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Rubber based Agroforestry Systems (RAS) as Alternatives for Rubber Monoculture System.

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ABSTRACT

Smallholder rubber plantations in Indonesia, representing more than 80% of the total rubber areas, are very unique in the world. Most smallholder rubber areas are multi-strata in nature. Rubber is not the only perennial crop in that area, but also mixed with timber trees (forest re-growth), fruit trees, and different annual crops. Scientists identified these multistrata systems or called "Jungle Rubber" have multiple functions such as main income source for many farmers; keeping certain level of the forest biodiversity; Carbon sequestration; soil and water conservation. Many efforts have been done by the Indonesian Government to improve the productivity of jungle rubber through monoculture system such as Nucleolus Estate for Smallholding (NES); Project Management Unit (PMU); and Partial System. However, the rate of rubber replanting through those specific projects are too small compared to the total rubber areas in Indonesia. Taking into account the positive aspects of the Rubber Based Agroforestry Systems (RAS), ICRAF, CIRAD and IRRI worked jointly to implement various RAS systems in order to provide farmers better technological options for managing their farms. Results presented in this paper are collected from both on-station and on-farm research. At on-station, rubber planted at a double rows spacing (6m x 2m x 14m) with and without perennial intercrops was monitored and compared to that of the normal spacing (6mx3m). Rubber girth with double row spacing reached tappable size at five years after planting and similar to that planted with normal spacing. Rubber growth at the plot planted with *Acacia mangium* a very fast growing tree, at the same time with rubber, was very slow: a haft of that of the other treatments. If the fast growing trees are planted two years after rubber planting, then rubber growth is similar to that of normal spacing. Three types of RAS were tested at farmers' plots (RAS1, RAS2, and RAS3). The total number of participants is about 150 farmers, in 100 ha plots, distributed in Jambi, West Kalimantan, West Sumatra and South Sumatra. Results of clone comparison in RAS 1 type of trial (maintenance only on rubber rows) showed that rubber growth variability was more due to the variability of farmers' plots and frequencies of weeding. Rubber clones such as *PB 260*; *RRIC 100* and *BPMI* planted under RAS 1 can adapt the RAS conditions and can be tapped at 5-7 years after planting. These findings provide farmers alternatives to develop more environmentally friendly and divers systems in their farms, compared to that of monoculture system. This paper presents also various results related to more intensive RAS (RAS1 and RAS 3).

Keywords: Agroforestry, rubber, timber trees, *Acacia mangium*, *Imperata cylindrica*, RAS, Jambi, West Kalimantan, West Sumatra, and South Sumatra.

INTRODUCTION

Rubber has been developed in Indonesia since more than a century and since then Indonesia has as the largest rubber area in the world (3.5 millions ha). However the productivity of smallholder rubber in this country is very low (650 kg/ha/year), or half of that of Thailand (....). This can be attributed firstly to the use of non-improved planting material (unselected seedling) and secondly to the low level of maintenance (low weeding, minimum fertilisation) practiced by most rubber smallholders (more than 80% of the total area). Due to this extensive management, smallholder rubber areas in Indonesia are mostly under “jungle rubber” forms, where rubber present as the main species grows together with other species such as timber, fruits, rattan, medicinal plants.

The most important government action on the development of the commodity was started at the beginning of 1970-ies and mainly on the 1980-ies, after the foreign earning of the country, based on petroleum, starts to decrease. Various development and rehabilitation projects for smallholder tree crops have been established, which were mainly, are grouped into two schemes: Perusahaan Inti Rakyat/Nucleus Estates of smallholder (PIR/NES) and Project Management Unit (PMU), later the government has also developed partially funded projects. Except for the later, all those projects were based on monoculture and credit scheme. These schemes have had rather successful in transferring various technology innovations that implemented by tree crop smallholders and had increased farmers’ income. Apart from technical factors, the low productivity performance of the most smallholder rubbers in Indonesia is also due to economic and social factors, and weaknesses of the supporting institutions for smallholder rubber development.

Traditionally smallholder rubbers in Indonesia are established after a slash and burn of secondary forest or old jungle rubber, followed by planting of annual food crops in between rubber rows for 2-3 years. The system is based on extensive management both for rubber and intercrops, either during the first two-three years of intercrop establishment, or afterward. After completion of annual intercrops, farmers abandon the land to seek other portions of land to be planted with similar intercropping system. Weeding or slashing of the forest re-growth was done once to twice a year in the first three years after intercrop and maximum once a year before rubber starts to be tapped. Even in a rural development context these systems are important sources of income for farmers; require only low capital, labour and cash inputs and produce a diverse ranges of foods, fruits and timber; however there is still needs to improve the productivity of the these systems with moderate changes in farmer's management in order to improve land productivity.

Various consequences of this low farm management are identified such as a) slow and heterogeneous rubber growth and long immature period or late reaching tappable size (8 to 12 years after rubber planting) and; b) rapid growth of forest re-growth. Some useful tree species re-growth may be kept by farmers due to its important economic value such as fruits, rattans, medicinal and timber trees, in the future.

These extensive and low management systems develop toward a complex agroforests based on rubber trees. De Foresta and Michon (1996) defined complex agroforests as forest structures managed by farmers for the production of various forest and agriculture products on the same

piece of land, mimic natural forest structures, with a complex structure and a closed or almost closed canopy dominated by few tree species. In other hand, simple agroforestry refers to associations involving a small number of components arranged with obvious, usually well ordered pattern: one or a couple of tree species, either as a continuous canopy, in equally distant lines or in edges, and some annual species for ground cover (Michon and de Foresta, 1998).

It was known that outside of those government project areas, most smallholders could not implement recommended technologies (Supriadi, 1997; Supriadi *et al.*, 1999; Supriadi and Nancy, 2001), mainly because of it is costly, the technologies are not always adapted to their various circumstances, lack of institutional and capacity buildings, and the technologies are sometimes not available for farmers. These constraints need to be taken into account in developing new technologies for smallholder farmers.

Rational of Rubber Agroforestry Systems (RAS)

The main challenge for researchers is to search and to test new models for improving smallholder rubber production systems, based on the current farmer practice ones rather than replacing them with estate-like or monoculture, conserving the biodiversity and environmental benefits of agroforestry practices.

The important characteristics of rubber clonal planting materials are well known such as high productivity (2-3 times of that seedling originated plants), homogenous growth, and response to production inputs (fertilizers, weeding). These clonal materials are costly for farmers (between 0.25–0.30 USD/polybag in 2005). However, due to it capacity to double or even triple latex production, compared to unselected rubber trees, it is worth to use clonal rubber in RAS. Clonal planting material has been historically selected for estate monoculture management and optimized for the highest level of maintenance. Testing clonal rubber in agroforest environments with a certain level of extensive practices means that clone will be selected for other environments where competition is far higher than that of monoculture and based on reduced inputs and labour.

Testing clonal materials includes also assessment of rubber production with and without fertilizer, growth under different levels of weeding and clones comparison under different levels of weeding. The research aims to identify the key components (use of improved planting material, fertilization, and combination of both) to improve productivity of the rubber agroforestry systems, which can be established in pioneer and buffer zones, as well as in zones where replanting is required.

Since 1994 and planned up to 2007, World Agroforestry Centre (ICRAF) in association with CIRAD-France and Indonesian Rubber Research Institute (Sembawa Research Station) established a network of trials to study rubber agroforestry systems and test different approaches suitable for different conditions under SRAP (Smallholder Rubber Agroforestry Project) and SRAS (Smallholder Rubber Agroforestry System) project. The project was funded by various funding agencies such as: USAID, French Embassy, Gapkindo, and CFC (the Common Fund for Commodities). This paper presents brief results of different Rubber Agroforestry Systems

(RAS), both simple and complex RAS, as alternatives to intensive rubber monoculture systems (Penot, 2001).

