Main agronomic results of RAS on-farm experimentation network in West Kalimantan

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Key words: Imperata cyclindrica, biodiversity, weeding, rubber clone, imperata

Introduction

The research programme is based on the 3 following major activities:

- the implementation and monitoring of a network of on-farm trials using participatory approach to test Rubber Agroforestry Systems (RAS) with innovations such as the use of clonal rubber planting material in forest environment (RAS1), food crop intercropping during the rubber immature period and combination of fruit and timber trees with rubber (RAS 2), and the establishment a combination of covercrops and fast growing trees (in RAS 3 on degraded land with a frame similar to that of RAS 2);
- the farming systems characterization surveys in order to identify a socio-agro-economical typology of situations (with 1 MSc students from France and 1 SRAP staff);
- a budwood garden programme, to test whether clonal rubber can be produced by the farmers at low cost with a good quality (with one MSc student from France and 1 SRAP staff).

The local partners for field implementation are the Rubber Research Institute of Indonesia: IRRI/Sembawa (Rubber), and a Development Projects: SFDP/GTZ (Social Forestry Development Project). We will focus in this paper on the main RAS agronomic results in the province of West Kalimantan.

The achievements in 1997 have been the following:

- the set-up of an operational team in the province with ICRAF and IRRI scientists as well as collaborators based in the sites. SRAP has developed a base for multi-disciplinary work on various other topics such as farming system research, biodiversity study, nutrient management, below ground competition;
- the identification of the main components of a RAS (Rubber Agroforestry Systems) methodology for on-farm experimentation after 1-3 years of experience in the field (the most critical phase of establishment for RAS);
- the completion of the on-farm trials network (63 fields in West Kalimantan) and the budwood garden network (9).

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The RAS on-farm trials network

The expected outputs of this programme in the mid-term are a complete set of technical recommendations for RAS. In the short term the main issue is to identify the conditions under which rubber can grow optimally in an agroforestry environment for the critical first 2 to 3 years, in terms of cropping patterns, type of clonal planting material, levels of weeding and fertilization and rubber/associated tree combination. Other aspects such as associated tree species combination, rice and palawija intercropping or covercrops and pulp trees/MPT combination are being tested. The network may be summarized in the following table (table 1):

Table 1: **Farmers and agricultural school involved in RAS on farm experimentation**

Province	Village	No. of Trial	RAS 1.1	RAS 1.2	RAS 1.3	RAS 2.1	RAS 2.2	RAS 2.5	RAS 3	Farmer	Agricultural school
West-Kalimantan	5	15	5	1		2	3		4	63	1

Preliminary results of RAS on-farm experimentation

In terms of RAS establishment, the 3 main factors being evaluated are rubber planting material (clonal rubber), weeding level and fertilization amount, in particular phosphate (P) (Penot, Fairhurst et al. 1996). The most critical period for RAS establishment is the first 2 years where competition with weeds (in RAS 3) and/or secondary forest (in particular RAS 1) is the most aggressive.

The set up of the network has been done in 2 years between December 1994 and November 1996. The main criteria to define RAS performances in such various environment is rubber growth (diameter 10 cm above grafting point, as well as height and number of whorls), recorded every 3 months for the first 3 years. Rubber trees diameter appears the most reliable criterion for measurement of growth and competition. Other data collected concerns rice production (RAS 2) and associate trees survivability (RAS 2 & 3). The trials protocols and methodology has been discussed with farmers in a participatory approach (Penot, De Foresta et al. 1995). The data concerning rice intercropping are presented in the paper no.12.

RAS 1 Trials

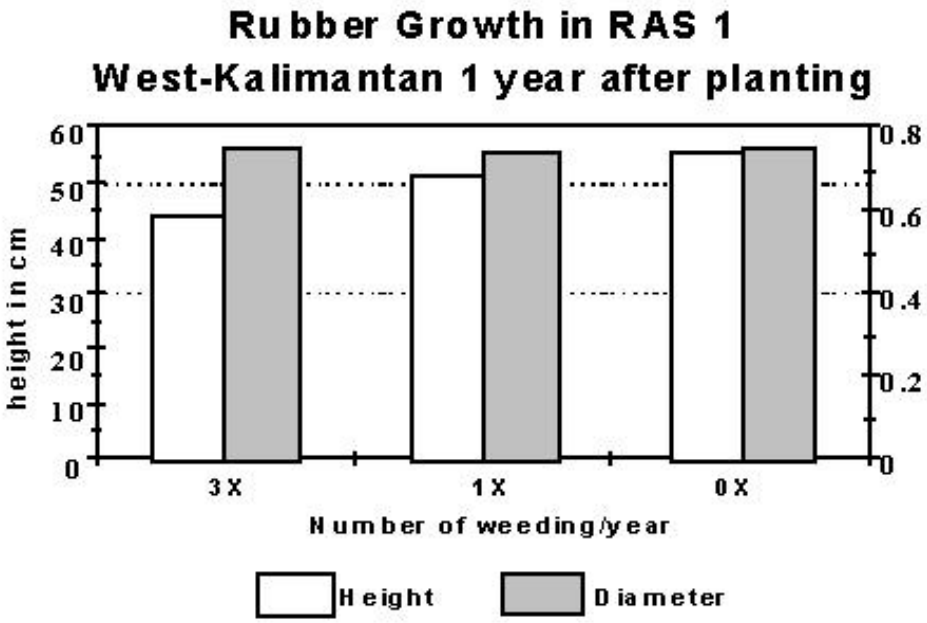
**Clonal rubber vs. secondary forest regrowth in RAS 1: the weeding level*

Early planting of rubber in polybag is an essential condition for all RAS establishment, in particular for RAS 1. The RAS 1 trial established in late 1996, at the beginning of the rainy season, with good quality planting material (from Goodyear North Sumatra) is as developed 7 months after planting than that of trial planted in January/February 1996, late in the rainy season. The treatment for the first year is based on 3 weeding levels (4x, 6x and 8x per year in West

Kalimantan, compared to 3x, 6x, 9x per year in Jambi). Protocols and in particular weeding frequency were not always followed in the first year of experimentation for the first set of trials. In West Kalimantan, generally "4x" was 2 to 4 weedings per year, "6x" was 4 weeding/year and "8x" was 4 to 6 weeding for the year 1 (only with the first set of trials planted in 1995). The control is 8 weeding per year and LCC in the inter-row (similar to monoculture cropping system). For the other sets of trials (planted in 1996 or 1997), or after the first year for the first set, farmers were following recommendations as confidence was built between researchers and farmers. In the year 3, the weeding frequency is reduced respectively to 2, 4 and 6 + control = 6 + LCC (monoculture) with one out of two weeding implemented with chemical ("Round Up" at 2 liters per ha on the rubber row only).

The first RAS 1 trials set has been planted in January/April 1995 in West Kalimantan, with only 0, 1 and 3 weeding/year. Figure 1 shows clearly that weeding level was not sufficient to overcome *Imperata* which systematically invaded all plots. Height and diameter of rubber trees is far below the normal growth level.

Figure 1



A minimum of 3 to 4 weeding/per year, regularly done due to regular pressure of *Imperata cylindrica*, is required as other coming figures demonstrate it. Figure 2 shows that rubber trees diameter is very similar for set 1995 and set 1996 with the fact that the set 1995 is 2 years old and the set 1996 is one year old only, showing therefore almost one year of growth delay for the first set of trials planted in 1995. We can see the same trend in figure 4 to 7, comparing 1995 and 1996 plantings. Figure 3 shows that the 2 sets of trials planted early 1996 (late in the 1995/96 rainy season) and late 1996 (early in the 1996/97 rainy season which is recommended) are very similar in term of growth which clearly indicate that

late planting in not recommended and is equivalent to almost 6 months of delay in growth.

Figure 2

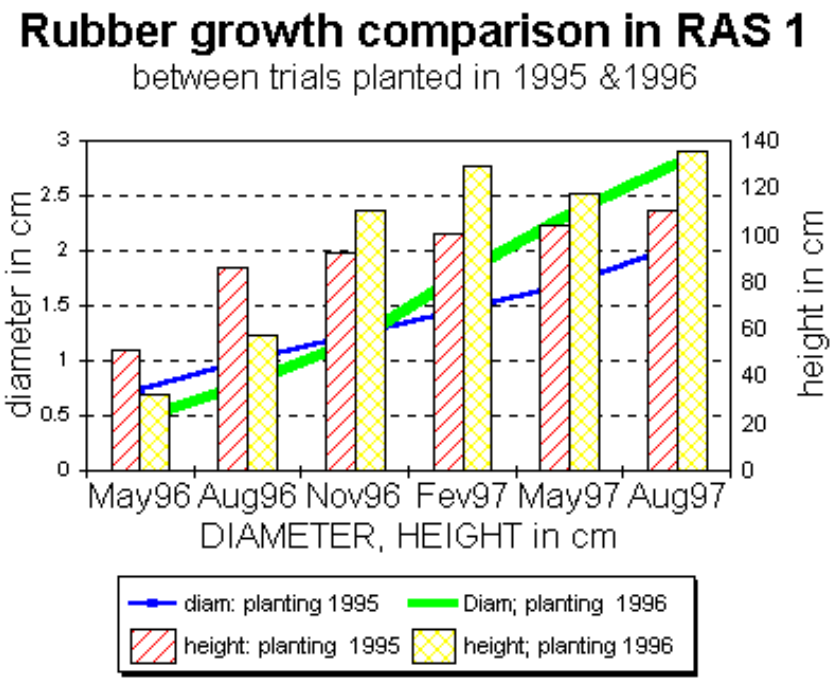


Figure 3

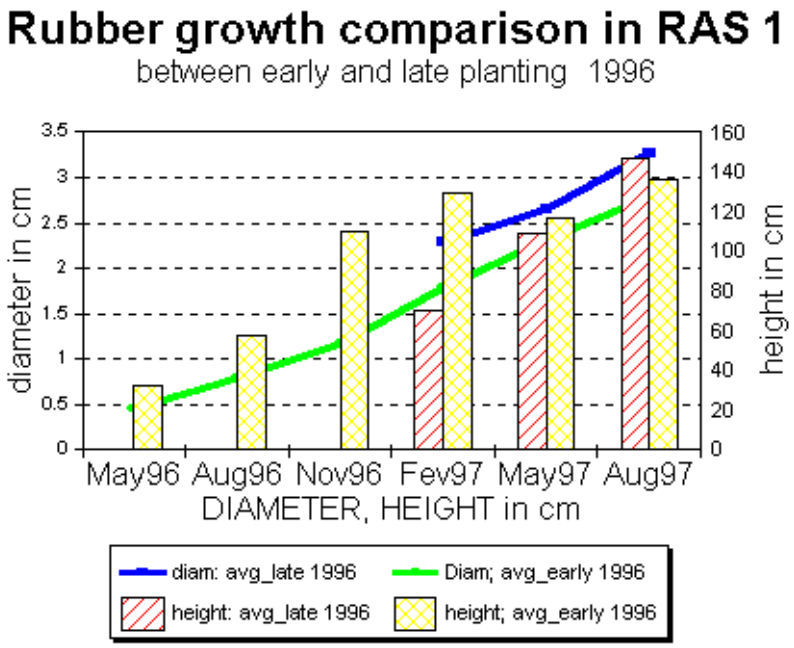
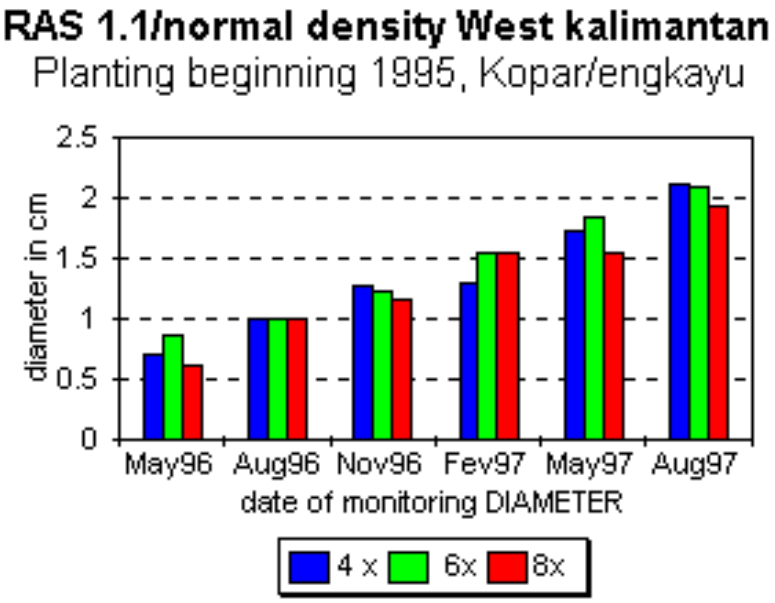


Figure 4



We must also inform that the fertilization amount was very limited for the first set of trials for the first year (200 grams of rock phosphate per tree at planting time only). Than that was clearly not sufficient in these very poor ferralitic soils. Looking at these results, our decision has been to provide a regular fertilization similar to that of TCSDP projects implemented every 3 months for all in coming trials. In any case therefore it is possible to compare the first and the other sets of trial. The first set of trials planted in 1995 should be considered as observations plots where both farmers and researchers were learning together from the very preliminary planting of RAS.

