable growing conditions in this experiment most plants from freshly sown seed had formed a second leaf within 100 days!

Storage in sawdust and particularly in charcoal greatly improved survival and growth after planting in comparison with storage in ambient air, but the reduction in the rate of growth with each extra week of storage remains a serious shortcoming of these media.

The findings suggest that the worsening results after prolonged storage are closely correlated with seed moisture content at the time of planting. Salak seeds rapidly lose

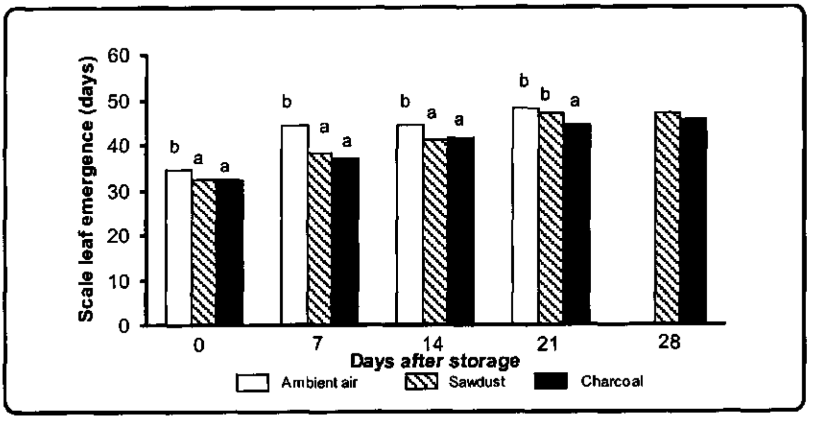

Figure 4.4. Time of emergence of the scale leaf after different seed storage treatments.
Columns bearing the same letter are not significantly different at P = 0.05.

Table 4.8. Number of leaves and leaf area (cm^2) per plant, 100 days after planting; analysis of data after transformation to $\sqrt{(x + ½)}$ (Steel and Torrie, 1980).

Storage period (days)	Ambient air		Sawdust		Charcoal	
	Number	Area	Number	Area	Number	Area
0	1.6	81 fg	1.6	86 g	1.7	85 g
7	1.0	64 def	1.4	72 fg	1.6	74 fg
14	1.0	37 bc	1.0	63 def	1.2	67 ef
21	1.0	34 b	1.0	53 de	1.0	56 de
28	0.0	0.0 a	1.0	49 cd	1.0	51 d

Means which have a letter in common are not significantly different at Duncan's Multiple Range Test 5%.

moisture, especially during the first week of storage. Nearly 50% of seed moisture was lost after 28 days in storage. The initial seed water content was so high, i.e. about 60% of total seed weight, that substantial moisture losses in storage are to be expected, contributing to the recalcitrant character of salak seed.

Sawdust and charcoal help to preserve viability of stored seeds; charcoal gave better results than sawdust. This may be due to the ability of charcoal to absorb water vapour from the surrounding air. Charcoal had 13% of moisture while sawdust had only 7%. Moreover, perhaps the fine charcoal particles ensured a closer contact between seed surface and medium than sawdust. The higher humidity around the seeds in media containing 7 - 13% moisture may have been able to delay irreversible dehydration of seeds (by limiting transpiration). Charcoal and sawdust can be used to store the seeds for as long as 21 days before planting. This should be long enough to allow for long distance transport. Other variables showed similar responses to duration of storage and the corresponding loss of water. Thus high seed water content is important for successful germination of salak.

According to Agrawal (1986) there are two important factors during storage, i.e. relative humidity of the atmosphere and temperature. Seeds will attain a characteristic moisture content at a given relative air humidity (RH) and temperature: the equilibrium moisture content. Rice and sunflower are examples of orthodox seeds. At RH between 75 and 90%, seeds have a moisture content of 14.4 to 18.4% for rice and 8.0 - 15.0% for sunflower at room temperature. During this experiment the RH values ranged from 75 to 81%. After 28 days storage in ambient air all seeds were killed, and the germination percentage dropped sharply even after 7 days. This result is very different from that reported for the orthodox group (Agrawal, 1986), but is in accordance with Schuiling and Mogea (1991) who reported that after a week in storage 50% of salak seeds lost their viability; after two weeks of storage all seeds were unable to germinate. Dickie et al. (1993) reported that palm seed cannot withstand desiccation, therefore seed banks and cryopreservation will pose problems. All of this supports the conclusion that salak seed is recalcitrant.

The media should be able to hold water permanently. Therefore, it is important to investigate the equilibrium between media water content and relative humidity in the storage room in combination with room temperature. Evaporation is mainly determined by humidity and temperature. Temperature during seed storage strongly influenced the germination of *Chrysalidocarpus lutescens* (Broschat and Donselman, 1988). No seed stored at 5 °C germinated, but the germination percentage remained above 50% for 420 days when seed was stored at 23 °C. The species belongs to the palm family and exhibits a recalcitrant seed character.

It is also necessary to experiment with different particle sizes of the storage media, because presumably the finest particles protect the seed more effectively. This may also lower the rate of seed respiration by reducing the supply of oxygen. One of the methods to store seeds of the orthodox group is to put them in sealed tins under low air pressure. This also reduces seed respiration.

Recently, a method of seed preservation based on ultra-drying was developed in China and the United Kingdom (Anonymous, 1990b). But also this technique was mainly designed for orthodox seeds. Appropriate technology for recalcitrant seeds is not readily available. In Malaysia, a method has been developed to preserve recalcitrant seed (Anonymous, 1990b). Excised embryos of jackfruit, dried to 8% moisture content, still germinated (80%). It may be worthwhile to test this technique on seeds of monocotyledons, such as salak.

Conclusions

1. Salak seed is recalcitrant. The seed has a high moisture content which rapidly drops in ambient air, associated with reduced viability: after 1 week of storage only 60% germinated, after 4 weeks germination failed completely.
2. Storage in sawdust (7% moisture) and in particular in charcoal (13% moisture) greatly improved germination and growth rate of the seedlings, but nevertheless every extra week of storage in these media reduced the rate of growth; 100 days after planting this was still reflected in lower numbers of leaves and a smaller leaf area per plant.
3. There is a close correlation between seed moisture content and successful germination.
4. Further research is needed, first to improve preservation of moisture and second to explore other approaches to successful long storage.

CHAPTER 5: AGRONOMIC STUDIES REGARDING SOILS, NUTRIENTS AND SHADE

This chapter reports on some experiments with certain environmental factors, i.e. soils, nutrients and shade. In a pot experiment with seedlings different soil types were compared; in a field experiment the response of seedlings to shading and nitrogen was observed. Finally, in an experiment on bearing plants the effect of a compound fertilizer on the growing fruits was studied.

5.1. Seedling growth in different soils

Introduction

Salak palm grows well in a range of soils. Schuiling and Mogea (1991) reported that Ultisols and Entisols are the typical soil types in the salak production centres. Based on a survey in five salak production centres in East Java, Ashari (1993) found quite a variety of soil types, i.e. Entisols in Bangkalan and Jombang, and Inceptisols in Bangkalan, Malang and Bojonegoro. Moreover, Kusumainderawati et al. (1992) reported that Oxisols are predominantly found in Karangasem of Bali province, where the Balinese salak is widely cultivated.

'Pondoh' is now increasingly grown in the above production centres on Java, replacing the varieties which are characteristic for each centre. Because the soils differ so much, a pot experiment was conducted to assess the early growth of 'Pondoh' in these different soils. Fast growth of the young seedlings should shorten the juvenile phase; this brings orchards into production sooner which facilitates the change-over to other varieties such as 'Pondoh'. Moreover, it was hoped that the effects of soil type on seedling growth can be linked to more specific agronomic factors such as organic matter requirement and nutrients needed.

Materials and methods

The soils used in the experiment were taken from four salak centres, namely Sleman ('Pondoh' grown at 411 m a.s.l.), Suwaru (in kabupaten Malang, 358 m a.s.l), Kacuk (in kota Malang, 400 m a.s.l.), and Bangkalan (on Madura island, 2 - 15 m a.s.l.). These soil types were compared to Jatikerto soil (300 m a.s.l.), also located in kabupaten Malang, into which 'Pondoh' is to be introduced. The climatic conditions of Sleman and Jatikerto are presented in Appendices 1 and 2.

Three orchards were randomly chosen in each of the 5 locations. With a soil auger, soil samples (0 - 45 cm depth) were taken at five sites in each orchard. Four samples were taken from each orchard corner (2 m away from other orchards) and the fifth from the centre. Fifty kg of soil was taken from each site. Total soil weight collected in each orchard thus was 250 kg. The bulk of the soil was mixed, air-dried, gently crushed and sieved (erroneously to < 2 mm, using a sieve that is meant for samples in soil analysis) in order to make it homogeneous. The soil of the three orchards in a location was mixed to obtain a composite sample representing the type of soil in that location.

With each of the five soil types, polybags, 10 cm in diameter and 25 cm in height, were filled with 1.5 kg soil. There were 30 bags per treatment replicated four times. The total number of potted plants in the experiment thus was 600. The bags were kept under natural light in a house covered with white polyethylene. The temperature during the experiment ranged from 18 to 32 °C.

Fully mature 'Pondoh' fruit was picked directly from a salak garden of a farmer in kabupaten Sleman. After the flesh was removed from the seeds, the seeds were washed thoroughly with tap water and dipped into insecticide solution, Dursban 20 EC (2ml/l water) for 3 minutes. The seeds were put into the polybags, which had previously been watered, 1 cm deep. Each polybag received 50 cc of distilled water, pH 5.5 - 6, weekly.

Detailed observations on the germination process are reported in Chapter 6. Criterion for germination was as described in Chapter 4.2. The first root was the root that grew at the centre of the cotyledonary sheath. Tomlinson (1960) called this root the rudimentary root, because it soon ceases to grow and is replaced by adventitious roots. The growth of the ligule was considered to start when the swelling growing point turned red. The adventitious roots were recorded by carefully removing the soil from a sample of the seeds. Germinated seed of cv. Pondoh is shown in Plate 4. The time of emergence of the first 3 three simple leaves, and the duration of the growth stages of these leaves were recorded as described in Chapter 2.1.

The experiment was terminated 6 months after sowing by determining dry weight of the plants. The mature (dark green) third leaf, counting from the spear leaf was used in destructive sampling, to analyse leaf content of N, P and K by standard procedures. In soil samples total N was determined by the Kjeldahl method, available P by the Olsen method and exchangeable K in 1 N NH_4OAc, pH 7.0. The pH, organic matter, Ca content, texture and field capacity of the five soil types were also measured. Soil pH was measured after mixing soil and a 1 N KCl solution in a ratio 1:1. The data collected were analysed, using a complete randomized block design and regression and correlation following Steel and Torrie (1980).

Results

Soil properties. Soil pH ranged from 6.1 to 7.0 (Table 5.1). The organic matter and the nitrogen contents of the soils were very low to low. Soil-P content of Suwaru was high, while others were low to fair. The five soils tested contained fair to high levels of K and Ca. This indicates that K and Ca would not be major factors limiting seedling growth.

The texture of the soils ranged from sandy-clay loam (Sleman, Bangkalan, Suwaru) to clay loam (Kacuk and Jatikerto) and is presented in Table 5.2. The table also shows that water volume at field capacity (in %) of the heavy-textured soils in Kacuk, and particularly in Jatikerto, is much higher than for the lighter soils from the other locations.

Germination. The growth of the primary root was slower than that of the adventitious roots. The adventitious roots, which originated from around the base of the ligule, grew strongly and became feeder roots. The time of emergence of adventitious roots was not convincingly affected by the soil types, but the emergence of the scale-leaf was retarded in the heavy-textured soils of Kacuk and Jatikerto (Table 5.3).

Leaf growth. Figure 5.1 shows the time of emergence of the first three leaves and the successive growth stages for each leaf. The first stage, spear extension, covers the period from emergence of the spear till it is fully extended, but also a possible period of

Table 5.1. Selected properties of the soils studied.

Soils	pH	C-org. (%)	N-total (%)	P (mg kg^{-1})	K (cmol kg^{-1})	Ca (cmol kg^{-1})
Sleman	7.0	1.50 l	0.16 l	16 l	0.33 f	4.44 f
Bangkalan	6.1	0.58 vl	0.10 l	13 l	1.93 vh	17.05 h
Suwaru	6.3	0.90 vl	0.13 l	57 h	1.11 vh	6.83 f
Kacuk	6.9	1.27 l	0.16 l	29 f	0.40 f	12.79 h
Jatikerto	6.6	0.28 vl	0.06 vl	11 l	2.39 vh	8.60 f

* vl: very low, l: low, f: fair, h: high, vh: very high (according to Hardjowigeno, 1987).

Table 5.2. Soil texture and field capacity.

Soil types	Percentage of			Textural class	Water volume at field capacity (%)
	Sand	Silt	Clay		
Sleman	72	3	25	Sandy-clay loam	24.5
Bangkalan	63	15	22	Sandy-clay loam	25.4
Suwaru	54	22	24	Sandy-clay loam	29.2
Kacuk	42	20	38	Clay-loam	39.6
Jatikerto	42	28	30	Clay-loam	48.2

Table 5.3. The germination of the salak seeds, in days after sowing.

Soil types	Emergence of	
	Adventitious root	Scale leaf
Sleman	11.8 a	14.2 a
Bangkalan	10.9 a	13.5 a
Suwaru	11.5 a	15.2 ab
Kacuk	12.8 a	16.2 bc
Jatikerto	13.5 a	17.5 c

Means in a column followed by the same letter are not significantly different at p=0.05.

'spear rest', i.e. without apparent activity after the spear has attained its full length (which ideally should have been recorded separately).

As shown in Figure 5.1 it took more than 30 days from sowing before the first leaf emerged, but it grew and matured quickly, completing its development in 31 - 36 days. The second and third leaves took much longer (resp. 41 - 51 and 37 - 45 days) to complete their development. The interval between emergence of successive leaves also increased, from 25 - 30 days between Leaves 1 and 2 to 39 - 51 days between Leaves 2 and 3. In the Suwaru soil both leaf growth and leaf succession proceeded fastest, but the only significant effect was the slow growth in Jatikerto soil, associated with delayed emergence of all three leaves.

The bars in Figure 5.1 suggest that unfolding proceeded faster when spear extension took longer. Since spear extension and spear rest were not recorded separately, it is likely that long periods of extension hide a rest period, during which the preparations for unfolding proceeded, so that the actual unfolding needed less time.

Plant dry weight. Total dry weight of the plants sown in Sleman and Suwaru soil was higher than that of plants in the other soils. Root weights did not differ much (Figure

5.2); in fact similar root weights differed greatly in the quantities of top growth which they could support. Consequently the top/root ratio ranged from 3.2 for plants in the Suwaru soil to 1.9 for plants in Jatikerto soil.

Leaf nutrient contents. The leaf-N, -P and -K contents were not significantly different (Table 5.4), but the mean values for N- and P-content were lowest for seedlings in the Jatikerto soil, whereas seedlings in the Kacuk soil had the lowest K-content. Thus the large differences in soil nutrient content (Table 5.1) were only weakly reflected in the nutrient status of the leaves.

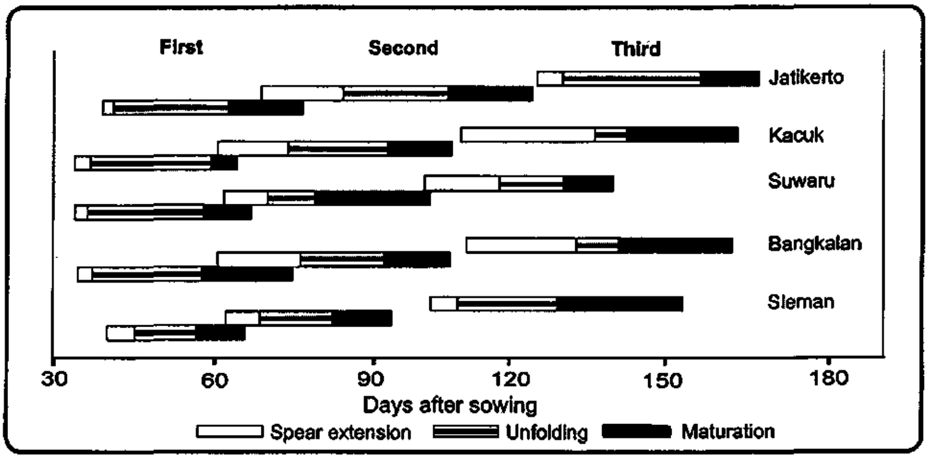

Figure 5.1. Growth stages of the first 3 leaves, in days after sowing.

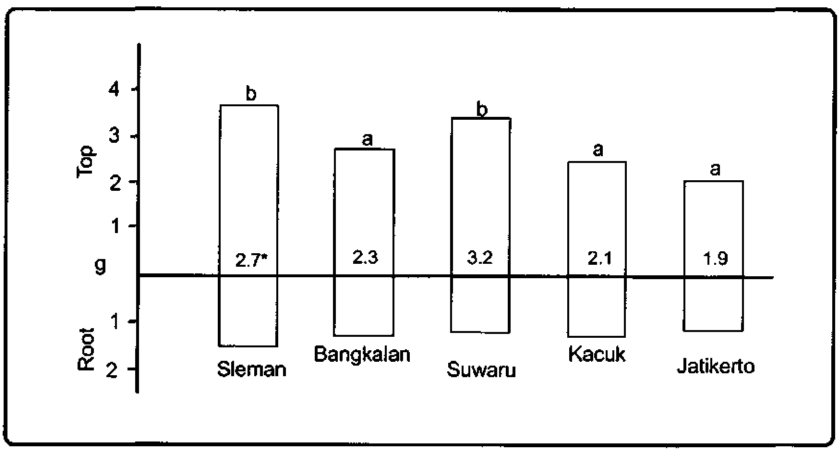

Figure 5.2. Dry weights of tops and roots, in g.
*) Figures are top/root ratios (g per g).
Columns bearing the same letter are not significantly different at P = 0.01.

Table 5.4. Nutrient content of the leaves in mg per g leaf dry weight.

Soil types	Nitrogen (mg/g)	Phosphorus (mg/g)	Potassium (mg/g)
Sleman	21.2	1.6	14.7
Bangkalan	22.8	1.4	12.2
Suwaru	23.8	1.6	12.8
Kacuk	21.4	1.7	10.6
Jatikerto	19.6	1.2	12.2

Table 5.5. Relationships between soil and leaf nutrient status, and between soil organic matter and nutrient content in leaves and soils.

Variables (Y) (X)	Regression equation	Remarks
Soil-N and leaf-N	Y = 0.4 X + 19.8	-
Soil-P and leaf-P	Y = 1.4 X + 12.5	-
Soil-K and leaf-K	Y = 0.5 X + 12.9	-
Soil-C and leaf-N	Y = 11.3 X + 18.6	*
Soil-C and leaf-P	Y = 59.9 X + 28.4	*
Soil-C and leaf-K	Y = 34.1 X + 59.1	*
Soil-C and soil-N	Y = 8.4 X + 4.6	*
Soil-C and soil-P	Y = 8.7 X + 17.3	-
Soil-C and soil-K	Y = -1.8 X + 2.8	*

-: correlation not significant; *: correlation significant at $P < 0.05$.

Nutrient uptake. The relationship between nutrient levels in soil and leaf is presented in Table 5.5. At the age of 6 months the leaf nutrient levels of the seedlings were not correlated with the soil contents. However, soil organic matter and the leaf nutrient contents were significantly correlated. Soil organic matter was also positively correlated to soil-N and soil-K, not to soil-P.

Discussion

Although the soils from the 5 locations differed both in texture and fertility, it still is surprising that they affected germination and growth so strongly and so consistently. In the heavy-textured soils of Kacuk and Jatikerto emergence of the ligule and the adventitious roots was delayed, and seedlings had the lowest dry weight and the lowest top/root ratio. From a fortnight after sowing till the age of 6 months the plants growing in these soils lagged behind, the only exception being the emergence and rate of development of the first leaf of plants in Kacuk soil. Growth was most delayed and least vigorous in the Jatikerto soil, the heaviest soil in the experiment. The initial delay in growth may be attributed to heavy texture of the soil. Perhaps inadequate watering before sowing played a role, because that would have made it harder for the seeds in the heavy soils to imbibe moisture. With the exhaustion of the endosperm, following the maturation of the first leaf, soil fertility may have come into play. The Jatikerto soil had the lowest N- and P- content and the extremely low organic matter content must have aggravated the deterioration of soil structure, which is a well-known problem in the research farm. Goldberg et al. (1990) reported that application of organic matter to an arid zone soil may enhance clay dispersion, thereby improving soil structure through binding of soil particles by roots and hyphae into aggregates.

The soils brought from Sleman, Suwaru and Kacuk were relatively fertile, with better than average contents of organic matter, N and P. Higher organic matter content was associated with better leaf nutrient status and higher N- and K-levels in the soil. For potassium this is supported by a study of Elkhatib and Hern (1988), who reported a positive interaction between organic carbon and exchangeable K in the soil. However, a possible problem with the Kacuk soil was its high Ca:K ratio, which may hinder the uptake of potassium; this might explain the low ranking of this soil later in the experiment and the low leaf-K value.

In as far as the results of a pot experiment are indicative, the Jatikerto soil is not really suitable for salak. Successful introduction of 'Pondoh' will require substantial improvements in both soil structure and fertility. Generous applications of manure are recommended, starting before planting; these should be supported by fertilizer N and P.

The dry weight ratio of tops and roots may be a useful indicator of the suitability of a soil for salak seedlings. The findings suggest that the ratio should be above 2.5.

It took the leaves in this experiment much longer, particularly for the second and third leaf, to complete their growth stages than was the case in the experiment described in Chapter 2.1; moreover the interval between the emergence of successive leaves increased so much that the second leaf matured before the third leaf emerged. Hence the mean interval of 33 days for 'Pondoh' calculated in Chapter 2.1 probably has no general validity for field-grown plants.