MATERIALS AND METHODS

The network trials were developed since the last 10 years either at controlled environments (on-station) or at farmers' circumstances (on-farm). Increase of productivity of jungle rubber in Indonesia may be attained by providing improved planting materials of the tree components to the farmers and evaluating which are the most appropriate and affordable for smallholders. This research program is based on four major components: a) the characterization of selected areas to achieve a "situation typology" covering a wide range of conditions, b) a network of on-farm trials using participatory approach, c) a farmer typology reflecting all strategies and constraints encountered in the rubber growing areas of Kalimantan and Sumatra, and d) in-depth studies on particular relevant agronomic and ecological topics. Data analysed in this paper present only on agronomic study of the RAS.

Sources of Data

Data analysed in this paper are explored from two types of trial, on-station controlled plots (Sembawa Research Station, South Sumatra province) and on-farm participatory plots established in Jambi, West-Sumatra, and West Kalimantan provinces of Indonesia.

On-station trials

A series of testing of simple RAS, in which rubber (BPM 24 clone) was mixed with *Paraserianthes falcataria*, a fast growing timber tree, planted at the same planting date with rubber was established in Sembawa Research Station. Rubber was planted in a double row spacing (4m x 3m x 16m) and three densities of *Paraserianthes falcataria* (3, 4, and 5 rows in between wide rubber rows, or comparable to 450, 600 and 750 trees/ha respectively). These treatments are compared to rubber monoculture planted in a double row spacing and in a normal spacing of 6.7m x 3m (500 trees/ha).

Apart from the above trial, another trial was established to test the effect of different planting densities of *Paraserianthes falcataria* (950, 475 and 240 trees/ha) on rubber growth planted under a two year old rubber (BPM 24 clone) with a normal spacing of 7m x 3m.

The third trial consist of testing various tree species under rubber planted in double rows spacing distance (6m x 2m x 14m) or of density of 500 rubber trees/ha. The non-rubber tree species tested are *Tectona gradis*, *Acacia mangium*, *Eucalyptus sp.* of a density of 450 trees/ha (3 rows). A normal density of rubber (500 trees/ha) of 6m x 3.3m spacing distance, planted without intercrop, was established as control plot. Rubber and intercrops were planted at the same planting time in 2000.

On-farm participatory network and RAS Types tested

A network of farmer-managed trials is carried out in Jambi, West-Sumatra and in West Kalimantan provinces of Indonesia. The trials were established in three different planting year

phases. The first phase: planting in 1995-1996 consist of 10 types of trial; the second phase: planting in 2001 consist of 3 types of trial; and the third phase: planting in 2004 consist of 7 types of trial. Results considered in this paper will be explored from the selected first phase of the trials only.

The trials, with an average of 3 to 5 farms or replications per trial, covering 100 hectares and involving about 150 farmers have been established. Each farmer's field is considered as a replication with 1 or 2 simple treatments such as: rubber weeding levels, rubber fertilization, rice variety x fertilization, type of associated trees, and types of cover crops (Multi Purpose Trees (MPT)/Fast Growing Trees (FGT)) combination. These experiments take into account the limited resources of smallholders. Labour is one the main factors being considered in assessment of a system's suitability.

The first, **RAS 1**, is similar to the current jungle rubber system, in which unselected rubber seedlings are replaced by adapted clones. The main objectives are to determine if clonal rubber germplasm succeed to grow well under jungle rubber environment, to increase yields significantly, and to assess the minimum required management level of RAS. A secondary objective is to assess the level of biodiversity conservation in the jungle rubber system. It is expected that the rubber clones be able to compete with the natural secondary forest growth.

Various planting densities, clones, and weeding protocols are tested. This will identify the minimum amount of management needed for the systems. RAS 1 requires a certain level of existing biodiversity (old jungle rubber, tembawang or other type of timber/fruits agroforestry systems, home gardens, secondary or primary forest) for establishment. In other words, RAS 1 is aimed not to be established in Imperata grassland areas (Penot, 1994; 1997).

The second, **RAS 2**, is a complex agroforestry system in which rubber and perennial timber and fruit trees are established after slashing and burning, at a density of 550 rubber and a range of 90/250 other perennial trees per hectare. It is very intensive, with annual crops being intercropped during the first 2-3 years, with emphasis on improved upland varieties of rice, with various levels of rice fertilization. RAS 2 is aimed to answer the following questions: how is total productivity and income affected by intercrops? what are the dynamics of species interactions? And what are the crop alternatives during rubber immature period?

Intercrops are annual (predominantly upland rice or rotation rice/leguminous such as groundnut) or perennial (cinnamon), during the first years of establishment. Previous experimentation has shown the positive effect of annual intercropping on rubber growth (Wibawa, 1996, 1997). The range of trees that can be grown in association with rubber in agroforestry associations and the market potential of their products are being examined: tekam (*Endospermum malaccensis*), meranti (*Shorea spp*), tembesu (*Fragraea fragrans*), and sungkai (*Pheronema canessens*) trees for timber trees; durian (*Durio zibetinus*), rambutan (*Nephelium lappaceum*), duku (*Lancium domesticum*), langsung (*Lancium sp*), cempedak (*Artocarpus sp*), petai (*Parkia speciosa*), jengkol (*Archidendron pauciflorum*), and tengkawang (*Shorea macrophylla*) for fruit trees.

The third system, **RAS 3**, planted only in West Kalimantan, is also a complex agroforestry system with rubber and other trees planted at the same density as that as in RAS 2, but with no

intercrops except in the first year, followed by a combination of leguminous cover crops, and Fast Growing Trees (FGT). It is established on degraded lands covered by alang-alang grass (*Imperata cylindrica*) (Penot, 1995). The grass bounds the growth of annual crops so selected cover crops (*Mucuna*, *Flemingia*, *Crotalaria*) or MPTs (*Calliandra*, Wingbean, *Gliricidia*) and FGTs (*G. arborea*, *P. falcataria*, *A. mangium*) are established with various density between 50-110 trees/ha. It had been assumed that the FGT could be harvested in 7 or 8 years to provide timber and wood for the existing pulp industry. The objective of RAS 3 is to reduce the weeding requirement by providing a favourable environment for rubber and the associated trees to grow, cover the soil as soon as possible to bound imperata growth.

The first of the RAS3 trials were planted in 1996 in three farmers' fields in Kopar village in West Kalimantan. High yielding clonal rubber plant (PB260), grew in polybags, were planted in the field after land clearing through slashing and burning. *Mucuna*, *Pueraria*, *Flemingia* were planted four rows between rubber rows planted at a density of 13-5.000 holes per hectare; the naturally occurring *Imperata* and *Chromolaena* were also retained for comparison.

At Trimulya village, in a Javanese transmigration zone, FGT were planted between rows of rubber trees planted at a density of 110/ha. All plots, both with cover crops and FGT, were weeded (manually or using herbicides) only along rubber rows every three months; limited fertilizers (rock phosphate and urea) were applied only in the first two years. Regular measurements of rubber trees, presence and dominance of ground vegetation were taken and form the basis for analysis of different treatments.

RESULTS AND DISCUSSION

Results derived from on-station trials

Effects of P. falcataria on rubber growth (double row spacing).

Rubber (BPM24 clone) growth planted in double row spacing (4mx3mx16m) up to 18 months is comparable to that planted in normal spacing 6.7m x 3m (**Fig. 1**). The gap of rubber girth between those two treatments increased afterward and started to be significant at 24 months. The presence of *P. falcataria* at different densities reduced rubber growth significantly since 24 months. At 51 months, rubber girth at intercropped plot was 30% and 15% less than that at monoculture normal spacing and at monoculture double row spacing respectively. The monthly increment of girth was 0.6cm; 0.8cm and 0.9cm respectively. The slowest increment was observed during dry season where intercrop reduced increment up to 70% compared to control and 50% if compared to monoculture double row spacing.

