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AGRONOMIC AND ECONOMIC BENEFITS OF HIGH DENSITY BANANA INTERCROPPING DURING THE IMMATURE PERIOD OF RUBBER WITH PARTICULAR EMPHASIS ON SMALLHOLDERS

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ABSTRACT

Intercropping with short duration crops alleviates the problem of no income during the immature period of the rubber crop. Banana is an important crop in this context and its present recommendations in Sri Lanka on planting density appear to be sub-optimal for rubber/banana intercropping. Therefore, this study aimed to evaluate the effects of planting density of banana with respect to resource use and productivity on immature rubber lands.

Field trails were conducted at two locations with a large-scale experiment (5 ha) and a small scale trial (1 ha). There were five treatments comprising sole crops rubber (R) and banana (B) and three intercrops consisting of an additive series of one (BR), two (BBR) and three (BBBR) rows of banana to one row of rubber. Biomass productivity and leaf area index showed a steady increase with increasing planting density in the rubber/banana intercrop. There was no indication of any negative effect of mutual shading on either crop; indeed growth was enhanced, resulting in a 25 and 36 % increase in biomass per plant of rubber and banana respectively, in the high density BBBR relative to the single row BR intercrop. As a result, the Land Equivalent Ratio (LER) for biomass increased by 76% from the BR to BBBR intercrop. Because treatments had no significant effect on bunch yield per banana plant or harvested percentage, yield per hectare increased three-fold from the current recommended BR to BBBR intercrop resulting in an estimated 350% increase in profits from the banana crop.

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An increase in resource capture was the principal cause of the increased productivity in high density intercrops and on average, radiation and water use in the BBBR intercrop increased by 73% and 140%, respectively, over the BR intercrop. Neither photosynthesis nor respiration was affected by the increase in mutual shading at the leaf level. Therefore, increased whole plant photosynthesis and hence light-use efficiency resulted from the increase in leaf area per plant. The increase in girth of intercropped rubber was maintained throughout the immature phase resulting in an earlier onset of tapping in the intercrop than in the sole crop rubber. The social implications of these findings are discussed.

Key words: banana, density, intercropping, rubber

INTRODUCTION

Rubber (*Hevea brasiliensis* Mull. Arg.) plays an important role in the economy of Sri Lanka; it contributes a significant share of the GNP and provides employment to over 500,000 people (Status Review Report of Rubber Research Institute of Sri Lanka 1992). Whilst most of the Sri Lankan rubber is grown on large and medium estates (*ca.* 70%), smallholders comprise the largest sector in terms of the total number of growers (Status Review Report of Rubber Research Institute of Sri Lanka, 1992), the majority of whom own less than one hectare (Rodrigo *et al.*, 2001a). In Sri Lanka, the large estates are still in the process of being carved up to provide land for the landless under the Land Reform Act of 1972, with further fragmentation taking place with the distribution of lands amongst siblings. This reflects a global trend in rubber production, moving away from the large estate sector towards smallholders (Rubber Statistical Bulletin, 2000).

Rubber cultivation is associated with a long immature period (*ca.* six years under good management conditions and possibly longer under low input conditions), during which no latex is harvested. Whilst the estate sector manages this problem by adopting an annual replanting cycle of *ca.* 3.3%, this is not an option for smallholders because of the limited land available. In the case of smallholders, intercropping with crops that have a short gestation period offers the most practical means of addressing the gap in income suffered after replanting. The provision of an alternative source of income is particularly important to farmers hovering on or below the poverty line and also to the land poor who have the opportunity to provide labour or contract in land for intercropping (Stirling *et al.*, 1998). Smallholders hold varying opinions as to the benefits of intercropping, some suggesting that the companion crop exerts a negative (Jayasena & Herath, 1986), whilst others suggest a positive (Rodrigo *et al.*, 2001a) effect on growth of rubber. However, where productivity has been evaluated, studies have shown that growth of rubber is improved in the intercrop relative to sole crop

(Chandrasekera 1984; Keli *et al.*, 1997; Kouadio *et al.*, 1997; Rosyid *et al.*, 1997; Rodrigo *et al.*, 1997).

The choice of intercrop will depend on several factors relating to local needs, capital required, access to markets and agroclimatic conditions. According to Jayasena & Herath (1986), banana appears to be the most popular intercrop of rubber in Sri Lanka. This could be due to the versatility of banana as evident by its ubiquitous presence in home gardens (Hitinayake, 1996; Rodrigo *et al.*, 2001a). Recommendations for intercropping in Sri Lanka are for a single row of banana planted between the rows of rubber. This low planting density, in which banana is planted at a density of only *ca.* 30% of that found in monocrops, is designed to minimise the risk of latex yield losses through competitive effects on the young rubber tree (Chandrasekera, 1984).

Intercropping offers a means of increasing income and land use efficiency during the unproductive immature phase of rubber (Rodrigo, 1997) and current recommendations for the planting density of banana in banana/rubber intercrops appear to be well below that which either crop can tolerate. We aimed to test this view by evaluating the effects of a range of planting densities of banana on intercrop performance. The specific aims of the study were; (i) to determine the optimum planting density for banana when grown in combination with an immature rubber tree crop, (ii) to quantify the effects of planting density on seasonal light and water use of banana and rubber and (iii) to evaluate the financial performance of different density intercrops.