Conclusions

1. Germination of 'Pondoh' seeds was retarded on the heavy soils; subsequent growth of the seedlings presumably was increasingly affected by differences in fertility. Growth was most retarded on the heavy-textured, infertile soil from Jatikerto. The growth rate was highest in soils from Suwaru and Sleman, important production centres.
2. Organic matter presumably played an important role in the growth of the seedlings. A higher organic matter content increased nutrient levels in the leaves, organic matter also being correlated to the levels of N and P in the soil; moreover organic matter is needed to improve the physical properties of the soil, particularly of heavy soils.
3. Soil types from four production centres and from Jatikerto were very low to low in organic matter, nitrogen and phosphorus, but medium to high in potassium and calcium. Application of nitrogen and phosphorus and especially organic matter is recommended.

5.2. Effect of nitrogen and shading on seedling growth

Introduction

The results of the previous section (Chapter 5.1) indicated that lack of soil nutrients may limit salak seedling growth. Salak seedlings grew poorest on the (chemically poor) Jatikerto soil. For further experiments with salak in the Jatikerto research farm both the physical structure and the nutrient status need to be improved, in particular the nitrogen supply. It is well established that young salak plants need shade and that there is a general interaction between nutrient uptake and light intensity. Therefore, a field experiment was conducted to test the influence of different shading intensities in combination with different levels of nitrogen supply on the growth of seedlings. Considering the functions of light and nitrogen, it is hypothesized that there will be synergism between these factors in determining salak seedling growth.

According to Tjahjadi (1989) and Soetomo (1990) salak needs 30 - 70% shade. Shade is considered essential for young plants. Growers plant salak under the shade of established trees such as rambutan, banana, langsat, etc. and in addition plant banana or *Sesbania grandiflora* to intensify the shade during the first years. When these short-duration intercrops have disappeared, the dense stand of salak with its large leaves ensures extensive mutual shading of the palms. Growers around Malang are not very concerned about shade in mature gardens and do not replace permanent shade trees which die.

Nitrogen is one of the major nutrients. The annual deposition of atmospheric nitrogen available for crop growth is less than 25 kg N per ha. Mineralization of soil nitrogen is about 100 kg per ha per year in the temperate zone (Neeteson and Zwetsloot, 1989). In the tropics mineralization should be higher, but losses of nitrogen (denitrification, ammonia volatilization, etc.) will also be larger. Nitrogen losses in dry regions are determined mostly by the temperature. The higher the temperature, the greater the nitrogen losses.

Materials and methods

The experiment was done at Jatikerto research station near Malang, in the dry season from April to November 1990. The temperature ranged from 25 to 29 °C and RH from 65 to 71%. During the investigation rainfall was nil.

Four months old 'Pondoh' seedlings were planted in the field at 75 x 75 cm. Two factors were combined, i.e. shading at 4 levels: 0, 25, 50 and 75% reduction of incident light at mid-day and also 4 urea levels: 0, 10, 20 and 30 g per plant (or 0, 4.6, 9.2 and 13.8 g N per plant). Application of urea was in four equal monthly doses, starting at transplanting. Each of the treatment combinations consisted of two seedlings and the treatments were arranged according to a split-plot design, with shading as main factor and urea as split factor. The trial was replicated three times.

The shading was made from thin cut bamboo and placed 150 cm above the plants. At planting time, each seedling was fertilized with farmyard manure of cattle, triplesuperphosphate and potassium chloride at the rate of 1 kg, 10 and 10 g per plant, respectively. Each seedling was watered every two days with 100 ml of water during the first month. Later on, 500 ml of water was given weekly or as required.

Number of leaves and leaf area per plant were measured fortnightly. The results were analysed using analysis of variance of a split-plot additive model and regression analysis according to Steel and Torrie (1980). In addition dry weight, of the above-ground part of the plants and leaf-N content were measured at the end of the experiment, nearly 4 months after the start. Leaf area was calculated by multiplying length and width of the largest leaflet with the number of leaflets and a shape factor. To determine dry weight of tops, the material was dried in an oven at 80 °C for three days or until the weight was constant.

The light intensity was measured by using a silicon light meter at mid-day. The light meter was placed in a north-south and an east-west direction; the two values were averaged. N content of leaves was measured at the Soil Science lab of Brawijaya University using the Kjeldahl method.

Results

The shade treatments corresponded to the intended levels, as shown by the averaged light measurements over 5 days (Table 5.6). The table also shows that the shade treatments substantially lowered temperature at soil level and more importantly that in full light nearly one-third of the seedlings had died by the end of the experiment. In fact the plants in full light declined almost from the start of observations, confirming the common wisdom that salak seedlings have to be raised under shade. Therefore the unshaded treatment is excluded from the analysis, leaving only the 25, 50 and 75% shade levels.

At transplanting the seedlings selected for the experiment had three mature leaves. At the final count – nearly 8 months after sowing – the number had increased to 5 - 7.5 (Table 5.7). The effects of urea exceeded those of the shade treatments: the number of leaves per plant was smallest in the absence of urea and highest with 10 g urea per plant. The curvilinear relationship between quantity of urea applied and number of leaves was significant ($P < 0.05$; $n = 12$). The two highest shade levels were slightly (non-significantly) better than 25% shade.

Table 5.6. Shading level, light intensity, temperature at soil level and death of seedlings.

Shading (%)	Light intensity (%)	Temperature (°C)	Death of seedlings (%)
0	100	39.2	31.9
25	74.5	31.2	0
50	49.2	30.4	0
75	24.8	30.2	0

Table 5.7. Mean number of leaves per plant at the end of the experiment, nearly 8 months after sowing in response to shade and urea application. For statistical data analysis based on regression, see text.

% Shade	Urea, g/plant			
	0	10	20	30
25	5.0	7.3	6.6	6.4
50	5.6	7.5	6.9	7.0
75	5.7	7.4	7.0	6.9

Leaf area per plant 112 days after transplanting ranged from 4.7 to 7.0 dm^2 (Table 5.8). As was the case for number of leaves per plant, the effects of urea were stronger than the effects of more shade. Plants receiving no urea had less than 5 dm^2, those dressed with 30 g urea about 6 dm^2 and the intermediate urea levels gave leaf areas approaching 6 dm^2 at 25% shade and 7 dm^2 at 50% and 75% shade. The 25% shade treatment was only clearly less effective at the intermediate N-levels. The curvilinear relations between urea level and leaf area or leaf area increase were statistically significant ($P < 0.05$), but differed for the three shade levels: the response to urea was less pronounced at 25% than at the two other shade levels.

This interaction between shade and urea resulted in the largest leaf areas for the combination of intermediate urea-level with the highest shade levels. This interaction can also be observed for the increment in leaf area during the second half of the experiment (Table 5.8): the increments were generally 50 - 60%, but for the four best treatment combinations they ranged from 76 to 90%.

The curvilinear relation between amount of urea applied and dry weight of the tops (data presented in Table 5.9) was significant ($P < 0.05$) for all three shade levels, but showed a more pronounced optimum for the shade levels 50 and 75%. The data on the dry weights of the tops clearly show that dry matter production was highest for the treatment combination of 10 g urea and 50 or 75% shade. The corresponding treatment combinations with 20 g urea, which attained nearly the same leaf areas, fell back somewhat in respect to dry matter yield, almost to the level of plants which received 30 g urea; dry weights were lowest in the absence of urea. Shade levels made no difference at the highest urea-level, but at 10 or 20 g of urea per plant 50% and 75% shade were advantageous.

The curvilinear relationships between amount of urea applied and leaf-N content (for data see Table 5.10) were statistically significant ($P < 0.05$) but very different for the three shading treatments, and even different for the shading levels 50% and 75%. As such a pronounced difference between 50% and 75% shade is unlikely, no general conclusions can be drawn.

Table 5.8. Mean leaf area per plant 112 days after transplanting (dm^2) and (between brackets) percentage increase (in % of the leaf area 56 days earlier). For statistical data analysis based on regression, see text.

% Shade	Urea, g/plant			
	0	10	20	30
25	4.8 (55)	5.7 (59)	5.8 (53)	5.7 (54)
50	4.7 (59)	7.0 (90)	6.9 (89)	6.2 (59)
75	4.8 (52)	7.0 (82)	6.8 (76)	6.0 (63)

Table 5.9. Dry weight of tops (g/plant) in response to shading and urea application. For statistical data analysis based on regression, see text.

Shading (%)	Urea, g/plant			
	0	10	20	30
25	8.6	14.7	13.1	13.0
50	13.4	23.3	15.6	13.6
75	10.1	19.9	15.0	13.1

Table 5.10. Leaf-N content (%) of the seedlings, 112 days after fertilization. For statistical data analysis based on regression, see text.

% Shade	Urea, g/plant			
	0	10	20	30
25	4.0	4.8	4.4	3.3
50	4.2	3.9	4.1	4.7
75	3.9	4.3	4.6	4.5

Discussion

Whereas the need for shade in mature salak orchards is disputed, it is common wisdom that young salak plants need shade, so it was going to extremes to include a treatment without shade during the dry season in the experiment. The results showed that fairly deep shade is desirable: plants grew almost equally well under 50% and 75% shade, and clearly better than those under 25% shade.

Young plants are generally more susceptible to stress and the main function of shade at the seedling stage appears to be to limit stress. That is why tree nurseries commonly are shaded.

Clove seedlings also do not tolerate full light (Hasan, 1986). The leaves gradually withered and in the end 95% of the plants were killed in the absence of shade. At 50% shade + 2 ppm plant growth hormones (Mixtalol) the death rate was still 24.5%.

Shade and urea interacted in such a way that plant growth was most vigorous in the treatment combinations of the highest shade levels and the intermediate N-levels. This finding is not in agreement with results in coffee and cocoa, plants which – like salak – are at home in the understorey of forests. In cultivation the optimum N-dressing for coffee and cocoa is higher at lower shade levels; moreover the combination of higher light intensity and extra nitrogen leads to higher yields (Beer et al., 1998; Wessel, 1985). However, these findings refer to bearing plants; extra nitrogen enables the leaves to function better and sufficiently long for the plants to sustain the heavier fruit load until the fruit matures.

The salak seedlings apparently require intensive shade and they did in fact respond strongly to nitrogen. That the plants grew less strongly at the highest N-dressings requires explanation, for an abundance of N as such need not depress growth. Perhaps watering was not quite adequate, raising at 20 and 30 g N per plant, hampering uptake by the roots from time to time.

With respect to number of leaves per plant and dry weight of tops, 10 g urea was somewhat better than 20 g. The experiment lasted only 4 months; if an advice for the entire first year after transplanting has to be based on the findings, 50% shade and 20 g urea per plant are recommended, in combination with a generous application of manure before planting.

The number of leaves – 7 per plant 8 months after sowing in the best treatments – reflects a similar leaf appearance rate as the 12 leaves in 13 months from sowing found for Pondoh in Chapter 2.1 and a much higher rate than the rates of leaf production by young Pondoh seedlings in Chapter 5.1.

Conclusions

1. Shade is essential for young salak plants; during the dry season in East Java the reduction of incident light at midday should be 50% or more.
2. Urea application - in addition to manure before transplanting - improved growth, 10 g per plant being best.
3. Plants grew best with 50 or 75% shade in combination with 10 g urea. Extrapolating the findings from 4 months to one year after transplanting, 50% shade, 20 g urea per plant and generous manuring are recommended.

5.3. Fertilization of adult salak palms

Introduction

Most salak gardens in Indonesia are quite old as they are handed down from father to son, sometimes over 4 - 5 generations. The aging plant parts are cut off and decay in the garden, thus recycling the nutrients (Schuiling and Mogea, 1991). Additional fertilizers are rarely used, so it is not surprising that the fertility of the garden soils tested in Chapter 5.1 was generally low, particularly with regard to organic matter, nitrogen and – in some production centres – phosphorus.

According to Kusumainderawati et al. (1992), 'Pondoh' needs about 50 g N, 100 g K, 32 g Ca, and 20 g Mg per plant per year. These authors found the desirable levels of elements in young, fully-extended (but still yellowish) leaves to be 1.7% N, 0.8% K, 1.2% Ca, 0.2% Mg and 0.8% S (P-fertilizer was not included in their study). Moreover, Sholeh et al. (1994) reported that besides N, P, K and Mg, 'Pondoh' also needs micro-elements such as Bo and Zn, respectively, 0.4 g and 1.4 g per plant per year. Their work also indicates that the kind of fertilizer and the rates needed by the palm depend on (1) the soil type, (2) climate, (3) cultivar and (4) age of the plant.

Growers are reluctant to use fertilizer because they believe that inorganic fertilizer harms the soil structure, causes fruit drop, increases the occurrence of split and decaying fruit, and shortens fruit life after harvest. To test the effects on the fruit, an experiment was laid out in an old garden near Malang with different rates of compound fertilizer on plants bearing young bunches.

Materials and methods

The trial was laid out in the garden of a farmer in desa Suwaru, Gondanglegi, kabupaten Malang, from April to September 1994. The palms in the experiment were more than 50 years old. The maximum temperature ranged from 21 to 29 °C. The relative humidity ranged between 81 and 92%.

Salak palms with two bunches (1 - 2 months after hand-pollination) were selected; the number of leaves was between 9 and 13 per plant. Before fertilization withering leaves were cut off and a soil sample from 0 - 45 cm depth was analysed to determine chemical and physical properties. The sampling and analysis procedures were as described in Chapter 5.1.

The NPK-fertilizer used was 'Nitrophoska' 15:15:15. The application rates were: 0, 30, 60, 90, 120, 150, and 180 g per plant. The fertilizer was mixed with the soil, 35 cm from the trunk, 10 cm deep. The experiment used was a randomized block design, each treatment consisted of three plants and was replicated three times. The variables measured were: area of the first leaf to emerge after fertilization, number of good and defective fruits per bunch, and the weight of fruits, flesh, skin and seeds.

Results

Soil properties. The soil properties are presented in Table 5.11. Nutrient contents for this soil, classified as loam, were low to very low, except for soil-K.

Table 5.11. Texture and fertility in the soil layer 0 - 45 cm.

Soil elements	Values	Remarks*
pH	7.0	Neutral
C (%)	1.26	Low
N (%)	0.14	Low
P (mg P/kg)	6.00	Low
K (cmol/kg)	0.36	Medium
Soil particles:		
a. Sand (%)	44	
b. Silt (%)	36	
c. Clay (%)	17	
d. Texture class		Loam

* According to Hardjowigeno (1987).

Emergence and growth of first new leaf. The first leaf to emerge after fertilization attained a significantly larger area at higher fertilizer doses. Rates of 120 to 180 g NPK per plant gave the largest leaf area (1.2 - 1.3 m^2); the control had the smallest leaves. The positive relationship between leaf area and fertilizer rate showed a quadratic response, with an R^2 = 0.817*. The calculated optimum rate is just above 200 g fertilizer per plant (see Figure 5.3).

Leaf nutrient content. Positive linear relationships between fertilizer rates and leaf nutrient content were found (Figure 5.4). N-content of the leaf increased steadily with an increase in fertilizer rate (R^2 = 0.787*). Leaf-K was significantly better at higher fertilizer doses (R^2 = 0.715*). The increment in P-content was less significant (R^2 = 0.225).

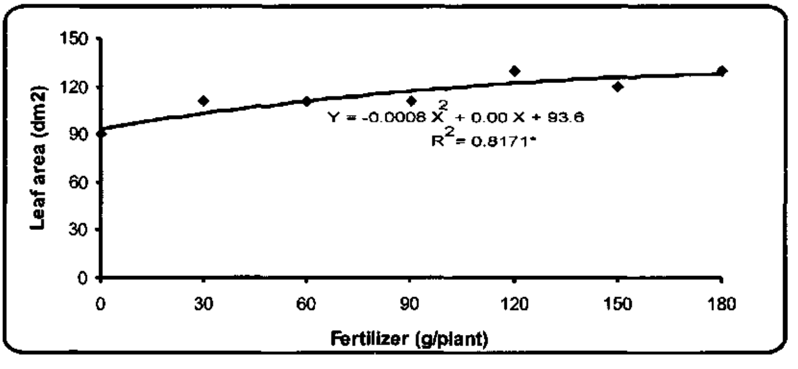

Figure 5.3. Area of the first leaf emerging after NPK application.

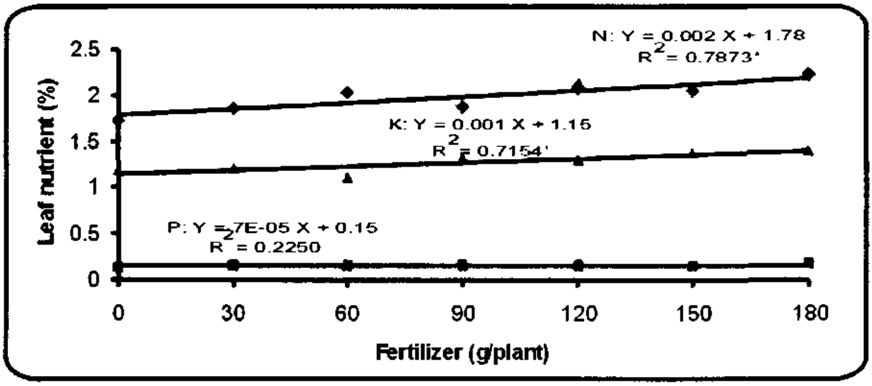

Figure 5.4. Leaf nutrient contents in response to NPK application.

Fruit yield. There was a strong tendency for the fertilizer to increase the number of fruits per bunch. Since fruits had already set before the experiment started, this can only be explained by reduced premature drop of fruits. This is supported by the observation that the numbers of defective fruits (split skin, rotting) declined with an increase in fertilizer rates. Consequently the number of good fruit per bunch showed a more marked response to fertilizer.

The relationship between fertilizer rates and number of fruits per bunch is presented in Figure 5.5. These responses are quadratic. The fertilizer strongly increased fruit numbers per bunch (R^2 = 0.770**), decreased the number of defective fruits (R^2 = 0.795**), and therefore increased the number of good fruits significantly (R^2 = 0.803**).

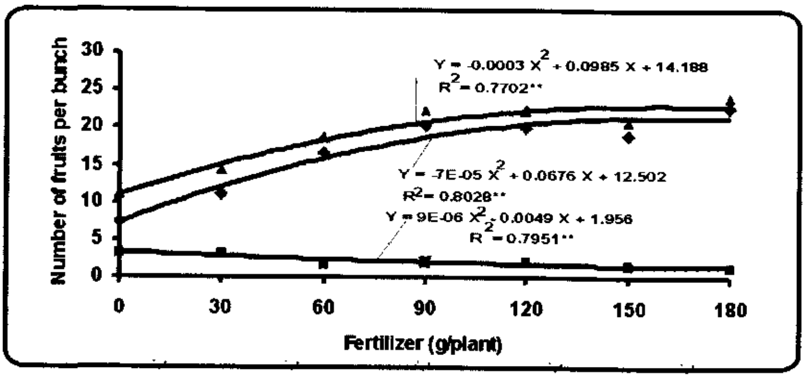

Figure 5.5. Number of fruits per bunch after NPK application.
Squares: number of defective fruits; diamonds: number of good fruits; triangles: total number of fruits.

Table 5.12. Means of weight per fruit and its components, in gram.

Fertilizer (g/plant)	Fruit weight	Flesh weight	Seed weight	Skin weight
0	70.0 a	48.9 a	13.2 a	7.8 a
30	72.3 ab	49.8 a	14.4 a	8.1 a
60	72.3 ab	51.2 a	15.6 a	5.9 a
90	73.8 bc	50.3 a	17.0 a	6.6 a
120	72.6 bc	51.0 a	14.2 a	7.7 a
150	75.6 c	50.2 a	16.6 a	8.7 a
180	75.0 bc	55.9 b	14.3 a	5.1 a

Means in a column followed by the same letter are not significantly different at 5%.

The fertilizer application increased both mean weight per fruit and flesh weight slightly, but did not increase the seed and skin weight (Table 5.12). The rate of 180 g NPK per plant gave the highest flesh weight per fruit, but in general fertilizer tended to increase fruit size.

Discussion

In this experiment the records were taken from organs which had already been formed before the trial started: the measured leaves had been developing for a long time in the bud and the fruits had already set. The full impact of fertilization can only come to light when the enhanced nutrient uptake can influence the growth of new organs from their meristematic beginnings till they mature or senesce. In salak, as in other palms, this takes a long time, because leaves and inflorescences are long-lived. Thus the 6-month experiment lasted much too short a period to fully assess the effect of fertilization; experiments of this kind should be planned to continue for several years.

In spite of the short duration, the experiment does show beneficial effects of fertilization both on growth and yield. Presumably the increased size of leaves and fruits is due to enlargement of the cells, because increased nutrient uptake occurred too late to affect the number of cells. Larger leaf size with higher nutrient levels should favour the growth of the axillary inflorescence and ultimately – when subsequent leaves also grow larger – increase the size of all the plant's organs. This explains the expected long-term effects, referred to above.

The results do not justify the notion held by growers that fertilizer may cause the fruit skin to split and enhances fruit rot and drop; on the contrary. Fruit drop may have been reduced by fertilizer application; it also reduced the numbers of split and rotting fruits. That the long period of cultivation without adding nutrients exhausts soil fertility is indicated by the low soil nutrient levels at the start of the trial. However, the contents of N and P in Table 5.11 are suspiciously low, not only in absolute terms, but also in relation to the organic matter content. Moreover, N, P and K levels for salak gardens in the same area (Suwaru) reported in Chapter 5.1 (Table 5.1) are so much higher, that the low values can hardly be correct.

It is not known what amounts of nutrients are removed from the orchard with the harvested fruit. The edible portion contains 0.4 g protein, 20.9 g carbohydrate, 28 g Ca, 18 g P and 4.2 mg Fe per 100 g (Sosrodihardjo, 1982) and considerable amounts of nutrients are contained in the seeds too. Manures and fertilizers therefore should be applied to attain high yield. The maximum fertilizer dose in this experiment (180 g

15:15:15, or 27 g each of N, P and K) is about half the annual dose recommended by Tjahjadi (1989) and Kusumainderawati et al. (1992) for N; the quantities of P and K correspond to those recommended by Tjahjadi (1989). Considering that this experiment lasted only 6 months, the results are in agreement with these recommendations.

