SUNGKAI (*Peronema canescens*) A PROMISING PIONEER TREE :

an experimental provenance study in Indonesia

by

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PROPOSITIONS

STELLINGEN behorende bij het proefschrift :
Sungkai (*Peronema canescens*) a promising pioneer tree :
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by Gusti M. Hatta, defended on October 26, 1999

1. The "neighbouring provenance approach" is promising for an optimal forest development in the Sungkai plantation forestry. (This thesis).

2. The use of either native provenances or the closest neighbouring provenances of Sungkai will increase the profit of the plantation enterprise, due to their high growth potential and low transportation risks of cuttings from the mother tree to the nursery. (This thesis).

3. Healthy ecosystems tend to favour a tree architecture capable of providing timber according to specifications. (This thesis).

4. Sungkai is superior in overcoming unpredictable impacts ("stresses"). (This thesis).

5. In designing a silvicultural system for Sungkai, four factors should be taken into account, i.e., the health of the plantation including the ecological profile of the tree, the end use of the wood, the secondary management aims and the cost of silvicultural measures. (This thesis).

6. Involvement of local inhabitants in plantation programmes provides greater security for both the plantations and the local inhabitants.

7. Visits by cattle to trial plots prove that such eventualities must be taken into account in plantation programmes and management plans.

8. Giving priority to indigeneous species for afforestation is making a first step towards sound forest plantations.

9. Plantation forestry is an indicator of political stability.

10. We cannot negotiate with nature about ecological limits.

11. Indonesian students in the Netherlands can build a bridge between the two cultures

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To my wife Violet

my children Gusti Noor Hidayat

and Gusti Noor Ramadani Saputra

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FOREWORD

The research presented in this book was inspired by the field findings during visits to and observations in the industrial forest plantations (IFP) of several private companies in South Kalimantan and Central Kalimantan Provinces, Indonesia. Sungkai cuttings today are collected wherever available, without the companies sufficiently aiming at high-quality stockplants. No effort have been made yet to increase the quality of cuttings by collecting them from different geographical origins. No provenance tests have been conducted so far. In fact, Sungkai can be found in many sites in Sumatera and Kalimantan. Another pressing reason for the present study was that most Sungkai timber is still being harvested in a largely non-sustainable way. Very little is known about the extent of genetic variations in wild populations, and few attempts, if any, have been made at genetic improvement.

Fortunately, the desire to know more about Sungkai coincided with the availability of a scholarship from the Six Universities Development and Rehabilitation (SUDR-ADB) project from the Ministry of Education and Culture of the Government of Indonesia. It was a very good opportunity or to conduct such research. The scholarship was for three years, but Nuffic provided a grant for the fourth year.

The results presented in this book are based on data and planting materials (cuttings) collected in the field in ten provinces in Indonesia which project started in May 1996, on nursery experiments (about five months), and on trial plot experiments (about twenty six months). The research proposal was prepared in The Netherlands from November 1995 to April 1996 under the supervision of Prof. Dr.Ir. R.A.A Oldeman. During my research in Indonesia, I consulted with my other promotor, Prof.Dr.Ir. Oemi Haniin Soeseno, from Gadjah Mada University, Yogyakarta, as well as with Prof. Oldeman. Luckily, Prof. Oldeman was able to visit Banjarbaru, South Kalimantan twice, so I was able to discuss my research and its constraints.

Perhaps, Nature wanted to teach me too. There were at least three disturbances of my trial plots, caused by cattle, drought and fire. The first disturbance occurred when my plantations were three months old, and this could be overcome with the help of the owners. In 1997, a drought occurred in Indonesia. During this period, extensive fires raged in Kalimantan and Sumatera. Their smoke disturbed even the whole of South East Asia over quite a long period. Although I had taken measures to protect my plantations against fire by employing field hands supplied by the BTR (Reforestation Technology Agency), Banjarbaru, inevitably the fire finally hit also the Sungkai trial plots and burned some trees and damaged others.

Indeed, this was a very useful real life experience which has to be taken into account in developing scientific models for the design of forest plantations or other forestry activities.

Wageningen, July 1999

CONTENTS

Chapter 1. INTRODUCTION

1.1. Increasing timber demand

The demand for wood in Indonesia tends to increase year by year, because of the population growth and the risen demand for wood from the forest industries which want to augment the export of wooden industrial products. It is clear that a continuous supply of timber is of paramount importance, with a growing local demand and the considerable share of forest industries in the overall economy, as seen against the rapid regression of the natural rain forests.

Since 1980 the forestry industries have progressed at a brisk pace in Indonesia. Within ten years a substantial number of sawmills and plywood mills were set up, as well as related industries (such as block board, particle board, pulp and rayon) were established. These forest industries have been utilising wood from the pristine tropical rain forests at a rate of 20 million m^3 per year (Prawirohatmodjo, 1994).

The Minister of Forestry of Indonesia in his opening speech at the national meeting of The Ministry of Forestry in April 1995, said that in the year 2000, Indonesia will need 70 million m^3 of wood, an annual demand which will have increased twofold by the year 2030. His data were provided by the FAO. Meanwhile, the Head of the Indonesian Timber Business People Association (ITBPA) held a slightly different view. He suggested that the total estimate of log demand in 1998 would be about 25 million m^3 and the supply of logs, both from natural forests and planted forests in the same period, was estimated to be about 31 million m^3 (Anon. 1995). It is clear that, notwithstanding the differences in "real" volume forecast, the wood demand in Indonesia is on the increase.

According to the Indonesian Timber Business People Association (1992, *in* Smits, et al.1994), forest industries are of major importance to the Indonesian economy. In 1991 about 2.5 million people depended directly on the forestry sector for their income, and 1.2 million indirectly. Moreover, the total number of people deriving their livelihood from the Indonesian forests exceeds 14 million, if the employment figures would include family members. Forest industries should, therefore, be provided with a continued supply of timber in order to support the Indonesian employment and the Indonesian economy in general. Timber supply can not be sustainable if it depends on natural forests; it should be increasingly supported and replaced by planted forests, such as industrial forest plantations (IFP).

In response to the increasing wood demand, steps have been taken by the Ministry of Forestry to develop industrial forest plantations with a target area of 4.4 million hectares in the next 10 to 20 years (Prawirohatmodjo, 1994). These activities will have several positive effects, such as providing wood for forest industries, decreasing dependence on wood supply from natural forests, and increasing tree resources in deforested areas, so as to meet the traditional needs of both local people and the urban population.

The production capacity of natural forests tends to decrease over time due to various disturbances and irresponsible utilization. Meanwhile, the forest product industry, especially the wood processing industry, has been growing very fast since the export ban on logs (roundwood) in 1984. To close the gap between the need for raw material and the capacity of natural forests to supply logs is a real challenge. Establishing forest plantations is one among several attempts to meet this challange.

Industrial plantations can not substitute the value and kind of the depleted old-growth forests, nor can they remove their sensitivity to environmental influences. However, they can relieve some of the pressures on these resources, and offer a realistic potential for a significant share of the world's fibre needs from a relatively small area. The sensitivity of industrial plantations may be reduced by implementing sound plantation and management practices (Bazzet, 1993).

1.2. Industrial Forest Plantations (IFP, Indon.HTI) for timber supply

The establishment of plantation forests is intended to reduce pressure on the natural forests, thereby contributing to national land conservation objectives, as well as supplying industrial raw material. The aim is also to regreen the denuded or unproductive forest lands. High yields and superior local tree species are prioritized. They can meet higher timber demand while at the same time maintaining or reducing the areas of harvested natural forest. The industrial forest plantation programme has provided job opportunities especially for local villages, and hence has reduced their economic reliance and their disturbing the natural forest (Anon, 1997).

The establishment of forest plantations (known as Hutan Tanaman Industri, or HTI) is implemented in permanent production forest areas, either inside or outside forest concession areas, and is meant to be implemented on unproductive forest areas. The Indonesian Government Regulation No. 7/1990 clearly states that the establishment of industrial plantation forests should be carried out on non-productive areas classed as "production forest" areas.

By establishing IFP, the Government of Indonesia appeals to the private sector, joint ventures and cooperatives on the village level, in addition to state-owned forestry companies.

From 1990 to1996, Indonesia was able to establish about 1.7 million, hectares new IFP, located mainly outside Java. Meanwhile, 2 million hectares of forest plantations were established by Perum Perhutani (State-owned Forest Company) in Java. So overall, Indonesia has established almost 4 million hectares of plantation forests, as well as forest plantations by smallholder farmer households (Anon, 1997).

In spite of the above success, however, constraints emerge during the implementation of as IFP establishment. The distribution of non-productive forest areas (in which the IFP are established), which are scattered throughout the production forest areas is not always clearly known. The occurrence of conflicting land use claims on the basis of existing customary rights is a major problem.

A weak coordination between the relevant central and regional-level institutions complicates the ventures. The funding to acquire the necessary inputs for planning, especially aerial photography, landsat images, GIS and GPS is inadequate. The private sector lacks capacity in mastering seed production technology; not all the vegetative propagation nurseries or seed sources are managed professionally by the private sector (Anon, 1997).

The above constraints have to be overcome if the IFP programme is to be successful. The success of forest plantations has to meet two objectives, namely a contribution to national land conservation and a supply industrial raw materials.

1.3. Industrial Forest Plantations and local people

Local people should play an integral part in a forestry plantation programme. They should be involved not only as daily workers in planting activities, but also in other phases in IFP programmes. Local and traditional knowledge may be useful inputs in identification, design, management and monitoring of forest plantations. Local inhabitants are masters in the environmental knowledge of their region. A lack of sense of belonging to a IFP programme may be caused by a lack of involvement in the programme. This may produce conflicting land use claims due to limited information.

A very simple, interesting example is shown in the Riam Kiwa trial areas, in South Kalimantan. The Reforestation Technology Agency, Banjarbaru which is in charge of the areas, gives local people the opportunity to collect seeds from its forest plantations. The seeds are sold to the IFP companies, which usually come to the areas. As the trees make additional income, the local people tend to care for the trees in order to maintain this additional income. Indeed, the sense of belonging has increased to some extent.

The Government of Indonesia (GOI) attempted to accommodate the needs of local inhabitants by regulation No. 7/1995, decreted by the Ministry of Forestry (MOF). This regulation stipulates that a unit of IFP has to consist of 70% of the area for desired trees, 10% of the area for native commercial trees, 5% of the area for non-timber forest products (NTFP), 10% of the area for conservation, and 5% of the area for infrastructures. The NTFP aims to provide local people, who live close to the IFP units with their daily needs. And conservation areas are designated as such in order to protect and conserve natural resources for future generations.

The existence of NTFP will be more useful if the needs of local people will be met. Hence, the local people should be involved in planning the desired NTFP. Local people will respect the IFP programme if they benefit from it, e.g. in terms of job opportunity and additional income. Negative responses are generally related to cases in which the IFP programme restricts the land use by local people. Hence, socio-economic studies are needed before the implementation of IFP. And the local people should be involved, if possible, in all phases (identification, design, management and monitoring).

1.4. Sungkai as one species in the IFP programme

The development programme of the IFP in Indonesia became operational as from the first year of The Five Years Plan IV (Repelita IV, 1984-1989). The Ministry of Forestry made the general pattern of an IFP unit into a guideline for its planning and implementation. The Ministry of Forestry recommended twenty species to be used in the IFP (Anon, 1987).

Not all of those species are either fast growing or light-demanding, e.g. *Gonystylus bancanus, Dryobalanops spp, Shorea spp, Dipterocarpus spp*. These tolerant trees may be considered for certain types of forest plantation or specific purposes. In relation to reafforestation of open lands or deforested areas such as *Imperata cylindrica* grassland and shrublands (Mutsaers, 1998), light-demanding, fast-growing species are appropriate for the purpose; one of these species is Sungkai (*Peronema canescens*), Verbenaceae. To compensate for its growing slightly slower than other fast-growing species, Sungkai offers some benefits. It can be regenerated by vegetative propagation, so it does not depend on flowering and fruiting seasons. Yet, according to Palmer (1994) Verbenaceous trees are tenacious survivors, even when grown far from their ecological optimum, although then stem form may be crooked and growth may be poor.

In the IFP development, especially in Kalimantan, *P. canescens* locally called Sungkai or lurus (meaning "straight"), is one among various species planted in the IFP areas. However, no efforts have been made yet to improve the quality of Sungkai planting stock. Usually, Sungkai is regenerated by cuttings rather than by seeds, because it is easily done and does not depend on the fruiting season. Generally, the availability of Sungkai cuttings in a certain site is considered more important than the quality of specific trees as a source of cuttings. As mentioned above, not all the vegetative propagation nurseries or seed sources are managed professionally by the private sector. In relation to critical factors determining adventitious root development in vegetative propagation, even in species in which these factors are not currently limiting, Leaky et al. (*in* Leakey and Newton, 1994) suggest that these processes may be influenced by several factors including the growing environment of the stock plants.

On the one hand, environmental factors codetermine the quality of produced seedlings. These factors either do or do not allow trees to express their genetic potential in the form of a useful phenotype.

On the other hand, genetic variation occurs among geographical provenances of a species, so the quality of cuttings also differs per provenance. A "provenance" is the geographical position in which a stand or a tree is growing; by extension foresters call "provenance" a tree or tree population from a certain place that should be well-defined. The stand representing a provenance may include other indigenous or non-indigenous trees. Therefore, a provenance trial of *Peronema canescens* must be conducted as a prelude to the production of genetically improved cuttings for optimization of the yield and/or other properties of planted stands.

1.5. Little known genetic variation of Sungkai in wild population

As mentioned, Sungkai (*Peronema canescens*) is among the species recommended for IFP by the Ministry of Forestry of Indonesia. Despite this fact, very little is known about the extent of genetic variation in wild populations, and few attempts, if any, have been made at genetic improvement. In fact, *P. canescens* can be found in many sites in Kalimantan and Sumatera. Meanwhile, the commercial wood of *P. canescens* continues to be extracted from natural forests.

In most places in the South Kalimantan Province, the demand for *P. canescens* timber is increasing, whereas the trees of natural forests are being depleted as a result of overexploitation. The same is going to happen in other provinces in both Kalimantan and Sumatera, since the wood is a "fancy wood", easy to work by machine or hand tools, and easy to match to other pieces of the same timber species.

Timber obtained from *P. canescens* is principally used for furniture. Especially in the South Kalimantan Province, people cut small trees (diameter < 10 cm) for bracing the house roof. As only few successful examples exist of cultivation in plantations, most timber is continually harvested in a largely non-sustainable way. Domestication of *P. canescens* and other pioneers is crucial for the development of a sustainable, high-quality timber resource.

As stated above, in the current practices of IFP, *P. canescens* cuttings are collected wherever available, rather than the companies seeking high-quality stockplants. Of course, in some sites the growth of *P. canescens* trees is not too good (personal observation). However, no effort has been made to increase the quality of cuttings by collecting them from different geographical origins ("provenance test").

Suseno et al. (1990) described provenance trials in Indonesia, carried out with some species, namely, *Tectona grandis, Gmelina arborea, Acacia mangium, Calliandra calothyrsus*. No active tree improvement activities with *Peronema canescens* were mentioned at all.

The problem is urgent. The available gene pool of *P. canescens* is being reduced, since timber is unsustainably felled in natural forests. So, natural populations are shrinking. However, hard information is scant.

Hatta (1992) carried out a first field trial of *P. canescens* provenances from various sites in the South Kalimantan Province. Indeed, growth differences occurred among the provenances, the one from Kabupaten Hulu Sungai Tengah showing the highest wood increments. Although these data concern one province only, Hatta suggests that more genetic diversity may be expected over the broad ecological and geographical range of *P. canescens* in Kalimantan and Sumatera.
Clearly, provenance research on *P. canescens* is a way to its genetic improvement and can thus provide silviculturally optimized *P. canescens* populations in the field. Wood industries want industrial forest plantations to produce long, straight stems, suitable for end-uses such as plywood and sawn timber. Tree conformity to these specifications depends particularly on tree architecture and trunk formation (Oldeman and Binnekamp.1994).

Tree architecture codetermines not only the economics of use, but also the "ecological profile" of the species. The "ecological profile" of an organism is the strategic pattern of its behaviour as a response to environmental dynamics in order to meet its ecological requirements. It is very important to know this profile, in order to produce timber according to the specifications. Through an ecological profile, the requirements of a certain species as to its environment are recognized, e.g. as expressed by an architectural strategy in response to stress.

Oldeman and Binnekamp (1994) stated that the architectural strategy differs between tree groups. Well-defined, widespread, successful survival strategies are found in Conifers, Leguminosae, Fagaceae, Dipterocarpaceae, and Myrtaceae. However, there is a 'miscellaneous' group uniting tree species, genera or small families with their own more specific success stories, like Meliaceae, Vochysiaceae, Moraceae and others.

Verbenaceae, the family to which *P. canescens* belongs, is to be included in the large,'miscellaneous' group. This group was called a "diffuse" group by Oldeman and Binnekamp (1994) because there is no taxonomic relationship among its members. Member species often owe their ecological success to parallelling some feature or other of one of the above major groups. However, this group also seems to contain some original, rather than common strategies, which enable the success of other member tree species as tropical rainforest trees.

Oldeman (1979) claimed that domestication and wood production should be examined in terms of architectural strategies (see also Oldeman and Binnekamp, 1994). Trees can either adjust or adapt (Hallé & al 1978). Adjustment is the change in growth and architecture of individual trees in response to environmental stimuli. Adaptation is the result of inherited change of behaviour and architectural strategy in a tree population in response to natural selection of surviving and reproducing members.

The architectural strategy of *P. canescens,* particularly its plasticity or flexibility, is basic information for the optimization of the species for wood production. Such knowledge helps to predict to what extent the tree is able to adjust (Vester,1997). So, directives for a successful reafforestation with *P. canescens* can be formulated.

As stated earlier, very little is known about *P. canescens* as a living organism, not even its architectural strategy. So, this aspect was reconnoitered in the present investigation.

1.6. Optimal contribution from Sungkai plantation to Indonesian land use

The wood of Sungkai is mostly used locally, especially for furniture; recently it has also been used for cabinet making, moulding, veneer, plywood and handycraft. The increasing demand for various products of Sungkai wood causes an increasing demand for the wood itself.

In most places in the South Kalimantan Province, the demand for *P. canescens* timber is indeed increasing, whereas the Sungkai of the natural forests are being depleted as a result of overexploitation. The same is going to happen in other provinces in both Kalimantan and Sumatera, since the wood is a "fancy wood".

Another indication of a growing demand for Sungkai was the case of a certain company from Jakarta, which came to the Riau Province in Sumatera (Fig.2.1) to obtain a constant volume of Sungkai wood to supply its mill. However, the company could not obtain it.

Sungkai wood is used from very simple purposes, e.g. roof trusses, to more specific ones, e.g. moulding, veneer, plywood, for local use and export, e.g. the export to Japan is becoming important. Certainly, this produces income for local people (villagers), government, and services for urban people in the form of various products of Sungkai wood.

The rapidly increasing demand for Sungkai wood made the government pay attention to the wood. The Riau provincial government proclaimed or announced, with ceremony, that it was asked to plant one million Sungkai in 1993. Thus the Riau Province became famous for its "one million Sungkai movement". Finally, the Ministry of Forestry recommended Sungkai as one among other species to be used in the IFP.

Since then Sungkai trees have been planted in many places in Kalimantan and Sumatera, especially by the IFP companies. And in several places Sungkai trees were also planted by local communities. Anon (1996) gave figures on Sungkai plantations by local people in the Riau province. For instance, there are three local community-owned Sungkai plantations in Kabupaten Bengkalis with areas ranging from 25 to 150 hectares; two community-owned Sungkai plantations in Kabupaten Indragiri Hilir with areas ranging from 1.5 to 50 hectares; twelve community-owned Sungkai plantations in Kabupaten Kampar with areas ranging from 3 to 180 hectares; and twenty-eight community-owned Sungkai plantations in Kabupaten Indragiri Hulu with areas ranging from 5 to 300 hectares. In total the areas of local community-owned Sungkai plantation cover 2579 hectares. In the South Kalimantan province, Sungkai trees are often used on local farms mixed with rubber trees or live fences. Sungkai was already commonly used for live fences by local people in the villages, before it was recommended as a species to be used in the IFP.

The IFP developments certainly need land. Although the IFP is carried out in "non-productive forest areas", its implementation may cause conflicts about land use rights between the investor and local communities. Especially in Kalimantan and Sumatera, where shifting cultivation is common practice, the existence of IFP may be considered to restrict the use of land by local people (cf.Padoch & Peluso 1996). Meanwhile, the companies need not only the land but also the legal possession of the areas. Land encroachment may threaten planned management and sustainable utilization.

Hence, socio-economic aspects are studied carefully before the implementation of IFP development. These large plantations have to fit in among farms and villages, and have to fit in socially as wel. Especially for the local people concerned an inventory of the existing land use has to be made, including the mensuration and demarcation of boundaries.

This social-economic study will benefit all parties or at least, reduce the chance of conflicts. For instance, the information can be used by the IFP company to determine the strategic position of the area for an NTFP (cf.Rukmantara 1998). This area is usually used as a buffer zone between the IFP areas and the community lands. Involving the local community in determining the area for NTFP and its kind of plantations is necessary in order to increase the use of the NTFP area and again, reduce the chance of conflicts.

This socio-economic study also provides basic information, as to specific problems and constraints in the area. For example, shifting cultivation may cause wildfires, or traditional cattle grazing, in which grasses are burned to provide young grasses for cattle. Cattle may also disturb young plantations. This should be anticipated and eliminated in attempts to secure both the plantations and the local inhabitants. It seems necessary to design plantations with the participation of local people.

Our own research results are expected to pinpoint the best provenance of Sungkai, a first assessment of the tree architecture of Sungkai, and specifications for highly productive and low-risk plantations. The tree architecture of Sungkai is described in Chapter 2, the best provenance of Sungkai is evaluated in Chapter 4, and attempts to design elements of highly productive and low-risk of Sungkai plantations are discussed and evaluated in Chapter 4 and Chapter 5. The methods of the research are described per chapter and evaluated in Chapter 5 (Discussions and Conclusion).

The result of this study will be useful especially for companies which establish industrial forest plantations which, in order to meet the requirements, must use good quality Sungkai cuttings. This, in turn, will result in Sungkai timber of good quality and quantity, and a successful reafforestation with Sungkai also for other purposes. For the Government, a successful reafforestation means a reduction of deforested land, an increase in wood supply, job opportunities, and higher incomes.

Chapter 2. PROVENANCES AND THEIR SITES

2.1. Introduction

Knowledge of their home sites is the best guide to know the environmental requirements of the provenances, including the original vegetation of Sungkai in each site. Site characteristics and original vegetation of each provenance will be described in Section 2.3.1 and Section 2.3.2.

The analysis of natural vegetation provides information which can be profitably applied to forest plantation management (Oldeman, 1990). This means that ecologically sound management principles are necessary to keep plantations healthy. They should be based on the fact that nature is very complex. Besides, the differences in behaviour among provenances when planted in trial plots may be explained wholly or in part by information on the original vegetation ecosystem of each Sungkai genotype.

Looking for Sungkai in its original vegetation is not easy because of the increasing demand for the wood which is met by destroying the natural population. The wood of Sungkai is mostly used locally, especially for furniture; presently, it is also used for moulding, veneer, plywood and handycraft. Export, e.g. to Japan, is also becoming important. Another indication of the growing demand for Sungkai was the case of a certain company from Jakarta, which came to the Riau Province in Sumatera (Fig.2.1) to obtain a constant volume of Sungkai wood to supply its mill. However, the company could not obtain it. The Riau Province is famous for its "one million Sungkai movement. Variants on this situation make it difficult to find the original vegetation of Sungkai in all ten provinces where it grows.

2.2. Material and Method

Ten provenances of Sungkai were studied throughout its known natural range. Burley and Wood *in* Matziris (1991) recommended that at least five or six provenances be tested to represent the geographic distribution of the species.
The location of ten provenances is shown in Fig.2.1. and the locality of each provenance is described in detail in Section 2.3.1. The original vegetation of each provenance is presented in Section 2.3.2.

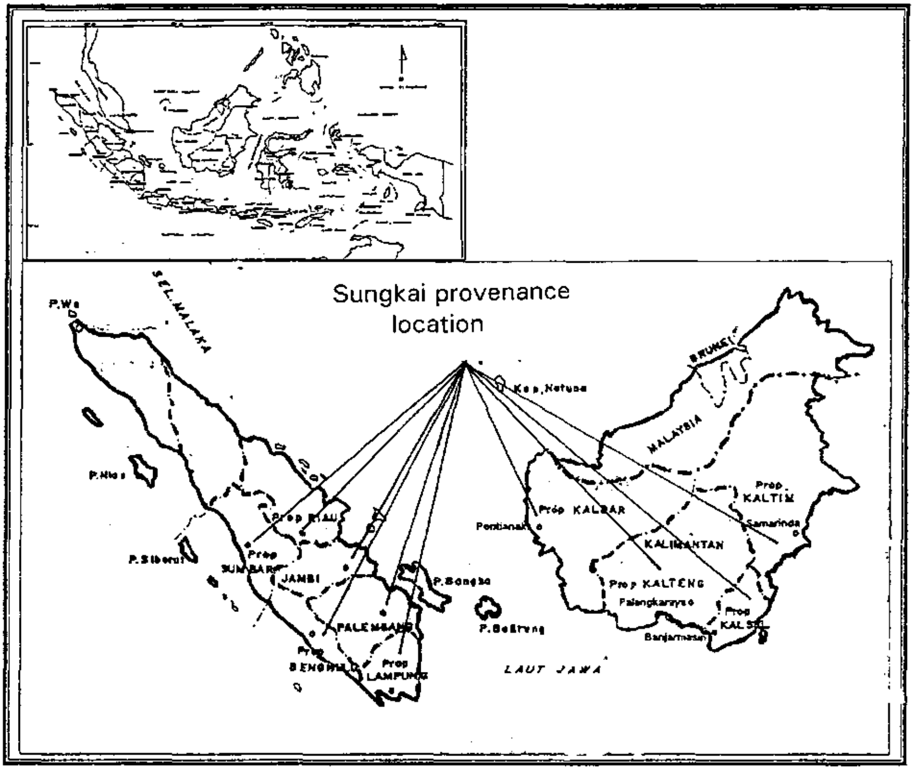


Fig.2.1. Location of the ten Indonesian provenances of Sungkai (*P. canescens*, VERBENACEAE) used in the experimental study described in the present book.

2.2.1. Selection of sites with worthwhile populations of *P. canescens*

Most literature contains only general statements about the geographic distribution of Sungkai in Sumatera and Kalimantan. Hence, three steps were taken in determining sites with worthwhile populations of Sungkai, i.e., (a) gathering information from universities, books, loggers, foresters and local people, (b) field assessment of the sites pinpointed during the first step, and (c) choosing one site per province.

The first step implied collecting information on the distribution of Sungkai in each province, including the accessibility of the site. There were two phases in the first step, i.e., collecting written or spoken information prior to going to the province concerned, and collecting field information in that province. Information was collected from books, reports and contact persons (foresters/loggers/universities) in each province, via correspondence. Afterwards, in each province secondary data were collected. Candidate sites in each province were found by comparing this information from various sources.

A preliminary survey of the site (second step) was conducted following the results from the first step. During the second step, candidate sites were visited and the vegetation was observed thoroughly. There were at least two sites to be visited in each province. Eventually, one site in each provenance was selected on the basis of field observations. During the site visits, some local people were contacted in order to engage field hands (tree climbers/tree spotters) for the fieldwork.

2.2.2. Collecting primary data in the selected sites

Once a site had been selected, ecological site characteristics were determined. Architectural life cycle series of each provenance were sketched according to the Oldeman protocol (1979). A rapid diagnostic forest line profile was made so as to understand the direct forest environment surrounding the *P. canescens* trees in their real site. In this diagnostic profile, the diameter at breast height, the height to the first living branch, the total height, the tree position and the diameter of the crown projection were measured. Transect width was 20 m, following Oldeman's rule of thumb that the width of transect is between one third and two third of the maximal height of the vegetation in the transect (Oldeman, 1983). The profile diagram was based on the above data. A diagnosis of trees in order to distinguish a "good phenotype" was also made. A high tree with a large diameter, a straight stem, and a crown architecture which was expected to capture most light was considered to be a "good" tree phenotype. Soil samples were collected in each site of the provenance and analysed at the soil laboratory of the Agricultural Faculty of Lambung Mangkurat University in Banjarbaru, South Kalimantan. Soil samples were collected from three places in the transect and after mixing packed into labelled plastic bags. The soil characteristics were analysed. These are texture, pH, C-organic, N total, P-total, K-total and field capacity water content.

2.2.3. Collecting secondary data

Secondary data were collected in the capital city of the Kabupaten and the Province where the ten provenances were located. A Kabupaten is an administrative unit below the province level, so one Province consists of several Kabupatens. Secondary data consist of latitude, longitude, altitude, regular climatic and edaphic data, topography and slope.

2.3. Results

2.3.1. Site characteristics of each provenance

As mentioned, cuttings were collected from ten provinces in Indonesia, namely, West Sumatera, Riau, Jambi, Bengkulu, Lampung and South Sumatera (in Sumatera island), West Kalimantan, Central Kalimantan, East Kalimantan and South Kalimantan. The regions surrounding the sites have the following characteristics, as far as the data are available :

2.3.1.1. West Sumatera

In this province, cuttings were collected from Kabupaten Sawah Lunto / Sijunjung. This Kabupaten is located from 0° 18′ 43″to 1° 45′ 46″ latitude South and from 100° 46′ 50″ to 101° 53′ 50″ longitude East. The topography is undulating and the altitude is between 100 and 1500 m above sea level (a.s.l). West Sumatera lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1994 to 1996 being between 21° and 33° C, the maximum day temperature being 34° C and the minimum night temperature 20° C. The average annual rainfall in Kabupaten Sawah Lunto/Sijunjung is 773 mm and the average monthly rainfall is 64 mm with 5 rainy days per month. The dry season is from May to September.

The soils in the area are latosols and yellow-red podzols on a matrix of alluvial and igneous rocks of volcanic origin. Their pH values range from 3.8 to 5.6, and they show comparatively low nutrient levels. The texture is sandy, silty clay.

Cuttings were collected from two villages, Sumpadang and Kumanis which belong to Kecamatan Koto VII (187 m a.s.l.) and Kecamatan Sumpur Kudus (243 m a.s.l.), respectively. A Kecamatan is an administrative unit below the Kabupaten level. The vegetation of the site consists of shrubs and young secondary forest.

2.3.1.2. Riau

In the Riau Province, cuttings were collected in Kabupaten Kampar. This Kabupaten is located from 1° 20′ North to 0° 30′ latitude South and from 100° 10′ to 103° 20′ longitude East. The topography is slightly undulating and the altitude is between 0 and 1000 m a.s.l.. Riau lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1989 to 1994 being between 21° and 31° C. The maximum day temperature is 32° C and the minimum night temperature 21° C. The average annual rainfall in Kabupaten Kampar is 2,480 mm (between 1989 and 1994), and the average monthly rainfall is 206 mm in 9 rainy days per month. The dry season is from June to September.

The soils in the area belong to yellow-red podzols, with pH values ranging between 3 and 4, and they show comparatively low nutrient levels. The texture is silty, clayey sand.

Cuttings were collected in the Petapahan village, Kecamatan Siak Hulu. The vegetation in the site consists of mixed species plantations (rubber trees, fruit trees, and other species).

2.3.1.3. Jambi

In the Jambi Province, cuttings were collected in Kabupaten Bungo Tebo. This Kabupaten is located from 0° 52′to 0° 59′ latitude South and from 101° 49′ to 102° 30′ longitude East. The topography of the site is undulating, with slopes between 0 and 15% , and the altitude is between 70 and 100 m a.s.l.. The Jambi Province lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1974 to 1986 being between 22.9° and 31.5° C (26.5° C in the site), the maximum day temperature being 32.2° C and the minimum night temparature 22.6° C. The average annual rainfall in Kabupaten Bungo Tebo is 2,311 mm, and the average monthly rainfall around the site is 192 mm with 15 rainy days per month. The highest rainfall (287 mm) is in April and the lowest rainfall (1 mm) is in June.

The soils in the area belong to yellow-red podzols with acid igneous rocks (in the plain) and sedimentary rocks (in the hill area), with pH values ranging from 4.6 to 4.9 , and they show comparatively low nutrient levels. The texture is clayey, sandy silt. The vegetation is made up of old secondary forests dominated by secondary species with a tree height ranging from 8 to 17 m and a diameter between 19 and 70 cm.

Cuttings were collected in the Pamayongan village, Kecamatan Tebo Tengah (85 m a.s.l.). The vegetation in the site is young secondary forest.

2.3.1.4. South Sumatera

In the South Sumatera Province, cuttings were collected in Kabupaten Muara Enim. This Kabupaten is located from 3° 5'to 4° 15' latitude South and from 103° 30' to 104° 12' longitude East. Meanwhile, Benakat itself is located from 3° 15' latitude South and 103° 50' longitude East (about 170 km of Southern West of Palembang). The topography is undulating with a relatively homogeneous slope of about 17 %, and the altitude is between 0 and 100 m a.s.l.. South Sumatera lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1992 to 1995 being between 22.3° and 31.8° C , the maximum day temperature being 33.6° C and the minimum night temperature 21.2° C (in the site itself, the day temperature is between 27° and 31° C). The average annual rainfall in Kabupaten Muara Enim is 2,490 mm and the average monthly rainfall is 266 mm with 16 rainy days per month. The dry season occurs from May to September, and the rainy season ranges from October to April.

The soils in the area belong to yellow-red podzols, with pH values ranging from 3.1 to 4.4, and they show comparatively low nutrient levels. The texture is sandy, silty clay.

Cuttings were collected in Benakat village, Kecamatan Gunung Megang (72 m a.s.l.). The vegetation in the site consists of shrubs and young secondary forest.

2.3.1.5. Bengkulu

In the Bengkulu Province, cuttings were collected in Kabupaten Bengkulu Selatan. This Kabupaten is located from 3° 47'to 4° 58'latitude South and from 102° 17' to 103° 52' longitude East.. The topography is undulating with a slope between 0 and 41%, in which slopes between 0 and 25% cover 55% of the total area, and the altitude is <100 m a.s.l.. Bengkulu lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1995 to 1996 being between 22.5° and 31.5° C , the maximum day temperature being 33° C and the minimum night temperature 22° C. The average annual rainfall in Kabupaten Bengkulu Selatan is 2,729 mm, and the average monthly rainfall is 228.6 mm with 11 rainy days per month.

The soils in the area belong to yellow-red podzols, with pH values ranging from 3.9 to 4.3, and they show comparatively low nutrient levels. The texture is silty, sandy clay.

Cuttings were collected in the Tais village, Kecamatan Tais (127 m a.s.l.). The vegetation consists of mixed species plantations (fruit trees, rubber trees, Sungkai trees, other tree species).

2.3.1.6. Lampung

In the Lampung Province, cuttings were collected in Kabupaten Lampung Utara. This Kabupaten is located from 3° 45' to 4° 55' latitude South and from 103° 50' to 105° 50' longitude East. The topography is slightly undulating and the altitude is between 15 and 120 m a.s.l. Lampung lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1990 to 1994 being between 21.7° and 32° C, the maximum day temperature being 33°C and the minimum night temperature 19.1°C. The average annual rainfall in Kabupaten Lampung Utara is 2,129 mm and the average monthly rainfall is 186 mm with 9 rainy days per month. The dry season is from June to September and the rainy season is from October to May.

The soils belong to yellow brown podzols, with pH values ranging from 4.3 to 4.8, and they show comparatively low nutrient levels. The texture is silty, clayey sand.

Cuttings were collected in Hanakau/Rebang, Kecamatan Sungkai Selatan (50 m a.s.l.). The vegetation consists of young secondary vegetation.

2.3.1.7. West Kalimantan

In the West Kalimantan Province, cuttings were collected in Kabupaten Ketapang. This kabupaten is located from 0° 25'to 3° 0' latitude South, and from 108° 30' to 111° 25' longitude East. The topography is undulating (relatively level in the site) and the altitude is between 0 and 500 m a.s.l.. West Kalimantan lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1992 to 1995 being between 26.7 and 31°C, the maximum day temperature being 31.9 ° C and the minimum night temperature 26.1°C. The average annual rainfall in Kabupaten Ketapang is 3,619 mm, and the average monthly rainfall is 301 mm with 16 rainy days per month. The lowest rainfall is in June, July and August.

The soils in the area are dominated by yellow-red podzols, which cover almost 50% of the Kabupaten area, especially in the eastern part; meanwhile, organosol, regisol and alluvial soils are generally found in the western part of the Kabupaten. pH values range from 3.5 to 4.6, and they show comparatively low nutrient levels. The texture is silty, clayey sand.

Cutting were collected in Sei Belit village, Kecamatan Suka Dana (20 m a.s.l.). The vegetation consists of shrubs and young secondary forest.

2.3.1.8. Central Kalimantan

In the Central Kalimantan Province, cuttings were collected in Kabupaten Kotawaringin Barat. This Kabupaten is located between 1° 19' and 3° 36' latitude South, and from 110° 25' to 112° 50' longitude East. The topography is undulating ; the slope in the site is between 8 and 15%, and the altitude between

7 and 100 m a.s.l. Central Kalimantan lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1993 to 1995 being between 22.4° and 32° C, the maximum day temperature being 33.5°C and the minimum night temperature 19.7°C. The average annual rainfall in Kabupaten Kotawaringin Barat is 2,683 mm (from 1987 to 1995), and the average monthly rainfall is 223 mm with 15 rainy days per month. The dry season is from June to September, and the rainy season ranges from October to May.

The soils in the area are yellow-red podzols, with pH values ranging from 3.9 to 4.5, and they show comparatively low nutrient levels. The texture is sandy, silty clay.

Cuttings were collected in the Lupu village, Kecamatan Balai Riam (52 m a.s.l.).
The vegetation consists of naturally dominated Sungkai Stands.

2.3.1.9. East Kalimantan

In the East Kalimantan Province, cuttings were collected in Kabupaten Kutai. This Kabupaten is located from 2° 15' South to 4° latitude North and from 114° - 119° longitude East,. The topography is undulating and the altitude of the site is between 100 and 400 m a.s.l.. East Kalimantan lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1982 to 1991 ranging between 27° C and 34° C, the maximum day temperature being 35.7° C and the minimum night temperature 25.3° C. The average annual rainfall in Kabupaten Kutai is 2,421 mm, and the average monthly rainfall is 201 mm with 9 rainy days per month.

The soils in the site are dominated by yellow-red podzols, and the rest is latosol and lithosol; with pH value ranging from 3 to 4.3. They show comparatively low nutrient levels. The texture of the site is silty, sandy clay. Cuttings were collected in the Batu Kajang village, Kecamatan Batu Sopang (168 m a.s.l.). The vegetation in the site is made up of old secondary forests.

2.3.1.10. South Kalimantan

In South Kalimantan, cuttings were collected in Kabupaten Hulu Sungai Tengah. This Kabupaten is located from 2° 30'to 2°45 ' latitude South and from 115° 12'to 115° 42'longitude East. The topography is undulating and the altitude is between 100 and 1200 m a.s.l.. South Kalimantan lies in the perhumid tropical climate region, the mean monthly temperature for the period from 1987 to 1996 being between 26.9 and 33.1°C, the maximum day temperature being 34°C and the minimum night temperature 25.3°C. The average annual rainfall is 2,438 mm, and the average monthly rainfall is 203 mm with 11 rainy days per month.

The soil is dominated by yellow-red podzols, with a pH value ranging from 4.3 to 4.6. The texture is sandy, silty clay.

Cuttings were collected in the Batu Tungku village, Kecamatan Birayang. The vegetation in the site consists of secondary forests mixed with rubber trees.

The above description of the whole provinces highlights the latitudinal distribution of Sungkai. It seems that the geographic distribution of Sungkai in Sumatera and Kalimantan tends to be restricted mainly to the South, rather than to the north of the equator. This was based on personal observations in the field in eleven provinces in Sumatera and Kalimantan, and supported by information from various sources, such as regional foresters, loggers, local people, and university researchers, especially from the forestry faculties.

Most literature contains only general statements on the geographic distribution of Sungkai in Sumatera and Kalimantan. Supriadi (1991) and Martawijaya et al.(1981) mentioned that Sungkai was known to occur naturally in the western Indonesian archipelago, especially in large parts of Sumatera and in the whole of Kalimantan. The latitudinal limits within the natural range were from 7° 20' South to 4° 10' North. Soerianegara and Lemmens (1994) mentioned the existence of Sungkai in the Riau Archipelago, in addition to Sumatera in general. They found that Sungkai occurred especially in the centre of Kalimantan.

Indeed, most of the provinces chosen to collect provenances from, lie south of the equator, except three, i.e. East Kalimantan, West Kalimantan and Riau. These three provinces are straddling the equator.

In the East Kalimantan Province, with three-fourth of its area situated to the north of the equator, Sungkai is commonly found in the Kabupaten Pasir, (between 0° 40'and 2° 25' latitude South), and in the part of Kabupaten Kutai situated below the equator. In Bontang, in the part of the latter Kabupaten situated to the north of and close to the equator, Sungkai is still found. However, it is not as abundant as in the southern part. In Tarakan and Long Bawang, situated in the northern part of East Kalimantan (between 3° and 4° latitude North), there are no indications of the existence of Sungkai.

In the West Kalimantan Province, with about half of its area situated to the north of the equator, Sungkai is also found in the south, i.e., in the Kabupaten Ketapang, and in a small part of the Kabupaten Mempawah, especially in its southern part. In the Kabupaten Sanggau, especially in the area between 0° and 1° latitude north, there are no indications of the existence of Sungkai.

In the Riau Province, with 70% of its areas north of the equator, the Sungkai distribution tends to be dense in the southern part, like in the Kabupaten Indra Giri Hulu and in a small part of the Kabupaten Indra Giri Hilir. In the north Sumatera Province, situated in the northern part of the Riau Province, there is no indication of the existence of Sungkai.

So it is assumed that, in terms of latitude, the distribution of Sungkai in the Sumatera and Kalimantan tends to abound below the equator and to become scarce above above the equator, where it rapidly peters out to the north. In Malaysia, Corner (1951) found Sungkai rather to the north.

The following distribution centres of Sungkai were found in Kalimantan and Sumatera :

In West Kalimantan : Sukadana, Tumbang Titi, Nanga Tayap, Sandai, and Air Kuning. In Central Kalimantan : Kota Waringin, Balai Riam, Nanga Bulik, *Kasongan, Tumbang Samba, Tumbang Hiran, Sampit, Kuala* Kuayan, *Muara* Kayang, Purukcahu, Muara Teweh, Buntok and Tamiyang Layang. In South

Kalimantan : Tanjung, Muara Uya, Haruai, Tanta, Amuntai, Juai, Lampihong, Barabai, Birayang, Pagat, Haruyan, Kandangan, Angkinang, Telaga Langsat, Sungai Raya, Rantau, Tambarangan, Binuang, Riam Kiwa, Riam Kanan, Belimbing, Pengaron, Karang Intan, Pleihari, Kintap, Batu Licin and Kota Baru. In East Kalimantan : Muara Koman, Batu Sopang, Kuaro, Batu Ampar, Sepaku, Loa Janan, Tenggarong.

In West Sumatera : Sijunjung, Koto VII, Sumpur Kudus and Pariaman. Riau : Bangkinang, Siak Hulu, Rengat, Tembilahan, Kampar and Pulau Kundur. Jambi : Tebo Tengah, dusun Pasir Mayang, Pulau Temiang, Pemayongan, Bangko, Rantaumaukapuas, Sarolangon, Pulau Pandan, and Pauh. South Sumatera : Pendopo, Benakat, Pangkalan Resik, Kota Agung, Batu Raja, Babat and Bayung Lencir. Bengkulu : Tais, Kampai, Manna and Arga Makmur. Lampung : Hanakau, Sungkai Selatan, Sungkai Utara, Negeri Ratu and Way Kambas.

2.3.2. Original vegetation surrounding each provenances

Though observations were carried out on ten provenances, only a few places where we found Sungkai could be considered "original natural vegetation". The rest of the Sungkai material was found in home gardens, live fences, and bush or shrublands. Sungkai is common in secondary forests and forest clearings, on river banks and along roads; it does not occur in primary forests (Anonymous, 1993). However, at least five places out of ten provenances can be considered "natural secondary vegetation", namely, East Kalimantan, Jambi, Riau, Central Kalimantan, and South Kalimantan.

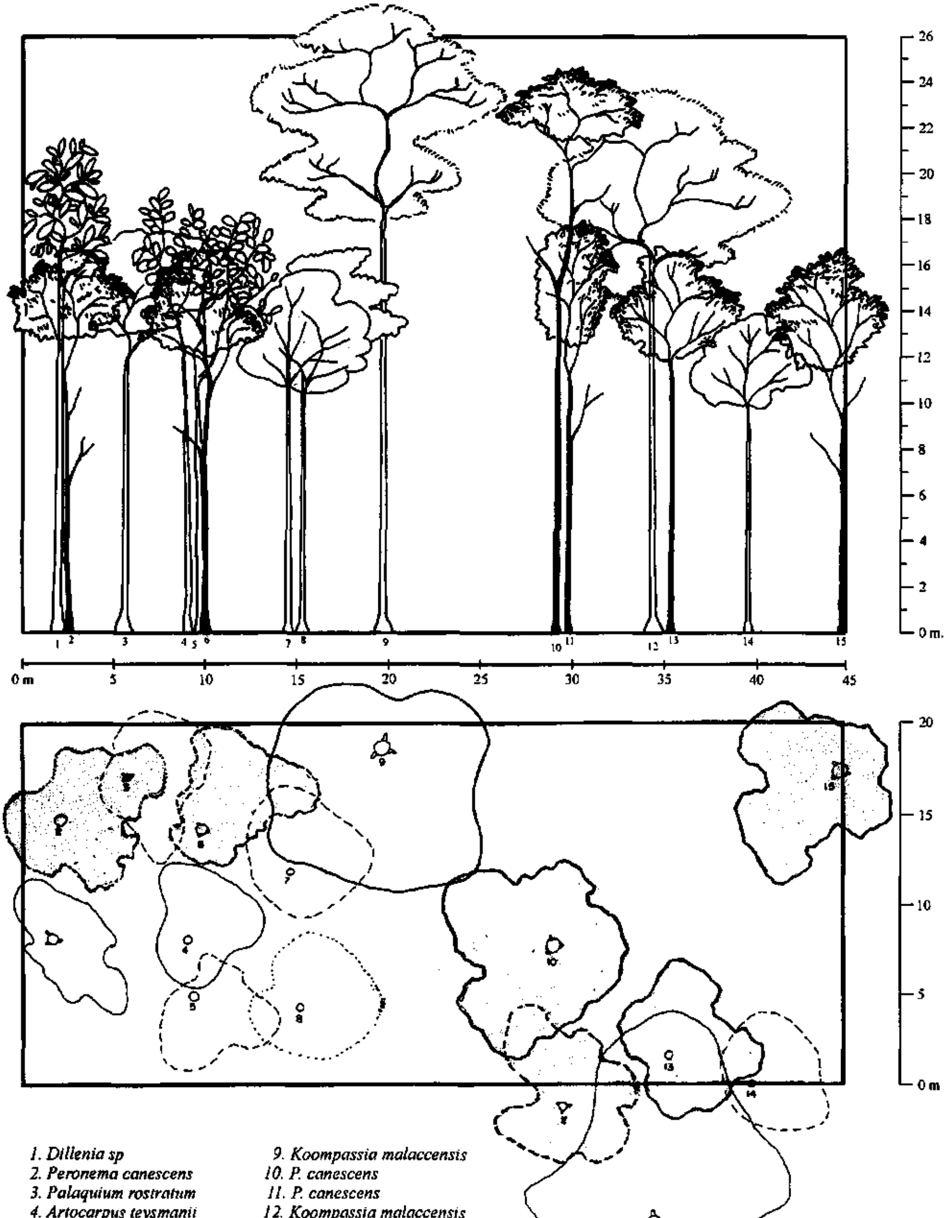
2.3.2.1. East Kalimantan

Compared with other provinces in Indonesia, a relatively intact natural vegetation of Sungkai was found in East Kalimantan. The stand is quite old, as shown by its species composition and tree diameters. For instance, the Sungkai were 73,71, 70, 69, 68 , 60 and 55 cm in diameter, *Koompassia* : 80, 71 and 60 cm; *Shorea* : 42, 40 cm; *Litsea* : 45, 43 cm, and *Artocarpus* diameter: 45, 43, 37, 33 cm. Small diameters of Sungkai trees were found as well as large diameters due to the appearence of a new gap or new skidding roads. Other species found in this plot are *Palaquium sp., Dillenia sp.* and *Vitex pubescens*. Sungkai is dominant, both in frequency and basal area. Flowering of Sungkai in this region is between January and February. There were several gaps in the forest area probably due to tree fall long ago. Then, pioneer species, including Sungkai, grew up and survived.