MATERIALS AND METHODS

Experimental site and design

A large scale experiment was established on a 5 ha area of the Kuruwita sub-station of Rubber Research Institute of Sri Lanka (RRISL), situated in the Rathnapura district of the low country wet zone. In addition to the main experimental site a small-scale replicate experiment was set up on a one hectare block in the Pallegoda estate of the Kalutara district, also in the low country wet zone.

The experiment comprised five treatments, sole crop rubber (R), sole crop banana (B) and three intercrops consisting of an additive series of one (BR), two (BBR) and three (BBBR) rows of banana to one row of rubber. Genotypes used for rubber and banana were Clone RRIC 100 and variety Kolikuttu (tissue cultured), respectively. Planting density of rubber remained at 500 plants ha^{-1} in both sole and intercrops, whilst that of banana varied 500, 1000, 1500 and 1700 plants ha^{-1} in BR, BBR, BBBR and B treatments, respectively. General crop husbandry was based on the recommendations of respective crop institutes. Treatments were laid out in four randomised blocks in the main experiment and in a single block at the Pallegoda site. Further details are given in Rodrigo (1997) and Rodrigo *et al.* (1997).

Growth and development

Whole plant samples of both rubber and banana were harvested periodically for growth analyses. In addition, height and girth at 0.9 m above the bud-grafted union of rubber, were measured for ten plants at the centre of each plot, coinciding with the destructive growth analysis. Whilst regular growth analyses of both crops were limited to the period up to 28 months after planting (MAP), girth measurements of rubber continued for a period of five years. The number of banana plants harvested in each plot and their bunch weights were recorded throughout the experiment. These measurements were restricted to the main experiment at Kuruwita. In addition, girth and height of rubber (ten plants per treatment) and fresh weight of banana (*i.e.* four plants per sole crop and for each row position in the intercrops) were measured at the end of the experiment (28 MAP) at the Pallegoda site.

Leaf photosynthesis and fractional light interception

Solarimeters were constructed locally at the National Engineering Research Development Centre and used to record daily incoming and transmitted radiation (Rodrigo 1997; Rodrigo *et al.,* 2001b). Seasonal fractional interception was calculated using data from tube solarimeters mounted above and below the canopies and at ground level in all experimental blocks. Gas exchange was measured using a portable infra-red gas analyser (LI6200, Li-Cor, USA). Full details of the sampling protocol are given by Rodrigo (1997) and Rodrigo *et al.* (2001).

Stomatal conductance and water use

Water use was calculated using the Penman-Monteith equation to estimate transpiration rates. Some of the input variables required by this equation, including net radiation, temperature, relative humidity and windspeed were measured directly by an automated weather station situated at the site (Campbell Scientific Ltd. UK). Stomatal resistance of component crops was measured using a steady-state porometer (LI1600, Li-Cor, USA), whilst other variables (boundary layer resistance, vapour pressure deficit and windspeed above the crop canopy) were derived using existing ecophysiological models, as described by Rodrigo (1997).

Data analysis

Data were analysed using the SAS statistical package (SAS Institute Inc., Cary, NC, USA) and the Proc. ANOVA and Proc. GLM procedures for balanced and unbalanced (*i.e.* for banana in which a different number of plants were harvested according to the treatment) models, respectively. Data for each harvest were analysed separately with the Randomized 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 (Azam-Ali *et al.*, 1990), whilst Land Equivalent Ratio, LER, (Willey, 1985) was used to evaluate the cropping system as a whole.