The canopy of rubber in double row spacing started to shade the soil since 30 months. Only about 60% of light penetrated in monoculture double row spacing, and far below that point in intercrop treatments (36-52%) and about 70% in normal spacing. At 54 months, in all double row plots, the intensity of light was below 35%, however in normal density the light intensity was 50% (**Table 1**). These data indicated that the intra-plant competition for light may be started

earlier in plots with intercrop and in plot without intercrop with double row spacing, compared to normal spacing.

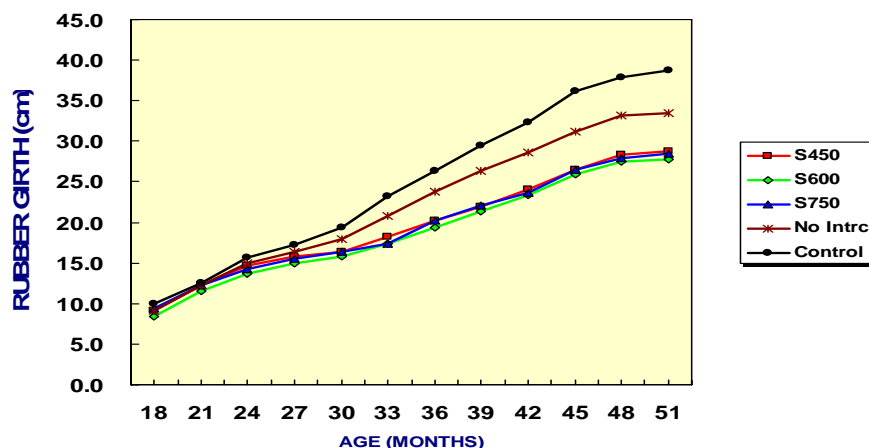


Fig. 1 Rubber growth planted at different treatments: double row vs. normal spacing and monoculture vs. *P. falcataria* intercrop

Similar to the above data, the light condition in between rubber row and in intercrop row (location B), was varied due to treatments. *P. falcataria* of a density of 750 trees/ha reduced light intensity since 18 months, and lesser reduction of light intensity due to lower *P. falcataria* density was observed. *P. falcataria* shaded the soil more than 50% since 18 months (**Table 1**).

Table 1. Light intensity (%) in different locations within double row plots (4mx3mx16m) and normal spacing plot (6.7mx3m) at different rubber ages.

Location	Treatment	Rubber age (months)		
		18	30	54
A	S450	99	30	16
A	S600	94	52	26
A	S750	99	26	31
A	No Intercrop	100	62	32
A	Control	99	69	50
B	S450	68	35	31
B	S600	52	41	31
B	S750	37	31	41
B	No Intercrop	98	82	70
B	Control	99	90	31
C	S450	49	36	34
C	S600	40	38	25
C	S750	20	35	37
C	No Intercrop	100	99	100
C	Control	-	-	-

A = Measurement in the middle of rubber rows

B = Measurement in between rubber row and intercrop row (1.5m from rubber)

C = Measurement in the middle of intercrop's row

Note: S450: means that density of *P. falcataria* is 450 trees/ha

The competitive effects of *P. falcataria* on rubber can be reduced by planting it, two years after rubber planting, with a density of about 250 trees/ha (planted 1 row/rubber inter-row and 6m within row). The trial in Sembawa showed (**Fig. 2**) that rubber planted without intercrop (monoculture) can reach a tappable size (girth at 1m above union is 45cm) 60 months after planting, and with intercrop (*P. falcataria*) 67 months after planting. This data is very useful for farmers who interest to develop such perennial intercropping with rubber. Providing good growth conditions to rubber during the first years of establishment phase, especially when the intercrops are the fast growing trees is a wise strategy. This strategy enables rubber to explore better factors of growth and compete with other perennials.

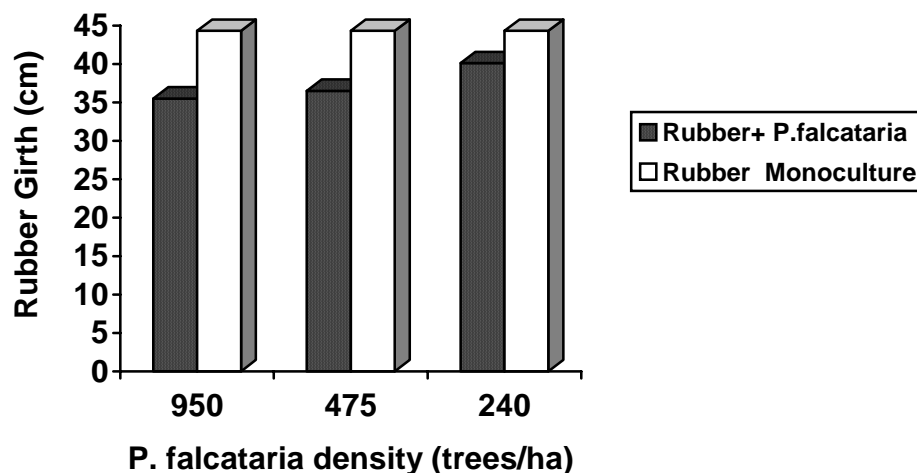


Fig. 2 Rubber growth, 60 months after planting, intercropped with *P. falcataria* with different densities which was planted two years after rubber planting.

Double row spacing for rubber as potential spacing for RAS

In order to search better rubber spacing for perennial intercropping under rubber, a new double row spacing was tested by widening the space within rubber (RRIC 100 clone) to 6m x 2m x 14m (same density of 500 rubber trees/ha). The trial was carried out in Sembawa since April 2000.

Results showed (**Fig. 3**) that rubber growth in double row spacing plots can be comparable with that grew in normal spacing (control) plot. These results were better than that mentioned above. This may be due to the wider rubber row spacing within rubber and rubber clone used, RRIC 100, a fast growing clone. This trial also indicated that planting perennial intercrop after rubber (almost 2 years) is a good strategy to avoid high competition to rubber. *Eucayptus sp* planted under rubber none significantly reduced rubber growth. However, *Acacia mangium* a fast growing timber tree which planted at the same time with rubber, competes rubber growth very significantly since the second year of the establishment. Rubber reach the tappable size between 56 to 63 months after planting, and no significant difference was observed between rubber girth

in double row with or without intercrops to that planted in monoculture normal spacing up to 62 months.

The findings from this trial may be very useful as basis of the recommendation of planting rubber in double row spacing (6mx2mx14m), as alternative to normal recommended ones (6mx3m or 7mx3m). The land in the wider space in between double rows (14m) can be used by farmers to grow food crops in a longer period (more than three years) and for perennial tree crops (timber or fruits). The light intensity is expected still more than 70% up to 54 months. The longer the intercrops are practiced the saver the plantation from the external factor pressure (fire, pests).