Some parameters measured in Sungkai in the plot are presented in Table 2.1. A classification of poles and mature trees is made in keeping with the criteria of the Indonesian selective cutting system. The volume is calculated by using the equation : $v = 0.7 \{\pi r^2 \times h_f\}$, in which h_f is the free trunk height and 0.7 is the form number of the tree. The same formula is also used for other provenances. A profile diagram and a crown projection map of the vegetation and the architecture of Sungkai trees from seedling to adult are shown in Fig. 2.2. and Fig. 2.3.

Table 2.1. Some parameters of Sungkai in the East Kalimantan site.
h1 is free trunk height; h2 is total height; g is basal area. Trees 1 to 9 are adult trees. Trees 10 to 19 are poles.

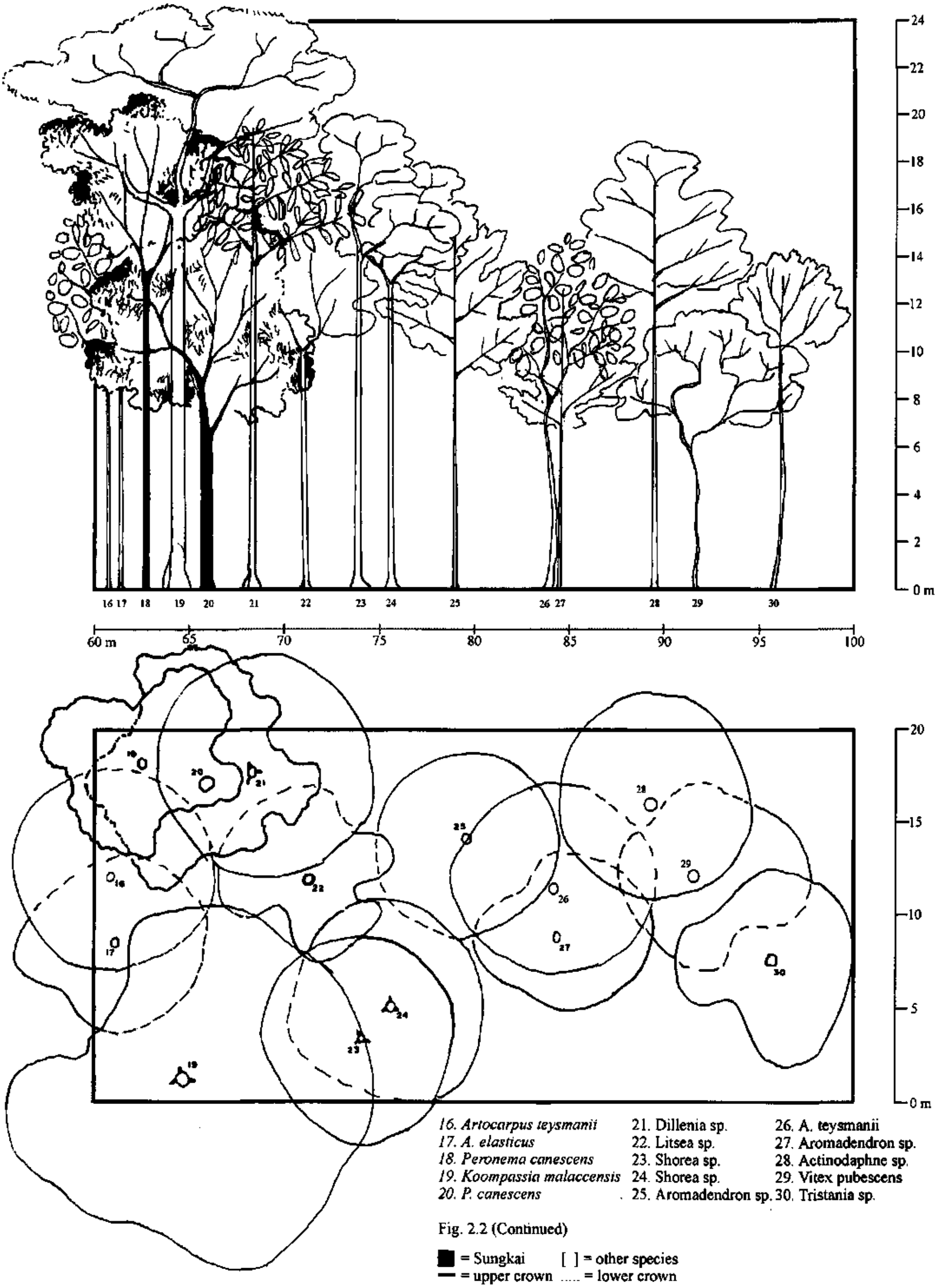
No.	Diameter(cm)	h1(m)	h2(m)	g(m)	V(m3)	Crown diameter(m)
1	73	7	16	0.15	1.87	13 x 14
2	71	16	16	0.40	4.43	18 x 12
3	70	7	17	0.39	1.89	16 x 15
4	69	8	17	0.37	2.17	14 x 13
5	68	8	18	0.36	2.29	12 x 13
6	60	7	15	0.28	1.40	15 x 12
7	55	7	17	0.24	1.99	14 x 14
8	46	13	21	0.17	1.51	11 x 11
9	21	3	7	0.04	0.08	10 x 9
10	19	5	12	0.03	0.10	10 x 11
11	15	5	11	0.02	0.06	11 x 11
12	15	5	11	0.02	0.06	8 x 8
13	14	3	7	0.02	0.03	10 x 10
14	13	8	14	0.01	0.07	10 x 9
15	13	5	11	0.01	0.05	8 x 9
16	12	5	12	0.01	0.04	18 x 10
17	12	3	7	0.01	0.03	10 x 10
18	12	3	8	0.01	0.02	9 x 10
19	12	3	9	0.01	0.04	10 x 10



1. *Dillenia sp*
2. *Peronema canescens*
3. *Palaquium rostratum*
4. *Artocarpus teysmanii*
5. *A. elasticus*
6. *P. canescens*
7. *Blumeodendron rostratum*
8. *Palaquium rostratum*
9. *Koompassia malaccensis*
10. *P. canescens*
11. *P. canescens*
12. *Koompassia malaccensis*
13. *P. canescens*
14. *Aromadendron sp.*
15. *P. canescens*

Fig. 2.2. Profile diagram and crown projection of natural, mixed older secondary forest, with frequent Sungkai in East Kalimantan

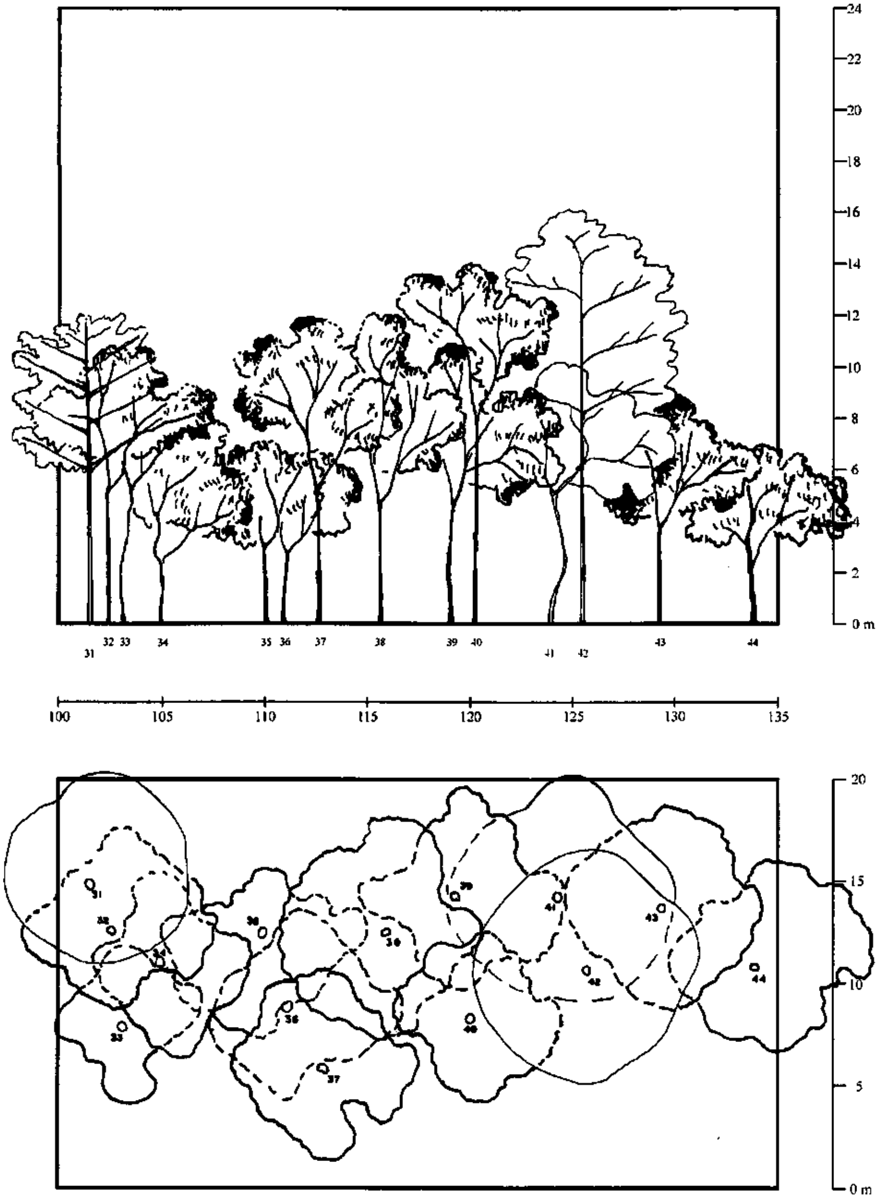
■ = Sungkai
▬ = upper crown
[ ] = other species
··· = lower crown (potential tree)



16. Artocarpus teysmanii
17. A. elasticus
18. Peronema canescens
19. Koompassia malaccensis
20. P. canescens
21. Dillenia sp.
22. Litsea sp.
23. Shorea sp.
24. Shorea sp.
25. Aromadendron sp.
26. A. teysmanii
27. Aromadendron sp.
28. Actinodaphne sp.
29. Vitex pubescens
30. Tristania sp.

Fig. 2.2 (Continued)

■ = Sungkai [ ] = other species
— = upper crown ..... = lower crown



31. Aromadendron sp. 36. P. canescens 41. Vitex pubescens
32. P. canescens 37. P. canescens 42. Nephelium sp.
33. P. canescens 38. P. canescens 43. P. canescens
34. P. canescens 39. P. canescens 44. P. cenescens
35. P. canescens 40. P. canescens

Fig. 2.2 (Continued)

■ = Sungkai [ ] = other species
— = upper crown .... = lower crown

A B C D

Figure 2.3. Sketch of the tree architecture of *P. canescens* for the Samarinda provenance, East Kalimantan. A. Unbranched seedling (epicotyledonary axis). B. Little branched sapling, only reiteration. C. Branched pole, built by reiteration, but no complete model is reiterated. D. Branched adult tree, rhythmic, orthotropic axes; abundant reiteration in this loose multi-array (Rossignol et al.1998, p.96). Note the open crown in young trees from open spaces (fig.2.2, m 100 to m 135) and the high inversion point (end of sole trunk, Oldeman 1974a) in the adult tree in an older secondary forest eco-unit (e.g. fig.2.2, m 20 to m 70)

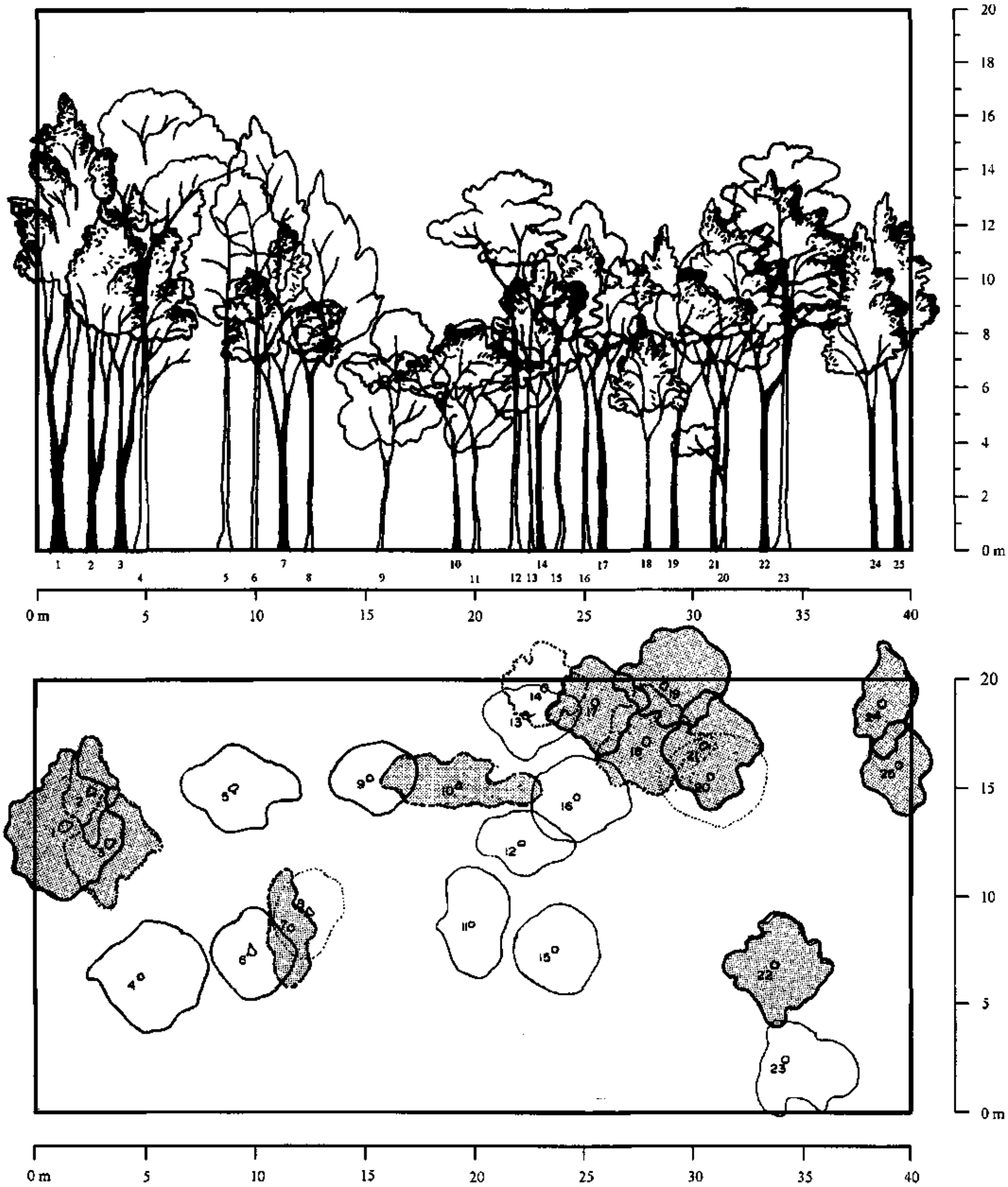
2.3.2.2. Jambi

Slightly different from East Kalimantan, in Jambi Sungkai was found in young secondary forest. Compared with the trees of the vegetation in East Kalimantan, the trees in Jambi seemed relatively younger. This was supported by the diameter composition of the Sungkai trees, dominated by diameters between 19 and 34 cm; only one tree achieved a diameter of 61 cm. In the site also some tree stumps of Sungkai were found, which indicated recent cutting activities on Sungkai. Some of the biggest tree were left, due to the bad wood quality of the tree. Meanwhile, other tree species were left to survive. The vegetation of the plot consisted of several species, i.e., *P. canescens, Dehaasia cuneata, Phitecellobium jiringa, Vitex gamosepala, Alseodaphne sp., Macaranga gigantea, Macaranga triloba, Ficus variegata, Artocarpus elasticus, Eugenia sp., Euphoria malaiensis, and Cananga odorata.* The dominant species was Sungkai, followed by *Phitecellobium jiringa* in the second place.

Some parameters measured in Sungkai in the plot are presented in Table 2.2. A profile diagram, a crown projection map of the vegetation and the architecture of a Sungkai tree in Jambi, from seedling to adult, are shown in Fig.2.4 and Fig.2.5.

Table 2.2. Some parameters of Sungkai in the Jambi site
h1 is free trunk height. h2 is total height. g is basal area. Trees 1 to 19 are adult tree. Trees 20 to 22 are poles.

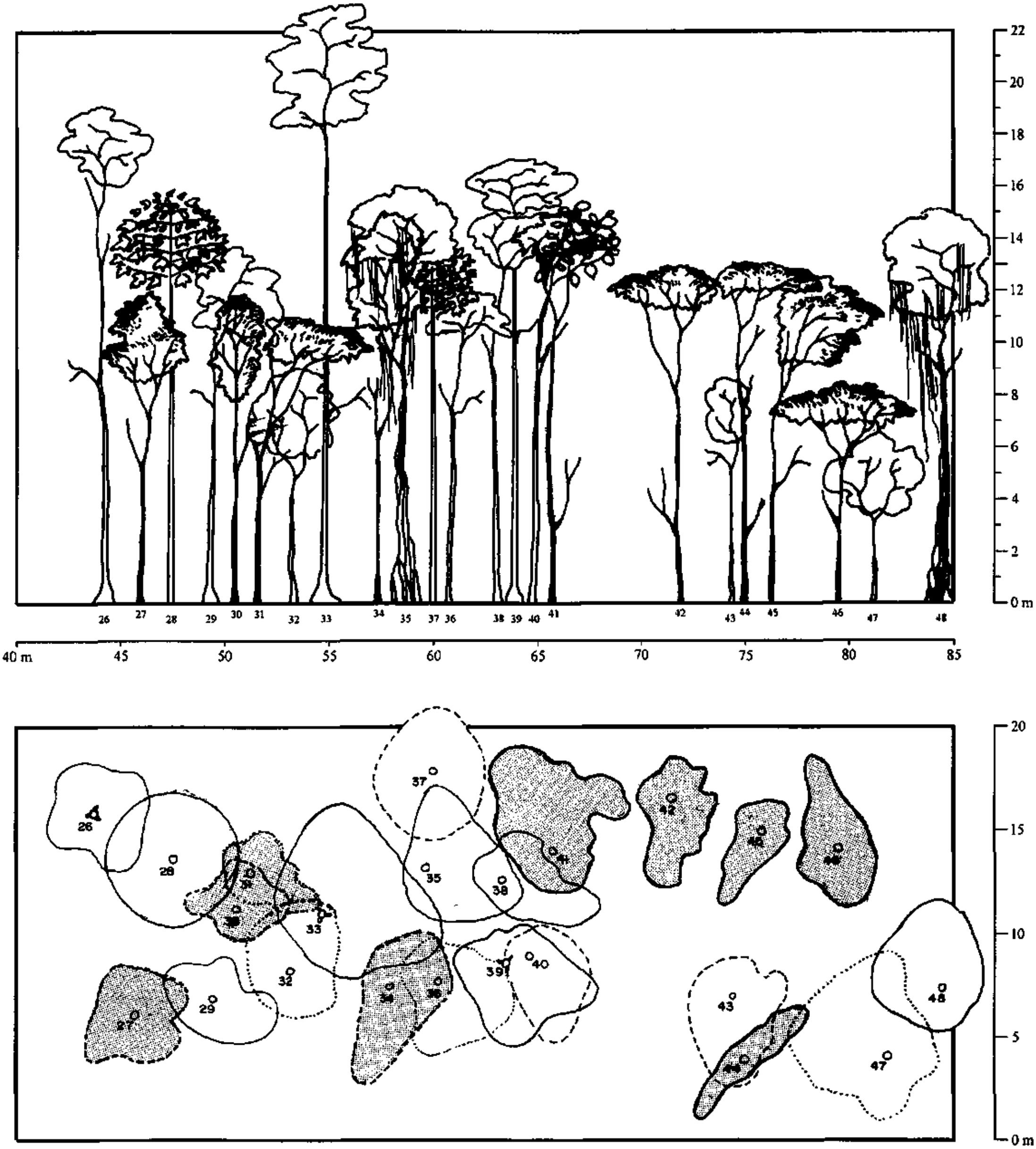
No.	Diamater(cm)	h1(m)	h2(m)	g(m2)	v(m3)	Crown diameter(m)
1.	61	2.1	17	0.29	0.43	5 x 12
2.	34	5.5	15	0.09	0.35	8 x 8
3.	33	5.0	12	0.08	0.30	7 x 6
4.	33	4.2	11	0.08	0.25	7 x 8
5.	32	2.2	13	0.08	0.12	8 x 9
6.	32	2.2	13	0.08	0.12	8 x 9
7.	31	6.0	12.5	0.07	0.32	10 x 10
8.	31	4.3	12	0.07	0.23	8 x 8
9.	30	5.0	12	0.07	0.25	10 x 9
10.	30	3.7	11	0.07	0.18	7 x 7
11.	29	5.7	13	0.07	0.26	9 x 8
12.	29	5.1	12	0.06	0.24	9 x 7
13.	29	3.0	8.5	0.06	0.14	9 x 9
14.	28	4.0	10	0.06	0.17	8 x 9
15.	28	2.0	15	0.06	0.09	11 x 7
16.	28	2.0	12	0.06	0.06	9 x 8
17.	26	2.3	13	0.05	0.07	7 x 6
18.	25	4.6	13	0.05	0.16	10 x 10.
19.	23	5.2	14	0.04	0.15	11 x 10
20.	20	3.0	8.3	0.03	0.07	9 x 9
21.	19	4.0	12.5	0.03	0.08	6 x 9
22.	19	4.0	10	0.03	0.08	6 x 7



1. *P. canescens*
2. *P. canescens*
3. *P. canescens*
4. *Pithecelobium jiringa*
5. *Dehaasia cuneata*
6. *Euphoria malaiensis*
7. *P. canescens*
8. *Eugenia malaiensis*
9. *Cananga odorata*
10. *P. canescens*
11. *Pithecelobium jiringa*
12. *Payena sp.*
13. *Xerospermum noronheanum*
14. *P. canescens*
15. *X. noronheanum*
16. *Vitex gamosepala*
17. *P. canescens*
18. *P. canescens*
19. *P. canescens*
20. *Pithecelobium jiringa*
21. *P. canescens*
22. *P. canescens*
23. *Gymnospermum sp.*
24. *P. canescens*
25. *P. canescens*

Fig. 2.4. Profile diagram and crown projection of natural, younger secondary forest built by Sungkai in Jambi

■ = Sunkai [ ] = other species
— = upper crown ..... = lower crown



26. *Alseodaphne sp.*
27. *P. canescens*
28. *Macaranga gigantea*
29. *Ficus variegata*
30. *P. canescens*
31. *P. canescens*
32. *Eugenia sp.*
33. *Actinodaphne sp.*
34. *P. canescens*
35. *Ficus sp.*
36. *Nephelium sp.*
37. *Macaranga triboba*
38. *Vitex gamosepala*
39. *Nephelium sp.*
40. *Arthocarpus elasticus*
41. *P. canescens*
42. *P. canescens*
43. *Nephelium sp.*
44. *P. canescens*
45. *P. canescens*
46. *P. canescens*
47. *Pithecelobium jiringa*
48. *Ficus variegata*

Fig.2.4. (Continued)

■ = Sungkai [ ] = orther species

— = upper crown ······ = lower crown

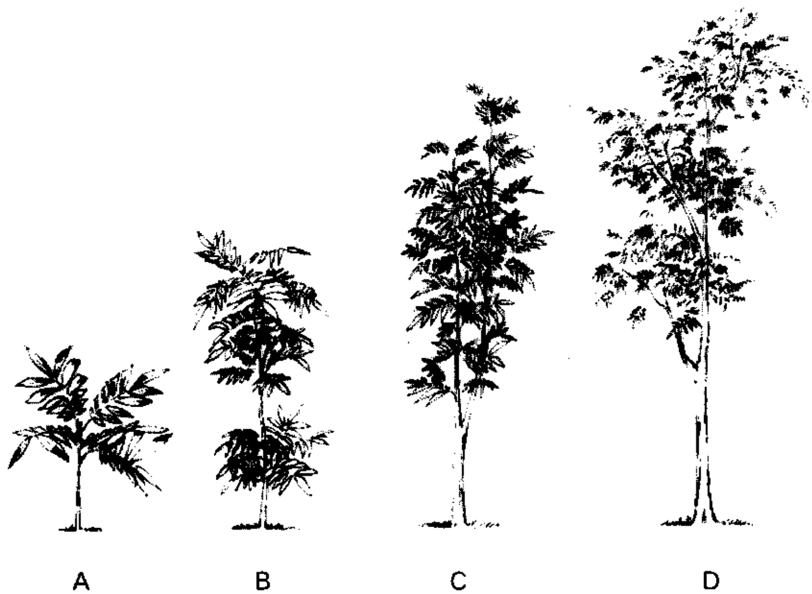


Figure 2.5. Sketch of the tree architecture of *P. canescens* for the Jambi provenance. A. Unbranched seedling (epicotyledonary axis). B. Branched sapling, only little reiteration. C. Branched pole, built by reiteration, no structures conforming to Scarrone's model (Hallé et al. 1978). D. Branched, early adult tree; rhythmic, orthotropic axes, monopodial with determinate growth. Note branches conforming to Scarrone's model (Hallé et al. 1978). The whole crown is a loose multi-array of branches and incomplete models (Scarrone, Leeuwenberg), but with a certain regularity probably linked to a pure eco-unit (fig.2.4, m 60 to m 70). The whole development is typical of young secondary forest (cf.Vester 1997), in which trees have to grow upwards in groups, first with much room each (fig.2.4, m 70 to m 85), later more constrained, also by lianes (fig.2.4, m 55 to m 65) and unilaterally exposed at the border of the eco-unit (e.g. fig.2.4, m 45 or m 65) as the vegetation goes through natural fragmentation of the mosaic (Oldeman 1990).

2.3.2.3. Riau

The biggest Sungkai tree in the ten provinces was found in the Riau Province, located in Dusun Petapahan I Kecamatan Tapung, Kabupaten Kampar. Its diameter was 89 cm and its height was about 25 m. According to the owner, the age of the tree was about 70 years. Local foresters proposed to protect this tree. The vegetation of the plot consisted of *P. canescens, Hevea brasiliensis, Durio zibethinus, Dillenia sp., Vitex gamosepala, Alseodaphne sp., Nephelium sp., Lansium domesticum, Garcinia sp.* The dominant species was *Hevea brasiliensis*. Based on the species composition, the former stand must have been a garden with fruit trees and rubber trees, later abandoned to nature as shown by the presence of *Alseodaphne, Vitex* and *Dillenia sp.*

The diameters have a wide range, e.g. Sungkai (89, 68.5, 48.7, 46.5, 25, 20.9, 8.3 cm), rubber tree (61.9, 49, 21.7, 18.8, 16.2, 19,4 cm), *Mangifera indica* (55 cm), *Durio* (31.2, 25.2 cm) and *Garcinia sp.*(33.8 cm). The domination of the diameter class between 10 and 25 cm in the stand indicated the occurrence of regeneration.

A profile diagram, a crown projection map of the vegetation and the architecture of a Sungkai tree are presented in Fig.2.6 and Fig.2.7. Some parameters measured in Sungkai in the plot are shown in Table 2.3.

Table 2.3. Some parameters of Sungkai in the Riau Site.h1 is free trunk height. h2 is total height. g is basal area. Trees 1 to 5 are adult trees. Trees 6 to 7 are poles.

No	Diameter(cm)	h1(m)	h2(m)	g(m2)	v(m3)	Crown diameter(m)
1.	89	17	25	0.62	7.40	7 x 7
2.	68.5	13	20	0.37	3.35	6 x 7
3.	48.7	8	15	0.19	1.04	6 x 6
4.	46.5	12	19	0.17	1.43	7 x 6
5.	25.2	12	20	0.05	0.42	6 x 5
6.	20.9	12	20	0.03	0.28	8 x 7
7.	8.3	6	14	0.01	0.02	5 x 6

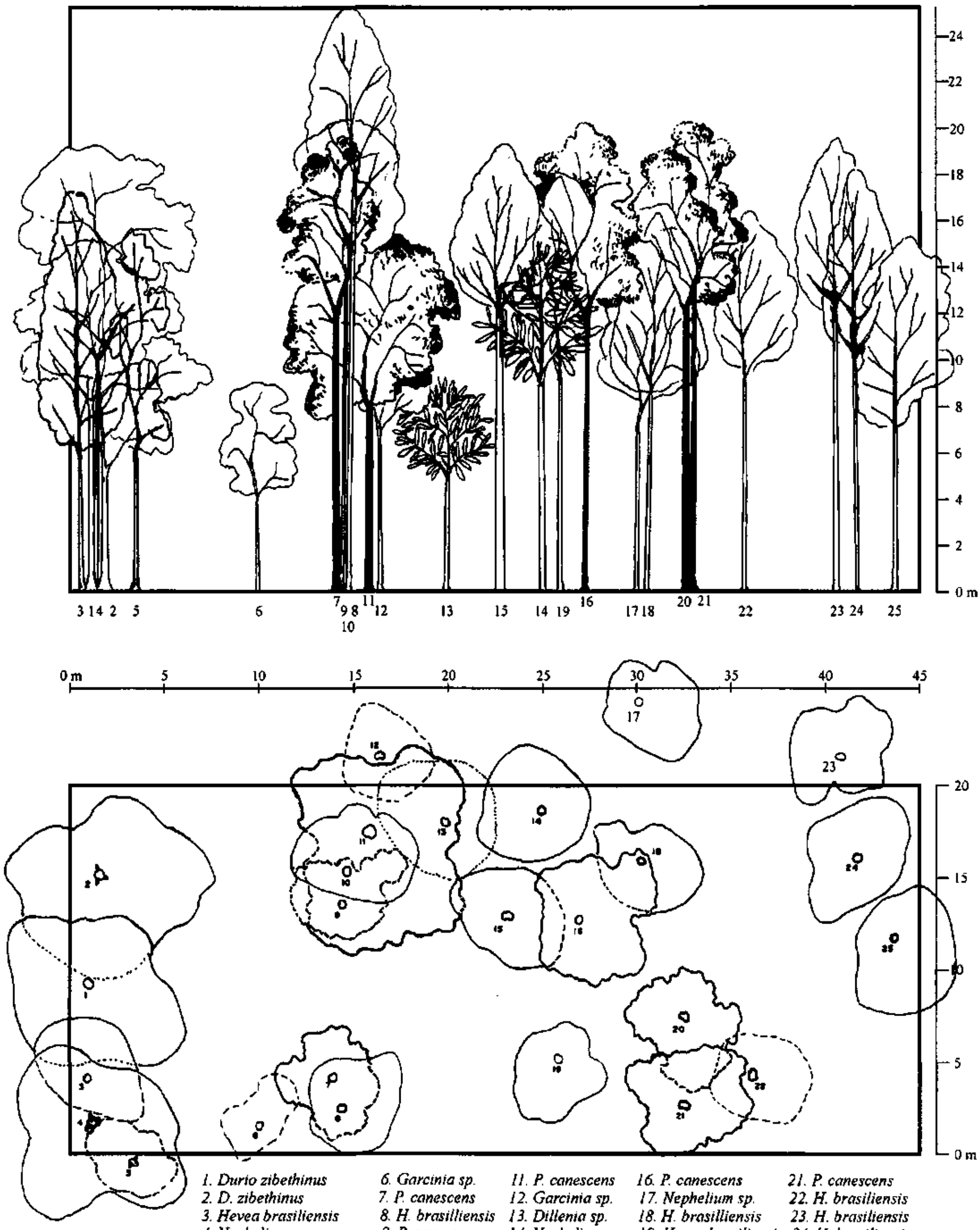


Fig. 2.6. Profile diagram and crown projection of natural, vegetation with Sungkai in Riau

■ = Sungkai [ ] = other species ▬ = upper crown ..... = lower crown

26. Garcinia sp.
27. Lithocarpus sp.
28. Lithocarpus sp.
29. Garcinia sp.
30. Pometia sp.
31. Lithocarpus sp.
32. Nephelium
33. P. canescens
34. Nephelium sp.
35. Durio zibethinus
36. Durio zibethinus
37. Alseodaphne sp.

Fig. 2.6.. (Continued)

■ = Sungkai [ ] = other species ▬ = upper crown ..... = lower crown

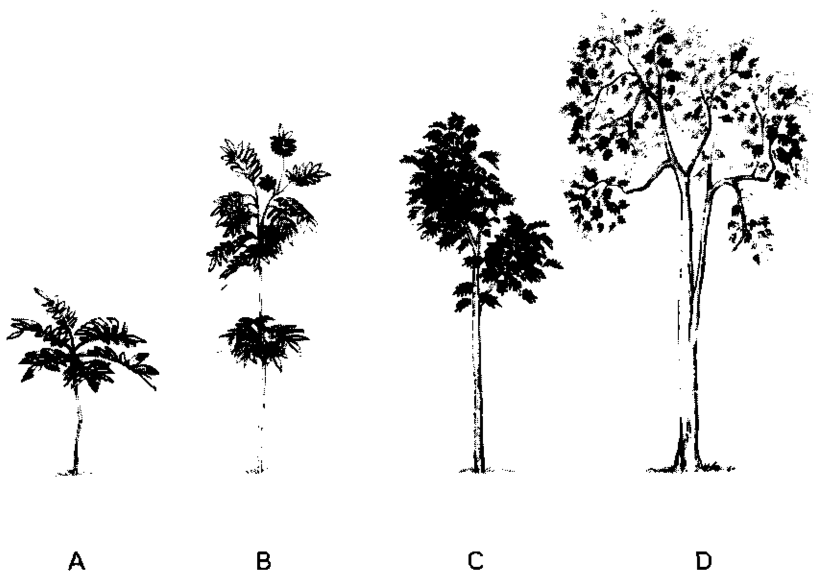


Figure 2.7. Sketch of the architecture of *P. canescens* for the Riau provenance. A. Unbranched seedling (epicotyledonary axis). B. Little branched sapling, only little reiteration. C. Branched pole, built by scarce reiteration of Scarrone's model (see above to the left). D. Branched adult tree, rhythmic, orthotropic axes, monopodial with definite growth. Fully expanded crown is a loose multi-array (Rossignol et al. 1998) of axes, branch complexes and incomplete models. Note the relatively low inversion point in the adult tree. Note the vegetation consisting of old fruit trees and old secondary species (fig.2.6).

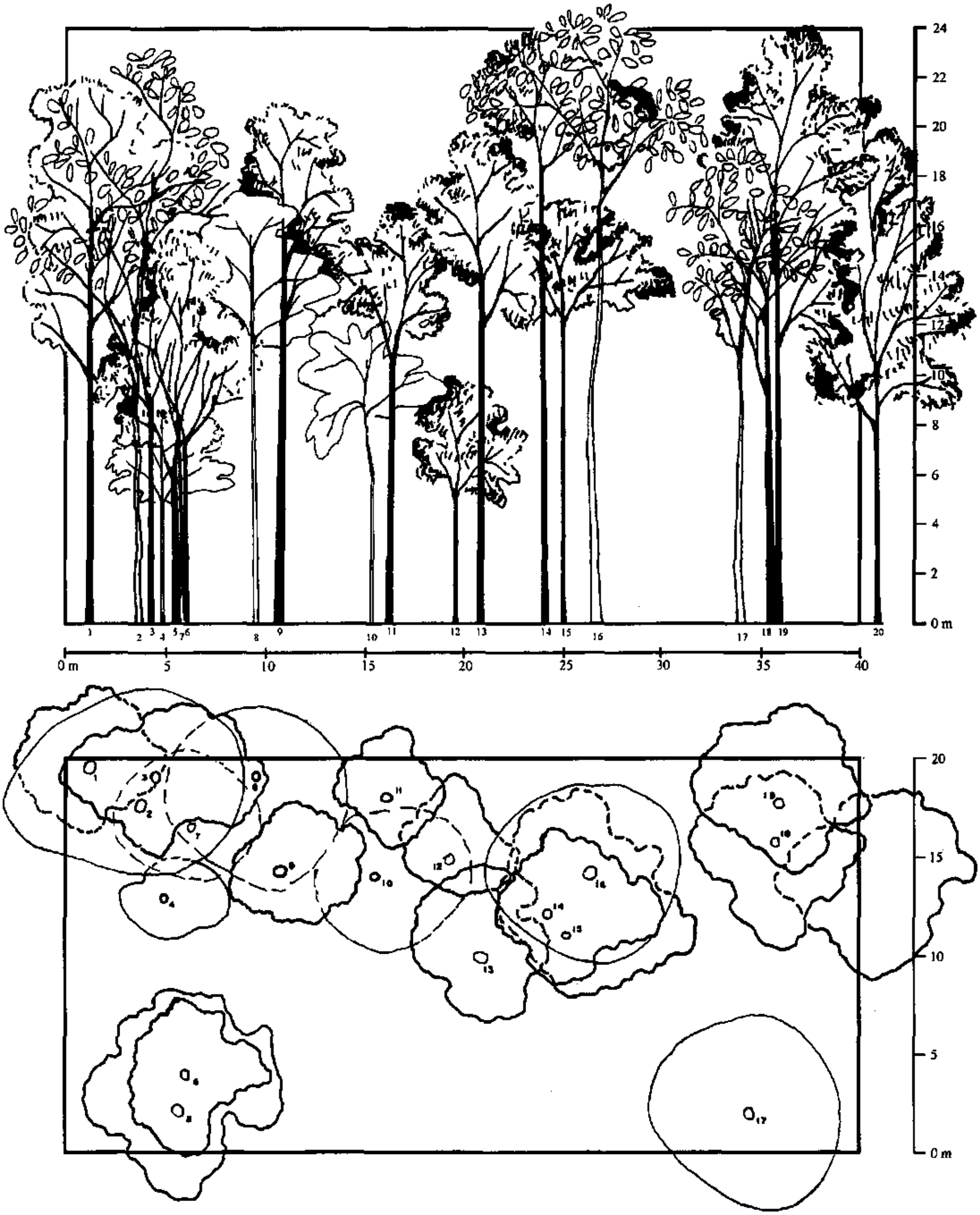
3.2.4. Central Kalimantan

The original Sungkai vegetation in central Kalimantan, especially in the sample plot and the immediate surroundings, showed a performance that differed from stands in other provinces in Indonesia. Sungkai trees constituted 70 % of all the trees in the sample plot, and showed a diameter distribution between 40 and 60 cm. According to local forestry officers (personal communication) who carried out surveys in the area two years ago, there was a hill which is covered by a homogeneous, pure Sungkai stand. They added that the Sungkai stands in the area were over fifty years old. It is said that Sungkai trees with a diameter exceeding 80 cm exist in the area; this was supported by the existence close to the sample plot of a dead Sungkai tree with a diameter of 86 cm.
Other tree species found in the sample plot are *Artocarpus sp., Dactylocladus stenostachys, Actinodaphne sp., Cinnamomum pendulum* and *Mangifera sp.*

Some parameters measured in Sungkai in the plot are presented in Table 4.4. A profile diagram, a crown projection map and the architecture of a Sungkai tree from seedling to adult tree are presented in Fig. 2.8 and Fig. 2.9.

Table 2.4. Some parameters of Sungkai in the Central Kalimantan Site
h1 is free trunk height. h2 is total height. g is basal area. Trees 1 to 21 are adult trees. Trees 22 to 25 are poles.

No.	Diameter(cm)	h1(m)	h2(m)	g(m2)	v(m3)	Crown diameter(m)
1.	59.2	12	20	0.27	2.31	7 x 8
2.	58.7	6	15	0.27	1.13	10 x 11
3.	54.4	18	24	0.23	2.92	9 x 8
4.	53.4	10	22	0.22	1.57	8 x 8
5.	52.5	13	21	0.22	1.96	7 x 6
6.	48.5	11	24	0.19	1.42	9 x 8
7.	47.7	9.5	21	0.18	1.19	8 x 9
8.	46.9	10.5	21	0.17	1.27	9 x 8
9.	46.8	9.5	23	0.17	1.14	10 x 8
10.	45.4	5	12	0.16	0.57	5 x 6
11.	44.7	7.5	16	0.16	0.82	7 x 8
12.	44.3	7.5	20	0.15	0.81	10 x 9
13.	42.7	10.5	17	0.14	1.05	5 x 6
14.	41.1	8	18	0.13	0.74	9 x 8
15.	31.5	7	15	0.08	0.38	9 x 7
16.	29.1	6.5	14	0.07	0.30	7 x 7
17.	28.3	12	17	0.06	0.50	10 x 11
18.	23.2	8	15	0.04	0.23	8 x 9
19.	22.8	6	15	0.04	0.17	9 x 8
20.	22.7	9	16	0.04	0.25	7 x 8
21.	22.1	6.5	16	0.04	0.17	8 x 9
22.	18.2	7.2	14.5	0.03	0.13	7 x 6
23.	16.4	7.4	13.5	0.02	0.11	6 x 5
24.	14.5	6.1	11.5	0.02	0.07	9 x 8
25.	13.9	5.3	15	0.01	0.06	6 x 7



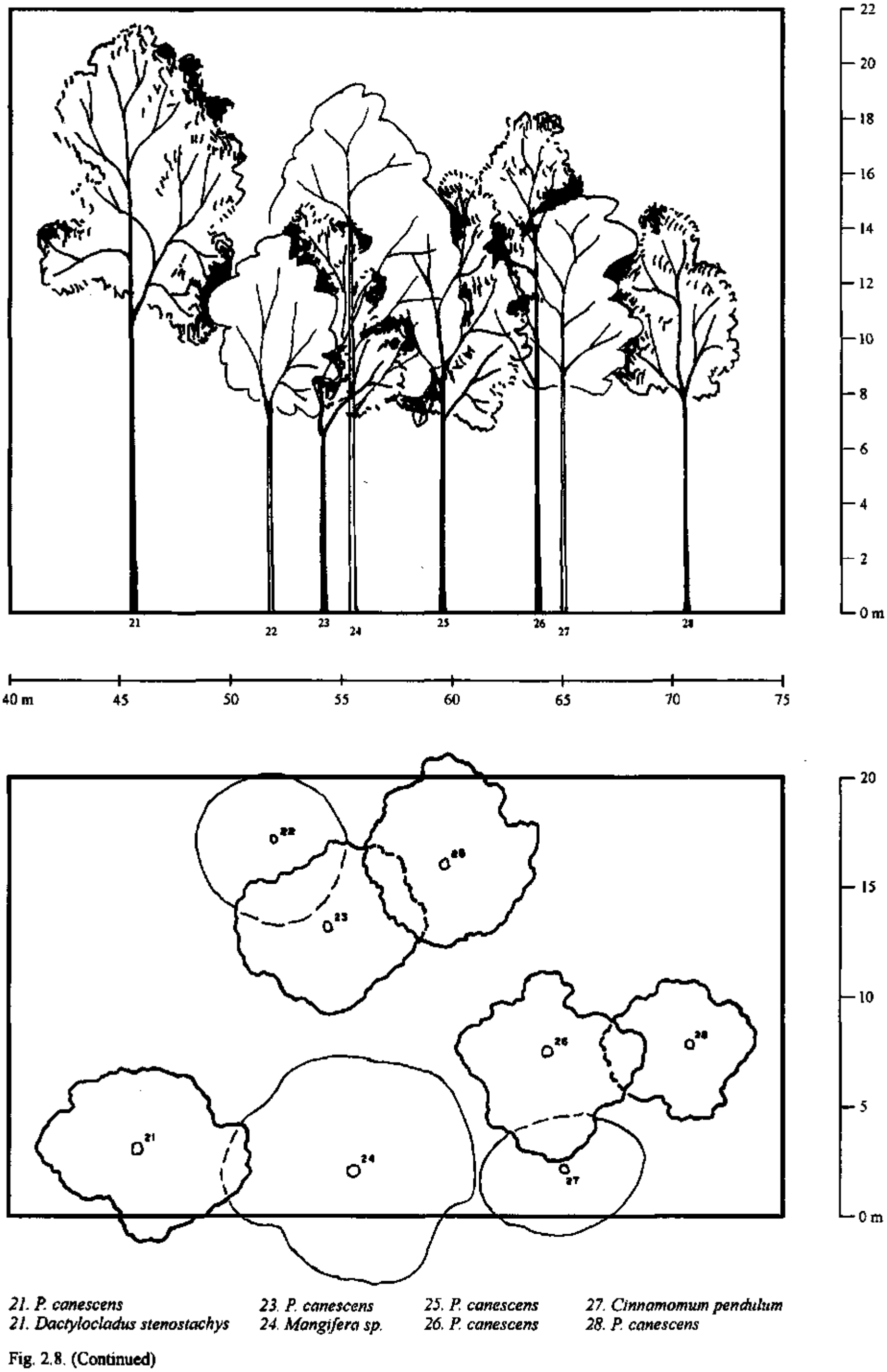
1. *Peronema canescens*
2. *Artocarpus sp.*
3. *Peronema canescens*
4. *Dactylocladus stenostachys*
5. *Peronema canescens*
6. *P. canescena*
7. *Cinnamomum pendulum*
8. *Actinodaphne sp.*
9. *Peronema canescens*
10. *Cinnamomum. pendulum*

11 - 15 P. canescens

16. *Artocarpus sp.*
17. *Artocarpus sp.*

18 - 20 P. canescens

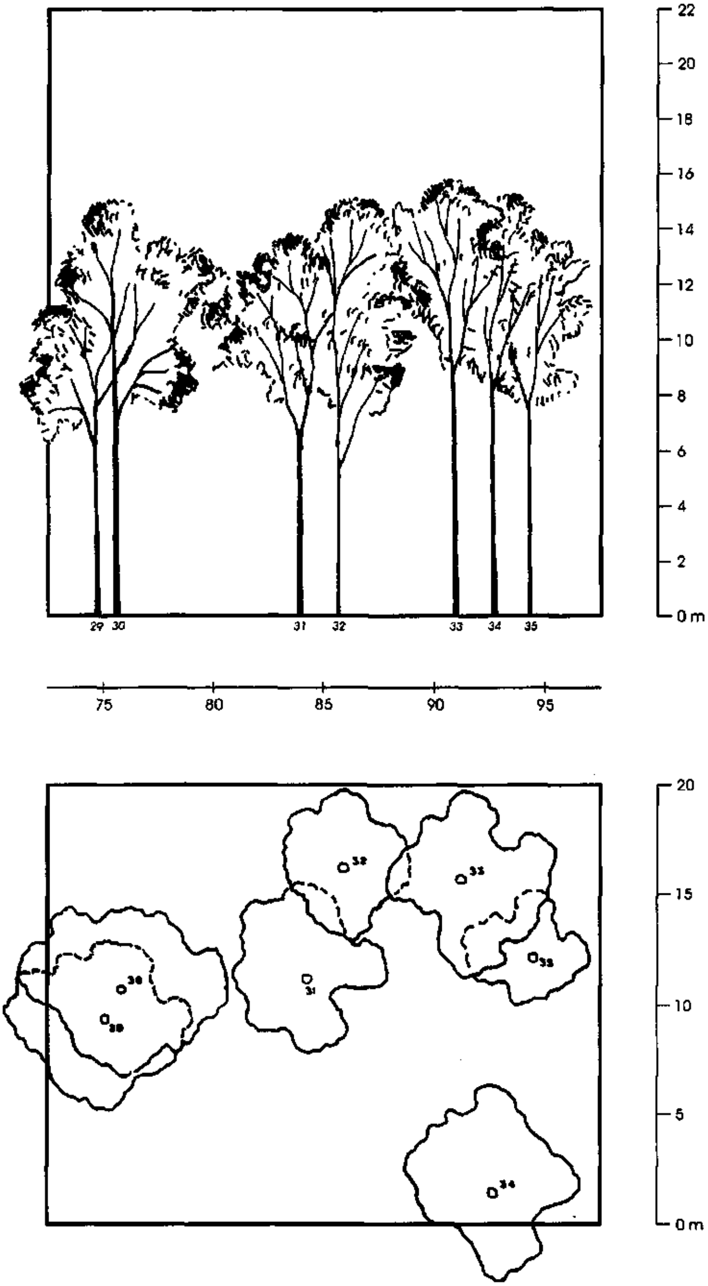
Fig. 2.8. Profile diagram and crown projection of natural vegetation of Sungkai (P. canescens) in Central Kalimantan.
■ = Sungkai [ ] = other species — = upper crown ..... = lower crown



21. P. canescens
21. Dactylocladus stenostachys
23. P. canescens
24. Mangifera sp.
25. P. canescens
26. P. canescens
27. Cinnamomum pendulum
28. P. canescens

Fig. 2.8. (Continued)

■ = Sungkai [ ] = other species ▬ = upper crown ..... = lower crown



29 - 35. Peronema canescens

Fig. 2.8. (Continued)

■ = Sungkai [ ] = other species — = upper crown ..... = lower crown

A B C D

Figure 2.9. Sketch of the architecture of *P. canescens* for the Palangka Raya provenance, central Kalimantan. A. Unbranched, low seedling (epicotyledonary axis). B. Branched sapling, Scarrone's model with some traumatic reiteration. C. Branched pole, like B, but reiteration much stronger. D. Branched adult tree, rhythmic, orthotropic axes, monopodial with determinate growth. Fully expanded crown is a loose multi-array with abundant reiteration (Rossignol et al. 1998). Note branches conforming to Scarrone's model (Hallé et al. 1978) with more or less regular patterns among the axes (Rossignol et al. 1998, p.96). Note the vegetation dominated by Sungkai trees (fig.2.8).