Financial assessment of intercrop performance

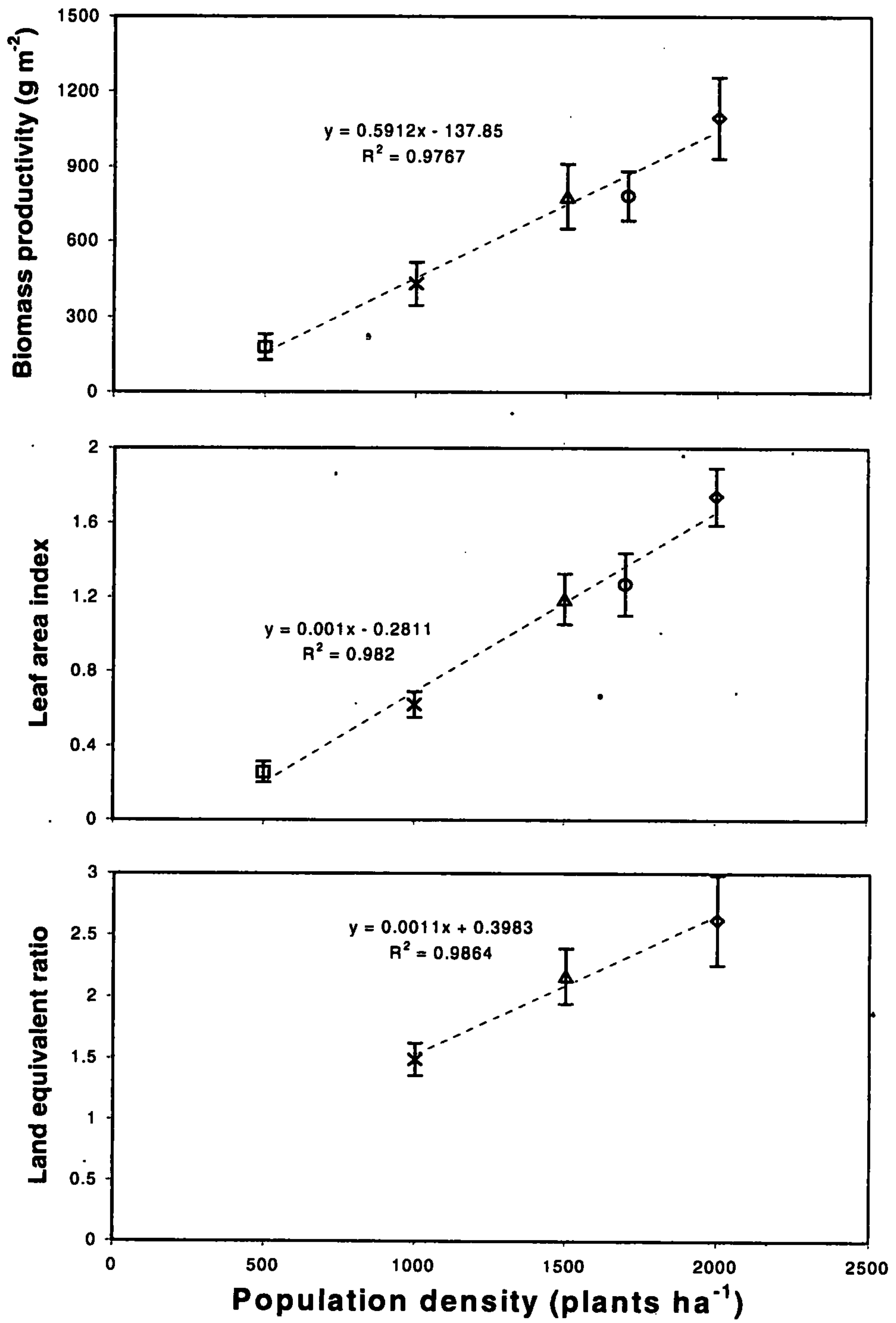
A financial assessment of rubber/banana intercropping was made using data available for the experiment (Rodrigo, 1997; Rodrigo *et al.*, 2001a). It was possible to harvest only a few banana plants in all treatments from the third year onwards due to crop losses during prolonged dry spells in 1996 and at the beginning of 1997. Therefore, the yield data available for analysis was for only two years, although banana, in general, could be grown as a rubber intercrop for three or more years. Whilst the cost involved in the third year of growth would be similar to that of the second year, yields may have varied significantly. Therefore, financial analysis over a three year period of banana growth was based on three scenarios in which yield of banana in the third year was (i) identical to, (ii) 75% and (iii) 50% of that produced in the second year. Both cost and benefit were calculated on a per hectare basis with values for a labour unit, 1kg of fertilizer and 1kg of banana fruit of Rs.83, 12 and 20, respectively. Labour cost was based on wages in the plantation sector and each unit referred to eight working hours, whilst values for fertilizer and banana fruit were determined by the general retailed price and farm gate price of Sri Lanka, respectively (Rodrigo *et al.*, 2001a).

RESULTS

Growth and yield

Both mean Total Dry Matter (TDM) and Leaf Area Index (LAI) showed a similar, positive relation with planting density: the lowest values were observed in the low density R crop and the highest in the high density BBBR treatment (Fig. 1). No significant difference in TDM and LAI was observed between the B and BBR treatments. According to the best-fit lines, the rate of increase in TDM and LAI with the density (plants ha^{-1}) was 0.59 (gm^{-2}) and 0.001, respectively. The LER for TDM exceeded unity in all intercrops and increased with planting density, reflecting a consistent intercropping advantage (Fig. 1c).

Fig. 1. Summary of treatment effects on (a) biomass productivity, (b) leaf area index and (c) land equivalent ratio. Data represent the mean for each treatment over the experimental period ± SE. Equations describing the regressions fitted to data (broken lines) are shown together with r^2. Data points at planting densities of 500, 1700, 1000, 1500 and 2000 refer to the sole rubber, sole banana, single, double and triple row rubber/banana intercrop treatments, respectively.


