EFFECTS OF AGROFORESTRY PRACTICE ON GROWTH OF TEAK, CROP PRODUCTION AND SOIL FERTILITY

by

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ABSTRACT

EFFECTS OF AGROFORESTRY PRACTICE ON GROWTH OF TEAK, CROP PRODUCTION AND SOIL FERTILITY

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To investigate the ecology of the tumpangsari agroforestry system as practiced in Java, teak (*Tectona grandis* L.) was grown in the Wanagama I forest area 36 kms south of Yogyakarta, in combination with rice (*Oryza sativa* L.), corn (*Zea mays* L.) and peanut (*Arachis hypogea* L.) in plots with or without a legume (*Acacia villosa* L.).

Teak grown with rice or peanut performed better than when grown with corn or without crop. With the exception of teak-rice combination 16 months after planting, the effect of acacia was found not significant. The type of crop significantly affected the performance of teak, although the difference between teak grown with rice and with peanut was not significant. The order of positive companionship of crops on teak was rice > peanut > corn and peanut > rice > corn at four and 16 months, respectively.

No significant reduction of crop yields observed

after the second cropping season. Acacia has shown a significant effect on yield of crop on the row basis but not on the plot basis. Root occupancy of the teak-crop combination was significantly affected by its distance from the teak but not by the depth of the soil. Roots of the teak-rice combination occupied the soil more extensively than the other teak-crop combinations.

Nitrogen, P, and organic carbon concentration of the surface soil decreased significantly after four months, while that of the subsurface soil increased. The effect of acacia on soil N was not significant. There was no significant effects on soil total exchangeable bases for both surface and subsurface soils.

The findings support the agrisilvicultural practice during forest establishment, and under the conditions of the experimental area, the suggested cropping sequence for tumpangsari is rice-peanut-corn.

To my mother, Toeti
and
in memory of my father, Roekanda.

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1. INTRODUCTION

Agroforestry is a system of land management that seems suitable for ecologically fragile areas since it combines the protective (and also productive) characteristics of forestry with the productive attributes of agriculture. In the words of King (1979), " It conserves and produces".

The practice of agroforestry on forest lands known as "tumpangsari" (an Indonesian term for taungya), is generally practiced during the agrosilvicultural stage of the teak life cycle (Figure 2.1), although some other alternatives are available (Becking, 1928). In this system farmers are permitted to grow their crops between rows of trees on condition that they tend the trees during the intercropping period, which lasts for two years (Kartasubrata, 1978). Tumpangsari is an old practice waiting for more scientific informations for further improvement. As was stated by Atmosoedaryo and Wijayakusumah (1979), foresters have taken interest only in the technical and production aspects of tumpangsari while leaving behind the need for intensive investigation into its ecological aspects The principal motive of a taungya system, which was a reduction in the cost of stand establishment by exploiting people's poverty (Contant, 1979), has changed. At least in Indonesia, there is an ongoing tendency to get into a fairer cooperation between both the forest service and the farmers. Attention is also being given to the general improvement of forest-farmers' living conditions and the diversification of their farming activities (Kartasubrata 1978, Atmosoedaryo and Banyard, 1979). At present, a high reliance on tumpangsari system to produce sufficient food for forest farmers is questioned (Wiersum, 1980), because less and less land is alotted to farmers and slow improvement of the system itself has occurred.

The present study was carried out in response to the problems mentioned above to add some information on the interference between teak and crops grown with it. More specifically, the main objectives of the study were to document the effects of interplanted crops on growth and productivity of teak, measure yield of the interplanted crops, and assess changes in nutrient status of the soil. Results of this study might be of important for recommending 1) the proper kind of crop to be grown with teak, and 2) the cropping pattern for tumpangsari under a condition similar to the experimental area. In addition, this study also provides additional ecological data which should be considered in determining whether or not tumpangsari should be practiced on forest land.

2. A REVIEW OF AGROFORESTRY AND THE TAUNGYA SYSTEM IN FORESTRY PRACTICE IN JAVA

2.1 AGROFORESTRY

2.1.1. The concept.

Agroforestry, in its simplest terms refers to a practice of growing woody plants with agricultural crops and or domestic animals together on the same land. Many definitions have been made describing agroforestry; e.g. those written in the first issue of the Agroforestry Systems Journal (Annon, 1982). The one that is being used by the International Cooperation for Research in Agroforestry (I.C.R.A.F) as stated by King and Chandler (1978) is : " Agroforestry .... a sustainable land management system which increases the overall yield of the land, combines the production of crops (including tree crops) and forest plants and/ or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population."

Most and in the tropics is not suitable for agriculture; either it is too dry, too steep, too infertile, or prone to annual flooding. Only 11 % of the land of the tropics is flat enough for arable agriculture (Mongi, 1979), implying that for most of the land, forest is the most suitable cover. However, due to population pressure, this ideal type of land cover, forest, has to be sacrificed for the production of people's basic needs, food.

The premises on which the concept of agroforestry is based are partly biological and partly socio-economic (King,1979). In general, trees in the forest have the ability to take nutrients up from deep within the soil profile, (at a depth not exploited by roots of agricultural crops), convert and utilize nutrients for production of plant material, and recycle them in the form of litter, which in turn will be transformed into humus and later incorporated into soil. Forests have an efficient nutrient cycle. The physiognomy of a forest is such that it provides protection from the effects of precipitation because the canopy or the intermediate strata of the forest reduce the potential impact of rain drops on the soil, so that erosion can be minimized.

Boerboom (1981) stated the tree components in agroforestry will have one or more of the following functions :

a. To produce a product for local consumption by man and cattle and for marketing externally.

b. To improve or have a stabilizing influence on the environment, locally and / or in adjacent areas (site improvement)

c. To create favorable conditions for the growth of other crops (habitat improvement).

When introducing trees to agricultural land being occupied with a given crop, consideration should be given to some tree characteristics ideal for agroforestry (King, 1979) :

- amenable to early wide spacing;
- good self pruning or ability to tolerate a relatively high incidence of pruning;
- low crown diameter-to-bole diameter ratio;
- light branching habit;
- tolerant to lateral shade, if indeed not to full overhead shade in the early stages of growth;
- phyllotaxis which permits the penetration of light to the ground;
- phenology, particularly with respect to leaf flushing and leaf fall, that is compatible with the growth of the companion annual crop;
- good litter producer with fast decomposition;
- the root system and root characteristics ideally should result in the exploration of soil layers that are

different from those being tapped by the agricultural species; and

- be an efficient nutrient "pump".

The socio-economic premises for introducing agro-forestry are even clearer. Forests in developing countries are disappearing under the pressure of population. More and more forest land is being converted by people who need land to produce food for their very existence, although the areas are not well suited to arable agriculture. Another factor contributing to this decrease of forest area is the time scale in the forest production cycle. Forestry practices typically result in delayed returns that do not meet the immediate needs of the local population. There is also the risk that the original planter might not profit from future yield due to in security of land and tree tenure. Shifting cultivation, which under low population pressure is considered as the most suitable method of manipulating the forest environ-ment, is no longer a viable alternative, because the time required for a proper fallow period can no longer be met. Finally, poor agricultural practices in the past indirect-ly contribute to the encroachment of forest land through the creation of abandoned land which is difficult to reclaim back into agricultural production.

2.1.2. The place of Agroforestry in Forestry in Java

Agroforestry ventures can be carried out either on agricultural land or on forest land. Outside the forest there is enormous potential for introducing trees on lands that are conventionally seen as strictly agricultural (F.A.O., 1981). However, forest land can also be used for a greater food production base for the rural population, although this means a specific approach of forest management beyond traditional practices.

The forest cover of Java is 22.7 % of the total land area (Table 2.1). Most of the forest land is surrounded by densely populated villages generally inhabitated by low income, subsistence farmers with a very limited chance of getting alternative sources of income. This socio economic situation was clearly described by Atmosoedaryo and Banyard (1979) as :

"...... an all too common problem facing forest managers in areas of dense population is how to protect the forest from destructive human activities. There are those who steal and destroy for financial gains and against whom preventive and repressive measures will always have to be taken. There are others, however, obtaining fuelwood, grazing, building material, and even arable land whose very existence depends upon the forest. The problem is aggravated by the fact that foresters can often sympathize with the motive of the offenders. A fine of being caught only make matters worse for the peasant and his family...."

The problem described above might also be true for forest managers in other developing countries. It shows how impossible it is to practice a good forest management with a total ignorance of the welfare of the people living in or near the forest.

Table 2.1. Land and forest area in Java (in hectares)

1. Total land area	13,218,700
2. Forest area:	3,007,222
2.1. Production forest	
2.1.1. teak	1,053,700
2.1.2. non teak	783,568
2.2. Protection forest and Natural reservation	
2.2.1. Protection forest	1,152,942
2.2.2. Natural Reservations	419,942
3. Percentage of forest to total land area	22%

Source : Perhutani (1981)

2.2. TUMPANGSARI SYSTEM

2.2.1. History

Forest management in Indonesia started in the late 19^{th} century when the Nederland Indische Goverment invited in some German foresters and asked them to establish a forest management plan for the Japara - Rembang forest district in Central Java. Later, similar plans were also established for all other forest districts in Java. At present, the State Forestry Corporation "Perum Perhutani", which was established in 1963, is responsible for the management of forest land. The corporation, although essentially a profit making organization, has an obligation to support the government's policy of improving the living standards of the rural community (Atmosoedaryo and Banyard, 1978). One of the available ways is to involve villagers in reforestation activities. The rate of teak reforestation under tumpangsari system is approximately 40,000 hectares per year (Kartasubrata, 1978), which, on the average, will include 160,000 farmers.

Taungya (taung= hill, ya= cultivated plot) is a Burmese word. This practice was started in Burma in the 19^{th} century as a modification of the undesirable practice of shifting cultivation. The Taungya system permitted squatters to grow their crops between rows of trees on condition that they tended the trees during the intercropping period, which lasted for two years (Kartasubrata, 1978). The system was introduced into Indonesia in 1875 by Buurman, a forest district administrator of Pemalang, central Java, and is locally known as tumpangsari.

The objectives in applying the tumpangsari system are:

1. to cut the establishment cost of a plantation,
2. to obtain additions income from agriculture during the juvenile stage of the tree stand,
3. to gain better maintenance of the young tree stand
4. to reclaim wasted lands by means of agriculture before stand establishment,
5. to solve meet the local shortage of good agricultural land.

Land hunger and population pressure, combined with unemployment, have been the conditions under which taungya works (Contant, 1979 ; King, 1979). The similar condition also is true for tumpangsari, which has been an obligatory technique for teak establishment in Java since 1881 (Becking, 1928). Before tumpangsari was introduced, there were at least two methods of planting; the "blandong " system, which is an artificial regeneration system employing blandongs (logging worker) as the paid labor, and the natural regeneration system (Hart, 1927). During the 1900-1930 period, foresters were strongly divided into two groups, one favoring tumpangsari and one against it. Wehlburg (1908) and Thorenaar (1928) suggested that tumpangsari should be rejected due to several disadvantages during the tumpangsari or after the contractors

(farmers) have left. During tumpangsari soil fertility is decreased due to strong withdrawal of nutrients by agricultural crops and the practice of burning during land clearing process. Furthermore, long exposure to sun and rain causes a rapid break down of humus and the danger of accelerated leaching due to intensive soil tillage. After the contractors have left, teak growth decreases because no tillage is done and because of strong competition from alang-alang (Imperata cylindrica) a dominating weed which increases rapidly because competing beneficial herbs and shrubs, are suppressed by cultivation.

Lugt (1909), a tumpangsari supporter responding to Whelburg, argued that 1. during tumpangsari, the soil is not bare but covered with crops, while the interplanted trees of kemlandingan (Leucaena glauca) cover the soil after the contractors leave; 2. the maintenance of crops has a far greater favorable influence on the physical condition of the soil than the presence of natural weeds (mostly alang-alang); and 3. deep soil cultivation is not necessary, since cultivation which is followed by mulching using crop residues maintains soil structure. Lugt further stressed that " often it is not the method used but rather the way it is done that is incorrect"

Thorenaar (1929) relaxed his opposition, suggesting that the duration of the tumpangsari be shortened to only half a year, only rice be allowed as a companion crop, planting without tillage, felling be restricted to the monsoon season, with no or just a short period of standing girdled, and maintenance of kemlandingan under growth after agricultural cropping is ceased.

Boer (1929), disagreed with Thorenaar's suggestion of using only rice, and the idea of reducing the duration of tumpangsari. He stated that in some areas maize was preferred to rice, and reducing the time of tumpangsari means increasing the possibility of invasion of wild climbing plants. However, he agreed that soil cultivation has to be reduced as much as possible. He also pointed out that the expenses involved in preventing the teak from being overgrown in plantations established without the intervention of contractors were extremely high. This opinion was also shared by Coster and Hardjowasono (1935) They found that the teak raised in tumpangsari is only " just a little behind " that of pure plantations which could be compensated by other advantages, such as the reduction in the cost of planting. So they concluded that tumpangsari is justifiable.

2.2.2. The principles of tumpangsari

Tumpangsari in Java is carried out as follows. During plantation establishment, a 0.5 ha parcel of land is alotted to each farmer. The income from this amount of land, along with some additional work (farmers also work on other forestry activities such as logging and road maintenance during their agricultural off-season) is considered sufficient for survival. The working capacity of a simple farmer, using only manual equipment, is about 1 "bahu" (bahu means shoulder) or about 0.7 ha (Hardjo-soediro, 1972). This area of land will keep the farmer and his family busy throughout the year. With the increasing population, the size of the land parcel is becoming smaller and smaller, and in some forest districts it is down to only 0.125 ha per farmer. However, the average size of land parcel alotted to a farmer at present is 0.25 ha (Perhutani, 1981).

