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The effect of planting density on growth and development of component crops in rubber/banana intercropping systems

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Abstract

The effects of planting density on growth and development of rubber (*Hevea brasiliensis* Muell. Arg., clone RRIC 100) and banana (*Musa* spp. cv. Kolikuttu) were examined to determine the optimum planting density of banana when grown in combination with rubber. The experiment comprised five treatments, sole crop rubber (R), sole crop banana (B) and three intercropping treatments consisting of an additive series of one (BR), two (BBR) and three (BBBR) rows of banana to one row of rubber. Planting density of banana was 500, 1000, 1500 and 1700 plants ha^{-1} in the BR, BBR, BBBR and B treatments and 500 plant ha^{-1} for rubber in all treatments. Growth analysis commenced at 8 months after planting (MAP) and at the onset of the experiment, rubber plants were four months old. Density had significant effects on both leaf area index (LAI) and total dry matter (TDM) of the stand, with the highest values in the most dense BBBR treatment. TDM, leaf area and dry matter partitioning to above-ground components of banana were significantly greater in the BBR and BBBR treatments than in the BR crop. Dry matter productivity and the crop performance ratio (CPR) of rubber also increased with planting density. Plant weight of rubber showed similar relations with both stem girth and height measurements, with improved performance in the intercrop relative to sole crop treatments. Treatments had little affect on bunch yield per banana plant, harvested percentage and CPR, with mean values of 6.2 kg, 65.3% and 0.95, respectively. Since yield per plant was similar across treatments, yield per hectare increased significantly with increasing banana density. Amongst intercrops, the highest density BBBR treatment always performed best in terms of both stand parameters and performance of individual component crops. It was concluded that increasing the density of banana, from a single to three rows, increased biomass productivity per unit area, with no adverse effect on the growth and yield of either component rubber or banana crops.

Keywords: Banana; Rubber; Intercropping; Land equivalent ratio; Planting density

1. Introduction

Rubber (*Hevea brasiliensis* Muell. Arg.) is commonly planted as a sole crop for latex production, at a density of 500 trees ha^{-1} and spacing of 2.4 m along rows spaced 8.1 m apart. The wide spacing is designed to meet the resource requirement of trees during the mature stage, but inevitably results in an inefficient use of land and resources during the immature phase, which can extend for six to seven years from planting to the onset of tapping for latex. This relatively long immature phase of rubber can

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Field Crops Research

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lead to problems of low income generation for smallholder farmers. Whilst the large-scale estate sector restricts the extent of immature rubber land area, by maintaining an annual replanting cycle, this option is not available to smallholders who have insufficient land available for a yearly replanting cycle.

Intercropping of rubber, by planting shorter duration annual or perennial crops, offers one possible solution to improving income generation during the establishment phase of the rubber plantation and as a short-term cash crop, banana (*Musa* spp.) presents a potentially profitable companion crop. The present planting recommendations for intercropping banana with rubber, in which a single row of banana is sown between each row of rubber, is based on the performance of banana when grown as a monoculture and is designed to impose minimum risks of latex yield losses through competitive effects on rubber. As a sole crop, banana is generally planted at a density of 1700 plants ha^{-1} and at a spacing of 2.4 × 2.4 m. In comparison, the present system of rubber/banana intercropping provides a maximum of 500 banana plants ha^{-1}, which represents only ca. 30% of the density of the sole crop (Chandrasekera, 1984). The rubber density, however, is the same for both sole and intercrops.

No adverse effect on growth of rubber has so far been recorded in rubber/banana intercrops and indeed, an improved performance of rubber in the present intercropping system has been reported (Yogarathnam, 1991). Increased growth of intercropped rubber has been attributed to improved crop husbandry, since farmers tend to be more attentive to intercrops than sole crops because of the additional, early income they provide. Nevertheless, the benefits of intercropping to growth of rubber provides some indication of the potential gains to be made from intercropping during the juvenile stage of the plantation, and not least from increases in the planting density of the companion crop. Furthermore, because intercropped banana is grown as a short-term crop, plants may be able to tolerate higher densities than that recommended for long-term ratoon cycles. According to Robinson (1993), sole crop banana can withstand a density of 3333 plants ha^{-1} for a single cycle compared to 1666 plants ha^{-1} for ten year plantation. This suggests that if banana is intercropped with rubber for only ca. 4 years, its density may be increased without adversely affecting individual plant yield.

Little is known of the optimum density for banana in rubber/banana intercropping systems and to date there has been no systematic study of the effects of planting density of banana on component crop growth and yield. In the present study, planting density of banana was increased from one to three rows in an immature rubber plantation and subsequent effects on development and productivity of component crops are reported.

2. Materials and methods

2.1. Experimental site

The experiment was established on a 5 ha area of the Kuruwita sub-station of the Rubber Research Institute of Sri Lanka (RRISL), situated in the low country wet zone of Sri Lanka. Latitudes and longitudes are 6°30′–7°00′N and 80°00′–80°30′E, respectively. The soil was acidic (pH 4.84) and belonged to the order Ultisol.

2.2. Planting material

One year old healthy nursery seedlings of rubber were bud-grafted with one of most popular clones in Sri Lanka, RRIC 100. After four weeks, successfully grafted plants were transplanted in poly-bags to minimise the mortality rate in field establishment. The Kolikuttu variety of banana, which belongs to the triploid genome group 'AAB' and subgroup 'Silk' (Stover and Simmonds, 1987), was selected because of its high popularity in Sri Lanka. Homogeneity among plants was achieved through propagation using tissue culture techniques.

2.3. Experimental design

The experiment comprised five treatments, sole crop rubber (R), sole crop banana (B) and three intercropping treatments consisting of an additive series of one (BR), two (BBR) and three (BBBR) rows of banana to one row of rubber. Treatments were laid out in four randomised blocks and in plots of ca. 0.2 ha, with the exception of the sole banana crop plots which were restricted to ca. 0.09 ha due to the high planting density and limitation on the number of propagated plants available.