The first results for other set sets of trials planted in 1996 and 1997 (figure 5, 6 and 7) show that the required weeding level during immature period in RAS 1 for clonal rubber is far higher than that of jungle rubber (0 or 1 weeding per year): 4-6 weeding/year are required in West-Kalimantan due to Imperata pressure for the first year (8 weedings were never actually really applied by farmers in West Kalimantan for the first year), compared to 3-4 weeding/year in Jambi. After an ANOVA analysis (R. Akiefnawati), there is no significant differences between the treatments showing that 4 weedings (if 2 are implemented with an adapted herbicide) is sufficient compared to 8 weeding (equivalent to that used in monoculture system).

Figure 5

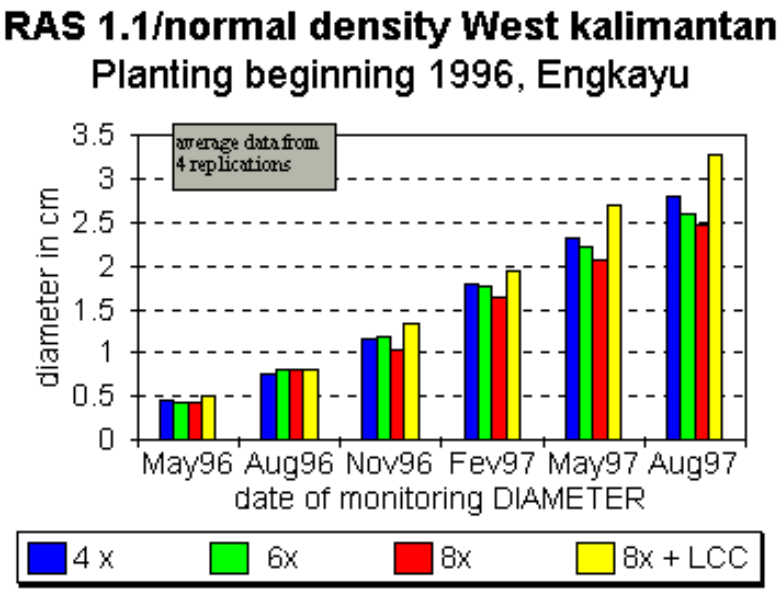


Figure 6

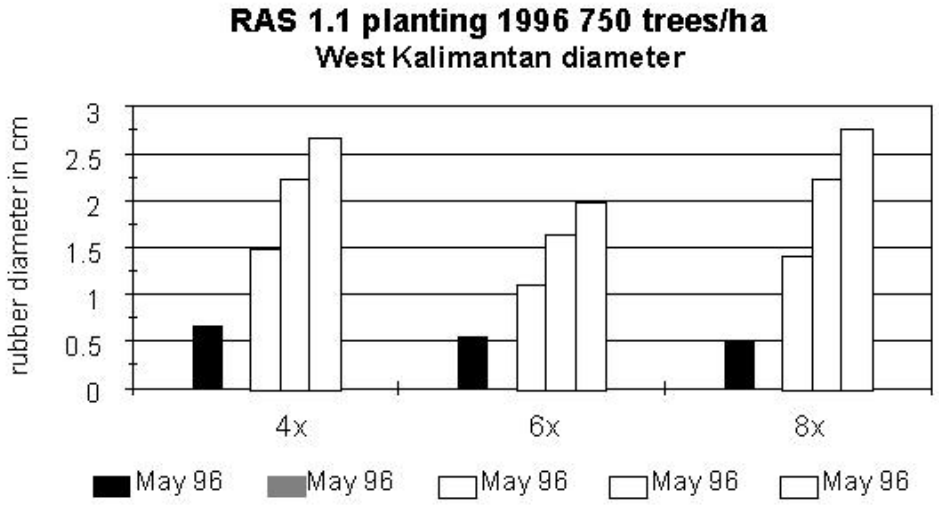
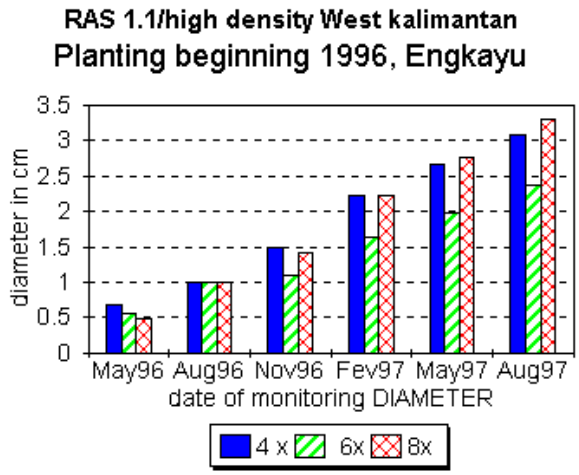


Figure 7



The regular number of weeding/year is relevant in West Kalimantan because *Imperata cylindrica* comes back regularly. In Jambi, the weeds pressure is depending on the environment (no *Imperata)*. For the second year, 2 to 4 weedings/year in Jambi and 2 to 4 weedings/year in Kalimantan are sufficient.

RAS 1.1 trial has been set up with 2 series of plots with 2 different planting density (550 and 750 trees/ha, the later without control with monoculture), no significant differences have been observed in the 2 series with 3 replications each planted in 1995 and 1996 (between the planting density, not between the years) (figure 6 to 10) except that the first set (1995) is obviously as we said before, very late in terms of rubber growth, due to insufficient weeding and fertilization level in the original protocol.

Figure 8

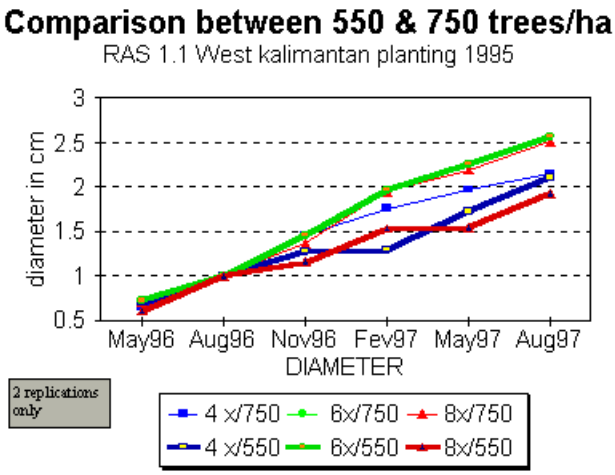


Figure 9

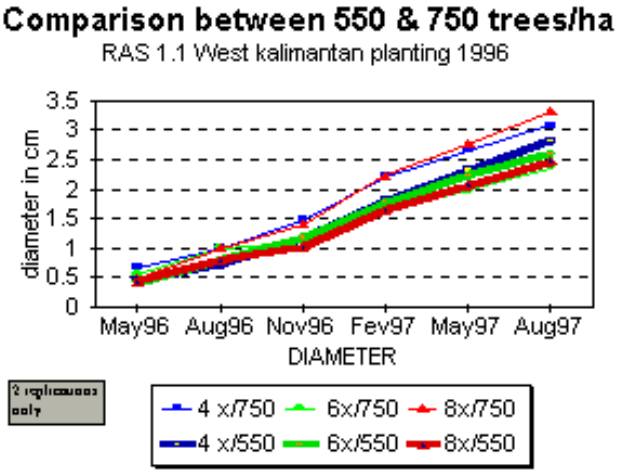
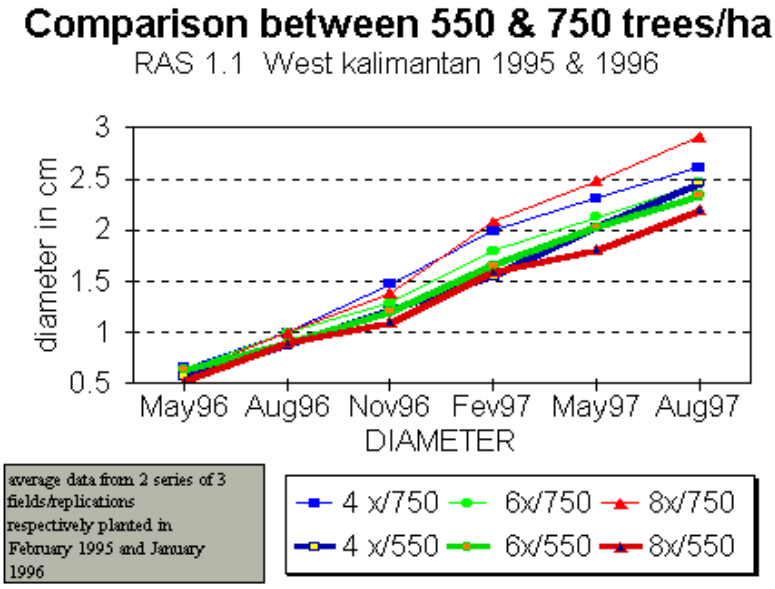


Figure 10



The weeding/fertilization couple is a key component in the trade off between rubber growth/competition and input/labour cost, in particular where fertilization is really required (Kalimantan). It is clear that after a sufficient fertilization supply is provide to the trees (it is not the case in Jambi province where fertilization is not required for the total immature period), the quality of weeding is a key thing in RAS establishment. It is also clear that 4 weedings per year, including some of them implemented with adapted herbicide are sufficient for a good rubber growth. This weeding level is half than that required by the monoculture system.

RAS 2 trials

**Annual intercropping in RAS 2.1 and 2.2: the most efficient alternative to favour rubber growth and optimize labour*

RAS 2 trials are divided into 2 different trials; RAS 2.1 focus on the effect of associated trees on rubber growth (in particular in the mid and long term), RAS 2.2 tests several combination of intercropping with the same frame of rubber and associated trees.

RAS 2.1

In RAS 2.1, treatments are on the type of associated trees combined with rubber. Weeding id done every 2 months (6x/year, for all RAS 2 trials). The inter-row is cropped with rice and/or palawija with an average fertilization. The Figure 11 shows that there is no effect of associated trees on rubber growth during the first 2 years. The small differences being due to other local factors and in particular temporary presence of Imperata in between two intercrops.

In fact, there is clearly no effect of associated trees during immature period as the selected associated trees have generally a slow growth (durian, rambutan) or, if fast growing, a non competitive canopy (such as Petai). We expect a possible competition of the associated trees, if any, between 10 and 20 years after plantation. Trials in Thailand show no such competition with similar fruit trees. Figure 12 displays the rubber growth in a specific RAS 2.1 field with 7 plots, established in the agricultural school of Sekadau (SPP Karya) where intercrops (vegetables) are established in both rainy and dry season. The differences between plots are explained by the presence or not of *Imperata cylindrica,* and not by the presence of a particular type of associated trees as these trees are too small at that stage to induce any competition.