Biomass productivity (g m-2)
1500
1200
900
600
300
0
y = 0.5912x - 137.85
R2 = 0.9767
Leaf area index
2
1.6
1.2
0.8
0.4
0
y = 0.001x - 0.2811
R2 = 0.982
Land equivalent ratio
3
2.5
2
1.5
1
0.5
0
y = 0.0011x + 0.3983
R2 = 0.9864
0
500
1000
1500
2000
2500
Population density (plants ha-1)

Benefits of high density banana intercropping

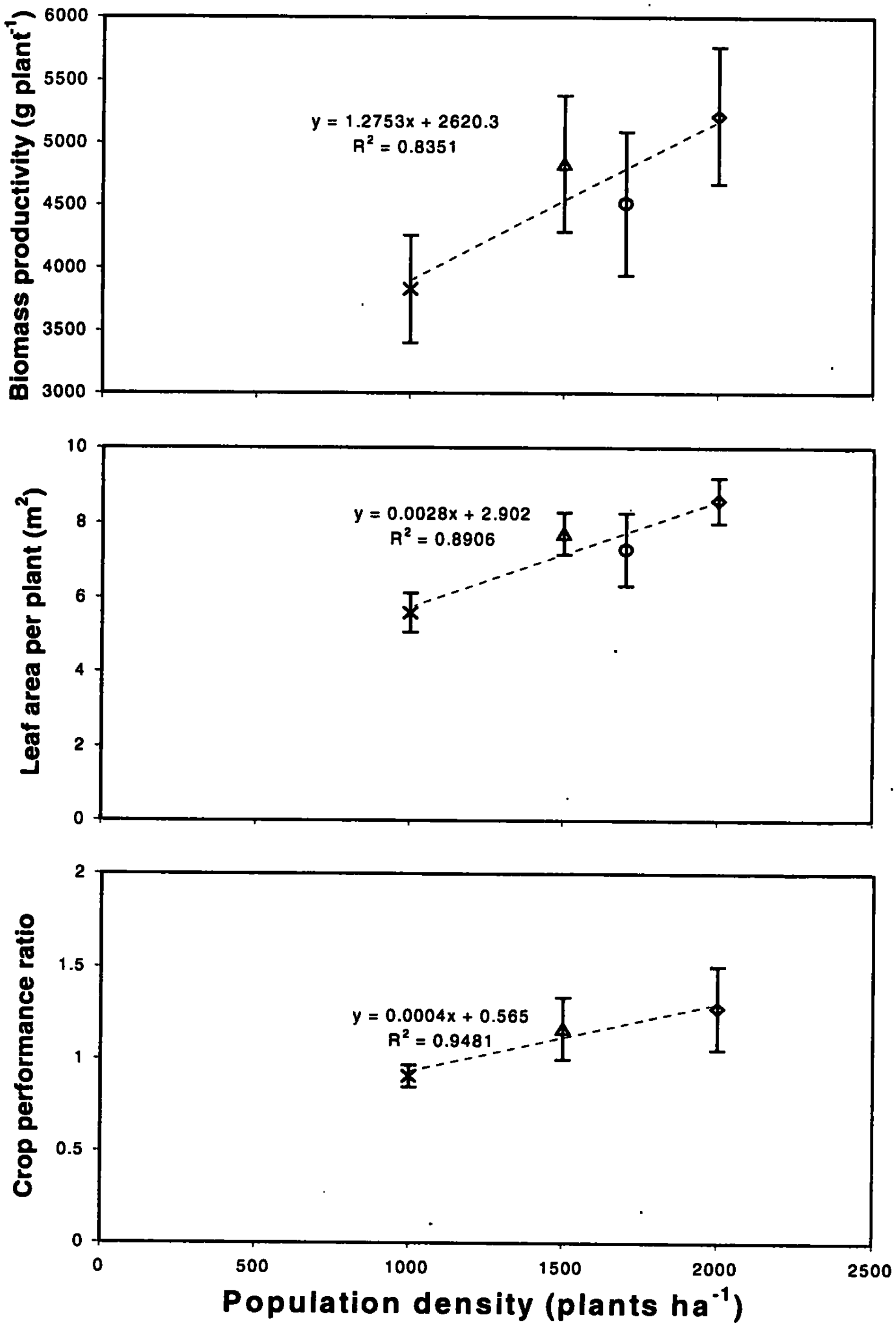
The performance of individual component crops was assessed in relation to whole treatment planting density. Values for banana represent the mean over the experimental period, *i.e.* up to 28 MAP (Fig. 2), whilst values for rubber are those obtained at final harvest at 28 MAP because unlike banana, rubber growth increased steadily with time and reached a maximum at 28 MAP (Fig. 3). Except in the low density BR intercrop, treatments had a little effect on biomass productivity and leaf area per plant of banana in high density systems and therefore, CPRs of BBR and BBBR were similar and greater than that of BR (Fig. 2c). In the case of rubber, biomass productivity and leaf area per plant were greater in the intercrops than the sole crop, particularly under the high density system (Fig. 3). In general, the greater the planting density, the greater the TDM and CPR of intercropped rubber.

Data from the second small-scale experiment at Pallegoda also indicated an improved performance of banana when intercropped than when grown alone, with CPRs (based on fresh weight at 28 MAP) greater in the higher density BBR and BBBR intercrops than in the BR system (Table 1). The magnitude and direction of the growth response of banana was similar at both sites, despite widely differing management and growth conditions.

Stem girth and height of rubber (Figs. 4 and 5) showed an improved performance in the intercrops relative to the sole crop throughout the experimental period. Likewise, intercropped rubber in the high density BBR and BBBR treatments performed best in terms of both girth and height at the Pallegoda site (Table 1). The onset of tapping is determined by the % of trees with a girth at a height of 90 cm above the bud-grafted union exceeding 50 cm. After 5½ years of growth, the high density BBR and BBBR systems of the main experimental site showed an increase in tappable trees with values of 69 and 72% respectively, compared with the sole (51%) and BR (60%) treatments.