Conclusions

1. Compound fertilizer increased the size of leaves and fruits which were in an advanced stage of growth already; presumably this is due to enlargement of the cells rather than an increase in number of cells.
2. Contrary to what growers believe, fertilizer application reduced the numbers of split and decaying fruits somewhat, associated with an increase in the number of good fruits per bunch.
3. There is a need for long-term on-farm fertilizer experiments, to establish application rates and timing of dressings and to convince growers of the usefulness of fertilizers.

CHAPTER 6: TOWARDS A PATTERN OF GROWTH AND DEVELOPMENT OF SALAK

The experimental work with salak was supplemented by botanical studies and observations on growth and development of the palm. The results are presented in this chapter. Experimental findings described in the previous chapters are recapitulated here in as far as they clarify aspects of growth and development. In combination with published information this material should add up to an outline of growth and development of the salak palm, drawing attention to aspects which require further study.

The discussion here follows the five phases of growth and development distinguished by Tomlinson (1990) and presented in the General Introduction of this thesis:

- embryonic phase
- seedling phase
- establishment phase
- mature vegetative phase and
- reproductive phase.

Because most experiments started with seed, this study contributed most to insight in the seedling and establishment phases; contributions to clarifying aspects of the embryonic phase, the mature vegetative phase and the reproductive phase are modest.

6.1. Embryonic phase

This phase, from the formation of the zygote till the mature seed, was not studied; the pollination experiments (Chapter 3) only served to clarify aspects of the reproductive phase. However, Plates 2 and 3, taken after hand pollination, show the position and the size of embryos of 'Pondoh'. Plate 2 was taken 2 months after pollination; it shows the circular whitish embryos in the endosperms of a fruit with 3 seeds, the endosperm surrounded by the sarcotesta (the seed coat which is to become the fruit flesh; as long as the embryo is transparent 'Pondoh' kernels are edible too). Plate 3 shows the squat conical embryos, 1-1.5 mm in diameter, excised from a mature fruit. In its natural position the base of the cone is visible as the 'eye' of the seed kernel, the tip pointing inwards.

6.2. Seedling phase

The germination process was observed closely in the experiment described in Chapter 4.1, where the endosperm was partly excised and growth of the haustorium and the embryo was followed. In Chapter 5.1 seedlings were raised in different soil types and further observations were made. On the basis of these findings the germination of salak can be described – in the terminology adopted by Tomlinson (1990) – as adjacent-ligular (Figure 6.1):

- the cotyledonary sheath extrudes only 5 -10 mm from the germ pore, so that the plumule is adjacent to the seed;
- the cotyledonary sheath forms an upright tubular extension, the ligule, through which the scale leaf and the first bladed leaf emerge.

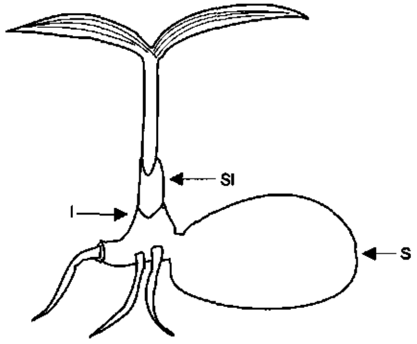

Figure 6.1. Germination in *Salacca zalacca*, adjacent-ligular germination
S: seed kernel, I: ligule, SI: scale leaf.

About 9 days after sowing the embryo starts to develop, the cotyledonary sheath is being pushed out of the seed kernel. From the base of the extruded cotyledonary sheath the radicle emerges; about 12 days after sowing it is fully extended and the first adventitious roots have already broken through the cotyledonary sheath. Very quickly these secondary roots make the radicle obsolete.

The ligule is 15 - 20 mm long and the first part to appear above-ground, about 19 days after sowing (Plate 4). There is only one scale leaf; it is followed by the first of a series of simple-bladed leaves.

While the developments outside the seed proceed, the distal part of the cotyledon, inside the seed kernel, is modified into a haustorium (Plate 4). The growth of this organ as it digests the endosperm is described in Chapter 4.1. Removal of half of the endosperm greatly reduced the rate of growth. This is once more demonstrated in Plate 5 which shows seedlings with intact and halved endosperm 77 days after sowing. Corner (1966) states that the endosperm of palms does not contain starch or sugar; in that experiment, however, it was shown that starch is the main constituent of the salak endosperm.

The seedling phase comes to an end as soon as the young plant depends on photosynthesis (autotrophic growth) instead of on the mobilization of seed reserves by the haustorium (heterotrophic growth). Chapter 4.1 indicated that this is the case shortly after the first simple leaf matures. The literature and the experiments reported in this study show that the age at which this stage is completed, varies greatly depending on growing conditions; in the poorly lit growth chamber of Chapter 4.1 it took 4 months, for the seedlings in Chapter 5.1 it took only 2.5 months. Chapter 4.2 showed that seed storage for one or more weeks also slows down germination and early growth.

6.3. Establishment phase

By increasing the number of leaves and leaf size, and by producing suckers the seedling establishes itself. The stage is completed when the growing point and the leaves emerging from it reach a more or less constant size. Probably this is also the time at which the rosette stage comes to end and the formation of the trunk starts.

The limited size of the plant during this stage facilitates the study of leaf growth, including phyllotaxis and bud positions in relation to the leaf axils, and the way in which suckering proceeds. The plants in Chapter 2.1 and 2.2 and additional 'Pondoh' seedlings planted simultaneously, were used to clarify these aspects.

Leaf growth stages. Each leaf emerges from the apical growing point through the sheath of the previous leaf and extends as a slender spear, which upon reaching its final length unfolds, after which the tender tissues mature. In some experiments it looked as if the spear, having reached its full length, did not immediately start to unfold. However, because of the sigmoid curve of leaf extension (Corner, 1966; Tomlinson, 1990), measurements of spear length are usually not sufficiently frequent and precise to establish exactly when extension is completed.

The unfolding leaf is light brown with longitudinal green streaks, quite different from the bright to dark green mature leaf. In Chapter 2.1, spear extension took about 33 days for both simple and compound leaves; simple leaves matured on average 48 days after emergence, compound leaves after about 65 days. Chapter 5.1 showed that the duration of the growth stages can vary considerably from one leaf to the next.

Leaf forms. More simple leaves follow the first bladed leaf, formed during the germination phase; in Chapter 2.1 the number of simple leaves ranged from 4 to 7 for the different varieties. In subsequent leaves one or several leaflets are separated from the main blade, so that the leaves are compound. With the increase in size of each new leaf the pinnate character comes more to the fore, but at the tip of the rachis a few leaflets usually remain united, a vestige of the simple leaf blade in the young seedling.

Apart from the larger pair of blades at the tip of the rachis, leaflet size varies little, but near the rachis base there are some smaller leaflets, sometimes including very small ones. The arrangement of the leaflets along the rachis is irregular: they are neither opposite nor alternate; some short or longer sections of the rachis bear no leaflets at all or only a leaflet on one side. The impression is of some – often quite a few – 'missing' leaflets here and there along the rachis.

The irregular distribution of the leaflets along the rachis is a rare feature in palms. It is hard to reconcile with the notion that in the early stages of development the palm leaf has a single, intricately folded lamina, which splits into separate leaflets along certain folds (Tomlinson, 1990).

Rate of leaf production. If the palm grows well each new leaf is larger than its predecessor and the spear of the new leaf will be extending before the previous leaf has matured. The interval between the emergence of successive leaves, the phyllochron, is often expressed as the reciprocal value, the rate of leaf production, e.g. 'one leaf per month' (coconut) or '24 leaves per year' (oil-palm). This suggests a constant phyllochron, characteristic for adult palms of the species.

However, during the seedling establishment stage of salak the phyllochron is far from constant; there is much evidence in the experiments reported in this study that the interval depends on the variety (Chapter 2.1) and growing conditions (Chapter 5.1); moreover there are indications that it increases with leaf size. The highest rates of leaf production, counted from the date of sowing, were observed in 'Pondoh': 7 leaves in 8 months (Chapter 5.4) and 12 leaves in 13 months (Chapter 2.1).

Phyllotaxis. Leaves are usually arranged in spirals along the stem. In some palms the arrangement can be studied by the leaf scars left on the trunk after abscission. In salak, however, the leaf bases adhere tightly to the stem; it has no 'self-cleaning' trunk. Therefore phyllotaxis was determined by dismantling 57 3-year-old 'Pondoh' plants, raised from the same seed lot as used for the experiment in Chapter 2.1 and grown next to it. Fifteen palms were unraveled right up to the growing point. The crown base was cut horizontally and drawn on millimeter paper. Each leaf scar was numbered and its position linked by a line to the centre of the crown.

It was found that the line for the sixth leaf coincided with that of the first, that for the 7th leaf with that for the 2nd, etc. (Figure 6.2 and Plate 6). Hence there are 5 orthostiches and the angle of divergence between the lines for successive leaves is about 144°. Thus salak fits in the Fibonacci series with a phyllotaxis of 2/5. The leaves are arranged in a spiral towards the growing point; out of 57 'Pondoh' plants the spiral ran in anti-clockwise direction in 50 plants or 88%, in a clockwise direction in the remaining 7 plants (12%).

Counting the numbers of exposed leaves in 15 crowns and that of the leaves still enfolded in the bud resulted in 10 - 13 and 5 - 6 leaves per crown, respectively. Thus there were twice as many exposed leaves as unexposed leaves. This is most unusual. Counts in other palms show near-equal numbers; in the few cases where this is not the case, the number of leaves in the bud is larger than the number of exposed leaves (Tomlinson, 1990). However, no microscopical dissection of the apex was attempted; the smallest leaf counted was about 2 mm high (Plate 8) and inside it there should be several more leaf initials.

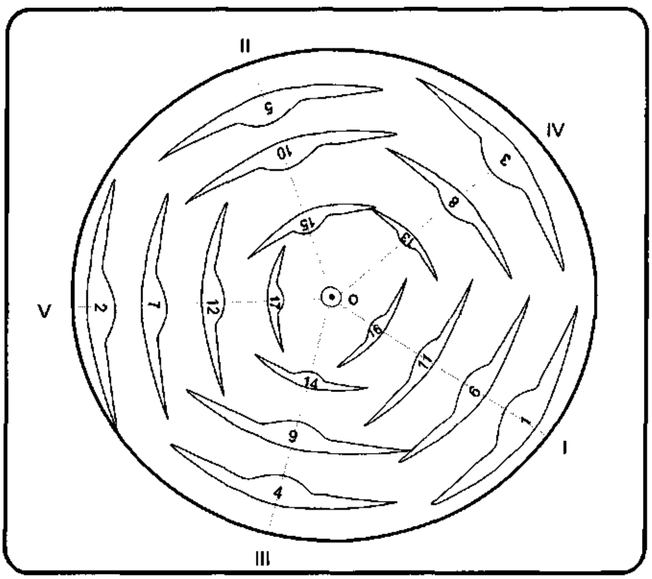

Figure 6.2. Phyllotaxis of salak: 2/5 with angle of divergence 144°.
1, 2, 3,...n: leaf traces, starting with the eldest leaf; I, II, III, IV and V: orthostiche; o: centre of the growing point.

Position of lateral buds. The inflorescence bud is situated in the leaf axil, i.e. inside and near the middle of the leaf base. Each leaf has a bud in that position. The suckers arise from a flange that clasps the stem for about one-third of its circumference; the bud on the flange is positioned on the leaf axis directly below a longitudinal groove in the leaf sheath (the groove being the site where the sheath will be split by the protruding inflorescence spear). The position of both buds in relation to the leaf base is shown in Plate 9.

Thus both the inflorescence bud and the vegetative bud are in line with the leaf axis, the inflorescence bud in the leaf axil, the vegetative bud directly below it. Fisher and Mogea (1980) reported that the sucker is initiated at the base of the leaf sheath, and positioned 130 - 180° away from the median of its subtending leaf. However, because the sucker bud is positioned so close to and in line with the leaf above it, it must be associated with that leaf, the shift with respect to the leaf below it of 130 - 180° corresponding to the 144° angle of divergence between successive leaves.

Suckering. At the age of 15 months, the palms in the experiment described in Chapter 2.1 started suckering; after 33 months the mean numbers of suckers ranged from 3 to 5 among varieties. Growers reduce the number of suckers to 2 per plant, but in a neglected plantation of 3-year-old 'Pondoh' larger numbers of suckers were found, including second-order suckers, resulting in compact clumps or stools of numerous stems.

Flach (1983) reported suckering behaviour of sago palm which belongs to the same tribe as salak. The sago seedling produced suckers in the first year after planting, and suckers may also produce second order suckers. Unchecked natural suckering appears to slow down the growth of the main trunk; therefore farmers practise desuckering to advance the harvest (Flach and Schuiling, 1989). Hence there are many similarities in suckering in the two crops. According to palm architecture models, *the salak palm is to be grouped in Tomlinson's model as trees which branch* exclusively from the base, subdivision pleonanthic palms (Tomlinson, 1990).

Emerging sucker buds form straight horizontal stems growing radially away from the trunk; the stems are short and soon become erect (see Plate 7). The suckers grow around the base of the trunk in different arrangements (Figure 6.3), the angle of divergence corresponding more or less to the phyllotaxis. The arrangements differ because the order of emergence of the suckers deviates to some extent from the order of emergence of the associated leaves.

6.4. Mature vegetative phase

The mature vegetative phase starts when the growing point has reached its ultimate size, so that the organs it initiates also attain a more or less constant size. Presumably this size varies in response to the growing conditions. Little attention was paid to characteristices of this phase, which is found in older plantations.

Leaf growth. Measurements of leaf growth in 20-year-old palms by an undergraduate student in a fertilizer trial (Indarwati, 1993) are presented in Figure 6.4. The mean length of the first leaf which emerged after the trial started, increased according to a sigmoid growth curve, which seems to be characteristic for palm leaves (Corner, 1966; Tomlinson, 1990.). However, it is hard to explain why this leaf grew to about 4 m length, whereas the previous one, which was already extending when the trial started,

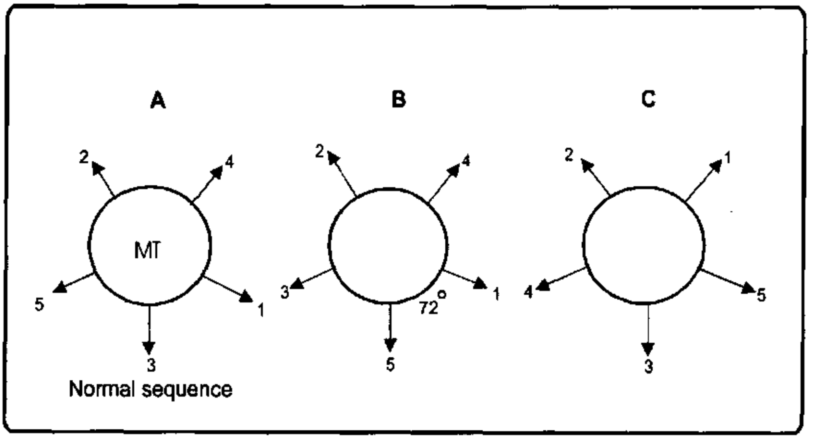

Figure 6.3. Spatial arrangements of suckers around the mother palm.
MT: mother plant; 1, 2, 3, 4, 5: sequence of suckers.

reached only 2.25 m. The interval between the emergence of these two leaves – about 30 days – was very short too, the third leaf emerging more than 50 days after the second.

These large differences cannot be attributed to fertilizer application, because the growth curves for leaves in all treatments, including the unfertilized control, were similar and have been averaged in Figure 6.4. At the start of the trial some old leaves were removed to improve access for observations; perhaps this affected growth of the new

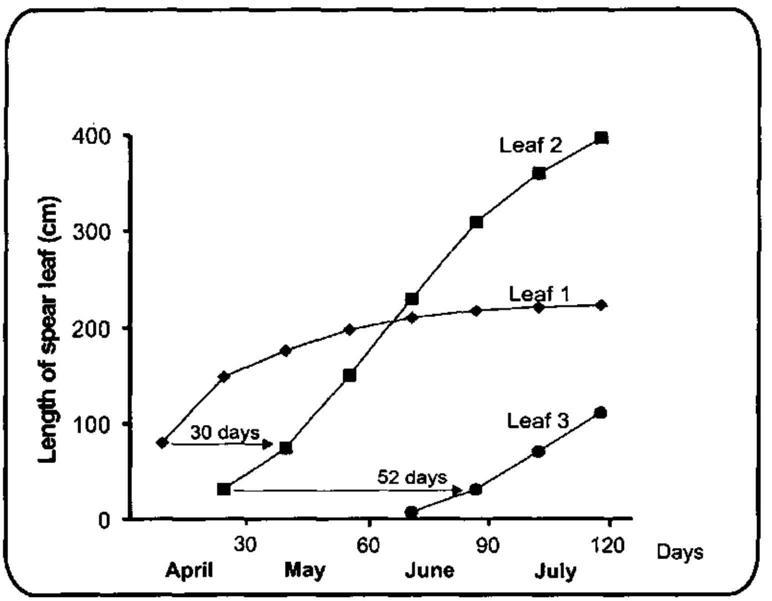

Figure 6.4. Mean growth curves of leaves in a nitrogen application trial; palms about 20 years old.

leaves, the more so as it coincided with the end of the wet season and hence higher light levels in the crop. The findings show that a constant interval between emergence of successive leaves and a constant leaf size cannot be taken for granted; effects of seasons and crop care need to be studied.

Suckering. In the mature vegetative phase the palms seem less inclined to form suckers. This may be a consequence of the dense stand leading to very low light levels in the crop. The suckers, which do emerge, are nearly always at the base of the trunk, i.e. close to the soil surface.

The walking palm. The mature palm has a trunk, which extends slowly. It never reaches a great height because the palm becomes unstable and topples before the trunk is a meter long. The growing point of the fallen palm is turned upright again by one-sided extension growth of the internodes. This is shown by salak 'Bali' from Karangasem (Plate 10). Re-erection starts by the unequal growth of the upper and lower sides of the internodes. The lower side of an internode in the curved portion of the trunk is about twice as long as the upper side (Figure 6.5 and Plate 11). This indicates that the plant is strongly orthotropic.

By repeating the process the salak palm 'walks' the ground, taking one step in 10 to 20 years! Falling over appears to restore the vitality of the palm, perhaps because roots no longer emerge far above ground level. Growers sometimes push trunks over and earth them up to fill gaps in the plantation and to revitalize the palms (Schuiling and Mogea, 1991).

According to Hartley (1988) the oil palm which in cultivation is seen as an erect palm, is in fact procumbent (procumbent: 'lying along the ground') (Jackson, 1971). An erect habit may be maintained for as long as 15 years, but thereafter a procumbent habit is generally assumed though the crown is in an erect position. A trunk lying on the ground over a distance of 7.6 m has been reported.

6.5. Reproductive phase

End of the juvenile phase; dioecy. The reproductive phase starts with the emergence of inflorescences. In Chapter 2.2, the first inflorescence was seen 28 months after sowing; 34 months after sowing flowering plants were found in all varieties and at the end of the experiment, after 42 months, the percentage of flowering plants in different

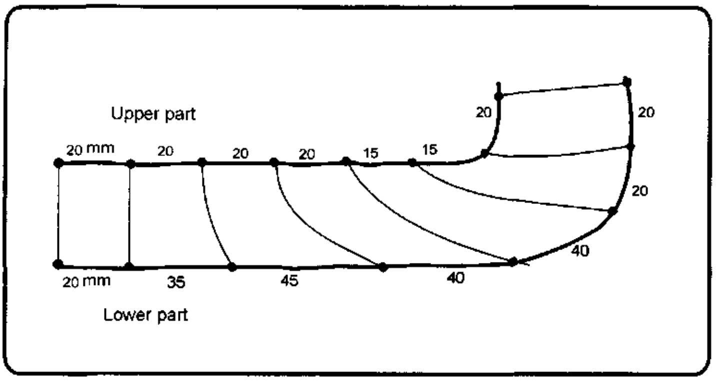

Figure 6.5. Diagram of re-erection growth of a salak stem.

varieties ranged from 50 to 83. These findings confirm those of Tohir (1983), Tjahjadi (1989), and Schuiling & Mogea (1991), indicating that juvenility comes to an end 3 - 4 years from sowing.

The salak palm is usually dioecious. In Chapter 2.2, the ratio of female to male-flowering plant varied greatly for different varieties, but the number of plants was too small to conclude that the ratio indeed deviates from one. Plates 12A and B show a female- and a male-flowering inflorescence, respectively.

Emergence of inflorescences. The inflorescence bud develops into a spear, which splits the basis of its subtending leaf to break into the open, helped by the groove in the leaf base. The leaf bases adhere to the trunk after the leaves have withered or have been cut by the grower. By inspecting whether or not these leaf bases have been split, emergence of the bud in their axil can be ascertained. Representative counts have not yet been made, but preliminary observations suggest that most of the buds do indeed produce an inflorescence.

It was also observed that in a few instances inflorescences emerged from leaves, which had withered long ago. This implies that these buds failed to emerge according to the normal age sequence ('when it was their turn'); it also shows that inflorescence buds can remain viable for a long time. Moreover, there are two harvest peaks in East Java, the major one in December to January, the other in June - July, which suggests seasonal variation in the emergence of inflorescences. This was indeed observed in Chapter 2.2, most inflorescences being issued early in the wet season, corresponding with the June - July harvest period. However, observations in mature stands are needed to clarify the pattern of seasonal flowering. Towards the end of the December - January harvest period many fruit bunches are lost due to decay in the wet season.

Anthesis; pollination. The female-flowering inflorescence consists of 1 - 3 spadices; the male-inflorescence consists of 3 - 10 spadices (Plates 12A-B). Anthesis is reached when the bracts enclosing the spadix open up to expose the flowers. This takes about one month from the time the inflorescence spear breaks through the leaf base. The salak floral unit is a dyad, made up of a pistillate flower and a sterile staminate flower in female-flowering palms (Uhl & Dransfield, 1987).

Pollination appears to be necessary for fruit set (Chapter 3.1). In the experiment described in that section intensive pollination led to heavy fruit set (75% of flowers) and seed set (90% 3-seeded fruit), showing that (almost) all ovules were functional. It follows that imperfect pollination, with respect to intensity, compatibility or timing, can easily become a yield-limiting factor.