Teak is regenerated by planting 3 to 5 seeds at each spot. The spacing generally is 2 x 1 m or 3 x 1 m, depending on the soil "bonita" (site class). The Perum Perhutani workers mark the planting spots with colored poles, after which the farmer takes over most of the activities until the end of the tumpangsari period. The farmer is allowed to grow rice (Oryza sativa), corn (Zea mays), tobacco (Nicotiana tabacum), chili pepper (Capsicum annuum), peanut (Arachis hypogea), and soybean (Glycine max). Except under certain condition, cassava (Manihot esculenta), sweet potato (Ipomoea batata), potato (Solanum tuberosum), banana

(*Musa paradisiaca*), plantain (*Musa sapientum*) and climber crops, are not permissible (Kartasubrata, 1978).

2.2.3. The activities schedule of Tumpangsari

Tumpangsari is carried out for 29 months starting from January each year. The activities of tumpangsari as described by Perhutani (1974) and Kartasubrata (1978) can be grouped into four categories ; site preparation, seed preparation, planting, and tending (Tables 2.1 - 2.5).

Table 2.2 Site Preparation

Kind of activities	Month of execution
1. A letter of instruction is issued	01
2. Boundary and inspection paths mapping	01
3. Field marking of boudaries and inspection paths.	02-03
4. Plantation contract agreement resume	02-03
5. Land clearing	03-04
6. Soil tillage 1	05-06
7. Soil tillage 2	07-08
8. Construction of erosion control structures	07-08
9. Soil tillage 3	08-09
10. Marking of plant-spot	09

Table 2.3. Seed preparation

Kind of activities	Month of execution
1. Teak seed collection	08-09
2. collection of legume seed	05-10
3. collection of non-teak seed	06-09

Table 2.4 Planting

Kind of activities	Month of execution
1. Planting teak seed	09-10
2. Interplanting leucaena	10
3. Hedge planting	11-12
4. Planting non-teak species	12
5. Blank filling (using seeds)	12 and 15-16
6. Blank filling (using seedlings or stumps)	13-15
7. Marking spots for blank filling next year	22-23

Table 2.5. Tending

Kind of activities	Month of execution
1. Pruning of leucaena	16-18 and 23-25
2. Selection for ultimate seedling	14-15 and 28-29
3. Last cleaning before contract ends	28-29
4. Contract ends, plantation submission	29

Within the 29-month operation of tumpangsari there are usually four to five rotations of agricultural crops. The example in Table 2.6 was given by Rachadi (1978), based on his experience in Bojonegoro, East Java .

Table 2.6 : Agricultural cropping pattern of tumpangsari in Bojonegoro, East Java (C= corn; SB= soybean; T= tobacco; R= dry rice paddy.

year	months 1 2 3 4 5 6 7 8 9 10 11 12
one	(C & SB) (T) (- - -
two	R & C) (C & SB) (- - -
three	R)

Source: Rachadi (1978)

2.2.4. The Silvicultural Implications of Tumpangsari

Along the life cycle of teak there are several time segments available for applying the tumpangsari system. In selecting the time and duration of tumpangsari one has to consider the types of crops, the cultivation technique, and the development stage at which trees are less affected by crops, although in a particular situation other non-technical reasons might be more significant.

2.2.4.1. The application time and duration of Tumpangsari

Under the current management system, teak needs to grow 60 to 80 years before it is harvested. During that period of time, teak plantations are subject to either agricultural or forestry treatments as shown in Figure 2.1.

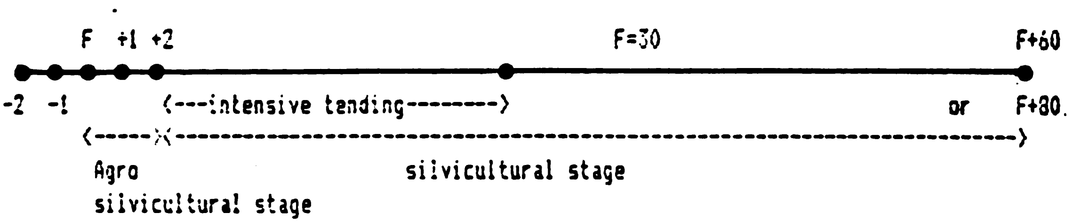


Fig. 2.1 A schematic life cycle of teak under present management system.

F -2 = Girdling period
F = Cutting
F -0 = After cutting activities (Land preparation and farmer reqruitment for the next plantation).
F 2-30 = Intensive tending, thinning etc.
F 30 = Thinning completed
F 60-80 = Cutting

The intercropping period in tumpangsari system may vary according to local conditions. Becking (1928), distinguished three alternatives: 1. agricultural crop cultivation before stand establishment, 2. agricultural crop intercropping starting at the time of stand establishment, 3. stand establishment at the same time as the start of the second crop rotation

In addition, there is the possibility of starting agrisilviculture when the stand reaches about 30 years of age. This possibility is based on the presumption that thinnings have been completed, reducing the number of stems to 100-150 per hectare and that the teak crowns have reached maximum size. As teak becomes older, crown diameters become smaller, whereas diameter growth may still increase (Hollerwgen, 1954). Teak must be given an advanced growth of at least 30 years, after which time it will not suffer from root competition by the intercropped herbs (De Veer , 1958).

At present, the second alternative suggested by Becking is being used, i.e. beginning intercropping at the same time as the tree planting, lasting for two years and four months (Perhutani, 1974). However, there is a developing tendency to lengthen the tumpangsari time to 5 years. However, the reason is more psychological than technical (Hardjosoediro, pers. comm.). For the first 5 years, teak stands are still vulnerable to disturbances caused by cattle since they are considered as favorable sites for people to herd their cattle. Permiting the farmers to stay longer will psychologically prevent this practice, since people will unlikely herd their cattle onto a field if they are convinced that the field is "owned" by someone.

2.2.4.2. Effects of tumpangsari on trees

Teak is very sensitive to crown as well as root competition. Its growth may be severely impeded by root competition of mixed species. Coster (1933) observed that after six years teak raised with Lantana shrubs (Lantana camara) had 33 % less growth in diameter than the adjoining pure teak. Research conducted by Coster and Hardjowasono (1935) demonstrated the negative effects of crops on the growth of teak (Table 2.7). They found that all crops studied retarded the growth of teak, especially cassava. The order of harmfulness of crops in their study was : cassava > dry paddy rice > corn > peanuts > goat pepper (Solanum spp).

A similar effect of crops on trees was shown by gmelina trees (Gmelina arborea) grown under a taungya system (Table 2.8). These results show a non significant difference in height and stem diameter of gmelina trees raised under taungya compared to a pure plantation. Under narrower spacing, taungya-raised gmelina seems to grow better in diameter than pure-planted gmelina.

Table 2.7 Mean height and mean girth at breast height of teak as influenced by crops in three observations after establishment in December 1933.

	Height (% of control treatment)			Girth (cm)
	Mar. 1934	Aug. 1934	Feb. 1935	Feb. 1935
Teak - control	100	100	100	11.9
Teak - rice + corn	83	85	95	10.3
Teak - peanuts/pepper	79	87	94	11.6
Teak - corn	71	84	92	10.8
Teak - rice	92	82	96	10.0
Teak - cassava	58	55	74	10.0

Source : Coster and Hardjowasono (1935)

Table 2.8. Growth of gmelina at 15 months from planting out either alone or under taungya. Annual crops were harvested 5 months before. Figures are overall mean values.

Cropping treatment	Spacing	diameter cm	height m
	1 x 2 m		
Gmelina alone		5.41	6.04
Gmelina with maize (twice)		5.30	5.74
Gmelina with beans (twice)		5.55	5.84
Gmelina with beans and maize		5.70	6.03
	2 x 3 m		
Gmelina alone		8.80	6.12
Gmelina with maize (twice)		7.52	5.55
Gmelina with beans (twice)		7.31	5.34
Gmelina with maize and beans		7.27	5.38

Source: (Combe and Gewald, 1979 as cited in Budowski: 1983).

2.2.4.3. The effect on agricultural crops

Intercropping may also have a negative effect on the yield of component crops. However, most research in tumpangsari has paid inadequate attention to the "agro" side compared to the "forestry" side.

To the critics, tumpangsari is just another form of shifting cultivation called "guided shifting cultivation". where the shifting is guided by the management of tree. By relying on natural soil fertility only, yield of crops grown under tumpangsari will undoubtedly follow the same trend as that grown under shifting cultivation. For example Hauck (1967) found that the yields of maize grown under shifting cultivation were less in the second and third year than that in the first year.

Since a tumpangsari plantation is usually established on fresh cleared forest land with higher natural fertility, it is plausible that the yield of crops grown under tumpangsari would be greater than the average yield of crops grown on general farm lands (Coster and Hardjowasono, 1935). However, more recent data showed a slightly different result. Without additional inputs, the yield of crops under tumpangsari was less than the average farm yield. Rachadi (1978) kept the yield of dryland rice under the tumpangsari higher by using good seed and fertilization, in an intensive approach to tumpangsari (Table 2.9).

Table 2.9. Yield (in Kg/Ha.) of some crops under tumpangsari and average farming in Java. Yields marked * were from intensified tumpangsari.

Crops	Tumpangsari			Average of Java	
	1935	1978	1981	1935	1983
Dryland rice	2037- 2284	1250	1690 3250 *	1200	1794
Corn	1000- 1540	1250	1500 2250 *	990	1636
Cassava	9400- 15880	-	-	8100	9800
Peanut	2300	-	-	730	927

Source: Coster and Hardjowasono (1935) ; Rachadi (1978) Perhutani (1981) ; B.P.S. (1984)

2.2.5 Present development of tumpangsari

Under the tumpangsari system farmers practice their agriculture under some restrictions, i.e. limited crop selection and competition of forest trees with their crops. Perhutani (1974) allowed only maize, rice, tobacco, peanut and chili pepper, while cassava and other crops which have their underground portion harvested, were prohibited. However, for socio economic reasons, the regulations are now being somewhat relaxed. Farmers are now allowed to grow cassava as a row border only. Also, potato can be planted under careful supervision, such as in a plantation project called "MAMA" (Martodiwirjo, 1981).

To obtain better yields, forest farmers are encouraged to follow the general agricultural intensification program being practiced by regular farmers. The program is called " Panca Usaha Tani ", which encompasses five endeavors in agriculture : 1) the use of good seed, 2) better soil tillage, 3) fertilization, 4) pest and disease control, and 5) correct adjustment of planting time in relation to rainfall.

However, the application of fertilizers in tumpangsari might need to be followed by some adjustments in the initial spacing. It was observed by Soekotjo (1975) that fertilization not only increased agricultural crop production but also stimulated the growth of teak so that canopy closured occurred earlier. This condition is disadvantageous farmers, since it means they will have to leave their land parcels sooner. The actions leading to spacing adjustment taken by the Perum Perhutani are still in the its experimental stage, but changing the initial spacing from the 3 x 1 m standard to 6 x 1 m is being considered.

3. MATERIAL AND METHODS

3.1 Area description

The study has been conducted on compartment 17 of the Wanagama-I Forest Research Area of the Gadjah Mada University, Yogyakarta, Indonesia. The area is situated about 36 km south of Yogyakarta at 200 m above sea level. Geographically, this area lies between longitude 110° 31′ 01″ to 110° 31′41″ East, and latitude 7° 31′19″ to 7° 54′ 46″ South (Figure 3.1).

Wanagama-I has an annual rainfall of 2,147 mm, an average daily temperature of 25.1° C and a relative humidity of 85%-90% during rainy seasons and 70%-80% during dry seasons.

The months from April to October are generally drier than the rest of the year. Months with less than 60 mm rainfall are categorized as dry, while those with more than 100 mm rainfall are classified as wet. The annual averaged number of drier months of 4.4 combined with the annual averaged number of the wet months of 7.0, placing this area into the C climate type category of Schmidt & Ferguson, which is equivalent to the Ama category of the Koppen's climatic classification system (Sukanto, 1969). A histogram of monthly rainfall during the 16 months of plantation is displayed in Figure 3.2.

The experimental site has a gentle topography with 1-2 % slope A soil profile adjacent to the experimental site showed the following characteristics :

1. horizon 1-3 cm deep: litter and humus (Ao)
2. horizon 3-18 cm deep of (5YR3/3) color, moderate to low organic matter and well rooted, has a clay loam texture, granular structure and firm consistence (A)
3. horizon 18-130 cm deep, lighter in color (5YR4/6), clay loam texture with sub angular blocky structure and firm consistence. Plithite concretions are found in the upper part of this horizon (B).

The described characteristics and the presence of plinthite concretions put the soil into an oxisol type of the USDA soil classification system (1975). In the older clasification, the soil of this area was classified as a lateritic and latosols complex. The soil of the surrounding area might be a transition between soils of the Baturagung soil zone and soils of the Central zone, as described by Khan (1964) and Darmokusumo (1986).