Bunch yield on a unit area and unit plant basis together with CPR and percentage of plants producing a marketable yield (*i.e.* where total finger weight per bunch exceeded 3 kg), during the second year of the crop are presented in Table 2. The CPR was based on the yield per hectare which was determined by yield parameters (*i.e.* yield per plant, planting density and percentage of plants producing a marketable yield). On a per plant basis, bunch yield, harvested percentage and hence the CPR remained fairly constant amongst treatments with means of 6158g, 65.3%

Fig. 2. Summary of treatment effects on (a) biomass productivity, (b) leaf area and (c) crop performance ratio of banana. Data represent the mean for each treatment over the experimental period ± SE. Equations describing the regressions fitted to data (broken lines) are shown together with r^2. Data points at planting densities of 1700, 1000, 1500 and 2000 refer to the sole banana, single, double and triple row rubber/banana intercrop treatments, respectively.


Biomass productivity (g plant-1)
6000
5500
5000
4500
4000
3500
3000
y = 1.2753x + 2620.3
R2 = 0.8351
Leaf area per plant (m2)
10
8
6
4
2
0
y = 0.0028x + 2.902
R2 = 0.8906
Crop performance ratio
2
1.5
1
0.5
0
y = 0.0004x + 0.565
R2 = 0.9481
0
500
1000
1500
2000
2500
Population density (plants ha-1)

and 0.95, respectively. However, yield per hectare differed significantly between treatments ($P < 0.001$) and increased with planting density of banana, with comparable yields in the sole and BBBR treatments (Table 2; Rodrigo *et al.*, 1997). Banana in all treatments was affected by severe dry spells in third year with the result that yields were extremely low and variable thereafter and so not presented.

Table 1. *Treatments effects at Pallaegoda experiment (a) crop performance ratio, leaf area index and plant weight of the sole banana crop and component banana in the intercrop treatments based on fresh weights, and (b) girth and height of rubber, at 28 months after planting.*

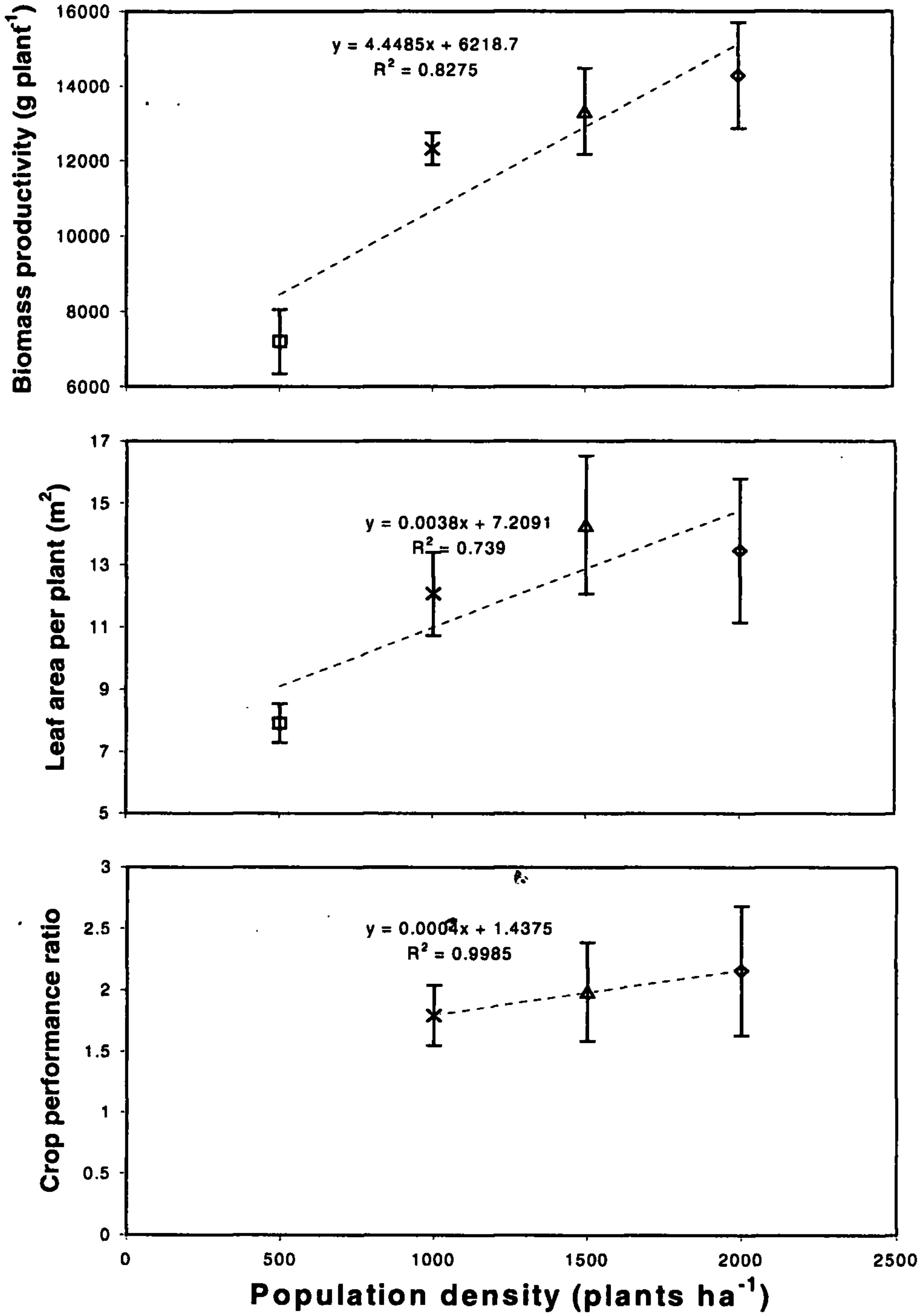
(a)	Sole crop banana	Single row banana intercrop	Double row banana intercrop	Treble row banana intercrop
Crop performance ratio		2.67	5.07	4.4
Leaf area index	0.35	0.35	0.73	1.22
Plant weight (kg)	17.38	46.02	88.07	76.34