Figure 11

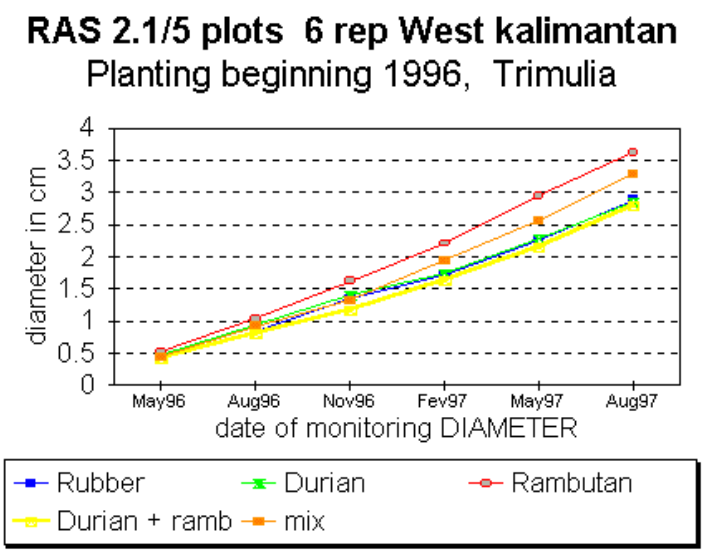
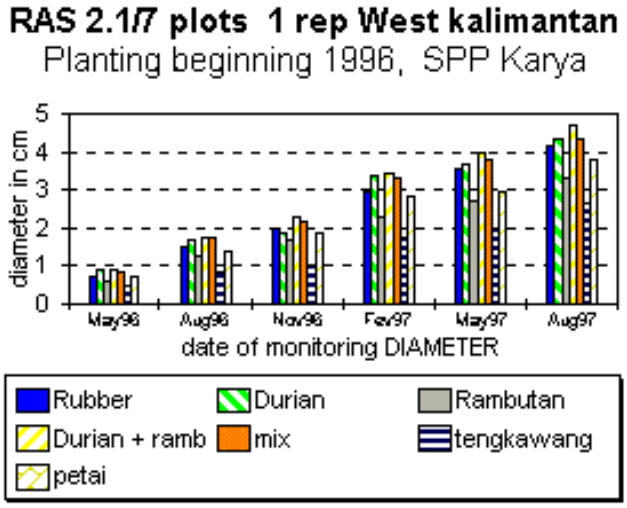


Figure 12



RAS 2.1 valid the fact that a limited number of associated trees (up to 250 trees/ha) with a certain selection (a limitation of big trees such as 25 Durian trees per hectare) do not influence rubber growth during immature period which is the most critical for RAS establishment.

RAS 2.2

By comparison with RAS 1, RAS 2.2 plots (Figure 13a and 13b) have a better growth performances close to that of a control, established with the average growth of 3 clones in monoculture well maintained (figure 14). High labour requirements have not been well accepted by some farmers indicating that farmers should know with precision the labour requirement of intercropping in RAS 2 before adopting such system. We arrived clearly to the extreme limit in term of labour that might be acceptable by Dayak farmers in West-Kalimantan for RAS 2.

Figure 13a

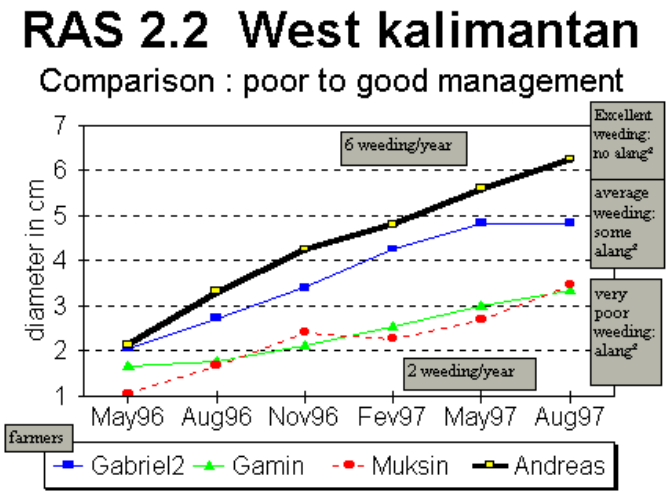
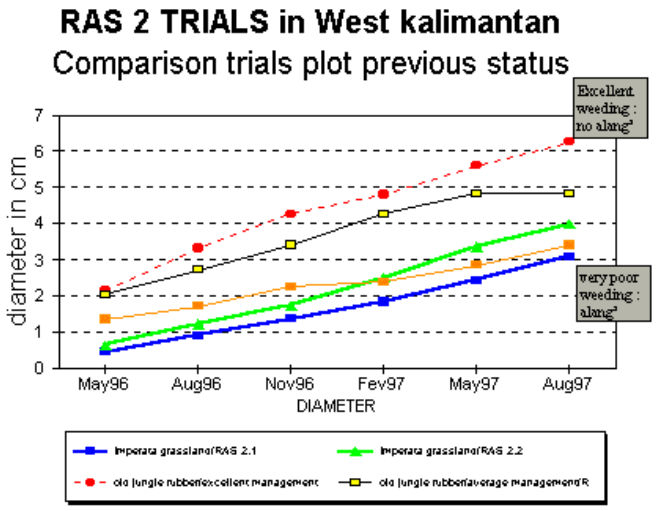
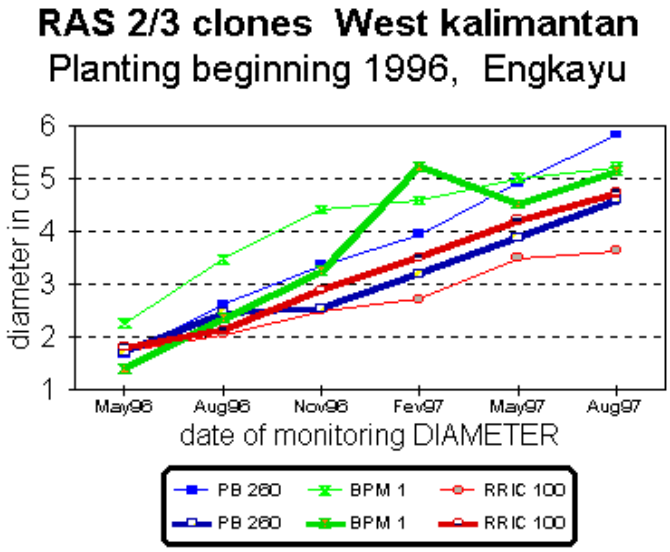


Figure 13b



It is also clear that the land status before RAS establishment is important in terms of land fertility and amount of work for weed control. The figure 13b shows that RAS 2 established after jungle rubber shows a better growth than that of RAS 2 in Imperata grasslands, due to Imperata competition.

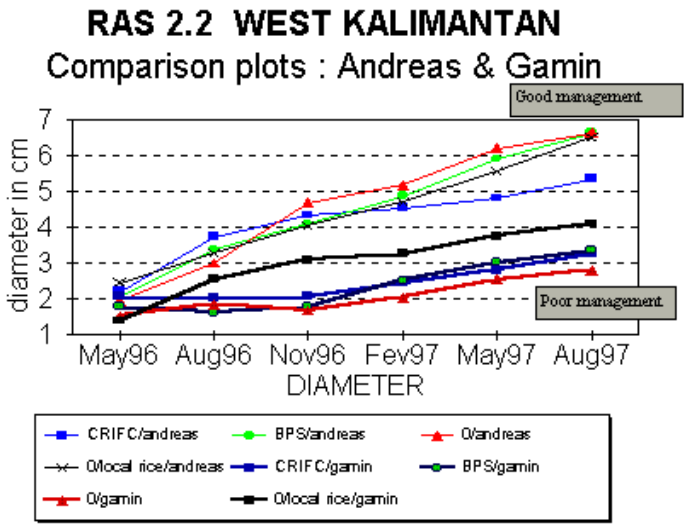
Figure 14



RAS 2.2 requires clearly a minimum weeding of intercrops (2 weeding during the intercrop season) and a good chemical weeding using Glyphosate ("Round-Up") before intercrop establishment in order to decrease the risk of Imperata cylindrica infestation during the crop. A continuous intercropping with an rotation of rice/groundnut is probably the best solution. But groundnut cropping requires a high amount of labour for ploughing the soil which seems to be acceptable by Javanese farmers in transmigration areas but not the by Dayak farmers in tradi-

tional areas. Figure 15 shows the effect on rubber growth of a poor intercrop management.

Figure 15



RAS 2.2 labour requirement is better accepted due to rice cropping and rice output in particular for the first year. The different rice fertilization level ("CRIFC" = high dose, "BPS" = medium dose and 0) have so far no effect on rubber growth during the first 2 years (see figure 16). Rice intercropping occurs only for the first 2 years as RAS 2.2 trials with rice up to the third year have shown that it is not economically interesting and very risky to grow rice during the third year (see paper n° 12 in these proceedings). Therefore the effect of rice fertilization on rubber growth is probably negligible as indicated by figure 16.

Figure 16

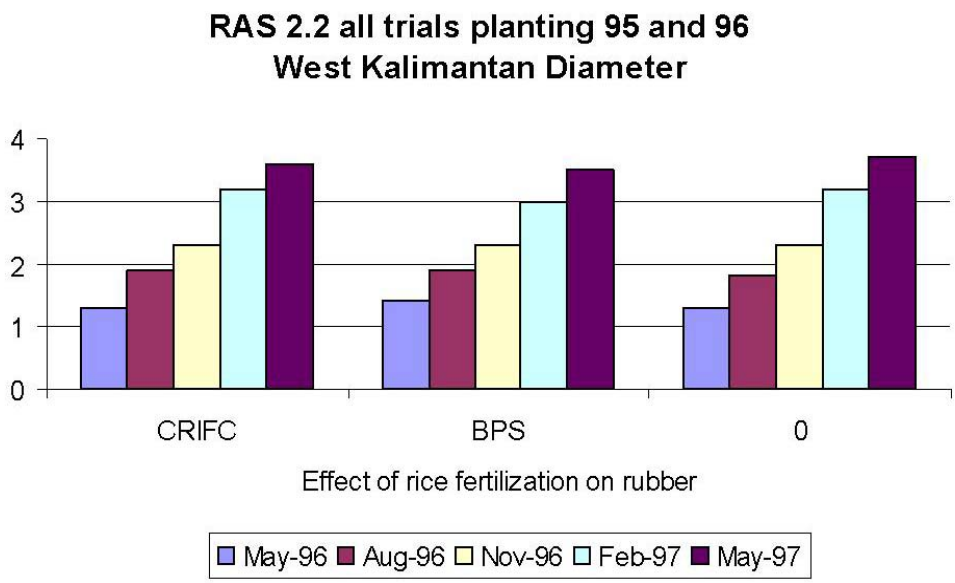
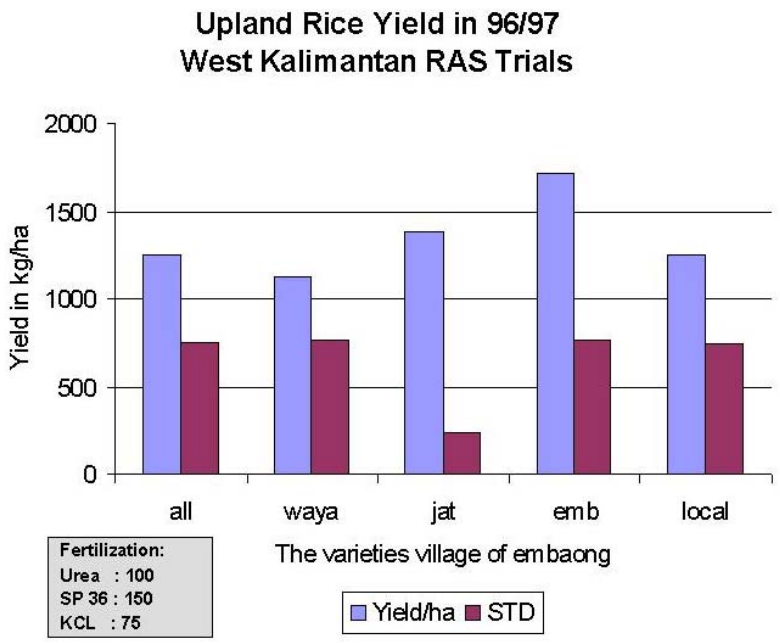
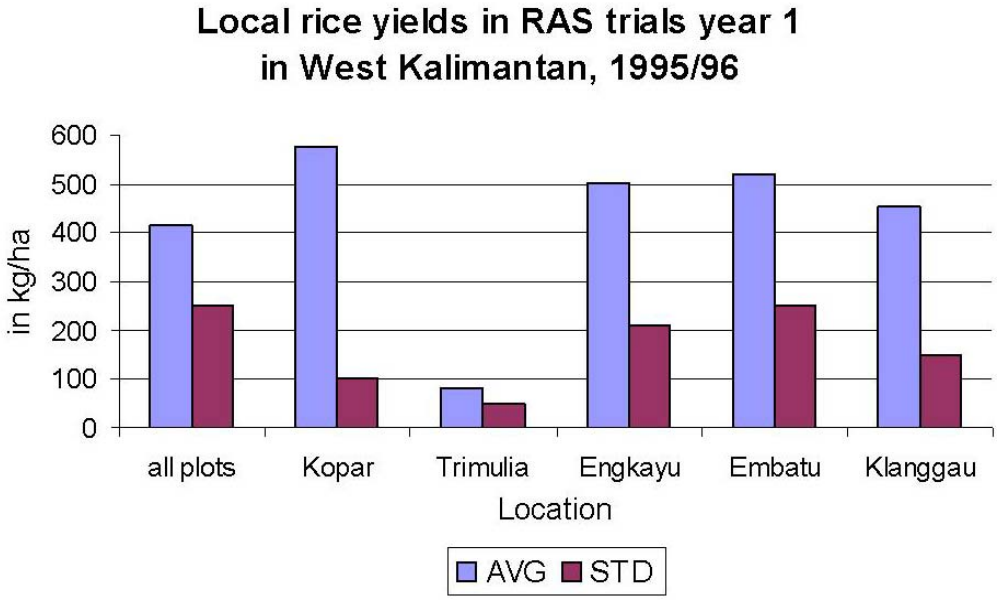


Figure 17.