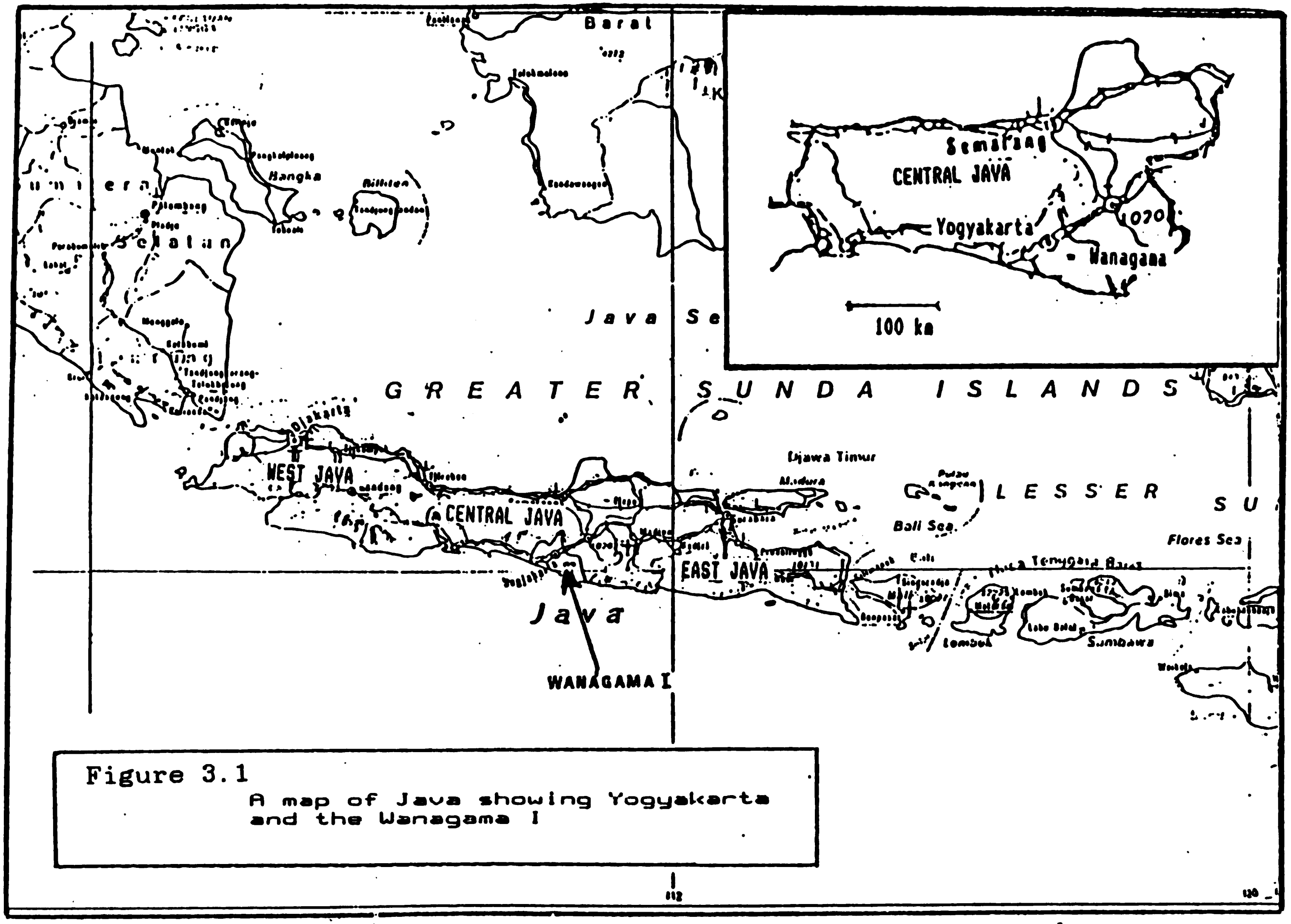


Figure 3.1
A map of Java showing Yogyakarta and the Wanagama I

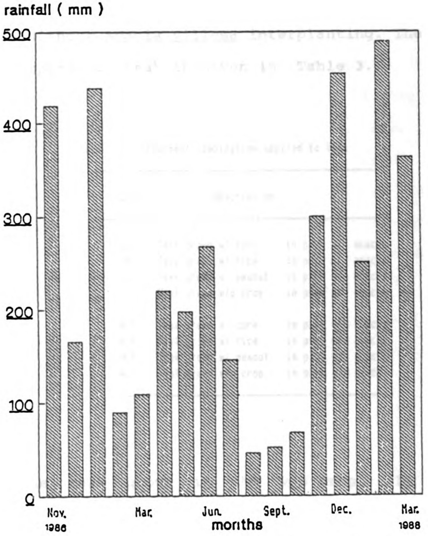


Figure 3.2
Monthly rainfall of the Wanagama I
during Nov. 1986 to Mar. 1988

3.2 Plantation establishment

In this study teak was grown following the practice of tumpangsari, in combination with crops either with or without Acacia villosa interplanting. The treatment scheme applied to teak is given in Table 3.1.

Table 3.1 Treatment combination applied to teak

Code	Description	
LC	Teak grown w/ corn	in plot w/ acacia
LR	Teak grown w/ rice	in plot w/ acacia
LP	Teak grown w/ peanut	in plot w/ acacia
LT	Teak grown w/o crop	in plot w/ acacia
NLC	Teak grown w/ corn	in plot w/o acacia
NLR	Teak grown w/ rice	in plot w/o acacia
NLP	Teak grown w/ peanut	in plot w/o acacia
NLT	Teak grown w/o crop	in plot w/o acacia

The teak grown in the w/o crop, LT and NLT treatments, was actually exposed to weed interference. Under the tumpangsari system competition continually controlled by farmers as they weed their agricultural crops. In a non tumpangsari plantation, weeding is carried out by paid workers who clean about 25 cm of the ground surrounding a tree (patch weeding). This practice was used in this experiment.

The experimental plots were established on freshly cut forest land area formerly covered by a kayuput oil (Melaleuca leucadendron) stand. The plots were arranged within three blocks using a split plot design. The acacia, factor A, was assigned at random to the whole plots within each block; the crops, factor B, were assigned at random to the subplots within each main plot. The whole experimental area was separated from the adjacent stands by a 8 to 10 m wide buffer zone of land covered by a mixture cropping of rice, peanut, corn, cassava (Manihot esculenta), and gajahan grass (Setaria spp). The closest forest tree plantation outside the buffer is a provenance trial stand of Eucalyptus urophylla established in 1983 (Figure 3.3).

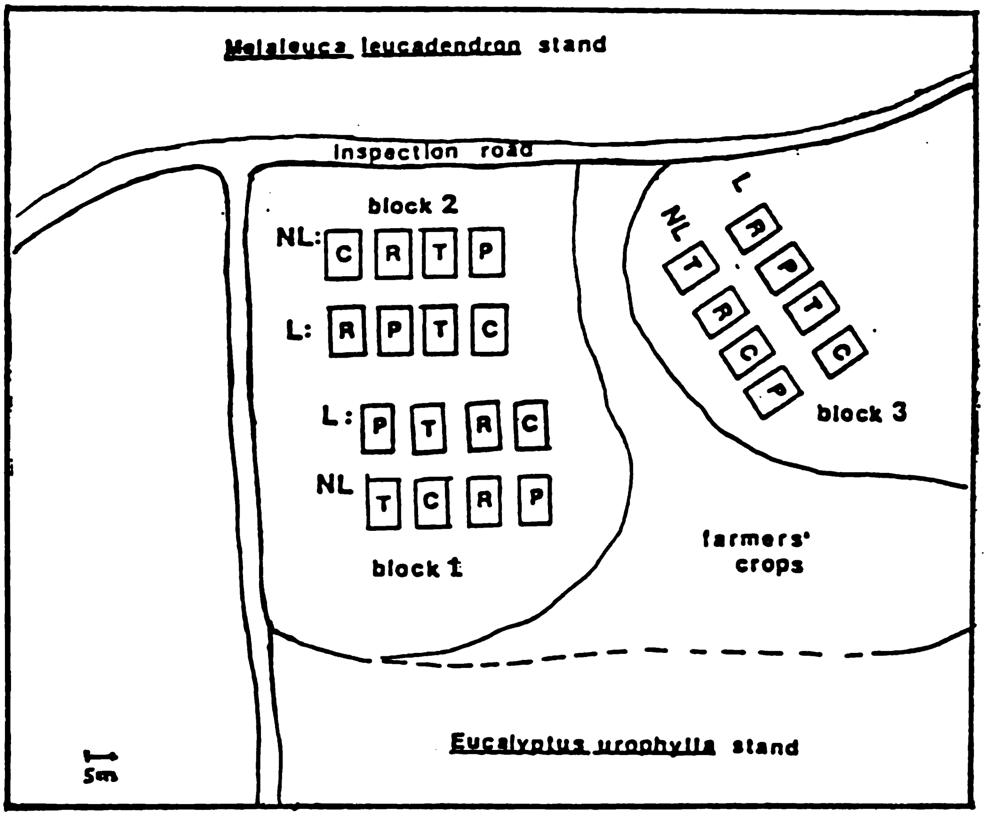
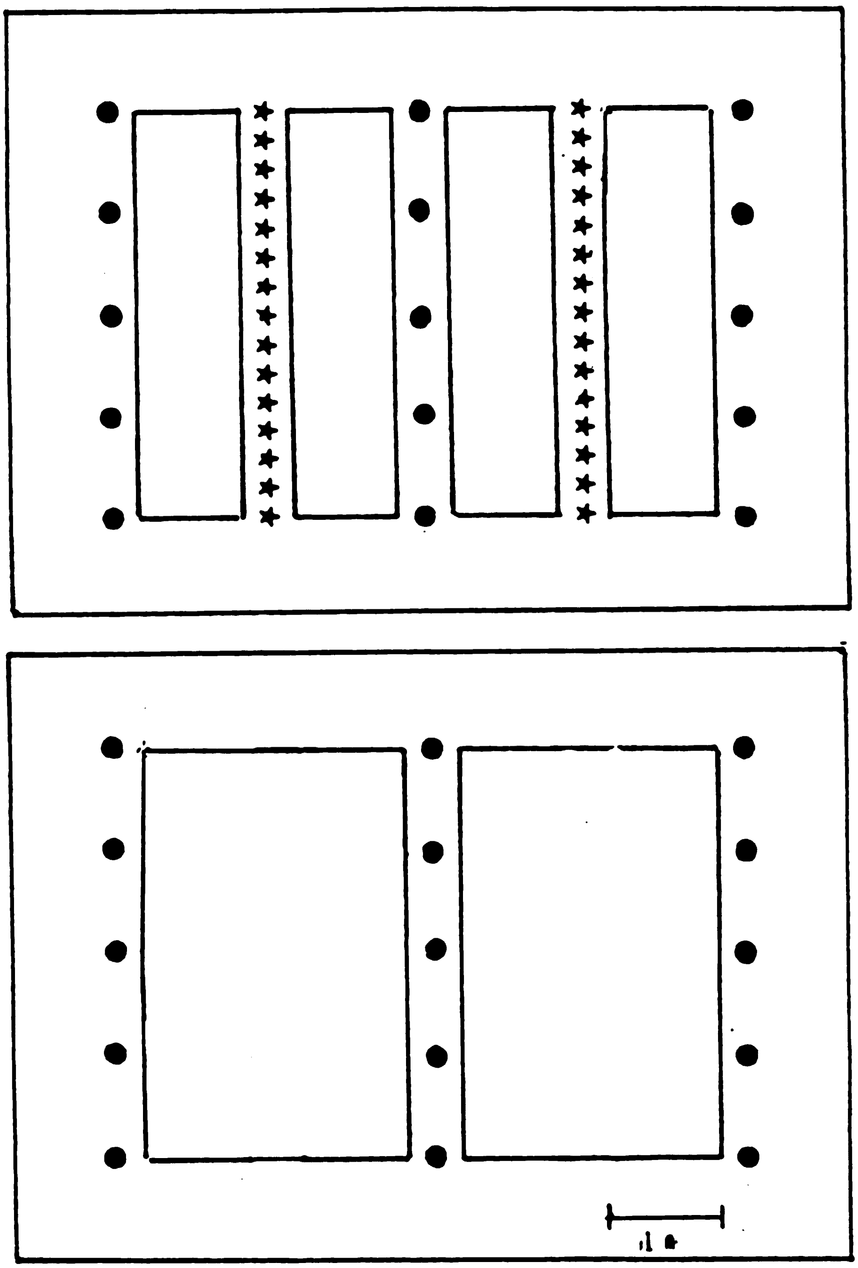


Figure 3.3
Field layout of the experimental plot

L = Plot w/ acacia NL = Plot w/o acacia
C = Teak w/ corn R = Teak w/ rice
P = Teak w/ peanut T = Teak w/o crop

Plant materials used in this experiment were obtained from the following sources : teak fruits from a single stand in the Randublatung Teak Seed Production Area ; Acacia villosa seeds from the Wanagama-I; and agricultural seeds from the Patuk Agricultural Extension Center, a local seed distributor.

Upon receipt, teak fruits were separated into size classes. Only fruits with diameter more than 14 mm were used in this study. The selected fruits were then planted in each of the 24 8 x 6 m plots, at 3 x 1 m spacing. Interplanting a row of brushy legume between two rows of teak for erosion protection, soil improvement, and fuelwood is a common practice in tumpangsari. In this experiment, Acacia villosa was selected simply because it is a common species being used in forestry in this area. It is a legume originated in the islands of Curacao, Aruba and Bonaire in West India and was introduced to Bunder, Yogyakarta in 1920, to replace Leucaena glauca, another legume Acacia villosa is superior to Leucaena glauca because of its better adaptation to drier regions, slower growth, and because it gives no shade to teak. Using this species also reduces pruning frequencies to the minimum (Verluys, 1922). Acacia villosa, hence-forward will be called acacia, was planted in half of the 24 plots in a continuous row. The acacia row was laid out in the middle between two rows of teak. Crops, i.e upland rice (Oriza *sativa*), corn (*Zea mays*), and peanut (*Arachis hypogea*) were planted within the designated area which was separated by 0.25 m from the teak or acacia rows. As many as three fruits of teak were planted around each spot, but after germination they were reduced to only one seedling per spot. Acacia seeds were sowed in a continuous row about 15 $g.m^{-1}$. Peanut and rice seeds were planted at 25 x 25 cm spacing, two and four seeds per spot, respectively. Corn was planted three to four seeds in each spot at 50 x 50 cm spacing, then reduced to only two plants in each spot. In each plot there were 20 rows of rice or peanut or 12 rows of corn. The arrangement of plant components in a plot is displayed in Figure 3.4.



A

B

Figure 3.4 Plants arrangement in the plots

A = A plot with interplanted acacia
B = A plot w/o interplanted acacia
● = Teak
✱ = acacia
□ = area designated for crops

3.3 Parameters measured

During the first four months, i.e. the first cropping season, growth of teak, yield of crop, acacia biomass, soil root occupancy, and soil fertility changes were monitored. At 16 months after planting, measurements of the growth parameters of teak (except biomass) and yield of crops were again taken. Neither watering nor fertilization was applied during the experiment; however, weeding within the teak-crop plots was applied manually, simulating one of the farmer's important obligations in tumpangsari. Figure 3.5 shows how sampling points were distributed within a plot.