(b)	Sole crop rubber	Single row banana intercrop	Double row banana intercrop	Treble row banana intercrop
Stem girth at 90 cm height (cm)	22.97	25.03	25.89	23.81
Plant height (cm)	765.7	765.3	835.2	804

Seasonal light and water use

Fractional interception, *f*, during the measurement period was greatest in the BBBR system (Table 3). By the end of the measurement period the total radiation intercepted by the BBBR treatment was 6374 MJ m^{-2}, 23 and 73% greater than in the BBR and BR, respectively. Also, Radiation use efficiency (RUE) tended to be greater for the intercrops relative to sole crop rubber.

Fig. 3. Summary of treatment effects on (a) biomass productivity, (b) leaf area and (c) crop performance ratio of rubber. Data represent the mean for each treatment at 28 months after planting ± SE. Equations describing the regressions fitted to data (broken lines) are shown together with r^2. Data points at planting densities of 500, 1000, 1500 and 2000 refer to the sole rubber, single, double and triple row rubber/banana intercrop treatments, respectively.


Biomass productivity (g plant-1)
16000
14000
12000
10000
8000
6000
y = 4.4485x + 6218.7
R2 = 0.8275
Leaf area per plant (m2)
17
15
13
11
9
7
5
y = 0.0038x + 7.2091
R2 = 0.739
Crop performance ratio
3
2.5
2
1.5
1
0.5
0
y = 0.0004x + 1.4375
R2 = 0.9985
0
500
1000
1500
2000
2500
Population density (plants ha-1)

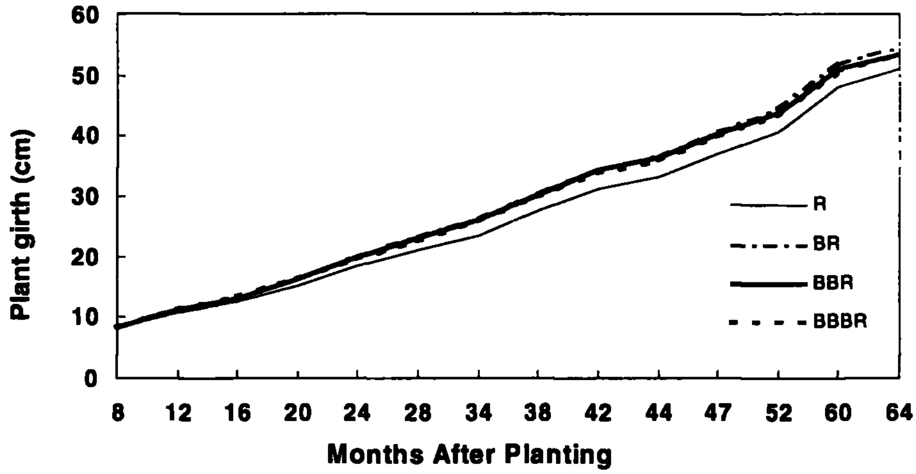


Fig. 4. Time course for treatment effects on the growth of rubber assessed in terms of the mean girth of the main stem measured at a height of 90 cm from the bud-grafted union. Treatments are: R = sole crop rubber, B = sole crop banana and BR, BBR and BBBR refer to the single, double and triple row banana/rubber intercrops