In row-intercropping, mutual shading of crops is expected to be greatest where rows are orientated in the north–south direction and least in east–west row alignments. Given that shading is expected to be one of the major factors determining the optimum planting density for intercrops (Monteith et al., 1991), a 'worse case' north–south row orientation was chosen for the study. In all treatments, rubber was planted at a spacing of 2.4 m within, and 8.1 m between, rows. A triangular planting pattern was used for banana in both the sole and intercrop treatments, with a plant spacing of 2.4 × 2.4 m in the sole crop. In the intercrop treatments, intra-row spacing was kept constant at 2.4 m whilst varying the inter-row spacing according to number of banana rows, ranging from 4.05 m in the BR, 2.7 m in the BBR to 2 m in the BBBR treatments. Planting density of banana was 500, 1000, 1500 and 1700 plants ha^{-1} in the BR, BBR, BBBR and B treatments.

2.4. Crop husbandry

A basal dressing of organic manure (i.e. ca. 5 kg of poultry litter) was applied to each planting hole of banana before planting. Thereafter, starting from two months after planting, each plant was supplied with ca. 750 g of fertiliser (Urea 2: Super phosphate 1: Muriate of potash 3) at four month intervals. Rubber plants were fertilised with mixture of Urea 26: Rock phosphate 50: Muriate of potash 24. At the start of the season, 50 g of the mixture together with 100 g of rock phosphate and 10 g of kieserite was applied to each planting hole of rubber. Fertiliser was applied in the first and second year of rubber growth to supply 12 and 15 g of MgO per plant. Plants detected with banana weevil infestation, were treated with 20 g of commercial mixture of Carbafuran.

2.5. Climatological measurements

Environmental conditions were monitored by a solar powered automatic weather station (Campbell Scientific, UK) installed at the experimental site. Irradiance, air temperature, relative humidity (RH%), wind-speed and direction were measured at five minute intervals and hourly and daily means recorded by a data logger (21 X, Campbell Scientific, UK). Total rainfall was recorded hourly and daily. On occasions, data were lost due to problems of battery failure caused during periods of heavy rainfall and during these periods data of rainfall were taken from the substation of RRISL and temperature and RH% from a station of the Meteorological Department of Sri Lanka situated in the same agro-climatological region, ca. 6 km away from the experimental site.

2.6. Growth analysis

Whole plant samples of both rubber and banana were harvested at ca. four monthly intervals between 8 to 28 months after planting. Destructive harvests were taken from the middle of each plot, leaving one row of plants as a guard row and three rows at the centre for instrumentation. In the sole crop treatments, two rubber and two banana plants were harvested at a time from adjacent rows in each plot. In the intercropping treatments, two rubber and single banana were harvested from their respective row positions.

The tap root and lateral roots of rubber were removed at each harvest by loosening the earth around the plant and pulling the roots out. Banana roots and the fine roots of rubber were sampled by excavating soil from a hole with an area of 0.81 m^2 and a depth of 0.9 m. In later harvests, some roots had extended beyond this depth and so the depth of the hole was increased to 1.2 m. Few, if any, roots were seen below this depth.

At each harvest, plants were divided into component parts, i.e. leaves, petioles, stem or pseudostem, roots and rhizome (for banana) and total fresh weight recorded. Preliminary studies showed that ca. 40% of total fresh weight of each component part of the plant was sufficient to achieve ca. 95% accuracy in estimating dry weights. Therefore, approximately 40% of the total fresh weight of each component part was oven-dried at 80°C to a constant weight and then removed for dry weight analysis. Total leaf area of rubber was measured using a leaf area meter (LI3050, Li-Cor, Lincoln), but because of practical difficulties in using the area meter for large banana leaves, an alternative method was developed. Over 50 banana leaves were used to analyse leaf area as a function of leaf length and maximum width, i.e. leaf area *f* leaf length × maximum leaf width and this relation was found to be linear with a slope of $0.755(\pm 0.0115) r^2 = 0.9328$.

In addition to destructive growth analysis, height and girth at 0.9 m above the bud-grafted union of rubber, were measured for ten plants at the centre in each plot. Plants were tagged, these measurements were repeated on the same plants coinciding with the destructive growth analysis. Assessment of rubber crop for latex exploitation is based on girth at 0.9 m (Liyanage and Peries, 1984). Similarly, ten banana plants from the sole crop and for each row position in the intercrops, were measured at the centre of each plot for height (i.e. only up to the crown where the pseudostem ends) and base girth of the pseudostem (i.e. at the point where the pseudostem start to taper). Since banana plants had to be removed after bunch harvest, different plants were subjected to repeated measurements. Number of banana plants harvested in each plot together with bunch weights were recorded throughout the experiment.

2.7. Data analysis

Partitioning of dry matter of component crops was assessed on the basis of below- to above-ground ratio (B:A). The more common term root:shoot ratio has been avoided here because although B:A was synonymous with root:shoot ratio in rubber, in the case of banana, the below-ground component comprised both roots and rhizome.

Data were analysed using the SAS statistical package (SAS Institute, Cary, NC) and the Proc. ANOVA and Proc. GLM procedures for balanced and unbalanced models, respectively. Data from each harvest were analysed separately with the Randomised Complete Block Design, whilst pooled data of all harvests were analysed with a model for the Split Plot Design in which each harvest was considered as a sub-plot (Roswell and Walters, 1976). The relative performance of component crops in different cropping systems were analysed in terms of crop performance ratio (CPR), which refers to the productivity of an intercrop per unit area of ground compared with that expected from sole crops sown in the same proportions (Azam-Ali et al., 1990). The land equivalent ratio, LER (Willey, 1985), was used to evaluate the cropping system as a whole.

3. Results

3.1. Climatological condition

Fig. 1 summarises the climatic conditions for the experimental site. Solar radiation data were missing for two periods (i.e. 67–69 and 110–113 weeks after planting, WAP), due to malfunctioning of the data logger. Although there were no prolonged periods without rain, relatively dry spells were experienced during 27–35, 71–86 and 121–126 WAP. These periods comprised two or more weeks in which total rainfall was less than 10 mm, i.e. 2, 7 and 5 weeks, respectively. The diurnal amplitude in temperature was greatest during these relatively dry periods, but averaged over the whole experimental period, mean weekly maximum and minimum air temperature remained remarkably constant at 33.0(±0.1)°C and 21.5(±0.1)°C, respectively. Weekly solar radiation showed an absolute range of 71.4 to 154.9 MJ m^{-2} with a mean of 106.0 MJ m^{-2} over the duration of the experiment. Due to heavy rainfall and condensation on the humidity probe, relative humidity (RH) values frequently exceeded 100%, suggesting that while the absolute values were not reliable, water vapour content of the air was close to saturation throughout a major period of the study.