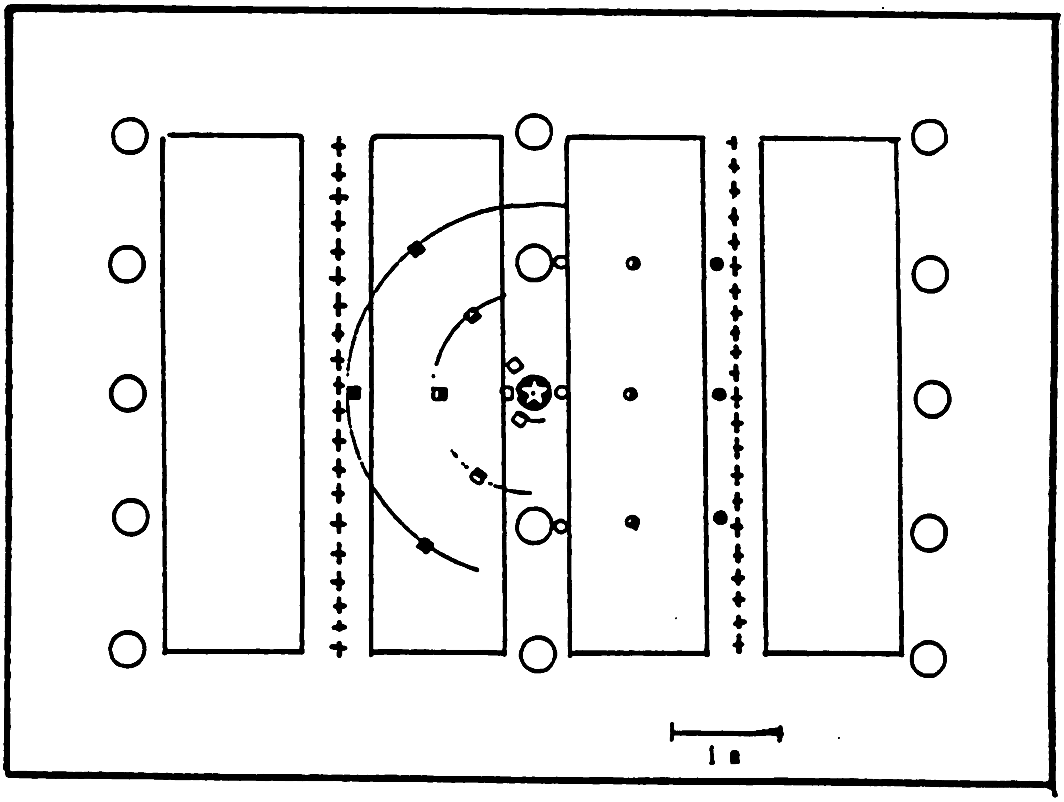


Figure 3.5 Sampling points in a plot

= sample tree
= soil fertility sampling points
= root occupancy sampling points
= teak + = acacia = crop

3.3.1. Teak growth parameters

Measurements were carried out on a sample tree in each plot which was randomly selected among three teak seedlings located in the middle of the center row. Stem height and diameter were measured bi-weekly until the crop harvest time, and at 16 months after planting. Leaf surface area was measured at the end of the first crop growing season and also at 16 months after planting. Height was measured from the soil surface to the end of an unopened young leaf using a ruler. Stem diameter was measured at the soil surface using a caliper.

Leaf surface area was measured by removing leaves from each tree, photocopying them, and measuring the images with a leaf area meter. Leaf surface area of the 16 month-old-teak was determined indirectly using a linear regression equation:

$$Y = -34.90 + 0.898X \qquad r= 0.965$$

where Y= leaf area (in sq. cm) and X= length times width. (in sq. cm). Leaf length was measured along the midrib, while width was measured perpendicular to the midrib between two points projected at the widest margin of the blade. The equation was calculated using data obtained from measuring 100 leaves obtained from an older stand of teak. Leaf blades were photocopied and then areas determined as above. If leaves were too large, they were cut into smaller portions. A linear regression analysis was selected to fit leaf area as a function of length times width because a linear regression model is simpler and adequately fit the need. Wargo (1978), working with leaves of black oak, white oak and sugar maple, and Manivel and Weaver (1974) working with "grenache" grape leaves, successfully used a linear model to predict leaf area.

Biomass measurement was accomplished by removing the whole plants from the soil. The soil around the stem of each plant was saturated with water so that the roots were easier to pull from the soil. Leaves were removed, stems were cut at the soil surface, and roots were separated from the soil by manually washing them with flowing water. All the plant parts were then oven dried at 75^{o}C for four days, and then weighed.

3.3.2 Crop parameters

Three 1 x 1 m.sq. plots were randomly established within each experimental plot. The crops were harvested from each plot and sundried for a week following the local practice. The dried unhusked rice, grained maize and peanut seeds then were weighed. The moisture content of seeds was measured using a seedbury digital moisture meter. These values of seed moisture content represented the " moisture content at harvest time " for further yield calculation. The yield of crop per hectare was calculated following a formula of Zandstra <u>et al</u> (1981),

$$\text{yield (kg/ha)} = \frac{\text{yield/plot (g)}}{100\ g} \quad \frac{10{,}000\ m^2}{\text{plot area}} \quad \frac{100\text{-MC}}{\text{MCS}}$$

where MC = moisture content at harvest time ;

MCS = standard moisture content i.e. 85%, 85%, and 88% for rice, maize and peanut respectively.

The influence of neighboring plant on crop yield was observed by measuring the yield in three positions, i.e. next to the teak row, next to the acacia row, and within the crop rows.

Crop residues were harvested from each plot. The " crop residue " of the pure teak plots was represented by the above ground part of the existing weeds. The residues were expressed in g fresh weight.

3.3.5 Acacia biomass

The biomass of acacia was measured by sampling the row of acacia within each plot. The sampling unit was 25 cm in length. Within each row of acacia, three sample units were randomly determined, then the acacia was harvested after the soil was soaked with water, separated into stem, leaf and root components, oven dried, and weighed.

3.3.4 Root occupancy

Root occupancy was measured in terms of g dry weight per sq.cm of soil. This was done by taking the soil from two depth levels, 0-15 cm and 15-30 cm, at three different distances, i.e 12.5 cm, 62.5 cm and 112.5 cm away from the teak (Figure 3.5). At each distance three sampling spots were randomly placed along a circumference with the corresponding distance as its radius, soils were sampled using a probe 2.5 cm in diameter and composited to represent the particular distance.

Soil was separated from roots by placing them into a fine sieve and manually shaking the sieve under running water. The roots were then ovendried and weighed.

3.3.3. Soil fertility measurement.

Changes in soil fertility were measured at two depth levels (0-15 cm and 15-30 cm) by comparing the nutrient contents before and after crop harvest. Soil was observed on the whole plot basis and on the basis of soil position relative to the covering vegetation. While the " on the whole plot basis " soil measurement embraced all of the 24 plots, the "position basis" soil measurement was limited only to plots containing acacia.

Relative to the vegetation cover, soil was further grouped into three categories, i.e soil of the teak-crop interface, soil of the crop-acacia interface, and soil of the crop-crop interface. For each of the soil positions mentioned, a representative sample was obtained by compositing soils taken from three randomly chosen spots (Figure 3.5).

The soil sample of each whole plot was a composite of soils taken from six to nine spots depending on whether the plot contained acacia. The spot locations were randomly selected throughout the plot by considering the position of soil relative to its vegetation covers.

Soils were analyzed for total N and total P using the semi-micro Kjehldal technique; the exchangeable K, Ca, Mg, and Na by extraction with 1 N $NH_4O\ A_c$ using absorption photometry (Heald, 1965); pH using a glass electrode assembly, and organic carbon according to the Walkey-Black (Potassium dichromate) method.

3.4 Statistical analysis.

The statistical analysis of the main data was carried out by the following analysis of variance (Little and Hills, 1978):

Number of blocks : B = 3

Factor treatments:

Main factors : L = Acacia (2 levels)

sub factors : C = Crops (4 levels)

Table 3.2 An analysis of variance table of a split plot design.

Source of variation	Degrees of freedom
Main plot	
Total	LB-1
Blocks	B-1
Acacia	L-1
Error(a)	(B-1)(L-1)
Sub Plots	
Total	LCB-1
Crops	C-1
Acacia x Crops	(L-1)(C-1)
Error (b)	(B-1)(C-1)+(B-1)(L-1)(C-1)

The root occupancy data was analyzed following the split-split plot analysis, where crop was the main treatment, distance the sub-plot, and depth as the sub- sub plot. The soil data, either from the whole plot basis or from the position basis, was analyzed following the split split plot design with main factor, sub and sub-sub factors given in Table 3.3. All data were analyzed using the MSTAT statistical program, and the means comparison using the Duncan Multiple Range (D), which was calculated as D = R(LSD) where R is a tabular value for degrees of freedom for error, level of significance, and distance of two means in an array of treatment means (Little and Hills, 1978). LSD is the least significant difference. In tables showing comparison of means, only the LSD values, are to be attached.

Table 3.3 Treatment factors observed in the soil data analysis.

	whole plot basis	Soil position basis
Main factor	time	time
Sub factor	depth	depth
Sub-sub factor	acacia	distance
Sub-sub-sub factor	crop	crop

Table 3.4 presents the kind of data collected and the way they were analyzed.

Tabel 3.4. Type of data, factors observed and statistical procedures

Type of data	No. plots With acacia	No. plots Without acacia	No. of samples	Factors observed	Statistical procedures
Teak parameters (height, dia., biomass, leaf area)	12	12	24	- acacia - crops	Split plot
Crop yield					
-Plot basis	3	3	6	- acacia	RCBD *
-Row basis	3	-	9	- row position	RCBD *
Crop residues (including weeds	3	3	3	-	-
Acacia	12	-	12	- crops	RCBD *
Root occupancy	12	-	72	- distance from teak - soil depths - crops	Split-split plot
Soil parameters					
- Plot basis	12	12	96	- time - depth - acacia - crops	Split-split-split plot
- Distance from teak basis	12	-	144	- time - depth - distance - crops	Split-split-split-plot

*= Randomized Complete Block Design.

4. RESULTS

4. 1 Effect of tumpangsari on teak.

The effects of tumpangsari on teak growth and development were examined during its first four-month period of growth (during the first agricultural cropping season) and during its 12-16 month period of growth (during the second agricultural cropping season).

At the end of first agricultural cropping season, the height of teak seedlings ranged from 6.3 cm to 11.5 cm., while at 16 months after planting it ranged from 32.6 cm. to 199.6 cm (Table 4.1).

Table 4.1 Height, diameter and leaf area of teak grown with and without various crops measured four and 16 months after planting.

	at 4 months			at 16 months		
	ht. (cm)	dia. (mm)	leaf area (sq.cm)	ht. (cm)	dia. (mm)	leaf area (sq.cm)
			With acacia interplant			
Teak w/ corn	7.6	3.6	154	76.4	26.8	12,681
Teak w/ rice	11.5	6.1	619	199.9	50.9	13,995
Teak w/ peanut	8.2	4.6	398	163.5	49.4	18,629
Teak w/o crop	7.6	4.4	273	32.6	16.1	2,809
			Without acacia interplant			
Teak w/ corn	6.5	4.1	269	69.7	22.7	7,604
Teak w/ rice	10.7	5.5	562	89.5	26.0	8,098
Teak w/ peanut	11.0	5.4	416	141.6	43.7	12,504
Teak w/o crop	6.3	4.1	282	38.2	15.7	3,181

Each of the teak parameters mentioned in Table 4.1 was signficantly affected only by the types of crop. The acacia factor and its interaction with crop had no significant influence. (Table 4.2).

Table 4.2 F values and their associated probability values (P) of intercropping variables influencing height (Ht.), diameter (Dia.) and leaf area of teak four and 16 months after planting.

Source of variation	DF	at 4 months						at 16 months					
		Ht.		Dia.		Leaf area		Ht.		Dia.		Leaf area	
		F	P	F	P	F	P	F	P	F	P	F	P
Acacia (a)	1	0.01	-- (ns)	2.48	- (ns)	0.34	- (ns)	0.63	- (ns)	0.47	- (ns)	5.44	.144 (ns)
Crops (b)	3	3.96	.035 (*)	8.03	.003 (**)	3.28	.058 (*)	8.70	.002 (**)	6.49	.007 (**)	4.26	.028 (*)
Ac. x cro.	3	0.88	-- (ns)	1.06	- (ns)	0.25	- (ns)	1.87	- (ns)	0.99	- (ns)	0.37	- (ns)

4.1.1. Height of teak 4 months after planting.

Teak in association with rice (TR) grew better in height than when grown alone (T) or with peanut (TP) or corn (TC). The average height of teak under TR conditions was about 1.6, 1.7, and 1.2 times taller than under T, TC, and TP conditions, respectively.

Biweekly observations on the growth of teak during its first 4-month period are presented in Figure 4.1. Up to six weeks after planting, teak showed no difference in its height regardless the kind of crop it was associated with. However beginning at week six, teak grown under TR and TP conditions grew faster than when grown under TC and T conditions. The slope of the height-growth line of teak under TC visibly declined after six weeks which was about the time corn entered its reproductive stage. Similar phenomena were shown by teak grown under TP conditions; a flatter slope of the height-growth line occurred after week eight, i.e. about a week after peanuts entered their flowering stage. Teak grown under TR condition showed no apparent reduction of height growth related to the stages of growth of rice. Teak grown under T condition were generally shorter, at any point of time, than when grown in association with crops.