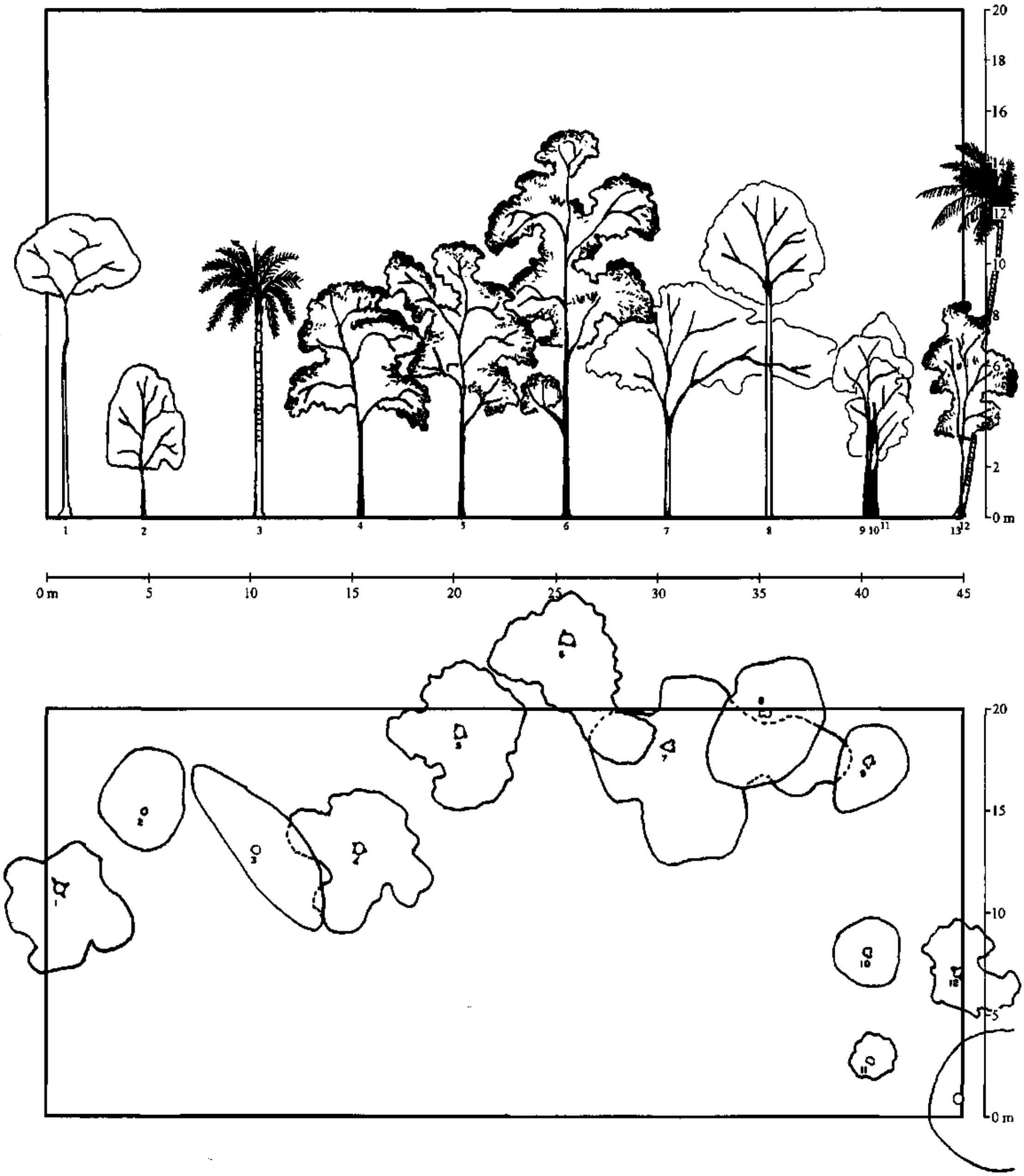
2.3.2.5. South Kalimantan

The use of Sungkai wood is very intensive in the South Kalimantan Province. In some places Sungkai with a diameter of 5 cm is used for roof trusses on account of its lightness and strength. Therefore, it is not easy to find thick Sungkai trees in a vegetation.

In South Kalimantan, Sungkai trees grow in a vegetation which comprises fruit trees and rubber trees. The fruit trees are *Mangifera odorata, Mangifera sp., Durio sp., Cocos nucifera, Bouea macrophylla , Syzygium aromaticum*, and *Arenga pinnata.* The diameter distribution in the plot varies from 7 to 45 cm, and diameters between 11 and 30 cm dominate. A profile diagram, a crown projection map and the Sungkai architecture of a tree are presented in Fig. 2.10 and Fig. 2.11. Some parameters measured in the plot are shown in Table 2.5.

Table 2.5. Some parameters of Sungkai in the South Kalimantan site.
h1 is free trunk height. h2 is total height. g is basal area. Trees 1 to 6 are adult trees. Trees 7 to 9 are poles.

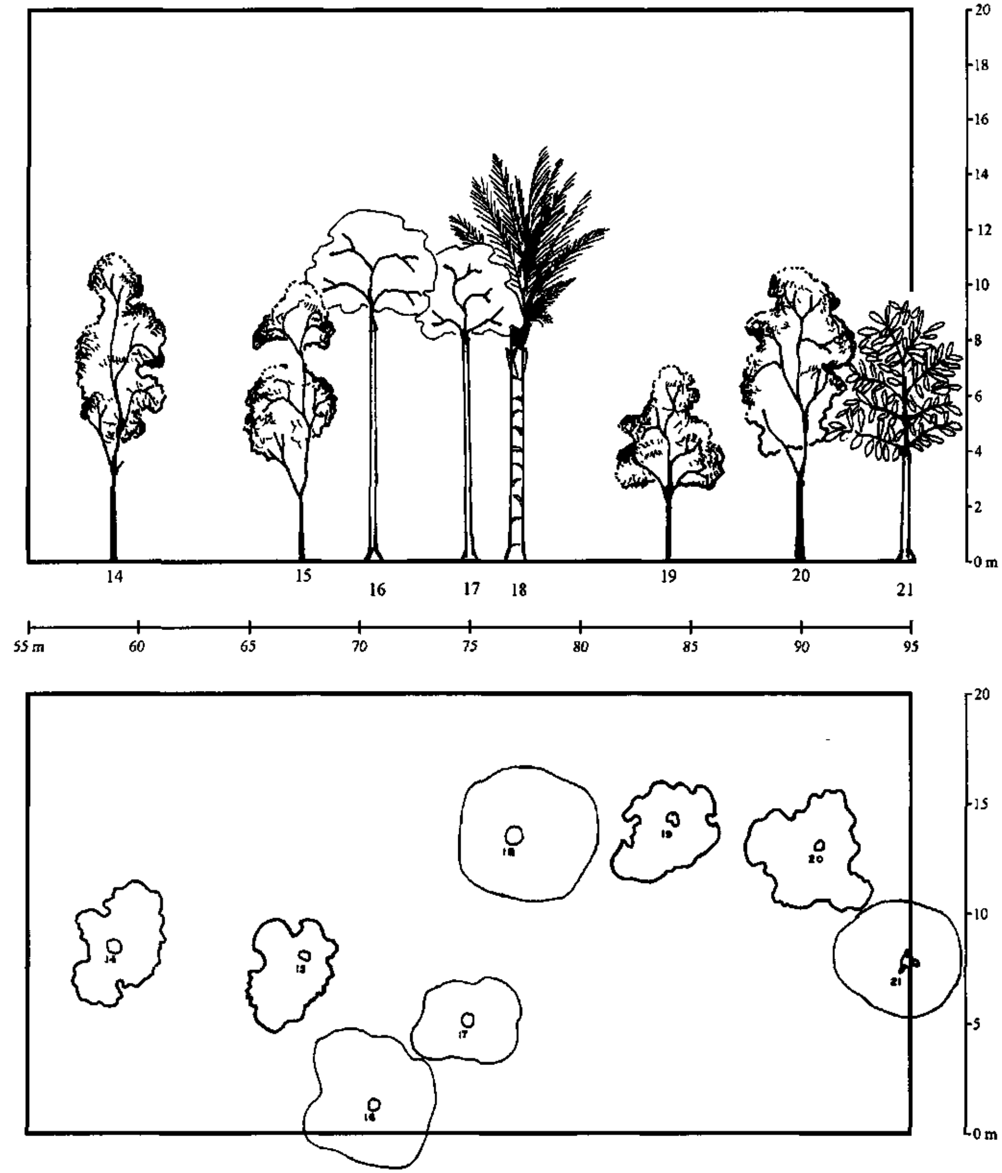
No	Diameter(cm)	h1(m)	h2(m)	g(m2)	v(m3)	Crown diameter(m)
1.	30.3	3.7	15	0.07	0.19	10 x 9
2.	28.1	3.5	9.5	0.06	0.15	7 x 8
3.	27.1	2.2	10.5	0.06	0.09	6 x 7
4.	22.3	2.0	10	0.04	0.06	5 x 5
5.	22.0	3.2	11	0.04	0.08	6 x 5
6.	21.0	3.0	10.5	0.03	0.07	5 x 7
7.	15.9	2.5	8.5	0.02	0.03	4 x 4
8.	15.6	2.5	7.5	0.02	0.03	6 x 4
9.	7.3	2.0	8	0.004	0.01	2 x 3



1. Mangifera odorata
2. Durio sp.
3. Arenga pinnata
4. Peronema canescens
5. P. canescens
6. P. canescens
7. Hevea brasiliensis
8. H. brasiliensis
9. Mangifera odorata
10. Eugenia aromatica
11. P. canescens
12. P. canescens
13. Cocos nucifera

Fig. 2.10. Profile diagram and crown projection of nutural vegetation of Sungkai (*P.canescens*) in South Kalimantan

■ = Sungkai [ ] = other species ▬ = upper crown ..... = lower crown



14. Peronema canescens
15. P. canescens
16. Hevea brasiliensis
17. Mangifera sp.
18. Arenga pinnata
19. P. canescens
20. Peronema canescens
21. Bouea macrophylla

Fig. 2.10. (Continued)

■ = Sungkai [ ] = other species
▬ = upper crown ..... = lower crown

Figure 2.11. Sketch of the architecture of *P. canescens* for the Banjarmasin provenance, South Kalimantan. A. Unbranched seedling (epicotyledonary axis). B. Sapling, without sequential branching, only reiteration. C. Branched pole, in its inferior two-thirds showing traces of Scarrone's model; above some reiteration. D. Branched adult tree, rhythmic, orthotropic axes reiterated in a polyarchical pattern (Edelin 1991). Note the inversion point (end of sole trunk, Oldeman 1974a) is low in the adult tree, probably linked to much room each (e.g. fig.2.10, m 70 to m 85; Oldeman 1990). The vegetation consists of fruit trees and secondary species (fig.2.10)

2.3.2.6. Bengkulu

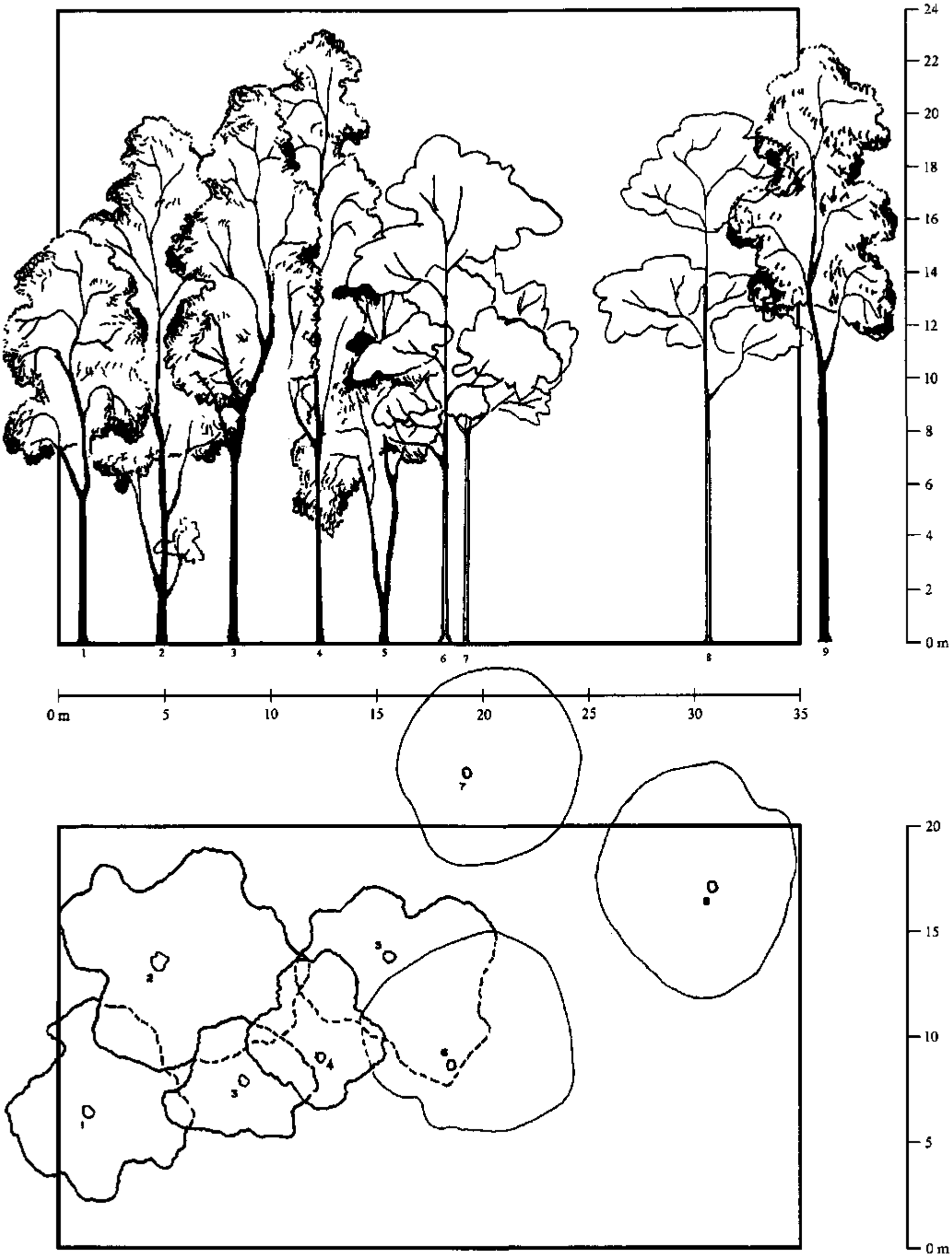
In Bengkulu the sample plot was a garden with several natural big trees and also planted trees. Other plants included grasses, shrubs, herbs, and several teak trees planted seven years ago by the owner of the land. Originally the stand was a natural vegetation. However, after the owner had installed a very simple sawmill in the site to produce planks and beams to supply both for his own needs and to meet the demands of the market in the village. Only a few big trees were left in the site, including Sungkai trees, whose pioneer temperament indicated that large quantities of wood had been harvested and had left behind large canopy openings.

The sample plot also hosted several seedlings and saplings of Sungkai. On close observation, many of them were stump suckers reiterating the architecture of Sungkai. Other species found in the sample plot were *Parkia speciosa, Hevea brasiliensis, Alstonia sp.* and *Garcia spi.* The diameter composition varied from 16.5 to 43 cm. According to the owner, the age of many Sungkai trees was about 25 years.

Some parameters measured in Sungkai in the plot are shown in Table 2.6, a profile diagram, a crown projection map of the vegetation, and the tree architecture of Sungkai from seedling to adult tree are presented in Fig.2.12 and Fig.2.13.

Table 2.6. Some parameters of Sungkai in the Bengkulu site
h1 is free trunk height. h2 is total height. g is basal area.

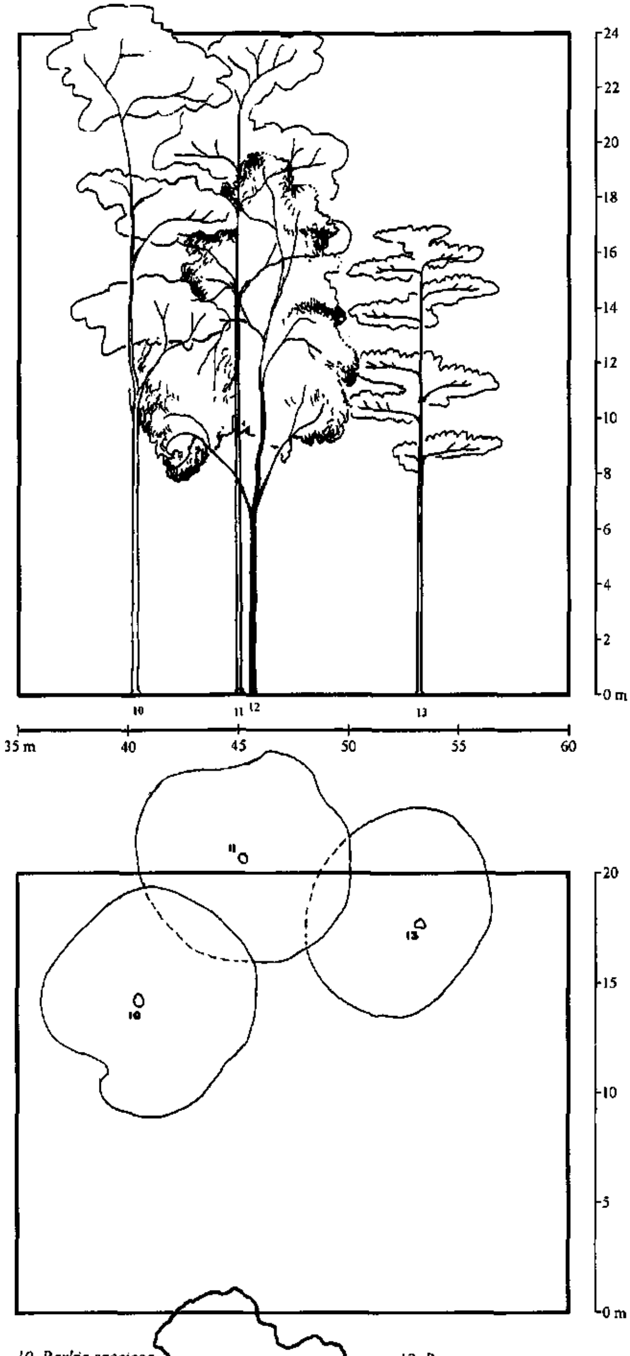
No	Diameter(cm)	h1(m)	h2(m)	g(m2)	v(m3)	Crown diameter(m)
1.	42.9	1.7	20	0.144	0.172	12 x 11
2.	31.3	10.3	22.5	0.077	0.554	8 x 10
3.	29.9	7.0	21	0.070	0.344	7 x 7
4.	28.3	7.3	23	0.063	0.322	7 x 8
5a	27.1	6.0	15	0.058	0.242	7 x 6
5b	24.1	5.6	15	0.046	0.179	6 x 5
6.	26.5	5.6	15.5	0.055	0.216	9 x 10
7.	21.0	6.2	19	0.035	0.150	11 x 11



1. Peronema canescens
2. P. canescens
3. P. canescens
4. Peronema canescens
5. P. canescens
6. Garcinia sp.
7. Hevea brasiliensis
8. Parkia speciosa
9. Peronema canescens

Fig. 2.12. Profile diagram and crown projection of natural vegetation with Sungkai *(P. canescens)* in Bengkulu.

■ = Sungkai [ ] = other species — = upper crown ..... = lower crown



10. Parkia speciosa
11. P. speciosa
12. Peronema canescens
13. Alstonia scholaris

Fig. 2.12. (Continued)
■ = Sungkai [ ] = other species
▬ = upper crown ····· = lower crown

Figure 2.13. Sketch of the architecture of *P. canescens* for the Bengkulu provenance. A. Unbranched seedling (epicotyledonary axis). B. Branched sapling with Scarrone's model, little branched as yet, and reiterated once (to the right). C. Branched pole, built by reiteration. D. Branched adult tree with rhythmic, orthotropic axes. Note sturdy reiteration pattern in the crown, and low inversion point (Oldeman 1974). The open architecture of the younger phases is typical of these trees from open gardens (fig.2.12), in which poles are later dense-crowned.

2.3.2.7. Lampung

In Lampung, Sungkai cuttings were collected in a sparse young secondary vegetation and on river banks in Kecamatan Sungkai. Prior to developing oil palm and rubber tree gardens, plenty of Sungkai tree were found in the northern part of Lampung, because of which the area was later called Kecamatan (district) Sungkai. Nowadays, the area is managed by PT Inhutani V (a State timber company) Lampung to plant industrial forests with some fast growing species, including Sungkai.

No profile diagram or crown projection map of the vegetation are presented, because no natural vegetation with Sungkai was available. The tree architecture of Sungkai from seedling to adult tree is presented in Fig.2.14.

2.3.2.8. Padang

In Padang Sungkai cuttings were collected in homegardens where Sungkai trees were planted as live fences or in hedges. Most Sungkai trees found in Padang are young , with a few exceptions. The diameter distribution ranged from 5.7 to 11 cm, and the height from 8 to 12 m. Old trees showed a diameter varying from 22 to 50 cm and a height from 10 to 15 m. Sometimes young trees were found in a group, and solitary when old.

The tree architecture of Sungkai from seedling to adult tree is presented in Fig.2.15. As in Lampung and for the same reason, no profile diagram and crown projection map of vegetation are presented.

2.3.2.9. Pontianak

In Pontianak, cuttings of Sungkai were collected in a vegetation strip along roads leading to Sukadana, in the territory of the Sei Belit village. Cuttings were collected from trees with diameters between 15 and 43 cm, and with total heights between 10 and 15 m.

The tree architecture of Sungkai from seedling to adult tree is presented in Fig.2.16.

3.2.10. Palembang

In Palembang cuttings were collected in home gardens and in the bush. Cuttings were collected from trees with diameters between 15 and 40 cm, and with total heights between 12 and 20 m.

The tree architecture of Sungkai from seedling to adult tree is presented in Fig.2.17.

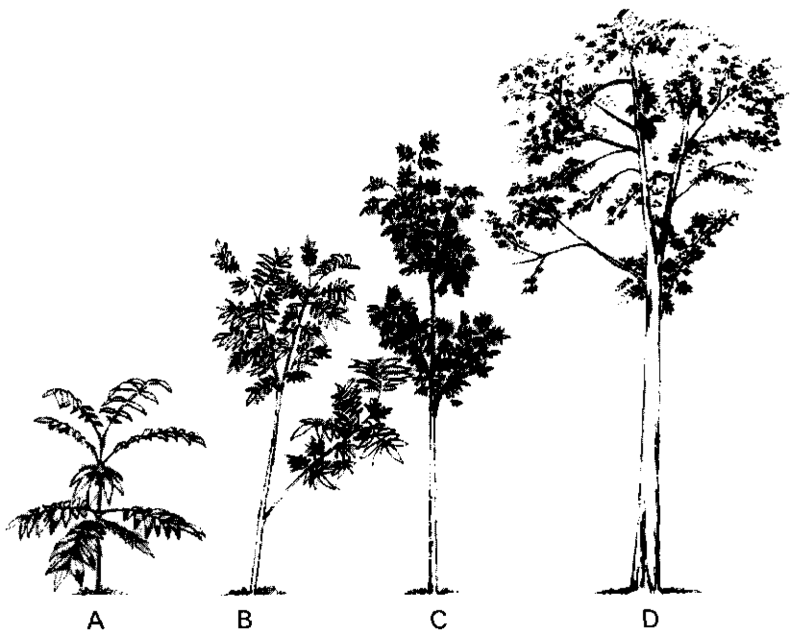


Figure 2.14. Sketch of the architecture of *P. canescens* for the Lampung provenance. A. Unbranched seedling (epicotyledonary axis). B. Sapling branched by reiteration, but barely any branching. C. Branched pole, built by reiteration of incomplete models. D. Branched adult tree, rhythmic, orthotropic axes. The fully expanded crown is a loose multi-array of axes and simple branched arrays (Rossignol et al. 1998 p.96). Note the open architecture of the younger phases in these trees from riversides and young secondary vegetation, in which poles are later dense-crowned (cf.Fig.2.15).

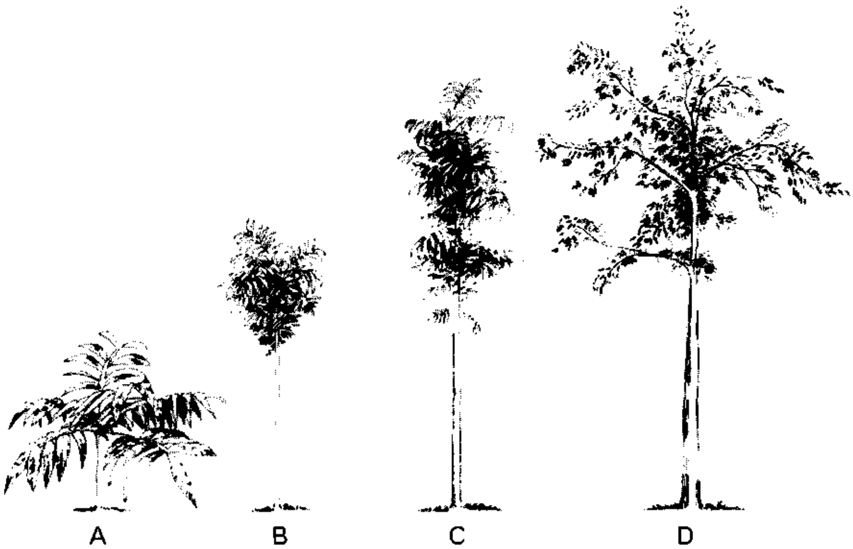


Figure 2.15. Sketch of the architecture of *P. canescens* for the Padang provenance, West Sumatera. A. Unbranched *seedling* (epicotyledonary axis). B. Little *branched sapling, only* reiteration. C. Little branched pole, only reiteration. D. Branched adult tree, rhythmic, orthotropic axes, monopodial with definite growth. The fully expanded crown is a more or less regular multi-array. *Note the dense, bushy physiognomy of saplings and poles in these trees from hedges and* live fences (fig.2.14).

Figure 2.16. Sketch of the architecture of *P. canescens* for the Pontianak provenance, West Kalimantan. A. Unbranched but regenerated seedling (epicotyledonary axis). B. Unbranched sapling, only some trunk regeneration by reiteration. C. Pole, with only a little reiteration but irregular stem shape indicating a regeneration pattern. D. Branched adult tree, rhythmic, orthotropic axes. The fully expanded crown is a loose array (like fig.2.13, but less voluminous and sturdy). Note that the young phases are open, with large leaves, high and typical of open environments (fig.2.15), poles and adult roadside trees being also comparatively open-crowned.

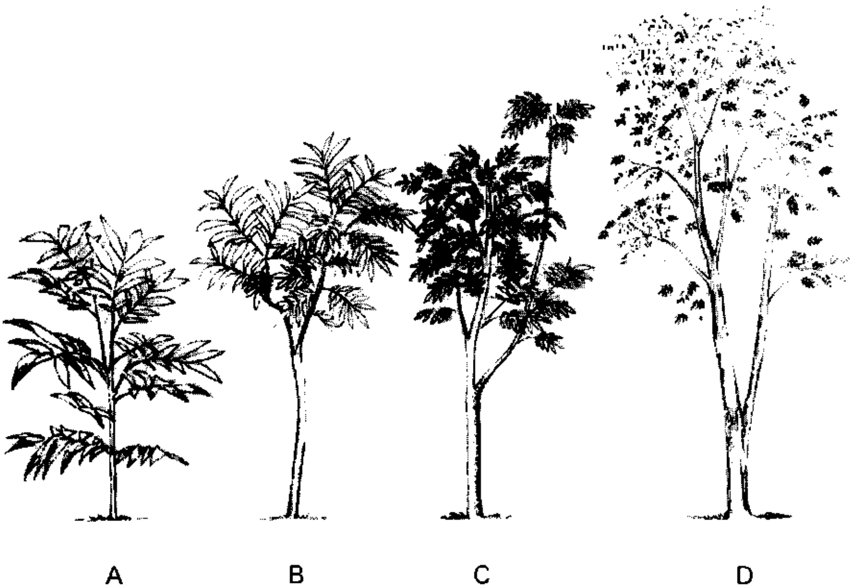


Figure 2.17. Sketch of the architecture of *P. canescens* for Palembang, South Sumatera. A. Seedling (epicotyledonary axis with early reiteration). B. Unbranched sapling, only some trunk regeneration by reiteration. C. Branched pole, built by reiteration. D. Branched adult multistemmed tree, rhythmic, orthotropic axes. The fully expanded crown is a loose array. Note the open crowns and big leaves in young phases, multistems and/or other forms of prolific reiteration in pole and adult crown of these trees from highly dynamic and stressful tree environments in home gardens (fig.2.12).

2.3.3. The tree architecture of Sungkai *(Peronema canescens)*

The characteristics of Sungkai trees are as follows : they are evergreen or deciduous shrubs or small to medium-sized trees up to 30 m tall. Branch modules are orthotropic with definite growth. The main trunk is monopodial with indefinite, rhythmic growth, bearing sympodial branch complexes. In its early development, the branch shows a repetition of the monopodial growth of the trunk, then sympodial branches begin due to terminal flowering. Each branch complex is three-dimensional, but not symmetric, as in Leeuwenberg's model. Each module has spirally arranged leaves (phyllotaxis is opposite-decussate). Leaves opposite, imparipinnate, with a purplish tinge when young; leaflets in 3 to 11 opposite or subopposite pairs, sessile or shortly stalked, lanceolate, up to 35 cm x 7.5 cm. Inflorescence paniculate, terminal or in the axils of the uppermost leaves, large and widely branched, erect, 25 to 60 cm, dense fig.2.18).

If the above characteristics are related to the architectural models (Hallé & Oldeman 1970; Hallé et al. 1978), Sungkai's architecture is close to both Scarrone's and Leeuwenberg's models. Scarrone's model has the following characteristics (Hallé et al. 1978, p. 213): "orthotropic rythmically axes, branch-complex orthotropic and sympodially branched as a result of terminal flowering". As described above, Sungkai conforms to those characteristics. Sungkai belongs to Scarrone's model because of the existence of a well-developed monopodial trunk, especially in the pole phase. However, the Sungkai tree architecture in the adult tree is more or less convergent with Leeuwenberg's model. The abundant reiteration of Scarrone's model obscures the distinctive single, rhythmic trunk.

According to Hallé et al.(1978, p. 98), "Leeuwenberg's model consists of equivalent orthotropic modules, each of which is determined in its growth by virtue of the ultimate production of a terminal inflorescence; branching is three-dimensional". Indeed, some characteristics of Leeuwenberg's model occur in Sungkai. These are its orthotropic modules with definite growth, the three-dimensional sympodial branching, and the terminal inflorescences. However, this convergence with Leeuwenberg's model only occurs at the end of the branch complexes, as described by Hallé & Oldeman, 1970, p.23) in *Fagara rhoifolia*. In addition, as a pioneer species, Sungkai is generally found in secondary vegetation, which is often the case with the species of both Leeuwenberg's and Scarrone's models. Hallé et al.(1978) mentioned that Leeuwenberg's model is less common in rain-forest species than in species of secondary vegetation and disturbed sites both in the tropics and in temperate regions.

So, based on the above description, the architecture of Sungkai represents the model of Scarrone, converging when older with Leeuwenberg's model. This confusion between one model and another which occurs within a single, old individual tree often occurs in other species (Hallé, et al.1978). It was recently interpreted by Rossignol et al. (1998, chapter 4) as an adult crown forming a loose "multi-array" of more or less reduced axes and more or less complete models, set together in an opportunistic pattern dictated by the irregular environment rather

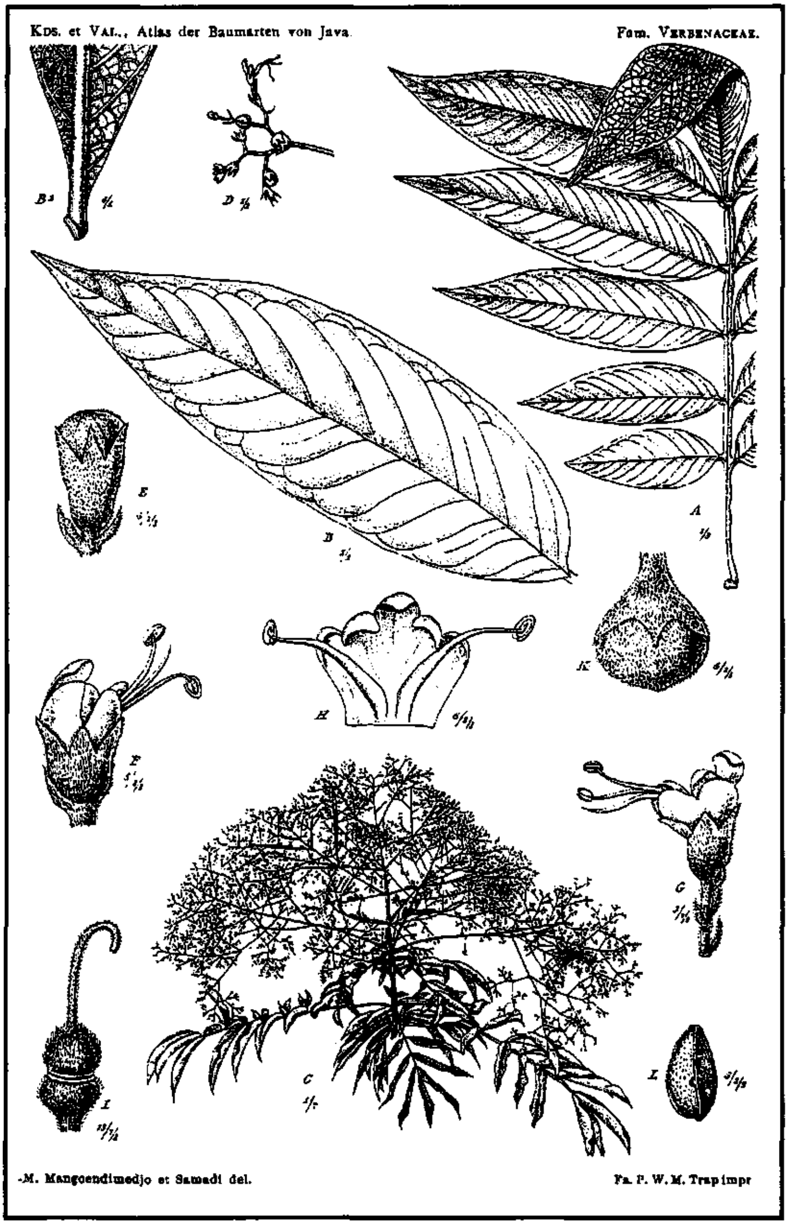


Fig. 2.18. *Peronema canescens* Jack. (VERBENACEAE): A leaf, B leaflets, B1 Part of the lower leaf surface, C Flowerering branch, D Part of inflorescence, E Flower bud, F - I Flower with analysis, K, L, Fruit with analysis (from Koorders & Valeton, 1914).

than by an inherited, regular architecture programme for the building of whole, big crowns. Edelin (1991) spoke of a polyarchic building plan of such crowns. Understanding these features has a bearing on Sungkai silviculture.

2.4. Ecological base of silviculture

Ecological information on a certain species is important and basic for silvicultural treatments. On the basis of ecological behaviour of the species or provenances, their growth can be improved. Tree growth can be increased by meeting ecological requirements.

Based on field study and cross-checks with references regarding Sungkai (*Peronema canescens*), several facts stand out in relation to the ecological base of silviculture of the species.

Three areas will be presented in this section, i.e., tree architecture of the Sungkai tree itself, flowering seasons and the direct environment of planting material.

* Tree architecture of the Sungkai tree

Due to a lack of information on the tree architecture of the Sungkai tree in the literature, the characteristics of the tree, such as axes, branching pattern, flowering form were studied. The architectural life cycle series (seedling, sapling, pole, mature tree) were sketched according to Oldeman's protocol (1979). The characteristics of the Sungkai tree were then compared with the characteristics of the existing tree architecture in Hallé and Oldeman, 1975, Hallé et al. 1978, Oldeman, 1983 and Oldeman 1990.

Based on the study of the above characteristics, the architecture of the Sungkai represents the model of Scarrone, converging when older with Leeuwenberg's model by forming a loose multi-array in which axes rather than models determine the architecture. Transitions between one model and another within a single, old individual often occur in other species (Hallé, et al.1978; Rossignol et al. 1998). Detailed description of the tree architecture of Sungkai is presented in Section 2.3.2 in this Chapter.

The tree architecture codetermines the "ecological profile" of the species. The "ecological profile" of an organism is the strategy pattern of the organism as a response to environmental dynamics, in order to meet its ecological requirements (Oldeman and Binnekamp, 1994). Earlier, Oldeman (1992) wrote of "production geometry". It is very important to know this profile, in order to produce timber according to the specifications. Through an ecological profile, the requirements of a species as to its environment are recognised, e.g. an architectural strategy as a response to site dynamics.

* Flowering season

The flowering season of Sungkai differs between Sumatera and Kalimantan. The flowering season in Sumatera falls between July and August, in Kalimantan between January and March. Soerianegara and Lemmans (1994) reported that the flowering season in Java occurs between June and July. These authors say that the first flowering happens when the trees are about five meters high, in Java at an age of approximately five years. This information is very important for seed collection. However, the propagation of Sungkai itself, if no seedtree selection is involved, is easier by cuttings.

* The direct environment of the Sungkai tree

"Direct environment" (Rossignol et al.1998) is the environment closely surrounding an organism, as opposed to the "far environment" of climatic and edaphic conditions.

Adaptability of a provenance or a species to new site conditions is a prerequisite to their health. Healthy plantations have much better chances to reach the specific objective of the plantation, i.e. to yield desired products or services. However, provenances or species frequently respond differently to each other in new sites, e.g. *Acacia mangium* in several sites (Anon, 1980) and European rabbits in Australia. Hence, the first step in the establishment of a plantation forest is to ensure that the provenance used is optimally adapted to the new site.

As mentioned earlier, the original vegetation surrounding each provenance varied from natural original vegetation to home gardens, bush or shrublands, and from a natural stand dominated by Sungkai to a mixed species stand (natural or artificial). Such conditions influence the tree architecture to some extent. Here follows a synopsis of this relationship.

The tree architecture of the Sungkai tree from East Kalimantan (old secondary forest) closely conforms to Leeuwenberg's model. Its inversion point is high in the adult tree; abundant reiteration in this loose multi-array (Rossignol et al.1998); see adult tree in fig.2.3. Meanwhile, the architecture of the Sungkai tree from Jambi, Sumatera (young secondary forest) is different from the first one. The tree shows incomplete models, in between Scarrone's and Leeuwenberg's model. The whole crown is a loose multi-array of branches, with certain regularity probably induced by its direct environment (m 60 to m 70 on the transect in fig.2.4; Rossignol et al. 1998). See also the adult tree in fig.2.5.

A different performance is shown by the architecture of Sungkai trees from central Kalimantan, which conforms to Scarrone's model. This performance differs from the above two. This is probably due to the direct environment, the vegetation dominated by Sungkai trees. This consists of many individual trees of the same species and with the same temperament (Sungkai). See also the adult tree in fig.2.9.

In general, the provenances from Padang, Bengkulu, Lampung and Pontianak were from open environments, although each site showed some variation. The trees showed incomplete models (Scarrone, Leeuwenberg) with a slight variation in crown performance. Sungkai trees from Padang showed a more or less regular multi-array in their crowns; Sungkai tree from Bengkulu showed a sturdy reiteration pattern in the crown and a low inversion point (Oldeman, 1974); the Lampung provenance showed a loose multi-array of axes and simple branched arrays (Rossignol et al. 1998); and the Pontianak provenance showed a loose multi-array in its fully expanded crown. See also adult trees in figures 2.13 to 2.16.

Hallé (1976) described the variation of vegetative architecture in certain species recorded by Kahn, e.g. *Euphorbia mellifera, Arbutus* unedo and *Mangifera indica*. These trees conform to Leeuwenberg's model in full sun, and to Scarrone's model in the shade. Their vegetative architecture is correlated with the direct environment, most closely with the amount of incident light.

As a general rule, the tree architecture is a constant, inherited character, valuable for specific identification. However, observation demonstrates that specific, qualitative variation of the vegetative architecture sometimes exists (Hallé, 1976).

The experiment with our planting material in Sungkai provenance trial is a further tool in attempting to achieve the above aims. Planting material (cuttings) which are from a relatively open environmental condition, showed a better growth in the trial plots. In contrast, cuttings originating from a closed environment, showed a slightly lower growth than the former. This is assumed to be due to the selection by the natural direct environment and the tree of the planting materials, in addition to general climatic and edaphic conditions. Generally, a new planting site is an open environment. This is, of course, different from environmental conditions in the original vegetation. Cuttings collected from a closed environment may be stressed to some extent by an open environment. Meanwhile, the cuttings collected from an open environment are already familiar with such conditions. Their stress is less and they are more adapted than the cuttings from the shaded environment.

Wangermann *in* Bakker (1998) stated that species under high stress, at the edge of their range, lived considerably longer than their unfortunate partners. Rossignol et al. (1998) stated that most forms of natural stress do not reach at most organs and organisms, because they have previously been filtered out or modified by the ecosystem. The architecture dictates growth, maintenance and exchange of matter and energy of a tree with its direct environment.

Chapter 3. SUNGKAI SILVICULTURE : THE NURSERY

3.1. Introduction

Ten groups of cuttings from geographically different sources referred to as provenances, were studied. The provenances and the characterization of the original ecological site of each provenance were obtained in ten provinces in Indonesia. They have been discussed in Chapter 2 (Provenances and their sites).

The objective of observation of provenances of *Peronema canescens* in the nursery stage was to define the initial performance of each provenance. This is useful in evaluating their later performance in the field.

Some parameters were observed. They are : a. nursery survival rate, b. rate of shoot formation, c. rate of finishing shoot formation of given cuttings, and d. start of root formation.