Generally 1, sometimes 2 weedings, are implemented for rice. Glyphosate herbicide ("Round Up") was applied before rice planting. Growing rice with good local varieties (Embatu, Saim) or improved varieties (Jatiluhur and Way Rarem) are successful with a small amount of fertilizers and crop protection against insects at least for the first and the second year, in particular after clearing an old jungle rubber (See figure 17). The third year of cropping is generally not possible due to canopy shade or due to soil compaction (such as in RAS 2 fields implemented in former Imperata grassland in Kalimantan). Erratic rains, drought (like in 1994 and 1997) and delay of rain season increase every seriously the risk of crop failure in West Kalimantan. Rice experimentation in RAS 2 has shown a significant effect of N-P-K fertilization (at economic level) but not sufficiently, related to crop failure risk to be adopted by farmers. However yields are often too low to off-set the cost of fertilization while fertility is the first constraint in particular in former Imperata grassland, other factors for low yields are: poor rice seed quality and availability, susceptibility of rice to insects pests and blast, and erratic rainfall at critical periods (in particular after flowering), traditional planting patterns, shading after the second year and insufficient weeding. Some selected local rice (see figure 18), such as Embatu and Klanggau gave relatively good results with limited crop failure risks with a cycle of 3 to 4 months compared to other local varieties with a 6 month cycle.

Figure 18



CRIFC trial in the Jambi province shows that HYV upland rice yields may reach 2-3 tons/ha with a complete package using rice varieties such as Way Rarem and Jatiluhur, fertilization, 3 weedings and crop protection. In Imperata grassland, zero or minimum tillage is not recommended and rice/groundnut with ploughing rotation is recommended.

In West-Sumatra, the continuous upland cropping (rice/groundnut rotation and other palawijas[1]) is very favorable for rubber growth. In West-Kalimantan the figures 13a and 13b show that rubber growth is significantly affected by quality and level of weeding of rice intercropping with the example of 4 farmers having cropped rice but with a different level of weeding and maintenance. However, rice fertilization does not have any significant impact on rubber growth during the first 2 years.

RAS 2.2 experimentation is West Kalimantan is successfully according to farmers ability to provide a certain amount of labour for intercrops generally, RAS 2.2 fits well Javanese transmigrants as it is the only way to optimize their small allocated land (2 ha). Some Dayak farmers are also very interested by RAS 2.2 at the condition that they are limited either in terms of land, or in terms of labour. RAS 1 fit better Dayak farmers in terms of labour allocation and risk management as long as land is still available for traditional slash and burn.

[1] Palawijas are secondary crops such as maize, cassava, vegetables, soybean, and groundnut.

RAS 3

**RAS 3: covercrops/MPT/FGT[2] vs. Imperata at low labour cost*

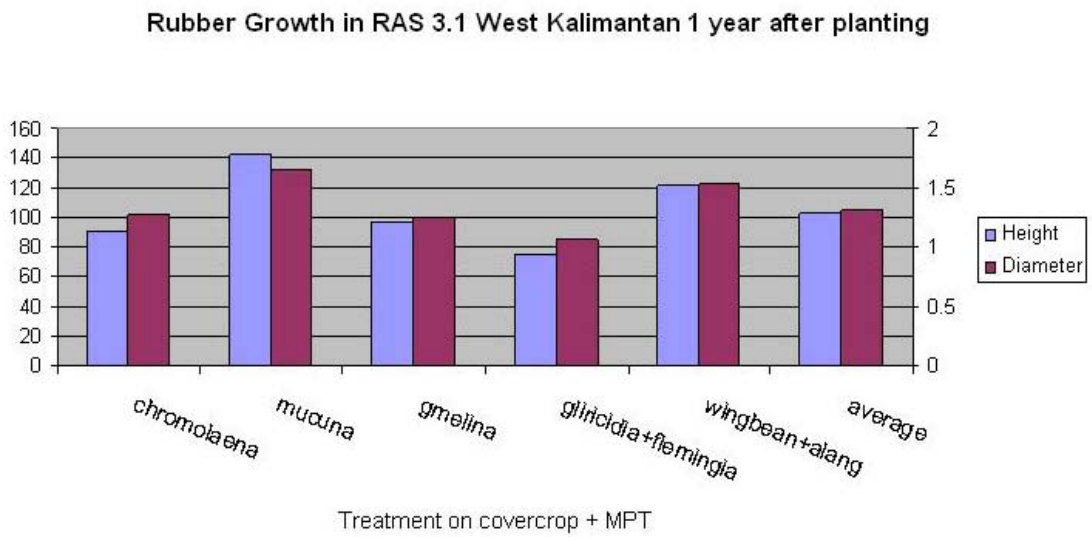
The main constraint for RAS establishment continues to be *Imperata cylindrica* in particular during the very first year after planting. The objective of RAS 3 is to find out what is the best combination with covercrops/MPT/FGT to overcome Imperata at a very low labour input.

The first set of treatments with various covercrops and MPT's has been entirely overcome by Imperata in 1995. Therefore, some RAS 3 trials have been transformed into RAS 1, because natural vegetation regrowth finally overcome Imperata after 1 year showing that a failure in establishing covercrops in RAS 3 may be recovered into RAS 1 according to the type of the surrounding vegetation.

RAS 3.1

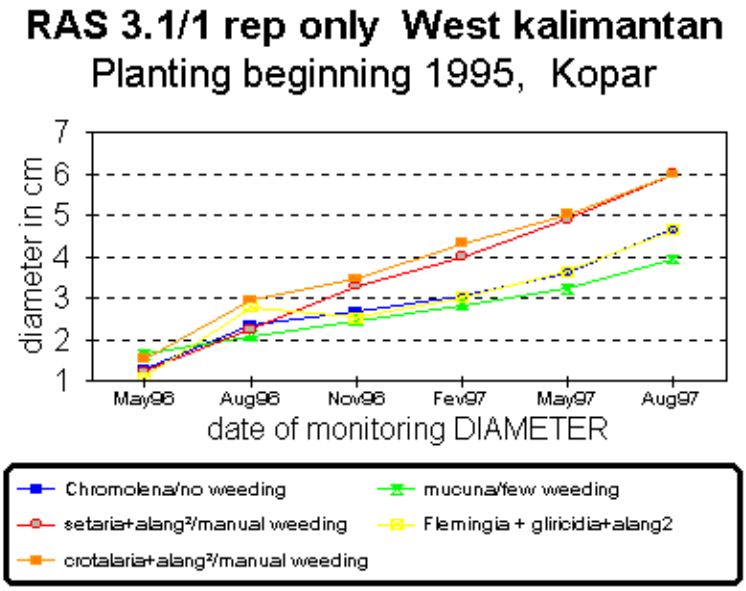
Following that first experience, a better selection of covercrops has been made on 1 "observation field" (RAS 3.1 see figure 19 and 20), in 1995 (the only RAS 3 field kept as RAS 3 from the first set planted in 1995).

Figure 19



[2] MPT = Multi Purpose Trees and FGT = Fast Growing Trees, namely pulp trees

Figure 20.



The best results were obtained with *Mucuna* and *Chromolaena odorata*. With *Chromolaena odorata*, *Imperata* is completely overcome and no weeding is necessary in the inter-row. One of the best result, with few weeding but the necessity to roll *Imperata*, is also reached with *Mucuna.*

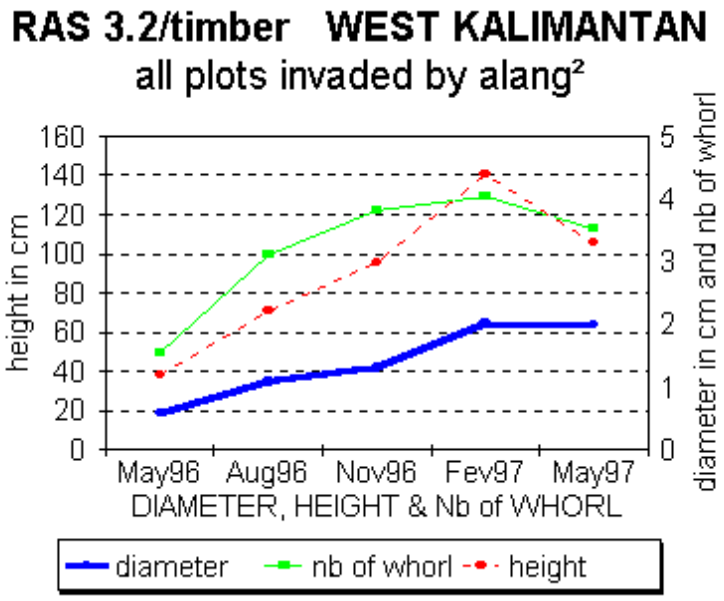
Preliminary observations on covercrop establishment in RAS 3 shows the following constraints:

- covercrop seed quality is very poor and lead to low density sprouting, generally rapidly overcome by Imperata,
- covercrops cannot grow well without a minimum supply of Phosphate (200 kg of rock phosphate per ha),
- the non-vine covercrop species (selected for minimizing weeding compared to classical LCC used in plantation such as *Calopogonium, Centrosema pubescens or Pueraria javanica*) such as *Flemingia Congesta, Crotalaria, Chromolaena Odorata, Wing bean and Mucuna* have difficulty in competing with *Imperata* in the first dry season.

RAS 3.2/timber

Rubber growth in RAS 3/2Timber (with timber trees only as associated trees) is very low due to Imperata that invaded entirely all plots, compared to rubber growth in RAS 3.1 with various covercrops. In fact, the very poor management of these 2 plots, completely invaded by *Imperata cylindrica* and the almost complete death of all associated trees lead to a complete failure of the 2 replications that can be considered as an *Imperata cylindrica* control. It is clear that a not controlled Imperata infestation lead to a complete stop of rubber growth and a high occurrence of rubber trees death within the next 12 months (figure 21).

Figure 21.



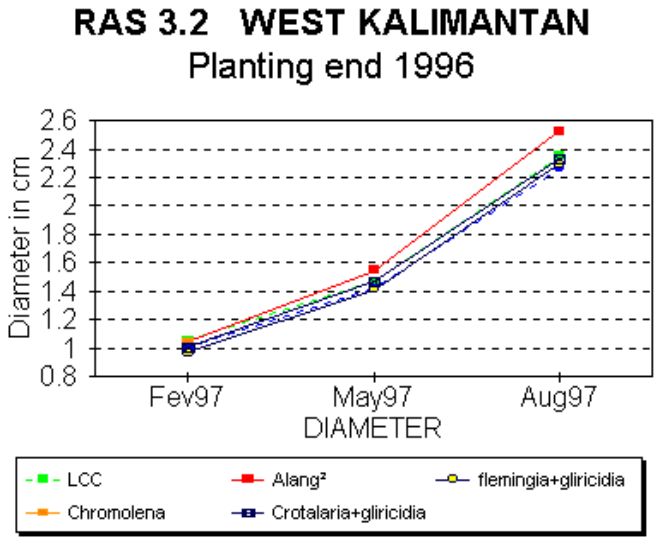
As covercrops cannot obviously overcome *Imperata* in current farmers 'conditions, shading seemed to be a low cost and efficient way to complement the role of covercrops in overcoming *Imperata* from the field

Shading from MPT=s or pulp trees, planted in October with rubber and rice, may help to overcome, or limit *Imperata* in the dry season. A combination of covercrops and MPT=s (*Gliricidia)* and fast growing pulp trees *(Gmelina arborea, Paraserianthes falcataria and Acacia mangium*) has been selected for experimentation in 1996 in RAS 3.2 (trials with various combination of covercrops and pulp trees),

RAS 3.2

Due to relatively poor management and poor Imperata control with Glyphosate at early stage of planting, most of the RAS 3.2 fields established in 1996 have been infested by *Imperata* and there is no significant effect between treatment during the first year (see figure 22).