All the varieties tested in Chapter 3.2 were self-fertile, but the occurrence of incompatibility factors is suggested by the very poor fruit set of two varieties in the reciprocal crosses, compared to fruit set after selfing.

Fruiting. The mean number of fruits per bunch (i.e. per spadix) varied from 6 - 9 for 'Kacuk' to 6 - 24 for 'Nganjuk' in Chapter 3.2, depending upon the pollinator variety; the 'Suwaru' palms in Chapter 5.4 had 11 - 24 fruits per bunch. Mean weight per fruit, 28 g, was lowest for selfed 'Nganjuk' and highest for 'Kacuk' selfed or pollinated by 'Suwaru' or 'Bangkalan', nearly 100 g (Chapter 3.1); 'Suwaru' fruit in Chapter 5.4 weighed 70 - 75 g on average.

Fruits with 2 or 3 seeds grow larger than single-seeded fruit; the shape of the seed (round or one or two flattened sides) shows whether it came from a single-, double- or triple-seeded fruit (Chapter 3.1; Plates 1A-C and Plate 13).

CHAPTER 7: GENERAL DISCUSSION

In this chapter, aspects of growth and development presented in the previous chapters will be considered first, followed by a discussion of the agronomic implications of the experimental work.

7.1. Growth and development

For this discussion the remaining gaps in the pattern of growth and development are more interesting than those that have been filled in the course of this study. The two main missing links in the pattern refer to the mature vegetative phase:

- the deviations from a steady pattern of growth,
- the scope for enhancing yield.

Palms grow continuously and in the mature vegetative state the terminal bud has reached its ultimate size, the size being influenced by the prevailing growing conditions. This should lead to a steady rate of growth, resulting in the appearance of leaves of near-equal size at fairly constant intervals. Leaf area measurements in palms are indeed based on the supposition that it suffices to measure a single leaf and multiplying its area with the number of leaves to obtain a fair estimate of leaf area per plant. Moreover this leaf area is supposed to be constant, each withering leaf being replaced by an unfolding spear leaf of similar size. The terminal bud of a palm stem is so obviously designed for a steady pace of leaf production, that suckering or flowering/fruiting may be the balancing item in the budget, leaf production being kept steady during a season with adverse growing conditions at the expense of suckering or bunch production.

It is common knowledge that salak in Indonesia has two harvest peaks; there is a clear periodicity in flowering and fruiting. Suckering becomes incidental during the mature vegetative phase. With regard to leaf growth this study shows that the interval between the emergence of successive leaves, the phyllochron, varied substantially in all the experiments with young plants as well as in the only experiment with mature plants where it was measured. And in the latter experiment mean length of two successive leaves was 2.25 and 4.00 m, respectively. Thus the indications are that leaf production is far from steady; if this is confirmed it implies that the periodicity of bunching may not be meant to allow for constant leaf growth.

The periodicity of flowering/fruiting is agronomically most important. It must be caused by seasonal changes in growing conditions, but it occurs in the humid climate of West Java as well as in the monsoon climate of East Java, indicating that no strong environmental trigger is needed.

In pejibaye (*Bactris gasipaes* Kunth) the development of the inflorescence stagnates until the subtending leaf withers. Mogea & Verheij (1991) explained seasonal fruiting of this suckering palm on the basis of accelerated withering of leaves after the dry season sets in, releasing within a short time all the inflorescences in their axils.

In salak peaks and troughs in flowering may result from two mechanisms:

- the flower bud in a leaf axil may remain dormant when it is its turn to develop and grow out at a later stage, even after the subtending leaf has been cut;
- the development of the inflorescence may stagnate at the spear stage, delaying anthesis.

In East Java the dry season normally starts in April and there is a flowering peak in June - July. Possibly improving growing conditions early in the dry season lead to accelerated emergence of flower spears resulting in a peak in bloom. Later in the dry season few inflorescences reach anthesis and those that do bloom, often fail to set fruit (the flowers appear to be desiccated and the male flowers may not release viable pollen). Probably the paucity of flowering is due to both mechanisms listed above.

The start of the wet season in November brings on better flowering with a secondary (minor) peak in December - January. The increase in the number of inflorescences reaching anthesis at this time may result from the resumed growth of delayed spears and belated emergence of flower buds in axils of very old leaf bases.

The interval between the two peaks in bloom is six months and since it also takes about 6 months for a flower to produce a mature fruit, the peaks in bloom and harvest tend to coincide: the main harvest period is December - January and the secondary peak is in June - July.

The above explanation for the occurrence of flowering peaks is only tentative; there clearly is a need to study the periodicity of flowering/fruiting in relation to growing conditions. Such a study can be combined with observations on the variations in leaf size and the phyllochron. If these variations are large it will be worthwhile to also check the variations in numbers of exposed and unexposed leaves in the crown in different seasons. Observations may include a closer look at where, when and why the few suckers in a mature stand emerge.

Whereas periodicity of flowering is the main cause of variations in yield in the course of the year, peaks and troughs in yield do become more pronounced because of events following flowering. The poor fruit set towards the end of the dry season has already been mentioned; in addition there appears to be a considerable loss of bunches due to moulds as the wet season advances. As a result there usually are brief periods without any crop in both seasons. In East Java truly continuous cropping throughout the year is only possible in irrigated gardens, but even irrigation does not completely level out the peaks in flowering/harvesting. In the much wetter conditions of West Java the yield is also highest during the wettest months (October to December, rainfall 200 - 500 mm per month). This was shown in a study of the salak harvest in Manonjaya (Mogea, 1979). This author concluded that heavy rainfall is most detrimental during flowering, leading to decay of spadices.

For the growers the overlap between flowering and maturation of fruit means an accumulation of work; harvesting has to be combined with hand pollination and cutting of the leaves subtending the harvested bunches. The practice of growers to cut ageing leaves may be a factor, which complicates periodicity in salak. Leaves are cut once or twice a year after a harvest peak. Usually the leaf below the harvested bunch is cut. The main reason is to keep the garden accessible, in particular for hand pollination; the leaves are left in the garden as mulch.

The second issue – enhancing yield – requires consideration of the different yield components: which part of the flower buds produces inflorescences, what is the mean number of spadices per inflorescence, how many flowers are found in a spadix, which percentage of the flowers sets fruit, what is the mean weight per fruit? The study contributed quantitative data, but there is still far too little information on most of these components. The issue is complicated because both genotype and environment may affect each component. Moreover, agronomically the question is not how a solitary plant behaves in a given environment, but how much a well-designed salak stand yields per hectare in that environment, the well-designed stand itself having a strong modifying effect on the environment.

This complication is illustrated in the first question: can an inflorescence develop in every leaf axil? Observations in the course of this study suggest that a high percentage does develop, but these observations were made in a fairly dense stand. A solitary plant may be more inclined to produce suckers than a plant in a well-designed stand, and increased suckering may impede development of flower buds, in particular the ones in the axils of leaves associated with a sucker. If there is indeed antagonism between suckering and floral development, the fruit yield of a plant growing under considerable competitive stress in a dense stand may be higher than that of a solitary plant of the same age!

The number of spadices in an inflorescence appears to be fairly stable, although within a female-flowering inflorescence it can vary from 1 to 3. The spadices are about the same size and the number of flowers in a spadix also does not seem to vary much.

The importance of adequate pollination was supported by the experiments in this study, but where all three stigmata of a flower were well-pollinated percentage fruit set and percentage seed set were quite high. It can be concluded that fruit set and seed set need not substantially limit yield. Fruit size did increase with the number of seeds per fruit. However, whereas in Chapter 3.1 fruit size improved with increased seed set in spite of a doubling of the number of fruit per spadix, in Chapter 3.2 there was evidence of competition between fruits, heavy fruit set resulting in smaller fruit size. This suggests that growing conditions must be favourable to limit competition between fruits at high yield levels.

Once the deviations from a steady growth pattern have been elucidated and the periodicity of flowering/fruiting has been explained, this information can be combined with the extent to which each of the yield components limits yield, in order to estimate potential yield of salak in production centres in Indonesia. The same information will be crucial in identifying growing techniques which can most enhance yield, perhaps including the best time to carry out these techniques to take advantage of the observed periodicity.

7.2. Agronomy

Climate and soil. Salak shows adaptation to varying climatic conditions, from the humid parts of Sumatera and West Java with 2000 - 3100 mm (Mogea, 1979; Anonymous, 1977) fairly well-distributed rainfall, to the monsoon climate of East Java, where rainfall is less than 2000 mm per year and limited to a 5 - 7-month wet season. In Bali the dry season is even more severe, but the Balinese salak is grown on the mountain slopes at elevations up to 400 m (Machfoedi, 1953) and in Turi up to 600 m (Lahiya, 1974), where temperatures are lower and rainfall may be higher. Salak is usually planted in areas with a high water table and even along river banks, but salak gardens are also found where the roots cannot reach the water table. Few growers apply irrigation water, but they plant salak under temporary and permanent shade trees.

In the experiment in which different shade levels were compared during the dry season, fully exposed young seedlings were killed and it was concluded that the shade above young plants should reduce incident light at midday to 50% or less.

There is also much variation in soil types in the salak production centres, including Inceptisols with a high clay content; the Kersikan clay cracks during the dry season. When 'Pondoh' seedlings were grown in pots filled with soils from 5 distinct areas, growth was poorest and the top:root ratio lowest in the 2 soils with the highest clay content. Thus heavy-textured soils may be less suitable for salak. All five soils were low to very low in organic matter and nitrogen; the phosphorus levels ranged widely and the potassium and calcium contents were fair to high; the pH ranged from 6 to 7.7. Presumably growth on heavy soils can be much improved by raising organic matter content to improve soil structure; in any case in this study the response to farmyard manure was always positive.

The soil of the Jatikerto research station, where most of the experiments reported in this study were conducted, proved less suited to salak: it has the heaviest texture and is lower in organic matter, N and P than any of the other soils which were analysed. K-content on the other hand is very high, but fixation may reduce the availability of this nutrient.

Most growers in Indonesia do not apply manure or fertilizer to salak; they think that fertilizers have adverse effects on fruit quality and usually only recycle the ageing leaves, which are cut and left to decompose in the garden. However, both experiments with nutrient application in this study stimulated growth and raised leaf nutrient levels, including the experiment in a mature garden where fruit grew larger and losses due to split and/or decaying fruit were reduced in response to compound fertilizer.

The limited scope of the fertilizer experiments (basically single applications, observations limited to a few leaves and bunches which had already been formed before the treatments were applied) leaves the question about quantities, frequency and timing of fertilizer applications in orchards open. Nevertheless the results show that deficiencies in organic matter and major nutrients are common.

The response to nitrogen needs to be studied further in connection with soil moisture; the extent of potassium fixation should also be investigated.

Propagation, cropping system. Salak seed is recalcitrant. Seeds should be sown fresh; viability decreases sharply, even after short periods of storage, as shown in Chapter 4.2. To transport seed to distant destinations a successful storage method should be found. The principle seems to be to establish a favourable balance between seed moisture content and ambient humidity. Charcoal is a good storage medium because it maintains a higher humidity around the seed, slowing down dehydration. Other materials may also be used, but substrates should be fine-textured and able to absorb water vapour. Before application the substance has to be exposed to attain equilibrium moisture content with the ambient air.

Seedlings are usually raised in a nursery. Until the first leaf has matured seedling growth depends on reserves stored in the seed. So if seedlings are transplanted before that stage, care should be taken not to detach the seed. If all the endosperm is excised (Chapter 4.1) the tiny embryo is still able to survive for a few days. This suggests that embryos can be cultured in artificial media, making embryo conservation possible for breeding purposes.

In Indonesia salak is intercropped with other perennials such as banana, rambutan, langsat, duku, durian, coconut, etc. It is generally accepted – and this was confirmed in this study – that shade is essential for young plants, i.e. in the nursery and in the first year(s) after planting. However, in a well-designed mature stand mutual shading by the salak plants is so intense that the importance of shade trees is doubtful. For one thing competition from the salak is too strong for most plants which are not much taller (e.g. banana) or not well-established (e.g. young fruit trees) to survive. Moreover, growers in Malang never replace dying shade trees in mature salak gardens. Leaves from shade trees tend to get trapped in the heart of the palms, where it is hard to remove them because of the spines. Therefore the growers prefer shade trees with fine leaves such as the leguminous Sesbania ('turi') and Parkia ('petai'), rather than large-leaved trees such as rambutan, durian etc. On the other hand it is not clear whether the debris accumulating in the heart of the palms is harmful.

The question about the need for permanent shade is related to the problem of designing a good salak plantation. Growers tend to plant closely, say 2 x 2 m for 'Pondoh', under the shade of established trees, supplemented by temporary shade provided by banana or *Sesbania grandiflora*. The young salak plants grow progressively and after about 1.5 years growth is further accelerated by the emergence of suckers; with the closure of the stand about one year later the number of suckers reaches a maximum.

Growers reduce the number of suckers to reduce competition with the main crown and to maintain access to the plantation. From the age of 3 years flowering starts and growers remove most male-flowering plants. By the time the roguing of male plants is completed the temporary shade has succumbed to the competition of the salak and a stand with gaps and crowded areas remains, because of the irregular distribution of the male plants and the scattering of permanent shade trees. If initially half the plants were male and after roguing one in ten plants are male, the mean spacing has increased from 4 to 7.2 m^2 per palm. The irregular distribution of males implies that some palms are still growing at 4 m^2, most have about 7 m^2, but there are also some enjoying more than 10 m^2. By thinning female plants in crowded parts the spacing can be evened out to the extent that the large majority of the plants has an area of 7 - 10 m^2.

Growers usually reduce the largest gaps in young gardens by planting 3 - 5 seeds close together where there is space for a plant; as soon as the sex is known all but one female plant are removed. In older gardens gaps occur only occasionally and growers fill them by planting suckers.

The current trend to propagate 'Pondoh' vegetatively makes it possible to plant at the optimum spacing, e.g. 3.5 x 2.5 m, since roguing is no longer needed. In so doing, the male pollinator plants can be sited strategically, e.g. as the first plant(s) in each row; the grower can collect the male-flowering spadices at anthesis and move down the row for hand pollination. It has been estimated (Ashari, 1993) that 30% of the annual production costs are for hand pollination, so improvements in efficiency are very welcome. In this study it was found (Chapter 4.1) that the pollinator variety may strongly influence both yield and fruit quality. If a superior pollinator for 'Pondoh' is identified, it should also be propagated vegetatively to fix its superior characters and to make sure that all plants are male.

Overall, it appears that understanding of deviations from a steady growth rate, and in particular the reason for periodic flowering, as well as determining the scope for enhanced yield are the important aspects to be considered. Concentrated flowering and fruiting during two short periods of the year increases the efficiency of hand pollination, harvesting and marketing. Possibly yield per plant will be higher if this periodicity can be eliminated, but the cost of pollination, harvesting and marketing will go up substantially if a few bunches have to be dealt with each week of the year. Manipulation of periodicity to advance or retard the peak harvest seasons would be much more advantageous, because it would combine high off-season prices with high labour productivity.

These considerations about a well-designed stand and periodicity indicate that there is great scope to make salak growing more profitable. However, if vegetative propagation has to be generally adopted, more efficient systems of layering suckers need to be developed or alternative propagation methods – e.g. tissue culturing – must be pursued. In the existing gardens the scope for improvements in pollination needs to be investigated. The percentage of male palms varies from 2 to 20, and growers too often depend on pollen supplied by colleagues, partly because anthesis of the staminate spadices does not always coincide with that of the pistillate spadices. The whole pollination process must be better managed. This includes pollen storage, application techniques, frequency of pollination and timing in relation to anthesis. In date palms dustblowers are used for pollination (Nixon and Carpenter, 1978) and these might also be tried in salak gardens.

Varieties. The growers' preference for 'Pondoh' is based largely on the fruit quality of this variety. Unfortunately 'Pondoh' could not be included as one of the bearing varieties in the comparison of pollinators (Chapter 3.2), so that the fruitfulness and fruit quality of 'Pondoh' could not be compared with other varieties in this study.

However, in the variety trial (Chapter 2.1) a few other characteristics of 'Pondoh' came to light:

- it grows less vigorously than other varieties because the leaves are smaller; so more plants can be accommodated per ha;
- leaves emerge in a rapid succession, leading to a potentially large number of bunches per year.

The combined effect of more plants per ha and more bunches per plant should substantially enhance yield per ha. Thus 'Pondo' may prove to be a high-yielding variety as well as a high quality fruit! Moreover, the smaller plant size makes 'Pondoh' easier to manage in cultivation. These advantages can be quite important. The 'Pondoh' fruit's price per kg and the price of a marcotted sucker of 'Pondoh' in 1996 were almost comparable i.e. Rp. 2,000.00 and Rp. 1,750.00 (Kasijadi, 1996). To improve the success rate in marcotting, farmers in Bali, Malang and Pasuruan use shallot extract which is cheaper than the growth substance IBA (Kasijadi et al., 1999). Recently, a type of 'Pondoh' which has thick flesh has been found to thrive at elevations of 400 to 600 m a.s.l. (Purnomo and Sudaryono, 1994).

The Balinese salak also has a reputation for fruit quality. Moreover it is monoecious which is a great advantage. Unfortunately the plants did not thrive in the variety trial at Jatikerto; perhaps the plants lacked vigour due to the seeds being too old. In Chapter 4.2 it was shown that if seeds are not sown fresh, the growth rate of the seedlings is reduced, even after storage in the best media. This salak type deserves a better comparison with the best varieties in Java. Salak 'Gula Pasir' is the sweetest among the Balinese salak types, found only at elevations above 650 m a.s.l. by Purnomo and Sudaryono (1994).

Purnomo and Dzanuri (1996) crossed 'Pondoh' with 'Gula Pasir', and reported a heterosis effect in the progenies, but a further assessment of the inheritance of specific traits – in particular the monoecy of the Balinese parent – is still awaited. Evaluation of the salak varieties has in fact only just begun. In view of the preference for 'Pondoh' and the increasing vegetative propagation of this variety, the likely development is that clones of 'Pondoh' will be named and compared in experiments. The consequence might be that the other varieties are phased out before their characteristics have been assessed, leading to a narrowing of the gene pool. To avoid this negative effect, in situ or ex situ conservation of varieties should be employed.

REFERENCES

Abercombie, M., C.J. Hickman and M.L. Johnson. 1961. A Dictionary of Biology. Hunt, Barnard & Co. Ltd. Aylesbury. 254 pp.

Agrawal, P.K. 1986. Seed Storage. In: Seed Production Technology. Srivastava and Simarski (Eds): Int. Cent. of Agric. Res. In The Dry Areas (ICARDA), Syria. p. 226 - 231.

Anonymous. 1977. Pemeriksaan Hujan. {Rain Observations}. Badan Meteorologi dan Geofisika. Jakarta. 133 pp.

Anonymous. 1987. Jawa Timur dalam Angka. {East Java in Figures}. Kantor Statistik Dati I Prop. Jawa Timur. (Indonesian).

Anonymous. 1990a. Kebijaksanaan Pengembangan Hortikultura di Indonesia. {Policy on Horticultural Development in Indonesia}. Ditjen Binpro Hortikultura. Simp. Nasional Hortikultura. p.15-29. (Indonesian).

Anonymous. 1990b. Annual Report 1989. IBPGR. Rome, Italy. 64 pp.

Anonymous. 1992. Sensus Nasional Tahun 1990. {National Census 1990}. Biro Pusat Statistik. Jakarta. (Indonesian).

Anonymous. 1993. *Perkembangan Singkat Komoditi Hortikultura Indonesia.* {An Overview of Horticultural Commodities Development in Indonesia}. Duta Rimba. 153-154 (XIX): 52-56. (Indonesian).

Anonymous. 1996. Statistical Yearbook of Indonesia 1996. Biro Pusat Statistik. 587 pp.

Ashari, S. 1993. Agribisnis Salak di Lahan Kering Jawa Timur. {Salak Agribusiness in the Drylands of East Java}. Lap. Pen. Hibah Bersaing I. Fak. Pertanian Unibraw. 130 pp. (Indonesian).

Baswarsiati, L. Rosmahani and L. Setyobudi. 1991. Kajian Serangga Polinator pada Persarian Salak. {Study of Pollinator Insects on Salak Pollination}. In: Sudaryono *et al.* (Eds.): Perbanyakan Cepat Secara Klonal dan Rekayasa Perbaikan Teknologi Produksi serta Mutu Salak. Sub Balithorti, Malang. p. 25-33. (Indonesian).

Baswarsiati and L. Rosmahani. 1992. Kajian Serangga Polinator pada Persarian Salak II. {Study on Pollinator Insects on Salak Pollination II}. In: Sudaryono *et al.* (Eds.): Perbanyakan Klonal Cara Cepat dan Rekayasa Perbaikan Produksi serta Mutu Salak. Sub Balithorti, Malang. p.19-26. (Indonesian).

Beach, J.W. 1984. The Reproductive Biology of the Peach or 'Pejibaye' Palm (*Bactris gasipaes*) and a Wild Congener (*B. porschiana*) in The Atlantic Lowlands of Costa Rica. Principes. 28: 107-119.

Beer, J., R. Muschler, D. Kass and E. Somarriba. 1998. Shade Management in Coffee and Cocoa Plantations. Agroforestry Systems 38: 139-164.

Bell, A.D. 1991. Plant Form. Oxford Univ. Press. New York. p. 92-93.

Bleasdale, J.K.A. 1973: Plant Physiology in Relation to Horticulture. Macmillan, London: 144 pp.

Broschat, T.K. and H. Donselman. 1988. Palm Seed Storage and Germination Studies. Principes. 32 (1): 3-12.

Carrol, S.B. and D.L. Mulcahy. 1993. Progeny Sex Ratios in Dioecious *Silene latifolia* (Caryophyllaceae). Amer. J. Bot. 80 (5): 551-556.

Child, R. 1974. Coconuts. Longman Group. Ltd. London. p. 38-40.

Chin, H.F. and H.W. Pritchard. 1988. Recalcitrant Seeds. A Status Report. IBPGR. Rome, Italy. 28 pp.

Copeland, L.O. 1976. Principles of Seed Science and Technology. Purgess Publ. Co. Mineapolis, Minnesota. p. 193-198.