3.2. Performance of sole and intercropping systems

Data from the first three harvests of banana referred to the mother crop (i.e. 8, 12, and 16 months after planting, MAP), and thereafter (i.e. 20, 24 and 28 MAP) harvests were based on the first ratoon crop (Fig. 2). Consequently, unlike the sole rubber crop which shows a steady increase in leaf area index (LAI) and total dry matter production (TDM) with time, banana growth was biphasic, depicting growth of the mother and daughter crops. Intercropping had a significant ($P \leq 0.001$) effect on both LAI and TDM with the greatest values in high density BBBR treatment (Table 1). Given that LAI of the sole banana was more than twice that of rubber crop, it is not surprising that LAI in the intercropping treatments closely reflected the planting density of banana, with values of the BBBR treatment generally similar to, or greater than the sole banana crop. LAI of the B crop declined at the final harvest due to an attack by the Fusarial wilt disease (Fig. 2a).

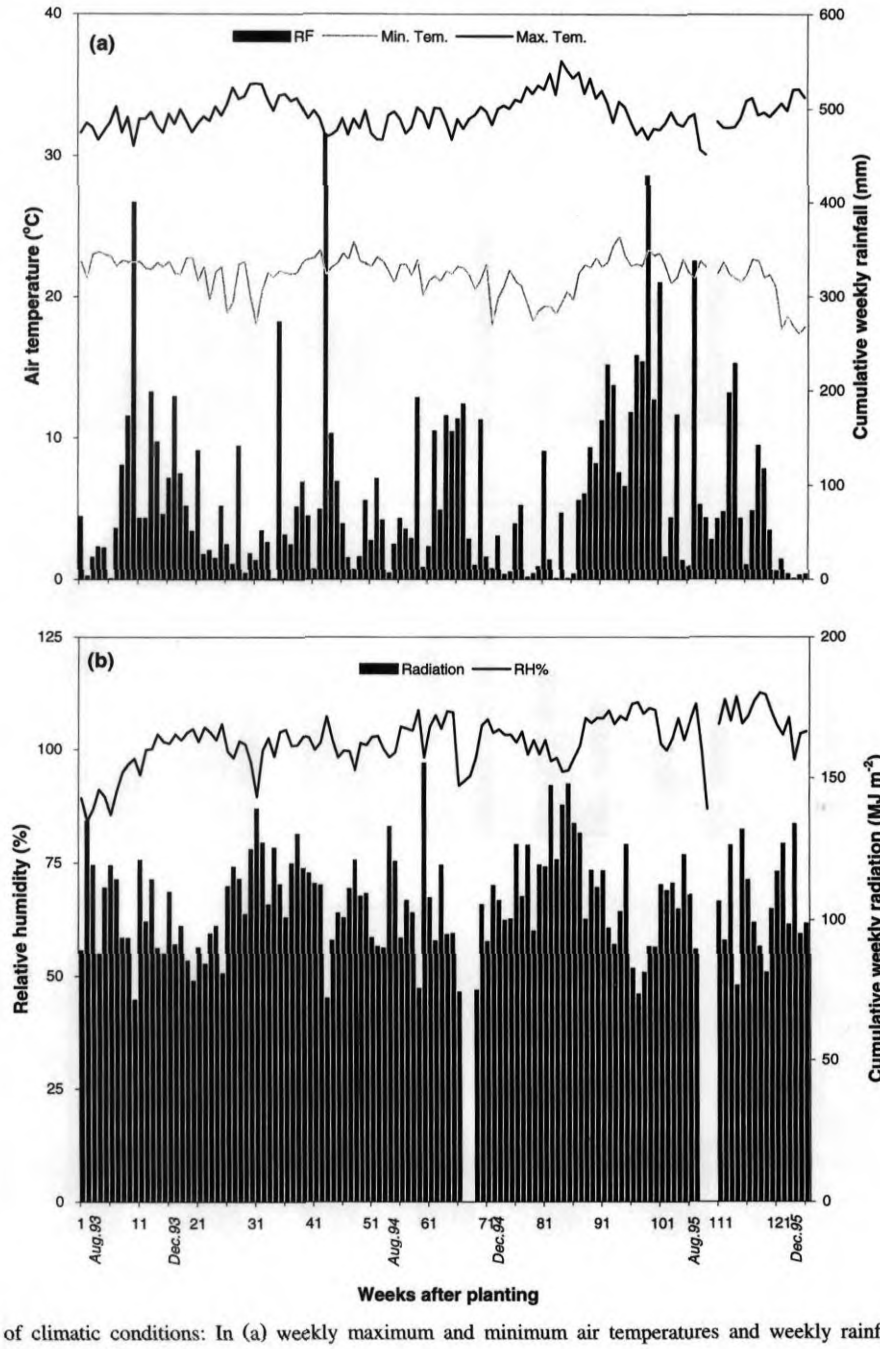

Fig. 1. Summary of climatic conditions: In (a) weekly maximum and minimum air temperatures and weekly rainfall, and (b) relative humidity and cumulative weekly radiation.