Figure 22.



Note written in August 1998: in fact in 1998, some treatments have been really successful, in particular that with pulp trees (*Acacia mangium* and *Gmelina arborea*). In places where *Flemingia congesta* couldn't take place, the local vegetation, in particular *Melastoma*, Jaracanda and some large leaves pioneer species, has overcome *Imperata*, leading to a relatively good rubber growth. *Flemingia congesta* seems to be really adapted to the local environment but seed quality is very low leading to a high risk of covercrop failure.

RAS 3.3 and 3.4

in RAS 3.3 (the selected covercrop is Flemingia with various pulp tress and other associated fruit and timber trees) and RAS 3.4 (the covercrops is Flemingia + pulp trees at higher density with no associated trees).

Preliminary results still show the difficulty of establishing covercrops in farmers conditions but pulp trees, in particular *Acacia mangium* were growing well and very fast, shading the inter-row, therefore limiting *Imperata*. It might be questionable to see if *Acacia mangium* will not be too competitive for rubber. No significant differences have been observed between treatment for the first 18 months (Figure 23 and 24 for RAS 3.3 and figure 25 and 26 for RAS 3.4), but differences are expected after 2 years, in particular with *Acacia mangium* and *Gmelina arborea*. No differences were recorded between plots in RAS 3.3 (with 100 fruit and timber associated trees/ha, similar to RAS 2 frame, figure 23) and in RAS 3.4 (no associated trees, only pulp trees, figureure 25).

One can summarize according to 2 types of soils:

- on relatively good soils, after an old jungle rubber for example, *Acacia mangium* grow to fast when *Gmelina* a. and *Paraserianthes Falcataria* and *Acacia carcicarpa* are well adapted.

- on very poor soils, Imperata grasslands or very degraded soils : *Acacia Mangium* and *Gmelina* a. are well adapted when *Paraserianthes f.* and *Acacia carcicarpa* are not sufficiently developed.

Figure 23.

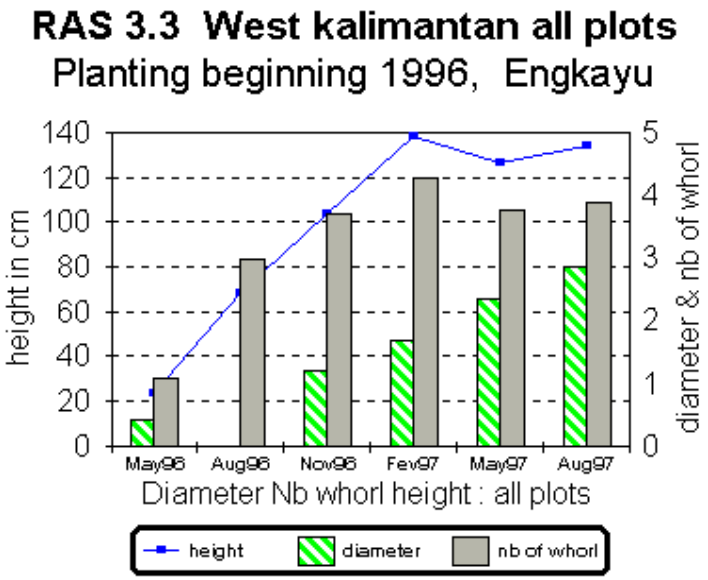


Figure 24

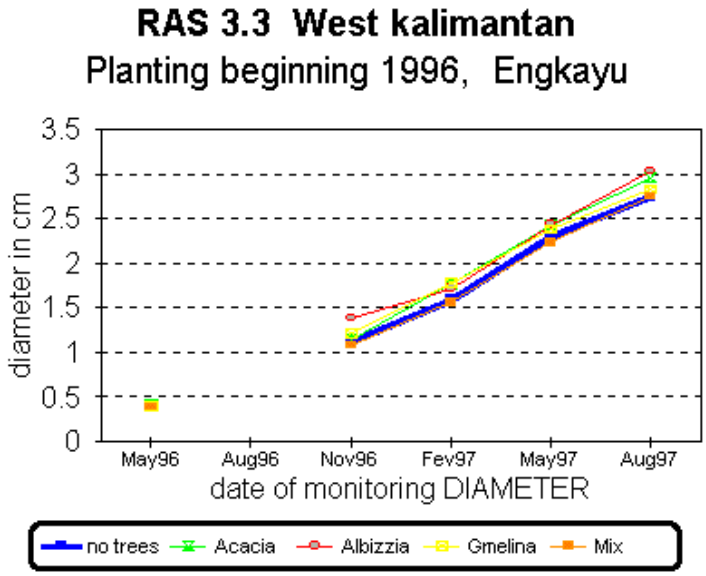


Figure 25.

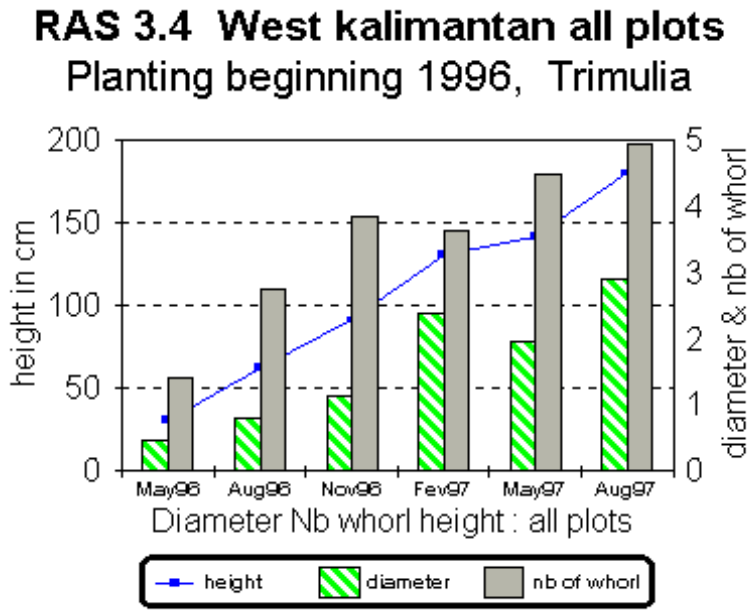
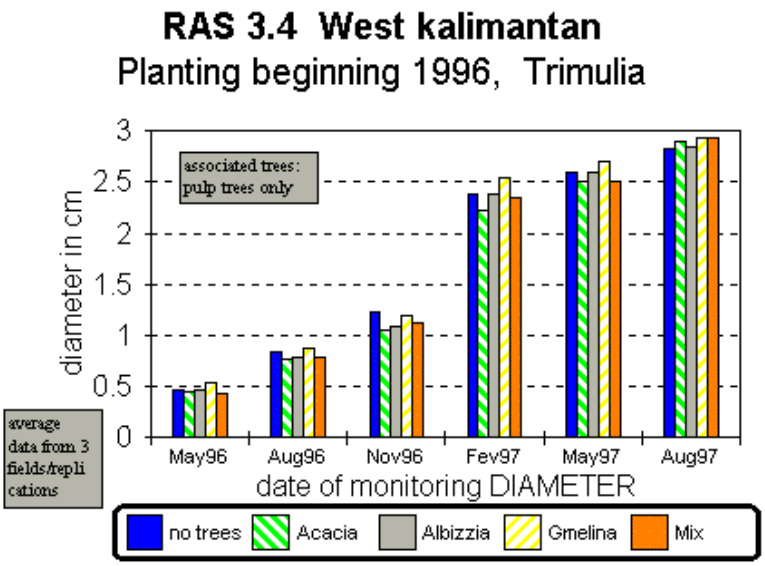
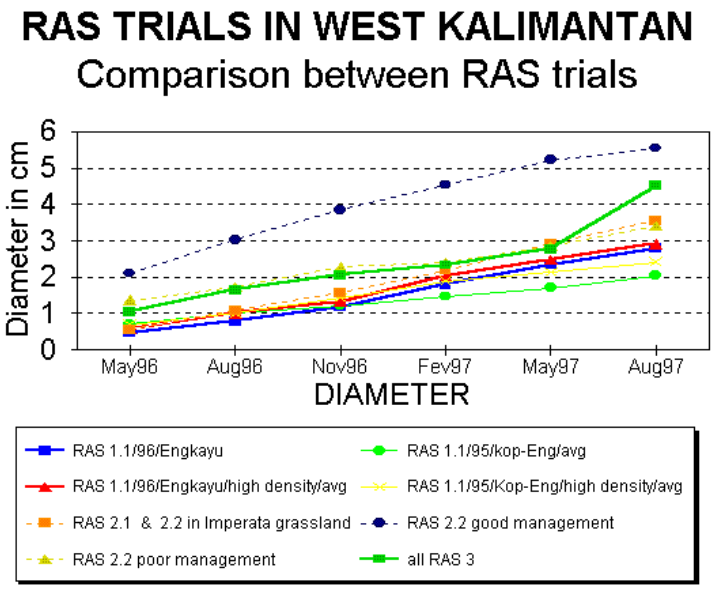


Figure 26.



The comparison between all RAS 3 trials (see figure 27) shows clearly that all plots have a very similar trend except the plot in RAS 3.1 with *Setaria* (1 replication only). Than that last plot has been largely manually weeded and might be considered as a control (Note; in fact in 1998 this particular plot is not anymore different).

Figure 27.



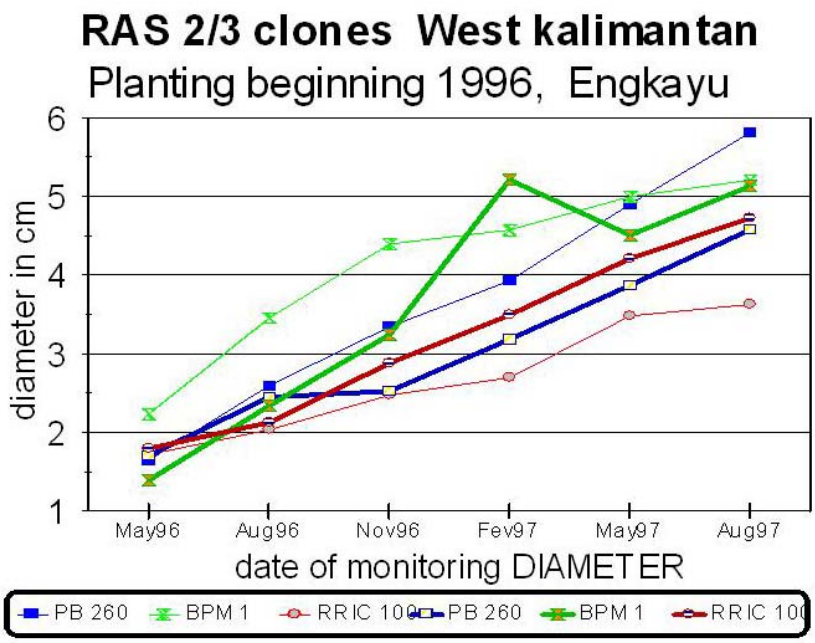
**Rubber fertilization: P is a key component for rapid rubber growth*

The first trials in West-Kalimantan have been planted with a very low level of inputs (200 grams of Rock Phosphate per tree at planting time) which has proved far from sufficient for growth of clonal rubber in competition with the forest re-growth in RAS 1, or with *Imperata* in the dry season with RAS 2. In West-Kalimantan, where the soils are very poor, the TCSDP fertilization programme (NPK every 3 months: 50 grams/tree N, 50 grams P and 40 grams K every 3 months) has been adopted for the first 3 years only and proved to be successful with also the supply of a large amount of Rock Phosphate (500 KG/ha) at planting time. In West-Sumatra, a previous demo plot (PKT/Pro-RLK/GTZ) showed the efficacy of large amount of rock phosphate (1 ton/ha) at planting time for rubber growth. P is definitely a major limiting factor in all sites, but N-K is also necessary in West Kalimantan, at least for the first 3 years (compared to the 6 years of rubber fertilization in TCSDP recommendations for Kalimantan).