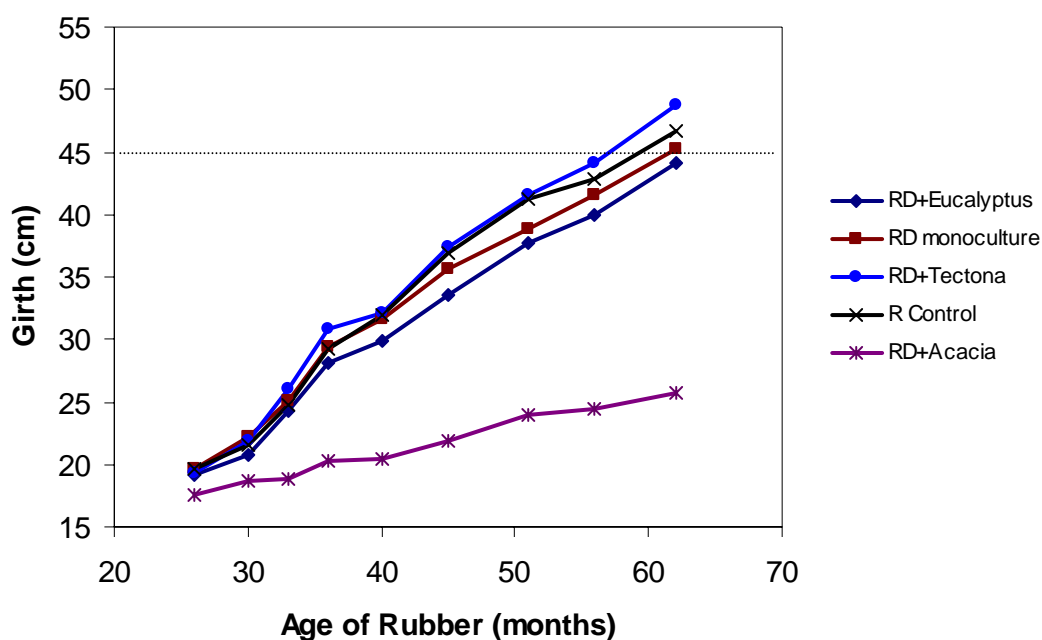


Fig. 3 Rubber growth planted in double row spacing (6mx2mx14m) and at different perennial intercrop treatments, compared to rubber planted in a normal spacing.

Note: R: Rubber with 6mx3.3m spacing and monoculture; RD Rubber with 6mx2mx14m spacing. Tectona grandis planted 21 months after rubber.

The timber trees planted under double row spacing of rubber grew well as in monoculture conditions. Stem growth (measured at 1m from soil) of timber trees planted under rubber (**Fig. 4**) indicated that Acacia has the fastest growth (twice of that of rubber), while Eucalyptus' slow growth was due to the virus leaf disease attacking the trees since two years old. The growth of Tectona is good at the current South Sumatra conditions.

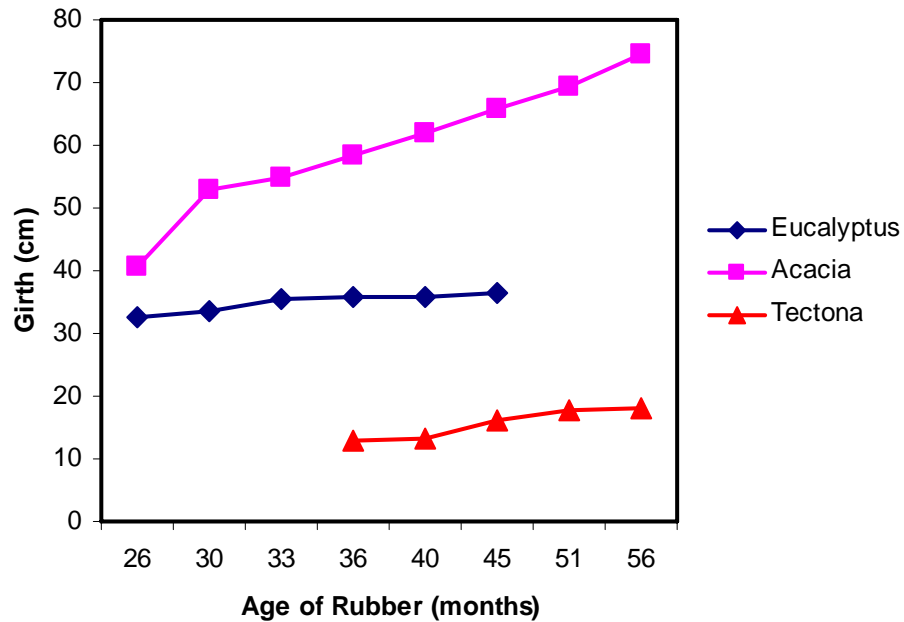


Fig. 4 Trees growth planted under double row spacing of rubber

Note: Acacia and Eucalyptus planted at the same time as rubber, while Tectona grandis planted 21 months after rubber. Eucalyptus was cut after 45 months due to virus leaf disease.

Results from On-Farm participatory experiments

Effects of levels of weeding on rubber growth under RAS 1

In West Kalimantan, farmers do not follow the protocol of the trial targeting to test the effects of frequencies of weeding within rubber row on rubber growth, since the first year of establishment (**Table 2**). The level of weeding implemented by farmers is less than that expected by the protocol of the trial. Farmers tend to weed rarely their plantation. Even, the lowest frequency (Low) is not respected by farmers. As results, rubber growth was slower than the expected one. The consequences were that we observed a comparable rubber growth (no significant difference) in plots “medium”, “intensive” or “intensive with LCC” due to the similar frequencies of weeding from the first up to 5th year. Rubber growth in this group of treatments was better than that in low weeding plot (**Fig. 5**)

Table 2. Frequencies of weeding within rubber row, expected to farmers and really implemented by farmers in RAS1 trials in West Kalimantan

Treatment	Expected frequency per year	Really implemented by farmers				
		1 st year	2 nd year	3 rd year	4 th year	5 th year
Low	4 then 2	2	1	0	0	1
Medium	6 then 4	2	2	1	1	1
Intensive	8 then 6	2	2	2	1	1
Intensive+LCC	8 then 6	2	2	2	1	1

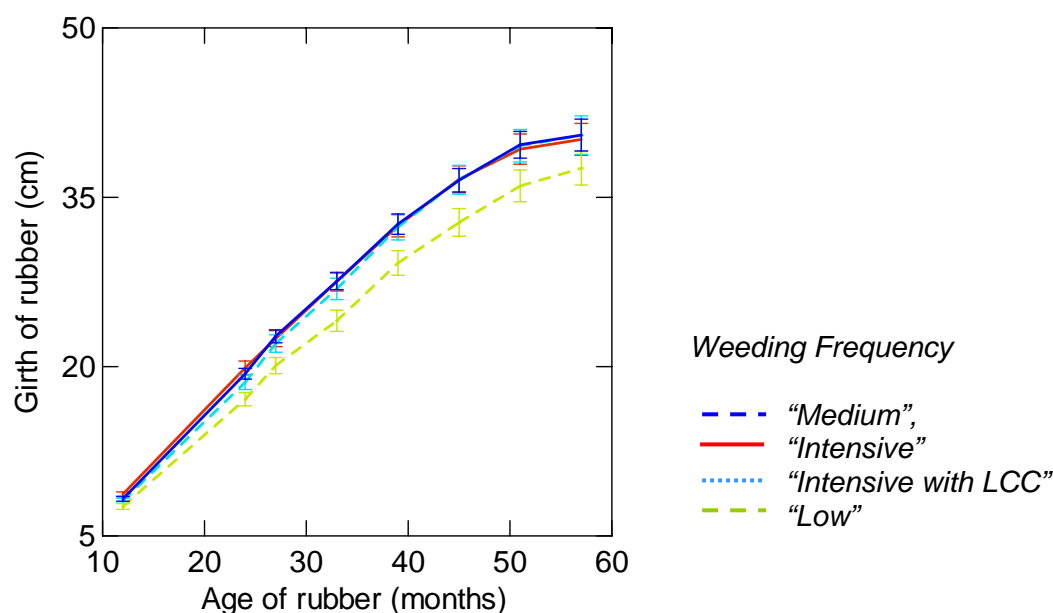


Fig. 5 Effects of weeding frequencies within rubber rows on rubber girth in West Kalimantan (RAS 1.1)

The variation of growth was more significant due to plot site (farmers) rather than the frequencies of weeding (**Fig. 6**). The slowest the “relatively” best rubber growth was observed in Loheng and Sidon plots respectively. In the first, especially after the third year upward, rubber rows were not well cleaned and infested by weeds (*Melastoma*, *Chromolaena*, and *Mikania*) that noxious for rubber. Vegetation in intra rows was dominated by the same weeds and various trees that reach more than two meters height. Many plants died due to white root disease since the second year and continue in the third year. In the later farmer, rubber rows were well maintained up to five years. The height of various vegetations in interrows may reduce rubber girth as shown in **Fig. 6**. The other four farmers maintained the rubber rows up to year 3 without noxious weeds (dominated only by grasses) and the inter row vegetation height was less than two meters. Eschbach (Mission Report, 2004) noted that a significant relationship was observed between the average height of vegetations in rubber interrows at year four and the average rubber growth at year five in West Kalimantan under RAS 1 (**Fig. 7**). It is clear that maintaining the

height of vegetations in intra rows, by slashing the branches up to lower than rubber height may reduce the competitiveness of intra-row's vegetation to rubber.