3.2. Material and Method

3.2.1. Sources of Cuttings

The cuttings were collected from ten provinces in Indonesia, i.e. West Kalimantan, East Kalimantan, Central Kalimantan, South Kalimantan, West Sumatera, Riau, Jambi, South Sumatera, Bengkulu and Lampung. Each provenance was named after the place in each province where it was found (Fig. 2.1).

In determining the candidate trees to become sources of cuttings, a phenotype performance approach was used for the diagnosis. A diagnosis of the trees was made in order to distinguish a "good" phenotype, prior to collecting cuttings. Suitability parameters for wood production in a tree phenotype were height, diameter, stem straightness, crown architecture and health of the tree. A high tree with a large diameter, a straight stem, and a crown architecture expected to capture most light was considered a "good" tree phenotype. Trees with such a suitable phenotype were chosen as a source of cuttings. According to Palmer (1994), vegetative propagation of a good phenotype boosts both stem form and growth rate.

The cuttings were chosen by considering the topophysical position within the whole tree architecture. Of course, Chapter 2 told us that all axes were equivalent, orthotropic, rhythmic and with a terminal inflorescens, so all meristems were equivalent, too. Hence, the topophysical position referred particularly to parts which were physiologically young, with dedifferentiated meristem (Rossignol et al. 1998). The dedifferentiated meristems were capable of reiterating the whole model from the start, including the roots and parts of tree crowns (Rossignol et al. 1998). Cuttings were taken with a small handsaw and lowered with a rope. The sizes selected were 10 to 12 cm in length and from 1.0 to 1.5 cm in diameter. They were sprinkled with water prior to be put in labelled jute or gunny sacks so as to prevent the cuttings from drying out during transport. The sacks were kept moist with water , then put into plastic bags and finally transported to Banjarbaru

Tabel 3.1. Relative survival rate of each provenance (%)

No.	Provenances	Provinces	Survival rate
1.	R i a u	Riau	100
2.	Banjarmasin	South Kalimantan	100
3.	Pontianak	West Kalimantan	100
4.	Jambi	Jambi	100
5.	Palembang	South Sumatera	90
6.	Bengkulu	Bengkulu	90
7.	Palangka Raya	Central Kalimantan	82
8.	Samarinda	East Kalimantan	81
9.	Padang	West Sumatera	53
10.	Lampung	Lampung Province	52

Among the main determinants of meristem shoot survival of the two provenances, are certainly the time it took to transport the cuttings from their original site in Sumatera to the Banjarbaru nursery in South Kalimantan, and the source of the cuttings itself. Compared with the other provenances, the transport from the Padang and Lampung cuttings took longer, 7 and 10 days respectively. Other provenances were only in transit for about 3 to 4 days. It must be assumed that some cuttings began to dry out due to the length of time of transport, so eventually they could not produce shoots. However, the remaining fresh cuttings from the Padang and Lampung provenances still had the ability to produce shoots, as proven by the rate of shoot formation of Lampung, only four days after insertion in the medium. This places the Lampung provenance in second position, together with Riau, in terms of the rate of shoot formation. The same occurred in the Padang provenance, though this one took only third position in terms of rate of shoot formation. As mentioned in Chapter 2, cuttings from Padang were collected in home gardens where Sungkai was planted as fences around the yard and along roadsides. Indeed, the source of cuttings varied from quite mature trees to relatively young trees, due to a limited number of Sungkai tree sites.

For the same reason, Lampung provenance contained a mixture of cuttings from young and mature trees, although they were collected in the secondary vegetation. Personal observations in the nursery of an industrial forest plantation (IFP) in central Kalimantan in 1997 showed that no more than a 50 to 60% survival rate was achieved by using young cuttings. The company tried to use their own four year-old *Peronema canescens* plantation to produce cuttings in order to support its IFP programme, but they were forced to search for other more satisfactory sources.

Another cause of low shoot survival are pests in the nursery. There were three kinds of pests found in the nursery, i.e., snails (*Achatina fulica*), grasshoppers (*Acrida turrita*) and ants (*Pheidologeton sp.*). Of these, snails were the most dangerous because they eat leaves of young seedlings. Although grasshoppers are also folivores, they seemed to have less impact. Ants were often found in the roots of cuttings. No clear indications exist as to the effect of ants on the roots. Based on our observations during the nursery period, almost all provenances were found to host the three organisms mentioned above, and their presence in each provenance was about equal. Therefore, the low survival rate of the Padang and Lampung provenances was ascribed to transport time and source (genotype) of cuttings rather than to pests. However, pests should, of course, always be kept under close scrutiny.

The provenances of Riau, Pontianak, Banjarmasin and Jambi finally showed the highest survival rate. They were followed by the provenances of Palembang and Bengkulu in second and third position, respectively. Meanwhile, although the provenances of Palangka Raya and Samarinda were not among those three upper positions, their survival rates are still above 80%. Only the provenances Padang and Lampung showed low survival rates (below 55%). As mentioned in Chapter 2, the cuttings from the Samarinda and Palangka Raya provenances were collected in a mature secondary vegetation, whereas the Padang and Lampung provenances were collected in home gardens and younger secondary vegetations, respectively. The different sources of the cuttings and the transport time certainly contributed to the differences in survival rate between the two groups.

3.3.2. Rate of shoot formation

The provenance which first showed shoot initiation on its cuttings on the third day after the insertion date of the cuttings in the medium, was the Palembang provenance. It was followed by the Riau and Lampung provenances on the fourth day. Palembang produced three shoots, Riau and Lampung produced four and ten shoots, respectively. On the basis of the appearance of shoots in the other provenances, they can be ranked as follows : Padang (sixth day), Pontianak and Jambi (seventh day), Bengkulu (eigth day), Banjarmasin and Samarinda (ninth day) and Palangka Raya (twelfth day).

As mentioned above, Palangka Raya was in the last position, although it had a good survival rate (82%). The Palangka Raya provenance started shoot initiation later than the others. Despite their quick initiation of shoot formation, Lampung (second position) and Padang (third position) provenances had poor survival rates. This phenomenon may have been caused by the source of cuttings. The cuttings from Palangka Raya came from trees relatively more mature than the cuttings from Padang and Lampung. As described in Chapter 2, the cuttings collected in Palangka Raya came from a mature vegetation, whereas in Padang and Lampung the cuttings were collected in younger secondary vegetations and home gardens. It is estimated that young cuttings tend to initiate shoots quicker than mature or old cuttings because they have more and physiologically younger meristematic tissue than mature cuttings. However, because stocks of carbohydrates in the cutting are insufficient to sustain the shoot until the cutting is fully rooted, the shoot is progressively stressed by a lack of nutrients, and will eventually die. That is why the Lampung and Padang provenances were quick to start shoot initiation, but few survived.

The Palangka Raya, Samarinda and Bengkulu provenances, despite their slow initiation of shoot formation (sixth and fifth positions), had a high survival rate (81% and 90%). Again, cuttings of the two provenances came from relatively more mature trees than the cuttings of the Padang and Lampung provenances. Hence, we see a tendency in cuttings collected from mature vegetation or mature trees, to start shoot initiation slowly, but to have a high survival rate. This fits in with the multistem architecture displayed by the species under stress (Chapter 5).

3.3.3. Rate of finishing shoot formation

The Riau and Pontianak provenances finished shoot formation in all their cuttings in fifteen days; they were faster than the rest. The last one to finish was the provenance from Palangka Raya. However, its shoot survival was higher (82%) than Padang (53%) and Lampung (52%). The Palangka Raya provenance finished its shoot formation in forty days. Meanwhile, the Padang and Lampung provenances finished after thirty and twenty days, respectively.

After Riau and Pontianak in first position (15 days), second position was taken by Palembang (18 days), and the third was shared by the Banjarmasin (20 days) and Bengkulu (20 days) provenances. The rate of finishing shoot formation of each provenance hence varies between 15 and 40 days. When the period of time between the start of shoot initiation and the end of shoot formation is considered, the Pontianak provenance finished shoot formation very fast. It only took 8 days. The second position was taken by Banjarmasin and Riau with 11 days.

So, the Pontianak provenance both started and ended shoot formation fastest. Meanwhile, the Riau provenance was first as to the insertion date and second regarding the starting time of shoot initiation. The Banjarmasin provenance was third as to the inserting date and second regarding the start shoot initiation.

The Padang and Lampung provenances were seventh and fifth regarding the finishing of shoot formation, respectively, though they were third and second regarding the start of forming shoots. Despite a late start of shoot formation, the Banjarmasin and Bengkulu provenances were faster than the Padang and Lampung provenances to finish shoot formation. Meanwhile, the Jambi and Samarinda provenances were the same regarding the start and the end of shoot formation.

The whole image of the end of the shoot formation period agrees with the initiation of shoot formation (3.3.2).

3.3.4. Start of root formation

The fastest root formation was shown by the Riau provenance, on the eighteenth day, followed by the Pontianak and Palangka Raya provenances, on the twenty-third day, and the Banjarmasin provenance on the twenty-sixth day. The latest root formation was shown by the Lampung provenance on the forty-first day. Meanwhile, the Padang provenance, which usually was slow as to other criteria, took fourth position in root formation.

It is generally assumed that the rates of root and shoot formation are linked (Kramer & Kozlowski, 1979). In spite of its last position as to the rate of shoot formation, Palangka Raya took only eleven days after shoot formation started to form roots on its cuttings. Meanwhile, the Palembang and Riau provenances at first and second position in the rate of shoot formation, respectively, started to form roots on their cuttings 30 and 14 days after shoot formation. The longest time period from shoot formation to root formation was shown by Lampung with 37 days, followed by Samarinda with 30 days. Supriadi (1991) reported that root initiation varied from 17 to 27 days after the inserting date, and he added that all cuttings, in general, had a high rooting success, ranging from 60 to 100% (Supriadi, 1991, p.54).

As mentioned, the objective of observing the provenances in the nursery stage was to define the initial performance of each provenance. In order to know the performance of each provenance, a ranking approach was used, in which the rank of each provenance was determined by the parameters discussed in the previous part. The first rank was considered to show the "best" performance (see 3.2.1) and the last rank the worst. In relation to *P. canescens* silviculture, the ranking resulting from the present study could only be approximate. However, it is a tool for giving direction to initial management decisions.

All provenances were ranked according to each parameter. For instance, the Riau provenance was first in terms of *survival rate, moment of finishing shoot formation*, and start of root formation, and second regarding the rate of shoot formation. These data were recapitulated for all provenances in Table 3.2. The table shows both the position of each provenance according to each parameter and the rank according to all parameters together. They were treated as if they had equal weight, which is justified because they represented mutually dependent processes of adaptation

The table shows two or more provenances of the same rank, defined by certain parameters. The same position means that two or more provenances reached the same results following the system of ranking used here. For instance, the Riau, Pontianak, Banjarmasin and Jambi provenances together occupy first position because all show a survival rate of 100%. Another instance are the Riau and Pontianak provenances, which are first in terms of time of finishing shoot formation, because they finished in the same time as the others or faster.

First, the position of each provenance was evaluated according to each parameter. Then, the ranking was determined based on the position levels of each provenance for all parameters. For instance, the Riau provenance ranks first among all provenances, due to its first position in three parameters and its second position in the fourth parameter. The Pontianak provenance ranks second with two parameters in the first position, one parameter in second position, and one parameter in fourth position. Meanwhile, the Palembang provenance is considered slightly better than the Banjarmasin provenance because it had two parameters in second position, and one parameter in the first and fifth positions, respectively, whereas the Banjarmasin provenance had two parameters in third position, and one parameter in first and sixth position. So the Palembang and Banjarmasin provenances ranked third and fourth.

Second, an arithmethic approach was used to add all rank numbers per provenance and per parameter. So, a certain provenance which had the smallest total number occupied the first rank. For instance, the total numbers of the Riau and Lampung provenances amounted to 5 and 22, so the Riau provenance ranked first and the Lampung provenance ranked much lower (eighth : see Table 3.2). The number in brackets shows the ranking of each provenance.

There is a slight change in ranks of the upper group of five by using the second approach, i.e. the Banjarmasin and Jambi provenances are of the same rank, whereas the Jambi provenance was ranked 5 by using the first approach. Meanwhile, in the lower group of five, there was a greater change, i.e., the rank of the Padang provenance changed from 9 to 6, Lampung from 10 to 8, Samarinda from 8 to 9, and Bengkulu from 6 to 5. However, the three best positions (the Riau, Pontianak and Palembang provenances) did not change, neither did Banjarmasin (rank 4).

The latter approach has a weakness. If there are several parameters and all are supposed to have equal weight, it may undervalue the importance of the survival rate. For instance, the Lampung provenance was in rank 10 based on the first approach, but it came down to rank 8 when the second approach was used. This is caused by the position of the Lampung provenance ranking second in shoot formation, whereas in fact its survival rate is lowest (see Table 3.2). The same is true for the Padang provenance, with its rank changing from 9 to 6. Again, its survival rate was low (52%). So if the second approach is used for a broad application, there must be a correction by weighing the parameters in order to make more accurate and reliable.

Based on the ranking system, the most promising provenance at the nursery stage in this trial is the Riau provenance, followed by the Pontianak and Palembang provenances. The Banjarmasin and Jambi provenances also have good prospects of yielding vigorous plants for transplantation. However, the results will have to be confirmed by the result of the follow-up of each provenance in the field stage.

Table 3.2 Ranking of the provenances in the nursery based on four parameters. A = first ranking approach, judging the number of parameters that rank first, second etc. B = second ranking approach, adding up the four ranking numbers

	Parameters					
Provenances	survival rate	rate of shoot formation	finishing of shoot formation	startof root formation	Ranking A	Ranking B
1.R i a u	1	2	1	1	1	5(1)
2.Pontianak	1	4	1	2	2	8(2)
3.Palembang	2	1	2	5	3	10(3)
4.Banjarmasin	1	6	3	3	4	13(4)
5.Jambi	1	4	4	4	5	13(4)
6.Bengkulu	3	5	3	6	6	17(5)
7.Palangka Raya	4	7	8	2	7	21(7)
8.Samarinda	5	6	6	7	8	24(9)
9.Padang	6	3	7	4	9	20(6)
10.Lampung	7	2	5	8	10	22(8)

3.4. How to optimize the nursery production for Sungkai

One of the main nursery objectives is to produce seedlings of high quality and in large quantities. For Sungkai, several efforts have been made to achieve this objective, e.g the use of cuttings of different lengths and diameters, various ages (young and mature cuttings), the topophysical location of the cuttings in the trees, the use of different growth media and their combination, and the use of fertilizers and plant growth regulators.

Generally, however, the cuttings used in the above efforts were taken from local Sungkai trees. As a matter of fact, Sungkai (*P. canescens*) is found in many sites in Kalimantan and Sumatera, even in one site in West Java. The use of various provenances of *P. canescens* in this research or in the above try-outs will enrich the existing information.

Optimizing the nursery production for Sungkai includes taking care of its biological requirements. Among these, nursery survival and the ability to root especially for cutting propagation, are considered to be the most crucial properties.

The use of the results of our provenance trials rests up on these and other properties. The best provenance is expected to provide silviculturally optimal cuttings. Their subsequent tree architecture is expected to be optimal too, so that the cuttings show superior form growth and yield. They also should become trees capable of performing well in interaction with other forest organisms, e.g mutualists, pathogens, pollinators or parasites. However, this exceeds the scope of the present study. The next chapter will mainly concern the architectural dynamics, growth and yield of the ten provenances, and their reaction to three important stress factors.

Table 3.1 indicates the existence of real differences among the provenances, especially in terms of survival rates. The table shows that the Banjarmasin, Riau, Pontianak and Jambi provenances had 100% survival rates, the rest varied between 50% and 95%. High rates of survival are most likely to indicate potential reliability as plantation species.

Most provenances proved to root well. However, differences existed among them in terms of the start of root formation. The fastest root formation was shown by the Riau provenance on the eighteenth day, followed by the Pontianak and Palangka Raya provenances in second position on the twenty-third day, and the Banjarmasin provenance in third position on the twenty-sixth day. Three out of these four provenances showed a 100% survival rate, their differences with other provenances being in root formation. So, different provenances showed different performances, at least on the basis these crucial criteria.

Although the above mentioned figures give the results of only a small-scale experiment, and other Sungkai provenance research is lacking, for the moment it is suggested to use the highest-ranked provenances of the present study as a source of cuttings in trying to optimize the nursery production for Sungkai.

Notwithstanding its preliminary nature, this recommendation is certain to improve current IFP practices. Many IFP companies currently collect cuttings wherever available rather than optimizing the choice of stockplants, certainly due to a scarcity of published information on Sungkai. Certain companies just ask the services of the Sungkai cutting collectors to meet their needs without specifying the stock quality wanted (personal observation). It was clear that in such cases it remained unknown to the company, from what kind and part of the Sungkai tree the cuttings were taken, how the cuttings were handled before and during transport time, and what kind of treatment was applied to avoid the drying out of the cutting during transport. The above factors are now known to influence the quality of the cuttings, as proved by the high variation in survival percentage among the nursery beds, from between 70 and 80% to below 50%.

So, optimizing nursery practices should now already be based on the present study by using the best provenances, by following the best available procedures of handling the cuttings. This means leaving the cuttings in the plastic tunnel for two or three weeks and then plant them in the field under a shading screen for about six weeks, and finally let them harden out in the open area for two months before planting them out in the field.

The following information from other authors is of direct benefit to forestry practices :

** Cuttings with a larger diameter have a better growth performance than those with a smaller diameter. The experiment by Supriadi (1991) showed that cuttings with diameters of 1.5 cm or 1.0 cm were superior in all characteristics. Soerianegara and Lemmens (1994) recommended to use cuttings with diameters of 1.5 to 2.0 cm and a length of 20 to 25 cm.

** The topophysical location from which the cuttings are taken influences the overall quality of cuttings, their ability to root and their subsequent architecture. Supriadi (1991) showed that stump-shoot cuttings perform better than root-sucker cuttings. Abdullah et al.(1991) showed that fully orthotropicstem cuttings grew better than cuttings from otherwise differentiated axes.

**Depending on their availability, the following mixed culture media for nurseries are advised : (a). a mixture of 50% topsoil and 50 % rice-husk compost or maize-stalk compost or sugar cane waste compost; (b). a mixture of 30% top soil and 70% rice-husk compost or maize-stalk compost or suger cane waste compost; (c). a mixture of 70% peat and 30% rice-husk compost. These mixtures are based on the results of the work done by Rusmana (1990) who used seedlings of *Acacia mangium* and *Eucalyptus camaldulensis* and cuttings of Sungkai (*Peronema canescens*) for his experiments.

Chapter 4. SUNGKAI SILVICULTURE : THE YOUNG STAND

4.1. Introduction

In this chapter field results are shown from twenty-six-months-old, planted Sungkai stands of each provenance in terms of their individual characteristics. These are : average survival, height, diameter, multistem reiteration, and crown diameter. The h/d ratio which is relevant to the architecture of the tree (Oldeman, 1990) will also be discussed.

During the drought in Indonesia in 1997, extensive fires raged in Kalimantan and Sumatera. Their smoke disturbed even South-East Asian regions for quite a long period. Anon. (1977, in Faidil and Anwar, 1998) stated that in 1997 the burnt forests and land covered about 167,500 ha in Indonesia, of which 29,000 ha in the South Kalimantan Province. Inevitably, the fire finally hit also the Sungkai trial plots and burned some but not all trees. Therefore, the survival strategy of Sungkai under fire is discussed later in this chapter. Prior to the presentation of the field results, material and methods used are discussed in section 4.2.

4.2. Material and Methods

4.2.1. Material

The cuttings having formed shoots were prepared during four months in the nursery before being planted in the field. The plantation trial plot was laid out in alang-alang (*Imperata cylindrica*) grassland in the reforestation trial area of Balai Teknologi Reboisasi (Reforestation Technology Agency) Banjarbaru, in Riam Kiwa, South Kalimantan (Fig. 4.1)

The Riam Kiwa trial area is located at latitude 3° 30′ S and longitude 115° E. The topography is undulating and the altitude is between 69 and 152 m a.s.l. (Faidil and Anwar, 1981). The average annual rainfall in Riam Kiwa during the experimental period between 1996 and 1999, was 2043 mm. The mean rainfall and number of rainy days for the period between 1996 and 1999 are presented in Table 4.1. Meteorological data were obtained by daily measuring in the Riam Kiwa site camp, about 850 m from the provenance trial. There is a clear dry season from June to September.

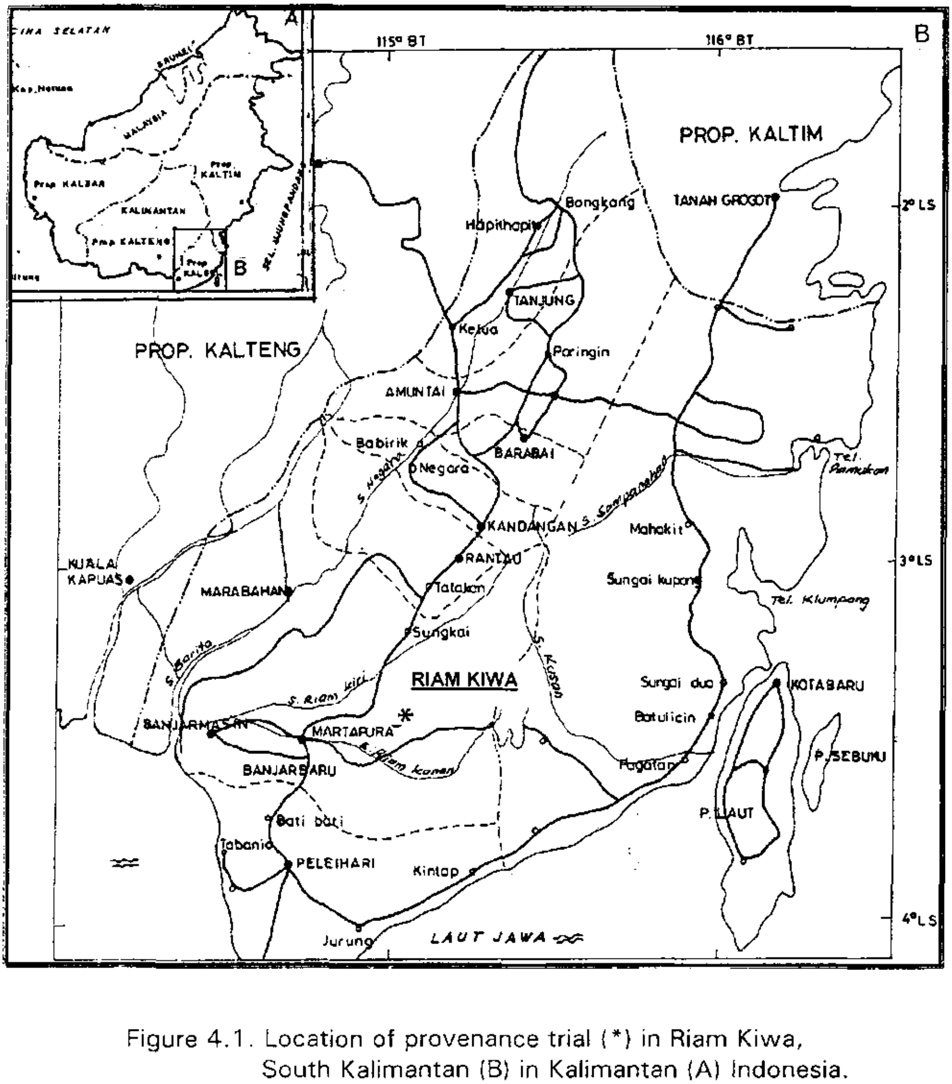


Figure 4.1. Location of provenance trial (*) in Riam Kiwa, South Kalimantan (B) in Kalimantan (A) Indonesia.

Table 4.1. Monthly precipitation (P, in mm) and number of rainy days in Riam Kiwa, South Kalimantan from January 1996 to March 1999.

Month	1996		1997		1998		1999	
	Monthly rainfall/P (mm) and number of rainy days (Dp) 1996 -1999							
	P	Dp	P	Dp	P	Dp	P	Dp
January	239	17	252	21	242	12	333	15
February	320	19	274	18	155	7	291	17
March	309	14	88	6	144	9	287	19
April	111	9	256	14	193	10		
May	65	5	65	3	187	17		
June	152	12	2	1	181	10		
July	82	10	6	2	154	10		
August	120	10	-	-	227	12		
September	151	8	-	-	162	5		
October	151	12	90	4	272	13		
November	169	18	134	12	375	20		
December	242	24	339	13	359	21		

Precipitation and number of rainy days were the lowest in 1997. There was even no rain fall at all for two months, and in the same year there was an extensive fire in Kalimantan, and Riam Kiwa. Compared with the period 1984 to 1992, precipitation and number of rainy days between 1996 and 1998 showed quite a decrease. The rainfall and number of rainy days in the former period were 2127 mm with 166 rainy days, and in the latter period 2090 mm with 133 rain days.

The soil in the experimental plot is of a yellow-red podzolic type, with pH values ranging from 3.5 to 4.3. The soil is heavily textured, with a clay content between 41 and 65%, silt between 20 and 29%, and sand between 5 and 33%. The soil was analysed at the soil laboratory of the Agricultural Faculty of Lambung Mangkurat University in Banjarbaru.

4.2.2. Trial Lay-out and Experimental Design

Randomized complete block design (RCBD) with three replications was used. It is the most commonly used design in forestry experiments. The primary objective of an experimental design for a provenance trial is to ensure estimates of growth and yield differences between tree populations, with precision and accuracy as specified in function of the questions asked. In the present case, precision is specified by the reconnoitering purpose of this study, not by the demand for very precise yield forecasting. In a field trial we usually face systematic variations in soil, microclimate, topography, aspect and other factors which inevitably prevail in every area. In all these cases the simplest, classical method of avoiding population differences being confused with systematic site variation is by *blocking. So, the experimental site was divided into blocks, each* one corresponding to the most important environmental sub-divisions. The blocks were of identical size, each including the same number of experimental plots.

In addition to blocking, assigning one provenance to one plot was done at random, too. This was done so as to avoid bias in the estimate of population *differences.*

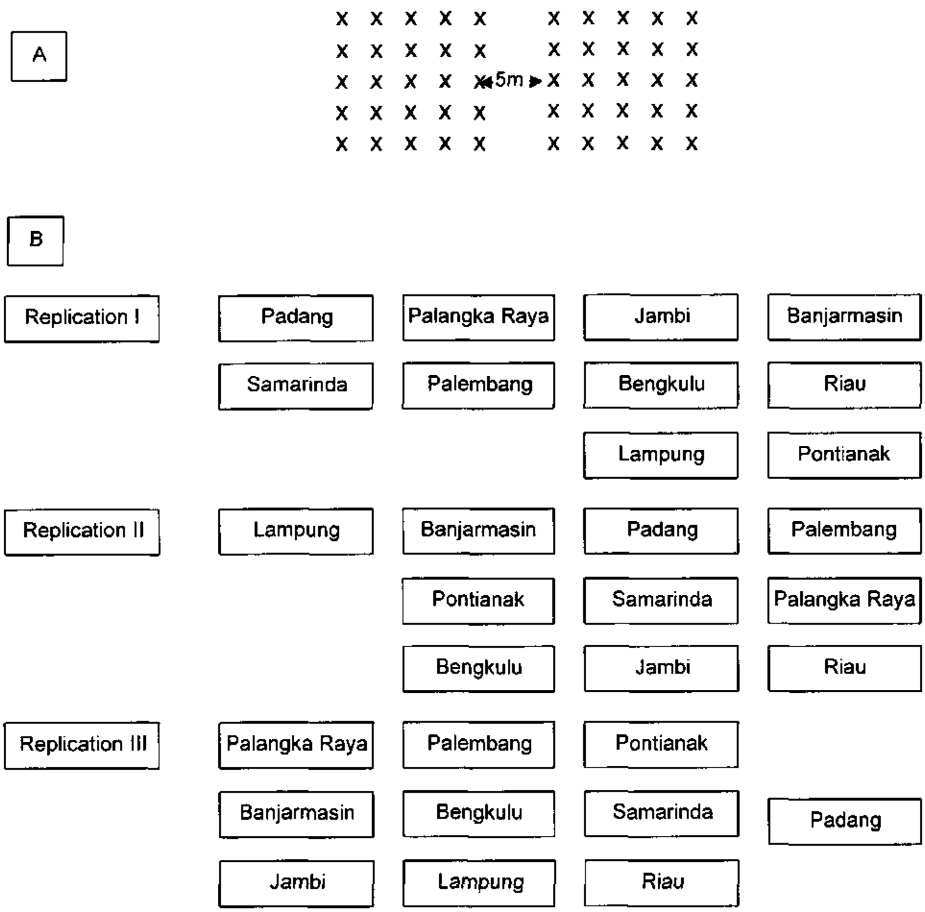


Fig.4.2 A -Plot lay-out of a provenance trial in Riam Kiwa,South Kalimantan. x = one seedling of a certain provenance. B - Provenance plots (each like in A) and their random distribution in 3 blocks.

Each provenance was represented by one 25 tree plot (5 trees x 5 trees), replicated three times. The spacing was 3x3m. The 25-tree plots were separated from each other by a 5 meter wide fire break (unplanted border) which was manually weeded at regular intervals. The lay-out is shown in Figure 4.2.

4.2.3. Planting and Tending

After four months in the nursery, the cuttings having formed shoots were planted in the field. Uprooting or desacking the cuttings was done in the field when they were ready to be planted in the prepared holes. The plastic bags which contained the cuttings in the nursery beds were transported in a wooden box to the trial plots; then each of them was put near the prepared hole. In this way root damage was avoided. No special planting hole was dug; one blow with a local hoe was enough to be able to plant the rooted cutting in the cultivated soil. The distance between the holes was 3 meters, the distance between the rows was 3 meters. Prior to planting, the plastic bag was opened carefully and the cutting with its substrate was planted. Then the holes were closed with soil around the holes. Organic enrichment was not applied in the trial plots, since this had been done in the nursery. Once planted, the new plantations were checked qualitatively by diagnosing the symptoms. Green, fresh plants were considered healthy. Discoloured, withered plants, including those with broken shoots were considered unhealthy.

As the area was dominated by alang-alang grassland (see Mutsaers, 1998), it was mechanically cultivated prior to planting, twice with a disc-plough and once with a rotovator. No fertilizers were used in the field. Manual weeding was carried out every four months, until the plantation was about 18 months old.

4.2.4. Measurements

In relation to the growth rate, total height, diameter (diameter above roots and diameter at breast height), crown diameter, multistem ratio and survival rate were measured. These parameters (except, of course, for survival) were measured eight times, at 3, 6, 9, 12, 15, 18, 21 and 26 months after planting. The survival rates of the different provenances were counted at the age of 26 months. The total height was measured with a measuring stick from ground level to the tip of the shoot. The diameter was measured by using small callipers at 20 cm above ground level for the diameter above roots, and at 1.30 m above ground level for the DBH at the end of the study. The crown diameter was measured by means of a measuring stick. It was assessed twice per tree crosswise and the average of these values was recorded. Nine trees in the middle (core trees) and sixteen border trees of each 25-tree plot were measured.

4.2.5. Data Processing

The averages of the measured parameters were calculated separately per plot with a calculator. The plot average was used as input data in the analysis of *variance (Anova).*

The statistical computation followed the GLM-Anova procedure of the SPSS version 8.0 software. Significant F-values established by Anova were further examined by pairwise comparisons of means in the SPSS software. For survival data and multistem ratios, they were transformed by arcsin transformation prior to the Anova.

4.3. Results

4.3.1. Performance of each provenance in terms of individual characteristics

In this part the field results are shown from the twenty-six-months old Sungkai plantations of each provenance in terms of their individual characteristics, i.e, average survival, height, diameter, multistem reiteration, and crown diameter.

Survival is a useful criterion in selecting silviculturally good provenances for further testing, selection and improvement; a high rate of survival in the field is most likely to indicate a reliable plantation genotype. Height and diameter are classical parameters of the growth rate of wood in each provenance. Multi-stem reiteration provides additional information on both the biological strategy of the trees and the quality and quantity of produced wood.

As the individual characteristics presented here are averages, statistically, the number of trees of each provenance should be the same. However, due to unexpected disturbances in the trial plots, (cattles, fire and termites) several provenances had a smaller number of surviving trees than other provenances. Examples of reduced tree populations are the Banjarmasin provenance in Block I (fire & termites), the Pontianak and Palembang provenances in Block III (fire), and the Riau, Jambi, and Lampung provenances in Block III (cattles).

As stated before (4.2.2) each provenance was represented by one 25 tree plot (5x5 trees), and replicated three times. Each complete plot contained 25 trees, i.e. 9 core trees and 16 border trees (Fig. 4.2).

4.3.1.1. Survival

Table 4.2 presents the survival rate of each provenance in each block and the average of the three blocks. The number in brackets shows the number of surviving core trees, and the other number shows the survival rate of all trees (core and border trees). In the table the type of disturbance in certain provenances in a certain block is marked. This provides initial information on the cause of a low survival rate.

Table 4.2. Provenance trial. Survival rate (%) and impacts for all trees per plot in legend K = Kalimantan; S = Sumatera; ☼ = fire; * = termites; ⁄ = cows. Number in parentheses ( ) : core trees.

No.	Provenances	Block I	Block II	Block III	Average
1.	Palangka Raya (K)	84 (66)	96 (100)	96 (100)	92 (88.7)
2.	Pontianak (K)	96 (88.9)	100(100)	68 (77.8)☼	88 (88.9)
3.	Samarinda (K)	72 (88.9)	80 (88.9)	76 (77.8)	76 (85.2)
4.	Banjarmasin (K)	32 (33)☼*	92 (100)	100(100)	75 (77.7)
5.	Palembang (S)	84 (89)	92 (100)	44(56)☼	73 (81.7)
6.	Riau (S)	84 (89)	84 (77.8)	40(66.7)⁄	69 (77.8)
7.	Jambi (S)	72 (55.6)	76 (88.9)	56(66.7)⁄	68 (70.4)
8.	Bengkulu (S)	40 (77.8)	48 (77.8)	48(66.7)	45 (74.1)
9.	Padang (S)	20 (55.5)	36 (100)	40(88.9)	32 (81.5)
10.	Lampung (S)	24 (66.7)	16 (44.4)	8(22.2)⁄	16 (44.4)

The Palangka Raya provenance showed the highest mean survival rate with 92 %, and the Lampung provenance showed the lowest one with 16% on average. Table 4.2 also shows that the survival rates of the provenances from Kalimantan were higher than the ones from Sumatera. The Kalimantan provenances were in first, second, third and fourth position.

Statistically, they also show significant differences (see Appendix 1). The mean survival rate shown by statistical analysis differs from the mean survival rate in Table 4.2. This is because the figures are codetermined by the covariates of the disturbances "fire" and "cattles" in the provenances mentioned above. Therefore, the ranking order of the Provenances becomes as follows : Pontianak, Banjarmasin, Palangka Raya, Palembang, Riau, Jambi, Samarinda, Bengkulu, Padang and Lampung (see Appendix 1). Pairwise comparisons show the following : the Pontianak provenance shows significant differences from all the other provenances (the highest); the Banjarmasin, Palangka Raya and Palembang provenances do not show significant differences among them, but the first and second provenances show significant differences from the Riau, Jambi, Samarinda, Bengkulu, Padang and Lampung provenances; and the Lampung, Padang and Bengkulu provenances (the lowest group) show significant differences from the other provenances.

So, in general, the average survival rate of most provenances is over 69% (by original counts) or over 55% (by statistical expectation), except for the Lampung, Padang and Bengkulu provenances. The Kalimantan provenances take first, second and third position. The average survival rate of core trees exceeds 70%. This is more than the average survival rate of the total number of trees in the three blocks, except for the Lampung provenance (44.4%), the whole population of which is in the low survival group.

4.3.1.2. Height

In this part, the mean height for both core trees and all trees in each provenance is presented. It is important to know whether or not the two groups of data indeed differ, since border trees are assumed to show a higher interception of light and are influenced by other ecological factors than core trees. The mean height of each provenance based on all trees is presented in Table 4.3.a and that on the core trees in Table 4.3.b.

Table 4.3.a shows that the Padang provenance has the highest mean height, followed by the Pontianak and Riau provenances. Most provenances achieve a mean height of over 210 cm, except Lampung with 195 cm. The tallest individual trees were shown by the Padang, Pontianak and Banjarmasin provenances with 410 cm in height.

A comparison of Table 4.3 (mean height of all trees) with Table 4.3.b (mean height of core trees) shows a slight change in the position of mean height for each provenance. The Banjarmasin and Palangka Raya provenances replace the Pontianak and Riau provenances in second and third position in the core trees, and the Padang provenance remains in first position. So, despite its low survival rate, the Padang provenance has a high mean height, both in core trees (first position) and in all trees (first position).

Though the tables show different mean heights between the provenances, statistically these differences are not significant, as proved by the analysis of variance (ANOVA) in Appendix 2 and 3. The ANOVA test shows only differences between blocks, Block I differing from Block II and Block III as to their effect on the growth of Sungkai plantation. There is no significant difference between Block II and Block III as demonstrated by the pairwise comparisons in Appendix 2 and 3. For the same reasons as those given above for mean survival, the mean height produced by statistical analysis differs from the mean height in Tables 4.3.a and 4.3.b. The ranking order of the provenances now becomes as follows : Padang, Riau, Banjarmasin, Pontianak, Palangka Raya, Jambi, Bengkulu, Lampung, Samarinda and Palembang for all trees. For core trees it is : Padang, Banjarmasin, Pontianak, Riau, Palangka Raya, Lampung, Bengkulu, Jambi, Samarinda and Palembang.

Table 4.3.a. Provenance trial. Mean height (cm) of each provenance for all trees

No.	Provenances	Block I			Block II			Block III			Mean
		N	h	sd	N	h	sd	N	h	sd	h
1.	Padang	5	224	59.5	9	244	49.7	10	373	30.9	280
2.	Pontianak	24	269	50.8	25	225	40.6	17	300	46.8	265
3.	Riau	21	240	42.5	21	282	45.5	10	259	61.1	260
4.	Banjarmasin	8	200	43.6	23	255	53.2	25	312	51.8	256
5.	Palangka Raya	21	264	31.1	24	191	63.2	24	310	48.2	255
6.	Samarinda	18	193	52.2	20	173	61.2	19	292	52.6	219
7.	Palembang	21	111	42.7	23	215	37.0	11	331	71.8	219
8.	Jambi	18	195	67.3	20	183	43.8	14	263	65.5	214
9.	Bengkulu	10	143	47.7	12	283	58.3	12	244	59.1	210
10.	Lampung	6	197	33.2	4	219	27.2	2	170	0.7	195

Table 4.3.b. Provenance trial . Mean height (cm) of each provenance for core trees

No.	Provenaces	Block I			Block II			Block III			Mean
		N	h	sd	N	h	sd	N	h	sd	h
1.	Padang	5	224	59.5	9	244	49.7	8	385	16.7	284
2.	Banjarmasin	3	222	29.2	9	249	32.6	9	340	31.8	270
3.	Palangka Raya	6	267	38.6	9	210	61.7	9	333	35.7	269
4.	Riau	8	245	25.5	7	293	62.4	6	267	52.0	268
5.	Pontianak	8	287	21.8	9	209	29.9	7	299	52.3	265
6.	Jambi	5	212	46.0	8	179	35.9	6	261	70.1	217
7.	Palembang	8	109	28.5	9	213	35.3	5	267	52.0	215
8.	Samarinda	8	165	37.9	8	150	68.1	7	316	50.5	210
9.	Bengkulu	7	122	35,3	7	245	31.8	6	258	69.2	208
10.	Lampung	6	197	33.2	4	219	27.2	2	170	0.7	195

4.3.1.3 Diameter

In this part, two types of diameter are presented, i.e. the diameter above roots and the diameter at breast height. The diameter above roots is needed for comparative purposes, e.g. data from Oldeman (1990), in several forest types in several countries. Like the previous parameters, each type of diameter contains a group of core trees and group of all trees.

Diameter above roots

The diameter above roots is presented for all trees in Table 4.4.a and for core trees in Table 4.4.b. Table 4.3.a shows that the Pontianak provenance has the highest mean diameter (6.7 cm), followed by the Banjarmasin (6.3 cm) and the Palangka Raya (6.1 cm) provenances. Table 4.4.b shows a slight change in the *position of mean height. The Banjarmasin provenance replaces the Pontianak* provenance in first position in core trees. Generally, these provenances achieve a mean diameter above 4 cm in twenty-six months, except Jambi. The largest diameter of an individual tree is shown by the Palembang provenance (12.9 cm), followed by Pontianak (11.7 cm) and Samarinda (10.9 cm).

Like in other parameters, the Kalimantan provenances once more rank highest as to their diameter. Only the Padang provenance from Sumatera is also in the upper group, in fourth position both in core trees and all trees in diameter above root. The fifth position of the upper group of five is taken by the Riau provenance in all trees, and by the Palembang provenance in core trees.

Statistically, however, they do not show significant differences (Appendix 4) and the position of each provenance in the tables changes. The change in position is caused by a correction for covariates such as cattle and fires and the number of trees of the provenances in each block. The new statistical rank order is : Riau, Pontianak, Banjarmasin, Palangka Raya, Padang, Palembang, Lampung, Samarinda, Bengkulu and Jambi for all trees (Table 4.4.a). For core trees (Table 4.4.b) the ranking is : Riau, Banjarmasin, Pontianak, Palangka Raya, Padang, Palembang, Lampung, Bengkulu, Samarinda and Jambi. So, statistically the Riau provenance is expected to be in first position, followed by the Pontianak, Banjarmasin, Palangka Raya and Padang provenances in the upper group of five both for core trees and all trees.

Table 4.4.a. Provenance trial. Mean diameter (above root) of each provenance for all trees (cm)

No.	Provenances	Block I			Block II			Block III			Mean
		n	d	sd	n	d	sd	n	d	sd	
1.	Pontianak	24	6.84	1.83	25	4.39	1.00	17	8.81	1.73	6.68
2.	Banjarmasin	8	5.10	1.71	23	5.72	1.54	25	8.06	1.59	6.29
3.	Palangka Raya	21	6.76	1.01	24	4.01	1.53	24	7.47	1.34	6.08
4.	Padang	5	5.27	2.07	9	5.45	2.00	10	6.80	1.47	5.84
5.	Riau	21	6.10	1.49	21	5.39	1.65	10	5.84	1.30	5.77
6.	Palembang	21	2.84	1.07	23	4.99	1.40	11	9.06	1.99	5.63
7.	Samarinda	18	4.63	1.44	20	3.15	1.21	19	7.13	1.50	4.97
8.	Bengkulu	10	3.55	1.00	12	4.27	1.15	12	6.57	2.14	4.80
9.	Lampung	6	4.66	1.36	4	4.53	1.26	2	3.80	0.28	4.33
10.	Jambi	18	4.14	1.36	20	2.66	0.76	14	5.03	1.53	3.94

Table 4.4.b. Provenance trial. Mean diameter (above root) of each provenance for core trees(cm)

No.	Provenances	Block I			Block II			Block III			Mean
		n	d	sd	n	d	sd	n	d	sd	
1.	Banjarmasin	3	5.88	1.79	9	5.80	1.38	9	8.71	1.25	6.79
2.	Pontianak	8	7.49	1.72	9	3.95	0.76	7	8.77	2.07	6.74
3.	Palangka Raya	6	7.26	1.03	9	4.27	1.43	9	8.05	0.82	6.52
4.	Padang	5	5.27	2.07	9	5.45	2.00	8	7.28	1.20	6.00
5.	Palembang	8	3.05	0.81	9	5.29	0.96	5	9.63	1.75	5.99
6.	Riau	8	6.71	0.98	7	5.25	2.04	6	5.75	1.15	5.90
7.	Bengkulu	7	3.18	0.78	7	4.30	0.53	6	7.72	2.49	5.07
8.	Samarinda	8	4.31	1.44	8	2.43	0.97	7	7.94	0.71	4.89
9.	Lampung	6	4.66	1.36	4	4.53	1.26	2	3.80	0.28	4.33
10.	Jambi	5	4.60	1.66	8	2.83	0.82	6	4.89	1.16	4.11

Diameter at breast height

As for the diameter at breast height, the Palangka Raya provenance is in first position both for all trees and core trees, as demonstrated in Table 4.5.c and Table 4.5.d. For all trees, the Pontianak provenance comes second, followed by Padang in third position. For core trees, the second position is taken also by the Pontianak provenance, followed by Banjarmasin in third position. Again, the Padang provenance shows to belong, with the Kalimantan provenances, to the upper mean diameter group. The largest diameter(dbh) of one individual tree is again shown by the Palangka Raya and Pontianak provenances (8.3 cm), followed by the Banjarmasin (7.7 cm, Samarinda (7.6 cm) and Palembang (7.4 cm) provenances.

As with the diameter above roots, statistically the dbh does not show significant differences between the provenances (see Appendix 5), but there is a slight change in the position of the provenances in the tables. The new ranking order is : Palangka Raya, Banjarmasin, Padang, Pontianak, Samarinda, Riau, Palembang, Bengkulu, Lampung and Jambi for all trees; and Palangka Raya, Padang, Pontianak, Banjarmasin, Palembang, Samarinda, Riau, Bengkulu, Lampung and Jambi for core trees. The positions in the upper group of five are maintained by the same provenances in the same positions, both for core trees and all trees.

So in the twenty-six months, the trees had reached an average diameter (dbh) between 2.5 and 4.6 cm for core trees, and between 2.5 and 4.3 cm for all trees. the Kalimantan provenances once more dominate the upper group of five, namely, the Palangka Raya, Pontianak and Banjarmasin provenances.