**Comparison between clones: the importance of good clonal recommendations*

Comparison between clones (figure 28) shows that BPM 1 and PB 260 have the best growth performances, followed by RRIC 100, however BPM 1 seems to be more variable.

Figure 28.



The selected clones are all high yielding, fast growing, resistant to leaf diseases (in particular *Colletotrichum*) and adapted to farmers tapping (BPM 1, PB 260, RRIC 100 and RRIM 600, introduced in 1996). In Jambi, GT 1 shows relatively good performance however Colletotrichum is rampant in that province (as well as in West-Sumatra). It is preferable to use in RAS clones that are tolerant or resistant to that leaf disease as a forest environment, the combination with other trees may increase the risk. Pigs and monkeys are the main constraints in forests margins in Jambi but are not a constraint on West Kalimantan.

The above indicated the importance of establishing accurate and reliable clonal rubber recommendations based on field trial observations in various ecological zones. This lead to the planting of a RAS 1.2 type trial with the 4 selected clones (and seedlings) in order to compare their performances in an agroforestry environment. These selected clones are PB 260, RRIC 100, RRIM 600 and BPM 1.

Conclusion on RAS experimentation

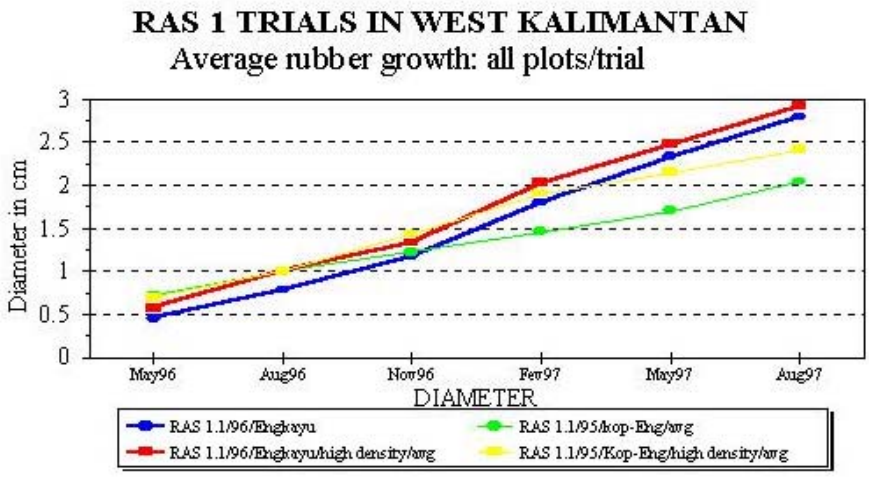
Early planting of stumps in polybag is a key in RAS establishment. In all cases, the early planting of rubber stumps with 1 whorl in polybag at the very beginning of the rainy season in October is an absolute necessity for a good RAS establishment and ensure a good rubber growth compared to that of secondary vegetation in RAS 1, as well as associated trees and crops in RAS 2 and 3. The direct planting of stumps has been partly a failure in West Kalimantan (and also in West-Sumatra) due to very poor soils, to erratic rainfall, and has also lead to high losses due to poor quality of planting material supplied by a local development project (though this may reflect the quality of planting material to which farmers may have access) in particular for the first set of trials planted in 1995

with TCSDP planting material. The "Tapih system" which consists in using local material such as banana leaves or bamboo to replace the polybag, has not been successful.

All other trials after this first 1995 set have been planted with stumps from PT Goodyear or stumps produced by SRAP, both of very good quality and size with maximum clonal purity guarantee.

Figure 29 shows clearly that the 1996 set of trials have a better rubber growth than the 1995 set for all RAS 1 plots confounded linked with more adapted practices in terms of planting date, type of planting material, number of weeding and fertilization. The 1995 set of trials can be considered as a preliminary test with farmers in participatory approach to clearly identify the shortcomings of the very first RAS protocols.

Figure 29.



The stumps in polybags have already developed in 3 to 4 months a good root system necessary for a rapid growth, in order to be sufficiently developed after plantation at the dry season (March-September) and to be able to compete with secondary forest regrowth in RAS 1 and *Imperata* in RAS 2 and 3. The availability of good quality stumps with sufficient girth is also a significant criterion. In West-Kalimantan, stumps are traditionally produced with a small diameter due to poor growth in nurseries and the fact that seeds for rootstock are available only in February compared to November in North Sumatra, leading to 6 months only in nursery (for 1 year in North Sumatra). This highlights the necessity to produce recommendations for building a clonal rubber planting material supply system with higher quality that may be achievable by farmers, in particular concerning rootstock seeds and budwood availability as well as technical information on nursery management 18 months instead of 6 months in West Kalimantan, in order to produce thick rubber stumps.

As competition with weeds is important, and in particular *Imperata*, water is probably the main constraint in the dry season (with a possible stop in growth) as shown also in experimentation in South-Sumatra (Wibawa, 1995), confirmed by

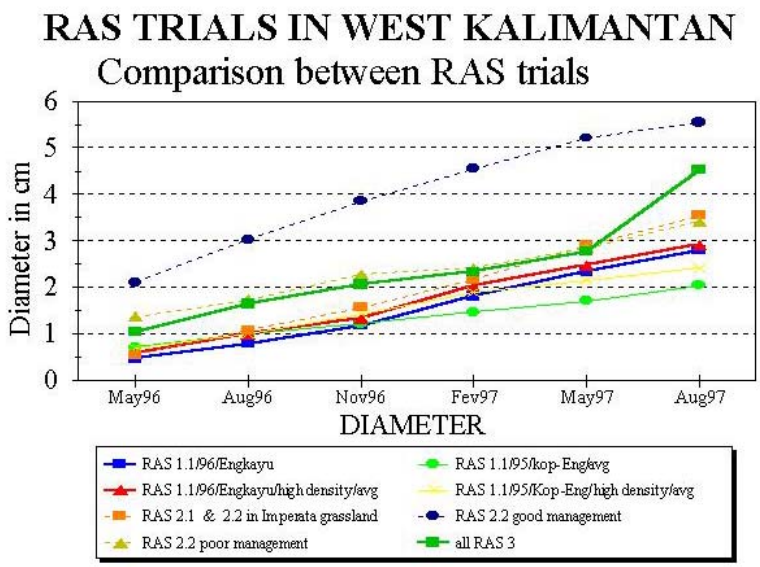
RAS experimentation when a late planting in the rainy season lead to almost a 6 months delay in growth compared to trials planted at the beginning of the rainy season. Another constraint in RAS 2 is the availability of associated fruit and timber trees, the necessity for the farmers to establish their own nursery and the relatively high mortality of the trees in the field due to insufficient weeding of fertilization. Labour investment is generally low (except by the Minang farmers in West Sumatra), justifying at least on a farmer's point of view the low labour approach. In West-Kalimantan, a medium level of inputs, in particular fertilization, is necessary for RAS establishment. It seems also reasonable to recommend the use of poultry organic matter for associated trees.

The use of Roundup to control Imperata is the best efficient way, both technically and economically speaking (as a labour saving technique), to control weeds and Imperata as it saves numerous days of manual weeding. Manual weeding can be partly or totally replaced by chemical weeding in the rubber row. Another advantage of chemical weeding using a systemic product (Glyphosate) is that the effectiveness of the product is higher (3 to 4 months) than that of manual weeding (1 to 2 months).

Comparison between all trials

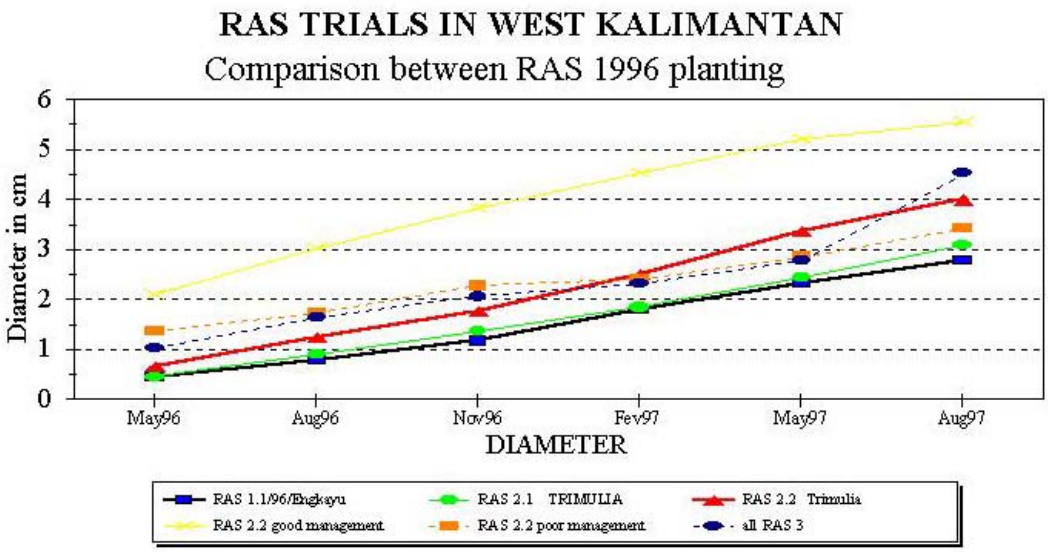
Globally, all plots confounded per trial (see figure 30), RAS2.2 with good management (good rice cropping and 6 wedding/year on the rubber row) shows the best results in terms of rubber growth, far above trees in RAS 1. But the first set of RAS 1 trials (1995 set) suffers from insufficient weeding and fertilization and are definitely not representative. Second series of RAS 1 trials (see figureure 31 with 1996 set of trials) show far better results. In fact in RAS 1 trial in Engkayu, rubber trees have a better growth than that of RAS 2 trees in transmigration areas (Trimulia) due to the negative effect of *Imperata* in these areas.

Figure 30.



As long as Imperata is controlled, rubber growth is correct in RAS 3 but further research is necessary for RAS 3 trials as more competition might be expected from some of the selected pulp trees through the trade-off between shading Imperata and competition to rubber (in particular for *Acacia mangium*).

Figure 31.



With such results, and according to RAS protocols (see in annex 1), it has been clearly demonstrated that the RAS 1 concept, very close to that of jungle rubber: clonal rubber + secondary forest in the inter-row, is a valid concept that is proven to be adapted to local smallholders conditions, in particular according to their limited capital and labour resources. The use of Glyphosate is clearly also the best labour saving method that enable a limited number of weeding in the rubber inter-row compared to that recommended in the monoculture system. It has been also proven that the secondary vegetation in the inter-row is, so far, not more competitive for rubber than the viny covercrops traditionally used in monoculture (control plots).

For RAS 2, the success of RAS establishment depends on the quality of management applied on intercrops where control of Imperata during and after the crops is essential. There is no negative impact of associated trees, even at high density such as 250 associated trees/ha (for 550 rubber trees /ha). Intercrops should be carefully chosen. A rotation rice/palawija (groundnut in particular) is essential in *Imperata* grasslands.

RAS 3 concept need further research but preliminary results show that the association between a simple non-viny covercrop (*Flemingia congesta* or *Chromolaena odorata*) with pulp trees (*Acacia mangium* or *carcicarpa*, *Gmelina arborea*) seems to be very promising as well as cost and labour-effective in suppressing *Imperata*.

Cost-Benefit analysis of RAS technologies compared to jungle rubber and TCSDP rubber monoculture system.

A preliminary economic analysis of 7 rubber based systems ranging from the least intensified, but the most used and traditional in Indonesia - jungle rubber - to the most intensified, RAS 2.2 with annual and perennial intercropping has been done (Penot 1996) through the calculation of NPV (Net Present Value), incremental benefit (compared to the jungle rubber system) and return to labour over the complete lifetime (up to 35 years), the productivity per type of crop, the return to labour and the incremental net benefit for various rubber based cropping patterns compared to jungle rubber in order to compare economic rationale of RAS to other systems (jungle rubber and monoculture). The 7 systems are described in table 2 and 3.