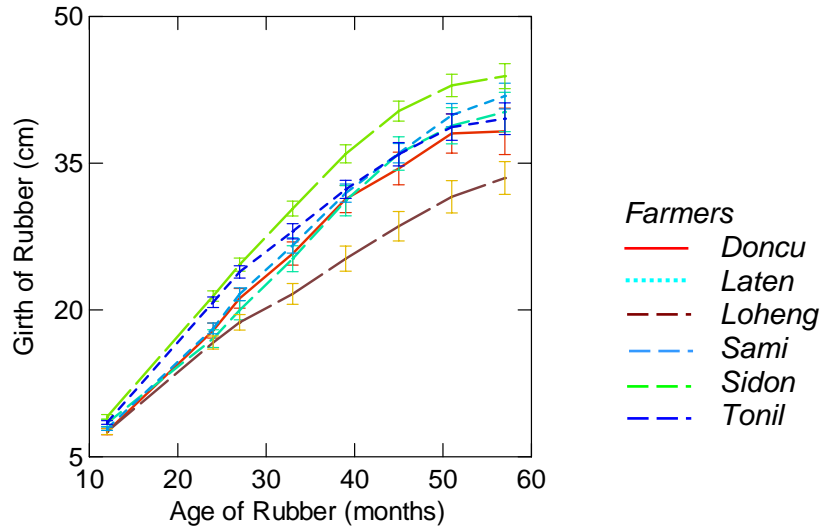


Fig. 6 Variation of rubber growth at different farmers' plots in West Kalimantan (RAS 1.1)

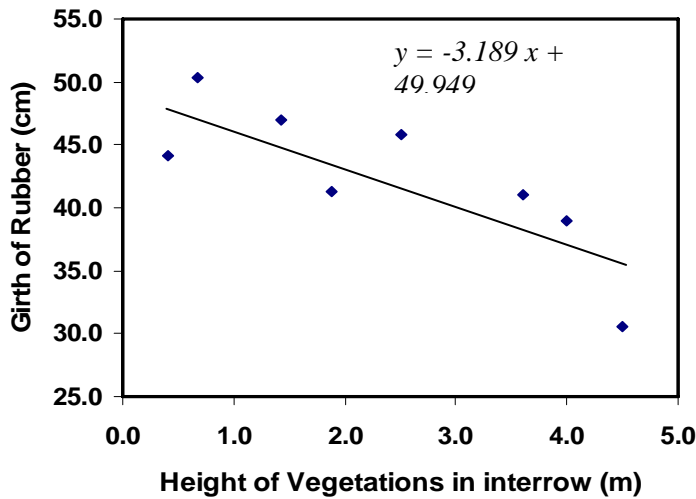


Fig. 7 Effect of average height of vegetations in rubber interrows at year four on average rubber growth at year five in West Kalimantan under RAS 1

Performance of different rubber clones under RAS 1 environments

There is perception of farmers in Sumatra and Kalimantan that rubber clones can not perform well under agroforest environments, compared to rubber seedling originated trees. Series of trials to test the performance of various rubber clones planted under agroforest environments (RAS1 series) were carried out in Jambi and West Kalimantan since 1996. The clones tested are PB260, BPM1, RRIC100, and RRIM 600, compared to seedling originated rubber tree.

As RAS1 principle, the land was previously jungle rubber or secondary forest, prepared through slash and burn practices. Various food crops were planted as intercrops during the first year. Weeding was only focused on rubber rows (1m each side of rubber row), carried out 3-6 times in the first year (considered as low and medium levels of weeding) and 3-4 times in the second year and only once in the third year. Vegetations in between rubber rows are expected to be kept by farmer in order to conserve certain level of biodiversity.

Results of the trials in Jambi indicated that frequencies of weeding influenced rubber growth positively since the early stage of establishment. It is clear that by focusing the weeding only within rubber rows (every two months during the first two years and every six months and only once a year during the third and fourth year respectively), without weeding the vegetations intra rows (in this case *Micania*, *Melasthoma*, *Chromolaena* up to 1.5 m height), rubber can reach the tappable size at five years after planting. However, if the frequency of weeding is reduced to three times per year or every four months, then rubber reach the tappable size at about 5.7 years after planting (**Fig. 8**).

Farmer knows that growth of rubber will be reduced due to competition with other vegetations. Similar to the RAS 1.1, in this RAS 1.2 plots in West Kalimantan, farmers not follow the protocol of trials. The implemented weeding levels follow the **Table 2**. Even it was mentioned that farmer has to maintained vegetation in interrows with certain frequencies of weeding, however most farmers do not follow the protocol of the trial. They slash the vegetations in intra-rows since the second year (once a year). Only few tree species are kept in the plots, especially those plants that have monetary value at the current circumstance. These result in slower rubber growth (compared to Jambi) and no significant difference of rubber growth was observed due to weeding level (**Fig. 9**).

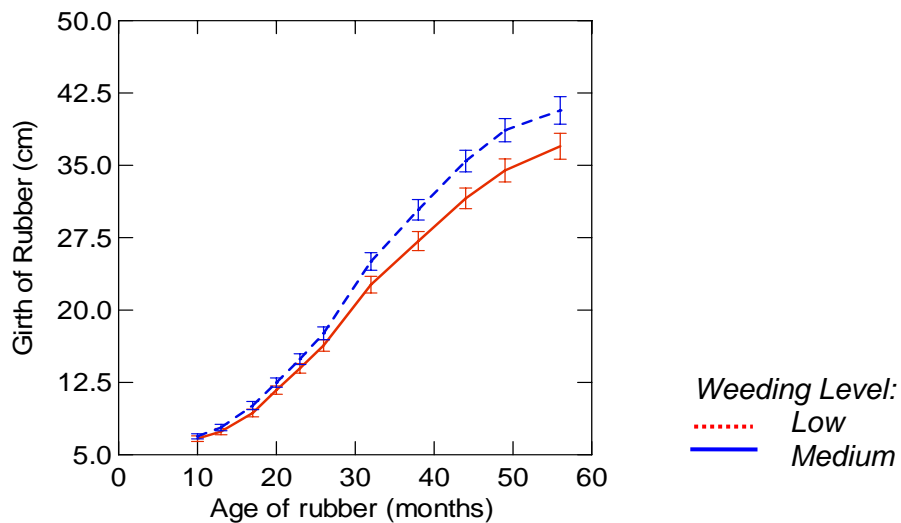


Fig. 8 Effects of levels of weeding on rubber growth in RAS 1 in Jambi

Note : Weeding level

Low : 3, 3, 2, and 1time(s)/year in the 1st, 2nd, 3rd and 4th respectively, in rubber rows only.

Medium : 6, 6, 2, and 1 time(s) per year in the 1st, 2nd, 3rd and 4th respectively.