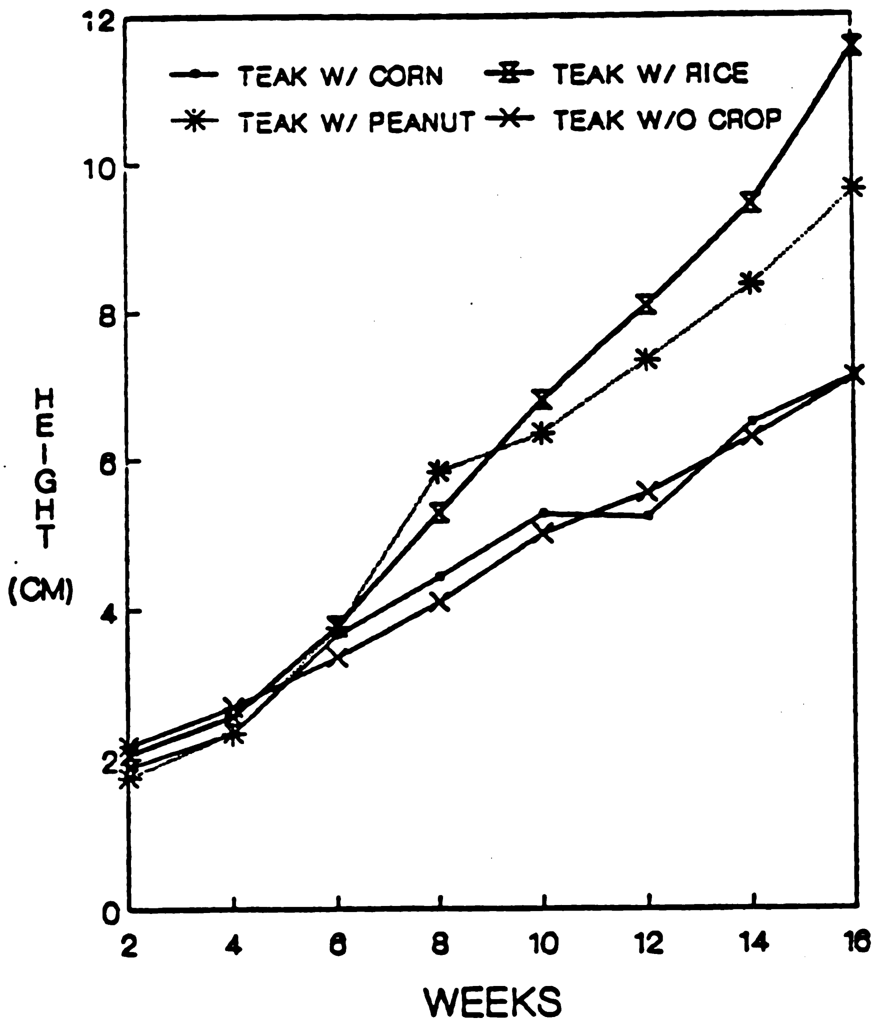


Figure 4.1
Height growth curve of teak in association with crops during the first four months of plantation

A comparison of average heights of teak as it was influenced by crops is presented in Table 4.3 and Figure 4.2. Teak grown with rice was significantly taller than when grown with corn or without a crop but not when grown with peanut. In terms of teak growth, rice and peanut are the preffered first rotation companion crops.

Table 4.3 Comparison of mean values of height, diameter and leaf area of teak grown with and without crop four and 16 months after planting. Means followed by the same letter are not significantly different.

	parameters observed		
Cropping combination	Height (cm)	Diameter (mm)	Leaf area (sq. cm)
	four months		
Teak w/ corn	7.10 a	3.87 a	211.680 a
Teak w/ rice	11.15 b	5.82 c	590.954 c
Teak w/ peanut	9.63 ab	5.07 bc	407.348 abc
Teak w/o crop	7.10 a	4.28 ab	278.080 ab
LSD .05 =	3.13	0.93	284.467
	16 months		
Teak w/ corn	73.05 a	24.88 ab	10,143.36 ab
Teak w/ rice	144.77 b	38.33 bc	11,046.82 b
Teak w/ peanut	152.57 b	46.40 c	15,567.22 b
Teak w/o crop	35.46 a	15.78 a	2,995.48 a
LSD .05 =	59.24	16.59	7,767.86

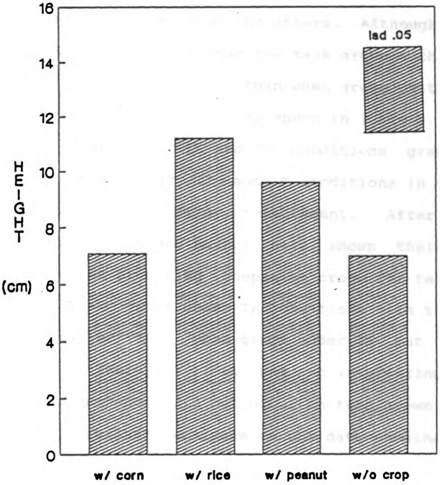


Figure 4.2
Height of teak in association with crops four months after planting

4.1.2 Height of teak 16 months after planting.

Measured at 16 months after planting the height of teak ranged from 32.6 cm under T condition to 199.6 cm under TP condition (Table 4.1). Teak grown with peanut (TP) grew taller than the others. Although it was not significantly taller than the teak grown with rice (TR), but significantly taller than when grown with corn (TC) or without a crop (T) as shown in Table 4.3 and Figure 4.3. Teak under TR and TP conditions grew faster in height than under TC and T conditions in the last 12 months after the first measurement. After two cropping seasons, rice and peanut have shown their consistent position as promising companion crops for teak.

Teak grown under TR conditions with the acacia was much taller than when grown under TR but without the acacia (Table 4.1). It was an interesting case since this phenomenon did not occur on teak grown with other crops. Further analysis on the data obtained from the teak-rice (TR) combination were conducted. By assuming that the TR was subjected to acacia treatment with three replications, it was found that the acacia effect was significant on height (Table 4.4).

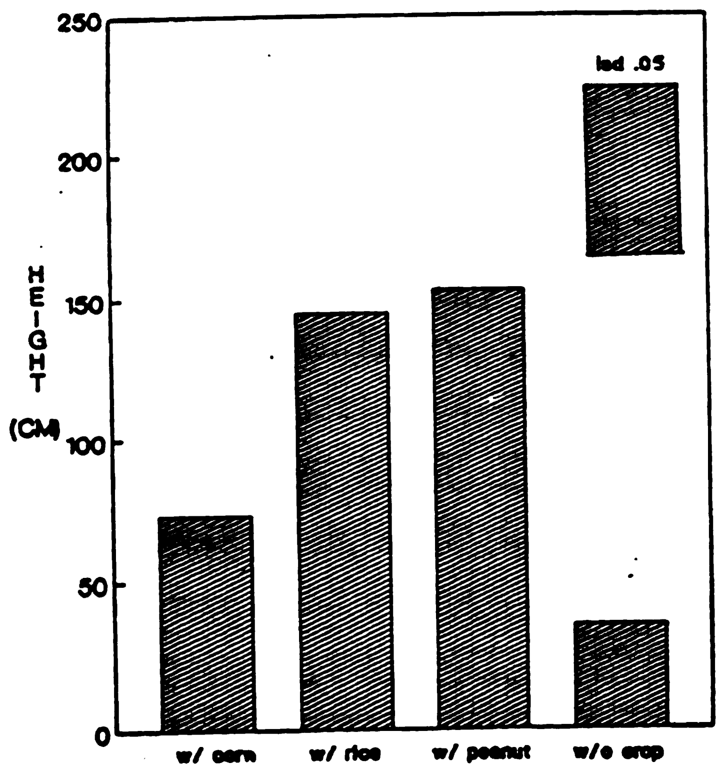


Figure 4.3
Height of teak in association with crops 16 months after planting.

Table 4.4 F values and associated probabilities (P) for the acacia factor as it influenced height, diameter and leaf area of teak grown with rice measured at 16 months after planting.

Factor observed	Parameters measured					
	Height		Diameter		Leaf area	
	F	P	F	P	F	P
Acacia	38.51	0.024 (*)	9.00	0.095 (ns)	6.57	0.124 (ns)

4.1.3 Diameter of teak 4 months after planting.

Diameter growth of teak showed similar trends to that of height. Teak grown in association with rice (TR) grew more in diameter than that in association with corn (TC), peanut (TP), or without a crop (T). The mean diameter at the end of the first crop growing season ranged from 3.6 mm under TC to 6.1 mm under TR (Table 4.1).

Without a crop association (T), which is actually under weed competition, teak continuously grew slower than with crops. The rates of diameter growth of teak under TP and TR conditions were about equal up to week 10. However, in the later stages teak under TR grew faster than that under TP. Teak grown under TC showed a declining diameter growth rate after week eight, which was commensurate with the time of corn flowering (Figure 4.4). Similarly to the case of height growth, the acacia factor had no significant effect on diameter growth of teak (P= .255) whereas the crop factor did have a significant effect (P= 003) (Table 4.2). Further analyses of the effect of crops on diameter growth of teak showed that diameter of teak grown under TR was significantly greater than that of teak grown with other companions except peanut (Table 4.3). The effect of crops on the diameter of teak four months after planting is displayed in Figure 4.5.

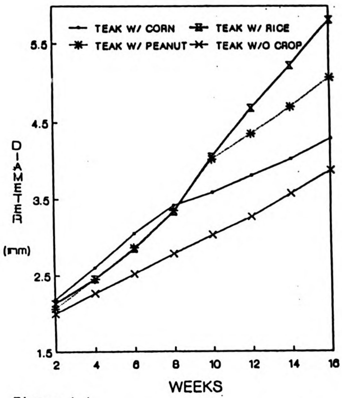


Figure 4.4
Diameter growth curve of teak in association with crops during the first four months of the plantation

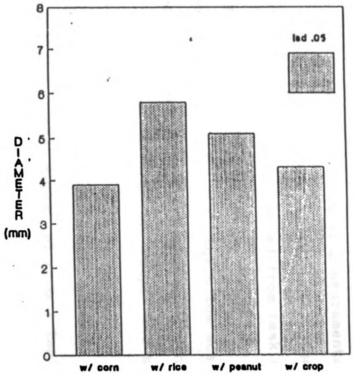


Figure 4.5
Diameter of teak in association with crops four months after planting

4.1.4 Diameter of teak 16 months after planting

The results of diameter measurements at 16 months after planting are shown in Table 4.1. The largest diameter (50.9 mm) was observed from teak grown in plots with acacia under TR condition, while the lowest was found in teak without crops (T). Again the acacia had no significant influence on the diameter growth of teak (Table 4.2), but the effect of crops was significant (P= 0.007).

Further comparison among diameter means of teak as influenced by the types of crop (Table 4.3 and Figure 4.6) indicates that teak grown with peanut (TP) performed best, i.e. peanut was the best companion crop for teak. By contrast, corn was found to be comparable to weeds (T).

Among teak plants under TR condition diameter was much bigger in plots containing acacia than in plots without acacia. However, unlike the case with height, a statistical analyses of this phenomenon (Table 4.4), indicated that the acacia had no significant effect (P = 0.095) on the diameter growth of teak.

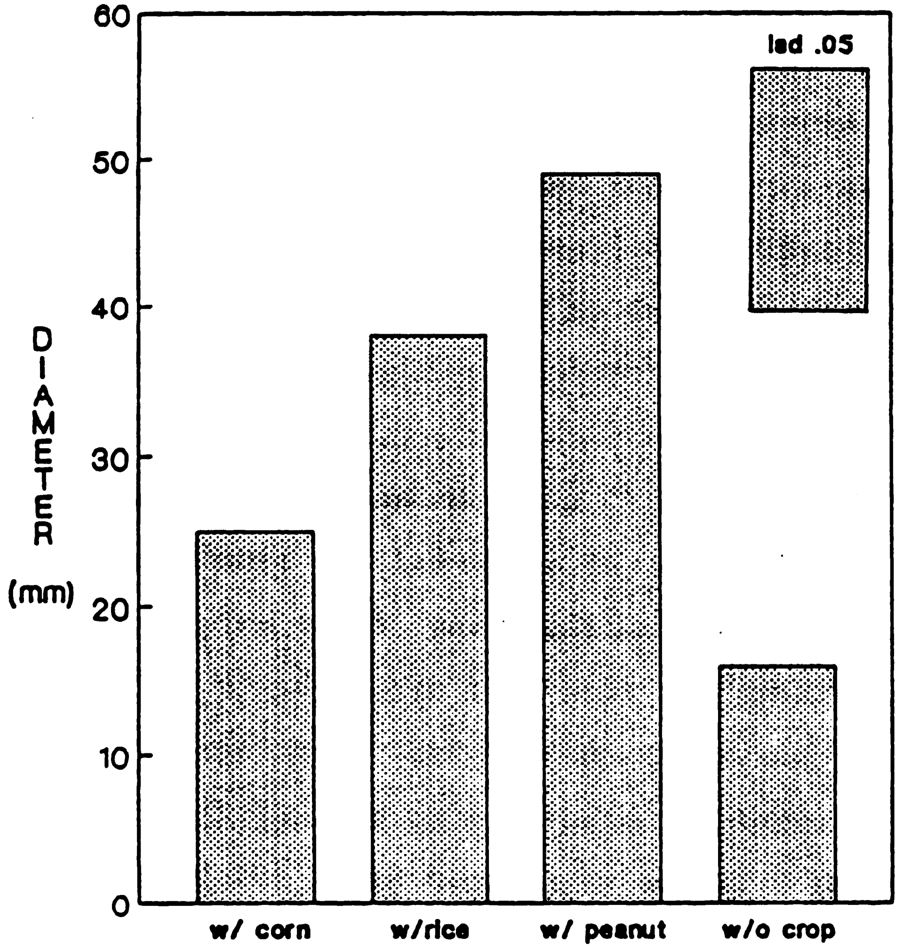


Figure 4.6
Diameter of teak in association with crops 16 months after planting

4.1.5 Leaf area of teak 4 months after planting

The average number of leaves per teak seedling at four months was nine to 11. Leaf area ranged from 154 sq.cm under TC with acacia, to 619 sq.cm under TR also in a plot with acacia (Table 4.1). As was the case with height or diameter, crops were found to be the only factor which significantly influenced the leaf area of teak (P= 0.058, Table 4.2). Figure 4.7 displays how the leaf area of teak was influenced by the kind of crops four months after planting.

4.1.6 Leaf area of teak 16 months after planting

The number of leaves at 16 months after planting ranged from nine to 15 per seedling, with leaf area about 10 to 80 times larger than what was measured at four months. The smallest leaf area was measured in teak grown alone (T) (2809 sq.cm), while the largest was with rice (TR) within plots containing acacia (18,629 sq.cm) (Table 4.1). The acacia factor was not significant (P=0.144), only the crop factor showed a significant effect on leaf area growth (P=0.028) (Table 4.2). A comparison of leaf area of teak as it was influenced by crops at 16 months is displayed in Figure 4.8. Teak under TP had the largest leaf area followed by teak grown under TR , although the difference between them was not significant (Table 4.3).