Table 2

The 7 systems are the following:

1. **Traditional jungle rubber with unselected rubber seedlings** (actual existing system): this system has no cost other than labour in term of inputs and is very extensive.
2. **Jungle rubber with clonal seedlings (GT1)** (existing system, in particular in areas close to estates, but not yet well developed**)**: this system uses a planting material available in all zones where estates have been established with clones. The cost of establishment is limited to the cost of the seeds or seedlings.
3. **TCSDP like monoclonal rubber plot** (existing as development schemes): this system is based on the traditional project technological package developed by TCSDP[3] including clones and a high investment of weeding and maintenance. This system requires a high level of input and labour and is, so far, considered the 'modern and intensified' rubber cropping pattern. Costs are TCSDP estimates (TCSDP reports, DGE), adapted with 1996 prices. In 1995, TCSDP has introduced upland rice intercropping in its technological package, so we did (for the first 3 years with improved rice and fertilization).
4. **RAS 1**[4] (experimental): this is basically a jungle rubber system using clones and a minimum of inputs (TCSDP like fertilization for the first 2 years) and labour (weeding is limited on the row). The inter-row is not weeded and secondary forest is allowed to grow replacing the traditional LCC covercrops used in TCSDP system. This system is similar to the

[3] TCSDP = Tree Crop Smallholder Development Project/World Bank

[4] All Rubber Agroforestry Systems have the following characteristics:

- Rubber is planted at 550 trees/ha (6 x 3 meters). The selected clones are PB 260, RRIC 100, RRIM 600 and BPM 1.
- Associated trees (if any) are fruits (local and improved rambutan) and local timber trees at 92 trees/ha (9 x 12 meters).
- FGT (Fast Growing pulp Trees) are planted at 3 x 3 in between rubber and associated trees (400 trees/ha). They are harvested the 5th year after planting.
- cinnamon is planted at 3 x 3 in the inter-row and harvested the 7th year.
- fertilization follows TCSDP recommendations for the first 2 years.

"jungle weeding" as referred by Djikman (1951) but adapted to modern clones. This is a low input/medium labour system. The challenge here in terms of research is to see if clones can compete and grow well in an agro-forestry environment at a given level of inputs (basic fertilization) and labour (minimum number of weeding per year). Emphasis is put on return to labour optimization. Biodiversity is expected to be similar to that of jungle rubber. The target is the farmers in pioneer or remote areas, as well as those with limited labour resources. Biodiversity in RAS 1 is high, similar to that of jungle rubber.

5. **RAS 2.2** (experimental): rubber + associated trees + rice intercropping the first 3 years. Associated fruits and timber trees are planted at a density of 92 trees/ha. Improved or 4 months local rice (with fertilization) is grown during the immature period. The system is intensive with a medium level of input/labour requirement. Income is diversified with rubber, rice, fruit and timber production.
6. **RAS 2.5** (experimental): rubber + cinnamon: this system is specifically developed for the Jambi province where cinnamon is a recent opportunity for local farmers. A cinnamon planting density of 3 x 3 meters results in 1100 cinnamon trees/ha intercropped with rubber.
7. **RAS 3.3** (experimental): rubber + associated trees + FGT (fast growing pulp trees): this system is designed for degraded lands where Imperata is a major risk. The first year is cropped with rice; immediately after the harvest non climbing covercrops such as Flemingia or Crotalaria are planted in order to limit the level of weeding. Associated trees and FGT are planted in the inter-row. FGT are harvested in the 5th year. This system is specifically developed for West-Kalimantan (Sanggau area) where pulpwood species can be sold to the planned pulp factory.

The main difference between RAS 1 and RAS 2/3 is that RAS 1 requires a specific environment to be set up with surrounding vegetation being forest, jungle rubber or tembawang with no Imperata. The associated trees are those which naturally growing and subsequently selected by the farmer. In RAS 2/3, associated trees are directly planted by the farmers who can choose the species among those which are adapted and are not too competitive with rubber. In RAS 2/3, tree diversity is limited to the cropped species, however farmers may select among the naturally growing species those which have an economic output.

All systems except RAS 2.5 have rice intercropping the first year.

Table 3. Economic analysis of rubber based cropping systems: characteristics of calculation.

In this first financial analysis, there is no depreciation of initial investment during the immature period. It is assumed that farmers do not use credit in order to simplify the assessment of rubber systems performances. To provide a criteria of comparison for this initial investment, we present the number of days of work at local opportunity cost (generally in an estate nearby for a daily wage of 3 500 Rp[5], that is the case in West-Kalimantan) that are required to cover costs of investment. A further analysis should include a credit scheme. A credit scheme will not significantly change the long term financial analysis. Costs and benefits are calculated in net present value (NPV) with value at the end of the period (1 year) with a rate of interest at 15 %, equivalent to the current real interest rate in Indonesia (table 1). The total net benefit includes that of rubber, rice, fruits, cinnamon and timber for the overall lifetime of each system, voluntary limited to 35 years (possibly more). RAS 2.2 and 3 systems with associated trees may also evolve, beyond the rubber lifespan, into fruit and timber based agroforestry systems. Rubber wood from seedlings is counted only as fuelwood with a limited value but may be sold later as a valuable product (for particle board or pulp for instance). Clonal rubber wood is expected to be sold as a valuable timber product in particular for furniture industry. In all case, rubber wood harvest is contracted.

Costs are effective costs observed in current on-farm experimentation of SRAP. Prices are those observed in February 1996. Production and labour requirements are assumptions based on previous surveys (Gouyon, Barlow....) or farmers interviews.

The analysis is based on the situation in West-Kalimantan with no fencing cost (except for RAS 2.5 system, based on rubber and cinnamon in Jambi only). In RAS 2.2 and 3, timber trees are harvested 35 years after planting yielding a modest benefit. Fruit production is annual for petai and jengkol and durian, duku and rambutan are assumed to fruit every 3 years. We also assume that yields are low and only 50 % of the production is actually sold for which gives us 40 producing trees/ha. Distribution between trees is the following: fruit trees are 75 % (70 trees/ha with 60 producing trees) and timber trees 25 % (22 trees/ha).

Labour for tapping is limited in RAS systems to 120 tapping days (1 tapping day is 0,5 man day) as PB 260 and other selected clones allow a D/3 tapping system (tapping every 3 days) without any decrease in production. Jungle rubber is tapped more frequently (200 tapping/year so 130 man days including other activities). Labour is converted into total man days in our calculation. It is assumed that rubber is tapped by the owner.

Production patterns have been carefully adjusted to account for the normal evolution of production including losses of trees. In RAS 1, 2.2 and 3: rubber yield

[5] However official minimum daily wage is 4600 Rp in March 1996 in Indonesia, the daily wage observed in West-Kalimantan and Jambi provinces is generally close to 3500 Rp.

has been slightly reduced (10 %) due to possible competition with associated trees compared to that of a TCSDP monoclonal rubber plot (this is an assumption). RAS 2.5 rubber production is assumed to be similar to that of TCSDP as cinnamon is harvested the 8th year with no further competition. Production and prices for fruit and cinnamon have been assessed from interviews with farmers and ENSO/West-Kalimantan for pulp trees production. TCSDP system may be adopted by farmers on their own or though projects. A line in table 2 shows the actual cost of TCSDP system in project, including project costs (evaluated at 1,5 millions Rp in 5 years).

RAS recommendation domains

In all cases, rubber is the main economic driving force of each system. Income diversification enable farmers to profit from market opportunities for fruits, timber, rattan and other non-timber products. RAS 1 and RAS 2.5 are designed for farmers in remote or pioneer areas with low cash availability and without land shortage. RAS 2.5 is targeted especially for piedmont zones close to the Barisan mountains in Sumatra. RAS 2.2 is the most intensive system aimed at farmers with severe land limitation such as transmigrants. Farmers in degraded areas with Imperata (in West-Kalimantan for instance where the risk is high) are targeted for RAS 3.

The economic rationale of RAS technology.

The incremental benefit of RAS systems is in the same range as that of TCSDP for RAS 1 (see figure 32) and significantly superior for RAS 2.2, 2.5 and 3 due to the non-rubber components production such as fruits, cinnamon or pulp trees production. The most intensive systems, TCSDP and RAS 2.2 are very sensitive to labour cost, in particular for RAS 2.2. Figure 32 shows RAS incremental benefit for 3 labour costs respectively: 2000 Rp/day for upland rice cultivation labour productivity, 3500 Rp/day equivalent to the real local opportunity cost (estate daily wage) and 5 000 Rp/day corresponding to the labour productivity of rubber share cropping.

RAS incremental benefit is far higher than that of jungle rubber, even using clonal seedlings, mainly due to the fact that the total income comes from rubber and rubber productivity with clones is multiplied by 3. In addition to other sources of income. Incremental benefit is still very attracting at high labour cost, but then systems are in the same range. RAS systems are aimed to decrease labour requirement and gives a very interesting output in the case of low opportunity cost, which is generally the case in most rubber producing areas except South and North-Sumatra provinces.

Figure 32.

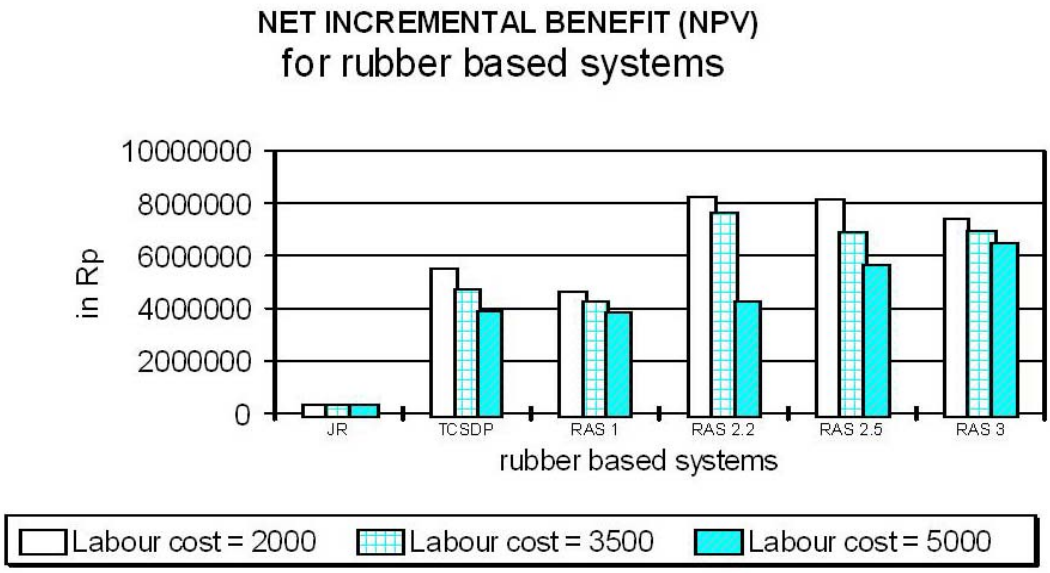
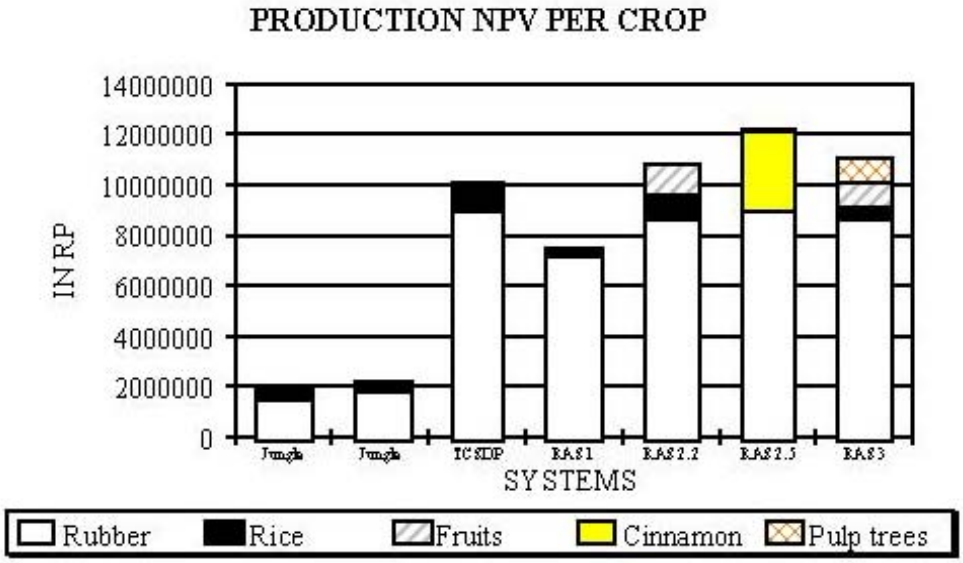


Figure 33 shows that rubber contributes to around 80 % of total income and to 95 % in RAS 1, but the use of Net Present Value of production increase the importance of rice during the immature period and decrease the final value of the wood at the end of lifetime. In fact, clonal rubber wood and timber output is expected to be high enough to able the farmer to further invest in whatever improved cropping system (monospecific plantation of rubber or oil palm or agroforestry systems). Jungle rubber produces not only rubber but also fruits, timber for local use, medicinal plants, rattan and firewood which are generally for self-consumption. Production for self-consumption is not taken into account in this calculation, but is considered as a general benefit for the farmer that is comparable for all systems except TCSDP[5] which is monoculture.