Corley, R.H.V. 1983. Potential Productivity of Tropical Perennial Crops. Experimental Agric. 19 (3) : 217-237.

Corner, E.J.H. 1966. The Natural History of Palms. Wiedenfeld and Nicolson. London. p. 43-81.

DeMason, D.A. 1984. Growth Parameters in the Cotyledon of Date Seedlings. Bot. Gaz. 145: 176-183.

DeMason, D.A. 1985. Histochemical and Ultrastructural Changes in the Haustorium of Date (*Phoenix dactylifera*). Protoplasma. 126: 168-177.

Dickie, J.B., M. Balick and I.M. Linington. 1993. Studies on the Practicality of Ex Situ Preservation of Palm Seeds. Principes. 37 (2): 94-98.

Dransfield, J. 1979. A Manual of the Rattans of the Malay Peninsula. Forest Depart. Ministry of Primary Industry. Malaysia. p. 7-16.

Dransfield, J. and J.P. Mogea. 1986. A Reassessment of the Genus Lophospatha Burret. Principes. 25 (4): 178-180.

Elkhatib, E.A. and J.L. Hern. 1988. Kinetics of Potassium Desorption from Appalachian Soils. Soil Sci. 145 (1): 11-19.

Evans, G.C. 1972. The Quantitative Analysis of Plant Growth. Blackwell Scientific Publ. Oxford, London. p. 127-154.

Ferguson, I.K. 1986. Observations on the Variation in Pollen Morphology of Palmae and its Significance. Can. J. of Botany 64: 3079-3090.

Fisher, J.B. and J.P. Mogea. 1980. Intrapetiolar Inflorescence Buds in Salacca (Palmae): Development and Significance. Bot. J. of the Linn. Soc. 81: 47-59.

Flach, M. 1983. The Sago Palm. FAO. Rome. 85 pp.

Flach, M. and D.L. Schuiling. 1989. Revival of an Ancient Starch Crop: A Review of the Agronomy of the Sago Palm. Agroforestry Systems. 7: 259-281.

Goldberg, S., B.S. Kapoor and J.D. Rhodes. 1990. Effect of Aluminium and Iron Oxides and Organic Matter on Flocculation and Dispersion of Arid Zone Soils. Soil Sci. 150 (3): 588-593.

Goldsworthy, P.R. 1984. Crop Growth and Development: The Reproductive Phase. In: Goldsworthy, P.R. and N.M. Fisher (Eds.): The Physiology of Tropical Crops, John Wiley and Sons. New York. p. 163-212.

Hallé, F., R.A.A. Oldeman and P.B. Tomlinson. 1978. Tropical Trees and Forests. An Architectural Analysis. Springer Verlag. Berlin-Heidelberg. Federal Republic of Germany. 441 pp.

Hardjowigeno, S. 1987. Ilmu Tanah. {Soil science}. PT. Mediyatama Sarana Perkasa. Jakarta: 50-128. (Indonesian).

Hasan, Z. 1996. Pengaruh Naungan dan zat Pengatur Tumbuh Terdahap Pertumbuhan Bibit Cengkeh Pemberitaan Penelitian Tanaman Industri. {The Effect of Shading and Plant Growth Regulator on the Growth of Clove Seedlings}. XII (1-2): 41-52. (Indonesian)

Hartley, C.W.S. 1988. The Oil Palm (*Elaeis guineensis* Jacq.) Longman Group Ltd. London. p. 47-94; 138-188.

Haryani 1994. Species Salak dan Varietasnya. (Salak: Its Species and Varieties). Trubus. 295 (XXV): 16 pp. (Indonesian).

Henderson, A. 1984. Observations on Pollination of *Crysophila albida*. Principes. 28 (3): 120-126.

Henderson, A. 1985. Pollination of *Socrata exorrhiza* and *Iriarta ventricosa*. Principes. 29 (2): 64-71.

Hickey, M. and C. King. 2000. The Cambridge Illustrated Glossary of Botanical Terms. Cambridge Univ. Press. 208 pp.

Hodel, D.R. 1993. The Growth of Some Palms in Tahiti. Principes. 37 (3): 124-138.

Ish-am, G. and D. Eisikowitch. 1998. Low Attractiveness of Avocado (*Persea americana* Mill) Flowers to Honeybees (*Apis mellifera* L.) limits Fruit Set in Israel. J. Hort. Science & Biotechnology. 73 (2): 195-204.

Jackson, B.D. 1971. A Glossary of Botanic Terms. Gerald Duckworth & Co. Ltd. London. 303 pp.

Kasijadi, F. 1996. Analisis Finansial Pola Usahatani Salak Kultivar Pondoh di Kabupaten Sleman Yogayakarta. {Financial Analysis of Salak cv. Pondoh in Sleman Regency of Yogyakarta}. J. Hort. (2): 204-210. (Indonesian).

Kasijadi, F., T. Purbiati, M.C. Mahfud, T. Sudaryono and S.R. Soemarsono. 1999. Penerapan Teknologi Pembibitan Salak Secara Cangkok. {Application of Marcotting Technology on Salak}. J. Hort. 9 (1): 1-7. (Indonesian).

Khvostova, V.V. 1983. Genetics and Breeding of Peas. Oxonian Press. Pvt. Ltd, New Delhi. p. 69-71.

King, M.W. and E.H. Roberts. 1980. Maintenance of Recalcitrant Seeds in Storage. In: Chin, H.F. and E.H. Pritchard (Eds.): Recalcitrant Crop Seeds. Tropical Press, Kuala Lumpur. p. 53-89.

Kovoor, A. 1983. The Palmyrah Palm ; Potential and Perspectives. FAO, Rome. 77 pp.

Kusumainderawati, E.P., M. Soleh and Q.D. Ernawanto. 1992. Penentuan Berbagai Kombinasi Pupuk Makro bagi Tanaman Salak. {Determination of Several Macro Elements in Salak Plants}. Lap. Lengkap Hasil Penel. Subbalihorti Malang: 27-34. (Indonesian).

Lahiya, A.A. 1984. Pembudidayaan Tanaman Salak di Beberapa Sentra Produksi di Indonesia. {Salak Cultivation in Production Centres in Indonesia}. Translated from: Ochse, J.J., W.H. de Jong and J.H. Bruckman. p.147-168.

Machfoedi, M. 1953. Biologi Bunga Salak Bali. {Floral Biology of Salak Bali}. Horticultura. Pasarminggu. p. 21-24. (Indonesian).

Manokaran, N. 1985. Biological and Ecological Considerations Pertinent to the Silviculture of Rattans. In: Wong, K.M. and N. Manokaran: Proc. of the Rattan Seminar. Kuala Lumpur. p. 95-105.

Mora-Urpi, J. and E.M. Solis. 1982. Polinizacion en Bactris gasipaes H.B.K. (Palmae). Revista Biologia Tropicale 28: 153-174.

Merlo, M.E., M.M. Aleman, J. Cabello and J. Penas. 1993. On the Mediterannean Fan Palm (*Chamaerops humilis*). Principes. 37 (1): 12-18.

Mogea. J.P. 1978a. Pollination in *Salacca edulis*. Principes. 22 (2): 56-63.

Mogea, J.P. 1978b. Germination and Seedling Form of *Salacca edulis*. Malay. Nat. J. 30 (3/4): 533-537.

Mogea, J.P. 1979. Faktor Musim dalam Pembuahan Salak (*S. edulis*). {Seasonal Factors in Salak Fruiting (*S. edulis*)}. Berita Biologi. 2 (4): 71-74. (Indonesian).

Mogea, J.P. 1980. The Flabellate-leaved Species of Salacca (Palmae). Reinwardtia. 9 (4): 461-479.

Mogea, J.P. 1986. A New Species of the Genus Salacca. Principes. 30 (4): 161-164.

Mogea, J.P. 1990. The Salak Palm Species in Indonesia. Voice of Nature. 85: 42, 62.

Mogea, J.P. and E.W.M. Verheij. 1991. *Bactris gasipes* Kunth. In: E.W.M. Verheij and R.E. Coronel (Eds.): Plant Resources of South-East Asia 2. Pudoc. Wageningen, The Netherlands. p. 100-104.

Moncur, M.W. 1988. Floral Development of Tropical and Subtropical Fruit and Nut Species. CSIRO. Australia. p. 127-130.

Moncur, M.W. and B.J. Watson. 1987. Observations on the Floral Biology of the Monoecious Form of *Salacca zalacca*. Principes. 31 (1): 20-22.

Nagarajan, M. and K.M. Pandalai. 1963. Studies on the Enzyme Activity in the Haustorium of the Germinating Coconut. Indian Coconut J. XVII (1): 25-34.

Neeteson, J.J. and H.J.C. Zwetsloot. 1989. An Analysis of the Response of Sugar Beet and Potatoes to Fertilizer Nitrogen and Soil Mineral Nitrogen. Neth. J. Agric. Sci. 37: 129-141.

Nixon, R.W. and J.B. Carpenter. 1978. Growing Dates in The United States. USDA. Washington D.C. 63 pp.

Ochse, J.J. 1931. Fruit and Fruit Culture in the Dutch East Indies (English version). G. Kolff & Co. Batavia. p. 95-97.

Ouvrier, M. 1984. Etude de la Croissance et du Development du Cocotier Hybride PB-121 (NJM x Goa) au jeune Age. Oléagineux. 39 (2): 73-82.

Padmosudarso, P. 2000. Kesesuaian Lahan Salak Pondoh (*Salacca edulis* Reinw) di Kecamatan Turi Sleman DIY. {Land Suitability For Salak Pondoh (Salacca edulis Reinw) in The Sub-district Turi, Sleman, Yogyakarta}. Disertasi UGM. 181 pp. (Indonesian).

Polprasid, P. 1991. *Salacca wallichiana* C. Martius. In: E.W.M. Verheij and R.E. Coronel (Eds.): Plant Resources of South-East Asia 2. Pudoc. Wageningen, The Netherlands. p. 278-281.

Pritchard, P.C.H. 1993. Thoughts on Hapaxanthy in Guyana. Principes. 37 (1): 12-18.

Purawinata, R. 1989. Budidaya Salak dan Tantangan ekspor. {Salak Cultivation and Export Challenge}. Tumbuh 1 (10): 32-36. (Indonesian).

Purnomo, S. and T. Sudaryono. 1994. Seleksi Tanaman Unggul dalam Populasi Salak Bali dan Salak Pondoh. {Selection for Superior Types in Populations of Salak Bali and Pondoh}. Lap. Hasil Penel. Sub-Balai Penelitian Hortikultura. Malang. p. 1-19. (Indonesian).

Purnomo, S. and Dzanuri. 1996. Kaitan Beberapa Aktifitas Ensim dan Pola Pewarisannya pada Persilangan Salak Bali dengan Salak Pondoh. {Relations Between Some Activities of Enzymes and Their Inheritance Pattern after Crossing Salak Bali and Salak Pondoh. Jurnal Hortikultura. 6 (3): 233-241. (Indonesian).

Purseglove, J.W. 1972. Tropical Crops; Monocotyledons. Longman Group Ltd. London. p. 433.

Purwanto, Y., R.D. Rahayu and H. Sutarno. 1988. Toleransi Biji Salak Terhadap Penurunan Kadar Air, Suhu dan Serangan Jamur. {Tolerance of Salak Seed to Reduction of Seed Water Content, Temperature and Fungal Attack}. Berita Biologi. 3 (8): 390-395. (Indonesian).

Ranganna, S. 1977. Manual of Fruit Analysis and Vegetables Products. Tata McGraw-Hill Publ. Co. Ltd. New Delhi. p.1-20.

Rillo, E.P. and M.B.F. Paloma 1991. Storage and Transport of Zygotic Embryos of *Cocos nucifera* L. for In Vitro Culture. Plant Genetic Resources Newsletter. IBPGR. FAO. p. 1-4.

Santoso, H.B. 1990. Salak Pondoh. {Pondoh Salak}. Kanisius, Yogyakarta. 60 pp. (Indonesian).

Sarwono, B. and M. Maryanti. 1990. Salak Manis asal Sumedang. {The Sweet Salak from Sumedang}. Trubus. 153 (XXI): 253. (Indonesian).

Schuiling, D.L and J.P. Mogea. 1991. *Salacca zalacca* (Gaertner) Voss. In: Verheij, E.W.M and R.E. Coronel (Eds.): Edible Fruits and Nuts. Plant Resources of South-East Asia 2. Pudoc, Wageningen, The Netherlands. p. 249-251.

Schmidtling, R.C. 1981. The Inheritance of Precocity and Its Relationship with Growth in Loblolly Pines. Silvae Genet. 30: 188-192.

Sholeh, M., Suhardjo and A. Suryadi. 1994. Pengaruh Dosis dan Saat Aplikasi Pupuk

Makro dan Mikro terhadap Produksi Salak. {The Effect of Rates and Timing of Application of Macro and Micro Fertilizers on Salak Production}. Lap. Hasil Penel. SubBalihorti, Malang. p. 64-74. (Indonesian).

Siswandono. 1989. Upaya Meningkatkan Mutu dan Produksi Buah Salak 'Pondoh'. {Ways to Improve Quality and Production of Salak 'Pondoh'}. Lap. Pen. FP. UGM. 25 pp. (Indonesian).

Soerojo, S.S.R. 1993. Pengembangan Agribisnis Hortikultura. {Agribusiness Development in Horticulture}. Pangan IV (16): 35-54. (Indonesian).

Soetomo, M.H.A. 1990. Teknik Bertanam Salak. {Method of Salak Cultivation}. Sinar Baru. Bandung. 83 pp. (Indonesian).

Sosrodihardjo, S. 1982. Perkembangan Fisik dan Kimiawi Salak Pondoh. {Physical and Chemical Development of Salak Pondoh}. Sub Balithorti Pasarminggu. Jakarta. 12 pp. (Indonesan).

Steel, R.G.D and J.H. Torrie. 1980. Principles and Procedures of Statistics. McGraw-Hill Kogakusha Ltd. p. 195-372.

Sudarmadji, S., Haryono and Suhardi. 1984. Prosedur Analisa untuk Bahan Makanan dan Pertanian. {*Analytical Procedures for Food and Agricultural Products*}. *Liberty*, Yogyakarta. p. 27-90. (Indonesian).

Sudaryono, T., S. Purnomo and M. Sholeh. 1991. Distribusi Varietas dan Prakiraan Wilayah Pengembangan Salak. {Distribution of Varieties and Estimate of Salak Expansion}. In: Sudaryono *et al.* (Eds.): Perbanyakan Cepat Secara Klonal dan Rekayasa Perbaikan Teknik Produksi serta Mutu Salak. SubBalithorti, Malang. p. 1-12. (Indonesian).

Sunaryono, H. 1990. Ilmu Produksi Tanaman Buah-buahan {The Science of Fruit Production). Sinar Baru Bandung. 209 pp. (Indonesian).

Swamy, B.G. and K.V. Krishnamurthy. 1980. From Flowers to Fruit: Embryology of Flowering Plants. Tata McGraw Hill Co Ltd. New Delhi. 162 pp.

Tjahjadi, N. 1989. Bertanam Salak. {Salak Cultivation}. Kanisius, Yogyakarta. 39 pp. (Indonesian).

Tohir, K.A. 1983. Bercocok Tanam Pohon Buah-buahan. {Fruit Trees Cultivation}. *Pradnya Paramita. Jakarta. p.* 306-331. (Indonesian).

Tomlinson, P.B. 1960. Essays on The Morphology of Palms. Principes. 4: 56-61.

Tomlinson, P.B. 1990. The Structural Biology of Palms. Clarendon Press Oxford. 477 pp.

Uhl, N.W. and J. Dransfield. 1987. Genera Palmarum. Allen Press. Lawrence, Kansas. p. 1-74; 233-278.

Verheij, E.W.M. 1972. Competition in Apple, as influenced by Alar Sprays, Fruiting, Pruning and Tree Spacing. Mededelingen 74-2 Landbouwhogeschool Wageningen, The Netherlands: 54 pp.

Verheij, E.W.M. and R.E. Coronel. 1991. Plant Resources of South-East Asia No. 2: Edible Fruits and Nuts. Pudoc, Wageningen, The Netherlands. p. 15-56.

Wardoyo. 1992. Opening Remark: Joint Symposium on Small Scale Vegetable Production and Horticultural Economics in Developing Countries. The Int. Society for Hort. Science. Bogor, Indonesia. p. 3-5.

Wessel, M. 1985. Shade and Nutrition. *In:* G.A.R. Wood and R.A. Lass (Eds.): Cocoa. 4th Edition. Tropical Agriculture Series. Longman, Harlow, UK. p. 166-194.

Whitmore, T.C. 1993. Arecoideae. In: Heywood, V.H: Flowering Plants of the World. B.T. Batsford Ltd. London. p. 301-304.

Widianto, S. Priyono, E.E. Wahyunie, D. Suprayoga, Y. Nuraini and Z. Kusuma. 1988. Data Collection: Crop, Soil and Weather. Dept. of Soil Sci. Fac. of Agric. Brawijaya

Univ. Malang. 59 pp.
Wolf, S., Y. Lensky and N. Paldi. 1999. Genetic Variability in Flower Attractiveness to Honeybees (*Apis mellifera* L.) within the Genus Citrullus. HortScience. 34 (5): 860-863.
Zona, S. 1987. Phenology and Pollination Biology of *Sabal etonia* (Palmae) in Southeastern Florida. Principes. 31 (4): 177-182.

B.Sc. THESES

Aliyah, M. 1992. Hubungan antara Kesempurnaan Penyerbukan dengan Pertumbuhan dan Perkembangan Bakal Buah Salak. {Relation between Pollination and Growth and Development of Salak Fruit}. Jurusan Budidaya Pertanian Fak. Pertanian, Unibraw. Malang. 50 pp. (Indonesian).
Christinawati, E. 1994. Peningkatan Produktivitas Buah Salak Lokal Suwaru dengan Seleksi Tepungsari. {Improvement of Salak Productivity by Selection of Pollen}. Jurusan Budidaya Pertanian. Fak. Pertanian, Unibraw. Malang. 77 pp. (Indonesian).
Indarwati, D. 1993. Pengaruh Pupuk Nitrogen Terhadap Pertumbuhan Vegetatif dan Generatif Tanaman Salak (*Salacca zalacca* (Gaertner) Voss di Desa Karangtengah, Kecamatan Winongan, Kabupaten Pasuruan. {The Effect of Nitrogen on Vegetative and Generative Growth of Salak (*Salacca zalacca* (Gaertner) Voss) in Karangtengah Village, Winongan Sub-district of Pasuruan}. Jurusan Budidaya Pertanian. Fakultas Pertanian. Unibraw. 88 pp. (Indonesian).
Kasih, Y.D. 1991. Perkecambahan Biji dan Pertumbuhan Bibit Salak 'Pondoh' dalam Kaitannya dengan Naungan dan Konsumsi Air. {Germination and Growth of Salak 'Pondoh' Seedlings in Relation to Shading and Water Consumption}. Jurusan Budidaya Pertanian. Fak. Pertanian Unisma. Malang. 65 pp. (Indonesian).
Zulkarnain. 1991. Pengaruh Berbagai Media Kemas dan Lama Penyimpanan terhadap Perkecambahan Benih Salak (*Salacca zalacca* (Gaertner) Voss) Jenis Pondoh. {Effect of Media and Duration of Storage on Germination of Salak Seed (*Salacca zalacca* (Gaertner) Voss) cv. 'Pondoh'}. Jurusan Budidaya Pertanian Fak. Pertanian UMM. Malang. 103 pp. (Indonesian).

APPENDICES

Appendix 1. Climatological data of Sleman (1988-1993).

Months	Rainfall (mm/month)	Temperature (°C)	Relative humidity (%)
January	413.5	26.2	85
February	387.3	26.2	85
March	319.0	26.9	82
April	250.6	27.0	83
May	119.3	27.7	80
June	85.3	27.2	77
July	37.5	26.2	74
August	72.5	26.0	78
September	31.2	26.2	81
October	127.0	26.4	82
November	264.5	26.2	84
December	327.0	26.2	83

Source: Agric. Depart. of Sleman regency.

Appendix 2. Climatological data of Jatikerto (1978-1980).

Months	Rainfall (mm/month)	Evaporation (mm/day)	Temperatures (°C)		Relative humidity (%)	
			Max.	Min.	Max.	Min.
January	303.7	4.8	31.1	21.4	98.7	58.7
February	241.3	5.5	30.4	21.2	100.0	56.3
March	206.3	4.8	31.1	21.3	100.0	57.3
April	159.0	5.5	31.4	21.7	99.8	60.3
May	124.3	4.1	31.9	21.1	98.5	58.5
June	68.0	4.0	31.7	20.4	99.3	48.0
July	40.0	4.0	30.7	19.5	98.0	36.0
August	67.0	4.0	30.8	19.8	96.7	42.3
September	56.0	4.8	32.1	20.8	96.3	43.0
October	155.3	4.5	31.6	21.6	97.3	44.0
November	220.7	4.0	31.0	21.8	97.7	52.3
December	306.5	4.9	31.1	22.2	100.0	56.0

Source: Widianto et al. (1988).

Appendix 3. Glossary of terms.