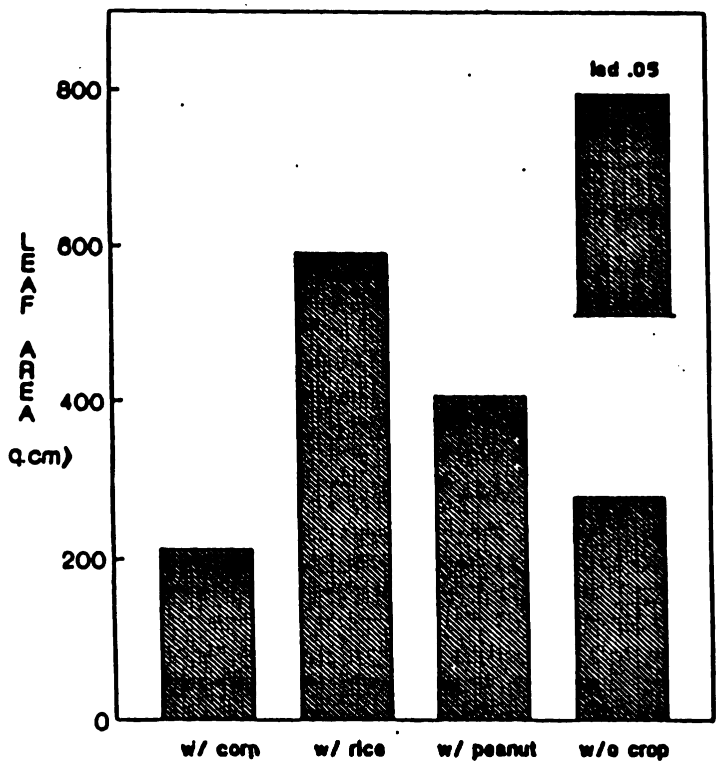


Figure 4.7
Leaf area of teak in association with crops four months after planting

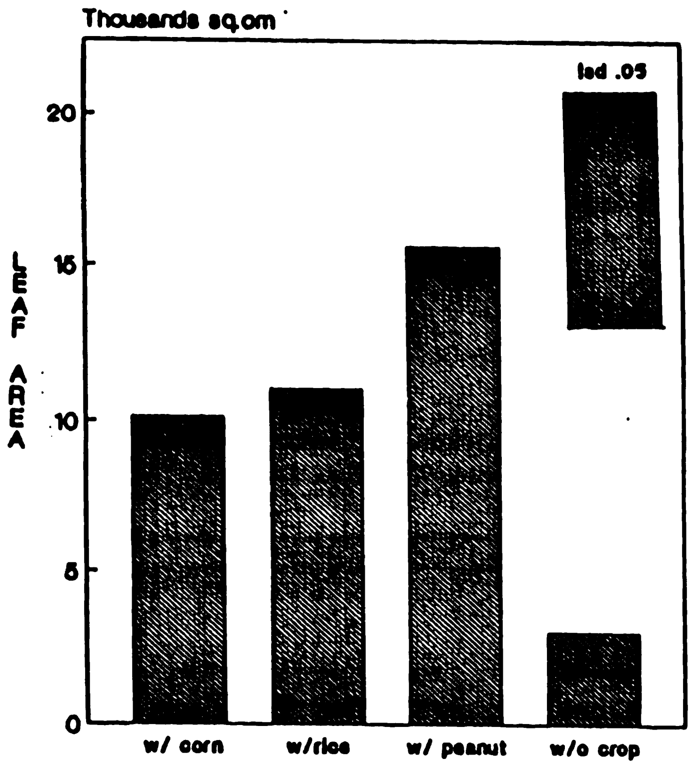


Figure 4.8
Leaf area of teak in association with crops 16 months after planting

4.1.7 Dry weight production.

The measurement of dry weight of teak was done four months after planting. Root dry weights ranged from 0.79 g, in teak grown with corn in plots w/ acacia to 3.57 g in teak grown with rice in plots without acacia. Stem dry weight ranged from 0.53 g in teak grown with corn without acacia to 1.21 g in teak grown with rice also in plots without acacia. Leaf dry weight ranged from 1.94 g in teak without a crop association nor acacia to 5.36 g in teak with rice but without acacia. The result of measurements is displayed in Table 4.5

Table 4.5 Biomass allocation of 4-month-old teak seedlings grown either alone or under tumpangsari.

Cropping combination	Oven-dry biomass (g)			
	Root	Stem	Leaf	Total
With acacia interplant				
Teak w/ corn	0.79	0.58	2.00	3.37
Teak w/ rice	3.41	1.19	4.92	9.52
Teak w/ peanut	1.99	1.85	3.62	7.46
Teak w/o crop	1.36	0.57	1.94	3.87
Without acacia interplant				
Teak w/ corn	0.97	0.53	2.51	4.01
Teak w/ rice	3.57	1.21	5.36	10.14
Teak w/ peanut	2.14	1.04	4.09	7.27
Teak w/o crop	1.07	0.55	2.51	4.13

Similar to its effect on diameter, height, and leaf area, the acacia did not significantly affect biomass of teak and only the crop factor had a significant effect on the biomass. (Table 4.6).

Comparison of mean values of biomass parameters as they were influenced by the type of crops is given in Table 4.7. While the allocation of biomass of teak seedling as it was influenced by crops four months after planting is presented in Figure 4.9.

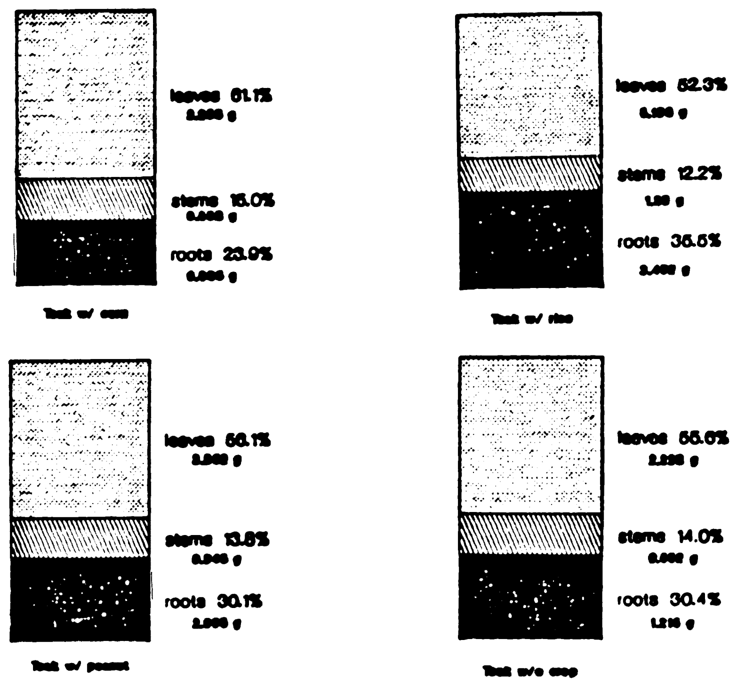


Figure 4.9
Biomass allocation of teak in association with crops four months after planting

Table 4.6 F - values and associated probabilities of variables as they influenced the biomass parameters of teak .

Source of variation	DF	Root F	Root P	Stems F	Stems P	Leaves F	Leaves P	Total biomass F	Total biomass P
Acacia (a)	1	0.17	ns	0.11	ns	1.485	ns	3.50	0.202 ns
Crops (b)	3	23.87	0.0 **	15.0	0.0 **	11.819	0.003 **	13.59	0.0 **
Leg.x Crops.	3	0.22	ns	0.46	ns	0.002	ns	0.02	ns

Table 4.7 Comparison of the mean values for root ,stem, leaf and total biomass parameters of teak at four months grown with crops (means followed by the same letter are not significantly different).

	biomass parameters (g dwt)			
	Root	Stem	Leaves	Total biomass
Teak w/ corn	0.89 a	0.55 a	2.26 a	3.67a
Teak w/ rice	3.49 c	1.20 c	5.14 b	9.83c
Teak w/ peanut	2.07 b	0.95 b	3.85ab	6.86b
Teak w/o crop	1.22 ab	0.56 a	2.22 a	4.41a
LSD .05	1.31	0.40	2.39	4.04

4.2 Effects on crops

4.2.1 Crop yields

The yields of crops were observed either on the whole plot basis or a row basis. While the first was intended to measure the crop yield per ha, the later was intended to determine if the yield of a crop in a row was influenced by its position, e.g. against teak, the acacia, or itself. Yields of crops per ha are shown in Table 4.8.

Table 4.8 Yield of crops obtained from a teak -tumpangsari plantation at first and second year of cropping

Cropping combination	Crop harvested	Yield (Kg ha^{-1}) first cropping	second cropping
	With acacia interplant		
Teak w/ corn	corn	1058.9	878.5
Teak w/ rice	rice	1032.3	976.3
Teak w/ peanut	peanut	679.5	755.6
Teak w/o crop	--	--	--
	Without acacia interplant		
Teak w/ corn	corn	712.9	758.8
Teak w/ rice	rice	1058.1	985.1
Teak w/ peanut	peanut	979.1	814.6
Teak w/o crop	--	--	--

Data were analyzed following a Randomized Complete Block Design (RCBD) procedure as if each crop was treated by planting it with and without acacia with three replications. The analysis showed that there was no significant effect of the acacia on the yield per ha of crops. (Table 4.9)

Table 4.9 F - values and the associated probabilities of the acacia as it influenced the yield of crops

Source of Variation	DF	crops: Rice F	P	Corn F	P	Peanut F	P
Acacia	1	1.47	0.349 (ns)	1.41	0.357 (ns)	0.51	--- (ns)

The non-significant effect of acacia on the yield of crops on a plot basis was was expected knowing the positions of the acacia rows; the 1 sq.m. subplot for harvesting crops, and the age of the plantation itself. However, without holding the level of alpha of 0.05 as the limit of significance, the results show that the effect of the acacia on peanut had much smaller influence on peanut yield compared to that on rice or corn. This could be intepreted as a sign of different degree of responsiveness between peanut on one hand and rice and corn on the other. The crop yield data that there was no significant difference between the yield of crop of the first year's of cropping season from that of the second year. (Table 4.10)

Table 4.10 F-ratio testing group variances (F) and the associated probabilities (P) of the crop yields.

Source of variation	crop yield of					
	Corn		Rice		Peanut	
	F	P	F	P	F	P
Year of harvest	1.18	0.429 (ns)	1.16	0.462 (ns)	1.13	0.34 (ns)

Observation on the yield of crop related to the row positions (Table 4.11) indicated that the position of the crop row had a significant influence on yield. For most crops, the closer the row to acacia the greater the yield, although the differences in yield between rows closer to the acacia and the two other positions were not always significant (Table 4.12). In general crops responded positively to the immediate presence of the acacia. However, there was no consistent pattern found in the yield of a crop with regard to its closeness to the acacia.

Table 4.11 F - values and associated probabilities of the row position factor as it influenced crop yields obtained from the tumpangsari plantation with acacia interplanted four months after planting

Source of Variation	DF	Rice F	Rice P	Corn F	Corn P	Peanut F	Peanut P
Row position	2	11.13	.023 (*)	6.43	.05 (*)	8.04	.039 (*)

In the cases of rice or peanut, the yield was significantly greater in the row close to acacia. However, this was not the case for corn. The greatest yield of corn was, in fact, obtained from the row adjacent to teak (Table 4.12).

The lowest yields of rice or peanut were measured in the row adjacent to teak, but in the case of corn the lowest yield was obtained from the within-crop row.

Table 4.12 Yield of crops on the row to row basis. The same letters following a mean indicates no significant difference.

Row of crop adjacent to	Yield (g m.row $^{-1}$) Rice	Peanut	Corn
Acacia row	24.61 a	16.36 a	38.09 a
Other crop row	22.13 ab	13.45 ab	32.91 b
Teak	18.88 b	10.97 b	43.00 ab
LSD .05	4.22	3.73	3.38

4.2.2 Crop residues and weeds

Most of the agricultural crop residues after harvest were taken and used for animal feed. The yield of residues measured at the first cropping season of this experiment ranged from 6.8 ton ha^{-1} of rice straw to 11.13 ton ha^{-1} of corn stalks Table 4.13)

Weeds occupied the empty area among teaks planted without crops. The average fresh weight of weeds measured from this system was about 4.6 ton ha^{-1}, consisting mainly of seven species listed in Table 4.14.

Table 4.13 Crop residue (fresh weight) from a teak tumpangsari plantation.

Cropping combination	residues	ton ha^{-1}
	With acacia interplant	
Teak w/ corn	corn stover	10.3
Teak w/ rice	rice straw	8.9
Teak w/ peanut	peanut stalk	7.5
Teak w/o crop	weeds	4.4
	Without acacia interplant	
Teak w/ corn	corn stover	11.1
Teak w/ rice	rice straw	7.2
Teak w/ peanut	peanut stalk	6.8
Teak w/o crop	weeds	4.7

Table 4.14 Main weeds found in the Teak - w/o crop plots and their percentage of total fresh weight

Weeds	% of total
Wedusan (Ageratum conyzoides)	6.45
Katemas (Boreria lanceolata)	42.13
Wedungan(Panicum maximum)	8.73
Kirinyu (Eupathorium pubescens)	2.91
Ilalang (Imperata cylindrica)	1.90
Rondomopol (Commelina sp.)	13.86
Ri rendet (Mimosa pudica)	1.70
Others	22.32

4.3 Acacia biomass

The acacia was planted in rows between two rows of teak. In plots where teak was associated with crops, acacia row laid between two rows of crop, while in plots where teak was grown without a crop, the acacia row was surrounded by weeds. The average diameter and height of the acacia were 8.5 mm and 54 cm, respectively. Total biomass of acacia per meter row as it was influenced by neighboring vegetation is shown in Table 4.15.