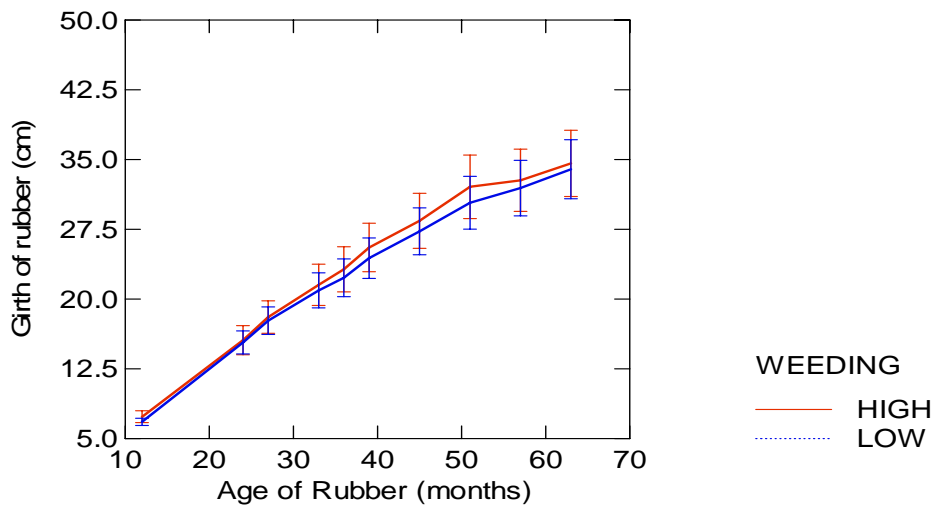


Fig. 9 Effects of levels of weeding on rubber growth in RAS 1 in West Kalimantan.

The performance of clones in RAS1 environments is encouraging (**Fig. 10**). Compared to seedling originated plants, clones perform better in term of growth since the beginning of the establishment. Up to 40 months, among clones, BPM 1 has the best growth followed by other clones, and seedling growth was the slowest. After 40 months, due to white root disease attack on BPM 1 and RRIM 600, the growth of those two clones was reduced and the growth of the

other two clones RRIC 100 and PB 260 was very good and ready to be tapped at 5 years. However the seedling originated plant can be tapped at about 5.5 years after planting. The frequencies of weeding (in rubber rows) of the plots in this trial were between 3-4 times per year.

It is re-confirmed from this trial that rubber seedling growth is lower to that of clonal rubber. Using this plot as a demonstration plot for farmers is very good as the rubber clones performance is significantly difference than that of seeding rubber. There is no significant difference of rubber growth due to intra farmers' performance in Jambi (data not shown), except in plot attacked by white root disease.

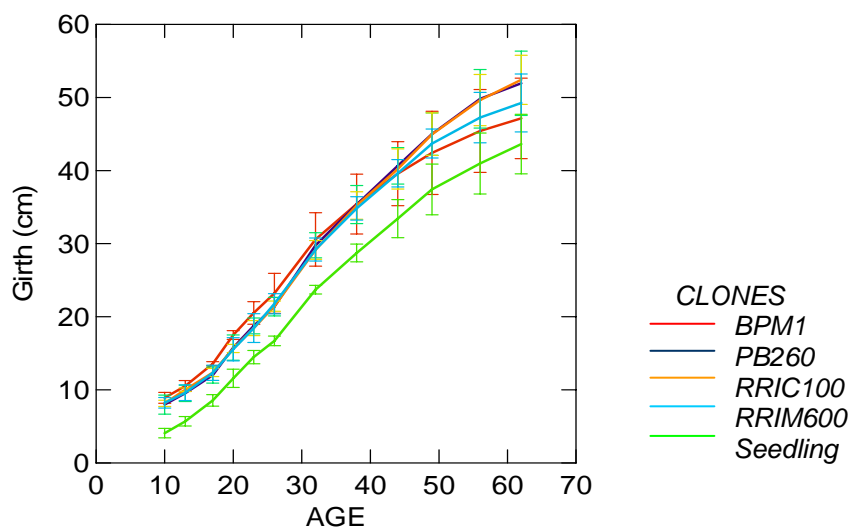


Fig. 10 Growth performance of different clones under RAS1 environment in Jambi

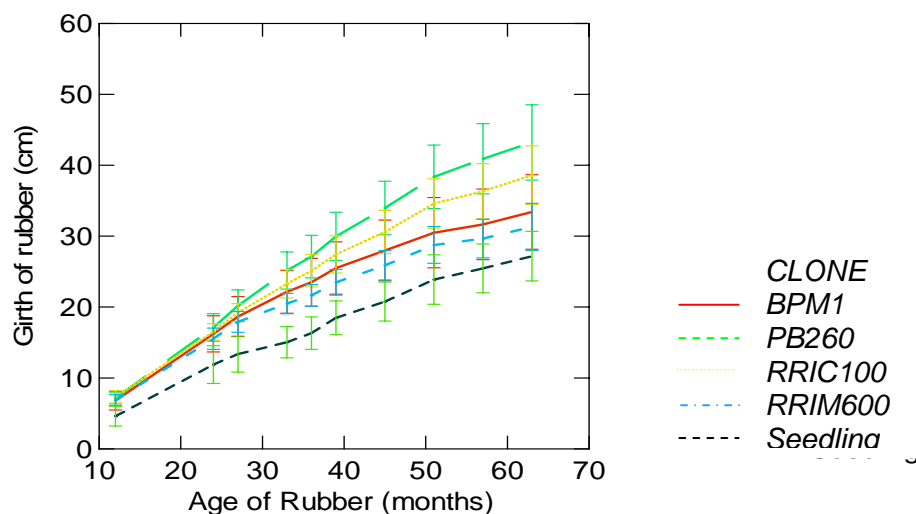


Fig. 11 Growth performance of different clones under RAS1 environment in West Kalimantan

Fertilizers needed in RAS 1 and RAS3

In Indonesia, most farmers not apply fertilizers (or if they apply, the quantity and types of applied fertilizers are very limited, less than half of the recommended one) for their rubber plantation. Trials carried out to study the effects of fertilizations on rubber growth in monoculture rubber plantation are very well documented in all over rubber producing countries. There are still many questions on fertilisation application in RAS. Fertilisation trial in RAS aim at understanding the effects of additional doses per type of fertilizers (urea, SP36, KCl) compared to the basal fertiliser (200 g urea, 160 SP36, 100 KCl in the first year; 100 urea, 80 SP36, and 50 KCl in the second year), on rubber growth. The frequency of fertilization is four times per year. The doses tested are listed in the Table 3.

Table 3. Doses of fertilizers (g/tree/year) applied in different treatments based on RAS1 and RAS3 in West Kalimantan.

RAS type	Treatment	First year (g/tree/year)			Second year (g/tree/year)		
		Urea	Sp36	KCl	Urea	Sp36	KCl
RAS1	Fu	300	160	100	100	80	50
	Fo	200	160	100	100	80	50
RAS3	Fu	300	160	100	100	80	50
	Fo	200	160	100	100	80	50
	Fs	200	240	100	100	80	50
	Fk	200	160	150	100	80	50

In RAS 1, since the first months of the establishment, rubber responds positively to additional urea. This additional urea, from 50g/tree/application to 75g/tree/application, is needed to increase rubber growth about 7% in 30 months after planting. Even the statistical test indicates no significant difference of girth due to those treatments; however the growth of rubber with additional urea is consistently above that without additional urea (**Fig.12a**).

Similar response, but less significant response was observed in RAS 3 trial in PANA, West Kalimantan on the effect of additional urea on rubber growth. Compared to the additional urea, rubber growth with additional SP36 or KCl is slightly less. The effects was lesser in the third year (**Fig. 12b**)

These results indicated that additional urea (nitrogen) is firstly needed as additional fertilizer compared to P and K to increase rubber growth. This result has been practiced by farmers who prefer to choose Urea first among fertilizers.

Farmers who practice annual intercropping provide beneficial effects to their rubber plant especially with horticulture species that need intensive fertilization (including organic fertilizers). Combination of perennials and intensive horticulture species as intercrop will enable positive relationship between rubber and intercrops (Wibawa, *et al* 1996).