Abaxial	on the side facing away from the stem or axis.
Acaulescent	lacking visible stem or stemless.
Adaxial	on the side facing the stem or axis.
Adjacent-ligular	in germination, the cotyledonary sheath axis is unextended, the ligule is positioned close to the seed.
Adventitious	in root, the roots emerging after the death or malfunction of the primary root.
Alternate	in leaf, one leaf at each node of stem, leaf face towards the stem. in stamina, between the petals
Androecium	the male element; the stamina as a unit of the flower.
Anemophilous	wind-pollinated.
Anther	the terminal part of the male organs (stamina), containing the pollen.
Anthesis	the time when pollen shedding takes place.
Apex	the growing point of a stem or root.
Apical	at the tip of any structure.
Apomixis	reproduction by seed formed without sexual fusion.
Armed	bearing some form of spines.
Axillary	borne in an axil.
Axis	the point or central line of development of a plant or organ.
Basal	borne at or near the base.
Basipetal	developing from the apex toward the base.
Bifid	cleft into two parts at the tip.
Bipinnate	the primary divisions (pinnae) of a pinnate leaf being themselves pinnate.
Bract	modified leaf associated with the inflorescence.
Bracteole	a small bract borne on a flower stalk, often present even when the flower is essentially sessile.
Calyx	the outermost or lowermost whorl of floral organs (the sepals)
Carpel	the single unit of the gynoecium.
Catkin	an inflorescence having a long stalk.
Cirrate	bearing a cirrus.
Cirrus	climbing organ, structurally a whiplike extension of the leaf rachis.
Clustered	with several stems.
Corolla	the second whorl of flower organs (the petals) inside or above the calyx.
Costapalmate	intermediate shape between palmate and pinnate leaves.
Cotyledonary sheath	extension of the cotyledon in germination, which carries the embryo out of the seed kernel.
Crown	the cluster of leaves borne at the tip of a palm stem.
Decumbent	reclining or lying on the ground.
Desa	village.
Dichotomous	stem, equally forking.
Dimorphic	with two different forms.
Dioecious	male and female flowers borne on different plants.
Distal	farthest from the place of attachment.
Distichous	arranged in two ranks.
Dyad	a pair.
Elliptic	oblong with regularly rounded ends.
Emarginate	distinctly notched at the apex
Embryo	the rudimentary plant present in a seed.

Endocarp	the innermost layer of the fruit wall.
Endosperm	in palms, the nutritive body of a seed.
Entire	undivided.
Eophyll	in a seedling, the first leaf with a blade.
Epicarp	the outermost layer of the fruit wall.
Fibrous	composed of or including fibres.
Flabellate	fan-shaped or wedge-shaped.
Flagellum	a whiplike climbing organ derived from an inflorescence, bearing reflexed spines.
Funiculus	the stalk of an ovule.
Glabrous	smooth, lacking hairs.
Gynoecium	the female element; the pistil as a unit of the flower.
Hapaxanthic	individual stems flower once only and then die.
Haustorium	structure which contains reserves used in the germination process of the palm seed
Hermaphrodite	flowers having both male and female elements.
Imbricate	overlapping like tiles.
Indeterminate	not bearing a terminal flower or other organs, capable of extending the axis in which it is borne.
Induplicate	V-shaped in cross section.
Inflorescence	one peduncle containing many flowers or florets.
Infrafoliar	borne below the leaves.
Interfoliar	borne among the leaves.
Internode	the space or part of a stem between the attachments of two leaves.
Kabupaten	regency.
Kecamatan	district.
Kotamadya	medium city.
Lanceolate	narrow, tapering at both ends, the basal end often broader.
Ligule	an organ preceding the growth of the scale leaf.
Linear	several times longer than wide.
Locule	the cavity in which the ovule is borne.
Mesocarp	the middle layer of the fruit wall, usually fleshy.
Micropyle	an aperture through the integuments of the ovule.
Midrib	the central or largest vein of a leaf.
Monocarpic	fruiting once then dying completely.
Monoecious	describing a plant bearing both male and female flowers.
Monopodial	with a single main axis.
Node	the stem level at which a leaf is attached.
Obovoid	egg-shaped, broader distally.
Ontogeny	the development of an individual through its various stages.
Orthostiche	in phyllotaxis, a vertical row.
Ovary	the ovule-bearing part of the pistil.
Palmate	leaf lacking a rachis.
Pedicel	a floral stalk.
Peduncle	the lower unbranched part of an inflorescence
Perfect flower	or hermaphrodite, a flower with functional male and female organs.
Perianth	the sepals and petals together.
Petal	one unit of the inner floral envelope or corolla.

Pinna	a leaflet of a pinnate leaf.
Pinnate	leaflets are borne on a rachis.
Pistil	female flower part, comprising ovary, style and stigma.
Pistillate	bearing a pistil (gynoecium).
Pit	a cavity formed by united bracts, enclosing flowers.
Phyllochron	the interval between the emergence of successive leaves.
Pleonanthic	stem capable of flowering continuously, flowering not leading to the death of the stem.
Plumule	the primary bud of an embryo or germinating seed.
Procumbent	lying along the ground.
Proximal	nearest to the attachment.
Rachilla	the branch that bears the flowers.
Rachis	the main axis of a compound leaf or inflorescence.
Radicle	the first root formed by the embryo.
Reduplicate	in leaf, inversely V-shaped in cross section.
Remote-ligular	in germination, the cotyledonary sheath axis is extended, the ligule is positioned at some distances from the seed.
Rhizome	underground diageotropic stem.
Rosette	a group of leaves arising closely together from a short stem, forming a radiating cluster on or near the ground.
Rudimentary root	a root which is unable to grow further.
Sarcostesta	a fleshy layer developed from the outer seed coat.
Scale leaf	unbladed leaf.
Sessile	without a stalk.
Sheath	the base of the leaf encircling partly or entirely the stem.
Shrub	a woody plant which branches from the base, there is no trunk.
Solitary	single stem, lacking suckers.
Spadix	a flower cluster.
Spear	folded leaf formed as a sword.
Stamen	the male organ of a flower.
Staminate	bearing a stamen.
Stigma	the pollen receptor of the pistil.
Stool	several stems rise from the same mother plant.
Sucker	horizontal branch originating from the trunk base.
Unisexual	of one sex, having stamens or pistils only.
Vein	the visible strands of conducting and strengthening tissues running through a leaf.
Whorl	the arrangement of leaves, petals, stamina so they are at the same level in an encircling ring.
Zoophilous	animal-pollinated.

SUMMARY

This study of the salak palm, *Salacca zalacca* (Gaertner) Voss, was started in 1989. Most of the experimental work has been conducted in the laboratories and the Jatikerto research station of Brawijaya University, Malang, and in farmers' orchards in East and Central Java. Additional information has been obtained by visits to West Sumatra and Bali. In most of the experiments the popular cv. Pondoh from Sleman (Central Java) has been used. 'Pondoh' is now quite well distributed in Indonesia.

The General Introduction (Chapter 1) argues that Indonesia requires more fruit to meet nutritional requirements of the population as well as to earn foreign exchange from export. This is a matter of raising productivity rather than mere area expansion, because to enable people to eat enough fruit the price should be lowered. Salak so far has received little attention from science and since it is very much an Indonesian crop it is in the first place up to Indonesian scientists to improve its productivity. The introduction continues with an overview of growth and development of palms, briefly outlines the genus *Salacca* and general aspects of salak growing in the country. The chapter closes with an outline of the thesis work and its limitations, in particular the short duration of most trials and the scarcity of experiments with mature palms.

Agronomic field experiments are presented in Chapters 2 to 5. In Chapter 6 botanical observations are combined with published information to outline a model of growth and development of salak. Chapter 7 contains the general discussion.

Chapter 2 presents the only long-term experiment, a variety trial which was followed from sowing till the end of juvenility, a period of 3½ years. Seedlings of 'Black Bali' were stunted; perhaps the seed of this monoecious variety was too old. The remaining 6 varieties produced on average 4 - 7 simple leaves, subsequent leaves being compound. 'Pondoh' plants (sown 3 months later than the other varieties) produced 12 leaves in the first 13 months, the other varieties 9.5 - 11 leaves in 16 months. 'Pondoh' leaves were smallest, but leaf area per plant (0.66 m^2 after 13 months) increased faster than in the other varieties. At the age of 15 months suckering started; at 19 months the average was 2, at 33 months 4 suckers per plant, 'Yellow Suwaru' having relatively few suckers. Farmers desucker to limit the density of the stand and to facilitate access for pollination.

The first plant flowered afer 28 months. At the age of 34 months several plants (had) flowered in all 6 varieties, and 42 months from sowing the percentage of flowering plants ranged from 50 to 84 (25% for the younger 'Pondoh' plants). The female:male ratio was 1.4; more extreme ratios were found in some varieties, but the numbers of plants were too small to exclude a sex ratio of 1.

The facts that leaf area measurements are cumbersome and of doubtful value because of the unusual and irregular leaf shape of salak, led to a comparison of different methods to assess leaf area. Two direct area measurements, using the photometer or a square centimeter grid (the area being given by the number of grid points covered by leaflets), were compared with estimates based on measured leaf attributes such as petiole diameter, rachis length and number of leaflets, etc. It turned out that these three attributes are good predictors of leaf area, whereas a method based on measuring length and width of the largest leaflet – used successfully in some other palms – did not yield a predictive value for salak leaves. The study did not result in a practical non-destructive method to estimate leaf area, but growers cut the senescing leaves and these may provide suitable samples for measurement.

Salak is pollinated by insects but in Java hand pollination is necessary for good yields and this labour-intensive work accounts for 30% of the production costs. Chapter

3 describes two pollination experiments. The first involved hand pollination of intact stigmata of bagged spadices in comparison with stigmata from which one or two of the three lobes had been excised, and with unpollinated controls. The results showed that pollination is necessary for fruit set and that most, if not all, ovules are functional: with intensive pollination 75% of the flowers set fruit and 90% of the fruit contained 3 seeds. This treatment more than doubled fruit number per bunch as compared with bunches in which stigmata lobes had been excised; nevertheless fruits were larger, showing that in a good orchard, competition between fruits in a bunch can be avoided.

In the other experiment 'Nganjuk' plants at Nganjuk were selfed or cross-pollinated with pollen from four other varieties; likewise 'Kacuk' plants near Malang were selfed or crossed with five other varieties. In both localities the pollinator strongly influenced yield, qualitatively (longevity, chemical constituents of the flesh) as well as quantitatively (numbers and weight of fruits per bunch, edible portion). The reciprocal crosses of 'Nganjuk' and 'Kacuk' suggested that incompatibility factors occur. The work reported in this chapter shows that intensive pollination is essential and that the choice of the pollinator can be an important factor.

Chapter 4 describes experiments regarding germination. In the first one it was studied how partial or total excision of the endosperm affects the haustorium and growth of the embryo. In the second experiment germination was studied after seed storage for 0 - 4 weeks in ambient air, sawdust or charcoal. In spite of complete removal of the endosperm the embryo gained fresh weight, but died within 12 days. Germination percentage was somewhat reduced and seedling growth retarded by halving the endosperm, but much more so where the endosperm had been cut longitudinally than in case of a transverse cut. In seedlings with intact endosperm the haustorium grew steadily and finally completely filled the space where the endosperm had been. Of the initial starch reserves in the endosperm little was left after 18 weeks and about half had been converted into sugar/energy, the remainder being recovered in the haustorium and shoot plus root. Eighteen weeks after sowing dry weight of the seedlings slightly exceeded the initial weight, showing that photosynthesis more than compensated the respiratory losses.

Salak seed is recalcitrant and the second experiment suggested a close correlation between seed moisture content and ability to germinate. Only 60% of the seeds germinated after storage in ambient air for 1 week; after 4 weeks storage germination failed completely. Storage in sawdust and particularly in charcoal helped greatly to sustain viability and the rate of growth of seedlings, but 100 days after sowing every extra week of storage was still reflected in smaller leaf areas.

The experiments in Chapter 5 dealt with environmental factors: soils, mineral nutrition and shading. Seedling growth was followed in a pot experiment comparing soils from four production centres with the soil of the Jatikerto research farm. This latter soil had a heavier texture, higher field capacity, and even lower organic matter and nitrogen contents than the other soils. P-content ranged from low to high, K from fair to very high and Ca-content was fair to high in all soils. Germination was delayed in the heavy-textured soils; subsequent growth appeared to be increasingly affected by differences in fertility, growth in the heavy, infertile Jatikerto soil being most retarded. Organic matter content may have played a large role in seedling growth, because it was correlated with N- and P- content in the soil and nutrient levels in the leaves.

In a factorial experiment with 4-month-old seedlings combining levels of shading and urea application, shade proved essential for survival; during the dry season in East Java the reduction of incident light at midday should be 50% or more. Growth was best under 50 - 75% shade in combination with 10 g urea per plant.

In an old salak garden palms with 2 bunches, 1 - 2 months after pollination, were treated with 0 - 180 g compound fertilizer. The experiment lasted only 6 months, but nevertheless the fertilizer led to an increase in size of new leaves and of the fruit in the selected bunches. Also, contrary to what growers contend, fertilizer application resulted in more good fruits and fewer split and decaying fruits per bunch.

In all three experiments, the effects of the environmental factors were measured on leaves and bunches which had already been formed before the treatments were applied. To assess the full impact of these factors the experiments should have been planned for much longer periods, preferably several years. Nevertheless the short-term results confirm that shade is essential for young plants. Moreover, generous applications of manure are recommended, and N-dressings for young plants. In further studies of these environmental factors, more attention should be paid to the role of soil moisture.

The five phases of growth and development, which are distinguished in palms, are the framework for the pattern of growth and development of the salak palm, outlined in Chapter 6.

The embryonic phase, from the formation of the zygote till the mature seed, was not investigated, but Plates 2 and 3 show the position of the embryos in the young fruit and shape and size of embryos from a mature fruit.

With respect to the seedling phase the germination process was given much attention. The timing and sequence of the emergence of the different organs was studied, as well as the mobilization of reserves in the endosperm by the haustorium and their incorporation in shoot and roots. The duration of the seedling phase was shown to vary greatly depending on growing conditions and duration and medium of seed storage.

The establishment phase lent itself to studying aspects of leaf growth, the morphology of the crown and suckering. The leaf growth stages from emergence and spear growth till unfolding and maturation were described and timed in several experiments; the duration can vary considerably from one leaf to the next. Leaves are simple in the young seedling but leaves emerging later are pinnate and the number of leaflets increases till the phase comes to an end. The size of the leaflets varies greatly and their arrangement along the rachis is most unusual. The phyllochron is not as steady as is generally supposed to be the case in palms; it was shorter in 'Pondoh' than in other varieties. Healthy growth implies that each new leaf is larger than the previous one and emerges before the previous one matures.

The phyllotaxis was shown to be 2/5, the angle of divergence of successive leaves being 144°. Lateral buds were found in line with the leaf axis, one in the axil (the inflorescence bud) and one just below the insertion of the leaf sheath (the sucker bud). Three-year-old 'Pondoh' crowns had 10 - 13 expanded leaves; 5 - 6 leaf initials were counted in the bud, the smallest one being 2 mm high; further microscopic dissection should clarify whether the number of initials is about equal to the number of unfolded leaves, as is the case in most palms which have been studied.

Suckers stand on short horizontal stems radiating from the mother stem. Growers leave only 2 suckers per stool, but in a neglected 'Pondoh' garden numerous suckers were found, including second-order suckers.

In the mature vegetative phase the palm crown has reached its ultimate size and in many species extension of the trunk is the only obvious change in vegetative features. In salak the palm soon becomes unstable when the trunk extends and topples over. The way in which the tip becomes erect again was studied by measuring internode length. In this way the palm 'walks', taking about 10 years for each step and rejuvenating itself in the process.

Measurements of leaf growth in a 20-year-old garden revealed large differences in leaf size (2.25 - 4 m long) and in days till emergence of the next leaf (30 - 52 days). The observations followed cutting of old leaves by the grower and coincided with the start of the dry season, but whatever the explanation may be, they show that even in the mature vegetative phase constant leaf size and phyllocron cannot be taken for granted.

In commercial gardens few suckers are formed in this phase, presumably because the dense stand leads to very low light levels in the crop.

The start of the reproductive phase is indicated by the emergence of the first inflorescence. The inflorescence bud develops into a spear and splits the base of the subtending leaf to break into the open. Because the leaf bases adhere to the trunk, slits in old leaf bases show which buds produced an inflorescence. Inflorescence buds do not necessarily develop in the order in which the leaves were formed. No convincing explanation could be proposed for the seasonality of flowering, resulting in a major and a minor harvest peak in the course of the year.

The heavy fruit set and seed set following intensive pollination showed that imperfect pollination, with respect to intensity, compatibility or timing, can easily become a yield-limiting factor. Yield records in the experiments show 6 - 9 fruits per bunch for 'Kacuk', 6 - 24 for 'Nganjuk' and 11 - 24 fruits per bunch for 'Suwaru'. Mean weight per fruit ranged from 28 g for selfed 'Nganjuk' to nearly 100 g for selfed 'Kacuk'; 'Suwaru' fruit averaged 70 - 75 g.

Because Chapter 6 already recapitulates much of the experimental work of the foregoing chapters, the general discussion in Chapter 7 focusses on the major gaps in our understanding of salak, both botanically and agronomically.

Botanically the deviations of a steady growth pattern in mature palms are most intriguing; if they prove as large as suggested by the few instances in this thesis work and can be adequately explained, this will improve the understanding of the growth of palms generally. One such deviation, the seasonal flowering peaks, is of direct agronomic importance; an explanation – starting with identification of the stage at which the development of the inflorescence stagnates – is badly needed, the more so if it provides clues enabling growers to extend or shift the harvest periods.

The other botanical issue – also of obvious agronomic importance – is to clarify in how far different components limit potential yield: do all buds produce inflorescences, how variable is the number of spadices and flowers per inflorescence, which percentage of flowers sets fruit and does competition between fruits affect fruit size. Does the contribution of each of these components to yield differ much:

- for different varieties?
- when a solitary palm is compared with a palm in a densely planted commercial garden?

This study mainly points to pollination as a factor which often limits yield.

Agronomically it would be a great bonus if sex would be known at planting, so that instead of ending up with an irregular crop stand following the removal of most male plants 3 years later, an orchard could be planted at the optimum spacing and including pollinator plants from the start. The possibilities are vegetative propagation, if necessary through tissue culture, or introduction of genetic markers which reveal the sex of seedlings. Permanent shade trees do not fit well in this approach; thus their indispensability needs to be questioned and alternatives (irrigation?) should be considered.

Evaluation of salak varieties has only just started. Growers' preference for 'Pondoh' is justified, but phasing out of other varieties will narrow the gene pool even before the available germplasm has been assessed.

SAMENVATTING

Deze studie van de salak palm, *Salacca zalacca* (Gaertner) Voss begon in 1989. Het onderzoek werd grotendeels uitgevoerd in de laboratoria en het Jatikerto veldstation van Brawijaya Universiteit, Malang, en in tuinen van telers in Oost en Midden Java. Aanvullende informatie werd verzameld tijdens bezoeken aan West Sumatera en Bali. In de meeste proeven werd de populaire cv. Pondoh van Sleman (Midden Java) gebruikt. 'Pondoh' is nu wijd verbreid in Indonesië.

In de Algemene Inleiding (Hoofdstuk 1) wordt gesteld dat Indonesië behoefte heeft aan meer fruit, terwille van een evenwichtige voeding zowel als om deviezen te verdienen door export. Daarbij gaat het niet om areaaluitbreiding maar om verhoging van de productiviteit, want om de bevolking in staat te stellen genoeg fruit te eten, moet de prijs omlaag. De wetenschap heeft tot dusverre weinig aandacht aan salak geschonken en omdat het in hoge mate een Indonesisch gewas is, ligt verhoging van de productiviteit in de eerste plaats op de weg van Indonesische onderzoekers.

De Inleiding vervolgt met een overzicht van groei en ontwikkeling van palmen, behandelt kort het geslacht *Salacca* en algemene gegevens betreffende de teelt van salak in eigen land. Het hoofdstuk eindigt met een overzicht van de onderwerpen die in het proefschrift aan de orde komen en de beperkingen van het onderzoek (met name de korte duur van de meeste proeven en het geringe aantal proeven met volgroeide palmen).

Teeltproeven worden beschreven in de Hoofdstukken 2 - 5. In Hoofdstuk 6 worden botanische waarnemingen gecombineerd met informatie uit publicaties tot een proeve van een model dat groei en ontwikkeling van de salak beschrijft. Hoofdstuk 7 bevat de algemene discussie.

Hoofdstuk 2 betreft de enige langdurige studie, een 3,5 jaar durende rassenproef die de periode van zaai tot het einde van de juveniele periode behandelt. Zes rassen hadden gemiddeld 4 - 7 enkelvoudige bladeren, alvorens samengestelde bladeren verschenen; het 7e ras, 'Black Bali', moest worden uitgesloten wegens zwakke groei (mogelijk was het zaad te oud). 'Pondoh' planten (3 maanden na de andere rassen gezaaid) kregen 12 bladeren in de eerste 13 maanden, de andere rassen 9.5 - 11 bladeren in 16 maanden. Hoewel het 'Pondoh' blad klein was, nam het bladoppervlak bij dit ras het snelste toe (tot 0.66 m^2 13 maanden na zaai). Uitstoeling begon toen de planten 15 maanden oud waren; na 19 maanden waren er gemiddeld 2, na 33 maanden 4 zijscheuten per plant; 'Yellow Suwaru' vormde minder scheuten dan de andere rassen. Telers beperken het aantal zijscheuten om de beplanting toegankelijk te houden, met name voor handbestuiving. De eerste plant bloeide na 28 maanden. Na 34 maanden hadden bij alle rassen tenminste enkele planten gebloeid, en 42 maanden na zaai varieerde het percentage bloembare planten van 50 - 84 (25% voor de jongere 'Pondoh' planten). De verhouding vrouwelijk:mannelijk bloeiende planten was 1,4 : 1; bij sommige rassen was de verhouding meer extreem, maar de aantallen planten waren te klein om een verhouding van 1 : 1 uit te sluiten.

De bladoppervlakte werd gemeten volgens een methode ontwikkeld voor andere palmen, gebaseerd op het aantal blaadjes per blad en lengte en breedte van het grootste blaadje. De voor een palm zeer onregelmatige bladvorm van salak wekte twijfel aan de bruikbaarheid van de methode; daarom werden in een vervolgstudie enkele methoden vergeleken. Kenmerken van een aantal 'Pondoh' bladeren, zoals doorsnee van de bladsteel, rachis-lengte en aantal blaadjes werden gemeten; de bruikbaarheid van combinaties van kenmerken als schatter van de bladoppervlakte werd getoetst middels vergelijking met rechtstreekse oppervlakte-meting van de

blaadjes op mm-papier (waarbij de oppervlakte gelijk is aan het aantal bedekte punten van een cm^2-raster) en op de gangbare foto-electrische apparatuur. Het bleek dat de drie bovengenoemde bladkenmerken goede schatters zijn, maar dat de breedte en lengte van het grootste blaadje bij salak geen voorspellende waarde hebben. De vergelijkende studie leverde geen praktisch bruikbare non-destructieve methode op, maar telers kappen de oudste bladeren en die kunnen wellicht voor oppervlakte-meting worden gebruikt.