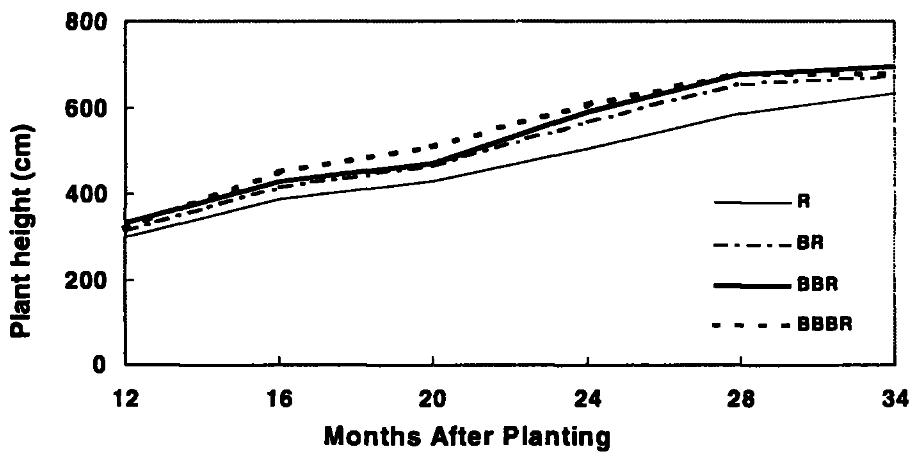


Fig. 5. Time course for treatment effects on the growth of rubber assessed in term of the mean plant height. Measurements were taken only up to 34 weeks after planting. Treatments are: R = sole crop rubber, B = sole crop banana and BR, BBR and BBBR refer to the single, double and triple row banana/rubber intercrops

Table 2. *Summary of treatment effects on economic yield of banana during the second year of the crop. Means of yield per hectare with different letters are significantly different at the P < 0.05 level. The means of other parameters were not significantly different*

Cropping system	Banana density (plants/ha)	Mean bunch yield (kg/plant)	% of plants harvested	Yield per hectare (kg/ha)	Crop performance ratio
Sole crop banana	1700	6.1	69.2	7359[a]	
Single row banana intercrop	500	5.9	63.8	1931[c]	0.9
Double row banana intercrop	1000	6.1	64.6	4099[b]	1.0
Triple row banana intercrop	1500	6.5	63.4	6370[a]	1.0

Table 3. *Summary of treatment effects on intercepted radiation and radiation use efficiency, RUE. Treatments are: R = sole crop rubber, B = sole crop banana and BR, BBR and BBBR refer to the single, double and triple row banana/rubber intercrops*

	R	B	BR	BBR	BBBR
Average fractional interception (%)	20	45	31	44	54
Cumulative intercepted radiation from 16 to 126 WAP (MJ m^{-2})	2357	5331	3691	5196	6374
Average radiation use efficiency (g MJ^{-1})	0.149	0.233	0.249	0.325	0.341

In general, rates of leaf photosynthesis (A_{leaf}) were alike in both banana and rubber (Table 4). Whilst some statistical differences in A_{leaf} among treatments were observed due to the large number of measurements made, the magnitude of the effect was physiologically negligible. No clear differences in treatment effect on dark respiration were observed (Table 4). Full details of the light use study appears in (Rodrigo *et al.,* 2001b).

Transpiration rate (Tr) and cumulative water use (ΣWU) increased dramatically with an increase in banana density (Table 5), with greater values in the B and BBBR treatments. However, no significant treatment effect on water use efficiency (WUE) or soil water status was observed (data not shown here, see Rodrigo 1997).

Financial appraisal of intercropping systems

The estimated profit, *i.e.* net present value (NPV) for the three year period of banana cultivation increased with increasing banana density and also with decreasing discount rate, resulting in an increased profit to the farmer (Table 6a). Cultivation of banana was financially viable under the first two scenarios in which third year yield was assumed to be equal, or 75% of that produced during the second year. Under the 'worst case' scenario No. 3, intercropping rubber with banana was profitable only in the BBBR system and under low discount rates with a value of 6.15% for the internal rate of return (IRR). Taking the best scenario for the third year yield, NPV in the BBBR system exceeded Rs.50,000 ha^{-1} at a 4.5% discount rate, whilst the currently practised BR system achieved only Rs.12,363. The sensitivity of profitability to yield in the third year was reflected in the IRR which exceeded 25% in all cropping practices for the best scenario and 12% for a 25% reduction in yield. If yield during the third year was only 50% of that produced during the second year then the IRR never exceeded 7%. Repeating the analysis, but assuming that no labour costs were involved, IRR never fell below 23%. The highest NPV was recorded as Rs.90,521 ha^{-1} for the BBBR intercrop under scenario 1, without labour cost and using a 4.5% discount rate.

Table 4. *Summary of treatment effects on the photosynthetic performance and respiration of component crops. Treatment codes are similar to those in Table 3 and MAP refers to months after planting. Mean for each crop followed by a different letter is significantly different at the P < 0.05 level*

	Mean assimilation rate over the mother crop period of banana ($\mu mol\ m^{-2}\ s^{-1}$)	Mean assimilation rate over the ratoon crop period of banana ($\mu mol\ m^{-2}\ s^{-1}$)	Rate of dark respiration ($\mu mol\ m^{-2}\ s^{-1}$)
Rubber			
R	6.0 ^{a}	7.3 ^{a}	1.0 ^{b}
BR	5.6 ^{b}	7.4 ^{a}	0.8 ^{a}
BBBR	5 ^{c}	6.6 ^{a}	0.9 ^{ab}
Banana			
B	6.2 ^{b}	6.5 ^{a}	1.7 ^{a}
BR	7.3 ^{a}	5.9 ^{b}	1.8 ^{a}
BBBR	6.6 ^{b}	5.8 ^{b}	1.7 ^{a}