Land equivalent ratio (LER) for total crop dry matter yield exceeded unity in all intercropping treatments and at all harvests, reflecting a consistent advantage of intercropping (Fig. 2c). The magnitude of the intercropping advantage increased during the later stages of the experiment when TDM included the first ratoon banana crop. Among the intercropping treatments which differed significantly ($P \leq 0.001$), the BBBR always performed better than BR and by final harvest LER ca. 100% greater in the triple than single row system. While the decline in TDM of the sole banana would partly explain the

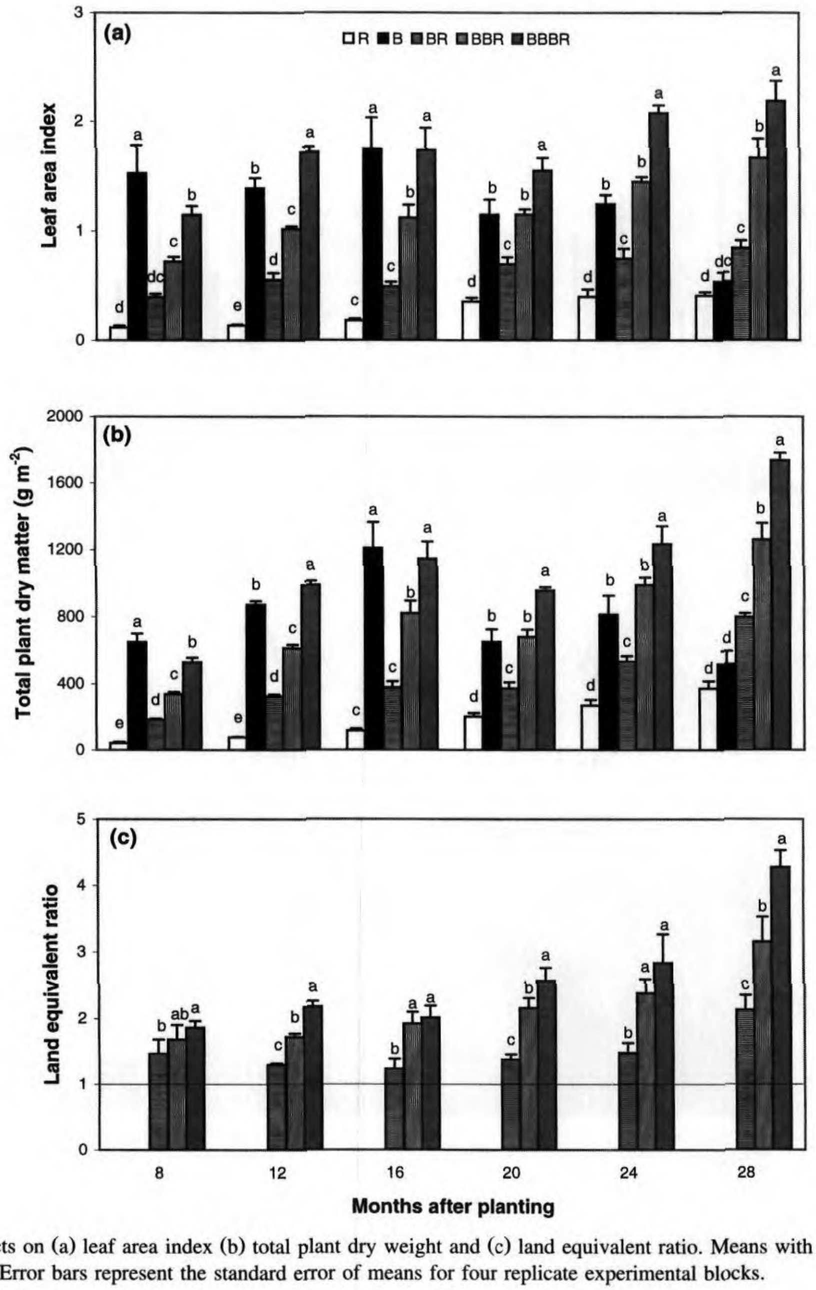

Fig. 2. Treatment effects on (a) leaf area index (b) total plant dry weight and (c) land equivalent ratio. Means with the same letter are not significantly different. Error bars represent the standard error of means for four replicate experimental blocks.

large increase in LER in the intercropping treatments, TDM in the intercropping treatments also show an increase at the final harvest relative to all previous harvests (Fig. 2b).

3.3. *Performance of component rubber and banana crops*

The performance of individual component banana and rubber crops was assessed in terms of leaf area index (LAI), total dry matter (TDM) and crop performance ratio (CPR) (Fig. 3). During the first three harvests, relative treatment effects on LAI of the component banana crop closely reflected that of the respective cropping system (Fig. 2a and Fig. 3a). LAI of intercropped banana remained relatively constant throughout the experiment with mean values of 0.29 in the BR, 0.79 in BBR and 1.33 in the BBBR resulting in respective percentages of 23, 63, 100 of that of the sole crop (Fig. 3a and Table 1). The largest variation in LAI of banana occurred in sole crop treatment with a decrease in LAI between 24 and 28 MAP, again reflecting the localised damage caused by the Fusarial wilt disease. In general, prior to 28 MAP, the performance of both component intercropped- and sole cropped-banana was similar, but by 28 MAP, TDM of banana differed significantly ($P \leq 0.001$) among treatments. Values were greater in the BBR and BBBR treatments relative to the sole crop and resulted in a CPR of 1.95 and 2.38, respectively (Fig. 3b and c).

The CPR for TDM of the component rubber in the three intercropping treatments was always greater than unity and increased by ca. 66% between 8 and 28 MAP, reflecting an improved productivity of rubber when intercropped (Fig. 3c and f). In general, the greater the planting density of banana, the greater the TDM and CPR of intercropped rubber. Averaged over the experimental period both TDM, and the respective CPR, of rubber differed significantly ($P \leq 0.001$ and ≤ 0.05, respectively), with greater values in high density intercropping treatments (Table 1).

Despite the significant differences in individual

Table 1
Summary of the treatment effect on different parameters of whole cropping pattern (a), component banana (b) and rubber (c). Each value refers to the mean for the whole duration of the experiment. Means with the same letter are not significantly different