Salak wordt door insecten bestoven, maar op Java is kunstmatige bestuiving nodig voor een goede oogst en dat is zo arbeidsintensief dat het 30% van de productiekosten uitmaakt. Hoofdstuk 3 beschrijft twee bestuivingsproeven. De eerste betreft handbestuiving van intacte stempels op ingehulde bloeikolven, in vergelijking met stempels waarvan één of twee van de drie stempellobben zijn gecoupeerd en een onbestoven controle. Zonder bestuiving trad geen bevruchting op, maar de meeste – zo niet alle – stampers konden worden bevrucht: 75% van de bloemen zette vrucht na intensieve bestuiving en bij 90% van de vruchten vormden alle 3 zaadknoppen zaad. Deze behandeling verdubbelde het aantal vruchten per tros ten opzichte van de behandelingen waarbij een of twee stempellobben waren verwijderd; niettemin waren de vruchten groter, hetgeen aangeeft dat in een goede boomgaard geen concurrentie tussen vruchten in een tros behoeft op te treden.

In de tweede proef werd zelf- of kruisbestuiving toegepast op 'Nganjuk' planten in Nganjuk; evenzo op 'Kacuk' planten nabij Malang. In het eerste geval werd stuifmeel van vier andere rassen gebruikt, in het tweede geval stuifmeel van vijf rassen. In beide gevallen werd de oogst sterk beïnvloed door de bestuivers, zowel kwalitatief (houdbaarheid, chemische samenstelling van het vruchtvlees) als kwantitatief (aantal en gewicht van de vruchten per tros, eetbare deel). In de reciproke kruisingen van 'Nganjuk' en 'Kacuk' leken incompatibiliteitsfactoren een rol te spelen.

De resultaten van beide proeven benadrukken het belang van intensieve bestuiving en de keuze van een geschikte bestuiver.

Hoofdstuk 4 behandelt kiemproeven, de eerste om de groei van haustorium en embryo te volgen na gedeeltelijke of gehele verwijdering van het endosperm, de tweede om kieming en groei te meten na opslag van het zaad gedurende 0 - 4 weken in houtskool, zaagsel of zonder medium. Het vers gewicht van de embryo's nam nog wat toe ondanks verwijdering van het complete endosperm, maar de kiemen stierven binnen 12 dagen. Het kiempercentage lag wat lager en de groei bleef achter na halvering van het endosperm, maar veel meer waar het embryo in het snijvlak lag dan waar haaks op de as van het embryo was gesneden. Bij zaailingen met intact endosperm groeide het haustorium tot het de ruimte vulde die eerder door het endosperm werd ingenomen. De zetmeelreserves van het endosperm waren vrijwel opgesoupeerd na 18 weken en ongeveer de helft was omgezet in suiker/energie; de rest werd teruggevonden in het haustorium en scheut en wortels. Na 18 weken was het drooggewicht van de zaailingen ook wat hoger dan het oorspronkelijke zaadgewicht, een bewijs dat fotosynthese de verliezen door respiratie ruimschoots had goedgemaakt.

Salakzaad is recalcitrant en de tweede proef wees op een nauw verband tussen het vochtgehalte van het zaad en kieming. Slechts 60% van de zaden kiemde na 1 week opslag zonder medium; na 4 weken kiemde het zaad in het geheel niet. Bewaring in zaagsel en vooral in houtskool verlengde de levensvatbaarheid van het zaad aanzienlijk en bevorderde de groei van de zaailingen, maar 100 dagen na zaai vond iedere extra week zaadopslag nog steeds zijn weerslag in een kleiner bladoppervlak per plant.

Hoofdstuk 5 beschrijft proeven met omgevingsfactoren: bodem, bemesting en schaduw. In een potproef werd de invloed van de grondsoort (van het Jatikerto veldstation en van vier teeltcentra) op de groei van zaailingen onderzocht. De grond van het veldstation is zwaarder, heeft een grotere veldcapaciteit, en een nog lager gehalte aan organische stof en stikstof dan de andere grondsoorten. Het P-gehalte varieerde van laag tot hoog, K van matig tot zeer hoog en Ca van matig tot hoog in de vijf grondsoorten. De kieming was vertraagd in de zware gronden; de verdere groei leek steeds meer te worden bepaald door verschillen in vruchtbaarheid, zodat de groei in de arme Jatikerto grond het zwakst was. Het organische-stof-gehalte speelde vermoedelijk een grote rol in de groei, want het was gecorreleerd met N- en P-gehalte van de grond en de gehalten van nutriënten in het blad.

In een factoriële combinatie van schaduw-niveaus en ureum-trappen bij 4 maanden oude zaailingen bleek schaduw onontbeerlijk voor overleving; gedurende de droge tijd in Oost-Java is een reductie van de instraling midden op de dag van meer dan 50% gewenst. De planten groeiden het best onder 50 - 75% schaduw in combinatie met 10 g ureum per plant.

In een oude salaktuin werden palmen met 2 vruchttrossen, 1 - 2 maanden na bestuiving, bemest met 0 - 180 g samengestelde mest. De proef duurde slechts 6 maanden, maar niettemin waren de nieuwe bladeren groter, evenals de vruchten in de geselecteerde trossen. Bovendien waren er, in tegenstelling tot wat telers verwachtten, meer verkoopbare vruchten en minder vruchten met een gespleten huid of rot.

In alle proeven in dit hoofdstuk werd de invloed van omgevingsfactoren gemeten aan bladeren en vruchten die al waren aangelegd vóór het begin van de proeven. Veel grotere effecten zijn te verwachten op organen die vanaf hun initiatie aan de behandelingen zijn blootgesteld, maar dit vereist een veel langere, liefst jarenlange, proefduur. Niettemin bevestigen de korte-termijn-resultaten dat schaduw nodig is voor jonge planten. Bovendien rechtvaardigen ze royale stalmestgiften, alsmede stikstof voor jonge planten. In nadere studies van deze omgevingsfactoren moet de vochtvoorziening van de planten meer aandacht krijgen.

De vijf fasen van groei en ontwikkeling die bij palmen worden onderscheiden, vormen de basis voor het in Hoofdstuk 6 beschreven model van groei en ontwikkeling. De embryonale fase, van de vorming van de zygoot tot het rijpe zaad, is niet bestudeeerd, maar twee platen tonen de plaats van de embryo's in de jonge vrucht en vorm en afmetingen van embryo's in rijpe vruchten.

In de zaailing-fase kreeg het kiemproces veel aandacht. Volgorde en tijdstip van verschijnen van de verschillende organen werden bestudeerd, evenals de mobilisatie van reserves in het endosperm door het haustorium en hun assimilatie in scheut en wortel. De duur van de zaailing-fase bleek sterk af te hangen van de groei-omstandigheden, en de duur en wijze van opslag van het zaad.

De 'vestigings'-fase (engels: establishment phase) leende zich voor observatie van de bladgroei, de morfologie van de palmkroon en de uitstoeling. De bladstadia van uitlopen en lengtegroei van de speer tot het ontvouwen en afrijpen van de blaadjes werden gevolgd in een aantal proeven; de duur van deze stadia kan sterk variëren voor opeenvolgende bladeren. In de jonge zaailing zijn de bladeren enkelvoudig, maar later zijn ze geveerd en het aantal blaadjes neemt toe tot het einde van de fase. De afmetingen van de blaadjes lopen sterk uiteen en hun rangschikking langs de bladsteel is zeer ongewoon voor een palm. Het phyllochron is niet zo constant als het geacht wordt te zijn in palmen; het was korter in 'Pondoh' dan in de andere rassen. Een goede groei houdt in dat ieder blad groter is dan het voorgaande en ontluikt vóór het voorgaande blad afrijpt.

De bladstand bleek 2/5 te zijn, bij een divergentiehoek tussen opeenvolgende bladeren van 144°. Zijknoppen liggen op de bladas, één in de oksel (de bloemknop) en één net onder de aanhechting van de bladschede (de bladknop). Drie-jaar-oude 'Pondoh' kronen hadden 10 - 13 ontvouwde bladeren; in de knop werden 5 - 6 bladbeginsels geteld, de kleinste 2 mm hoog. Verdere ontleding onder de microscoop moet duidelijk maken of het aantal initialen ongeveer gelijk is aan het aantal ontvouwde bladeren, zoals bij de meeste onderzochte palmen.

Zijscheuten ontstaan uit bladknoppen, die straalsgewijs vanuit de kroon een stukje horizontaal uitlopen, alvorens de scheuttop zich opricht. Telers houden niet meer dan 2 zijscheuten per plant aan, maar in een verwaarloosde 'Pondoh' tuin waren het er veel meer, inclusief zijscheuten van de tweede orde.

In de volwassen vegetatieve fase heeft de palmkroon zijn uiteindelijke afmetingen bereikt; bij veel soorten is verlenging van de stam de enige opvallende verandering in vegetatieve kenmerken. De salakpalm wordt instabiel als de stam zich verheft en valt om. De top richt zich weer op door eenzijdige verlenging van de internodiën. Zo 'wandelt' de palm, in stappen van een jaar of tien, en verjongt zichzelf gaandeweg.

Bladmetingen in een 20-jaar-oude salaktuin brachten grote verschillen in bladlengte (2.25 - 4 m) en in aantal dagen tot ontluiken van het volgende blad (30 - 52) aan het licht. De waarnemingen volgden op het kappen van de oudste bladeren en vielen samen met het begin van de droge tijd, maar wat de verklaring ook moge zijn, ze tonen aan dat zelfs in de volwassen vegetatieve fase bladgrootte en phyllochron bepaald niet constant zijn.

In commerciële tuinen worden in deze fase nauwelijks zijscheuten gevormd, waarschijnlijk omdat het gewas zo dicht is dat weinig licht onder de kronen doordringt.

De reproductieve fase dient zich aan met de verschijning van de eerste bloeiwijze. De bloemknop loopt uit tot een speer die de basis van het bijbehorende blad splijt om zich een weg naar buiten te banen. De bladbases blijven zitten, zodat achteraf nog aan de hand van de spleten kan worden vastgesteld hoeveel bloemknoppen zijn uitgelopen. De bloemknoppen lopen niet altijd uit in de volgorde waarin ze zijn aangelegd. Voor de jaarlijkse pieken in de bloei, die resulteren in een hoofd- en een neven-oogstperiode, kon geen bevredigende verklaring worden gegeven.

De zware vrucht- en zaadzetting na intensieve bestuiving wijst erop dat onvolkomenheden in de bestuiving, qua intensiteit, compatibiliteit, of timing, aldra tot oogstverliezen leiden. Vruchttellingen kwamen tot 6 - 9 vruchten per tros voor 'Kacuk', 6 - 24 voor 'Nganjuk' en 11 - 24 vruchten voor 'Suwaru'. Het gemiddeld vruchtgewicht liep van 28 g voor zelfbestoven 'Nganjuk' tot bijna 100 g voor zelfbestoven 'Kacuk'; 'Suwaru' vruchten wogen gemiddeld 70 - 75 g.

Omdat Hoofdstuk 6 al veel onderzoek – vermeld in eerdere hoofdstukken – recapituleert, spitst de algemene bespreking in Hoofdstuk 7 zich toe op de lacunes in ons begrip van groei en ontwikkeling van salak, zowel botanisch als teeltkundig.

Botanisch zijn de afwijkingen van een stabiel groeipatroon in volgroeide palmen het meest intrigerend; als ze inderdaad zo groot zijn als in de paar gevallen in dit proefschrift en als een passende verklaring kan worden gevonden, is dat een bijdrage tot het begrip van palmen in het algemeen. Eén zo'n afwijking, de concentratie van de bloei in twee piekperioden, is van groot belang in de teelt; een verklaring – beginnend met het stadium waarin de ontwikkeling van bloeiwijzen stagneert – is hard nodig, met name als die telers zou helpen om de oogst te vervroegen of te spreiden.

Een ander botanisch aspect – ook van groot teeltkundig belang – is opheldering van de beperking van de potentiële productie in opeenvolgende stadia: welk deel van de bloemknoppen vormt bloeiwijzen, hoe variabel is het aantal kolven/bloemen per bloeiwijze, welke beperkingen liggen besloten in bestuiving en bevruchting, en in de concurrentie tussen vruchten? Dit vereist systematisch onderzoek, temeer omdat verschillen tussen rassen en bij uiteenlopende plantdichtheden wellicht een grote rol spelen. De uitkomsten geven de potentiële ruimte aan voor verhoging van de productiviteit van salaktuinen.

Teeltkundig zou bekendheid met de sekse bij het planten een doorbraak betekenen. Het maakt van meet af aan een vast plantverband, inclusief bestuivers, mogelijk; nu wordt de teler na 3 jaar met een onregelmatige beplanting opgescheept, als gevolg van de verwijdering van het gros van de mannelijke planten. De mogelijkheden zijn vegetatieve vermeerdering, zo nodig middels weefselkweek, dan wel koppeling van kenmerken van de jonge zaailing aan de sekse. Permanente schaduwbomen passen minder goed in zo'n nieuwe teeltwijze en de vraag rijst of ze onmisbaar zijn of dat bijvoorbeeld irrigatie een alternatief biedt.

Wat betreft bodem en bemesting geeft deze studie niet veel meer dan de richting waarin verbeteringen moeten worden gezocht. Ook ten aanzien van vergelijking van rassen is deze studie slechts een begin. De voorkeur van telers voor 'Pondoh' lijkt gerechtvaardigd, maar met de vervanging van andere rassen door 'Pondoh' dreigt een beperking van de genetische variatie nog voordat het beschikbare kiemplasma in kaart is gebracht.

RINGKASAN

Studi mengenai tanaman salak, *Salacca zalacca* (Gaertner) Voss dimulai pada akhir tahun 1989. Sebagian besar penelitian telah dilaksanakan di laboratorium dan di Kebun Percobaan Universitas Brawijaya di Jatikerto, Malang serta di kebun-kebun petani salak di Jawa Tengah dan Jawa Timur. Informasi pendukung lainnya diperoleh dari hasil kunjungan lapang ke Sumatera Barat dan Bali. Sebagian besar topik penelitian menggunakan *cv. Pondoh* yang berasal dari kabupaten Sleman (Daerah Istimewa Yogyakarta). Belakangan ini salak tersebut sudah menyebar luas ke beberapa tempat di Indonesia.

Pada bagian pendahuluan dari disertasi ini (Bab 1) diinformasikan bahwa guna memenuhi kebutuhan nutrisi penduduk yang standart selain untuk mendapatkan devisa negara dari eksport, Indonesia membutuhkan buah-buahan dalam jumlah besar. Dalam kondisi seperti ini peningkatan produksi buah-buahan adalah lebih mendesak dibandingkan dengan areal tanam. Agar daya beli masyarakat terhadap buah-buahan meningkat maka harga buah harus murah dan terjangkau. Sejauh ini tanaman salak belum memperoleh perhatian serius dari kalangan ilmuwan dan ini dirasa sangat perlu dalam rangka peningkatan produksi. Lebih lanjut, Bab 1 juga menguraikan pertumbuhan dan perkembangan .tanaman suku Palmae (Palem-paleman) secara ringkas, menguraikan genus *Salacca* dan aspek umum budidaya tanaman salak di negeri ini. Bab 1 diakhiri dengan gambaran ringkas pelaksanaan penelitian serta beberapa kelemahannya (terutama pendeknya waktu penelitian dan keragaman bahan penelitian pada tanaman salak dewasa).

Penelitian mengenai agronomi tanaman disajikan di Bab 2 hingga Bab 5. Pengamatan mengenai botani tanaman yang dikombinasikan dengan informasi yang ada dirangkum menjadi satu guna menggambarkan sebuah pola pertumbuhan dan perkembangan tanaman salak, diutarakan pada Bab 6. Selanjutnya, pembahasan secara umum diuraikan di Bab 7.

Penelitian jangka panjang (sekitar 3½ tahun) diuraikan di Bab 2. Bab ini menguji pertumbuhan beberapa jenis salak sejak biji ditanam hingga tanaman berbuah. Salak 'Bali Hitam' tumbuh kerdil; mungkin biji salak monosius ini sudah lama sehingga pertumbuhannya lemah. Sementara itu 6 varietas salak lainnya rata-rata mempunyai 4 - 7 lembar daun sederhana (simple leaves). Daun yang muncul selanjutnya adalah daun majemuk (compound leaves). Salak 'Pondoh' yang umurnya 3 bulan lebih muda mempunyai 12 daun dalam kurun waktu 13 bulan, sedangkan varietas lainnya pada umur 16 bulan mempunyai daun sekitar 9½ - 11 lembar. Ukuran daun salak 'Pondoh' paling kecil diantara jenis lainnya, namun luas daun per tanaman meningkat lebih cepat dibandingkan dengan varietas lainnya (0.66 m^2 dalam umur 13 bulan). Pada umur 15 bulan tanaman salak mulai menghasilkan anakan (sucker); pada umur 19 bulan, satu tanaman rata-rata mempunyai 2 anak, pada umur 34 bulan beranak 4, varietas 'Suwaru Kuning' kurang begitu banyak anaknya. Petani membuang sebagian anakan ini untuk menurunkan kepadatan tanaman sekaligus agar memudahkan penyerbukan dan perawatan tanaman.

Sejak dari biji tanaman salak mulai berbunga pada umur 28 bulan. Pada umur 34 bulan hampir seluruh varietas sudah berbunga, dan pada umur 42 bulan persentase tanaman berbunga berkisar antara 50 hingga 84% (untuk tanaman salak 'Pondoh' baru 25%). Rasio tanaman salak betina: jantan adalah 1.4; rasio yang lebih ekstrem juga terlihat pada beberapa varietas, namun jumlah ini masih terlalu kecil untuk mencapai rasio 1. Bentuk daun salak yang aneh dan tidak beraturan menyebabkan kurang akuratnya hasil pengukuran luas daun, sehingga perlu membandingkan beberapa

metode pengukuran. Dua metode ukur langsung yaitu fotometer dan sentimeter grid (luas daun ditentukan dengan menghitung jumlah grid yang tertutup oleh daun), dibandingkan dengan perkiraan berdasarkan pengukuran komponen daun seperti diameter tangkai, panjang rakhis, dan jumlah anak daun. Tiga komponen daun ini cukup baik untuk digunakan sebagai peramal pengukuran luas daun, namun metode panjang-lebar anak daun terbesar kurang sepadan. Studi ini tidak menghasilkan metode praktis pengukuran luas daun non-destraktif karena terbatasnya sampel, namun demikian daun salak tua yang selalu dibuang oleh petani dapat digunakan sebagai sampel untuk mengukur luas daun.

Walaupun penyerbukan bunga salak dapat dibantu oleh serangga, namun di Jawa bantuan penyerbukan oleh manusia (hand-pollination) sangat dibutuhkan agar produksinya tinggi. Pekerjaan penyerbukan ini memerlukan biaya sebanyak 30% dari total biaya produksi perawatan tanaman per tahun. Penelitian mengenai penyerbukan buatan disajikan pada Bab 3. Penelitian pertama mengenai jumlah kepala putik yang diserbuki. Bunga betina salak mempunyai 3 kepala putik. Kepala putik tersebut diserbuki semua, diserbuki 2, dan diserbuki 1. Sebagai kontrol tidak dilakukan penyerbukan. Sesudah perlakuan bunga salak ditutup dengan kertas tipis untuk menghindari kemungkinan terjadinya kontaminasi dengan tepungsari lainnya. Hasil penelitian menyimpulkan bahwa penyerbukan buatan masih diperlukan dan sebagian besar indung telur (walaupun tidak semua) adalah fungsional: penyerbukan yang intensif menghasilkan buah sebanyak 75%; 90% dari buah tersebut berisi 3 biji. Perlakuan ini meningkatkan hasil 2 kali lipat daripada yang kepala putiknya dibuang: buah yang dihasilkan rata-rata lebih besar, dan menunjukkan bahwa untuk mencapai produk yang baik kompetisi antar buah dalam tandan harus ditiadakan.

Penelitian penyerbukan buatan yang lain dilaksanakan di 2 lokasi, yaitu Nganjuk dan Kacuk. Bunga betina salak 'Nganjuk' diserbuki dengan bunga jantan salak 'Nganjuk' (selfing), dan disilangkan dengan 4 varietas salak lainnya. Bunga salak 'Kacuk' (terletak dalam kota Malang) juga diserbukkan sendiri dan disilangkan dengan tepungsari dari 5 jenis salak. Hasil penelitian di 2 tempat tersebut mengisyaratkan bahwa jenis tepungsari sangat berpengaruh atas hasil buah salak baik kualitatif (daya simpan, kandungan nutrisi daging buah) maupun kuantitatif (jumlah dan berat buah per tandan serta rasio bahan termakan). Silang balik dari salak 'Nganjuk' dan 'Kacuk' menandakan adanya gejala inkompatibilitas. Hasil penelitian penyerbukan ini memperlihatkan bahwa penyerbukan yang intensif sangat diperlukan disamping jenis tepungsari juga merupakan faktor yang penting dalam budidaya tanaman salak.

Bab 4 dari disertasi ini mengetengahkan perkecambahan biji salak. Penelitian pertama untuk mengetahui perkembangan haustorium ('kentos') dan pertumbuhan embrio, sebagian atau seluruh endosperm dihilangkan. Penelitian selanjutnya adalah penyimpanan biji salak. Biji salak disimpan dalam beberapa metode; di udara terbuka, dalam serbuk kayu dan serbuk arang. Embrio dari biji walaupun tanpa endosperm, terus meningkat beratnya, namun 12 hari berikutnya embrio tersebut mati. Pemotongan separo endosperm dengan arah memanjang menyebabkan turunnya persentase perkecambahan biji dan memperlambat pertumbuhan bibit. Walaupun demikian penurunan ini tampak lebih rendah dibandingkan dengan endosperm yang dipotong melintang. Sebaliknya biji dengan endosperm utuh menunjukkan pertumbuhan haustorium konstan dan akhirnya haustorium tersebut mengisi seluruh ruang bekas endosperm tadi. Pati sebagai kandungan makanan yang tersimpan dalam endosperm tinggal sedikit pada umur 18 minggu sesudah semai, sekitar separuhnya telah diubah menjadi gula/energi, sisanya tersusun kembali dalam haustorium, batang serta akar. Delapan belas minggu sesudah semai berat kering tanaman melebihi berat awal, hal ini menggambarkan fotosintesis telah menghasilkan asimilat melebihi dari kehilangan akibat respirasi tanaman.