[5] TCSDP like monoclonal rubber plot is the only system without non-rubber products but it is also not an agroforestry system.

Figure 33.

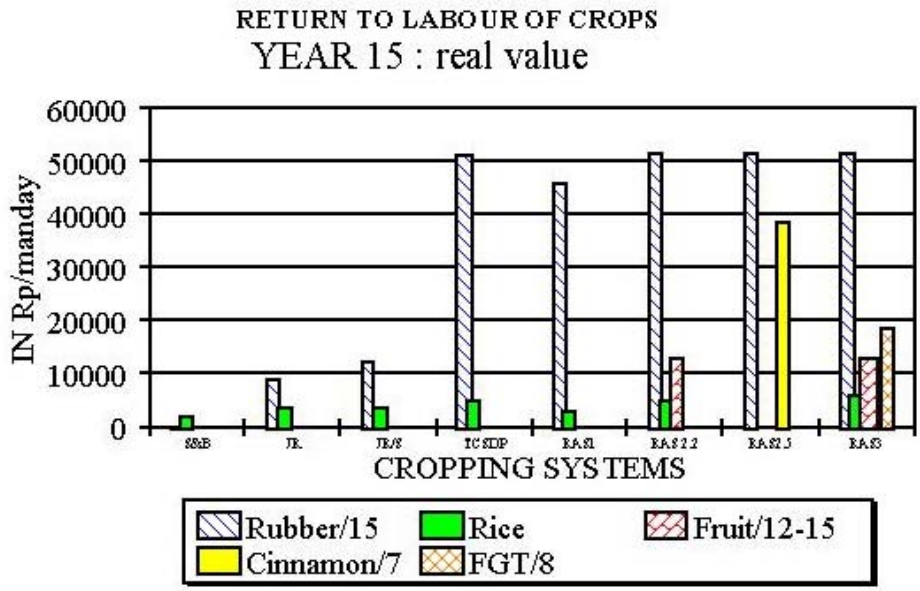


<u>The return to labour: a sensitive argument for farmers in selecting a cropping system.</u>

The evolution from an input extensive system such as jungle rubber into an intensive system such as RAS 2.2 or TCSDP is generally limited by cash availability and labour. Two conditions must prevail for adoption of new technology: limited risks and high return to labour, or at least conservation of return to labour comparable than that of a jungle rubber.

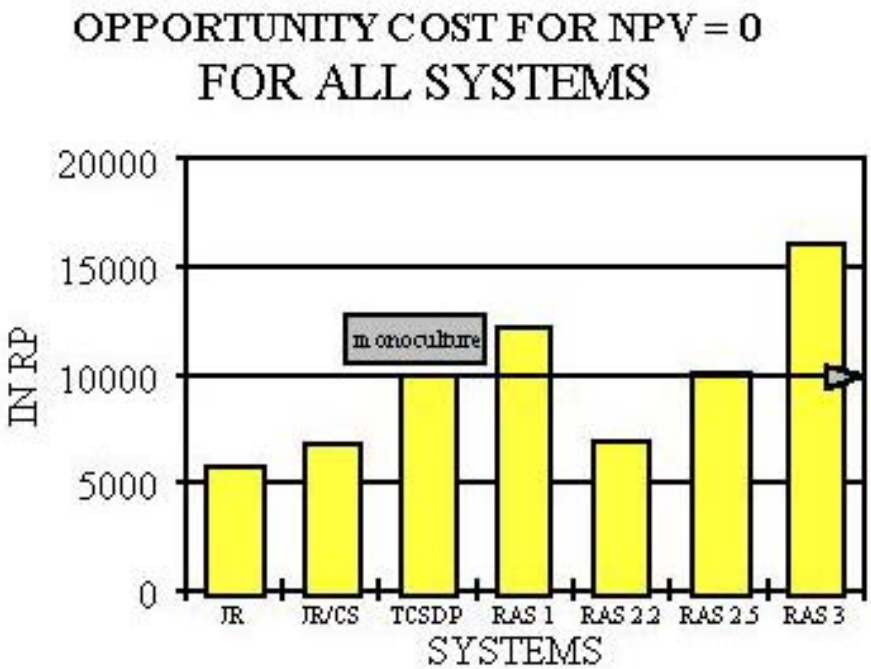
Figure 34 shows rubber return to labour is definitely improved with TCSDP and RAS (around 50 000 Rp/man day compared to 9 000 Rp/man day for jungle rubber at the year 15 in full potential production).

Figure 34.



A better estimation of the return to labour in the long term may be done using the labour cost that leads to Net Present Value equal to zero (figure 35).

Figure 35.



The interest of these intermediate systems is that they are still affordable for farmers (investment cost is limited) with limited labour requirement and a good optimization of labour. RAS 1 is typical of that situation. A possible constraint is the distribution of required labour, in particular during the immature period.

TCSDP and RAS require labour prior to production systems (respectively 300 to 500 man days for RAS and 600 for TCSDP) in contrasting with jungle rubber (54 man days). In RAS, labour required during immature period is less than TCSDP. The main constraint for adoption of a clonal rubber based system is the necessary minimum level of maintenance during the immature period.

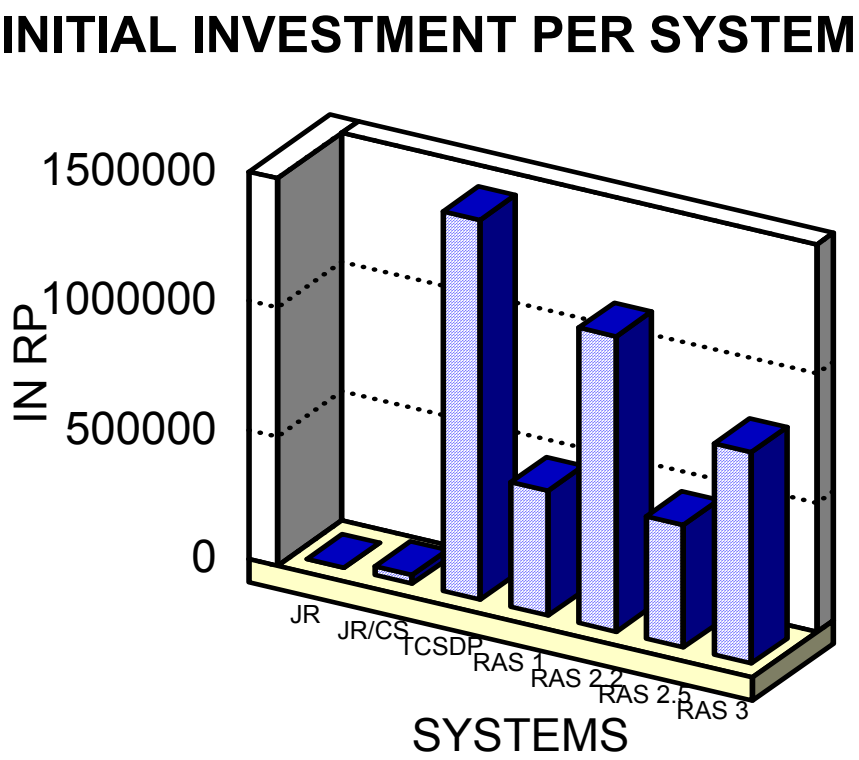
The first 2 to 3 years are critical as rubber clones require a minimum level of weeding (3 to 6 weeding/year compared to 12 weeding/year for monoculture). Labour requirement in RAS systems is 50 to 75% that of TCSDP monoculture system leading to a better adoption of clones by farmers as far as labour during immature period is concerned.

After opening, the low tapping frequency of clones leads to a significantly improved return to labour. For these reasons, the use of clonal seedlings do not yield a real significant impact on return to labour as well as income. Exploitation system and tapping frequency are key issues in improving return to labour during production period.

Return to labour is optimized in the RAS 1 system. RAS 1 is aimed to decrease the labour requirements by 30% during immature period. For RAS 2.2, rice intercropping has significant benefits for rubber growth however rice production does not have a great economic value compared to that of rubber. Nevertheless, it is important for some farmers to grow rice during the immature period in order to valorize labour investment, in particular for those with limited access to land such as transmigrants. This extensive system fits also local farmers' strategies focused on low labour investment. For RAS 3, pulp trees are an important source of additional income. This may help the farmer to reimburse credit.

The initial investment is also an important component of farmers strategies. RAS systems are low to medium inputs systems. Figure 36 shows the importance of initial investment in NPV related to that of TCSDP with respectively 30%, 55% and 78% for RAS 1 and 2.5, RAS 3 and RAS 2.2 of that of TCSDP (if adopted by farmers on their own without projects cost). If we had the TCSDP project cost, estimated at 1.5 millions RP rock phosphate/ha, then it is clear that RAS technology is more affordable for farmers and constitute a very interesting alternative to the current rubber development policy. That is confirmed by the results of the farming systems characterization (see paper 7).

Figure 36.



RAS economic analysis shows that the cost of clonal planting material is important (up to 50 % of total costs for RAS 1 for instance). The production of clonal stumps by farmers themselves seemed to be a possible solution in reducing that initial cost as well as developing a cooperation between farmers through the implementation of nursery activity. That statement leads to the development of a village/community budwood garden and nursery programme in villages where RAS have been implemented, according to farmers demand.

The village budwood garden programme

After 1 year of experimentation with RAS in selected villages, discussions with farmers showed their interest in producing themselves clonal rubber planting material which represent more than 50 % of the total cost of establishment for RAS (E Penot, 1996). Preliminary information has been provided on clones, grafting, nursery and budwood garden techniques to farmers who show motivation for production. The main constraint for farmers is the budwood availability and quality (clonal purity) as well as technical information and training on grafting in order to acquire the technical skill. The main idea was to provide to farmers the external components (innovations) that are out of reach for them without an external aid: basically budwood gardens and training. All other components are provided by farmers themselves.

***Table 4*: The village budwood garden (VBG) programme**

Provinces	Community VBG	Private BG	BG in schools or projects
West-Kalimantan	7		2
Jambi	0	2	1
West-Sumatra			1
Total	7	2	4

In West Kalimantan, the majority of farmers wish to have community based village budwood gardens. In Jambi, in front of a lower interest and apparent motivation, private budwood gardens have been developed in 2 villages.

The study of the implementation and use of budwood gardens in 1997 and planting material production has been done by W Shueller (french MsC student) and Ir Sunario in West-Kalimantan. The main outputs of this study are presented in paper 5.

Main Conclusion

Very promising results have been obtained with RAS experimentation both on technical point of view, however sometimes data are not al all easy to process to a large variability, and on the social point of view of innovations adoption. Information on RAS 1 and 2 may be exploited for releasing technical recommendations for the establishment phase in the very next future, however some hypotheses, such as "no effect of associated trees on rubber yields (at planting density selected for current RAS)" still need to be confirmed within the next 20 years. RAS experimentation is a long term research.

Specific studies enable us to have a better in-depth agronomic knowledge on RAS components. Another important component that has not been yet covered is biodiversity evolution in RAS systems, in particular in RAS 1 and comparison with existing biodiversity in jungle rubber.

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