	Sole crop rubber	Sole crop banana	Single row banana intercropping	Double row banana intercropping	Triple row banana intercropping
(a)					
Leaf area index	0.26 ^{d}	1.27 ^{b}	0.62 ^{c}	1.19 ^{b}	1.74 ^{a}
Total dry matter (g m^{-2})	179 ^{d}	784 ^{b}	430 ^{c}	782 ^{b}	1097 ^{a}
Land equivalent ratio			1.49 ^{c}	2.17 ^{b}	2.62 ^{a}
(b)					
Leaf area index		1.27 ^{a}	0.29 ^{c}	0.79 ^{b}	1.33 ^{a}
Plant weight (g)		4514 ^{b}	3829 ^{c}	4831 ^{ab}	5214 ^{a}
Crop performance ratio			0.91 ^{b}	1.17 ^{ab}	1.28 ^{a}
Below to above ground ratio		0.66 ^{b}	0.84 ^{a}	0.67 ^{b}	0.58 ^{b}
Leaf weight ratio		0.20 ^{a}	0.17 ^{a}	0.19 ^{a}	0.20 ^{a}
Leaf area per plant (cm^{2})		72886 ^{b}	55873 ^{c}	77138 ^{ab}	85955 ^{a}
Specific leaf area (cm^{2} g^{-1})		87.8 ^{a}	88.2 ^{a}	87.3 ^{a}	89.2 ^{a}
(c)					
Leaf area index	0.26 ^{c}		0.33 ^{b}	0.39 ^{a}	0.41 ^{a}
Plant weight (g)	3484 ^{c}		4533 ^{b}	5534 ^{a}	5680 ^{a}
Crop performance ratio			1.23 ^{b}	1.47 ^{a}	1.48 ^{a}
Below to above ground ratio	0.62 ^{a}		0.59 ^{a}	0.48 ^{b}	0.44 ^{b}
Leaf weight ratio	0.14 ^{a}		0.14 ^{a}	0.13 ^{a}	0.13 ^{a}
Leaf area per plant (cm^{2})	51400 ^{c}		64733 ^{b}	76473 ^{a}	79794 ^{a}
Specific leaf area (cm^{2} g^{-1})	128.5 ^{a}		132.7 ^{a}	134.9 ^{a}	136.9 ^{a}

harvests, pseudostem girth of banana remained relatively constant at ca. 0.71 m throughout the experimental period, with no significant treatment effect (Fig. 4). Although there was no clear treatment effect on plant height in the ratoon plants, during the mother crop period, plants in the B and BBBR treatments were taller than BR banana. At final harvest, girth and plant height of banana were signif-

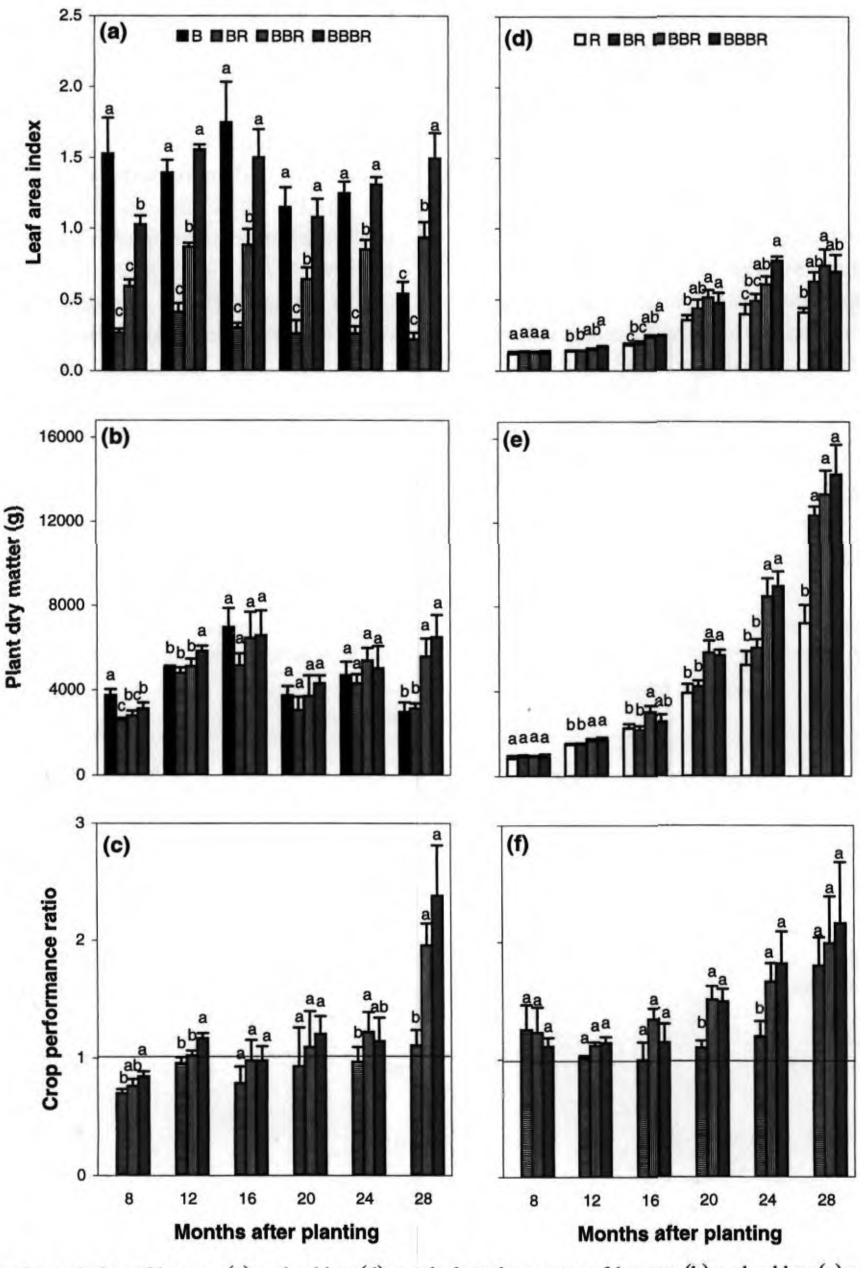

Fig. 3. Analysis of leaf area index of banana (a) and rubber (d), total plant dry matter of banana (b) and rubber (e) and crop performance ratio of banana (c) and rubber (f). Means with the same letter are not significantly different. Error bars represent the standard error of means for four replicate experimental blocks.