Biji salak adalah rekalsitran dan penelitian ini menunjukkan adanya korelasi erat antara kadar air dengan kemampuan perkecambahan biji. Bila disimpan di udara terbuka selama seminggu hanya 60% biji yang berkecambah; sesudah 4 minggu disimpan semua biji tidak mampu berkecambah lagi. Penyimpanan biji dalam serbuk kayu dan terutama serbuk arang dapat mempertahankan viabilitas biji dan pertumbuhan bibit. Namun demikian akibat penyimpanan biji, hingga umur 100 hari sesudah tanam bibit salak menghasilkan daun yang rata-rata kecil ukurannya.

Penelitian pada Bab 5 mengenai kaitan tanaman salak dengan beberapa faktor luar: tanah, nutrisi mineral dan naungan. Pot plastik (polybag) berisi tanah dari 4 daerah sentra produksi salak dan jenis tanah Jatikerto digunakan untuk melihat perbedaan pertumbuhan bibit salak. Tanah Jatikerto selain tinggi kandungan liatnya juga tinggi pula kapasitas lapangnya. Akan tetapi, kandungan bahan organik dan nitrogennya lebih rendah dibandingkan dengan 4 jenis tanah lainnya. Kandungan unsur P-tanah berkisar antara rendah hingga tinggi, K berkisar dari cukup hingga sangat tinggi dan kandungan Ca bervariasi dari cukup hingga sangat tinggi. Tanah yang sangat liat menghambat perkecambahan biji salak; pertumbuhan bibit selanjutnya ditentukan oleh tingkat kesuburan tanah, bibit salak yang ditanam pada tanah Jatikerto yang kurus dan berstruktur berat mengalami hambatan pertumbuhan. Kandungan bahan organik tanah berpengaruh nyata terhadap pertumbuhan bibit salak, karena hal ini berkorelasi dengan kandungan N dan P-tanah dan status nutrisi daun.

Dalam percobaan faktorial kombinasi antara naungan dan urea pada tanaman salak muda umur 4 bulan diperoleh hasil sebagai berikut: naungan terbukti sangat potensial untuk kehidupan tanaman muda; selama musim kering di Jawa Timur tanaman muda memerlukan reduksi sinar matahari sebanyak 50% atau lebih. Pertumbuhan terbaik ditunjukkan oleh tanaman yang mendapat penaungan 50 - 75% dengan pemupukan 10 - 20 g urea per tanaman.

Penelitian pemupukan juga diterapkan pada tanaman salak dewasa. Pohon salak betina, mempunyai 2 tandan buah, umur buah 1 - 2 sejak penyerbukan dipupuk dengan pupuk NPK dengan dosis yang bervariasi mulai 0 hingga 180 kg. Penelitian berlangsung selama 6 bulan, walaupun demikian pupuk NPK masih mampu meningkatkan ukuran daun baru dan tandah buah. Pemberian pupuk NPK juga meningkatkan kualitas buah dan dalam 1 tandan hanya beberapa buah saja yang rusak (pecah kulit dan busuk).

Ketiga penelitian mengenai faktor luar diterapkan pada tanaman salak yang sedang berbuah dengan mengukur variabel daun dan tandan buah. Untuk menilai pengaruh yang menyeluruh dari perlakuan maka penelitian harus direncanakan untuk kurun waktu yang panjang, bila mungkin beberapa tahun. Sekalipun demikian, naungan dibutuhkan oleh tanaman salak muda. Selanjutnya dianjurkan agar pupuk kandang dan pupuk N diberikan pada tanaman muda secara berkala. Penelitian lanjutan yang perlu dilaksanakan adalah peranan air atau kelembaban tanah pada pertumbuhan tanaman.

Suku palem-paleman mempunyai 5 fase pertumbuhan dan perkembangan yang berbeda. Bahasan ini merupakan kerangka pokok dalam menyusun sebuah pola pertumbuhan dan perkembangan tanaman salak, disajikan pada Bab 6. Fase embrionik (embryonic phase), dimulai dari pembentukan zigot hingga masaknya biji tidak diamati, namun dari hasil foto dapat diketahui posisi embrio dalam buah muda dan bentuk serta ukuran embrio pada buah salak yang sudah matang.

Dalam kaitannya dengan fase pertumbuhan bibit (seedling phase) pengamatan lebih ditekankan pada proses perkecambahan. Waktu dan urutan pertumbuhan organ tanaman diamati secara detail demikian juga mobilisasi cadangan makanan dalam endosperm oleh haustorium serta kaitannya dengan cadangan makanan yang ada dalam batang dan akar. Kurun waktu pertumbuhan bibit mempunyai variasi yang cukup besar tergantung pada kondisi pertumbuhan saat itu selain media penyimpanan benih.

Fase kemapanan (establishment phase) meliputi aspek pertumbuhan daun, pembentukan mahkota tanaman (crown) serta pembentukan anakan (sucker). Tahap pertumbuhan daun, mulai saat munculnya, pembentukan stadia daun pedang (spear) sampai mekar dan masak diuraikan dibeberapa penelitian. Kurun waktunya sangat bervariasi dari satu daun ke daun berikutnya. Tanaman salak muda mempunyai bentuk daun sederhana (simple leaf), selanjutnya daun yang tumbuh adalah daun majemuk, yaitu mempunyai beberapa anak daun (leaflets) di kedua sisi rakhisnya. Jumlah anak-anak daun terus bertambah sampai berakhirnya fase kemapanan ini. Ukuran anak-anak daun bervariasi, selain daripada itu duduk daun pada rakhis tampak berbeda dari pola umum posisi daun yang sudah ada. Filokron tidak konstan sebagaimana yang umum dijumpai pada suku palem-paleman; filokron pada salak 'Pondoh' lebih cepat dibandingkan dengan varietas yang lain. Tanaman yang sehat mempunyai daun baru dengan ukuran yang lebih besar daripa daun pendahulunya, selain itu daun tersebut muncul sebelum daun terdahulu masak.

Filotaksis salak adalah 2/5, sudut divergensi antara dua daun berurutan sebesar 144°. Tunas lateral ditemukan lurus dengan poros daun, 1 tunas ada di poros (tunas bunga) dan 1 lainnya di bawah tempat duduk pelepah daun (tunas anakan). Mahkota tanaman salak 'Pondoh' yang berumur 3½ tahun mempunyai daun luar sebanyak 10 - 13; 5 - 6 helai daun masih terbungkus dalam tunas, tinggi calon daun terkecil 2 mm; pengamatan irisan pucuk secara mikroskopis selanjutnya akan dapat membuktikan apakah jumlah daun dalam kuncup akan sebanding dengan jumlah daun luar, sebagaimana yang ditemukan pada suku palem-paleman lainnya.

Anakan salak berasal dari batang pendek horizontal yang bersumbu pada tanaman induk. Petani biasanya hanya meninggalkan 2 anak per batang, namun pada kebun salak 'Pondoh' yang kurang rawat ditemukan beberapa anakan, tergolong pola anakan orde-2.

Pada fase masak vegetatif (mature vegetative phase) mahkota tanaman telah mencapai ukuran tertentu dan pada beberapa spesies peningkatan diameter batang merupakan tanda perubahan nyata dari fase pertumbuhan vegetatif. Batang tanaman salak terus bertambah tinggi sehingga tidak stabil dan akhirnya roboh. Proses penegakan kembali ujung tanaman dari rebah dapat diketahui dengan mengukur panjang ruas batang bagian atas dan bagian bawah. Dengan cara ini tanaman salak *berjalan* satu langkah selama 10 tahun atau lebih dan dengan cara tersebut tanaman salak telah melakukan proses peremajaan secara alamiah.

Pengukuran pertumbuhan daun tanaman salak yang berumur 20 tahun menunjukkan perbedaan panjang daun yang cukup besar (2.25 - 4 m) serta kurun waktu kemunculan daun berikutnya (30 - 52 hari). Pada saat penelitian berlangsung petani memotong daun-daun tua dan tibanya musim kemarau, sekalipun demikian faktanya pada tanaman salak dewasapun ukuran daun dan filokron tidak dapat dijadikan jaminan pengukuran.

Pada kebun salak komersial beberapa anakan juga terbentuk pada saat fase pertumbuhan vegetatif, hal ini kemungkinan karena populasi yang padat menyebabkan berkurangnya sinar matahari yang masuk ke dalam kebun/tanaman.

Awal fase reproduktif (reproductive phase) ditandai dengan munculnya bunga untuk pertama kalinya. Bunganya berbentuk pedang (mancung), tumbuh menerobos bagian dasar daun untuk keluar keudara terbuka. Karena pelepah daun melekat erat pada batang, celah pada dasar daun tua memperlihatkan ada atau tidak adanya kaitan dengan produksi mancung. Mancung tidak selalu terbentuk dengan mengikuti pola pembentukan daun, sekalipun daun, bunga dan anakan tumbuh pada titik yang sama. Belum ada penjelasan lengkap yang dapat diberikan mengenai pembungaan musiman, yang menghasilkan panen raya dan panen susulan setiap tahun.

Penyerbukan yang intensif akan menghasilkan banyak buah dan biji, hal ini menunjukkan bahwa penyerbukan yang kurang sempurna, intensitas dan saat serbuk serta kompatibilitas dapat merupakan faktor pembatas produksi tanaman. Catatan dari hasil panen dalam penelitian salak 'Kacuk' mempunyai jumlah buah per tandan antara 6 - 9; salak 'Nganjuk' 6 - 24 dan salak 'Suwaru' 11 - 24 buah. Berat buah salak rata-rata bervariasi antara 28 g untuk persilangan 'Nganjuk' x 'Nganjuk' hingga 100 g untuk 'Kacuk' x 'Kacuk'; sedangkan salak 'Suwaru' antara 70 - 75 g.

Karena Bab 6 merupakan rekapitulasi data dari Bab-Bab terdahulu, pembahasan umum pada Bab 7 ditekankan pada perbedaan pokok dari pemahaman tentang salak baik dari pandangan botani maupun agronominya.

Secara botanis deviasi pola pertumbuhan yang teratur dari suku palem-paleman sangat menarik untuk diketahui; apabila pola tersebut sama seperti yang diuraikan dalam thesis ini secara memadai, hal ini akan meningkatkan pemahaman pertumbuhan tanaman palem pada umumnya.

Salah satu deviasi sebagai contoh adalah puncak pembungaan musiman, juga sangat penting dalam bidang agronomi; informasi penting – diawali dari identifikasi pada tahap dimana pembungaan mengalami stagnasi – sangat diperlukan Lebih daripada itu hal ini akan memberikan petunjuk bagi petani untuk memperpanjang atau merubah/mengatur masa panen.

Isu lainnya dari aspek botani – yang juga penting dibidang agronomi – adalah klarifikasi sejauh mana perbedaan antar komponen membatasi potensi hasil: apakah semua mancung menghasilkan bunga, berapa variasi jumlah dompol dan jumlah bunga per mancung, dompolan yang mana dari bunga berkembang menjadi buah dan apakah kompetisi antar buah akan mempengaruhi ukurannya. Apakah kontribusi masing-masing komponen tersebut terhadap produksi berbeda nyata:

- untuk varietas yang berbeda ?
- bila tanaman salak tunggal dibandingkan dengan tanaman lain yang tumbuh dalam kebun komersial dengan populasi padat?

Jawaban atas pertanyaan tersebut harus mengarah pada aspek peningkatan produtifitas perkebunan salak. Studi ini terutama diarahkan pada penyerbukan sebagai faktor yang sering membatasi produksi.

Dari segi agronomi adalah merupakan suatu bonus yang berharga apabila jenis kelamin bibit (betina atau jantan) sudah diketahui pada saat tanam. Dengan demikian pertanaman salak yang tidak teratur karena salak jantan dibuang setelah 3 tahun kemudian dapat dihindari. Lebih jauh sebidang kebun dapat ditanami dengan jarak tanam optimal dengan rasio jenis kelamin tanaman tertentu sejak awal. Kemungkinan untuk menentukan jenis kelamin yang tepat adalah dengan perbanyakan secara vegetatif, bila perlu dengan teknik kultur jaringan, atau memperkenalkan tanda-tanda genetik yang mengisyaratkan jenis kelamin bibit. Pohon penaung permanen tidak sesuai dengan hasil penelitian ini; dengan demikian pohon penaung perlu dievaluasi lagi dan alternatif lainnya (misalnya pengairan) seharusnya dipertimbangkan.

Evaluasi terhadap varietas salak baru dimulai. Petani memang lebih menyukai salak 'Pondoh', sekalipun demikian mengganti varietas lainnya akan mengurangi satu kelompok genetik apalagi penilaian atas plasma nutfah yang tersedia belum dilaksanakan.

PLATES

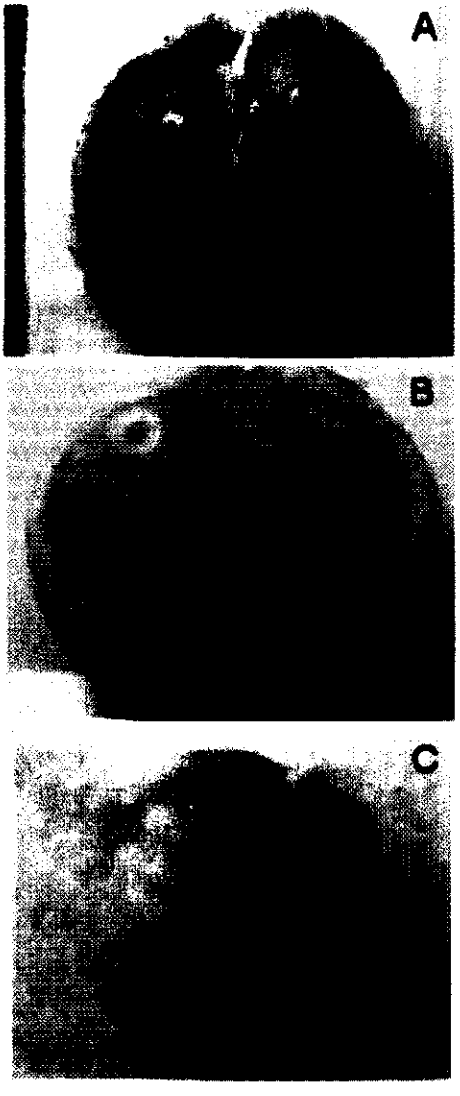

Plate 1. Seed forms of salak

A. Trigonous seeds in triple-seeded fruits
B. Flattened seeds and one rudimentary seed
C. A globular-seeded fruit with two rudimentary seeds in single-seeded fruit, 20 weeks after pollination

Plate 2. 'Pondoh' fruit with three seeds, 2 months after pollination, showing the position of the embryos
a: embryo, b: seed, c: seed coat

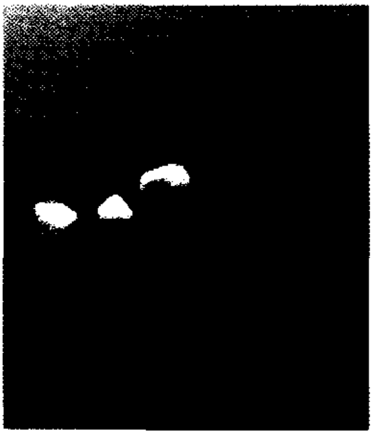

Plate 3. Mature embryos of 'Pondoh'

Plate 4. Germinated seed of 'Pondoh'
a: cotyledonary sheath; b: ligule; c: primary root; d: adventitious roots;
e: haustorium; f: seed kernel

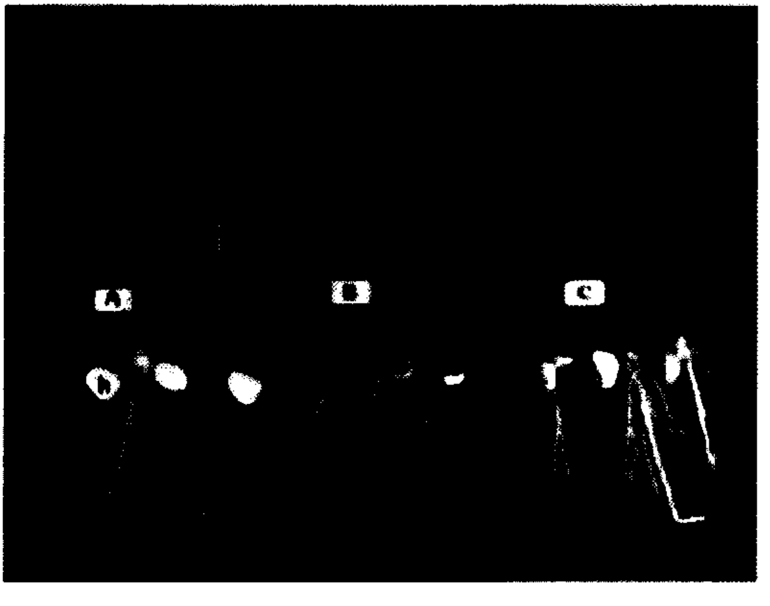

Plate 5. Seedlings 77 days after sowing with intact or halved endosperm
A. intact endosperm
B. endosperm halved longitudinally
C. endosperm halved transversely
h. haustorium

Plate 6. The leaf arrangement of 'Pondoh'

Plate 7. Pondoh plant with suckers, 30 months after sowing

Some leaf bases and spines have been removed; suckering follows pattern A in Figure 6.3

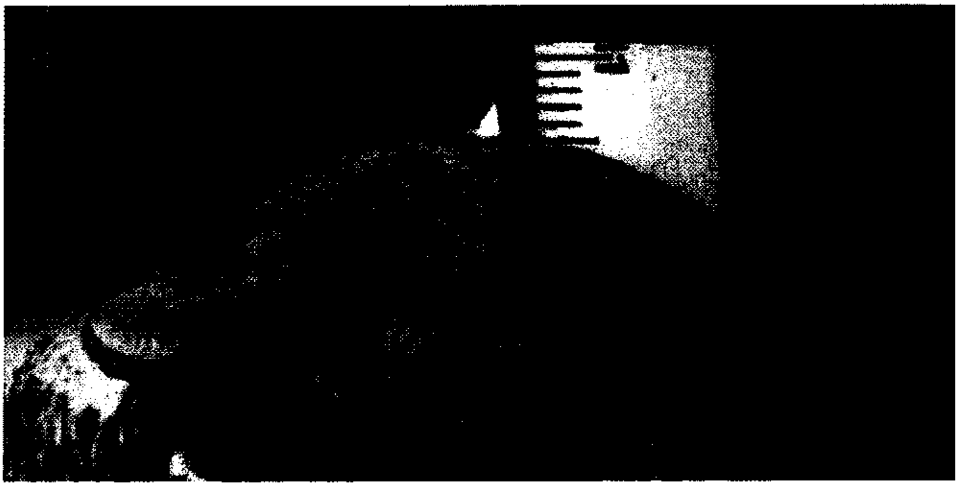

Plate 8. The apex after careful removal of leaves and leaf initials, down to a 2 mm height

Plate 9. Bud positions on a 'Pondoh' stem
A: leaf base, B: vegetative bud on a flange, C: inflorescence bud

Plate 10. The trunk of 'Bali', lying on the ground
a: trunk, b: crown base

Plate 11. The re-erection growth of the salak palm

Plate 12. Inflorescences
A: female inflorescence consisting of 3 spadices,
B: male inflorescence consisting of 8 spadices

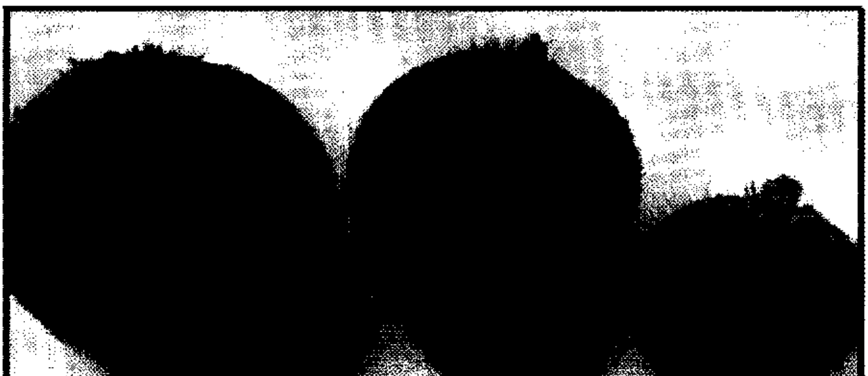

Plate 13. Size and shape of fruit, 20 weeks after pollination
Pollinated stigmata A: three, B: two, C: one

CURRICULUM VITAE

Sumeru Ashari, the youngest son of the late Mochammad Ashari, was born in Malang, Indonesia on 28th March 1953. He graduated from Sekolah Dasar Tjepokomuljo in 1966 and from Sekolah Menengah Pertama Muhammadiyah in 1969. Sekolah Menengah Atas Negeri III Malang was his Senior High School. He left secondary school in 1972. In 1973 he joined the Faculty of Agriculture, Brawijaya University which is also located in Malang. He graduated from the faculty in 1979. During the years 1986 - 1989 he took an M.Sc. programme at the Waite Agricultural Research Institute of Adelaide University, South Australia.

During 1982 - 1985 he served as a manager of the Bank Indonesia Nurseries in Pasuruan. He also took part in the NUFFIC's fruit tree progamme. In 1990 - 1994 he was the Head of the Research Station at Jatikerto of the Brawijaya University. He organized the Study Programme on Horticulture from 1997 - 1999. Now, he is the Head of the Agronomy Department, Faculty of Agriculture, Brawijaya University.

He is a lecturer in Tropical Fruit Trees, Flowering Biology and Nursery Management. His research interests include propagation, cultivation, and flower development of tropical fruit trees (mango, jackfruit, salak, etc.).

He and his wife, Endah Sri Handayani, have three children, the oldest son: Dadang Meru Utomo; Astri Warih Anjarwi their daughter and Yordan Wicaksono Ashari the youngest son.