Table 4.15 Biomass of acacia as influenced by the neighboring vegetation

Neighboring vegetation	total biomas ($g.m^{-2}$)
Weeds	94.7
Rice	157.1
Corn	132.8
Peanut	152.9

The available data of acacia biomass were analyzed using the RCBD (Randomized Complete Block Design) procedure as if the acacia was treated with different sourrounding plants (rice, corn, peanut or weeds) The effects of surrounding plants on the biomass of the acacia was not significant. This is an important characteristic for a plant intended to be a nurse crop for other plants.

4.4 Root occupancy

Root occupancy of the plantation was observed on the basis of distances from the teak at two different depth levels. There were three different distances from teak observed ; i.e. A = 0 -12.50 cm, B = 12.50 - 62.50 cm, and C = 62.50 - 112.50 cm, which represent the soils between teak and crop, between crop rows(soil under the crop), and between crop and acacia, respectively.

Data analysis shown in Table 4.16 indicates that cropping combination, distance from teak and their interaction have a significant effect on soil root occupancy.

Table 4.16 Analysis of variance of root occupancy in the soil in respect to teak cropping combination, distance from teak, and soil depth.

Source of variance	DF	Sum of squares	Mean square	F	Prob
Replication	2	127.37	63.686	0.46	
Crops	3	2046.65	682.217	4.94	0.046 *
Error (a)	6	827.87	137.979		
Distances	2	534.40	267.302	4.39	0.030 *
Crops x Dist.	6	1370.24	217.874	3.58	0.019 *
Error (b)	16	973.26	60.829		
Depth	1	71.84	71.840	1.01	0.324 ns
Crops x Depth	3	638.91	179.637	2.52	0.081 ns
Dist. x Depth	2	260.11	130.057	1.83	0.182 ns
Crops x Dist.x Depth	6	818.75	136.458	1.92	0.118 ns
Error (c)	24	1707.49	71.145		

How roots of the teak- crop combinations occupied the soil in relation to the distance from the teak is presented in Table 4.17. In the case of teak alone, or with peanut, the difference of root occupancy of the soil between teak and crop and the soil under crop was not significant. For both cropping combinations the root occupancy of the soil laid between crop and acacia was significantly less extensive than the other two positions, whereas unnder the teak-rice or teak-corn conditions, the greatest root occupancy was under the crop itself. This fact may be explained by the fact that both corn and rice are are members of the grasses family, Graminea. Rice is characterized by a compact, fibrous rooting system tend to develop horizontally rather than vertically (Grist, 1986)

It was also reported by IRRI in 1979, that rice roots are relatively shallow, and in upland rice 40-60% of root weight found in the top 20 cm of soil (Norman et al, 1984). The soil root occupation of teak-rice cropping was the most extensive than the other teak-crop combination being studied and the difference was significant (Table 4.18).

Table 4.17 Means soil root occupancy of teak-crop combination at three different distances from teak. The same letter following a value indicates no significant difference.

Distances from teak (cm)	Cropping combination			
	Teak w/ rice	Teak w/corn	Teak w/ peanut	Teak w/o crop
	root occupancy ($g\ m^{-3}$)			
A (0-12.5)	23.8 a	17.4 a	25.8 a	28.1 a
B (12.5-62.5)	44.4 b	24.6 b	23.1 a	24.3 a
C (62.5-112.5)	34.5 c	19.6 a	17.3 b	20.6 b

LSD .05= 4.89

Table 4.18 Mean root occupancy of soil under teak- crop combinations. The same letter following a mean indicates no significant difference .

Cropping combination	root occupancy ($g.m^{-3}$)
Teak w/ rice	32.224 a
Teak w/ corn	20.532 b
Teak w/ peanut	22.064 b
Teak w/o crop	24.274 ab

LSD .05 = 9.58

4.5 Effects on soil fertility.

One of the study objectives is to determine the effect of tumpangsari on soil fertility as for many years it has been feared that cropping may induce negative effect on soil fertility especially in industrial forest plantation.

The chemical properties of the soil of the experimental site at the beginning of the study are shown in Table 4.19. The site which had previously been under a stand of Melaleuca leucadendron, was a rather good site with medium level of organic matter and nitrogen. The C/N ratio of nearly 12 indicates satisfactory mineralization (Young, 1976). Soil pH was within a desirable range (5.00-7.00) for both nutritional and biological aspects (Wilde 1958).

Table 4.19 Some characteristics of surface (0-15 cm), and subsurface (15-30 cm) soil at the initiation of the trial.

Soil properties	Depth of soil	
	surface (0-15 cm)	subsurface (15-30 cm)
Total N (ppm)	2076	1428
Total P (ppm)	544	431
pH	6.5	6.6
C - organic (%)	2.4	1.7
C/N ratio	11.6	11.9
K (ppm)	70	52
Ca (ppm)	3034	2788
Na (ppm)	66	75
Mg (ppm)	346	310

As it was explained earlier in chapter 3, the analysis of soil has been attempted on two basis, i.e in term of whole plot (plot basis) and in term of vegetation cover (distance from teak basis).

4.5.1 Effects on soil nitrogen and carbon

At the initiation of the trial the total nitrogen concentration of in the surface soil (0 - 15 cm depth) and subsurface soil (15 - 30 cm depth) ranged from 1961 to 2151 ppm, and 1794 to 2057 ppm. At the first crop harvest, the ranges were 1286 to 1615 ppm in the 0 - 15 cm depth, and 1553 to 1906 in the 15 - 30 cm depth (Table 4.20). The surface soil contained more nitrogen than the subsurface soil. Table 4.21 presents the F values of various factors influencing the chemical characteristics of the soil and interactions among them.

Table 4.20a Some chemical characteristics of surface (0-15 cm and 15-30 cm) soil under tumpangsari plantation before trial and at four months after planting (the first cropping season). A= before trial , B= 4 months after planting

Treatment	N (ppm)				P (ppm)				C (%)				pH			
	Depth of soil				Depth of soil				Depth of soil				Depth of soil			
Cropping	0-15 cm		15-30 cm		0-15 cm		15-30 cm		0-15 cm		15-30 cm		0-15 cm		15-30 cm	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
With acacia																
Teak w/ corn	2151	2057	1385	1906	483	544	367	521	2.7	2.5	1.6	2.0	6.6	6.8	6.8	6.7
Teak w/ rice	2101	1926	1615	1824	526	520	424	496	2.5	2.6	1.6	2.1	6.3	6.5	6.5	6.5
Teak w/ peanut	2091	1887	1437	1671	554	550	505	502	2.5	2.1	1.7	1.9	6.2	6.5	6.4	6.6
Teak w/o crop	2135	1802	1411	1553	521	431	405	435	1.9	2.1	1.7	1.8	6.4	6.6	6.5	6.6
Without acacia																
Teak w/ corn	2065	1794	1443	1607	514	449	409	394	2.5	2.3	1.7	1.8	6.3	6.6	6.5	6.6
Teak w/ rice	1961	1930	1286	1606	548	433	362	397	2.4	2.2	1.6	1.8	6.5	6.5	6.4	6.6
Teak w/ peanut	2081	1972	1533	1878	613	507	496	486	2.3	2.1	1.4	2.3	6.7	6.6	6.3	6.6
Teak w/o crop	2026	1824	1312	1648	609	445	482	448	2.2	2.1	1.9	2.1	6.8	6.4	6.8	6.5

Table 4.20b Extractable bases of surface (0-15 cm and 15-30 cm) soil under tumpangsari plantation before trial and at 4 months after planting (the first cropping season) A= before trial, B= 4 months after planting.

Treatment	K				Ca				Mg				Na			
	Depth of soil				Depth of soil				Depth of soil				Depth of soil			
Cropping	0-15 cm		15-30 cm		0-15 cm		15-30 cm		0-15 cm		15-30 cm		0-15 cm		15-30 cm	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
With acacia																
Teak w/ corn	104	64	53	53	2066	2500	1990	2453	326	317	296	297	77	43	84	65
Teak w/ rice	63	57	89	57	2963	2566	3030	2880	337	333	298	364	65	57	76	57
Teak w/ peanut	70	65	42	56	2975	2203	2966	2140	357	336	341	329	64	60	80	69
Teak w/o crop	72	63	50	41	3680	3373	2853	2536	342	340	274	281	56	61	59	58
Without acacia																
Teak w/ corn	48	62	46	52	3590	3073	2453	2960	348	362	279	352	65	62	66	76
Teak w/ rice	82	57	52	41	3216	2936	3333	3049	366	344	342	341	67	53	77	69
Teak w/ peanut	70	40	54	53	3263	2726	3180	3263	355	343	324	347	64	58	76	61
Teak w/o crop	72	42	37	43	2520	2063	2500	2680	337	326	328	330	69	75	87	75

Tabel 4.21   F values and associated probabilities of some variables influencing soil chemical characteristics

Source of variance	DF	N F	N P	P F	P P	pH F	pH P	C F	C P	K F	K P	Ca F	Ca P
Time (a)	1	3.10	0.220	0.14	-	1.26	0.377	1.88	0.304	0.30	-	0.69	-
Depth (b)	1	93.81	0.000	101.17	0.000	1.28	0.325	26.08	0.006	36.04	0.003	0.72	-
Time x depth	1	28.91	0.005	41.56	0.002	0.29	-	5.32	0.082	7.62	0.050	2.11	0.220
Acacia (c)	1	3.82	0.086	1.05	0.336	0.02	-	0.44	-	8.51	0.019	0.88	-
Time x acacia	1	-	-	13.19	0.006	1.22	0.301	0.07	-	0.27	-	0.02	-
Depth x acacia	1	0.00	-	0.82	-	0.41	-	0.21	-	0.64	-	Q.15	-
Time x depth x acacia	1	0.07	-	0.50	-	1.00	-	0.09	-	0.08	-	0.28	-
Crops (d)	3	1.64	0.193	11.09	0.000	2.52	0.069	0.73	-	1.14	0.340	0.66	-
Time x crop	3	0.39	-	4.93	0.004	1.65	0.191	0.21	-	0.10	-	0.69	-
Depth x crop	3	0.29	-	0.52	-	0.16	-	2.24	-	0.13	-	0.46	-
Time x depth x crop	3	0.24	-	0.93	-	0.51	-	0.95	-	0.18	-	0.05	-
Acacia x crop	3	2.91	0.044	5.97	0.001	2.23	0.096	0.92	-	1.23	0.309	2.92	0.043
Time x acacia x crop	3	1.94	0.135	1.25	0.301	3.04	0.038	0.93	-	2.02	0.123	0.33	-
Depth x acacia x crop	3	0.96	-	0.25	-	1.36	0.265	0.01	-	0.32	-	0.93	-
Time x depth x acacia x crop	3	0.13	-	0.70	-	0.43	-	0.41	-	0.09	-	0.13	-

Tabel 4.21 (continued)

Source of variance	DF	Mg F	Mg P	Na F	Na P
Time (a)	1	0.88	-	27.13	0.034
Depth (b)	1	51.77	0.001	5.82	0.073
Time x depth	1	22.10	0.009	0.06	-
Acacia (c)	1	2.33	0.165	2.27	0.170
Time x acacia	1	0.07	-	1.09	0.327
Depth x acacia	1	0.18	-	0.04	-
Time x depth x acacia	1	0.03	-	0.00	-
Crops (d)	3	2.39	0.079	0.16	-
Time x crop	3	0.54	-	1.03	0.389
Depth x crop	3	0.74	-	0.25	-
Time x depth x crop	3	0.26	-	1.18	-
Acacia x crop	3	0.50	-	2.98	0.040
Time x acacia x crop	3	1.71	0.176	2.19	0.101
Depth x acacia x crop	3	1.37	0.262	0.58	-
Time x depth x acacia x crop	3	0.49	-	0.33	-

Four months after planting, the nitrogen concentration of the surface soil dropped from 2075 ppm to 1901 ppm. This is significant (Table 4.22) and might due to activities involving planting of crops and teak which lead to leaching of nitrogen and organic matter to the subsurface soil. A significant increase in nitrogen and organic carbon in the subsurface soil from 1430 ppm to 1713 ppm supported this. The increase, however can also be attributed to the root development of crops and acacia beyond the 0-15 cm depth as the interaction between acacia and crops is significant at P= 0.042 (Table 4.22) The significant increase in organic carbon from 1.7 % to 2% might due to the increase of root biomass of crops and acacia reported earlier (Table 4.15)

The soil N (also P) concentration was also investigated at distances of 12.5 cm, 62.5 cm and 112.5 cm away frow teak, representing soils between teak and crops, under crops, and between crops and acacia, respectively. and it was found that the distance factor had no significant effect (Appendix A and B).

Table 4.22 F values and associated probabilities of some variables influencing N, P, and organic carbon concentrations of surface (0-15 cm) and subsurface (15-30 cm) soil four month after planting.

Source of variance	DF	N F	N P	P F	P P	C F	C P
			surface soil (0-15 cm)				
Time (a)	1	18.09	0.051 *	-	-	0.56	-
Acacia (b)	1	2.50	0.188 ns	0.35	-	0.49	-
Time x acacia	1	0.51	-	9.07	0.039 *	0.12	-
Crops (c)	3	0.47	-	5.39	0.005 **	3.50	0.03 *
Time x crop	3	0.41	-	4.80	0.009 **	0.68	-
Acacia x crop	3	0.48	-	1.26	0.310	0.56	-
Time x acacia x crop	3	0.49	-	0.02	-	0.19	-
			subsurface soil (15-30 cm)				
Time (a)	1	59.79	0.016 **	-	-	43.04	0.022 *
Acacia (b)	1	1.28	0.320 ns	10.10	0.033 *	0.33	-
Time x acacia	1	0.02	-	13.85	0.020 *	0.13	-
Crops (c)	3	1.90	0.156 ns	8.05	0.000 **	0.05	-
Time x crop	3	0.37	-	2.24	0.109 ns	0.90	-
Acacia x crop	3	3.18	0.042 *	2.45	0.088 ns	0.16	-
Time x acacia x crop	3	1.28	0.303 ns	1.83	0.169 ns	1.02	0.402 ns

4.5.2 Effects on soil phosporus

Phosporus concentration in the subsurface soil increased significantly (P= 0.03) with the presence of acacia. Crops also showed a significant effect on soil P but only on plots with acacia as soil P increased from 425 ppm to 506 ppm right after the first harvest. The interaction of crop and time was also significant

(P=0.039)(Table 22). As soil P in this case is total P, it would be more interesting to look at the available P in soil using extracable solution such as Bray-1 or Bray-2. Ojeniyi et al (1980), in a study on effects of agrisilviculture on soil chemical properties in Nigeria indicated that interplanting of crops increased (though insignificantly) nitrogen and phosporus (Bray-1 extractable) in the top surface soil (to the depth of 12 cm). As these increases might reflect reduction and degradation of soil organic matter 30 months after planting it was not the case for soil in this study after the first harvest of crops. The development of root system of crops beyond the surface depth apparently was the major contributor to the increase in soil organic C, N, and P in the subsurface soil.