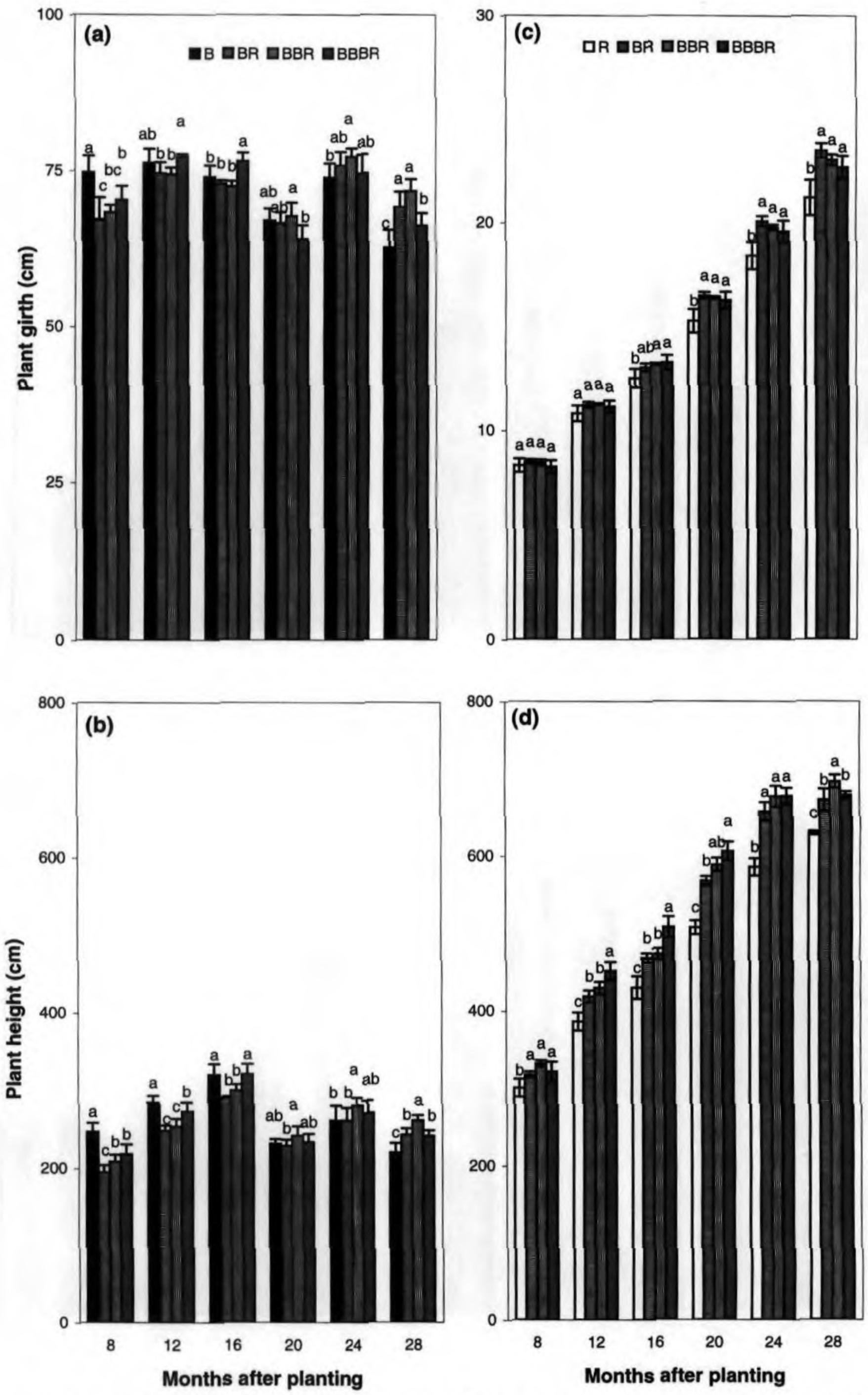

Fig. 4. Plant development in girth of banana at base (a) and of rubber (c) at the height of 90 cm of the stem and height of banana (b) and rubber (d). Means with the same letter are not significantly different. Error bars represent the standard error of means for four replicate experimental blocks.