Table 4.5.c. Provenance trial. Mean diameter(dbh) of each provenance for all trees (cm)

No.	Provenances	Block I			Block II			Block III			Mean
		n	d	sd	n	d	sd	n	d	sd	
1.	Palangka Raya	21	4.71	0.94	19	2.71	1.03	24	5.48	1.47	4.30
2.	Pontianak	24	4.86	1.60	25	2.60	0.73	17	5.43	1.42	4.29
3.	Padang	5	3.83	0.95	9	3.27	1.40	10	5.44	0.92	4.18
4.	Banjarmasin	8	3.29	0.69	23	3.51	1.21	25	5.47	1.31	4.09
5.	Samarinda	16	3.11	1.17	15	2.99	0.97	19	5.24	1.15	3.78
6.	Riau	21	3.42	1.01	21	3.16	1.03	10	3.83	1.36	3.47
7.	Palembang	8	2.24	0.36	23	2.81	0.84	11	4.91	1.49	3.31
8.	Bengkulu	5	2.30	0.58	11	2.59	0.76	12	3.59	1.35	2.82
9.	Jambi	15	3.04	0.99	15	1.87	0.41	14	3.19	1.16	2.70
10.	Lampung	5	3.33	1.17	4	2.70	0.92	2	1.55	0.21	2.52

Table 4.5.d. Provenance trial. Mean diameter(dbh) of each provenance for core trees (cm)

No.	Provenances	Block I			Block II			Block III			Mean
		n	d	sd	n	d	sd	n	d	sd	---
1.	Palangka Raya	6	5.13	1.13	8	2.59	0.98	9	6.25	1.17	4.65
2.	Pontianak	8	5.61	1.34	9	2.27	0.55	7	5.72	1.32	4.50
3.	Banjarmasin	3	3.31	0.45	9	3.48	1.03	9	6.10	1.10	4.30
4.	Padang	5	3.83	0.95	9	3.27	1.40	8	5.57	0.84	4.22
5.	Riau	8	3.74	0.88	7	2.88	1.27	6	3.76	0.95	3.46
6.	Samarinda	7	2.38	0.86	7	2.23	0.60	7	5.72	1.58	3.44
7.	Palembang	2	2.25	0.07	9	2.93	0.73	5	5.07	1.02	3.42
8.	Bengkulu	2	2.35	0.21	7	2.51	0.74	6	4.20	1.48	3.02
9.	Jambi	5	3.20	1.12	6	1.77	0.39	6	3.12	1.08	2.69
10.	Lampung	5	3.33	1.17	4	2.70	0.92	2	1.55	0.21	2.53

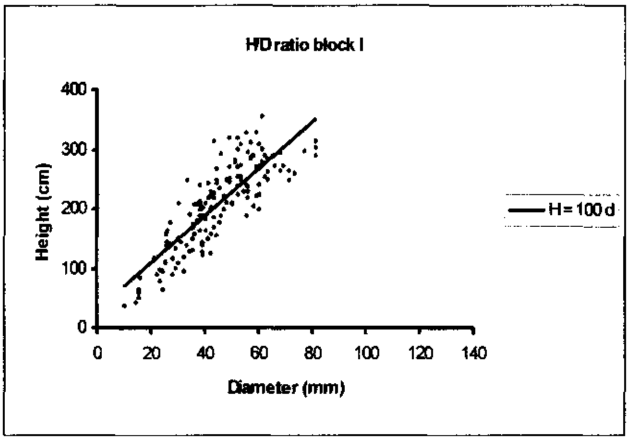
4.3.1.4. H/d ratio

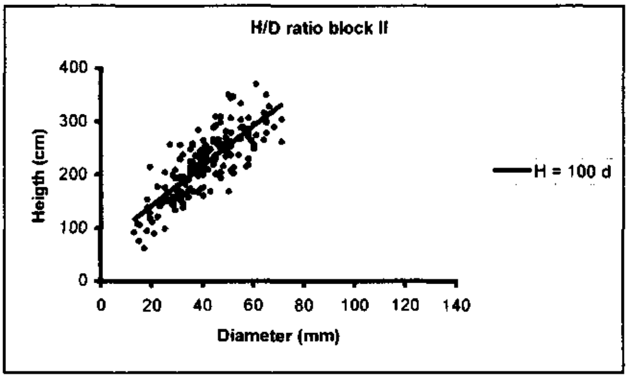
After presenting the height and diameter of each provenance, the relationship is shown between the two parameters in the form of height/diameter ratio (h/d ratio). According to Oldeman (1974a,1990) this ratio is related to the architecture of the tree. Oldeman (1974a), Hallé et al.(1978) and Oldeman (1990) found that nearly all model-conforming trees in French Guyana showed the ratio of $h = 100\ d$. These authors proved in French Guyana, that if a young tree broke off, the ensuing regenerative reiteration pushed this ratio upward ($h > 100\ d$); and when a tree grew out by abundant reiteration within the crown, the ratio became $h < 100\ d$. We assume for the moment that this is also the case in *Peronema canescens*, although its architectural model has a fuzzy expression (Ch.2, illustration).

The h/d ratio, based on individual trees in each block is presented in Figure 4.3. In the graphs presented here, a reference line $h = 100\ d$ is drawn in order to know the tendency of h/d distribution. Note that line $h = 100d$ is not a regression curve, but a line of reference to a property of trees conforming to their architectural model.

In general, the distribution of dots in the graphs tends to be abundant or dense around the reference line for each block. However, Block III shows a slight difference from Block I and Block II, as several trees show an h/d further away from the reference line. In other words, several trees in Block III begin to show clearly $h > 100d$ or $h < 100d$, not to be confused with random scatter. The h/d ratio is related to the architecture of the tree. In fact, more trees in Block III are multistemmed than in Block I and Block II, as shown in Table 4.6.

So, at an age of twenty-six months, planted Sungkai trees did not display any obvious tendency towards either $h > 100d$ or $h < 100d$. They still oscillated around $h = 100d$. In other words, the model-conform trees still showed a height-diameter ratio of $h \approx 100d$. It seemed that the trees still showed a relative balance of their metabolism resulting in endogeneously and mutually adjusted cambial and height growths and root development.





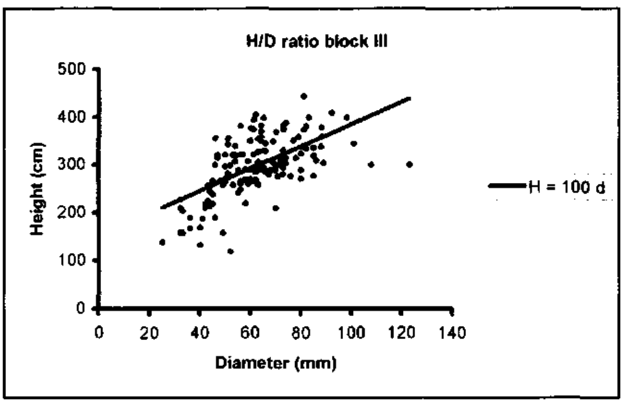


Fig. 4.3. H/D Ratio of ten provenances in blocks I, II, III. Diameter is above roots. Note that H = 100.d is architectural reference line, no regression curve (Hallé at al. 1978)

4.3.1.5 Multistem reiteration

A tree in an open area behaves differently from a forest tree. In free-standing trees, including plantation trees in the early development phase, the availability of light and other ecological factors along horizontal gradients influences its growth, sometimes inducing a multistem architecture. Depending on the plantation objective, multistem architecture is either useful or not useful. Especially in the early development phase it may still be corrected. One-stemmed tree architecture may be considered best, if good timber is the main objective. If, however, the main focus is on the rehabilitation of *Imperata cylindrica* grassland, multistemmed trees are preferred because of their outshading grass. So, specific silvicultural practices must be conceived and applied in order to achieve a specific objective.

Table 4.6 presents the occurrence of multistem architecture in the ten provenances in each block. As shown in the table, all the provenances had multistem trees. Only in certain blocks, some provenances had no multistemmed trees, e.g in Block I for Bengkulu, Block II for Samarinda, Bengkulu and Lampung, and Blocks III for the Lampung provenance.

The latter three provenances had also a low mean share of multistems (below 20 %). The rest had a high mean percentage ($\geq$ 31%). The highest mean percentage is shown by the Pontianak provenance (66%), followed by the Banjarmasin (54%) and Palangka Raya (48%) provenances. These three provenances are from Kalimantan.

Four provenances had fewer multistemmed trees, i.e. the Lampung (5%), Bengkulu (5%), Jambi (17%) and Samarinda (19%) provenances. Only one out of these four was from Kalimantan, i.e. the Samarinda provenance. They may be considered the best group, if good timber is the main objective. However, other factors have to be taken into account for that purpose, such as survival, height and diameter growth.

Table 4.6 Provenance trial. Multistem reiteration of ten provenances (%)

No.	Provenances	Block I	Block II	Block III	Average
1.	Pontianak	70	40	88	66
2.	Banjarmasin	25	66	72	54
3.	Palangka Raya	47	42	54	48
4.	Riau	42	45	40	40
5.	Palembang	14	43	54	37
6.	Padang	20	44	30	31
7.	Samarinda	17	0	21	19
8.	Jambi	16	15	21	17
9.	Bengkulu	0	0	16	5
10.	Lampung	16	0	0	5

Statistically, they also showed significant differences (see Appendix 6). Pairwise comparison gives the following result. the Pontianak provenance differed significantly from the Palembang, Padang, Samarinda, Jambi, Bengkulu and Lampung provenances, but it did not differ from the Banjarmasin, Palangka Raya and Riau provenances (see Table 4.6). The Banjarmasin provenance differed from the Samarinda, Jambi, Bengkulu and Lampung provenances, but it did not differ from the rest.

The Samarinda, Jambi, Bengkulu and Lampung provenances had fewer multistems, shown both by Table 4.6 and statistical analysis. The statistical analysis showed only a slight difference in rank e.g the Samarinda provenance replaces the Lampung provenance together with Bengkulu in the lowest position. Meanwhile, ranks 1 to 6 remain the same, both by statistical analysis and according to the counts in Table 4.6.

4.3.1.6. Crown Diameter

Industrial forest plantations (IFP) in *Imperata cylyndrica* grasslands, have two objectives, namely to suppress the grass and to produce harvestable trees (cf.Mutsaers 1998). So the species should be able to grow notwithstanding the grass and maintain an acceptable growth rate.

In order to suppress the grass, species or provenances with fast canopy development are appropriate. Table 4.7 shows crown diameters representing the canopy development of the ten provenances in each block. Statistically, they do not show significant differences (see Appendix 7).

Generally, at 26 months the provenances achieved a mean crown diameter above 132 cm, except Jambi (119 cm). Like for the other parameters, the Pontianak provenance again maintains its highest rank (175 cm), in the group with the Palangka Raya (174 cm) and Padang (176 cm) provenances. If the result is related to the plantation with a 3x3 m spacing, only 3 or 5 provenances may achieve a fast canopy closure within 26 months, namely the Pontianak, Palangka Raya, Padang, Banjarmasin and Palembang provenances.

Table 4.7. Provenance trial. Crown diameter (cd) of ten provenances (cm) at 26 months

No.	Provenances	Block I			Block II			Block III		Mean	
		N	cd	sd	N	cd	sd	N	cd	sd	cd
1.	Pontianak	24	180	39.1	25	134	22.4	17	215	43.2	176
2.	Padang	5	169	28.0	9	135	19.0	10	222	32.6	175
3.	Palangka Raya	21	178	28.3	24	131	31.1	24	212	34.4	174
4.	Palembang	21	101	31.9	23	159	26.8	11	227	40.9	162
5.	Banjarmasin	8	147	16.0	23	143	21.1	25	195	28.3	162
6.	Samarinda	18	142	29.2	20	124	18.5	19	193	40.6	153
7.	Riau	21	156	29.9	20	141	12.7	10	153	28.1	150
8.	Bengkulu	10	112	29.0	12	140	17.1	12	165	27.8	139
9.	Lampung	6	120	28.0	4	149	12.1	2	128	3.5	132
10.	Jambi	18	117	32.6	20	103	20.7	14	137	33.2	119

4.3.2. Survival strategy of Sungkai under fire

As mentioned in the introduction of this chapter, during the abnormally long drought in Indonesia in 1997, due to "El Niño" (cf Rossignol et al. 1998), long and widespread forest fires raged in Kalimantan and Sumatera. Inevitably, the fire eventually hit also the trial plots of the Sungkai plantation and burned some. Then the survival strategy of Sungkai against fire (after burning) was revealed.

Faidil and Anwar (1998) mentioned that in the last decade five extensive forest fires have occurred in Indonesia, in 1982, 1987, 1991, 1994 and 1997. The largest one occurred in 1982. As quoted by Wirawan (1993), Schindele, Thoma and Panzer claim that in East Kalimantan, the fire destroyed 2,717,000 hectares of swamp and dryland forests or 3,193,000 hectares when settlements and agricultural areas are included. It was such a conflagration that it was called a national catastrophe. Since the frequency of forest fires tends to increase, information on the Sungkai survival strategies is needed by the industrial forest plantation companies, so that they can select tree species in order to avoid or at least diminish the risk of fire.

Prior to discussing the survival strategy of Sungkai as a species, the level of damage of each individual tree should be clarified. When there is a forest fire, a number of trees burn directly, whereas others are only heated by the burning trees in the immediate vicinity. Moreover, burnt trees have also to be differentiated into totally and partially burnt ones.

This was what happened also on the Sungkai plantation. A number of Sungkai trees burned directly and totally (leaves, branches and stem all gone) and several other trees were burned only partially, (leaves, crown, excluding the stem, part of the crown, or other parts). Other trees were only heated by the burning trees immediately around them. The difference in level of burning is determined by the presence and amount of fuel. In the Sungkai plantations, this was dry grass.

Heikkila, et al. (1993) say that all fires result from a chemical process involving three essential elements : fuel, heat and oxygen which in combination cause combustion, in their words the "fire triangle". They added that the amount of the fuel affects the intensity with which a fire burns and determines the total heat released by the fire. The total heat volume plays a major part in the spread of a fire.

Though manual weeding was carried out every four months, the alang-alang (*Imperata cylindrica*) grass recovered fast, so there was always fuel present, although its volume varied from place to place. It is assumed that the totally burnt trees were surrounded by a higher volume of fuel than the partly burnt trees.

Partly burnt trees, in general, seem to be able to survive by prolific reiteration, which in turn, creates multistemmed trees. This was confirmed by the partly burnt trees of the Pontianak provenance, where the surviving trees formed multistems. The same happened in the trees of the Palembang and Banjarmasin provenances. The sprouts appeared just above the ground.

Totally burnt trees may either perish, or if they live, survive by root suckering. This also makes for multistemmed trees. However, there is a slight difference between the multistemmed, partly burnt trees and the completely burnt trees. The new sprouting of the totally burnt trees appeared from the buried stem base or from the root of the trees (see Figures 4.4. and 4.5)

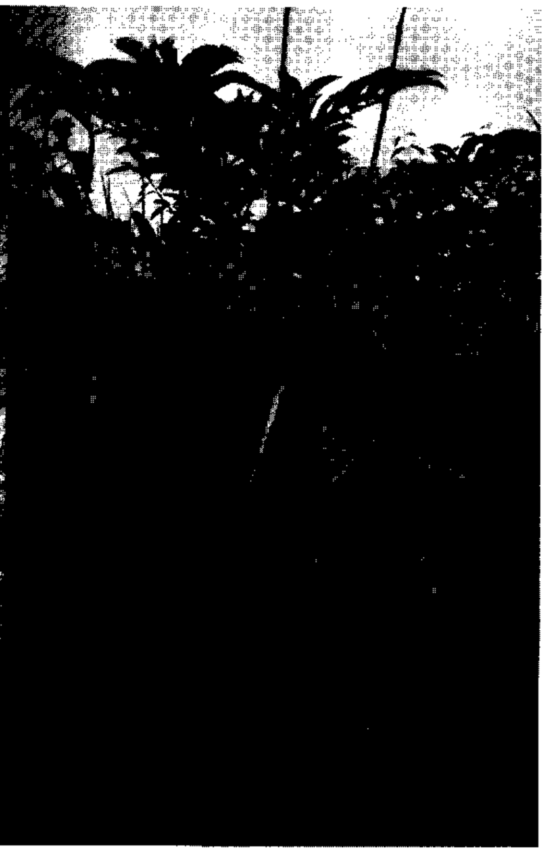
Generally, the partly burnt trees could survive, but only a few of the totally burnt trees survived. For example, only six out of twelve totally burnt trees of the Pontianak provenance survived, two out of five totally burnt trees of the Palembang provenance survived, and only three out of eighteen totally burnt trees of the Banjarmasin provenance survived. However, the Banjarmasin provenance was extra hard hit, its trees having been attacked by termites as well as by fire.

Tree survival among totally burnt trees demands attention. There are always slight differences in the intensity of burning between them, although all belong to the class of "totally burnt trees". Some trees faced only surface fire, others faced both surface and sub-surface fire. Surface fire is the fire which only burns the surface fuel on the ground, such as grass, brush wood, surface litter (twigs, dry leaves, and other undecomposed material). Sub-surface fire burns organic material under the surface litter (Heikkela, et al. 1993). This second type may have caused the burning of Sungkai roots. That is why the roots of several burnt trees were not able to develop root suckers. However, there was one more cause of death of totally burnt trees, i.e. tremites. Among the above three burnt provenances, the Banjarmasin provenance showed the lowest number of surviving burnt trees, because the trees were attacked by termites, as well as by fire.

So, there are two types of strategy for Sungkai to survive by reiteration, i.e., by prolific sprouting and by root suckering. The same strategy was also found when trees were broken by physical impacts such caused by cattle or tree falls. Sungkai is superior in overcoming unexpected impacts ("stresses"). This characteristic of Sungkai is common in the species of Verbenaceae which, as we saw, are tenacious survivers (Palmer 1994).

In spite of Sungkai's superiority, however, silvicultural treatment should convert multistemmed trees of Sungkai into monostems, if the objective of the forestry company is wood production.

a



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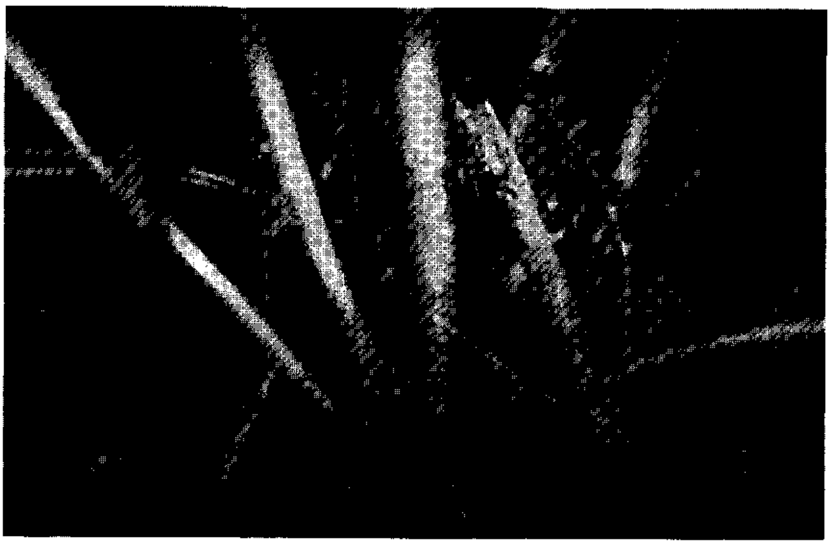

c

ERRATUM

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Fig. 4.4. Survival strategy of Sungkai under fire.
a and c are totally burned trees. Sprouts appear from the buried stem base. a is a tree inside and c is outside the trial plot.
b is partly burned. Sprouts appear above ground, like in a pollard. The original stem is at the centre; it burned and died at the top.

Fig.4.5. Survival strategy of partly burned trees (a,b) and totally burned trees (c) R = reiterated axes.

4.4. How to optimize the mutual adaptability of provenance and site

Before discussing how to optimize the mutual adaptability of provenance and site, the results presented in section 4.3 will be discussed.

The Kalimantan provenances generally showed higher values of almost all parameters, except height. However, statistically only two out of six parameters showed significant differences; in survival rate and multistem architecture.

The survival rate is higher in the provenances from Kalimantan than in those from Sumatera, both by original counts and by statistical expectation. The Banjarmasin provenance, a native of South Kalimantan, indeed survived best, as proven by its survival rate in block II (92%) and block III (100%). However, due to fire and termite damage combined in block I, the survival rate there is lower than in the three other provenances from Kalimantan

The different performances of the Kalimantan and Sumatera provenances may be linked to the trial plots being located in Kalimantan. Nevertheless, it is assumed that the low survival rate for the provenances from Sumatera is not merely due to the biogeographical distance between the original biotope and the trial plots, but also to the impact of disturbances. For instance, the low survival rate of the Palembang provenance in block III was caused by fire. Its survival rate in block I and II is high enough (84% and 92%). Another example is the survival rate of the Riau and Jambi provenances; the low survival rate of the two provenances in block III is due to grazing by cows, whereas their survival rates in block I and II are quite high (above 70%). The Bengkulu provenance is an exception with low survival rates in all plots.

The low survival rates of the Lampung and Padang provenances in the field are assumed to be related to their low survival rate in the nursery. The Lampung and Padang provenances showed significantly poorer survival rates than the others (Chapter 3). A combination of low growth rates, i.e. low vitality, in the nursery, and drought in the field is the probable cause of the low survival rate in the trial plots. In addition to those factors, the disturbance by cattle in the Lampung provenance, especially in block III, also contributed to a low survival rate.

The average survival rate of most provenances was above 69%, except for the Lampung, Padang and Bengkulu provenances. The upper group of five ranged from 73 to 92%. If there had been no drought or fires in 1997, and no disturbances from cattle, the figure would certainly have been higher. For the same reason, the survival rates of the Kalimantan provenances are comparable with the results of Hadi and Adjers (1989). These authors reported that among indigenous pioneers tested on grassland in South Kalimantan, Sungkai had a survival rate close to 100%. A survival rate above 85% is regarded as sufficient for silvicultural purposes.

The Kalimantan provenances once more dominate the upper group of five in mean tree height, but less so than in the case of survival rate. As said the Kalimantan provenances take positions 1 to 3 as to survival rate, whereas according to mean height of "all trees", first and third positions are now taken by the provenances from Sumatera (the Padang and Riau provenances). For core trees, the Padang and Riau provenances take first and fourth position.

In spite of its low survival rate, the Padang provenance showed the highest mean height both for core trees and for all trees. However, for all other growth parameters the Kalimantan provenances rate highest. Perhaps, the combination of its similar tree height and a lower tree number in its plot makes the mean height for the Padang provenance slightly higher than for the others, due to a higher resource allocation per tree resulting from a lower density per hectare.

As a matter of fact, at the last measuring, the Padang provenance had only 5 trees in Block I, 9 trees in Block II and 10 trees in Block III, whereas the Kalimantan provenances ranged from 18 to 24 trees in Block I, from 20 to 25 trees in Block II and from 19 to 25 trees in Block III. In addition, the individual tree heights of the Kalimantan provenances showed more variation than those in the Padang provenance, as proven by their standard deviations in Blocks II and III (Table 4.3.a). The two above factors, density and tree height, may have produced a slightly higher mean height in the Padang provenance. And, because their growing space was larger than in the Kalimantan provenances, these trees had more available ecological resources. However, statistically, the differences were not significant, so that our empirical explanation lacks formal proof.

As shown in Table 4.3, the mean height of twenty-six-months old Sungkai plantations varied from 195 to 280 cm for all provenances and from 255 to 280 cm for the upper group of five. By using Sungkai from South Kalimantan in a mixed plantation with *Gmelina arborea*, fertilized by NPK, and using herbicide treatment during site preparation, Madya et al.(1995) reported that in six years, the height of Sungkai reached 6.9 m. Meanwhile, by using the same Sungkai source in monoculture with intensive care, including the use of fertilizer, Hadi & Vuokko, (1995) reported that Sungkai reached a height of 7.6 m in six years' time.

Although strictly speaking the above three results are not mutually comparable due to different treatments and ages, they are interesting enough to be discussed in more general terms. The main difference is that no fertilizers and herbicide treatments were used in our provenance trial. If such treatments had been applied, our data would lead us to expect that after six years, the Sungkai provenance plantation, especially the upper group of five, would have achieved or even exceeded the performance shown by the authors cited above.

This expectation is based on the following considerations. Data on the first year show a height increment in the Sungkai provenance trial of between 137 and cm 155 cm in the upper group of five. Based on observations in a logged-over site in East Kalimantan, Soerianegara and Lemmens (1994) found that the mean annual height increment of Sungkai over three years was 120 cm. Although the two figures originate from different sites, the latter figure is the more plausible because it is based on a longer period. It, therefore, is a realistic warning against overestimating the Sungkai performance. On a basis of 120 cm per year, the existing provenance trial, showing a mean height from 195 to 280 cm in twenty-six months, may be expected to achieve a mean height of 675 to 760 cm in the next four years. These figures come close to those of the above authors. If fertilizers had been used in this experiment, the results in terms of estimated height growth, would have been significant.

Keogh (1996) stated that growth may be boosted in some cases by fertilizers, but the identification of the necessary chemicals and their optimum rates of application are not fully understood. This best case scenario may be far too optimistic taking into account possible environmental impacts during four years, e.g droughts or fires, and the uncertainties stated by Keogh (1996).

The Kalimantan provenances once more rank highest if judged by their diameter. Only the Padang provenance from Sumatera joins the upper group, with a fourth position in diameter above root both in core tree and all trees. The fifth position of the upper group of five is taken by the Riau provenance in "all trees", and by the Palembang provenance in "core trees"

This was also the case for diameter at breast height. The Kalimantan provenance still dominates, both in diameter above root and diameter at breast height. Statistically the differences between the provenances are not significant.

The h/d (height/diameter) ratio of twenty-six-months old, planted Sungkai trees does not display as yet any obvious tendency towards either $h > 100d$ or $h < 100d$. This relation still oscillates around $h = 100d$. In other words, the model-conform trees still show a height-diameter ratio of $h \approx 100d$. The trees still show a balanced metabolism resulting in endogeneously and mutually adjusted cambial and height growths, and root system development.

We saw that this ratio, parametric of tree architecture, is $h \approx 100d$ in trees conforming to their model, $h < 100d$ in young trees after breakage and regeneration, and $h > 100d$ after the start of crown expansion.

As shown in Table 4.6, all provenances had multistems. However, statistically they showed significant differences. Most Kalimantan provenances had high percentages of multistemmed trees (above 48%), except the Samarinda provenance (19%). Four provenances had fewer multistemed trees, Lampung (5%), Bengkulu (5%), Jambi (17%) and Samarinda (19%). They may be considered "the best group", if good timber is the main objective. However, other factors have to be taken into account for that purpose, e.g survival, height and diameter growth. For instance, the Pontianak, Palangka Raya and Banjarmasin provenances showed better survival, height, diameter and crown diameter, although multistem frequency was high. Attempts should be made to reduce multistem to monostem architecture if the management aim is for the trees to produce good timber.

Generally, at twenty-six months the provenances had achieved a mean crown diameter above 132 cm, except the Jambi provenance (119 cm). When judging by other parameters, the Pontianak provenance maintained its highest rank (176 cm), in the group with the Palangka Raya (174 cm) and Padang (175 cm) provenances. If the result is related to the plantation with a 3x3 m spacing, only 3 or perhaps 5 provenances may have achieved a fast canopy closure within 26 months, i.e. the latter three provenances, Banjarmasin and Palembang provenances.

Compared with the other provenances, the above five provenances are most likely to have the potential to reliably outshade the *Imperata cylindrica* grass because of their multistem architecture acting as an umbrella. As to the other provenances, which show relatively good quality according to other parameters, such as survival, height and diameter growth, their ability to suppress the grass may increase by using narrower spacing in plantation, e.g 3 x 2 m. This is assumed to improve the effectiveness in suppressing the grass without leading to an unbalanced nutrient budget. So, the above objectives of grass suppression and acceptable growth rate for timber production may both be met.

This may also be done by lopping back multistem trees. The choice depends on the cost of the options, and on the reversible or irreversible results of lopping.

Several facts emerge from the above discussions. First, generally the Kalimantan provenances showed a faster growth than the Sumatera provenances, as proved by their high values of almost all parameters. Second, based on their individual characteristics, the ranking in decreasing order of the Kalimantan provenances is as follows : Pontianak, Palangka Raya, Banjarmasin and Samarinda. For the Sumatera provenances this is : Riau, Padang, Palembang, Bengkulu, Jambi and Lampung. And the overall ranking is : Pontianak, Palangka Raya, Banjarmasin, Riau, Padang, Samarinda, Palembang, Bengkulu, Jambi and Lampung. Third, because of their better performance in growth, the Pontianak, Banjarmasin and Palangka Raya provenances may be regarded as promising provenances for Industrial Forest Plantations (IFP). However, specific silvicultural practices must be conceived and applied in order to achieve the timber objective, particularly with regard to multistem architecture. Good timber trees require long, straight cylindrical boles (single stems) and large diameters. So, probably pruning is unavoidable in certain periods during their growth in the plantation. Fourth, experiments outside the Sumatera, Riau, Padang and Palembang provenances may sometimes be recommended, if and only if the time of transport of propagation material can be controlled and cuttings can be well packaged.

Finally, how can we optimize the mutual adaptability of provenance and new home site ? As mentioned in the previous chapter the cuttings were collected from ten provinces in Indonesia, i.e. six provenances from Sumatera and four provenances from Kalimantan, while the trial was carried out in the South Kalimantan Province.

Evens and Hibberd (1993) mentioned that provenances sometimes respond differently relative to each other in different environments. This is known as genotype (provenance) environment interactions (GEI). These authors added that at provenance level interactions were principally with climatic parameters, but at family level interactions were often associated with edaphic factors.

The variation between the home site (Chapter 2) and the new site of the provenances, such as different vegetation cover, climate and soil type, is certainly linked to a different adaptability. The larger the area to be reforested, the higher the site variation. The problem, of course, is not simple. For instance, over what distance between old and new site may a provenance displaying superior yield be transferred ? The safest choice is to use the provenances that are well within their geographic range or climatic condition of their natural habitat and to prevent them from growing close to their requirement limit in climatic terms, such as extreme seasonal drought. Indeed, attempts to optimize the mutual adaptability of provenance and site are required in order to optimize silvicultural practice by maximizing the ecosystem health of the plantation.

Actually, Sungkai as a pioneer species has a relatively wide range of site conditions (see Chapter 2). However, the provenances still showed solidly established differences in the trial plots. The trial plots were established in South Kalimantan, and at least three out of four Kalimantan provenances were in the upper group of five in all parameters and often in the first to third position. Meanwhile, three out of the six Sumatera provenances, i.e. the Padang, Riau and Palembang provenances were also in the upper group of five, but in turns when considered per parameter. Perhaps, the climatological conditions during the experiment due to "El Niño" (cf Rossignol et al. 1998), causing drought and fires in 1997, can explain why the Sumatera provenances could not adapt well to the new site. Only the provenances adapted to site conditions close to the trial site show a better growth. The closer the site condition of the home site of the provenance corresponds to its new site, the closer the mutual adaptability of provenance and new site. This statement is not self-evident, as the temperament of a tree species may also be flexible enough to fit in in a broad array of sites (Vester, 1997). However, our data point to a strong adaptation to quite suitable sites, at least for this species and for plantation life cycles.

Indeed, how to optimize the mutual adaptability of provenance and site in general ? Raymond and Lindgren (1990 ex Hattemar, 1991) discussed the procedures of deploying provenances over sites. They proposed an approach based on the reaction of the provenances to given changes in ecological severity between the home site and the new site.

At least two features should be properly considered, namely the climate and the soil of the site. Rainfall is of great importance for its effect on the temperature of a site, and the supply of water. Rainfall varies from year to year, and the provenance planted should be suitable not only for good and average years, but also for those moderately below average. However, in a certain period (once in ten or twenty years) there is an exceptionally high probabilty of drought. This risk must be taken into account in every planting plan. Climatological conditions of a new site should indeed be analysed in the long term in order to know how to plant and what trees to choose.

For example, a very dry period occurred in Indonesia in 1982, which caused 2.7 million hectares of swamp and dryland forests to be burned in East Kalimantan alone (Schendele et al. in Wirawan, 1993). In 1997 there was again a drought in Kalimantan and Sumatera. Between 1982 and 1997, there were also droughts, although these were less serious than the first two (Faidil et al., 1998). The above high frequency of dry periods may be linked to "El Niño". As quoted by Wirawan (1993) Nicholls mentioned that the extended drought that delayed the start of the rainy season in 1982 was associated with a very strong "El Niño" effect. Since "El Niño" was associated with drought in much of South-East Asia, an accurate prediction was vital in order to take precautious against the serious effects of drought and large-scale fires.

Such information is vital to determine the planting time. As generally recognized, young seedlings tend to be more sensitive to climatic stress than young and mature trees. Usually, tolerance increases with age. Sungkai seems to follow this rule.

The above data show us that young seedlings of the provenances should not be exposed to the periodical drought, at least not until they will have reached the age of two years. It is considered that a two-year-old plantation can endure climatological change, at least moderately below average or above . So planting activities should begin after the passage of years expected to be very dry. According to climatological data (Rossignol et al., 1998) there will be an obvious rise in temperature in the near future.

A more detailed climatic analysis should be made both for the original and the new site of the provenance in order to ascertain the presence or absence of strong climatic stresses. This is important in determining the climatically suitable region, the upper and lower limits of tolerance for a particular provenance, and the optimum time for planting, namely as early as practicable in the rainy season, avoiding young seedlings to face exceptionally severe stress. In conformity with a climatically suitable region, for larger areas such as Kalimantan and Sumatera, maps should be produced, indicating the optimal sites for each provenance.

The second feature is the soil. According to Evans and Hibberd (1993) there are at least three factors to be considered, namely physical soil structure including depth, nutritional soil status including organic matter content, and acidity of the soil (pH). Maps of soil factors should be developed, as is routinely done in Central European forestries. Hence, soil surveys of the new site are necessary.

The combination (overlay) of climatic and edaphic factors between the home and the new site will demonstrate the degree of hospitality of a new site for a particular "optimally fitted" provenance. In this way each provenance can be deployed in a region that suits it. The optimum mutual adaptability of provenance and site so is thus achieved.

Based on site maps, provenance-site suitability for Sungkai can be defined by adding several other factors/parameters, such as heat, water availability, root zone characteristics (e.g. see Yasman 1995), nutrient retention, and relief. The level of provenance-site suitability ("suitable", "moderately suitable", "unsuitable") depends on the quality indicated by those parameters.

Root zones can be defined by soil drainage, soil texture and soil depth; nutrient retention by cation exchange capacity and pH ; terrain by slope; and heat by a temperature range.

The above parameters should be further developed and the parameter range should be refined. Specific considerations for a certain site may be included. Perhaps, the higher the number of parameters involved, the higher the precision achieved. However, cost and convenience should be taken into account. The parameters and methods used are not too elaborate and complicated, but easy to implement. They also should preferably be comprehensible for local inhabitants, without whose participation so many silvicultural projects have failed (see Ch.5).

Chapter 5. DISCUSSION AND CONCLUSIONS

5.1. Evaluation and optimization of Sungkai for wood production

Wood production is usually the principal aim in the plantation forestry. Therefore, a tree must grow well where it is planted. Healthy, vigorously growing trees are desired, because they tend to be highly productive in the given environment. However, to obtain such trees is not simple. There are site and tree genotypes in infinite variety. Besides, planting sites tend to be limited to non-agricultural land, such as *Imperata cylindrica* grasslands, non-productive land classed as production forest areas, eroded soils, steep slopes and wastelands (Anon. 1997; Davis and Roberts, 1990). This was the problem : what provenance of Sungkai will give the desired product ?

Actually, Sungkai has a relatively wide range of site conditions (see Chapter 2), and like many other Verbenaceae, Sungkai is a tenacious survivor, even when grown far from its ecological optimum (Palmer, 1994). This is substantiated by our trials, in which the burnt Sungkai trees could survive, although they did so by a multistemmed tree architecture. Such trees, of course, can still be used for household purposes. However, if the main objective is to produce industrial wood, which is usually highly specified for its end use, the mutual adaptability of provenance and site should be optimal. Most users of sawn timber will prefer the following characteristics : long lengths with straight, even grain; large width and depth; uniformity throughout the piece; branch knots absent or few, well scattered and small; lack of inclusions such as calcite, silica and resin pockets (Palmer, 1994).

The experience of our Sungkai provenance trial is one tool in attempts to achieve the above aims. As mentioned in Chapter 3, we used cuttings in Sungkai propagation. Sungkai propagation is by stem cuttings selected from straight trees rather than by seeds, because collected seeds do not germinate well (Supriadi, 1991; Soerianegara & Lemmens, 1994). Sungkai seeds had a low germination rate of about 30% in North Lampung (personal observation).

There are at least three features to be taken into account so as to optimize Sungkai for wood production, namely (1) to use the "best" material among the provenances, (2) to create provenance-site harmony and (3) to tend the plantations including the prevention of and protection against pests and diseases. However, the following description emphasizes the provenance-site harmony. To some extent the first feature, including the use of the existing procedures in handling the material has been discussed briefly in Chapter 3.

Based on our present study on growing Sungkai provenances in a new site, five areas should be paid attention to, if a certain provenance is desired to grow well : (1) the home site of each provenance, (2) transport from the home site to the new site, (3) behaviour in the nursery, (4) transport from the nursery to the planting site, and (5) behaviour in the planting site. The above five factors determine the future performance of provenances. The first and fifth area define provenance-site harmony.

* The home site of provenances

Knowledge of the home site is the best guide to know the climatic and *edaphic requirements of a candidate provenance. Hence, it is necessary to study* and evaluate the environmental demands of the provenances. As described in Chapter 2, the cuttings of each provenance were collected from various vegetation types. For example, the cuttings were collected from a relatively intact natural vegetation in an old stand (Samarinda provenance) and a young secondary vegetation (Jambi provenance), home gardens or farmyards (Padang provenance) and vegetation strips or river banks (Pontianak and Lampung provenances). Another example were cuttings collected from a natural stand dominated by Sungkai (Palangka Raya provenance), a mixed species stand (Samarinda and Jambi provenance) or artificially mixed species stands or gardens (Padang provenance). Such situations display different "immediate environments" of each provenance, in addition to general climatic and edaphic conditions. The "immediate environment" (Oldeman 1990, Rossignol et al. 1998) is the environment closely surrounding and so directly influencing an organism, as opposed to the "far environment" of general climatic and edaphic conditions. It is necessary to record these facts, because they may reveal different reactions to the new site condition.

To some extent, the above statement is proved by the provenances of Pontianak and Banjarmasin. The two provenances which were from a relatively open environment, showed a higher growth in the trial plots. In contrast, the Samarinda and Jambi provenances, which originated from a closed environment, showed a slightly lower growth than the first two. The Padang provenance which originated from both an immediate and a far environment relatively similar to the first two provenances, also showed a better growth. Its low survival rate was due to other causes. The harsher original environment of the last three provenances certainly explains in part why they could withstand their new environment. Wangermann *in* Bakker (1998) stated that a species under a lot of stress, on the edge of their range, lived considerably longer than their unfortunate partners. Rossignol et al. (1998) stated that most forms of natural stress do not affect at most organs and organisms, because they have previously been filtered out or modified by the ecosystem. Its architecture dictates growth, maintenance and exchange of matter and energy of a tree, because it determines its direct environment.

However, such variation may have other causes, particularly genetic variations. Ennis and Marcus (1996) stated that the ability to acclimatize to a new climate is linked to the existence of a large genetic variation within a given species. This increases the chance of some individuals to survive environmental change. If they do not have these abilities to cope with a certain change, the deficiency could prove fatal. A "solution of last hope" is then the adaptive response of somatic mutation (Rossignol et al. 1998).

For all these reasons, the differences between the home site of the provenance and its new site, such as different vegetation cover, climatic and edaphic factors should be recorded, and a detailed analysis of climatic and edaphic factors should be made. Such a study would constitute a necessary supplement to the present book.

The whole data and information set must provide the site requirements of the provenances, the limit of resistance to drought, or other specific limitations. These requirements are used as specifications in attempting to match a provenance and a new site. FAO (1979) stated that in Eucalypts, experience over twenty years had confirmed the value of environmental matching and had somewhat reduced the emphasis on individual and population adaptability.

* Transport from the home site to a new site

Transporting cuttings from their home site to a new site takes time. The length of transport time between sites depends on the accessibility of the means of transport to the new site. The shorter the distance between the sites, and the easier the transport, the shorter the time. The length of transport time is usually a parameter of stress upon the plant materials (cuttings), even if the materials have been treated and packed well. This is shown by the Padang and Lampung provenances, which have a low survival rate due to a longer transport time than in the other provenances (see Section 3.3.1.).

The distance and accessibility from the home site to the new site should be taken into account in choosing provenances for large scale plantation, but for research it is necessary to obtain the whole picture of success and failure. The use of closely neighbouring provenances is usually acceptable. Sungkai plantations in the South Sumatera Province are grown from the best provenance from other provinces in Sumatera, and in the South Kalimantan Province the best provenance comes from other provinces in Kalimantan. This is explained by cuttings being less stressed, which in turn, enhances the capacity of cuttings to form shoots and roots.

The "neighbouring provenance approach" has two benefits, : the climatic and edaphic conditions between the home site and the new site approach one another. The closer the site condition of the home site of the provenance corresponds to its new site, the closer is the mutual adaptability of provenance and site. The Kalimantan provenances showed better growth than the Sumatera provenances in the trial plots, which proves the importance and the appropriateness of matching climatic and edaphic conditions between the home site and the new site of the provenances. The second benefit is that due to a shorter transport time, the stress on cuttings is reduced.

The transport of cuttings from several original sites to the new site indeed causes stress in cuttings, and so, influences the subsequent performance of the trees in Sungkai plantations.

* In the nursery

Upon arrival at the nursery, the cuttings are usually given a follow-up treatment. Depending on the treatment given, the vigorous growth of cuttings will be stimulated. There are two critical periods faced by Sungkai cuttings during the time spent in the nursery : the period of shoot and root formation, and the period afterwards. In the first period, stressed cuttings are very slow to form shoots and roots, even tend to dry out, and eventually die off (personal observation in several nurseries). There are two factors that may stress the cuttings, a lack of water and the sequels of transport from the original to the new site. During rooting, the nursery environment should be carefully maintained at an optimal level (Hartmann, et al., 1990). The same is also true in the second period, when due to a lack of watering the cuttings with shoots may become stressed. New shoots grow and transpire actively during their stay in the nursery (FAO, 1979). It is clear that abundant watering is indispensable in order to avoid drought stress in the cuttings in the nursery.

Stressed cuttings tend to have smaller shoots, a smaller number of primary roots and low root ball compactness. Supriadi (1991) mentioned that root ball compactness is one parameter reflecting how well the roots grow. Cuttings with vigorous root growth produce compact root balls and vice versa. However, perhaps this is effective for a peat growth medium, whereas for a soil growth medium this may have disadvantages. Munyanziza (1994) in East Africa stated that the use of earthball in the nursery can hamper seedlings and microbes interacting. The earthball may cause a broken soil structure and a compact mixture. This change of soil properties has a negative impact on the mycorrhizal fungal population.

Young plants cannot be transplanted directly because of their tenderness and ill-adaption to the hard environmental conditions in the field. It is well-known that they have to be hardened. Besides, as they come from different sites (provenance), they face the climatic and edaphic conditions of the new site. Selection of cuttings at the beginning, prior to use for the production of Sungkai planting material, is important in optimizing the nursery process.

* Transport from the nursery to the planting site

Transport from the nursery to the planting site may again stress the cuttings having formed shoots if they are not handled well. In comparison with the transport of cuttings from the home site to the new site, transport of cuttings with shoots and roots is certain to be more stressful, because their transpiration is higher.

The strain can be seen by the wilting of leading shoots and leaves. Sometimes the leading shoots even break. The young tree may then reiterate one or more new leading shoots in order to survive. Cuttings with shoots should be stressed as little as possible so as not to hinder their subsequent growth, especially if they have to recover from damage. In the field the cuttings will face harder environmental conditions than in the nursery.

* In the planting site

As in the home site, climate, relief and edaphic conditions of the new site should be analysed in order to know to what extent they fit the ecological requirements of provenances. The establishment of site maps is an urgent task in Indonesia. If the environmental conditions in the new site are much harsher than in the home site, the provenance will certainly be stressed. Ennis and Marcus (1996) stated that if the environmental temperatures rise, species living near their upper thermal limits are stressed. This is because they cannot maintain their proper internal temperature, which in turn affects the rate of biological processes. Planting sites tend to be limited to non-agricultural land, e.g eroded soils, steep slopes, wastelands, saline soils and *Imperata* grasslands (Davis and Roberts, 1991). This is a worldwide phenomenon (e.g. see Oldeman 1990). The Indonesian Government Regulation No. 7/1990 clearly states that the establishment of industrial plantation forests should be carried out on non-productive areas classed as "production forest" (Anon, 1997). In such situations it is a real problem what species or provenance to choose so as to obtain the desired product. Indeed, the wood industry requires specific materials and tends to search for sites where they may be economically grown. On a poor site, even the most suitable species cannot be expected to produce as much as the most suitable species on a good site (FAO, 1979). Modification of the environment is impossible or uneconomic, so it is necessary to search for provenances which have the greatest possible tolerance (resisters) to the limiting factors in question. Careful physical investigation of soil characteristics and climatic conditions are hence indispensable in order to ascertain the degree of hospitality of a new site towards a certain provenance, especially on such planting sites as mentioned above.

Oldeman (1993) stated that a site is more or less hospitable depending on the steepness of slopes, valley hydrology, role of shallow root floors, or laterite shields on hill tops, and other features related to topography. Hence, site analyses should be carried out carefully, with regard to all factors influencing forest dynamics, so as to estimate where a particular one determines the environmental hospitality. A precise regional soil map should be the basis for the matching process, because it will show various degrees of hospitality in the new site of which only the optimum combination should be chosen. Van IJssel and Sombroek (1987) emphasized that a survey and mapping of environmental conditions are indispensable tools for land evaluation and land use planning.

By matching the new site and the original site of provenances, the degree of provenance-site suitability is determined. A comprehensive judgment is vital in this process due to reciprocal interaction of environmental factors. This comprehensive image is Oldeman's "site hospitality" (1983). However, weighing the many environmental factors involved is also necessary. This can be done by examining the main factors which govern the growth of certain provenance. The more accurate the matching, the higher the degree of provenance-site suitability. It is not easy to reconcile the requirements of provenances with the conditions offered by their new home sites, due to the infinite variety of both the sites and the genotypes of trees. According to Evans and Hibberd (1993), the best match between species and site to yield high growth and health quality of crops, based on knowledge of genotype (provenance) and environment (GEI) can only be realized by a more detailed climate analysis. Goor (1987) emphasized how important the matching is in the process of land evaluation.

All relevant requirements of provenances are set out against mapped land properties, then to be analysed. Inevitably, the inherent fuzziness of matching becomes apparent (Rossignol et al. 1998). This produces a fuzzy set of "correct" matchings (Kosko 1993). From the analysis of the matching process, combinations are chosen which are silviculturally optimal.

The provenance-site suitability approach makes it possible to distinguish between suitable and unsuitable sites in the new region. This helps to deploy the provenances in the optimum arrangement in the land, according to their growth requirements. In addition, this also indicates the optimum time for planting, i.e., as early as possible in the rainy season, to protect seedlings from drought stress. Zimmermann (1977) stated that seedlings were more responsive than mature trees to site changes due to the close proximity of seedling shoots to roots, and the rather immediate effect of one upon the other. The above information helps diminish risks in forest plantations, such as dieback or the appearance of multistemmed trees. Unsuitable land should be left for other tree species or for purposes other than forestry.