4.5.3 Effects on soil acidity and extractable bases

There was no signficant change in pH soil between the time of trial initiation and the time of harvesting the first crops. (Table 4.21). Soil pH was not influenced either by the kind of crop, depth of soil.

The concentration of extractable K, Ca, Mg, and Na in the soil at the beginning of the trial were 61, 2911, 328, and 71 ppm while after crop harvest they were 53, 2712, 334 and 63 ppm, respectively (Table 4.20b). The differences in extractable bases before the trial and at first crop harvest (four months after planting) were generally not significant .

Magnesium, Na, and Ca concentrations of the plots with acacia were generally lower than those of plots without acacia, although the difference was not significant. On the contrary, the K concentration was significantly influenced by acacia (P=0.019)(Table 4.21) as soil of the plots with acacia contained more K than the ones without acacia. Crops showed no significant influence on extractable bases. Total exchangeable bases with combine Mg, N, Ca and K showed no effect with time, acacia or crops for both surface and subsurface soils.

The results agree with the study of Ojeniyi et al (1980) which showed no significant changes in soil total exchangeable bases as result of agrisilviculture.

5. DISCUSSION

In the first four months of its life, teak showed a characteristic of allocating more biomass to the leaves and roots (Figure 4.9), which likely will change with age. A study conducted on growth and nutrient requirements of teak in Nigeria indicated that nutrient proportion chanelled to foliage decreased while those to trunk and branches increases with age. The distribution of all the elements followed a similar trend and varied with stand age. (Nwoboshi, 1984)

During the first 16 months of plantation, Acacia villosa, the interplanted legume, has shown no significant effect on teak (Table 4.2) as well as on crops. During the duration of the study, the acacia apparently did not contribute as much as is usually expected from a N-fixing species. A longer study on the role of acacia or other interplanted legumes in tumpangsari system is needed to see if this is a continues trend. Results of the present study add evidence for a necessary reexamination of the assumption underlying current nitrogen credit recommendations for legumes in crop rotation as suggested by Hesterman et.al (1987).

During 16 months of plantation the growth of teak was significantly influenced by crops. Diameter and especially height were growth parameters which showed stronger response to the treatment than did the leaf area (Table 4.2). Up to six weeks after planting, teak seedlings showed no difference in height growth no matter with what was kind of crop it had been associated (Figure 4.1). This may be an indication that up to this point, the growth of seedlings still fully depended on the reserve food stored within the seed, which was about the same amounts (fruits had been selected based on the same size). From then on, the growth of teak should reflect the influence of treatment since the teak fruits had been collected from a same seed stand.

Although it is logical to expect that a significant difference in one kind of growth parameter will likely be followed by a significant difference in another parameter that is closely related (such as among height, diameter and leaf area), the present study indicates otherwise. It was observed in this study (Table 4.3), that the significant difference in height or diameter did not always mean a significant difference in leaf area. It was observed that after 16 months of plantation, the significant difference in height was not accompanied by a significant different in leaf area (compare teak w/rice or teak w/peanut v. teak w/corn). It was a sign of poorer performance in term of photosynthesis of the teak grown with corn than when grown with rice or peanut. This performance was likely due to the greater degree of shading caused by corn foliage that those caused by rice or peanut foliages.

Generally, teak grown with rice or peanut gave a better performance compared with that grown with corn or without a crop. It was evident that teak growing alone without companion crops was inferior at the 4- and 16-month period after planting than when grown with any of the crops used in this experiment. These results are contrary to the results of the study carried out by Coster (1937) who concluded that crops actually had a negative influence on the growth of teak after 3 years of plantation. The difference between this experiment from that of Coster's may stem from the difference in the duration of the study and the facts that patch weeding, a common practice for non tumpangsari plantations, was applied to this experiment. Teak without crops was actually exposed to weed interference. An investigation in Sudan indicated that teak responded to clean weeding with higher survival and better growth than when subjected to strip or patch-weeding (Annon.,1954). Results of a study carried out by J.Combe and N.Gewald in 1979 (cited by Budowski, 1983) indicated that the advantage of growing crops with forest trees in taungya could be a complementary interaction. The study showed that at 2 x 3 m spacing, gmelina planted alone after 15 months of plantation, was not significantly better than when grown with crops, either in diameter or in height.

By incorporating a crop into the teak plantation, each hectare was able to produce, on the average, about 886 kg corn, 1045 kg rice or 829 kg peanut in the first cropping season and about 818, 980, or 786 kg of corn, peanut, rice, respectively in the second season (Table 4.9). There was no indication of a great yield reduction in the second cropping season. The differences in yields of crops between the first season and the second season was not significant. The experimental site is located in the climatically rather dry region of Java, and Nye and Greenland (1960) had observed that the decline of yield of the shifting cultivation in the drier region is slower than that in the wetter zone.

An agrisilviculture study in southern Nigeria interplanted young gmelina with corn, yam, and cassava, (Ojeniyi et al., 1980) indicated that the practice usually resulted in slight but insignificant increases in soil N and P, a decrease in organic C, and no change in exchangeable bases and pH compared with pure gmelina stands. The study investigatied three ecological zones of southern Nigeria and showed that cultivation or cropping could result in reductions of C/N ration of surface soils;

Continuous cropping showed no effect as soil pH did not fall below 5 on farm plots, and concluded that soil fertility was not affected by interplanting of single or multiple food crops with forest crops.

At the beginning of the study the surface soil contained more nutrients (N,P, organic C, Mg, K, Ca, Na) than the subsurface soil. Concentrations of N, P, and organic C in the surface soil decreased after four months while those in the subsurface soil increased (the time-depth interaction was significant). The accelerated decomposition process of the humus during cropping and further leaching by rainfall may be responsible for the deposition of nutrients into the subsurface soil. If the forest cover is cleared, the nitrification process becomes more rapid because the exposure of surface organic colloids is followed by a moisture-induced population burst of nitrifying bacteria (Birch, 1958). The nitrate is then moved downward by rain to the lower horizon. Jones (1975) worked with soil under corn in Nigeria and estimated that the downward rate of nitrate movements was about 0.2 to 0.3 cm per cm of rainfall. In another experiment carried out by Wetselaar (1962) a downward nitrate movement of 2.7 cm per cm of rainfall was observed.

Some phosporus may also be released during humus mineralization. Phosphate ions may move downward during the rain and be deposited on the subsurface soil, although they are unlikely to be leached in significant amounts beyond the top few inches (Nye and Greenland, 1960). The fact that increased concentrations of organic carbon in the sub-surface soil was accompanied by increased N and P concentrations was rather unusual. The increase in soil N or P, especially in tropical soils, normally reflects the reduction and degradation instead of the increase of soil organic matter. Considering the nature of the teak-crop plantation, this phenomenon could be due to the root system development beyond the 15 cm depth and a deposition of organic matter from the surface soil into the subsurface soil. This deposition was caused either by the activities of soil fauna or by farmers husbanding their crops.

There was no significant change in total exchangeable bases and acidity after the first cropping season. Nye and Greenland (1960) also observed no considerable decrease or increase in exchangeable bases in soils under shifting cultivation. The soil reaction values (pH) between 5.00 to 7.00 had little influence on the choice of plants to be planted (Wilde, 1958), implying that during this study crops were not growing under pH stress.

This study was aimed at the determination of suitable companion crops for teak in tumpangsari plantations. Although the response of teak at four months and 16 months after planting still followed a similar trend, further observation on what happens afterwards is still needed. Among the crops under investigation, corn was the least positive companion crop of teak. However, it still is a better alternative to grow teak with corn than letting the area become covered by weeds. Corn should be planted after rice so that teak has a chance to gain better growth capital before it is exposed to a much stronger competitor; teak grown with rice had about four and three times greater root biomass and leaf area, respectively, than that grown with corn. Effects of rice and peanut were not significantly different so that as far as teak is concerned, it does not matter which one is to be planted first. However, because 1) the forest farmers usually grow crops in sequence (or at least in a relay cropping system), and 2) the first crop grown in the sequence may affect the successful growth of the following crop (allelopathic effects), rice should be grown first. It was observed that the highest yield of rice was obtained when it was planted after fallow than when planted after soy bean (Glycine max), cowpea (Vigna unguiculata), mungbean (Phaseolus ureus), or sorghum (Sorghum bicolor) (Hamid et.al, 1982). It is reasonable, then, to suggest the rice-peanut-corn sequence for a teak tumpangsari plantation under the Wanagama I condition, which is also one of the most common cropping patterns in Indonesia (Birowo, 1975).

6. SUMMARY AND CONCLUSION

Teak was grown in combination with rice, corn and peanut in plots with or without a legume, following the common practice of tumpangsari, on an oxisol soil in the Wanagama I forest area. Teak grown without a crop, a control treatment, was patch weeded while those grown with crops were clean weeded as the farmers maintain their agricultural crops.

Although the acacia factor was not statistically significant, leaving behind the type of crop, teak grown in the plots with acacia were on the average taller at four months than when grown in the plot without acacia; a similar situation was also found after 16 months. Analysis of the individual effects of crop on height growth of teak related to acacia at 16 months after planting indicated that only teak grown with rice was significantly effected by the acacia. The type of crop was the only factor that significantly influenced the growth of teak. Both at four or 16 months after planting, teak grown with rice or peanut performed better than when grown with corn or without a crop.

The yield of corn, rice, and peanut, in the first cropping season was 886, 1045, and 829 $kg.ha^{-1}$, while in the second cropping season yields were 818, 980, and 786 $kg.ha^{-1}$, respectively. There was no significant difference between crops harvested from plots with acacia or without acacia. The influence of acacia was significant only on the yield of rice in the row adjacent to acacia, but not on the yield of the other crops.

Crop residues constituted harvestable yield utilized by farmers to feed their livestock. In this experiment, the fresh weight of crop residues harvested were about 10.7 , 8.0, 7.2 ton ha^{-1} of corn stover, rice straw, and peanut stalk, respectively. For comparison, the average weight of weeds collected from the no-crop plots was 4.6 ton ha^{-1}.

The acacia biomass ranged from 94 to 157 $g .m^{-1}$ row. There was no significant difference between acacia biomass when its neighboring plants were corn, rice, peanut, or weeds.

Root occupancy of a teak-crop combination was different according to its distance from teak. Depth of soil had no effect on root occupancy . Roots of the teak-rice combination occupied the soil more extensively than did the other teak-crop combinations.

Some changes in the chemical status of soil after four months of plantation were observed. The surface soil contained more nutrients (N, P, organic C, Mg, K, Ca, and Na) than the subsurface soil. Nutrient concentrations in the surface soil decreased after four months, while those in the subsurface soil increased.

Patch weeded teak grown without a crop did not perform better than when grown with a crop association. In fact, it performed much more poorly. The order of positive influence of companion crop with respect to teak growth was rice > peanut > corn, at the first cropping season (four months of plantation) and peanut > rice > corn at the second cropping season (16 months of plantation). Since the difference in the effect of rice or peanut on teak was not significant, either one may be selected as the best companion crop for teak. However, other considerations such as 1) the farmers' cropping practice, and 2) possible allelopathic effects, had lead to selecting rice over peanut.

Based on these observations on the first 16 months of the plantation, it may be concluded that growing crops in association with teak is ecologically justifiable and the reasonable cropping sequence for tumpangsari practice in the Wanagama I, or other areas with similar conditions is, rice - peanut - corn.

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APPENDICES

APPENDIX A

F values and associated probabilities of variables influencing N concentration of surface (0-15 cm) and subsurface (0-15 cm) soils at three different distances from teak before the trial and four months after planting

Source	Degrees of Freedom	F Value	Prob	
Time	1	0.84	-	ns
Distance	2	0.11	-	ns
Time x Dist	2	1.26	0.33	ns
Depth	1	170.28	0.00	**
Time x Depth	1	36.28	0.00	**
Dist x Depth	2	1.00	-	ns
Time x Dist x Depth	2	0.02	-	ns
Crops	3	2.82	0.04	*
Time x Crops	3	3.44	0.02	*
Dist x Crops	6	0.35	-	ns
Time x Dist x Crops	6	0.80	-	ns
Depth x Crops	3	1.40	0.25	ns
Time x Depth x Crops	3	0.69	-	ns
Dist x Depth x Crops	6	0.77	-	ns
Time x Dist x Depth x Crops	6	0.45	-	ns

APPENDIX B

F values and associated probabilities of variables influencing P concentration of surface (0-15 cm) and subsurface (0-15 cm) soils at three different distances from teak before the trial and four months after planting

Source	Degrees of Freedom	F Value	Prob	
Time	1	2.02	0.29	ns
Distance	2	0.23	-	ns
Time x Dist	2	1.07	0.39	ns
Depth	1	63.72	0.00	**
Time x Depth	1	17.57	0.01	**
Dist x Depth	2	0.63	-	ns
Time x Dist x Depth	2	0.00	-	ns
Crops	3	5.63	0.01	*
Time x Crops	3	0.91	-	
Dist x Crops	6	0.96	-	ns
Time x Dist x Crops	6	1.47	0.20	ns
Depth x Crops	3	0.82	-	ns
Time x Depth x Crops	3	0.83	-	ns
Dist x Depth x Crops	6	1.29	-	ns
Time x Dist x Depth x Crops	6	0.82	-	ns