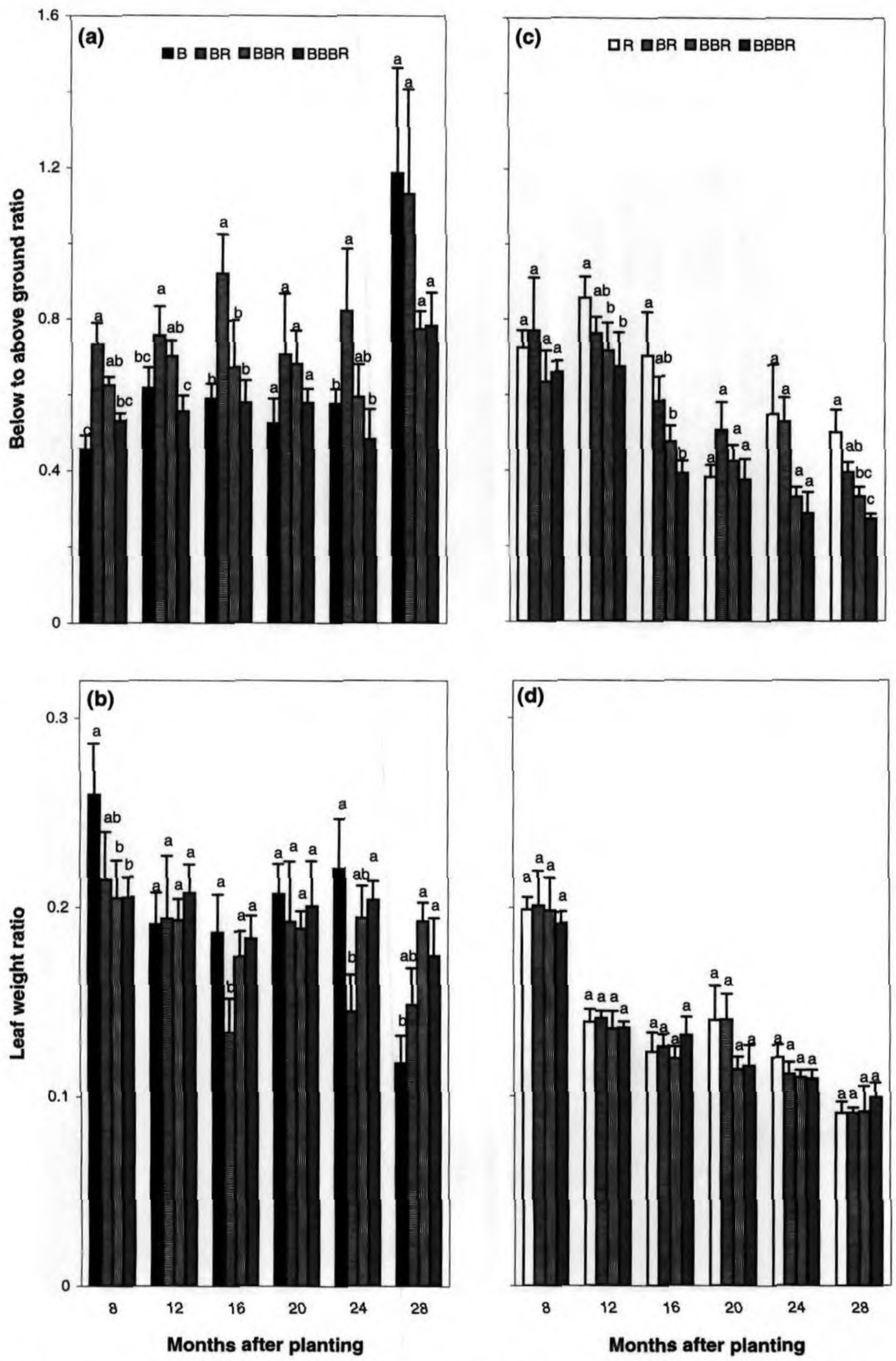

Fig. 5. Summary of dry matter partitioning as below to above ground ratio of banana (a) of rubber (c) and leaf weight ratio of banana (b) and rubber (d). Means with the same letter are not significantly different. Error bars represent the standard error of means for four replicate experimental blocks.

icantly different ($P \leq 0.001$), with values greater in the intercropping than sole crop treatments.

Plant weight of rubber showed similar relations with both stem girth and height measurements (Fig. 4c and d), with improved performance in the intercropping treatments relative to sole crop treatment.

In general, dry matter partitioning of banana to below and above-ground components (B:A) differed significantly between treatments, with the highest value ($P \leq 0.05$) in the lowest density intercropping treatment (Fig. 5a and Table 1). However, in each treatment, the ratio was similar in magnitude with the course of time, with a mean of 0.66 in B, 0.84 in BR, 0.67 in BBR, 0.58 in BBBR treatments. Dry matter partitioning to leaves (LWR) also remained fairly constant with a mean of 0.19($\pm$0.006) (Fig. 5b). A similar pattern was observed in the rubber crop, with B:A significantly lower ($P \leq 0.001$) in the high density intercropping treatments. The results show a general ontogenetic decline of ca. 50% in partitioning of dry matter to both below-ground components (B:A) and leaves (LWR) in rubber over the duration of the experiment (Fig. 5c and d). Specific leaf area (SLA) was not significantly affected by

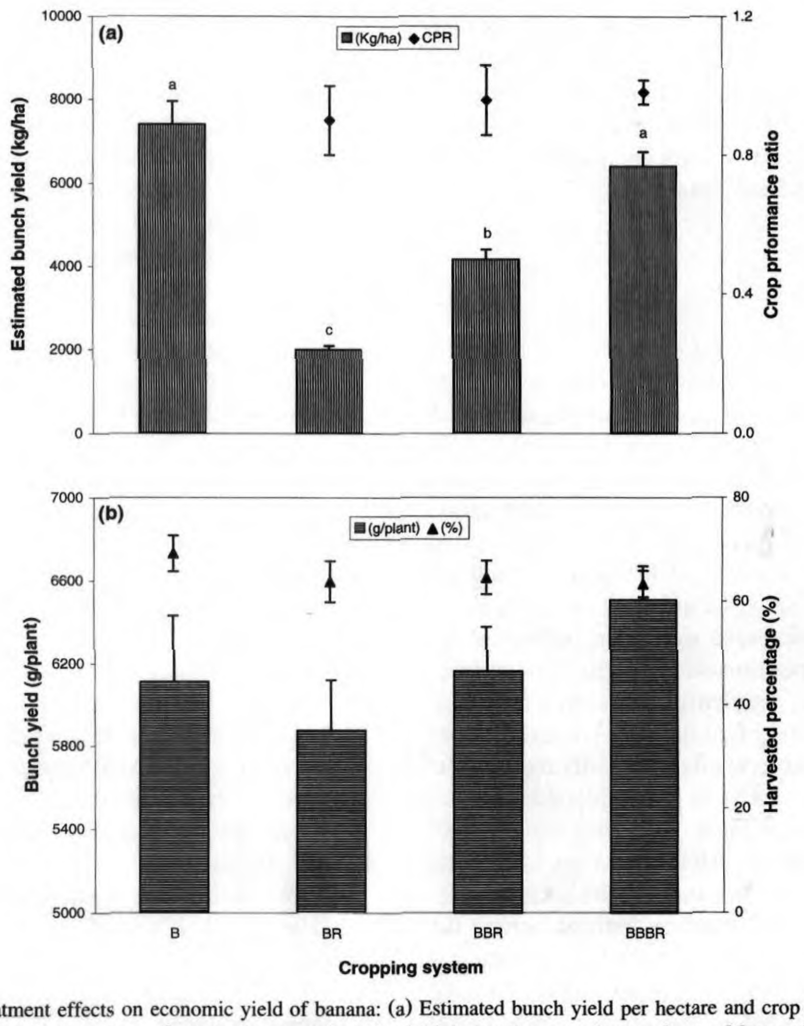

Fig. 6. Summary of treatment effects on economic yield of banana: (a) Estimated bunch yield per hectare and crop performance ratio, and (b) bunch yield per plant and percentage of plants giving marketable yield during the second year of crop. Means of yield per hectare with the same letter are not significantly different and the means of other parameters are not significantly different, thus not presented. Error bars represent the standard error of means for four replicate experimental blocks.

planting density and remained unchanged over the experimental period with a mean of 88.11($\pm$0.4) in banana and 133.26($\pm$1.8) cm^2 g^{-1} in rubber (Table 1).