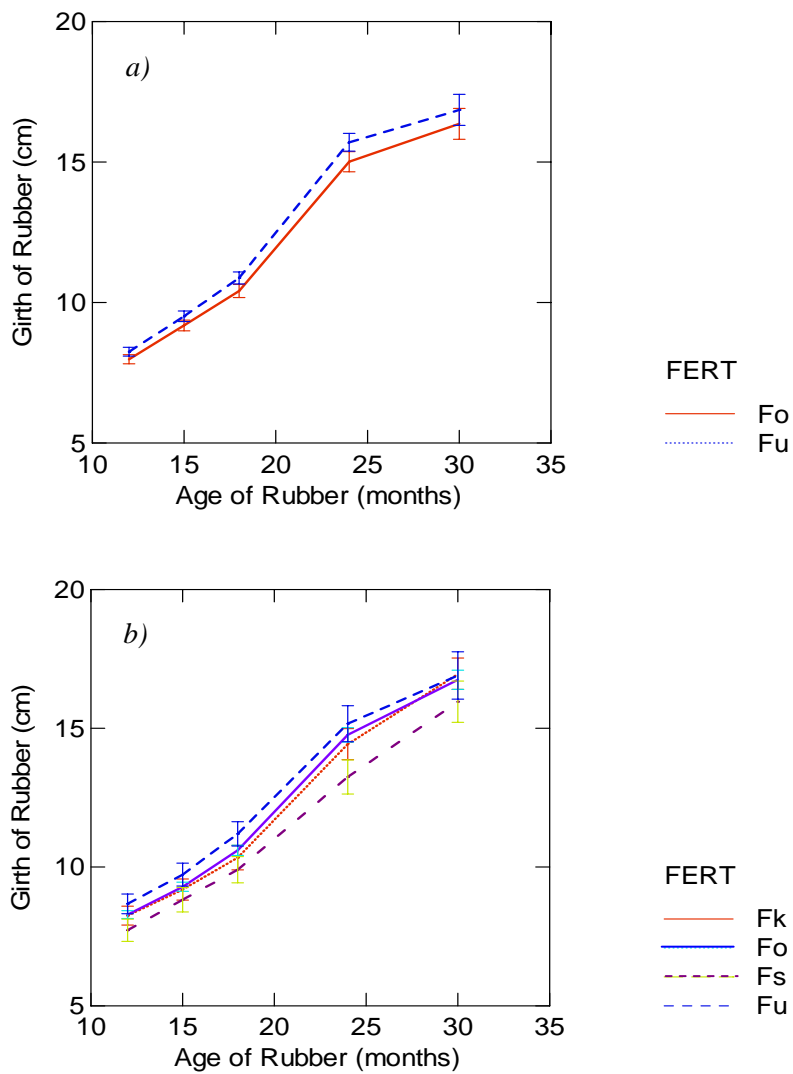


Fig. 12 Results of the fertilization trials in RAS1 (above) and in RAS3 in West Kalimantan.

Note: Fk, Fo, Fs, and Fu refer to **Table 3**

Rubber and non-rubber species performance under RAS 2

Rubber growth at different treatments of perennial intercrops (fruit trees, timber) under RAS 2 conditions show that the variation intra farmers is bigger than that intra treatments (**Fig. 13**), especially after the second year. The effects of perennial intercrops on rubber growth vary from year to year, except for treatment with durian, there is no significant difference observed due to

intercrops, at 54 months. However difference rubber performance was due more by sites/farmers participant of the trial rather than by different intercrops (**Fig. 13**).

The growth of intercrops was not well exploited yet; however from the field observation, we know that farmers are still maintaining the fruit trees under rubber. Due to shading of the trees, those fruit trees can not produce fruit as good as the fruit trees planted in open areas. The RAS 2 trials in West Kalimantan were not as intensive as it was expected. The annual intercrops (upland rice mainly) was only practiced during the first two years. It is also clear that if the spacing of rubber is 6m x 3m, planting perennial plant under rubber is not encouraging in term of the fruit production. Most of fruit trees under rubber are not producing yet, and it is predicted that those fruit trees will not producing due to high shading. If farmers interested in planting trees, then double row spacing is a better option. Rubbers reach tappable size between 6 -7 years after planting.

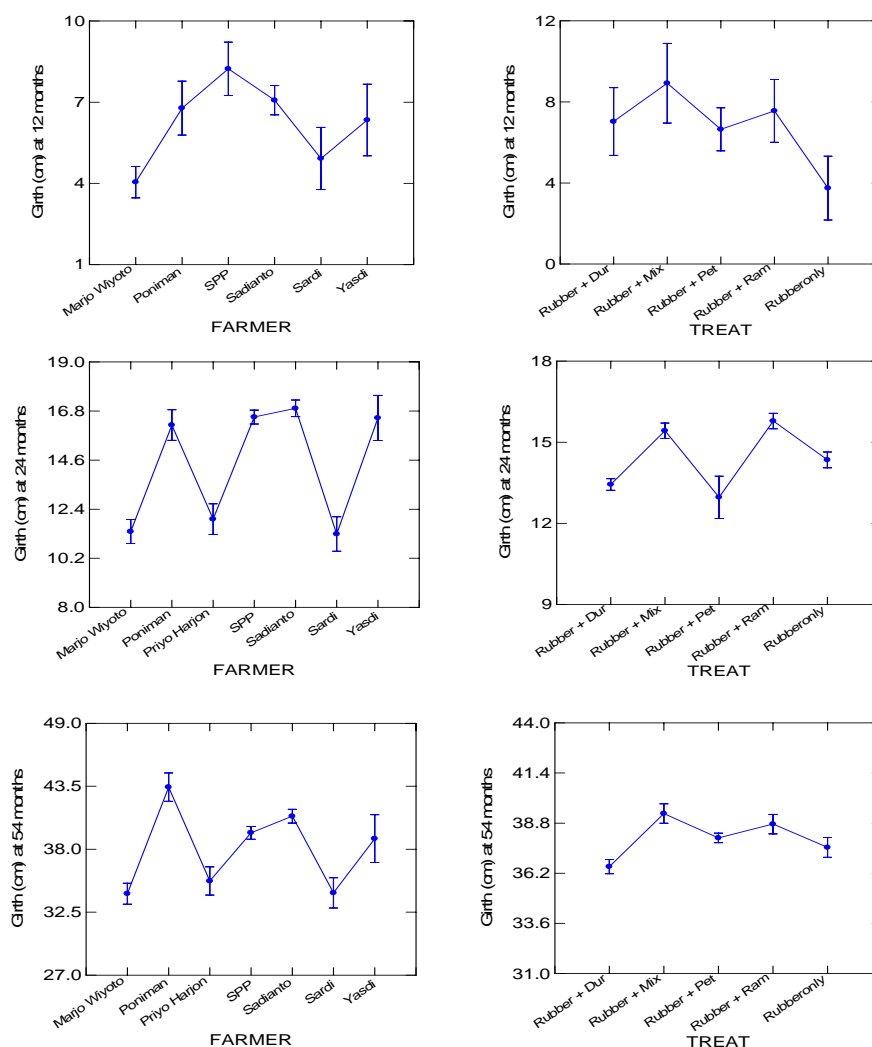


Fig. 13 Variation of rubber girth at different ages, sites and treatments in RAS 2 in West Kalimantan.

Improving imperata grassland productivity through RAS 3

Roles of cover crops on controlling imperata

Combined results from over six years of monitoring in three experiment sites in Kopar village indicated that legume cover crops have different potential in checking *Imperata* growth; thereby influencing growth of young rubber trees (Fig. 14). The creeping legumes were clearly the top performers in controlling *Imperata*. *Pueraria* was slightly better than *Mucuna* for rubber growth (statistically significant). While among the erect legumes, *Flemingia* was good for rubber; but *Crotalaria* proved disappointing. Rubber trees with no cover crops but with *Imperata* or *Chromolaena* had not yet reached tapping size. This finding is consistent with earlier work done in Sembawa Research Station where it took over 10 years for rubber trees without proper *Imperata* control (Wibawa, 2001).