Interaction with the site, of course, determines the performance of a tree. An example is the occurrence of multistem architecture in our trial plots. In fact, almost all provenances have multistemmed trees, although in frequencies ranging from 66% to 5% (see Table 4.6). Originally, their cuttings were collected from "good" tree phenotypes, i.e., high trees with a large diameter and one straight stem. However, they still create multistemmed trees. There are two types of multistem architecture after stress, the first above ground and the second underground from buried stems or roots of the trees. Partly burnt trees form new stems in their aerial parts and completely burnt trees form new stems from the buried stem base or from the root of the trees (see Figures 4.4. and 4.5).

Is such a multistem architecture resulting from the fire and drought stress which occurred during the experimental period ? Or is it due to the genotype of Sungkai itself, or to both ? Trees can either adjust or adapt. Adjustment is a change in growth and architecture of individual trees in response to actual environmental stimuli. Adaptation is the result of inherited change of behaviour and architectural strategy in a tree population in response to the natural selection of surviving and reproducing members (Hallé et al. 1978)

However, as matching covers a requirement range of a certain provenance, the risk that any single site factor causes a wrong choice is assumed to be small within the margin of single factors becoming limiting in an absolute sense. Hence, a precise matching of climatic and edaphic environment between the natural home site and the new site is indispensable.

So, our approach covers three vital aspects. The provenance-site suitability defines the optimum site for a provenance to grow, whereas the transport of materials and nursery treatments determine the condition of the planting material (cuttings), and tending supports the later growth of the trees. If those activities are carried out properly, healthy and vigorous trees will indeed result from these measures. Of course, strict silvicultural management should be supported by other silvicultural measures, such as soil management of the planting site in order to avoid erosion and to maintain the soil fertility, to control pests and diseases, or to optimize interaction with other plants.

There is no doubt that some species suffer more in interaction with grass while others suffer in interaction with other woody plants and climbers. The interaction with grasses and dicotyledonous weeds in a situation of scarcity of water and available nutrients is frequently so great as to limit severely the growth of young trees. It may even result in their death. Other site-related factors also influence species/provenance choice such as the resistance of a provenance against grass fires, the tolerance to flooding or other disturbances. (Davies, 1987).

5.2. Designing A Silvicultural System for Sungkai

In designing a silvicultural system for Sungkai, at least four factors should be taken into consideration, (1) the health of the plantation including the ecological profile of the tree, (2) the end use of the wood, (3) the secondary management aims, and (4) the cost of silvicultural measures. This is the translation of Oldeman's (1991) set of four management criteria.

The "ecological profile" or temperament of an organism is the strategy pattern of the organism in a response to environmental dynamics in order to meet its ecological requirements (Oldeman and Binnekamp, 1994). It is very important to know this profile in order to produce timber according to specifications. In the ecological profile the requirements of a certain species as to its environment are recognised, e.g. an architectural strategy as a response to site dynamics.

As mentioned in Section 5.1 planting sites for Sungkai or other trees for plantation forestry tend to be in marginal lands, such as *Imperata cylindrica* grasslands, eroded soils and steep slopes (Anon, 1997; Davis and Roberts, 1990; Mutsaers, 1998). To produce wood with high quality specifications on such marginal lands needs investment. Grasses and broad leaved weeds consume the scarce water and available nutrients frequently in such quantities that they limit severely the growth of young trees and even cause their death (Davies, 1984). In the dry season *Imperata* grasses become a potential fuel which will threaten the fate of Sungkai plantations, especially in areas (e.g. Kalimantan and Sumatera) where shifting cultivation is common. Meanwhile, burnt Sungkai trees tend to become multistemmed if they manage to survive (see Chapter 4). Such trees are not desired as sawn wood or plywood.

Different end-uses need different characteristics. Sawnwood, pulp and plywood have higher specifications than other uses. Most of the users of sawn timber, would prefer the following characteristics : long lengths with straight, even grain; large width and depth, uniformity throughout the piece; branch knots absent or few, well scattered, small; free of inclusions such as calcite, silica and resin pockets (Palmer, 1994).

The design of a plantation often focuses on the means to obtain maximum volume yields against minimum investment, and on sustainablility. Meanwhile, secondary management aims are hardly regarded or sometimes even neglected. The emphasis on the first objective without caring about ecosystem health may lead to the destruction of the producing system.

Silvicultural measures aim at yielding healthy, vigorous trees so as to obtain the desired products. Certainly, those measures cost money. As long as the silvicultural measures will increase the profits, such actitivities should be conducted. However, low cost is always desirable. Oldeman (1991) stated that the choice of cheap and adequate measures are a better guarantee for management success than a "quantitative"yield forecast.

For instance, larger spacing will allow grass to grow rapidly because Sungkai crowns are slow in closing the canopy. This leads to high cost if tending is to be carried out often during the whole rotation. It is also a potential threat to the plantation especially in the dry season, if tending is not carried out. So, narrow spacing is both cost-efficient and ecologically efficient to diminish the problem in the specific case of alang-alang.

The above examples illustrate, how the above four objectives have to be kept in mind when designing silvicultural systems for Sungkai.

The design of a plantation is a blueprint for the structure of the stand from establishment through tending to harvest and regeneration (Brünig, 1994). This author added that plantations should be designed in such a manner that they function effectively and efficiently in converting inputs from the physical environment into desired output into forestry for transfer into the socio-economic and socio-political level. In relation to agroforestry, Raintree (1984) mentioned the criteria for a good agroforestry design, i.e., productivity, sustainability and adaptability. Oldeman (1990) says that a greenprint is a design involving the definition of the objective, the analysis and evaluation of resources and constraints, and the structuring of the functional interrelationship of the system components.

The following discussion focuses on the implementation of the above four objectives (end use, ecological profile, secondary management aims, silvicultural measures) in four successive silvicultural phases (establishment, tending, harvest, regeneration). They have to contain a broad range of techniques, a few basic ones of which are discussed here.

End use is the specific use by the industrialist of the wood yielded by a plantation forest. As mentioned, a different end use needs different characteristics of the wood produced. Wood industries require industrial forest plantations to produce long, straight stems, suitable for end-uses such as plywood and sawn timber. Tree conformity to these specifications depends on tree architecture and trunk formation in particular. Tree architecture codetermines the "ecological profile" of the species (Oldeman and Van Dijk, 1991 ; Oldeman and Binnekamp, 1994). These authors stated that architectural strategy differs between tree groups.

As described in Chapter 2, the architecture of Sungkai represents the model of Scarrone, converging when older with Leeuwenberg's model. In young Sungkai trees, the architecture conforms to Scarrone's model, and in adult trees, fragmentation and reduction make it resemble Leeuwenberg's model. This transition between one model and another which occurs within a single, old individual tree often occurs in other species (Hallé, et al.1978). These authors mentioned that Leeuwenberg's model is less common in rain forest species than in species of secondary vegetation and disturbed sites, both in the tropics and in temperate regions.

The second feature to be taken into account in establishment activities is spacing. Spacing influences the performance of trees in general, including our provenances. Wide spacing may lead to poor timber quality in terms of stem form and branch size. In addition, it will allow grasses and other herbaceous plants to grow densely around the newly planted trees. Closer spacing may reduce early branching and encourage straight, vertical stems and early establishment of a closed canopy. However, according to Hamilton in Evans and Hibberd (1993), closer spacing reduces individual girth increment as the crops mature, except if the tree number was reduced by thinning. In general, poor sites require a wider spacing and rich sites a closer spacing (FAO, 1979). Therefore, our Sungkai plantations on alang-alang land should be spaced *as densely as possible in these poor sites with each provenance.*

Based on the measurements of crown diameters (see Chapter 4), closer spacing is favourable for Sungkai trees planted in grass areas. As described in Chapter 4, by using a 3x3m spacing only three or perhaps five provenances may achieve a fast canopy closure within 26 months. Grass in great volumes is dangerous in Sungkai plantations due to high fire risks caused by the common practice of shifting cultivation in Kalimantan. As said, partly burnt Sungkai trees adopt a multistem architecture. Such trees are undesirable from a timber perspective. However, closer spacing is costly in labour and number of plants. A 2x3 m spacing may be a good compromise for Sungkai plantations.

The next feature to be taken into account in plantation establishment is the prevention or reduction of environmental factors which stimulate multistem architecture in Sungkai plantations. Chapter 4 showed that fires or other physical pressure (such as the impact of cattles or tree falls) cause multistemmed trees to grow as a consequence of its survival strategy. Soerianegara and Lemmens (1994) claimed that shoot-boring insects may also attack and deform the tops of young trees in the field. However, the damage was not serious. Inevitably, such factors may also have an impact on healthy plantations. Pruning, therefore, has to be carried out in the unnaturally dense plantations, particularly in the tending phase. Pruning is very important in Sungkai plantations because the tree easily reiterates, especially when facing stress factors. In our provenances, multistemmed trees vary in mean percentage from 5% to 66% (Table 4.6). To diminish multistems early pruning is recommended, as soon as the trees begin to show multistem formation. Self-pruning is not sufficient, so, artificial pruning is necessary. Wounds caused by artificial pruning heal fast and seldom cause rot (Soerianegara & Lemmens, 1993).

The clear felling system is common in harvesting even-aged plantations. During the establishment, the site condition is essential to provide maximum hospitality from the new site to the provenance planted. In the harvest phase, the site is to be conserved carefully, so as to reduce potentially negative influences upon sustainability caused by clear felling.

As mentioned before, plantation forests including Sungkai generally occupy marginal lands such as steep slopes and eroded soils. Careful planning is needed in selecting harvesting operations, appropriate equipment and machinery, and their deployment in the field (Hibberd *in* Evans and Hibberd, 1993). Wood is harvested by extracting individual trees in such a way that the whole system is not threatened (Kuper, 1997).

There are three basic forms of harvesting wood, i.e., pole length, short wood and whole trees. In pole length harvesting, each tree trunk is removed from the site in its total length for conversion elsewhere. In short wood harvesting, the tree trunk is cut up into shorter lengths before being removed from the site. Whole tree harvesting implies removing the whole tree including the branches from the site to be processed elsewhere (Evans and Hibberd, 1993).

Forest health is best served by shortwood harvesting in order to prevent or reduce soil compaction and erosion. This is commonly done in teak forests in Java. In certain places in Kalimantan, the local people's experience in hauling felled trees with the help of buffaloes may be adapted, especially on slopes. This will decrease soil compaction and erosion. Besides, the trees in areas with very steep slopes should only be felled in a well-designed pattern, so that there is always a protective forest cover.

Hence, the design of forestry plantations should emphasize not only financial returns and economic benefits, but also long-term environmental impacts (Wiersum, 1983). Trees should be managed well because they are long-lived carriers of major ecological and economical functions. Each product or service is linked to a carrier in the local system (Oldeman, 1991b). Therefore, secondary management aims should be paid attention to, and if possible be increased. Perhaps, the failure of forestry plantations is due to a lack of attention to particular socio-economic and physical conditions of the region. Anon. (1997) stated that only a small portion of the profit is invested in forest resource development efforts. Most is invested in logging operations and the processing industry. The key issues for sustainability of non-commercial value are : maintenance of soil fertility, forest cover and biodiversity (Kuper, 1997).

Oldeman (1991) stated that only multivalent forests will allow the development of whole new fields of contribution to human society, as well as forms of transition management. This author said that mathematical tools exist today to assess precisely the socio-economic and/or ecological potential of any set of measures, using a system analysis with different bias. For the moment, however, many forest managers still hesitate to enlarge their set of simultaneous objectives. Many options seem to them, but not to the local people (Rukmantara 1998), to be weak, uncertain, derisive. Hence it often is the forester himself who is a social obstacle to new forms of management (Neugebaur & al 1996).

As mentioned earlier silvicultural measures aim at increasing the quality of the plantation, but they cost money. According to Kuper (1997) investment is profitable if it will increases the net present value. This author mentioned three ways to increase the present net value, i.e., by a smart use of the available forest, by investment allowing replacement or improvement, and by reducing cost and risks. For example, thinning is one of the silvicultural measures to enhance the present net value. Thinning converts trees into cash and at the same time provides more growing space for trees of a higher quality.

As to Sungkai plantations, the use of native Sungkai provenances in the plantation rather than immigrated provenances, is considered to increase the profits. As shown in our trial plots Kalimantan provenances had a higher growth (high survival rate and other parameters) than the Sumatera provenances. They grew better although they faced a dry period and many disturbances (fire and cattle) during the experimental period. A high survival rate, height and diameter led to a high timber volume. In addition, transport cost was low due to a short transport time and the risk of stressed cuttings was low. So, as emphasized by Oldeman (1991) and Kuper (1997), reducing cost and risks will maximize the financial profits. According to Kuper (1997) this approach also ensures the sustainability of the socio-economic forest function.

Other aspects in Sungkai plantation are pruning and spacing. Based on our research in our Sungkai plantation, pruning is needed to enhance the quality of timber. As a consequence of its strategy to survive in bad conditions, Sungkai trees reiterate strongly. Such trees tend to assume a multistemmed tree architecture. Pruning increases its net present value by improving the timber quality.

Unappropriate spacing may lead to a poor stemform of the trees and allow grass to grow rapidly due to a slow canopy closure by the Sungkai crown. This causes a decrease in the quality of produced wood, so, in profit. Besides, dense grass threatens the plantations, especially the areas where shifting cultivation is practiced. It is asssumed that investing in narrow spacing will make the plantation more robust and will reduce economic risks.

Harvesting should be planned early, using the data or the information produced in the matching process of the site and the ecological requirements of provenances. These data include terrain factors (terrain class, slope angle, relative relief), soils (soil type, soil texture, soil depth, soil drainage class, soil infiltration), and climate (rainfall, rain days, temperature).

In the last few decades, the design of a forest plantation has been conventionally dogmatic and sectoral. A stiff application of narrowing optimizing principles will produce disappointing results (Brünig, 1984).

Plantation designs often focus exclusively on the means to achieve maximum yields. Meanwhile, carrying capacity of the ecosystem and social factors are being neglected (Wiersum, 1984; Oldeman, 1991; Padoch & Peluso, 1996; Neugebaur & al 1996). In designing Sungkai plantations the above factors should be taken into account.

Practical forestry conventionally assesses wood production by using increment data from other sites, supported by statistical analyses. Sometimes inputs, e.g, fertilizers, are applied in order to obtain the expected yields. To estimate the volume production, however, demands attention for the carrying capacity of the ecosystem, which is important in order to support sustainable production. Statistical analyses in estimating the wood volume should be used with caution. The result depends on the given inputs. Statistics is a tool to help us to know future probabilities, e.g, the probable volume in case of wood production. However, because of the dynamics of environmental conditions, this should not be taken at face value. The environmental conditions change frequently and in a heterogeneous pattern. We cannot negotiate with nature about ecological limits (Anon, 1999). The increment is not predestined. Therefore, such methods should be used carefully, otherwise they may easily disappoint.

For example, in our provenance trial we found differences between the survival rate based on original counting and statistical expectation. Based on the original counting, the Samarinda provenance is third among ten, and seventh statistically (see section 4.3.1.1). It is obvious that the statistical analysis tends to calculate the results towards a "normal" situation. In real life the occurrence of droughts, fires, cattle disturbances, pests and diseases complicate the image. The statistical approach, in a complex situation, may ignore reality, for instance, if the near future will see the effects of "El Niño" in South East Asia and of global warming (Rossignol et al. 1998).

Ecosystem security and social constraints in which Sungkai plantations are established should be emphasized, rather than that the focus is on the mere estimate of wood production. A sound ecosystem is the best and cheapest guarantee for healthy plantations, which in turn will sustain the production.

As mentioned, forest plantation design is conventionally sectoral and social factors are often neglected. The involvement of local people in plantation establishment is too often inadequate, carried out to meet formality rather than reality. In such a case, it is insufficient (Padoch & Peluso 1996; Rukmantara, 1998).

In Sungkai plantations design, the participation of local people should be increased both quantitatively and qualitatively. The local inhabitants should be involved, if possible, in all phases (identification, design, management and monitoring). Their involvement will have several benefits, e.g, to increase a sense of belonging to the plantations (due to respect), additional income, reduction of conflicts, better security for the plantations and the local inhabitants. Compared with other common species used in reforestation, afforestation and IFP (*Acacia mangium, Eucalyptus spp, Gmelina arborea*), the Sungkai tree is well-known by many local people in the villages. They have been using the trees for live fences in home gardens or farmyards, and certainly know the environmental requirements of the tree in pre-scientific terms. Their local knowledge is certain to provide beneficial inputs in designing the plantations, including the prevention of and protection against pests and diseases, fire and cattle. Local people will respect plantation programmes only if they will benefit from them.

New initiatives should be introduced in Sungkai plantations. For instance, the IFP company should give local people the opportunity to manage several Sungkai plantations under supervision and guidance from the company. It is relevant to the national programme of the Government of Indonesia to develop village cooperative units. So, local people will get job opportunities and additional incomes and the IFP company will obtain an improved wood production. Many strategies can be devised and implemented. Eventually, it all depends on the willingness of the company to follow this course of action. Participation is a two-way street for both villages and companies.

5.3. Conclusions

The present book leads to the following conclusions.

1. Generally, the Kalimantan provenances of *Peronema canescens* Jack. (VERBENACEAE) show a faster growth than the Sumatera provenances, as proved by the high values of almost all growth parameters. The Kalimantan provenances are often in the upper group of five of the ten provenances.

2. Based on their individual characteristics, the ranking in decreasing order of the Kalimantan provenances is as follows : Pontianak, Palangka Raya, Banjarmasin and Samarinda. For the Sumatera provenances this is : Riau, Padang, Palembang, Bengkulu, Jambi and Lampung. The overall ranking is Pontianak, Palangka Raya, Banjarmasin, Riau, Padang, Samarinda, Palembang, Bengkulu, Jambi and Lampung.

3. The "neighbouring provenance approach" gives good prospects in the Sungkai plantation forestry, as proved by the above points 1 and 2. It is suggested to use either native provenances, or the closest neighbouring provenances in the development of Sungkai plantations. This is a conservative but safe approach, and should be applied until new research shows alternative, better options.

4. The use of native provenances in plantations is assumed to increase the profits due to their high growth potential and short distance between trees for seeds or cuttings and the nursery. High growth (high survival rate and other parameters) produces high timber volumes and a short distance will reduce the cost and risks of stressed propagules. This will maximize the potential financial profits.

5. Although our Sungkai plantation trees faced dry periods and many negative impacts (fire and cattle) during the experimental period, their survival rates are high, from 75% to 92% for the Kalimantan provenances and from 68% to 73% for the Sumatera provenances.

6. The mean height of twenty-six-months old Sungkai plantations varied from 195 to 280 cm for all provenances and 255 cm to 280 cm for the upper group of five. The mean diameter at breast height varied from 2.5 to 4.3 cm for all provenances and from 3.8 to 4.3 cm for the upper group of five.

7. Almost all provenances can display multistem architecture, although they vary in percentage, from 5% to 65%. To some extent this is caused by the drought period and the fires in 1997. However, there is also a tendency for the provenance with better growth (according to every parameter) to show a high percentage of multistemmed trees.

8. Multistems have to be reckoned with if good timber is the main objective in plantation forests. Hence, all factors stimulating multistem formation should be prevented or reduced. Among those factors are fires or other physical impacts

(such as those by herbivores or tree falls), which stimulate the formation of multistemmed trees as a tool to survive in bad conditions. Specific silvicultural practices, e.g. pruning in certain periods during of plantation development must, therefore, be conceived and applied in order to achieve the timber objective.

9. The architecture of Sungkai represents the model of Scarrone, converging when older with Leeuwenberg's model. In young Sungkai the tree architecture conforms to Scarrone's model, and in adult trees, fragmentation and reduction make it resemble Leeuwenberg's model. Tree architecture reflects a strategic pattern to meet the ecological challenges. Different conditions of the original vegetation surrounding each provenance influence the tree architecture to some extent. Healthy ecosystems tend to favour a tree architecture which may produce timber according to specifications.

10. In attempts to optimize the mutual adaptability of the provenance and the new site, a provenance-site harmony must be aimed at. This approach leads to a high degree of hospitality of a new site towards a particular provenance. It is suggested to use the optimum ecological combination of the ecological requirements of the provenances and the properties of their new home sites.

11. In attempts to optimize nursery production of Sungkai, the best materials among the provenances must be used, as well as the best existing procedure in handling the cuttings in the nursery, and the best tending techniques in the plantation.

12. In attempts to optimize Sungkai for wood production, there are a few features to pay attention to : establishing provenance-site harmony on a new site, and prevention against pests and diseases. In relation to the above factors, there are five areas that should be taken into consideration, i.e., the home site of the provenances, transport from the home site to the new site, behaviour in the nursery, transport from the nursery to the planting site, and behaviour in the planting site.

13. In designing a silvicultural system for Sungkai, four factors should be taken into account, i.e., the health of the plantation including the ecological profile of the tree, the end use of the wood, the secondary management aims and the cost of silvicultural measures. These factors should and can be involved in successive silvicultural phases, such as establishment, tending, harvest and regeneration.

14. The statistical approach may in a complex situation ignore reality. Therefore, such methods should be used cautiously, otherwise they may easily disappoint.

15. The local inhabitants should be involved in plantation programmes, if posible in all phases (identification, design, management, monitoring). Their involvement will provide greater security for both the plantations and the local inhabitants.

SUMMARY

Sungkai (*Peronema canescens* Jack.), Verbenaceae, is one among the fancy woods of Indonesia. Sungkai belongs to a small number of species recommended by The Ministry of Forestry for use in the development of industrial forest plantations (IFP). The IFPs are carried out in response to an increasing wood demand and aim at reducing pressure on the natural forests, thereby contributing to national land conservation objectives, as well as to the supply of industrial raw materials.

The wood of Sungkai is used in various ways from roof trusses in the village more specific purposes (veneers). The attractive grain makes Sungkai suitable for veneer, furniture and cabinetwork (Martawijaya et al.1981). Hence, Sungkai has the potential to be planted by local people on their own land for their own use and as a cash crop, in addition to IFPs for industrial purposes. Among indigenous pioneers tested on grasslands in South Kalimantan, Sungkai has a survival rate close to 100%. Usually, Sungkai is regenerated by cuttings rather than by seeds, because this is easy and does not depend on the fruiting season.

Although Sungkai is used in IFPs in Indonesia, no efforts have been made yet to develop the quality of Sungkai planting stock. Generally, availability rather than quality of Sungkai cuttings in a site is considered. Not all vegetative propagation nurseries or seed sources are managed professionally by the private sector. Genetic variation in wild populations is virtually unknown, and few attempts, if any, have been made at genetic improvement. Wild Sungkai can be found in many sites in Kalimantan and Sumatera.

Only a few successful plantations exist, so most timber continues to be harvested non-sustainably. Domestication of Sungkai is crucial for the development of a sustainable, high-quality timber resource.

A first field trial of Sungkai (*P. canescens)* provenances from various sites in the Province of South Kalimantan (Hatta, 1992) showed growth differences among the provenances. More genetic diversity may be expected over the broad ecological and geographical range of *P. canescens* in Kalimantan and Sumatera.

Clearly, provenance research on Sungkai (*P. canescens)* will lead to genetic improvement and so provide silviculturally optimized *P. canescens* populations in the field. Wood industries require industrial forest plantations to produce long, straight stems, suitable for end-uses such as plywood and sawn timber. Tree conformity to these specifications depends on tree architecture and trunk formation in particular.

Tree architecture codetermines the "ecological profile" of the species. The architectural strategy of Sungkai, particularly its plasticity and flexibility is basic information for the optimization of the species for wood production. Such knowledge helps predict the tree's capacity to adjust.

The present study pinpoints the best provenances of Sungkai, the tree architecture of Sungkai, and specifications for highly productive and low-risk plantations. This is useful especially for industrial forest plantations which have to meet high requirements. Using good quality Sungkai cuttings makes for good

diameter at breast height varied from 2.5 to 4.3 cm for all provenances and from 3.8 to 4.3 cm for the upper group of five.

The h/d (height/diameter above root) ratio of twenty-six months old, planted Sungkai trees has not yet shown any obvious tendency towards either $h > 100d$ or $h < 100d$. This relationship still oscillated around $h = 100d$. In other words, the model-conform trees still showed a height-diameter ratio of $h \approx 100d$. This indicates a balanced metabolism with endogeneously and mutually adjusted cambial and height growths.

This ratio is related to the architecture of the tree. Several authors found that nearly all model-conforming trees in French Guyana and elsewhere showed the ratio of $h = 100$ d. In the field, if a young tree breaks off, the ensuing regenerative reiteration pushes this ratio upward ($h > 100$ d); and when a tree expands its crown by abundant reiteration, the ratio become $h < 100$ d

All Sungkai provenances can form multistems. However, statistically they are significantly different. Most Kalimantan provenances have a high share of multistemmed trees (above 48%), except Samarinda (19%). Four provenances have fewer multistems, i.e. Lampung (5%), Bengkulu (5%), Jambi (17%) and Samarinda (19%). They may be considered "the best group" for timber quality. However, other factors must be considered for that purpose, i.e. survival, height and diameter growth. The formation of a multistem architecture should be counteracted if good timber is the production objective.

Generally, at 26 months the provenances achieved a mean crown diameter above 132 cm, except Jambi (119 cm). As with other parameters, the Pontianak provenance maintained its highest rank (176 cm), in the group with the Palangka Raya (174 cm) and Padang (175 cm) provenances. If the results are related to the plantation with a 3x3 m spacing, only 3 or perhaps 5 provenances may have achieved fast canopy closure within 26 months, i.e. Pontianak, Palangka Raya, Padang, Banjarmasin and Palembang. Their capacity to suppress the grass may have increased by narrower spacing in plantation, e.g 3 x 2 m., so grass suppression and an acceptable rate of timber production may both have been achieved.

Several facts emerge. First, the Kalimantan provenances show a faster growth than the Sumatera provenances, as proved by their high values of almost all parameters. Second, based on their individual characteristics, the Kalimantan provenances rank in decreasing order as follows : Pontianak, Palangka Raya, Banjarmasin and Samarinda. For the Sumatera provenances this is : Riau, Padang, Palembang, Bengkulu, Jambi and Lampung. And overall : Pontianak, Palangka Raya, Banjarmasin, Riau, Padang, Samarinda, Palembang, Bengkulu, Jambi and Lampung. Third, as to its better growth performance, the Pontianak, Palangka Raya and Banjarmasin provenances are promising provenances for Industrial Forest Plantations (IFPs). Fourth, for experiments outside Sumatera, the Riau, Padang and Palembang provenances may be satisfactory as long as the transport time of the propagation material is short and cuttings are well packaged.

In optimizing the mutual adaptability of provenance and a new site, at least two features are important, i.e., climate and soil of the site. A more detailed climatic analysis is needed, both for the original and the new site of the provenance in order to assess climatic stress. The climatically suitable region, the upper and lower limit of tolerance for a particular provenance, and the optimum time for planting, i.e., planting early in the rainy season, avoiding severe stress for young seedlings (pluriannual drought periods) have to be known. For large areas such as Kalimantan and Sumatera, site maps should be produced per provenance.

The second feature is soil. There are at least three factors to be considered, i.e., physical soil structure including depth, nutritional soil status including organic matter content, and acidity of the soil (pH). Soil factors should be included in site maps, so, soil surveys of the new site are necessary.

The combination (overlay) of climatic and edaphic factors of the home site and the new site will show the degree of hospitality of a new site towards a particular provenance. So, we will be able to deploy each provenance in each suitable region. The optimum mutual adaptability of provenance and site then is achieved.

In Chapter 5 the optimization of the wood production and the design of the silvicultural system of Sungkai are discussed. Wood production is the usual aim in plantation forestry. A tree must grow well where it is planted. Healthy, vigorously growing trees are desired, which are highly productive in the given environment.

Three points are essential in order to optimize Sungkai wood production : (1) to use the "best" provenances, (2) to achieve provenance-site harmony and (3) to tend plantations well, including prevention of and protection against pests and diseases.

Based on this present study five items should be paid attention to if a certain provenance is to grow well : (1) the home site of the provenance, (2) transport from the home site to the new site, (3) behaviour in the nursery, (4) transport from the nursery to the planting site, and (5) behaviour in the planting site. These five factors determine the performance of provenances.

In designing a silvicultural system for Sungkai, there are four essential points : health of the plantation including the ecological profile of the tree, end use of the wood, secondary management aims, and cost of silvicultural measures.

The "ecological profile" or temperament of an organism is the strategy pattern of the organism as a response to environmental dynamics in order to meet its outside world. This profile is very important for the production of timber according to specifications. The ecological profile becomes visible as an architectural strategy in response to site dynamics.

Different end uses need different characteristics. Sawn timber, pulpwood and plywood each have their specifications. Most users of sawn timber prefer long trunk lengths with straight, even grain; large width and depth, uniformity throughout the piece; branch knots absent or few, well scaterred, small; free of inclusions such as calcite, silica and resin pockets (Palmer, 1994).

The design of a plantation often focuses on maximum yields, the volume of the investments, and the life-span of the tree. Meanwhile, secondary management aims are being neglected. Emphasizing the first objective without caring for ecosystem capacity will lead to the destruction of the producing system itself and to economic instability.

Silvicultural measures serve to yield healthy, vigorous trees so as to obtain the desired products. Certainly, those measures cost money. As long as silvicultural measures may increase the profits, their implementation should be considered. However, low cost is always desirable. The choice of cheap and adequate measures may well be a better guarantee for management success than a "quantitative"yield forecast.

Indeed, as shown by the present study, such forecasts are proved worthless by unexpected and unforseen events (fire, cattle, insects). Statistical forecasts, therefore, are to be treated with caution, because forecasts are only virtual reality. It is always safer to optimize the cost-benefit ratio in the present.

In a complex situation the statistical approach may lose touch with reality. Therefore, statistical methods should be used carefully, otherwise, they may easily disappoint.

The Local inhabitants should be involved in the plantation programme, if possible in all phases (identification, design, management, monitoring). Their involvement will be beneficial to both plantations and local inhabitants.

SAMENVATTING

Sungkai (*Peronema canescens* Jack), Verbenaceae, is een boomsoort die tegenwoordig in Indonesië erg in zwang is. Sungkai behoort tot een kleine groep van soorten die door het Ministerie van Bosbouw wordt aanbevolen voor gebruik in industriële houtplantages (industrial forest plantations, IFP). Deze plantages zijn opgezet met het oog op de toenemende houtbehoefte en hebben als doel de druk op het natuurlijke bos te verminderen, en tevens bij te dragen aan het nationale beleid voor landbehoud, en aan de grondstoffenvoorziening voor de industrie.

Het hout van Sungkai wordt gebruikt voor zowel meer algemene constructiedoeleinden (bijvoorbeeld plaatselijk voor daksporen), als voor meer specifieke doeleinden (fineerhout). De mooie tekening maakt Sungkai geschikt voor fineer en voor toepassing in de meubelmakerij (Martawijaya et al. 1981). Sungkai is daarom geschikt voor aanplant door de plaatselijke bevolking voor zowel eigen gebruik, als voor verkoop voor industriële doeleinden, in aanvulling op het IFP-programma. Van de inheemse soorten beproefd op gedegradeerde graslanden in Zuid Kalimantan, heeft Sungkai een overlevingspercentage van bijna 100 %. Omdat Sungkai gemakkelijk is te stekken, wordt meestal op deze wijze vermeerderd en niet via zaad. Men is daardoor onafhankelijk van een goede zaadproductie.

Hoewel Sungkai in Indonesië in het IFP-programma wordt gebruikt, heeft men tot nu toe nog geen onderzoek gedaan naar de kwaliteit van de bomen in de plantages. Meestal wordt meer op de beschikbaarheid van stekken gelet, dan op de kwaliteit ervan. Het beheer van de particuliere kwekerijen waar wordt gestekt of via zaad wordt vermeerderd is niet altijd professioneel. Hoe groot de genetische variatie in de oorspronkelijke populaties is, is vrijwel onbekend en er is slechts weinig of niets gedaan aan selectie en veredeling. Van nature komt Sungkai voor op veel groeiplaatsen in Kalimantan en Sumatra.

Omdat er slechts weinig succesvolle plantages bestaan, wordt het meeste hout nog steeds geoogst op niet-duurzame wijze. Domesticatie van Sungkai is cruciaal voor de ontwikkeling van een duurzame bron van kwalitatief hoogwaardig hout.

Een eerste veldproef van herkomsten van Sungkai (*Peronema canescens*) van verschillende standplaatsen uit de provincie Zuid-Kalimantan (Hatta, 1992), toonde aan dat er groeiverschillen zijn tussen de verschillende herkomsten. Een nog grotere genetische diversiteit kan verwacht worden als het gehele ecologische en geografische verspreidingsgebied van *P. canescans* in Kalimantan en Sumatra in aanmerking wordt genomen.

Herkomstonderzoek aan Sungkai (*P. canescens*) zal tot genetische verbetering leiden en daardoor tot in teeltkundig opzicht geoptimaliseerde *P. canescens*-populaties. De houtindustrie verlangt lange, rechte stammen, geschikt voor producten als multiplex en zaaghout. De geschiktheid van bomen voor

dergelijke producten wordt bepaald door de boomarchitectuur en meer in het bijzonder de stamvorm.

De boomarchitectuur bepaalt mede het "ecologische profiel" van de soort. De strategie van Sungkai door middel van zijn architectuur, in het bijzonder zijn plasticiteit of flexibiliteit, is bepalend voor de optimalisatie van de houtproductie van de soort. Kennis hieromtrent helpt om het aanpassingsvermogen van de boom vast te stellen.

Het hier gedane onderzoek is er op gericht de bruikbaarste herkomst van Sungkai, alsmede de architectuur van de soort te bepalen en na te gaan hoe te komen tot plantages met hoge productiviteit en met weinig risico. Dit is vooral nuttig voor industriële plantages die aan hoge verwachtingen moeten voldoen. Gebruik van goede kwaliteit stekken zal leiden tot houtproductie van goede kwaliteit en kwantiteit en daarmee tot een succesvolle herbebossing. Voor de regering is een succesvolle herbebossing van betekenis voor een herstel van ontboste gronden, een toename van de houtproductie, meer werkgelegenheid en meer inkomen.

In hoofdstuk 2 wordt de oorspronkelijke standplaats en vegetatie van elke herkomst besproken, alsmede de architectuur en ecologie van de Sungkai als basis voor de teelt.

Kenmerken van de standplaats zijn geografische breedte en lengte, hoogte boven zeeniveau, topografie, jaarlijkse neerslag en aantal regendagen per maand, gemiddelde maandtemperatuur, maximum- en minimum dagtemperatuur en bodemeigenschappen. Behalve de naam van de standplaats waar stekken zijn verzameld is ook de naam van het dorp en het district vermeld.

De oorspronkelijke vegetatie van elke herkomst is onderzocht met behulp van een snelle diagnose van een lijntransect in de directe omgeving van de geselecteerde bomen. Bovendien zijn de bomen beoordeeld op hun fenotype. De goede werden geselecteerd om te stekken. Om de architectuur te bepalen werden een kiemplant, een boom in de dichte fase, een boom in de stakenfase en een volwassen boom getekend.

Sungkai groeit aanvankelijk volgens het architectuurmodel van Scarrone. Wanneer hij volwassen wordt gaat hij via fragmentatie en reductie lijken op het model van Leeuwenberg (Hallé en Oldeman. 1970; Hallé et al. 1978).

De oorspronkelijke vegetatie van de tien herkomsten varieert van oud secundair bos (herkomst Samarinda) en jong secundair bos (herkomst Jambi) tot erfbeplantingen (herkomst Padang) en wegbeplantingen of rivieroeverbos (herkomsten Pontianak en Lampung). Ook kwamen natuurlijke opstanden gedomineerd door Sungkai voor (herkomst Palangka Raya), gemengde opstanden (herkomsten Samarinda en Jambi) en kunstmatig gemengde opstanden of erfbeplantingen (herkomst Padang).

Ten aanzien van de geografische verspreiding van Sungkai in Sumatra en Kalimantan zijn alleen algemene gegevens gepubliceerd. Voor zover bekend komt Sungkai van nature voor in het westen van de Indonesische Archipel, met name in de lager gelegen delen van Sumatra en in geheel Kalimantan. De grens van het natuurlijk verspreidingsgebied in het zuiden is 7°20' en in het noorden 4°10'. In Kalimantan komt Sungkai vooral in het centrale deel voor.

Op basis van waarnemingen en locale informatie tijdens het verzamelen van de stekken, kunnen we nu aannemen dat binnen Indonesië Sungkai in Sumatra en Kalimantan vooral voorkomt beneden de evenaar en slechts weinig erboven. Hoofdstuk 2 laat het verspreidingsgebied van Sungkai op de eilanden Kalimantan en Sumatra zien.

Architectuur is de strategie van de boom ten aanzien van de ecologische factoren, die op hun beurt ook weer invloed uitoefenen op de boomarchitectuur. In gezonde ecosystemen is de boomarchitectuur een indicator voor de houtkwaliteit.

Hoofdstuk 3 laat de eerste ontwikkeling van elke herkomst op de kwekerij zien. Van de tien herkomsten zijn er vier met 100 % overleving: Pontianak, Banjarmasin, Riau en Jambi. De rest varieert van 95 tot 50 % overleving (tabel 3.1). Alleen de herkomsten Padang en Lampung hebben een significant lager overlevingspercentage dan de andere, hetgeen ongewoon is voor kwekerijen, waar gewoonlijk een overlevingspercentage van tenminste 80 % wordt behaald.

De belangrijkste factoren die de overleving van de stekken bepalen zijn in elk geval de duur van het transport van de stekken van Sumatra naar de kwekerij in Banjarbaru op Zuid-Kalimantan en de herkomst van de stekken.

De stekken van de herkomst Palembang vormen het eerst scheuten en wel op de derde dag nadat ze in het medium zijn geplaatst. De herkomsten Riau en Lampung volgen op respectievelijk de tweede en derde plaats.

De herkomst Riau vormt als eerste wortels op de achttiende dag, gevolgd door de herkomsten Pontianak en Palangka Raya.

In het geheel genomen is de ontwikkeling van de herkomsten van goed naar minder goed: Riau, Pontianak, Palembang, Banjarmasin, Jambi, Bengkulu, Palangka Raya, Samarinda, Padang en Lampung.

Hoofdstuk 4 laat de ontwikkeling van de herkomsten in het veld zien. De beoordeelde individuele eigenschappen van Sungkai-aanplanten van 26 maanden oud, zijn respectievelijk overlevingspercentage, hoogte, diameter boven wortelaanzet en op borsthoogte, kroondiameter, meerstammigheid en H/D- (hoogte/diameter) verhouding. Verstoringen in de proefvakken, in het bijzonder brand, leidden tot een discussie over de overlevingsstrategie van Sungkai bij bosbrand. Ook is beschreven hoe de herkomsten zich in hun nieuwe omgeving inpassen.

Het proefveld is aangelegd in een alang-alang-grasland (*Imperata cylindrica* (L.) Pal., Gramineae) in Riam Kiwa, Zuid-Kalimantan, als een gewarde blokkenproef met drie herhalingen. Elke herkomst werd vertegenwoordigd door een plot van 25 bomen (5x5 bomen) in 3 herhalingen. De plantafstand in een plot was 3x3 m. De plots werden van elkaar gescheiden door een brandgang van 5 m breed die regelmatig handmatig werd gewied. Voor het planten werd het alang-alang-grasland twee keer met een schijveneg bewerkt en een keer met een cultivator. Er werd niet bemest. Totdat de aanplant 18 maanden oud was, werd elke 4 maanden handmatig gewied. De gegevens werden statistisch verwerkt via de GLM-Anova-procedure van het statistische pakket SPSS versie 8.0.

Twee van de zes parameters vertoonden statistisch gezien significante verschillen, namelijk overlevingspercentage en meerstammigheid.

Het overlevingspercentage van herkomsten van Kalimantan was hoger dan van herkomsten van Sumatra. Het gemiddelde overlevingspercentage van de meeste herkomsten was boven de 69 %, behalve van de herkomsten Lampung, Padang en Bengkulu. De beste vijf herkomsten varieerden in dit opzicht van 73 % tot 92 %. Aangenomen mag worden dat zonder de droogte en branden in 1997 en zonder verstoring door vee, de overlevingspercentages hoger zouden zijn geweest.

Bij de vijf beste herkomsten ten aanzien van de gemiddelde boomhoogte waren de herkomsten van Kalimantan ook in de meerderheid, maar de dominantie ten aanzien van dit kenmerk was minder uitgesproken dan ten aanzien van het overlevingspercentage. De eerste en derde positie werd ingenomen door herkomsten van Sumatra (herkomsten Padang en Riau). De gemiddelde hoogte van 26 maanden oude Sungkai-plantages varieerde van 195 tot 280 cm voor alle herkomsten en van 255 tot 280 cm voor de vijf beste herkomsten.

Ten aanzien van de diameter, zowel boven de wortelaanzet als op borsthoogte, behoorden de herkomsten van Kalimantan eveneens tot de beste. De gemiddelde diameter op borsthoogte varieerde van 2,5 to 4,3 cm voor alle herkomsten en van 3,8 to 4,3 cm voor de beste vijf.

De H/D- (hoogte/diameter boven wortelaanzet) verhouding van 26 maanden oude Sungkai bomen vertoonde nog geen duidelijke tendens tot $h > 100d$ of tot $h < 100d$. Deze verhouding beweegt zich nog steeds rond $h = 100d$. Met andere woorden, de model-conforme bomen vertonen een hoogte-diameter verhouding van $h \approx 100d$. Dit duidt op een uitgebalanceerd metabolisme met een endogeen bepaalde en wederzijdse aanpassing van cambium- en hoogtegroei.

De H/D-verhouding is gerelateerd aan de architectuur van de boom. Verschillende auteurs vonden voor vrijwel alle model-conforme bomen in Frans Guyana en elders een verhouding van $h = 100d$. Als in het veld een jonge boom afbreekt, wordt deze verhouding hoger ($h > 100d$) als gevolg van de daardoor optredende regeneratieve reïteratie. Wanneer een boom zijn kroon vergroot door veelvuldig te reïtereren, wordt de verhouding lager ($h < 100d$).

Meerstammigheid komt bij alle Sungkaiherkomsten voor. Toch zijn er statistische verschillen tussen de herkomsten ten aanzien van dit kenmerk. De meeste herkomsten van Kalimantan hebben een hoog percentage meerstammige bomen (> 48 %), behalve de herkomst Samarinda (19 %). Vier herkomsten hebben een lager percentage meerstammige bomen, en wel Lampung (5 %), Bengkulu (5 %), Jambi (17 %) en Samarinda (19 %). Vanuit het oogpunt van houtkwaliteit bezien, kunnen deze als de beste beschouwd worden. Echter ook andere factoren zijn van belang, zoals overlevingspercentage en hoogte- en diametergroei. Meerstammigheid is ongewenst als het beheersdoel hoge houtkwaliteit is.

Op een leeftijd van 26 maanden hebben de herkomsten een gemiddelde kroondiameter van meer dan 132 cm, behalve de herkomst Jambi (119 cm). De herkomst Pontianak heeft voor dit kenmerk, evenals voor veel andere kenmerken, de hoogste waarde (176 cm), samen met Palangka Raya (174 cm) en Padang (175 cm). In een opstand met een plantafstand van 3x3 m vertonen slechts 3, of misschien 5, herkomsten een snelle sluiting van het kronendak binnen 26 maanden: Pontianak, Palangka Raya, Padang, Banjarmasin en Palembang.

Onderdrukken van de grasgroei zal nog sneller plaatsvinden bij een kleinere plantafstand, bijvoorbeeld 3x2 m, waarmee zowel een snelle onderdrukking van grasgroei alsmede een acceptabel snelle houtproductie bereikt zou kunnen worden.

Verschillende conclusies kunnen worden getrokken. Ten eerste, de herkomsten van Kalimantan groeien sneller dan die van Sumatra, zoals blijkt uit hun hogere waarden voor bijna alle parameters. Ten tweede, op basis van hun individuele eigenschappen kunnen de herkomsten van Kalimantan in afnemende volgorde gerangschikt worden: Pontianak, Palangka Raya, Banjarmasin en Samarinda. Voor de herkomsten van Sumatra is deze volgorde: Riau, Padang, Palembang, Bengkulu, Jambi en Lampung. De volgorde voor alle herkomsten tezamen is: Pontianak, Palangka Raya, Banjarmasin, Riau, Padang, Samarinda, Palembang, Bengkulu, Jambi en Lampung. Ten derde op basis van betere groei en ontwikkeling zijn de herkomsten Pontianak, Banjarmasin en Palangka Raya veelbelovend voor industriële bosplantages (IFP). Ten vierde, voor proeven buiten Sumatra zijn de herkomsten Riau, Padang en Palembang, geschikt, mits de duur van het transport van het stekmateriaal kort is en het stekmateriaal goed wordt verpakt.

Ten aanzien van de geschiktheid van een herkomst voor een nieuwe standplaats, zijn tenminste twee factoren van groot belang, en wel klimaat en bodem.

Van zowel de oorspronkelijke als de nieuwe standplaats van een herkomst is een meer gedetailleerde analyse van het klimaat nodig om de mate van klimatologische stress te kunnen bepalen. Kennis is nodig van het meest geschikte klimaat (de boven- en ondergrens van de tolerantie voor de verschillende klimaatsfactoren) voor een bepaalde herkomst en het optimale planttijdstip, bijvoorbeeld vroeg in het regenseizoen planten om ernstige stress voor de jonge planten te vermijden (meer droogteperiodes per jaar). Voor grote gebieden als Kalimantan en Sumatra zijn per herkomst groeiplaatskarteringen nodig.

De tweede factor is de bodem. Tenminste drie factoren dienen beschouwd te worden, en wel (1) fysische bodemstructuur, inclusief diepte, (2) vruchtbaarheid, inclusief organische stofgehalte en (3) de zuurgraad (pH). Deze factoren dienen in de kartering meegenomen te worden. Ook van de nieuwe standplaatsen zijn bodemkaarten nodig.

Vergelijking van klimaats- en bodemfactoren van de oorspronkelijke en de nieuwe standplaats geeft een indicatie van de geschiktheid van de nieuwe standplaats voor een bepaalde herkomst. Voor elke standplaats kan zo de meest geschikte herkomst worden vastgesteld.

In hoofdstuk 5 wordt een teeltplan ontworpen voor een optimale productie van Sungkai-hout. Houtproductie is het gebruikelijke doel van aangeplante bossen. Gezonde, goed groeiende bomen met een hoge productiviteit zijn gewenst.

Essentieel voor een optimale houtproductie van Sungkai zijn de volgende zaken: (1) gebruik van de 'beste' herkomsten, (2) gebruik van herkomsten die geschikt zijn voor de betreffende standplaats en (3) een goede bosverzorging met inbegrip van voorkomen en bescherming tegen ziekten en plagen.