3.4. Banana bunch yield

Bunch yield on a unit area and unit plant basis together with CPR and percentage of plants with marketable yield are presented in Fig. 6. CPR was based on the yield per hectare which was determined by yield parameters, i.e. yield per plant, planting density and number of plants given marketable yield. Bunch yield per plant and harvested percentage, thus CPR remained fairly constant among treatments with means of 6158 g, 65.3% and 0.95, respectively. However, yield per hectare among treatments differed significantly ($P \leq 0.001$) and increased with increasing banana density, with comparable yields in both the sole and BBBR crops.

4. Discussion

The results of the present study showed that LER of all three intercropping treatments exceeded unity and on all harvest dates (Fig. 2a). Planting density of rubber remained constant across treatments, with CPR values for total dry matter in intercropping treatments, always equal to or greater than unity, thus any additional yield from banana provided an overall advantage in terms of biomass productivity of the intercropping systems. LER advantages of rubber generally increased over time, reflecting the improved growth performance of rubber when intercropped. Increasing the density of banana from single to triple rows, increased biomass productivity per unit area with no adverse effect on individual plants. In fact, by final harvest at 28 MAP, biomass production at the individual plant level was significantly greater in the double and triple row crops than in the sole and single row intercropping treatments, suggesting that increased planting density across the range used in the present study had no detrimental effect on growth of banana. The maximum planting density of banana used in the present study (1700 plants ha^{-1} in the sole crop) was well below that which the crop can tolerate in a single ratoon (3333 plants ha) and similar to that which it can withstand in a ten year plantation (Robinson, 1993). Based on total dry matter yields, the results suggest that intercropping banana with rubber has the potential to provide an overall yield advantage across a wide range of planting densities of banana i.e. from ca. 30 to 90% of the sole banana crop system.

Since girth of mature rubber is closely correlated with latex yield (Thattil et al., 1991; Napitupulu, 1973), the improved girth expansion of intercropped relative to sole crop rubber may have important implications for latex yield at later stages of growth. Girth circumference is used to determine the tappable stage (i.e. time of harvesting) of the rubber crop. In Sri Lanka, if 50% of the rubber trees in a plantation have a girth exceeding 0.5 m at a stem height of 0.9 m, the crop is considered mature enough for tapping of latex (Liyanage and Peries, 1984). The more rapid girth expansion observed in the intercrop than sole crop implies that the period between planting and yield return would be reduced, thus partly alleviating the problems of poor economic return from the early stage of rubber plantations. In addition, timber of rubber has a high consumer demand and the increased girth, presumably concurrent with increased height of rubber in the intercrop would lead to improved trunk volume and so high timber yield at the time of uprooting of rubber crop.

At the final harvest, damage by the Fusarial wilt disease was significant only in the sole crop of banana, with little or no incidence of disease in the intercropping systems. This explains the increase in CPR for TDM of banana at 28 MAP, compared with the previous harvest with values 60 and 100% greater in the double and triple row intercrops, respectively. The significant decline in growth of sole crop banana between 24 and 28 MAP and the high incidence of damage by the Fusarial wilt disease, provided evidence of the reduced risk of yield losses through disease in intercropping versus sole cropping systems. While reduced incidence of disease has been cited as an advantage of mixed over sole cropping systems (Trenbath, 1976; Okigbo and Greenland, 1976), there is little actual evidence of this in the literature. Natarjan et al. (1985) have reported a decreased incidence of Fusarial wilt of pigeonpea in polyculture systems with sorghum.

Leaf area of banana is high, but the spiral growth habit tends to minimise mutual shading within the canopy (Stover and Simmonds, 1987). Consequently, leaves of banana in the single row system in the present study are likely to have operated at very high radiation levels, which may be detrimental to plant growth. For example, temperatures above 37°C cause leaf scorch (Turner and Lahav, 1983) and growth ceases at 38–40°C (Stover and Simmonds, 1987). On occasions (e.g. 27–30 WAP), maximum ambient temperature of the experimental site approached 35°C and rainfall was relatively low, with the result that where little mutual shading occurred (e.g. in the low density BR treatment), leaves were likely to have been exposed to damaging temperatures and radiation loads.

Dry matter partition to shoot growth of banana increased with planting density, possibly reflecting the effects of increased shading, which is known to improve partitioning to above-ground components (Wiebel et al., 1994; Stoneman and Dell, 1993). In the sole banana crop, damage to shoots by the Fusarial wilt disease accounted for the apparent increase in partitioning to below ground at final harvest. Rubber also showed an increase in partitioning to shoots with increasing planting density, again most likely reflecting the beneficial effects of shade provided by the companion banana crop. Ontogenetic drift would explain the decrease in B:A of rubber with time (Gedroc et al., 1996). Plant height could vary in intercrops with the plant response to light (Jaswal et al., 1993). Plant height of both rubber and banana was greater in the intercrop than respective sole crops, providing further support for the view that increased shading was a major factor influencing the growth response of component crops when intercropped.

Since small tissue cultured plants of banana were used for the experiment, no bunch yield was recorded during the first year. In the second year, however, bunch yield ha^{-1} was highest in the sole crop and triple row intercrop treatments, whilst CPR for bunch yield ha^{-1} in the intercrops was more or less at unity, reflecting the dependency of yield ha^{-1} on planting density. This is in agreement with the banana component CPR for total biomass, indicating that despite the change in planting density, harvest index of banana remained constant. It is possible that this yield pattern could vary in subsequent years, with the following ratoons and with maturity of the companion rubber crop. The increase in component CPR and LAI of rubber indicates that rather than being at a disadvantage in terms of competition with banana, the rubber crop actually benefitted from increased planting density. This effect was most probably due to improved shading of rubber by the banana crop and consequent alleviation of radiation and heat stress.

In conclusion, an increase in planting density from the present recommended single row to three rows of banana, had no detrimental effect on growth and yield of either banana or rubber. Banana could be maintained for several further ratoons and until the rubber canopy matures to a stage when insufficient radiation is available for growth of banana. Further studies are therefore required to evaluate whether the initial advantage from increased planting density is maintained in later years. The observed benefits of intercropping on early rubber growth also demand further investigation, in order to assess whether such advantages translate into improved latex and/or timber production. If the improved growth of intercropped rubber results in a shortening of the period between establishment and onset of tapping for latex, then this offers an extremely important and practicable means of improving income generation of smallholder farmers.

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