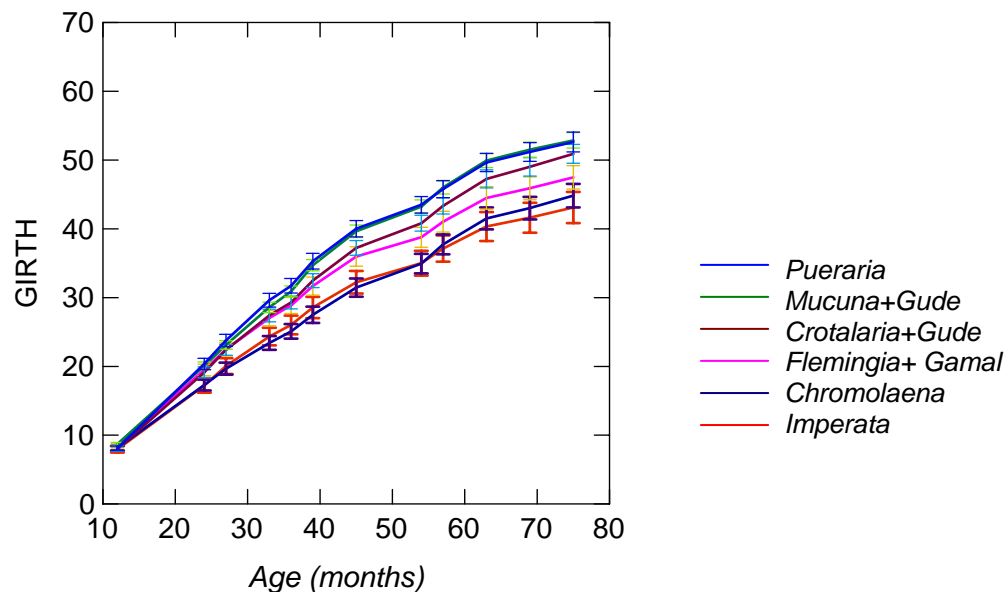


Fig. 14 Rubber tree growth on RAS3 trial plot with different covers crops.

Both *Pueraria* and *Mucuna* grew well and managed to suppress re-growth of *Imperata*. However, the creeping legumes required to be ‘weeded’ regularly from the rubber rows as they entangled the trees. Another major problem with *Mucuna* was the need to plant its seeds repeatedly as its life cycle was shorter than six months. This required additional labour. However, the seed of *Mucuna* from the previous crop could be sown to maintain the cover. The seed of *Pueraria* cannot be produced locally and it is not readily available in the local market. Likewise *Flemingia* also has problems with seed supply.

The fast growing trees may control imperata

The FGT in trials in Trimulya village were showed that all FGT were relatively successful in controlling *Imperata* re-growth, although nearly in half of the plots, *Imperata* was still

encountered. This is not surprising as the young trees in their early stage only had small crowns and could not shade out *Imperata* effectively.

There was no significant difference between the FGT species tried – *Acacia*, *Paraserianthes*, and *Gmelina*, either on controlling *Imperata* or on rubber growth. The negative effect of *Acacia* on rubber trees was obvious from the early years, however the reduction in rubber growth was quickly recovered after *Acacia* was cut down after three years. The rubber trees in these plots took around 6 years to reach tapping stage of 45 cm girth at 1 m above ground.

Comparison of rubber data from cover crop trials and FGT trials yielded quite interesting results. While FGT are better than *Imperata* and *Chromolaena*, they are not as good as legume crops in controlling *Imperata*. Rubber trees in FGT plots also grew slower and took an extra a year to reach tappable size compared to creeping legume crops (**Fig. 15**).

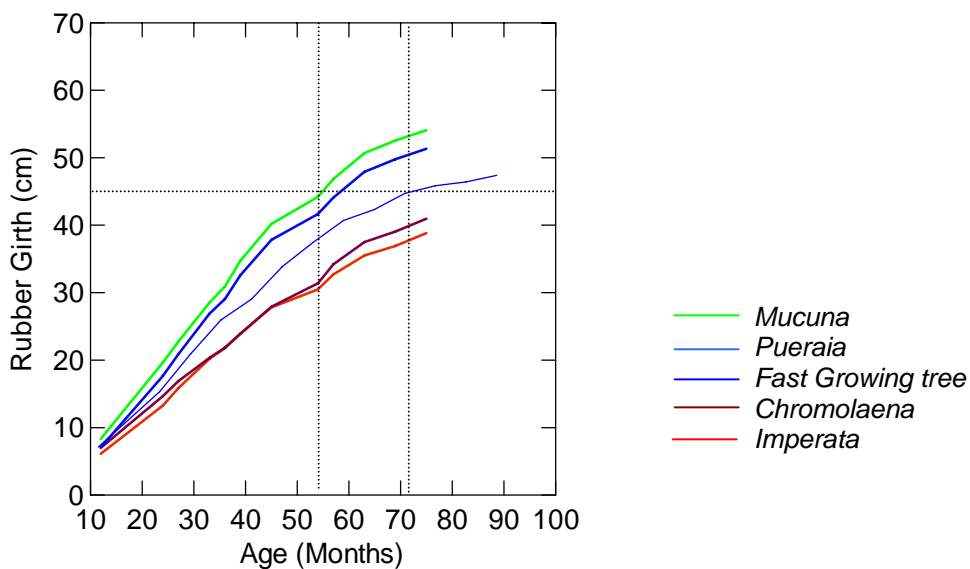


Fig. 15 Rubber growth in RAS3, with different species grown between rows

CONCLUSION AND RECOMMENDATION

Comparing results collected from on-station trials and on-farm participatory trials need certain precautions. However, implementing these two approaches, by understanding roles of certain growth factors, are very interesting. The analysis of results obtained from on-farm participatory trials is more difficult due to the un-control factors that may be interfered to the main factors set previously. The inventory of possible factors influencing the growth needs to be carried out very carefully.

Implementing participatory trials need a close relationship and continuous communication with farmers. Planning, implementing and modifying the trials have to be carried out under close discussion with farmers. Trust building between researchers and farmers is needed since the beginning of the activity, in order to achieve the objective of the on-farm trial. Once the trust is built, then the following programs and activities could be carried out more efficiently.

It is very common that farmers not follow all protocols that designed and fixed by researchers previously. This kind of problems is observed both in Jambi and in West Kalimantan. Again, a close relationship with farmers and try to understand why they do not follow the protocol is one of the tasks of the on-farm participatory trials. Beside that, intensive discussion is important to choose better technical options that adapted to farmers' needs.

From this brief summary of results, it is now clear that certain questions related to the double row spacing is partly answered, especially on the good spacing certain RAS. In term of rubber growth and possible longer exploitation of wider interrows for annual intercrops and tree crops, the 6mx2mx14m double row spacing is very encouraging model, using the fast growing rubber clones such as RRIC 100, PB 260 and BPM1 as the main tree crop.

Results summarised from this paper indicated that the trade-off between inputs (fertilisers, labours, chemicals) and growth or plant diversity is always of interest of most peoples. Due to many constraints faced by farmers, especially cash money for most Indonesian farmers, they have to choose between spending money and allocating family labours. The maximum rubber growth is not always the objective of farmers in establishing various RAS. The critical question is how providing technology options to farmers considering their constraints and opportunities.

The SRAS project has identified the important components to develop productive RAS for farmers. The first component is the availability of good planting materials, either for rubber (clone) or non-rubber species, the second is adaptability of RAS technology to farmers responding to the needs on low to medium cost of establishment (adjusting the available labour and cash), the third is capacity building of farmers and its necessary institutions (farmer group, market and marketing chains, funding institutions).

Comparing and analysing data acquired from Indonesia and other rubber producing countries, especially on the farming system aspects of RAS will be very interesting information, considering the dynamics of the farming systems in both countries. This analysis may be focused on different strategies of farmers in both countries facing the international price of rubber.

Acknowledgement

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