Gebaseerd op het huidige onderzoek kan geconcludeerd worden dat voor een goede groei van een bepaalde herkomst aan de vijf volgende zaken aandacht besteed dient te worden: (1) de natuurlijke standplaats van elke herkomst, (2) het transport van het materiaal naar de nieuwe standplaats (kwekerij), (3) de ontwikkeling van het materiaal op de kwekerij, (4) het transport van de kwekerij naar de plek van aanplant, en (5) het gedrag van het materiaal op de plaats van aanplant. Deze vijf factoren bepalen de prestatie van de herkomsten.

Bij het ontwerpen van een teeltsysteem voor Sungkai zijn vier punten essentieel: de gezondheid van de aanplant, inclusief het ecologisch profiel van de boom, het eindgebruik van het hout, de secundaire beheersdoeleinden, en de kosten van de teeltkundige maatregelen.

Het "ecologische profiel" ofwel het temperament van een organisme is de strategie van het organisme in zijn reageren op de dynamiek van de omgeving. Dit profiel is zeer belangrijk voor de mogelijkheden van de soort om het gewenste hout te kunnen produceren. Het ecologische profiel komt tot uiting in de wisselwerking tussen architectuur van de boom en de dynamiek van de groeiplaats.

Verschillende einddoelen vereisen verschillende eigenschappen. Zaaghout, pulphout en schilhout hebben hun eigen specificaties. Voor zaaghout zijn lange, rechte , dikke, volhoutige stammen vereist en dient het hout recht van draad te zijn, geen of weinig, in het laatste geval kleine, regelmatig verdeelde, noesten te bezitten en bovendien vrij te zijn van insluitingen als calcium, silicium en hars (Palmer, 1994).

Bij het ontwerpen van een plantage wordt vaak alleen gelet op een maximale volumeproductie, de grootte van de investering en de omlooptijd van de bomen. Intussen worden secundaire beheersdoeleinden verwaarloosd. Nastreven van de eerste doelstelling zonder te letten op de capaciteit van het ecosysteem, leidt tot destructie van het productiesysteem zelf en tot economische instabiliteit.

Teeltmaatregelen dienen te leiden tot de productie van gezonde, levenskrachtige bomen die het gewenste product leveren. Deze maatregelen kosten geld. Zolang teeltkundige maatregelen de winst doen toenemen, dienen ze voor uitvoering in aanmerking te komen. Het economisch risico wordt echter beperkt door de kosten laag te houden. De keuze van goedkope en adequate maatregelen zou heel wel een betere garantie voor succes van het beheer kunnen zijn dan een voorspelling van de grootte van de opbrengst.

Wanneer onverwachte en onvoorspelbare gebeurtenissen plaatsvinden hebben dergelijke voorspellingen geen waarde, zoals in het huidige onderzoek is gebleken (brand, vee, insectenaantastingen). Statistische voorspellingen dienen daarom met de nodige voorzichtigheid bekeken te worden, zij zijn slechts een virtuele realiteit. Veiliger is het om te streven naar een optimale kosten-batenverhouding.

In een complexe situatie kan een statistische benadering ver bezijden de realiteit zijn. Daarom dienen dergelijke methoden met voorzichtigheid gehanteerd te worden, anders kunnen zij tot grote teleurstellingen leiden.

De locale bevolking dient bij de plantage-programma's betrokken te worden, zo mogelijk in alle fasen (planvorming, ontwerp, beheer, procesbewaking). Betrokkenheid van de locale bevolking komt zowel de mensen als de beplantingen ten goede.

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APPENDICES

Appendix 1. Analysis of variance for Survival rate

Descriptive Statistics

Dependent Variable: SURVIVAL

PROVENAN	BLOCK	Mean	Std. Deviation	N
1.00	1.00	66.0000	.	1
	2.00	78.5000	.	1
	3.00	78.5000	.	1
	Total	74.3333	7.2169	3
2.00	1.00	78.5000	.	1
	2.00	90.0000	.	1
	3.00	55.6000	.	1
	Total	74.7000	17.5120	3
3.00	1.00	58.1000	.	1
	2.00	63.4000	.	1
	3.00	60.7000	.	1
	Total	60.7333	2.6502	3
4.00	1.00	34.3000	.	1
	2.00	73.6000	.	1
	3.00	90.0000	.	1
	Total	65.9667	28.6238	3
5.00	1.00	66.0000	.	1
	2.00	73.6000	.	1
	3.00	41.6000	.	1
	Total	60.4000	16.7189	3
6.00	1.00	66.0000	.	1
	2.00	66.0000	.	1
	3.00	39.2000	.	1
	Total	57.0667	15.4730	3
7.00	1.00	58.1000	.	1
	2.00	63.4000	.	1
	3.00	48.4000	.	1
	Total	56.6333	7.6068	3
8.00	1.00	39.2000	.	1
	2.00	43.9000	.	1
	3.00	43.9000	.	1
	Total	42.3333	2.7135	3
9.00	1.00	26.2000	.	1
	2.00	36.9000	.	1
	3.00	39.2000	.	1
	Total	34.1000	6.9376	3
10.00	1.00	29.3000	.	1
	2.00	23.6000	.	1
	3.00	16.4000	.	1
	Total	23.1000	6.4645	3
Total	1.00	52.1700	18.3256	10
	2.00	61.2900	20.4734	10
	3.00	51.3500	21.1146	10
	Total	54.9367	19.8409	30

Tests of Between-Subjects Effects

Dependent Variable: SURVIVAL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	11039.278[a]	13	849.175	36.052	.000	.967
Intercept	76015.264	1	76015.264	3227.213	.000	.995
PROVENAN	8628.186	9	958.687	40.701	.000	.958
BLOCK	383.808	2	191.904	8.147	.004	.505
COW	757.465	1	757.465	32.158	.000	.668
BURN	2385.681	1	2385.681	101.284	.000	.864
Error	376.871	16	23.554			
Total	101957.270	30				
Corrected Total	11416.150	29				

a. R Squared = .967 (Adjusted R Squared = .940)

Parameter Estimates

Dependent Variable: SURVIVAL

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Eta Squared
Intercept	35.854	3.851	9.310	.000	27.690	44.018	.844
[PROVENAN=1.00]	43.338	4.200	10.318	.000	34.434	52.242	.869
[PROVENAN=2.00]	56.062	4.302	13.033	.000	46.943	65.181	.914
[PROVENAN=3.00]	29.738	4.200	7.080	.000	20.834	38.642	.758
[PROVENAN=4.00]	47.329	4.302	11.003	.000	38.210	56.448	.883
[PROVENAN=5.00]	41.762	4.302	9.709	.000	32.643	50.881	.855
[PROVENAN=6.00]	33.967	3.963	8.572	.000	25.566	42.367	.821
[PROVENAN=7.00]	33.533	3.963	8.462	.000	25.133	41.934	.817
[PROVENAN=8.00]	11.338	4.200	2.699	.016	2.434	20.242	.313
[PROVENAN=9.00]	3.104	4.200	.739	.471	-5.800	12.008	.033
[PROVENAN=10.00]	0[a]	.	.	.	.	.	.
[BLOCK=1.00]	-9.994	2.567	-3.893	.001	-15.436	-4.551	.486
[BLOCK=2.00]	-4.581	2.678	-1.710	.107	-10.259	1.097	.155
[BLOCK=3.00]	0[a]	.	.	.	.	.	.
COW	-23.687	4.177	-5.671	.000	-32.542	-14.832	.668
BURN	-37.074	3.684	-10.064	.000	-44.883	-29.264	.864

a. This parameter is set to zero because it is redundant.

Estimated Marginal Means

Estimates

Dependent Variable: SURVIVAL

PROVENAN	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	68.257[a]	2.867	62.179	74.335
2.00	80.982[a]	2.938	74.755	87.209
3.00	54.657[a]	2.867	48.579	60.735
4.00	72.248[a]	2.938	66.021	78.476
5.00	66.682[a]	2.938	60.455	72.909
6.00	58.886[a]	2.967	52.597	65.175
7.00	58.453[a]	2.967	52.164	64.742
8.00	36.257[a]	2.867	30.179	42.335
9.00	28.024[a]	2.867	21.946	34.102
10.00	24.920[a]	2.967	18.630	31.209

a. Evaluated at covariates appeared in the model: COW = .1000, BURN = .1000.

Pairwise Comparisons

Dependent Variable: SURVIVAL

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1.00	2.00	-12.725*	4.149	.007	-21.519	-3.930
	3.00	13.600*	3.963	.003	5.199	22.001
	4.00	-3.991	4.149	.350	-12.786	4.803
	5.00	1.575	4.149	.709	-7.219	10.370
	6.00	9.371*	4.200	.040	.467	18.275
	7.00	9.804*	4.200	.033	.900	18.708
	8.00	32.000*	3.963	.000	23.599	40.401
	9.00	40.233*	3.963	.000	31.833	48.634
	10.00	43.338*	4.200	.000	34.434	52.242
2.00	1.00	12.725*	4.149	.007	3.930	21.519
	3.00	26.325*	4.149	.000	17.530	35.119
	4.00	8.733*	3.963	.043	.333	17.134
	5.00	14.300*	3.963	.002	5.899	22.701
	6.00	22.096*	4.302	.000	12.977	31.214
	7.00	22.529*	4.302	.000	13.410	31.648
	8.00	44.725*	4.149	.000	35.930	53.519
	9.00	52.958*	4.149	.000	44.163	61.753
	10.00	56.062*	4.302	.000	46.943	65.181
3.00	1.00	-13.600*	3.963	.003	-22.001	-5.199
	2.00	-26.325*	4.149	.000	-35.119	-17.530
	4.00	-17.591*	4.149	.001	-26.386	-8.797
	5.00	-12.025*	4.149	.010	-20.819	-3.230
	6.00	-4.229	4.200	.329	-13.133	4.675
	7.00	-3.796	4.200	.380	-12.700	5.108
	8.00	18.400*	3.963	.000	9.999	26.801
	9.00	26.633*	3.963	.000	18.233	35.034
	10.00	29.738*	4.200	.000	20.834	38.642

Based on estimated marginal means

Pairwise Comparisons

Dependent Variable: SURVIVAL

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
4.00	1.00	3.991	4.149	.350	-4.803	12.786
	2.00	-8.733*	3.963	.043	-17.134	-.333
	3.00	17.591*	4.149	.001	8.797	26.386
	5.00	5.567	3.963	.179	-2.834	13.967
	6.00	13.362*	4.302	.007	4.243	22.481
	7.00	13.796*	4.302	.005	4.677	22.914
	8.00	35.991*	4.149	.000	27.197	44.786
	9.00	44.225*	4.149	.000	35.430	53.019
	10.00	47.329*	4.302	.000	38.210	56.448
5.00	1.00	-1.575	4.149	.709	-10.370	7.219
	2.00	-14.300*	3.963	.002	-22.701	-5.899
	3.00	12.025*	4.149	.010	3.230	20.819
	4.00	-5.567	3.963	.179	-13.967	2.834
	6.00	7.796	4.302	.089	-1.323	16.914
	7.00	8.229	4.302	.074	-.890	17.348
	8.00	30.425*	4.149	.000	21.630	39.219
	9.00	38.658*	4.149	.000	29.863	47.453
	10.00	41.762*	4.302	.000	32.643	50.881
6.00	1.00	-9.371*	4.200	.040	-18.275	-.467
	2.00	-22.096*	4.302	.000	-31.214	-12.977
	3.00	4.229	4.200	.329	-4.675	13.133
	4.00	-13.362*	4.302	.007	-22.481	-4.243
	5.00	-7.796	4.302	.089	-16.914	1.323
	7.00	.433	3.963	.914	-7.967	8.834
	8.00	22.629*	4.200	.000	13.725	31.533
	9.00	30.862*	4.200	.000	21.958	39.766
	10.00	33.967*	3.963	.000	25.566	42.367
7.00	1.00	-9.804*	4.200	.033	-18.708	-.900
	2.00	-22.529*	4.302	.000	-31.648	-13.410
	3.00	3.796	4.200	.380	-5.108	12.700
	4.00	-13.796*	4.302	.005	-22.914	-4.677
	5.00	-8.229	4.302	.074	-17.348	.890
	6.00	-.433	3.963	.914	-8.834	7.967
	8.00	22.196*	4.200	.000	13.292	31.100
	9.00	30.429*	4.200	.000	21.525	39.333
	10.00	33.533*	3.963	.000	25.133	41.934
8.00	1.00	-32.000*	3.963	.000	-40.401	-23.599
	2.00	-44.725*	4.149	.000	-53.519	-35.930
	3.00	-18.400*	3.963	.000	-26.801	-9.999
	4.00	-35.991*	4.149	.000	-44.786	-27.197
	5.00	-30.425*	4.149	.000	-39.219	-21.630
	6.00	-22.629*	4.200	.000	-31.533	-13.725
	7.00	-22.196*	4.200	.000	-31.100	-13.292
	9.00	8.233	3.963	.054	-.167	16.634
	10.00	11.338*	4.200	.016	2.434	20.242

Based on estimated marginal means

Pairwise Comparisons

Dependent Variable: SURVIVAL

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
9.00	1.00	-40.233*	3.963	.000	-48.634	-31.833
	2.00	-52.958*	4.149	.000	-61.753	-44.163
	3.00	-26.633*	3.963	.000	-35.034	-18.233
	4.00	-44.225*	4.149	.000	-53.019	-35.430
	5.00	-38.658*	4.149	.000	-47.453	-29.863
	6.00	-30.862*	4.200	.000	-39.766	-21.958
	7.00	-30.429*	4.200	.000	-39.333	-21.525
	8.00	-8.233	3.963	.054	-16.634	.167
	10.00	3.104	4.200	.471	-5.800	12.008
10.00	1.00	-43.338*	4.200	.000	-52.242	-34.434
	2.00	-56.062*	4.302	.000	-65.181	-46.943
	3.00	-29.738*	4.200	.000	-38.642	-20.834
	4.00	-47.329*	4.302	.000	-56.448	-38.210
	5.00	-41.762*	4.302	.000	-50.881	-32.643
	6.00	-33.967*	3.963	.000	-42.367	-25.566
	7.00	-33.533*	3.963	.000	-41.934	-25.133
	8.00	-11.338*	4.200	.016	-20.242	-2.434
	9.00	-3.104	4.200	.471	-12.008	5.800

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Analysis of Variance

Descriptive Statistics[a]

Dependent Variable: HIGH

PRPVENAN	BLOC	Mean	Std. Deviation	N
1.00	1.00	223.6000	.	1
	2.00	244.3000	.	1
	3.00	373.3000	.	1
	Total	293.7375	234.4087	3
2.00	1.00	268.8000	.	1
	2.00	224.7000	.	1
	3.00	300.0000	.	1
	Total	260.1318	173.5074	3
3.00	1.00	240.0000	.	1
	2.00	281.5000	.	1
	3.00	259.0000	.	1
	Total	260.4135	95.1535	3
4.00	1.00	200.0000	.	1
	2.00	255.4000	.	1
	3.00	311.6000	.	1
	Total	272.5750	208.5610	3
5.00	1.00	264.4000	.	1
	2.00	191.0000	.	1
	3.00	310.1000	.	1
	Total	254.7652	294.1258	3
6.00	1.00	193.0000	.	1
	2.00	172.7000	.	1
	3.00	291.8000	.	1
	Total	218.8105	279.0490	3
7.00	1.00	111.1000	.	1
	2.00	214.8000	.	1
	3.00	330.6000	.	1
	Total	198.3655	423.3665	3
8.00	1.00	195.3000	.	1
	2.00	183.2000	.	1
	3.00	263.0000	.	1
	Total	208.8731	169.5795	3
9.00	1.00	143.3000	.	1
	2.00	242.8000	.	1
	3.00	244.1000	.	1
	Total	213.9941	188.1626	3
10.00	1.00	196.7000	.	1
	2.00	219.5000	.	1
	3.00	169.5000	.	1
	Total	199.7667	41.5102	3
Total	1.00	208.5349	217.4271	10
	2.00	221.1928	153.7439	10
	3.00	297.1278	140.4220	10
	Total	240.0830	227.4395	30

a. Weighted Least Squares Regression - Weighted by NOTREE

Tests of Between-Subjects Effects[c]

Dependent Variable: HIGH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	1161216.98[b]	13	89324.383	4.217	.004	.774	54.820	.974
Intercept	15026870.1	1	15026870.1	709.409	.000	.978	709.409	1.000
PRPVENAN	366627.022	9	40736.336	1.923	.122	.520	17.308	.611
BLOC	503296.800	2	251648.400	11.880	.001	.598	23.760	.983
BURN	126286.678	1	126286.678	5.962	.027	.271	5.962	.631
COW	12156.141	1	12156.141	.574	.460	.035	.574	.110
Error	338915.991	16	21182.249					
Total	28994344.3	30						
Corrected Total	1500132.97	29						

a. Computed using alpha = .05

b. R Squared = .774 (Adjusted R Squared = .591)

c. Weighted Least Squares Regression - Weighted by NOTREE

Estimates[b]

Dependent Variable: HIGH

PRPVENAN	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	284.310[a]	30.084	220.535	348.085
2.00	269.177[a]	18.277	230.432	307.921
3.00	275.263[a]	20.500	231.804	318.721
4.00	273.241[a]	21.780	227.070	319.412
5.00	232.579[a]	19.303	191.658	273.501
6.00	221.094[a]	19.711	179.309	262.880
7.00	196.982[a]	20.250	154.055	239.909
8.00	223.021[a]	21.049	178.399	267.643
9.00	222.662[a]	26.077	167.381	277.942
10.00	222.449[a]	42.316	132.743	312.155

a. Evaluated at covariates appeared in the model: BURN = 6.918E-02, COW = .1111.

b. Weighted Least Squares Regression - Weighted by NOTREE

Pairwise Comparisons[b]

Dependent Variable: HIGH

(I) PRPVENAN	(J) PRPVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1.00	2.00	15.134	34.869	.670	-58.786	89.053
	3.00	9.047	36.207	.806	-67.708	85.803
	4.00	11.069	38.038	.775	-69.568	91.706
	5.00	51.731	35.437	.164	-23.393	126.854
	6.00	63.216	35.497	.094	-12.033	138.465
	7.00	87.328*	36.168	.028	10.656	164.001
	8.00	61.289	37.353	.120	-17.897	140.475
	9.00	61.648	40.538	.148	-24.288	147.584
	10.00	61.861	52.271	.254	-48.949	172.672
2.00	1.00	-15.134	34.869	.670	-89.053	58.786
	3.00	-6.086	27.014	.825	-63.352	51.180
	4.00	-4.065	29.252	.891	-66.076	57.947
	5.00	36.597	26.835	.192	-20.289	93.484
	6.00	48.082	26.354	.087	-7.785	103.949
	7.00	72.195*	27.334	.018	14.249	130.141
	8.00	46.155	28.225	.122	-13.680	105.991
	9.00	46.515	32.339	.170	-22.040	115.069
	10.00	46.728	46.124	.326	-51.051	144.507
3.00	1.00	-9.047	36.207	.806	-85.803	67.708
	2.00	6.086	27.014	.825	-51.180	63.352
	4.00	2.022	30.547	.948	-62.736	66.779
	5.00	42.683	28.486	.154	-17.705	103.072
	6.00	54.169	28.031	.071	-5.254	113.591
	7.00	78.281*	28.848	.015	17.125	139.437
	8.00	52.242	29.555	.096	-10.412	114.895
	9.00	52.601	33.507	.136	-18.430	123.632
	10.00	52.814	46.944	.277	-46.702	152.330
4.00	1.00	-11.069	38.038	.775	-91.706	69.568
	2.00	4.065	29.252	.891	-57.947	66.076
	3.00	-2.022	30.547	.948	-66.779	62.736
	5.00	40.662	30.484	.201	-23.961	105.285
	6.00	52.147	30.336	.105	-12.162	116.456
	7.00	76.259*	30.625	.024	11.338	141.181
	8.00	50.220	28.470	.097	-10.133	110.573
	9.00	50.579	31.788	.131	-16.808	117.967
	10.00	50.792	47.013	.296	-48.870	150.455

Pairwise Comparisons[b]

Dependent Variable: HIGH

(I) PRPVENAN	(J) PRPVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
5.00	1.00	-51.731	35.437	.164	-126.854	23.393
	2.00	-36.597	26.835	.192	-93.484	20.289
	3.00	-42.683	28.486	.154	-103.072	17.705
	4.00	-40.662	30.484	.201	-105.285	23.961
	6.00	11.485	27.722	.684	-47.283	70.253
	7.00	35.598	26.631	.200	-20.858	92.053
	8.00	9.558	29.704	.752	-53.412	72.529
	9.00	9.917	33.611	.772	-61.335	81.169
	10.00	10.130	47.153	.833	-89.829	110.090
6.00	1.00	-63.216	35.497	.094	-138.465	12.033
	2.00	-48.082	26.354	.087	-103.949	7.785
	3.00	-54.169	28.031	.071	-113.591	5.254
	4.00	-52.147	30.336	.105	-116.456	12.162
	5.00	-11.485	27.722	.684	-70.253	47.283
	7.00	24.112	28.336	.407	-35.957	84.182
	8.00	-1.927	29.361	.948	-64.170	60.316
	9.00	-1.568	33.333	.963	-72.230	69.095
	10.00	-1.355	46.836	.977	-100.642	97.933
7.00	1.00	-87.328*	36.168	.028	-164.001	-10.656
	2.00	-72.195*	27.334	.018	-130.141	-14.249
	3.00	-78.281*	28.848	.015	-139.437	-17.125
	4.00	-76.259*	30.625	.024	-141.181	-11.338
	5.00	-35.598	26.631	.200	-92.053	20.858
	6.00	-24.112	28.336	.407	-84.182	35.957
	8.00	-26.039	29.779	.395	-89.167	37.088
	9.00	-25.680	33.686	.457	-97.090	45.730
	10.00	-25.467	47.162	.597	-125.446	74.511
8.00	1.00	-61.289	37.353	.120	-140.475	17.897
	2.00	-46.155	28.225	.122	-105.991	13.680
	3.00	-52.242	29.555	.096	-114.895	10.412
	4.00	-50.220	28.470	.097	-110.573	10.133
	5.00	-9.558	29.704	.752	-72.529	53.412
	6.00	1.927	29.361	.948	-60.316	64.170
	7.00	26.039	29.779	.395	-37.088	89.167
	9.00	.359	32.170	.991	-67.838	68.556
	10.00	.572	46.721	.990	-98.471	99.616
9.00	1.00	-61.648	40.538	.148	-147.584	24.288
	2.00	-46.515	32.339	.170	-115.069	22.040
	3.00	-52.601	33.507	.136	-123.632	18.430
	4.00	-50.579	31.788	.131	-117.967	16.808
	5.00	-9.917	33.611	.772	-81.169	61.335
	6.00	1.568	33.333	.963	-69.095	72.230
	7.00	25.680	33.686	.457	-45.730	97.090
	8.00	-.359	32.170	.991	-68.556	67.838
	10.00	.213	49.144	.997	-103.967	104.394
10.00	1.00	-61.861	52.271	.254	-172.672	48.949
	2.00	-46.728	46.124	.326	-144.507	51.051
	3.00	-52.814	46.944	.277	-152.330	46.702
	4.00	-50.792	47.013	.296	-150.455	48.870
	5.00	-10.130	47.153	.833	-110.090	89.829
	6.00	1.355	46.836	.977	-97.933	100.642
	7.00	25.467	47.162	.597	-74.511	125.446
	8.00	-.572	46.721	.990	-99.616	98.471
	9.00	-.213	49.144	.997	-104.394	103.967

Based on estimated marginal means

Appendix 3. Analysis of variance for Height for core trees

Descriptive Statistics[a]

Dependent Variable: HEICORE

PRPVENAN	BLOC	Mean	Std. Deviation	N
1.00	1.00	223.6000	.	1
	2.00	244.3000	.	1
	3.00	384.5000	.	1
	Total	290.5773	236.9345	3
2.00	1.00	221.7000	.	1
	2.00	248.7000	.	1
	3.00	340.3000	.	1
	Total	284.1000	160.2899	3
3.00	1.00	266.6000	.	1
	2.00	210.2000	.	1
	3.00	332.5000	.	1
	Total	270.1625	183.5883	3
4.00	1.00	245.1000	.	1
	2.00	293.0000	.	1
	3.00	266.6000	.	1
	Total	267.2095	65.4558	3
5.00	1.00	286.6000	.	1
	2.00	208.6000	.	1
	3.00	299.0000	.	1
	Total	260.9667	141.5321	3
6.00	1.00	212.4000	.	1
	2.00	178.5000	.	1
	3.00	261.3000	.	1
	Total	213.5684	108.4320	3
7.00	1.00	108.8000	.	1
	2.00	213.3000	.	1
	3.00	266.6000	.	1
	Total	187.4136	208.3557	3
8.00	1.00	165.2000	.	1
	2.00	149.6000	.	1
	3.00	316.0000	.	1
	Total	205.6696	248.4575	3
9.00	1.00	122.1000	.	1
	2.00	245.1000	.	1
	3.00	257.8000	.	1
	Total	205.8600	195.0323	3
10.00	1.00	196.7000	.	1
	2.00	219.5000	.	1
	3.00	169.5000	.	1
	Total	199.7667	41.5102	3
Total	1.00	201.9563	158.5964	10
	2.00	220.1949	110.7068	10
	3.00	304.9600	127.9964	10
	Total	241.0721	174.3748	30

a. Weighted Least Squares Regression - Weighted by NOMTREE

Levene's Test of Equality of Error Variances[a,b]

Dependent Variable: HEICORE

F	df1	df2	Sig.
.	29	0	.

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+PRPVENAN+BLOC+BURN+COW

b. Weighted Least Squares Regression - Weighted by NOMTREE

Pairwise Comparisons[b]

Dependent Variable: HEICORE

(I) PRPVENAN	(J) PRPVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
5.00	1.00	-39.877	36.395	.289	-117.030	37.276
	2.00	-28.441	37.397	.458	-107.720	50.838
	3.00	-21.274	36.228	.565	-98.073	55.525
	4.00	-36.216	38.667	.363	-118.186	45.755
	6.00	30.098	38.123	.441	-50.719	110.915
	7.00	60.906	34.682	.098	-12.618	134.430
	8.00	27.092	38.008	.486	-53.481	107.666
	9.00	26.609	39.127	.506	-56.336	109.553
	10.00	21.920	44.091	.626	-71.550	115.389
6.00	1.00	-69.975	36.560	.074	-147.479	7.528
	2.00	-58.539	37.031	.133	-137.041	19.962
	3.00	-51.372	35.829	.171	-127.327	24.583
	4.00	-66.314	38.629	.105	-148.205	15.577
	5.00	-30.098	38.123	.441	-110.915	50.719
	7.00	30.808	37.674	.426	-49.057	110.672
	8.00	-3.006	37.993	.938	-83.548	77.536
	9.00	-3.489	39.112	.930	-86.403	79.425
	10.00	-8.178	44.009	.855	-101.474	85.117
7.00	1.00	-100.783*	36.122	.013	-177.359	-24.208
	2.00	-89.347*	37.042	.028	-167.872	-10.822
	3.00	-82.180*	35.780	.035	-158.030	-6.329
	4.00	-97.122*	37.985	.021	-177.647	-16.597
	5.00	-60.906	34.682	.098	-134.430	12.618
	6.00	-30.808	37.674	.426	-110.672	49.057
	8.00	-33.813	37.328	.378	-112.945	45.318
	9.00	-34.297	38.466	.386	-115.841	47.247
	10.00	-38.986	43.466	.383	-131.131	53.159
8.00	1.00	-66.970	36.934	.089	-145.267	11.327
	2.00	-55.534	37.745	.161	-135.549	24.482
	3.00	-48.366	36.236	.201	-125.183	28.450
	4.00	-63.308	35.200	.091	-137.928	11.312
	5.00	-27.092	38.008	.486	-107.666	53.481
	6.00	3.006	37.993	.938	-77.536	83.548
	7.00	33.813	37.328	.378	-45.318	112.945
	9.00	-.484	35.649	.989	-76.057	75.089
	10.00	-5.173	41.760	.903	-93.700	83.354
9.00	1.00	-66.486	38.084	.100	-147.221	14.249
	2.00	-55.050	38.871	.176	-137.452	27.353
	3.00	-47.883	37.407	.219	-127.183	31.417
	4.00	-62.824	36.436	.104	-140.065	14.416
	5.00	-26.609	39.127	.506	-109.553	56.336
	6.00	3.489	39.112	.930	-79.425	86.403
	7.00	34.297	38.466	.386	-47.247	115.841
	8.00	.484	35.649	.989	-75.089	76.057
	10.00	-4.689	42.796	.914	-95.412	86.034
10.00	1.00	-61.797	43.124	.171	-153.215	29.621
	2.00	-50.361	43.851	.268	-143.321	42.600
	3.00	-43.194	42.492	.325	-133.273	46.886
	4.00	-58.135	42.362	.189	-147.938	31.667
	5.00	-21.920	44.091	.626	-115.389	71.550
	6.00	8.178	44.009	.855	-85.117	101.474
	7.00	38.986	43.466	.383	-53.159	131.131
	8.00	5.173	41.760	.903	-83.354	93.700
	9.00	4.689	42.796	.914	-86.034	95.412

Based on estimated marginal means

Appendix 4. Analysis of variance for Diameter above root

Descriptive Statistics[a]

Dependent Variable: DIAMARAL

PROVENAN	BLOCK	Mean	Std. Deviation	N
1.00	1.00	6.8400	.	1
	2.00	4.3900	.	1
	3.00	8.8100	.	1
	Total	6.4194	10.1085	3
2.00	1.00	5.1000	.	1
	2.00	5.7200	.	1
	3.00	8.0600	.	1
	Total	6.6761	6.6625	3
3.00	1.00	6.7600	.	1
	2.00	4.0100	.	1
	3.00	7.4700	.	1
	Total	6.0504	8.9123	3
4.00	1.00	5.2700	.	1
	2.00	5.4500	.	1
	3.00	6.8000	.	1
	Total	5.9750	2.4261	3
5.00	1.00	6.1000	.	1
	2.00	5.3900	.	1
	3.00	5.8400	.	1
	Total	5.7633	1.6380	3
6.00	1.00	2.8400	.	1
	2.00	4.9900	.	1
	3.00	9.0600	.	1
	Total	4.9831	11.8170	3
7.00	1.00	4.6300	.	1
	2.00	3.1500	.	1
	3.00	7.1300	.	1
	Total	4.9440	8.8582	3
8.00	1.00	3.5500	.	1
	2.00	4.2700	.	1
	3.00	6.5700	.	1
	Total	4.8700	5.3115	3
9.00	1.00	4.6600	.	1
	2.00	4.5300	.	1
	3.00	3.8000	.	1
	Total	4.4733	.7512	3
10.00	1.00	4.1400	.	1
	2.00	2.6600	.	1
	3.00	5.0300	.	1
	Total	3.8104	4.9622	3
Total	1.00	5.1469	5.8152	10
	2.00	4.4206	4.3999	10
	3.00	7.2843	4.8914	10
	Total	5.5165	6.9035	30

a. Weighted Least Squares Regression - Weighted by NOTREEAL

Tests of Between-Subjects Effects[b]

Dependent Variable: DIAMARAL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	1097.447[a]	13	84.419	4.745	.002	.794
Intercept	9218.651	1	9218.651	518.166	.000	.970
PROVENAN	241.002	9	26.778	1.505	.228	.458
BLOCK	526.062	2	263.031	14.785	.000	.649
BURN	13.301	1	13.301	.748	.400	.045
COW	52.906	1	52.906	2.974	.104	.157
Error	284.655	16	17.791			
Total	15898.273	30				
Corrected Total	1382.102	29				

a. R Squared = .794 (Adjusted R Squared = .627)

b. Weighted Least Squares Regression - Weighted by NOTREEAL

Parameter Estimates[b]

Dependent Variable: DIAMARAL

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Eta Squared
Intercept	6.283	.823	7.638	.000	4.539	8.027	.785
[PROVENAN=1.00]	1.940	.849	2.284	.036	.140	3.739	.246
[PROVENAN=2.00]	1.868	.881	2.120	.050	9.077E-05	3.737	.219
[PROVENAN=3.00]	1.531	.835	1.834	.085	-.239	3.301	.174
[PROVENAN=4.00]	1.316	1.094	1.204	.246	-1.002	3.635	.083
[PROVENAN=5.00]	2.002	.830	2.411	.028	.242	3.762	.266
[PROVENAN=6.00]	.708	.870	.814	.428	-1.136	2.553	.040
[PROVENAN=7.00]	.460	.865	.532	.602	-1.374	2.295	.017
[PROVENAN=8.00]	.343	.982	.349	.732	-1.739	2.424	.008
[PROVENAN=9.00]	.672	1.355	.496	.627	-2.201	3.545	.015
[PROVENAN=10.00]	0[a]	.	.	.	.	.	.
[BLOCK=1.00]	-2.313	.577	-4.008	.001	-3.536	-1.090	.501
[BLOCK=2.00]	-3.047	.564	-5.407	.000	-4.242	-1.852	.646
[BLOCK=3.00]	0[a]	.	.	.	.	.	.
BURN	.745	.862	.865	.400	-1.082	2.573	.045
COW	-1.858	1.077	-1.724	.104	-4.142	.426	.157

a. This parameter is set to zero because it is redundant.

b. Weighted Least Squares Regression - Weighted by NOTREEAL

Estimates[b]

Dependent Variable: DIAMARAL

PROVENAN	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	6.391[a]	.546	5.233	7.549
2.00	6.320[a]	.577	5.098	7.542
3.00	5.983[a]	.517	4.886	7.080
4.00	5.768[a]	.871	3.922	7.614
5.00	6.453[a]	.614	5.152	7.755
6.00	5.160[a]	.586	3.918	6.401
7.00	4.912[a]	.567	3.710	6.113
8.00	4.794[a]	.730	3.246	6.343
9.00	5.123[a]	1.231	2.515	7.732
10.00	4.451[a]	.633	3.109	5.794

a. Evaluated at covariates appeared in the model: BURN = 7.547E-02, COW = 5.451E-02.

b. Weighted Least Squares Regression - Weighted by NOTREEAL

Pairwise Comparisons[b]

Dependent Variable: DIAMARAL

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1.00	2.00	7.119E-02	.785	.929	-1.594	1.736
	3.00	.408	.766	.601	-1.215	2.032
	4.00	.623	1.040	.557	-1.581	2.827
	5.00	-6.250E-02	.830	.941	-1.823	1.698
	6.00	1.231	.772	.130	-.404	2.867
	7.00	1.479	.799	.083	-.215	3.174
	8.00	1.597	.923	.103	-.360	3.554
	9.00	1.268	1.351	.362	-1.597	4.132
	10.00	1.940*	.849	.036	.140	3.739
2.00	1.00	-7.119E-02	.785	.929	-1.736	1.594
	3.00	.337	.770	.667	-1.295	1.969
	4.00	.552	1.036	.602	-1.645	2.749
	5.00	-.134	.864	.879	-1.965	1.698
	6.00	1.160	.817	.175	-.572	2.892
	7.00	1.408	.805	.099	-.298	3.114
	8.00	1.526	.926	.119	-.437	3.489
	9.00	1.196	1.374	.397	-1.715	4.108
	10.00	1.868*	.881	.050	9.077E-05	3.737
3.00	1.00	-.408	.766	.601	-2.032	1.215
	2.00	-.337	.770	.667	-1.969	1.295
	4.00	.215	1.001	.833	-1.907	2.336
	5.00	-.471	.816	.572	-2.201	1.259
	6.00	.823	.792	.314	-.856	2.501
	7.00	1.071	.755	.175	-.530	2.671
	8.00	1.189	.884	.197	-.685	3.062
	9.00	.859	1.342	.531	-1.986	3.704
	10.00	1.531	.835	.085	-.239	3.301

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: DIAMARAL

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
4.00	1.00	-.623	1.040	.557	-2.827	1.581
	2.00	-.552	1.036	.602	-2.749	1.645
	3.00	-.215	1.001	.833	-2.336	1.907
	5.00	-.686	1.079	.534	-2.974	1.603
	6.00	.608	1.059	.574	-1.637	2.854
	7.00	.856	1.028	.417	-1.323	3.035
	8.00	.974	1.125	.400	-1.412	3.359
	9.00	.644	1.517	.677	-2.572	3.861
	10.00	1.316	1.094	.246	-1.002	3.635
5.00	1.00	6.250E-02	.830	.941	-1.698	1.823
	2.00	.134	.864	.879	-1.698	1.965
	3.00	.471	.816	.572	-1.259	2.201
	4.00	.686	1.079	.534	-1.603	2.974
	6.00	1.294	.852	.148	-.512	3.100
	7.00	1.542	.847	.087	-.254	3.337
	8.00	1.659	.966	.105	-.387	3.706
	9.00	1.330	1.352	.340	-1.535	4.195
	10.00	2.002*	.830	.028	.242	3.762
6.00	1.00	-1.231	.772	.130	-2.867	.404
	2.00	-1.160	.817	.175	-2.892	.572
	3.00	-.823	.792	.314	-2.501	.856
	4.00	-.608	1.059	.574	-2.854	1.637
	5.00	-1.294	.852	.148	-3.100	.512
	7.00	.248	.824	.768	-1.499	1.995
	8.00	.366	.945	.704	-1.638	2.369
	9.00	3.624E-02	1.364	.979	-2.856	2.929
	10.00	.708	.870	.428	-1.136	2.553
7.00	1.00	-1.479	.799	.083	-3.174	.215
	2.00	-1.408	.805	.099	-3.114	.298
	3.00	-1.071	.755	.175	-2.671	.530
	4.00	-.856	1.028	.417	-3.035	1.323
	5.00	-1.542	.847	.087	-3.337	.254
	6.00	-.248	.824	.768	-1.995	1.499
	8.00	.118	.914	.899	-1.820	2.056
	9.00	-.212	1.361	.878	-3.097	2.674
	10.00	.460	.865	.602	-1.374	2.295
8.00	1.00	-1.597	.923	.103	-3.554	.360
	2.00	-1.526	.926	.119	-3.489	.437
	3.00	-1.189	.884	.197	-3.062	.685
	4.00	-.974	1.125	.400	-3.359	1.412
	5.00	-1.659	.966	.105	-3.706	.387
	6.00	-.366	.945	.704	-2.369	1.638
	7.00	-.118	.914	.899	-2.056	1.820
	9.00	-.329	1.438	.822	-3.378	2.719
	10.00	.343	.982	.732	-1.739	2.424

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: DIAMARAL

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
9.00	1.00	-1.268	1.351	.362	-4.132	1.597
	2.00	-1.196	1.374	.397	-4.108	1.715
	3.00	-.859	1.342	.531	-3.704	1.986
	4.00	-.644	1.517	.677	-3.861	2.572
	5.00	-1.330	1.352	.340	-4.195	1.535
	6.00	-3.624E-02	1.364	.979	-2.929	2.856
	7.00	.212	1.361	.878	-2.674	3.097
	8.00	.329	1.438	.822	-2.719	3.378
	10.00	.672	1.355	.627	-2.201	3.545
10.00	1.00	-1.940*	.849	.036	-3.739	-.140
	2.00	-1.868*	.881	.050	-3.737	-9.077E-05
	3.00	-1.531	.835	.085	-3.301	.239
	4.00	-1.316	1.094	.246	-3.635	1.002
	5.00	-2.002*	.830	.028	-3.762	-.242
	6.00	-.708	.870	.428	-2.553	1.136
	7.00	-.460	.865	.602	-2.295	1.374
	8.00	-.343	.982	.732	-2.424	1.739
	9.00	-.672	1.355	.627	-3.545	2.201

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

b. Weighted Least Squares Regression - Weighted by NOTREEAL

Descriptive Statistics[a]

Dependent Variable: DIAMARCR

PROVENAN	BLOCK	Mean	Std. Deviation	N
1.00	1.00	7.4900	.	1
	2.00	3.9500	.	1
	3.00	8.7700	.	1
	Total	6.5358	7.1555	3
2.00	1.00	5.8800	.	1
	2.00	5.8000	.	1
	3.00	8.7100	.	1
	Total	7.0586	4.6351	3
3.00	1.00	7.2600	.	1
	2.00	4.2700	.	1
	3.00	8.0500	.	1
	Total	6.4350	5.9052	3
4.00	1.00	5.2700	.	1
	2.00	5.4500	.	1
	3.00	7.2800	.	1
	Total	6.0745	3.0308	3
5.00	1.00	6.7100	.	1
	2.00	5.2500	.	1
	3.00	5.7500	.	1
	Total	5.9490	2.0360	3
6.00	1.00	3.0500	.	1
	2.00	5.2900	.	1
	3.00	9.6300	.	1
	Total	5.4618	8.1752	3
7.00	1.00	4.3100	.	1
	2.00	2.4300	.	1
	3.00	7.9400	.	1
	Total	4.7609	7.6105	3
8.00	1.00	3.1800	.	1
	2.00	4.3000	.	1
	3.00	7.7200	.	1
	Total	4.9340	5.9548	3
9.00	1.00	4.6600	.	1
	2.00	4.5300	.	1
	3.00	3.8000	.	1
	Total	4.4733	.7512	3
10.00	1.00	4.1400	.	1
	2.00	2.8300	.	1
	3.00	4.8900	.	1
	Total	3.8253	2.7588	3
Total	1.00	5.1711	4.2981	10
	2.00	4.4290	3.2070	10
	3.00	7.5686	3.9190	10
	Total	5.6385	5.1487	30

a. Weighted Least Squares Regression - Weighted by NOTREECR

Tests of Between-Subjects Effects[b]

Dependent Variable: DIAMARCR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	606.804[a]	13	46.677	4.612	.002	.789
Intercept	5036.750	1	5036.750	497.622	.000	.969
PROVENAN	113.174	9	12.575	1.242	.337	.411
BLOCK	319.876	2	159.938	15.802	.000	.664
BURN	3.878	1	3.878	.383	.545	.023
COW	59.040	1	59.040	5.833	.028	.267
Error	161.946	16	10.122			
Total	7381.538	30				
Corrected Total	768.751	29				

a. R Squared = .789 (Adjusted R Squared = .618)

b. Weighted Least Squares Regression - Weighted by NOTREECR

Parameter Estimates[b]

Dependent Variable: DIAMARCR

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Eta Squared
Intercept	6.955	.993	7.007	.000	4.851	9.060	.754
[PROVENAN=1.00]	1.668	1.065	1.566	.137	-.589	3.925	.133
[PROVENAN=2.00]	1.945	1.084	1.794	.092	-.354	4.243	.167
[PROVENAN=3.00]	1.519	1.051	1.446	.168	-.708	3.747	.116
[PROVENAN=4.00]	1.217	1.068	1.140	.271	-1.046	3.481	.075
[PROVENAN=5.00]	2.054	1.009	2.035	.059	-8.543E-02	4.194	.206
[PROVENAN=6.00]	.841	1.068	.787	.443	-1.423	3.106	.037
[PROVENAN=7.00]	2.113E-02	1.052	.020	.984	-2.209	2.252	.000
[PROVENAN=8.00]	.208	1.083	.192	.850	-2.087	2.503	.002
[PROVENAN=9.00]	.576	1.186	.486	.634	-1.938	3.090	.015
[PROVENAN=10.00]	0[a]	.	.	.	.	.	.
[BLOCK=1.00]	-2.792	.664	-4.207	.001	-4.199	-1.385	.525
[BLOCK=2.00]	-3.577	.642	-5.573	.000	-4.938	-2.216	.660
[BLOCK=3.00]	0[a]	.	.	.	.	.	.
BURN	.634	1.025	.619	.545	-1.538	2.806	.023
COW	-2.815	1.166	-2.415	.028	-5.286	-.344	.267

a. This parameter is set to zero because it is redundant.

b. Weighted Least Squares Regression - Weighted by NOTREECR

Estimates[b]

Dependent Variable: DIAMARCR

PROVENAN	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	6.356[a]	.689	4.895	7.817
2.00	6.633[a]	.709	5.129	8.137
3.00	6.208[a]	.664	4.801	7.615
4.00	5.906[a]	.692	4.439	7.372
5.00	6.743[a]	.743	5.168	8.318
6.00	5.530[a]	.703	4.040	7.019
7.00	4.709[a]	.672	3.284	6.135
8.00	4.896[a]	.719	3.371	6.422
9.00	5.264[a]	.937	3.278	7.251
10.00	4.688[a]	.786	3.023	6.354

a. Evaluated at covariates appeared in the model: BURN = 7.212E-02, COW = 6.731E-02.

b. Weighted Least Squares Regression - Weighted by NOTREECR

Pairwise Comparisons[b]

Dependent Variable: DIAMARCR

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1.00	2.00	-.277	.973	.780	-2.339	1.785
	3.00	.149	.973	.881	-1.913	2.210
	4.00	.451	.991	.656	-1.651	2.552
	5.00	-.386	1.033	.713	-2.577	1.804
	6.00	.827	.941	.393	-1.168	2.822
	7.00	1.647	.977	.111	-.423	3.717
	8.00	1.460	1.009	.167	-.680	3.600
	9.00	1.092	1.175	.366	-1.398	3.582
	10.00	1.668	1.065	.137	-.589	3.925
2.00	1.00	.277	.973	.780	-1.785	2.339
	3.00	.425	.962	.664	-1.614	2.465
	4.00	.727	.981	.469	-1.352	2.807
	5.00	-.110	1.056	.919	-2.349	2.130
	6.00	1.103	.988	.280	-.990	3.197
	7.00	1.924	.974	.066	-.142	3.989
	8.00	1.737	1.008	.104	-.399	3.873
	9.00	1.369	1.197	.269	-1.168	3.906
	10.00	1.945	1.084	.092	-.354	4.243
3.00	1.00	-.149	.973	.881	-2.210	1.913
	2.00	-.425	.962	.664	-2.465	1.614
	4.00	.302	.939	.752	-1.689	2.293
	5.00	-.535	1.019	.607	-2.695	1.625
	6.00	.678	.979	.499	-1.398	2.754
	7.00	1.498	.930	.127	-.473	3.470
	8.00	1.311	.965	.193	-.734	3.357
	9.00	.943	1.162	.429	-1.520	3.407
	10.00	1.519	1.051	.168	-.708	3.747

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: DIAMARCR

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
4.00	1.00	-.451	.991	.656	-2.552	1.651
	2.00	-.727	.981	.469	-2.807	1.352
	3.00	-.302	.939	.752	-2.293	1.689
	5.00	-.837	1.037	.431	-3.035	1.362
	6.00	.376	.998	.711	-1.739	2.491
	7.00	1.196	.951	.226	-.819	3.212
	8.00	1.009	.985	.321	-1.079	3.097
	9.00	.641	1.178	.594	-1.857	3.140
	10.00	1.217	1.068	.271	-1.046	3.481
5.00	1.00	.386	1.033	.713	-1.804	2.577
	2.00	.110	1.056	.919	-2.130	2.349
	3.00	.535	1.019	.607	-1.625	2.695
	4.00	.837	1.037	.431	-1.362	3.035
	6.00	1.213	1.037	.259	-.984	3.411
	7.00	2.033	1.018	.063	-.126	4.192
	8.00	1.846	1.050	.098	-.379	4.072
	9.00	1.478	1.158	.220	-.976	3.933
	10.00	2.054	1.009	.059	-8.543E-02	4.194
6.00	1.00	-.827	.941	.393	-2.822	1.168
	2.00	-1.103	.988	.280	-3.197	.990
	3.00	-.678	.979	.499	-2.754	1.398
	4.00	-.376	.998	.711	-2.491	1.739
	5.00	-1.213	1.037	.259	-3.411	.984
	7.00	.820	.982	.416	-1.263	2.903
	8.00	.633	1.015	.542	-1.519	2.785
	9.00	.265	1.177	.825	-2.230	2.761
	10.00	.841	1.068	.443	-1.423	3.106
7.00	1.00	-1.647	.977	.111	-3.717	.423
	2.00	-1.924	.974	.066	-3.989	.142
	3.00	-1.498	.930	.127	-3.470	.473
	4.00	-1.196	.951	.226	-3.212	.819
	5.00	-2.033	1.018	.063	-4.192	.126
	6.00	-.820	.982	.416	-2.903	1.263
	8.00	-.187	.973	.850	-2.249	1.875
	9.00	-.555	1.161	.639	-3.015	1.905
	10.00	2.113E-02	1.052	.984	-2.209	2.252
8.00	1.00	-1.460	1.009	.167	-3.600	.680
	2.00	-1.737	1.008	.104	-3.873	.399
	3.00	-1.311	.965	.193	-3.357	.734
	4.00	-1.009	.985	.321	-3.097	1.079
	5.00	-1.846	1.050	.098	-4.072	.379
	6.00	-.633	1.015	.542	-2.785	1.519
	7.00	.187	.973	.850	-1.875	2.249
	9.00	-.368	1.188	.761	-2.887	2.151
	10.00	.208	1.083	.850	-2.087	2.503

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: DIAMARCR

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
9.00	1.00	-1.092	1.175	.366	-3.582	1.398
	2.00	-1.369	1.197	.269	-3.906	1.168
	3.00	-.943	1.162	.429	-3.407	1.520
	4.00	-.641	1.178	.594	-3.140	1.857
	5.00	-1.478	1.158	.220	-3.933	.976
	6.00	-.265	1.177	.825	-2.761	2.230
	7.00	.555	1.161	.639	-1.905	3.015
	8.00	.368	1.188	.761	-2.151	2.887
	10.00	.576	1.186	.634	-1.938	3.090
10.00	1.00	-1.668	1.065	.137	-3.925	.589
	2.00	-1.945	1.084	.092	-4.243	.354
	3.00	-1.519	1.051	.168	-3.747	.708
	4.00	-1.217	1.068	.271	-3.481	1.046
	5.00	-2.054	1.009	.059	-4.194	8.543E-02
	6.00	-.841	1.068	.443	-3.106	1.423
	7.00	-2.113E-02	1.052	.984	-2.252	2.209
	8.00	-.208	1.083	.850	-2.503	2.087
	9.00	-.576	1.186	.634	-3.090	1.938

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

b. Weighted Least Squares Regression - Weighted by NOTREECR

Appendix 5. Analysis of variance for Diameter at breast height

Descriptive Statistics[a]

Dependent Variable: DBHALL

BLOCK	PROPENAN	Mean	Std. Deviation	N
1.00	1.00	4.7100	.	1
	2.00	4.8600	.	1
	3.00	3.8300	.	1
	4.00	3.2900	.	1
	5.00	3.1100	.	1
	6.00	3.4200	.	1
	7.00	2.2400	.	1
	8.00	2.3000	.	1
	9.00	3.0400	.	1
	10.00	3.3300	.	1
	Total	3.7052	3.2733	10
2.00	1.00	2.7100	.	1
	2.00	2.6000	.	1
	3.00	3.2700	.	1
	4.00	3.5100	.	1
	5.00	2.9900	.	1
	6.00	3.1600	.	1
	7.00	2.8100	.	1
	8.00	2.5900	.	1
	9.00	1.8700	.	1
	10.00	2.7000	.	1
	Total	2.8475	1.8598	10
3.00	1.00	5.4800	.	1
	2.00	5.4300	.	1
	3.00	5.4400	.	1
	4.00	5.4700	.	1
	5.00	5.2400	.	1
	6.00	3.8300	.	1
	7.00	4.9100	.	1
	8.00	3.5900	.	1
	9.00	3.1900	.	1
	10.00	1.5500	.	1
	Total	4.8451	3.6678	10
Total	1.00	4.4050	6.4914	3
	2.00	4.1508	7.0716	3
	3.00	4.2908	3.4385	3
	4.00	4.3536	5.3187	3
	5.00	3.8834	5.3155	3
	6.00	3.3938	1.2379	3
	7.00	3.2514	4.6328	3
	8.00	2.9668	2.0549	3
	9.00	2.6889	2.7770	3
	10.00	2.7773	1.5106	3
	Total	3.7570	4.3785	30

a. Weighted Least Squares Regression - Weighted by NOTREEAL

Tests of Between-Subjects Effects[b]

Dependent Variable: DBHALL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	450.121[a]	13	34.625	5.234	.001	.810
Intercept	3656.093	1	3656.093	552.717	.000	.972
BLOCK	218.144	2	109.072	16.489	.000	.673
PROPENAN	126.836	9	14.093	2.131	.090	.545
BURN	2.328E-02	1	2.328E-02	.004	.953	.000
CATTLE	4.652	1	4.652	.703	.414	.042
Error	105.836	16	6.615			
Total	6724.091	30				
Corrected Total	555.957	29				

a. R Squared = .810 (Adjusted R Squared = .655)

b. Weighted Least Squares Regression - Weighted by NOTREEAL

Parameter Estimates[b]

Dependent Variable: DBHALL

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Eta Squared
Intercept	4.169	.849	4.908	.000	2.368	5.969	.601
[BLOCK=1.00]	-1.187	.366	-3.244	.005	-1.963	-.412	.397
[BLOCK=2.00]	-2.052	.359	-5.719	.000	-2.812	-1.291	.672
[BLOCK=3.00]	0[a]	.	.	.	.	.	.
[PROPENAN=1.00]	1.235	.856	1.444	.168	-.579	3.049	.115
[PROPENAN=2.00]	1.183	.854	1.386	.185	-.627	2.994	.107
[PROPENAN=3.00]	1.139	.954	1.195	.250	-.882	3.160	.082
[PROPENAN=4.00]	1.193	.868	1.375	.188	-.646	3.032	.106
[PROPENAN=5.00]	.699	.882	.792	.440	-1.172	2.570	.038
[PROPENAN=6.00]	.645	.854	.755	.461	-1.165	2.455	.034
[PROPENAN=7.00]	.585	.875	.668	.514	-1.271	2.440	.027
[PROPENAN=8.00]	-.184	.934	-.197	.846	-2.163	1.795	.002
[PROPENAN=9.00]	-.375	.880	-.427	.675	-2.242	1.491	.011
[PROPENAN=10.00]	0[a]	.	.	.	.	.	.
BURN	3.032E-02	.511	.059	.953	-1.053	1.114	.000
CATTLE	-.580	.692	-.839	.414	-2.047	.887	.042

a. This parameter is set to zero because it is redundant.

b. Weighted Least Squares Regression - Weighted by NOTREEAL

Estimates[b]

Dependent Variable: DBHALL

PROPENAN	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1.00	4.297[a]	.331	3.595	4.998
2.00	4.245[a]	.329	3.547	4.942
3.00	4.200[a]	.533	3.071	5.329
4.00	4.254[a]	.351	3.510	4.999
5.00	3.760[a]	.388	2.937	4.583
6.00	3.706[a]	.376	2.909	4.504
7.00	3.646[a]	.429	2.737	4.555
8.00	2.878[a]	.495	1.828	3.927
9.00	2.686[a]	.393	1.852	3.520
10.00	3.061[a]	.784	1.399	4.724

a. Evaluated at covariates appeared in the model: BURN = .1007, CATTLE = 5.263E-02.

b. Weighted Least Squares Regression - Weighted by NOTREEAL

Pairwise Comparisons[b]

Dependent Variable: DBHALL

(I) PROPENAN	(J) PROPENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1.00	2.00	5.182E-02	.476	.915	-.958	1.062
	3.00	9.610E-02	.617	.878	-1.211	1.403
	4.00	4.216E-02	.478	.931	-.972	1.056
	5.00	.536	.523	.320	-.572	1.644
	6.00	.590	.509	.264	-.490	1.670
	7.00	.651	.553	.257	-.521	1.823
	8.00	1.419*	.584	.027	.180	2.657
	9.00	1.611*	.504	.006	.542	2.679
	10.00	1.235	.856	.168	-.579	3.049
2.00	1.00	-5.182E-02	.476	.915	-1.062	.958
	3.00	4.428E-02	.634	.945	-1.299	1.388
	4.00	-9.660E-03	.480	.984	-1.026	1.007
	5.00	.485	.486	.333	-.545	1.514
	6.00	.538	.506	.303	-.534	1.611
	7.00	.599	.548	.291	-.563	1.760
	8.00	1.367*	.603	.038	8.883E-02	2.645
	9.00	1.559*	.520	.009	.456	2.661
	10.00	1.183	.854	.185	-.627	2.994

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: DBHALL

(I) PROPENAN	(J) PROPENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
3.00	1.00	-9.610E-02	.617	.878	-1.403	1.211
	2.00	-4.428E-02	.634	.945	-1.388	1.299
	4.00	-5.394E-02	.632	.933	-1.393	1.285
	5.00	.440	.669	.520	-.978	1.859
	6.00	.494	.660	.465	-.905	1.893
	7.00	.554	.692	.435	-.912	2.021
	8.00	1.323	.715	.083	-.194	2.840
	9.00	1.515*	.654	.034	.128	2.901
	10.00	1.139	.954	.250	-.882	3.160
4.00	1.00	-4.216E-02	.478	.931	-1.056	.972
	2.00	9.660E-03	.480	.984	-1.007	1.026
	3.00	5.394E-02	.632	.933	-1.285	1.393
	5.00	.494	.519	.355	-.605	1.594
	6.00	.548	.528	.315	-.571	1.667
	7.00	.608	.565	.297	-.589	1.805
	8.00	1.377*	.600	.036	.106	2.648
	9.00	1.568*	.525	.009	.456	2.681
	10.00	1.193	.868	.188	-.646	3.032
5.00	1.00	-.536	.523	.320	-1.644	.572
	2.00	-.485	.486	.333	-1.514	.545
	3.00	-.440	.669	.520	-1.859	.978
	4.00	-.494	.519	.355	-1.594	.605
	6.00	5.381E-02	.553	.924	-1.118	1.226
	7.00	.114	.591	.849	-1.139	1.368
	8.00	.882	.640	.187	-.474	2.239
	9.00	1.074	.563	.075	-.120	2.268
	10.00	.699	.882	.440	-1.172	2.570
6.00	1.00	-.590	.509	.264	-1.670	.490
	2.00	-.538	.506	.303	-1.611	.534
	3.00	-.494	.660	.465	-1.893	.905
	4.00	-.548	.528	.315	-1.667	.571
	5.00	-5.381E-02	.553	.924	-1.226	1.118
	7.00	6.038E-02	.538	.912	-1.081	1.202
	8.00	.829	.631	.207	-.508	2.166
	9.00	1.020	.550	.082	-.145	2.186
	10.00	.645	.854	.461	-1.165	2.455

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: DBHALL

(I) PROPENAN	(J) PROPENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
7.00	1.00	-.651	.553	.257	-1.823	.521
	2.00	-.599	.548	.291	-1.760	.563
	3.00	-.554	.692	.435	-2.021	.912
	4.00	-.608	.565	.297	-1.805	.589
	5.00	-.114	.591	.849	-1.368	1.139
	6.00	-6.038E-02	.538	.912	-1.202	1.081
	8.00	.768	.663	.264	-.637	2.174
	9.00	.960	.590	.123	-.290	2.210
	10.00	.585	.875	.514	-1.271	2.440
8.00	1.00	-1.419*	.584	.027	-2.657	-.180
	2.00	-1.367*	.603	.038	-2.645	-8.883E-02
	3.00	-1.323	.715	.083	-2.840	.194
	4.00	-1.377*	.600	.036	-2.648	-.106
	5.00	-.882	.640	.187	-2.239	.474
	6.00	-.829	.631	.207	-2.166	.508
	7.00	-.768	.663	.264	-2.174	.637
	9.00	.192	.624	.762	-1.130	1.514
	10.00	-.184	.934	.846	-2.163	1.795
9.00	1.00	-1.611*	.504	.006	-2.679	-.542
	2.00	-1.559*	.520	.009	-2.661	-.456
	3.00	-1.515*	.654	.034	-2.901	-.128
	4.00	-1.568*	.525	.009	-2.681	-.456
	5.00	-1.074	.563	.075	-2.268	.120
	6.00	-1.020	.550	.082	-2.186	.145
	7.00	-.960	.590	.123	-2.210	.290
	8.00	-.192	.624	.762	-1.514	1.130
	10.00	-.375	.880	.675	-2.242	1.491
10.00	1.00	-1.235	.856	.168	-3.049	.579
	2.00	-1.183	.854	.185	-2.994	.627
	3.00	-1.139	.954	.250	-3.160	.882
	4.00	-1.193	.868	.188	-3.032	.646
	5.00	-.699	.882	.440	-2.570	1.172
	6.00	-.645	.854	.461	-2.455	1.165
	7.00	-.585	.875	.514	-2.440	1.271
	8.00	.184	.934	.846	-1.795	2.163
	9.00	.375	.880	.675	-1.491	2.242

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

b. Weighted Least Squares Regression - Weighted by NOTREEAL

Descriptive Statistics[a]

Dependent Variable: DBHCORE

BLOCK	PROPENAN	Mean	Std. Deviation	N
1.00	1.00	5.1300	.	1
	2.00	5.6100	.	1
	3.00	3.8300	.	1
	4.00	3.3100	.	1
	5.00	2.3800	.	1
	6.00	3.7400	.	1
	7.00	2.2500	.	1
	8.00	2.3500	.	1
	9.00	3.2000	.	1
	10.00	3.3300	.	1
	Total	3.7876	2.6583	10
2.00	1.00	2.5900	.	1
	2.00	2.2700	.	1
	3.00	3.2700	.	1
	4.00	3.4800	.	1
	5.00	2.2300	.	1
	6.00	2.8800	.	1
	7.00	2.9300	.	1
	8.00	2.5100	.	1
	9.00	1.7700	.	1
	10.00	2.7000	.	1
	Total	2.7071	1.4082	10
3.00	1.00	6.2500	.	1
	2.00	5.7200	.	1
	3.00	5.5700	.	1
	4.00	6.1000	.	1
	5.00	5.7200	.	1
	6.00	3.7600	.	1
	7.00	5.0700	.	1
	8.00	4.2000	.	1
	9.00	3.1200	.	1
	10.00	1.5500	.	1
	Total	5.0880	3.2043	10
Total	1.00	4.6848	5.4011	3
	2.00	4.3896	5.6894	3
	3.00	4.2336	3.4248	3
	4.00	4.5786	4.2733	3
	5.00	3.4433	5.2203	3
	6.00	3.4590	1.3270	3
	7.00	3.5138	3.0307	3
	8.00	3.1647	2.3194	3
	9.00	2.6671	1.9338	3
	10.00	2.7773	1.5106	3
	Total	3.8059	3.5781	30

a. Weighted Least Squares Regression - Weighted by NOTRECOR

Tests of Between-Subjects Effects[b]

Dependent Variable: DBHCORE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	294.511[a]	13	22.655	4.722	.002	.793
Intercept	1994.825	1	1994.825	415.793	.000	.963
BLOCK	162.361	2	81.180	16.921	.000	.679
PROPENAN	74.213	9	8.246	1.719	.165	.492
BURN	.281	1	.281	.059	.812	.004
CATTLE	13.330	1	13.330	2.778	.115	.148
Error	76.762	16	4.798			
Total	3137.832	30				
Corrected Total	371.273	29				

a. R Squared = .793 (Adjusted R Squared = .625)

b. Weighted Least Squares Regression - Weighted by NOTRECOR

Parameter Estimates[b]

Dependent Variable: DBHCORE

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Eta Squared
Intercept	4.646	.795	5.844	.000	2.961	6.332	.681
[BLOCK=1.00]	-1.465	.483	-3.031	.008	-2.490	-.441	.365
[BLOCK=2.00]	-2.616	.453	-5.771	.000	-3.577	-1.655	.676
[BLOCK=3.00]	0[a]	.	.	.	.	.	.
[PROPENAN=1.00]	1.331	.831	1.601	.129	-.431	3.092	.138
[PROPENAN=2.00]	1.164	.831	1.401	.180	-.597	2.925	.109
[PROPENAN=3.00]	.991	.836	1.185	.253	-.781	2.762	.081
[PROPENAN=4.00]	1.239	.847	1.463	.163	-.556	3.034	.118
[PROPENAN=5.00]	.102	.854	.119	.907	-1.708	1.911	.001
[PROPENAN=6.00]	.638	.819	.780	.447	-1.097	2.374	.037
[PROPENAN=7.00]	.955	.870	1.097	.289	-.890	2.800	.070
[PROPENAN=8.00]	-6.539E-02	.900	-.073	.943	-1.973	1.842	.000
[PROPENAN=9.00]	-.625	.871	-.717	.483	-2.471	1.222	.031
[PROPENAN=10.00]	0[a]	.	.	.	.	.	.
BURN	.167	.691	.242	.812	-1.299	1.633	.004
CATTLE	-1.384	.830	-1.667	.115	-3.144	.376	.148

a. This parameter is set to zero because it is redundant.

b. Weighted Least Squares Regression - Weighted by NOTRECOR

Estimates[b]

Dependent Variable: DBHCORE

PROPENAN	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1.00	4.537[a]	.470	3.542	5.533
2.00	4.370[a]	.470	3.374	5.367
3.00	4.197[a]	.479	3.182	5.212
4.00	4.445[a]	.489	3.409	5.481
5.00	3.308[a]	.506	2.235	4.381
6.00	3.845[a]	.513	2.757	4.933
7.00	4.161[a]	.590	2.910	5.412
8.00	3.141[a]	.580	1.911	4.371
9.00	2.582[a]	.540	1.437	3.726
10.00	3.206[a]	.674	1.778	4.635

a. Evaluated at covariates appeared in the model: BURN = 8.901E-02, CATTLE = 6.806E-02.

b. Weighted Least Squares Regression - Weighted by NOTRECOR

Pairwise Comparisons[b]

Dependent Variable: DBHCORE

(I) PROPENAN	(J) PROPENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1.00	2.00	.167	.677	.808	-1.268	1.601
	3.00	.340	.654	.610	-1.045	1.726
	4.00	9.182E-02	.669	.893	-1.327	1.511
	5.00	1.229	.704	.100	-.263	2.721
	6.00	.692	.712	.345	-.817	2.202
	7.00	.376	.768	.631	-1.253	2.005
	8.00	1.396	.729	.073	-.149	2.941
	9.00	1.956*	.701	.013	.470	3.441
	10.00	1.331	.831	.129	-.431	3.092
2.00	1.00	-.167	.677	.808	-1.601	1.268
	3.00	.173	.682	.803	-1.272	1.619
	4.00	-7.494E-02	.670	.912	-1.496	1.346
	5.00	1.062	.655	.124	-.326	2.451
	6.00	.525	.711	.471	-.983	2.034
	7.00	.209	.768	.789	-1.418	1.837
	8.00	1.229	.757	.124	-.375	2.833
	9.00	1.789*	.726	.026	.249	3.329
	10.00	1.164	.831	.180	-.597	2.925

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: DBHCORE

(I) PROPENAN	(J) PROPENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
3.00	1.00	-.340	.654	.610	-1.726	1.045
	2.00	-.173	.682	.803	-1.619	1.272
	4.00	-.248	.675	.718	-1.679	1.183
	5.00	.889	.709	.228	-.614	2.392
	6.00	.352	.717	.630	-1.168	1.872
	7.00	3.591E-02	.771	.963	-1.598	1.670
	8.00	1.056	.734	.170	-.501	2.613
	9.00	1.616*	.708	.036	.115	3.116
	10.00	.991	.836	.253	-.781	2.762
4.00	1.00	-9.182E-02	.669	.893	-1.511	1.327
	2.00	7.494E-02	.670	.912	-1.346	1.496
	3.00	.248	.675	.718	-1.183	1.679
	5.00	1.137	.695	.121	-.336	2.610
	6.00	.600	.730	.423	-.946	2.147
	7.00	.284	.779	.720	-1.366	1.935
	8.00	1.304	.746	.100	-.278	2.887
	9.00	1.864*	.722	.020	.332	3.395
	10.00	1.239	.847	.163	-.556	3.034
5.00	1.00	-1.229	.704	.100	-2.721	.263
	2.00	-1.062	.655	.124	-2.451	.326
	3.00	-.889	.709	.228	-2.392	.614
	4.00	-1.137	.695	.121	-2.610	.336
	6.00	-.537	.738	.478	-2.102	1.028
	7.00	-.853	.793	.298	-2.535	.829
	8.00	.167	.781	.833	-1.489	1.823
	9.00	.727	.752	.348	-.867	2.320
	10.00	.102	.854	.907	-1.708	1.911
6.00	1.00	-.692	.712	.345	-2.202	.817
	2.00	-.525	.711	.471	-2.034	.983
	3.00	-.352	.717	.630	-1.872	1.168
	4.00	-.600	.730	.423	-2.147	.946
	5.00	.537	.738	.478	-1.028	2.102
	7.00	-.316	.734	.672	-1.872	1.240
	8.00	.704	.791	.386	-.972	2.380
	9.00	1.263	.758	.115	-.344	2.871
	10.00	.638	.819	.447	-1.097	2.374

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: DBHCORE

(I) PROPENAN	(J) PROPENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
7.00	1.00	-.376	.768	.631	-2.005	1.253
	2.00	-.209	.768	.789	-1.837	1.418
	3.00	-3.591E-02	.771	.963	-1.670	1.598
	4.00	-.284	.779	.720	-1.935	1.366
	5.00	.853	.793	.298	-.829	2.535
	6.00	.316	.734	.672	-1.240	1.872
	8.00	1.020	.836	.240	-.752	2.792
	9.00	1.580	.812	.070	-.143	3.302
	10.00	.955	.870	.289	-.890	2.800
8.00	1.00	-1.396	.729	.073	-2.941	.149
	2.00	-1.229	.757	.124	-2.833	.375
	3.00	-1.056	.734	.170	-2.613	.501
	4.00	-1.304	.746	.100	-2.887	.278
	5.00	-.167	.781	.833	-1.823	1.489
	6.00	-.704	.791	.386	-2.380	.972
	7.00	-1.020	.836	.240	-2.792	.752
	9.00	.560	.778	.483	-1.090	2.209
	10.00	-6.539E-02	.900	.943	-1.973	1.842
9.00	1.00	-1.956*	.701	.013	-3.441	-.470
	2.00	-1.789*	.726	.026	-3.329	-.249
	3.00	-1.616*	.708	.036	-3.116	-.115
	4.00	-1.864*	.722	.020	-3.395	-.332
	5.00	-.727	.752	.348	-2.320	.867
	6.00	-1.263	.758	.115	-2.871	.344
	7.00	-1.580	.812	.070	-3.302	.143
	8.00	-.560	.778	.483	-2.209	1.090
	10.00	-.625	.871	.483	-2.471	1.222
10.00	1.00	-1.331	.831	.129	-3.092	.431
	2.00	-1.164	.831	.180	-2.925	.597
	3.00	-.991	.836	.253	-2.762	.781
	4.00	-1.239	.847	.163	-3.034	.556
	5.00	-.102	.854	.907	-1.911	1.708
	6.00	-.638	.819	.447	-2.374	1.097
	7.00	-.955	.870	.289	-2.800	.890
	8.00	6.539E-02	.900	.943	-1.842	1.973
	9.00	.625	.871	.483	-1.222	2.471

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

b. Weighted Least Squares Regression - Weighted by NOTRECOR

Appendix 6. Analysis of variance for Multistem reiteration

Descriptive Statistics[a]

Dependent Variable: MULTISTE

BLOCK	PROVENAN	Mean	Std. Deviation	N
1.00	1.00	56.7800	.	1
	2.00	30.0000	.	1
	3.00	43.2800	.	1
	4.00	40.3900	.	1
	5.00	21.9700	.	1
	6.00	26.5600	.	1
	7.00	24.3500	.	1
	8.00	23.5700	.	1
	9.00	.0000	.	1
	10.00	23.5700	.	1
	Total	32.6180	61.5728	10
2.00	1.00	39.2300	.	1
	2.00	54.3300	.	1
	3.00	40.3900	.	1
	4.00	38.0500	.	1
	5.00	40.9700	.	1
	6.00	41.5500	.	1
	7.00	.0000	.	1
	8.00	22.7800	.	1
	9.00	.0000	.	1
	10.00	.0000	.	1
	Total	31.8476	79.1820	10
3.00	1.00	69.7300	.	1
	2.00	58.0500	.	1
	3.00	47.2900	.	1
	4.00	39.2300	.	1
	5.00	47.2900	.	1
	6.00	33.2100	.	1
	7.00	27.2700	.	1
	8.00	27.2700	.	1
	9.00	23.5700	.	1
	10.00	.0000	.	1
	Total	43.0483	63.1989	10
Total	1.00	53.4679	70.0963	3
	2.00	52.5150	49.4827	3
	3.00	43.6696	16.9691	3
	4.00	39.2449	5.2960	3
	5.00	34.9795	54.9846	3
	6.00	34.9521	19.6758	3
	7.00	16.7795	66.1575	3
	8.00	24.2623	9.4662	3
	9.00	8.3188	46.4416	3
	10.00	11.7850	28.8672	3
	Total	35.4821	69.0737	30

a. Weighted Least Squares Regression - Weighted by NOOFTREE

Tests of Between-Subjects Effects[b]

Dependent Variable: MULTISTE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Eta Squared
Corrected Model	114571.358[a]	13	8813.181	5.927	.001	.828
Intercept	327030.501	1	327030.501	219.918	.000	.932
BLOCK	11380.860	2	5690.430	3.827	.044	.324
PROVENAN	91652.840	9	10183.649	6.848	.000	.794
BURN	2.291	1	2.291	.002	.969	.000
COW	2202.806	1	2202.806	1.481	.241	.085
Error	23792.919	16	1487.057			
Total	737637.090	30				
Corrected Total	138364.277	29				

a. R Squared = .828 (Adjusted R Squared = .688)

b. Weighted Least Squares Regression - Weighted by NOOFTREE

Parameter Estimates[b]

Dependent Variable: MULTISTE

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Eta Squared
Intercept	24.398	12.199	2.000	.063	-1.462	50.259	.200
[BLOCK=1.00]	-12.004	5.277	-2.275	.037	-23.192	-.817	.244
[BLOCK=2.00]	-13.835	5.153	-2.685	.016	-24.759	-2.911	.311
[BLOCK=3.00]	0[a]	.	.	.	.	.	.
[PROVENAN=1.00]	38.755	12.353	3.137	.006	12.568	64.942	.381
[PROVENAN=2.00]	35.558	12.558	2.831	.012	8.936	62.180	.334
[PROVENAN=3.00]	27.737	12.269	2.261	.038	1.728	53.746	.242
[PROVENAN=4.00]	27.567	12.379	2.227	.041	1.325	53.810	.237
[PROVENAN=5.00]	21.012	12.475	1.684	.112	-5.434	47.458	.151
[PROVENAN=6.00]	18.243	13.874	1.315	.207	-11.168	47.653	.098
[PROVENAN=7.00]	1.026	12.443	.082	.935	-25.351	27.404	.000
[PROVENAN=8.00]	12.571	12.389	1.015	.325	-13.694	38.835	.060
[PROVENAN=9.00]	-7.666	13.146	-.583	.568	-35.535	20.203	.021
[PROVENAN=10.00]	0[a]	.	.	.	.	.	.
BURN	-.309	7.881	-.039	.969	-17.015	16.397	.000
COW	-11.998	9.858	-1.217	.241	-32.895	8.900	.085

a. This parameter is set to zero because it is redundant.

b. Weighted Least Squares Regression - Weighted by NOOFTREE

2. PROVENAN

Estimates[b]

Dependent Variable: MULTISTE

PROVENAN	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	53.861[a]	4.994	43.275	64.448
2.00	50.664[a]	5.272	39.489	61.840
3.00	42.843[a]	4.731	32.813	52.873
4.00	42.674[a]	5.672	30.649	54.699
5.00	36.118[a]	5.353	24.770	47.467
6.00	33.349[a]	7.960	16.474	50.224
7.00	16.133[a]	5.182	5.148	27.117
8.00	27.677[a]	5.791	15.400	39.954
9.00	7.441[a]	6.679	-6.717	21.598
10.00	15.107[a]	11.250	-8.743	38.956

a. Evaluated at covariates appeared in the model: BURN = 7.563E-02, COW = 5.462E-02.

b. Weighted Least Squares Regression - Weighted by NOOFTREE

Pairwise Comparisons[b]

Dependent Variable: MULTISTE

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	95% Confidence Interval for Difference[a] Upper Bound
1.00	2.00	3.197	7.180	.662	-12.025	18.418
	3.00	11.018	7.002	.135	-3.825	25.861
	4.00	11.187	7.638	.162	-5.004	27.379
	5.00	17.743*	7.054	.023	2.790	32.696
	6.00	20.512*	9.505	.046	.363	40.662
	7.00	37.729*	7.308	.000	22.236	53.221
	8.00	26.184*	7.763	.004	9.728	42.640
	9.00	46.421*	8.442	.000	28.525	64.317
	10.00	38.755*	12.353	.006	12.568	64.942
2.00	1.00	-3.197	7.180	.662	-18.418	12.025
	3.00	7.821	7.039	.283	-7.100	22.742
	4.00	7.990	7.946	.330	-8.854	24.835
	5.00	14.546	7.470	.069	-1.291	30.383
	6.00	17.315	9.475	.086	-2.771	37.401
	7.00	34.532*	7.356	.000	18.937	50.126
	8.00	22.987*	8.058	.012	5.905	40.070
	9.00	43.224*	8.467	.000	25.275	61.173
	10.00	35.558*	12.558	.012	8.936	62.180

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: MULTISTE

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
3.00	1.00	-11.018	7.002	.135	-25.861	3.825
	2.00	-7.821	7.039	.283	-22.742	7.100
	4.00	169	7.506	.982	-15.743	16.082
	5.00	6.725	7.239	.367	-8.620	22.070
	6.00	9.494	9.148	.315	-9.900	28.888
	7.00	26.711*	6.903	.001	12.078	41.343
	8.00	15.166	7.635	.064	-1.019	31.351
	9.00	35.403*	8.080	.000	18.273	52.532
	10.00	27.737*	12.269	.038	1.728	53.746
4.00	1.00	-11.187	7.638	.162	-27.379	5.004
	2.00	-7.990	7.946	.330	-24.835	8.854
	3.00	-.169	7.506	.982	-16.082	15.743
	5.00	6.556	7.834	.415	-10.052	23.164
	6.00	9.325	9.905	.361	-11.674	30.323
	7.00	26.541*	7.788	.004	10.032	43.050
	8.00	14 997	7.627	.067	-1.171	31.165
	9.00	35.233*	8.867	.001	16.436	54.030
	10.00	27.567*	12.379	.041	1.325	53.810
5.00	1.00	-17.743*	7.054	.023	-32.696	-2.790
	2.00	-14.546	7.470	.069	-30.383	1.291
	3.00	-6.725	7.239	.367	-22.070	8.620
	4.00	-6.556	7.834	.415	-23.164	10.052
	6.00	2.769	9.684	.779	-17.760	23.299
	7.00	19.986*	7.534	.017	4.014	35.958
	8.00	8.441	7.956	.304	-8.424	25.307
	9.00	28.678*	8.640	.004	10.363	46.993
	10.00	21.012	12.475	.112	-5.434	47.458
6.00	1.00	-20.512*	9.505	.046	-40.662	-.363
	2.00	-17.315	9.475	.086	-37.401	2.771
	3.00	-9.494	9.148	.315	-28.888	9.900
	4.00	-9.325	9.905	.361	-30.323	11.674
	5.00	-2.769	9.684	.779	-23.299	17.760
	7.00	17.216	9.396	.086	-2.703	37.136
	8.00	5.672	10.000	.578	-15.526	26.871
	9.00	25.909*	10.288	.023	4.099	47.719
	10.00	18.243	13.874	.207	-11.168	47.653
7.00	1.00	-37.729*	7.308	.000	-53.221	-22.236
	2.00	-34.532*	7.356	.000	-50.126	-18.937
	3.00	-26.711*	6.903	.001	-41.343	-12.078
	4.00	-26.541*	7.788	.004	-43.050	-10.032
	5.00	-19.986*	7.534	.017	-35.958	-4.014
	6.00	-17.216	9.396	.086	-37.136	2.703
	8.00	-11.544	7.912	.164	-28.317	5.229
	9.00	8.692	8.357	.314	-9.024	26.408
	10.00	1.026	12.443	.935	-25.351	27.404

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: MULTISTE

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
8.00	1.00	-26.184*	7.763	.004	-42.640	-9.728
	2.00	-22.987*	8.058	.012	-40.070	-5.905
	3.00	-15.166	7.635	.064	-31.351	1.019
	4.00	-14.997	7.627	.067	-31.165	1.171
	5.00	-8.441	7.956	.304	-25.307	8.424
	6.00	-5.672	10.000	.578	-26.871	15.526
	7.00	11.544	7.912	.164	-5.229	28.317
	9.00	20.237*	8.976	.039	1.209	39.264
	10.00	12.571	12.389	.325	-13.694	38.835
9.00	1.00	-46.421*	8.442	.000	-64.317	-28.525
	2.00	-43.224*	8.467	.000	-61.173	-25.275
	3.00	-35.403*	8.080	.000	-52.532	-18.273
	4.00	-35.233*	8.867	.001	-54.030	-16.436
	5.00	-28.678*	8.640	.004	-46.993	-10.363
	6.00	-25.909*	10.288	.023	-47.719	-4.099
	7.00	-8.692	8.357	.314	-26.408	9.024
	8.00	-20.237*	8.976	.039	-39.264	-1.209
	10.00	-7.666	13.146	.568	-35.535	20.203
10.00	1.00	-38.755*	12.353	.006	-64.942	-12.568
	2.00	-35.558*	12.558	.012	-62.180	-8.936
	3.00	-27.737*	12.269	038	-53.746	-1.728
	4.00	-27.567*	12.379	.041	-53.810	-1.325
	5.00	-21.012	12.475	.112	-47.458	5.434
	6.00	-18.243	13.874	207	-47.653	11.168
	7.00	-1.026	12.443	.935	-27.404	25.351
	8.00	-12.571	12.389	.325	-38.835	13.694
	9.00	7.666	13.146	.568	-20.203	35.535

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

b. Weighted Least Squares Regression - Weighted by NOOFTREE

Appendix 7. Analysis of variance for crown diameter

Descriptive Statistics[a]

Dependent Variable: CROWNALL

BLOCK	PROVENAN	Mean	Std. Deviation	N
1.00	1.00	169.0000	.	1
	2.00	180.0000	.	1
	3.00	178.0000	.	1
	4.00	101.0000	.	1
	5.00	147.0000	.	1
	6.00	142.0000	.	1
	7.00	156.0000	.	1
	8.00	112.0000	.	1
	9.00	120.0000	.	1
	10.00	117.0000	.	1
	Total	144.5921	118.9149	10
2.00	1.00	135.0000	.	1
	2.00	134.0000	.	1
	3.00	131.0000	.	1
	4.00	159.0000	.	1
	5.00	143.0000	.	1
	6.00	124.0000	.	1
	7.00	141.0000	.	1
	8.00	140.0000	.	1
	9.00	149.0000	.	1
	10.00	103.0000	.	1
	Total	134.9500	66.5270	10
3.00	1.00	225.0000	.	1
	2.00	212.0000	.	1
	3.00	212.0000	.	1
	4.00	227.0000	.	1
	5.00	195.0000	.	1
	6.00	193.0000	.	1
	7.00	153.0000	.	1
	8.00	165.0000	.	1
	9.00	128.0000	.	1
	10.00	137.0000	.	1
	Total	192.1181	113.2877	10
Total	1.00	179.5833	139.7781	3
	2.00	170.8182	179.9220	3
	3.00	173.4783	199.1849	3
	4.00	150.4545	242.3754	3
	5.00	166.7857	134.2487	3
	6.00	152.6842	157.1501	3
	7.00	149.5294	35.0336	3
	8.00	140.5882	87.5449	3
	9.00	131.0000	31.9374	3
	10.00	117.0000	68.9928	3
	Total	155.3235	140.1696	30

a. Weighted Least Squares Regression - Weighted by NOOFTREE

Tests of Between-Subjects Effects[b]

Dependent Variable: CROWNALL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	454362.494[a]	13	34950.961	4.845	.002
Intercept	7322821.84	1	7322821.84	1015.158	.000
BLOCK	227528.704	2	113764.352	15.771	.000
PROVENAN	82426.896	9	9158.544	1.270	.324
FIRE	2816.678	1	2816.678	.390	.541
COW	27018.762	1	27018.762	3.746	.071
Error	115415.683	16	7213.480		
Total	12053468.0	30			
Corrected Total	569778.176	29			

a. R Squared = .797 (Adjusted R Squared = .633)

b. Weighted Least Squares Regression - Weighted by NOOFTREE

Parameter Estimates[b]

Dependent Variable: CROWNALL

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Intercept	170.513	16.565	10.293	.000	135.396	205.630
[BLOCK=1.00]	-52.804	11.623	-4.543	.000	-77.444	-28.165
[BLOCK=2.00]	-62.198	11.350	-5.480	.000	-86.258	-38.138
[BLOCK=3.00]	0[a]	.	.	.	.	.
[PROVENAN=1.00]	43.395	22.024	1.970	.066	-3.294	90.084
[PROVENAN=2.00]	40.273	17.097	2.356	.032	4.029	76.516
[PROVENAN=3.00]	40.670	16.815	2.419	.028	5.023	76.316
[PROVENAN=4.00]	23.944	17.523	1.366	.191	-13.203	61.090
[PROVENAN=5.00]	27.812	17.748	1.567	.137	-9.812	65.436
[PROVENAN=6.00]	20.670	17.426	1.186	.253	-16.272	57.611
[PROVENAN=7.00]	33.389	16.798	1.988	.064	-2.221	68.999
[PROVENAN=8.00]	7.558	19.768	.382	.707	-34.349	49.465
[PROVENAN=9.00]	14.624	27.287	.536	.599	-43.222	72.471
[PROVENAN=10.00]	0[a]	.	.	.	.	.
FIRE	10.846	17.357	.625	.541	-25.948	47.640
COW	-42.019	21.711	-1.935	.071	-88.044	4.007

a. This parameter is set to zero because it is redundant.

b. Weighted Least Squares Regression - Weighted by NOOFTREE

2. PROVENAN

Estimates[b]

Dependent Variable: CROWNALL

PROVENAN	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
1.00	174.100[a]	17.532	136.933	211.266
2.00	170.977[a]	10.999	147.661	194.293
3.00	171.374[a]	10.421	149.284	193.465
4.00	154.648[a]	11.790	129.654	179.642
5.00	158.516[a]	11.611	133.903	183.130
6.00	151.374[a]	11.412	127.181	175.567
7.00	164.094[a]	12.493	137.610	190.577
8.00	138.262[a]	14.709	107.080	169.444
9.00	145.329[a]	24.778	92.801	197.857
10.00	130.704[a]	12.755	103.666	157.743

a. Evaluated at covariates appeared in the model: FIRE = 7.563E-02, COW = 5.462E-02.

b. Weighted Least Squares Regression - Weighted by NOOFTREE

Pairwise Comparisons[b]

Dependent Variable: CROWNALL

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1.00	2.00	3.123	20.934	.883	-41.256	47.501
	3.00	2.725	20.149	.894	-39.989	45.440
	4.00	19.451	21.329	.375	-25.764	64.667
	5.00	15.583	20.868	.466	-28.656	59.822
	6.00	22.725	20.695	.288	-21.147	66.598
	7.00	10.006	21.816	.653	-36.243	56.254
	8.00	35.837	22.659	.133	-12.199	83.873
	9.00	28.771	30.556	.360	-36.006	93.547
	10.00	43.395	22.024	.066	-3.294	90.084
2.00	1.00	-3.123	20.934	.883	-47.501	41.256
	3.00	-.397	15.421	.980	-33.089	32.295
	4.00	16.329	15.535	.309	-16.604	49.262
	5.00	12.461	15.814	.442	-21.064	45.985
	6.00	19.603	16.096	.241	-14.519	53.724
	7.00	6.883	16.822	.688	-28.779	42.545
	8.00	32.715	18.593	.098	-6.700	72.130
	9.00	25.648	27.207	.360	-32.028	83.324
	10.00	40.273*	17.097	.032	4.029	76.516

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: CROWNALL

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
3.00	1.00	-2.725	20.149	.894	-45.440	39.989
	2.00	.397	15.421	.980	-32.295	33.089
	4.00	16.726	15.943	.310	-17.071	50.524
	5.00	12.858	15.502	.419	-20.005	45.721
	6.00	20.000	15.203	.207	-12.228	52.228
	7.00	7.281	16.532	.666	-27.766	42.327
	8.00	33.112	17.796	.081	-4.615	70.839
	9.00	26.045	27.022	.349	-31.239	83.329
	10.00	40.670*	16.815	.028	5.023	76.316
4.00	1.00	-19.451	21.329	.375	-64.667	25.764
	2.00	-16.329	15.535	.309	-49.262	16.604
	3.00	-16.726	15.943	.310	-50.524	17.071
	5.00	-3.868	16.453	.817	-38.748	31.011
	6.00	3.274	16.594	.846	-31.904	38.452
	7.00	-9.446	17.255	.592	-46.024	27.133
	8.00	16.386	19.028	.402	-23.952	56.724
	9.00	9.319	27.476	.739	-48.928	67.566
	10.00	23.944	17.523	.191	-13.203	61.090
5.00	1.00	-15.583	20.868	.466	-59.822	28.656
	2.00	-12.461	15.814	.442	-45.985	21.064
	3.00	-12.858	15.502	.419	-45.721	20.005
	4.00	3.868	16.453	.817	-31.011	38.748
	6.00	7.142	16.202	.665	-27.204	41.489
	7.00	-5.577	17.501	.754	-42.677	31.523
	8.00	20.254	18.648	.294	-19.277	59.786
	9.00	13.188	27.659	.640	-45.446	71.821
	10.00	27.812	17.748	.137	-9.812	65.436
6.00	1.00	-22.725	20.695	.288	-66.598	21.147
	2.00	-19.603	16.096	.241	-53.724	14.519
	3.00	-20.000	15.203	.207	-52.228	12.228
	4.00	-3.274	16.594	.846	-38.452	31.904
	5.00	-7.142	16.202	.665	-41.489	27.204
	7.00	-12.720	17.152	.469	-49.081	23.642
	8.00	13.112	18.406	.486	-25.906	52.130
	9.00	6.045	27.405	.828	-52.050	64.141
	10.00	20.670	17.426	.253	-16.272	57.611
7.00	1.00	-10.006	21.816	.653	-56.254	36.243
	2.00	-6.883	16.822	.688	-42.545	28.779
	3.00	-7.281	16.532	.666	-42.327	27.766
	4.00	9.446	17.255	.592	-27.133	46.024
	5.00	5.577	17.501	.754	-31.523	42.677
	6.00	12.720	17.152	.469	-23.642	49.081
	8.00	25.832	19.529	.205	-15.568	67.231
	9.00	18.765	27.265	.501	-39.034	76.563
	10.00	33.389	16.798	.064	-2.221	68.999

Based on estimated marginal means

Pairwise Comparisons[b]

Dependent Variable: CROWNALL

(I) PROVENAN	(J) PROVENAN	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
8.00	1.00	-35.837	22.659	.133	-83.873	12.199
	2.00	-32.715	18.593	.098	-72.130	6.700
	3.00	-33.112	17.796	.081	-70.839	4.615
	4.00	-16.386	19.028	.402	-56.724	23.952
	5.00	-20.254	18.648	.294	-59.786	19.277
	6.00	-13.112	18.406	.486	-52.130	25.906
	7.00	-25.832	19.529	.205	-67.231	15.568
	9.00	-7.067	28.955	.810	-68.448	54.314
	10.00	7.558	19.768	.707	-34.349	49.465
9.00	1.00	-28.771	30.556	.360	-93.547	36.006
	2.00	-25.648	27.207	.360	-83.324	32.028
	3.00	-26.045	27.022	.349	-83.329	31.239
	4.00	-9.319	27.476	.739	-67.566	48.928
	5.00	-13.188	27.659	.640	-71.821	45.446
	6.00	-6.045	27.405	.828	-64.141	52.050
	7.00	-18.765	27.265	.501	-76.563	39.034
	8.00	7.067	28.955	.810	-54.314	68.448
	10.00	14.624	27.287	.599	-43.222	72.471
10.00	1.00	-43.395	22.024	.066	-90.084	3.294
	2.00	-40.273*	17.097	.032	-76.516	-4.029
	3.00	-40.670*	16.815	.028	-76.316	-5.023
	4.00	-23.944	17.523	.191	-61.090	13.203
	5.00	-27.812	17.748	.137	-65.436	9.812
	6.00	-20.670	17.426	.253	-57.611	16.272
	7.00	-33.389	16.798	.064	-68.999	2.221
	8.00	-7.558	19.768	.707	-49.465	34.349
	9.00	-14.624	27.287	.599	-72.471	43.222

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

b. Weighted Least Squares Regression - Weighted by NOOFTREE

Curriculum Vitae

Gusti Muhammad Hatta was born on September 1, 1952 in Banjarmasin, South Kalimantan, Indonesia. He studied forestry at the Faculty of Forestry of Lambung Mangkurat University in Banjarbaru, South Kalimantan for three years then continued at the Faculty of Forestry at Bogor Agricultural University till 1979. From these universities he obtained the degrees of BSc. and Ir., with silviculture as his major. After graduating he worked at the Faculty of Forestry of Lambung Mangkurat University in Banjarbaru. In 1985 he studied for his Master's degree at Gadjah Mada University, which he obtained in 1987. He followed several training courses, i.e., Human Ecology (1980, carried out by MAB-Indonesia and Unesco), Design and Analysis of field experiments (1990, carried out by FINNIDA and WINROCK F-RED), and Environmental Impact Analysis (1993). He is co-author of The Ecology of Kalimantan (1990). Until 1996, he held the position of Head of Silvicultural Section at the Faculty of Forestry at Lambung Mangkurat University.

Wageningen, July 1999

Gusti Muhammad Hatta