Table 5. *Summary of treatment effects on water use. Treatments codes refer to: R = sole crop rubber, B = sole crop banana and BR and BBBR = single and triple row banana/rubber intercrops, respectively*

	R	B	BR	BBBR
Average rate of transpiration (mm/week)	1.96	8.25	4.36	10.48
Cumulative water use from 35 to 122 WAP (mm)	172	726	384	923

The cost involved in each component and hence the total cost, increased with planting density of banana with the greatest value recorded in the BBBR system (Table 6b). Fertilizer cost always contributed towards the greatest share of the total cost and was followed by the cost of labour. Full details of the financial appraisal of these cropping systems appear in Rodrigo *et al.* (2001a).

Table 6. *Financial implications of intercropped banana with respect to: (a) profitability expressed in terms of Net Present Value (NPV) under three scenarios whereby yield in the third year was equal (scenario 1), 75% (scenario 2) and 50% of that produced during the second year (scenario 3) and analysed under different discount rates and with/without labour cost, (b) major components of the cost involved for a three year growth period. All values are expressed in Sri Lankan rupees*

(a)	BR	BBR	BBBR
Scenario 1;			
With labour cost			
Discount rate 10%	8398.58	24338.85	43497.75
Discount rate 4.5%	12362.81	33291.52	57875.95
Internal Rate of Return	26.92	33.87	37.99
Without labour cost			
Discount rate 10%	18597.97	44737.64	74095.94
Discount rate 4.5%	23244.40	55054.68	90520.69
Internal Rate of Return	55.52	63.37	68.06
Scenario 2;			
With labour cost			
Discount rate 10%	1148.39	8940.65	19568.38
Discount rate 4.5%	3906.55	15331.82	29965.91
Internal Rate of Return	12.65	19.99	24.32
Without labour cost			
Discount rate 10%	11347.78	29339.44	50166.57
Discount rate 4.5%	14788.13	37094.98	62610.65
Internal Rate of Return	41.54	49.65	54.48
Scenario 3;			
With labour cost			
Discount rate 10%	-6101.80	-6457.55	-4361.00
Discount rate 4.5%	-4549.71	-2627.88	2055.86
Internal Rate of Return	-7.26	1.25	6.15
Without labour cost			
Discount rate 10%	4097.60	13941.25	26237.19
Discount rate 4.5%	6331.87	19135.28	34700.60
Internal Rate of Return	23.62	32.39	37.56

Benefits of high density banana intercropping

(b)	BR	BBR	BBBR
Labour	11537	23074	34611
Inorganic fertilizer	40500	81000	121500
Other	8900	17800	26700

DISCUSSION

Increasing the planting density of banana in the intercrop had significant agronomic and economic advantages over the present recommended single row intercrop. No adverse effects of increasing planting density of banana on either the component rubber or banana crop growth were observed and instead both crops appeared to benefit from each other through the provision of shade. On average, up to a 36 and 25% increase in biomass yield was observed on a plant basis for banana and rubber crops respectively, as planting density of banana was increased from one to three rows. Consequently, total biomass per unit area increased by more than 150% from the BR to BBBR treatment.

As C3 crops, light saturation of leaf photosynthesis of both banana (Rodrigo 1997) and rubber (Nugawela, 1989) occurs well below full sunlight and therefore shading had a minimal effect on photosynthesis in the intercrops. Also, there was no marked treatment effect on dark respiration. Shading in the intercrops would have resulted in fewer leaves in the canopy being light saturated with respect to photosynthesis and so less light would have been wasted, resulting in an increase in RUE. Moreover, canopy size of both crops increased with planting density, thereby contributing to an increase in whole plant photosynthesis.

The ground area covered by the surface vegetation, *i.e.* cover crop (*Pueraria phaseoloides*), depended on the total crop density of treatments. Although total water use by banana and rubber increased with planting density, the soil moisture status was unaffected by treatments (Data not shown here – see Rodrigo 1997). This indicates that planting density did not result in an increase in total water use but only the proportion of soil moisture that was use by the crop component rather than the ground cover crop.

In addition to plant growth, the economic yield of banana was unaffected by an increase in density and a large increase in net profit was predicted for the high density intercrop under a wide range of scenarios for yield in the third year and with different levels of discount rate, labour use and market price of banana (Rodrigo *et al.*, 2001a). Market price of banana should not be affected by the adoption of the high density banana/rubber intercrop system either at the smallholder or estate levels (Stirling *et al.*, 1998). The observed increase in banana yield and economic return of the high density systems would have the effect of increasing food supply and help to improve the living standards among resource poor smallholders. The demands for extra labour inputs associated with high density intercropping may be met in some cases by family labour. With respect to poverty, people in the farming community who are below or hovering at the poverty line may benefit from high density rubber/banana intercropping which appears to generate significant amount of income in low input systems (Stirling *et al.*, 1998). Even the landless households may benefit from intercropping through the provision of labour and/or contracting others' immature rubber lands for intercropping (Janowski, 1997; Stirling *et al.*, 1998). Furthermore, the improved economic returns during the immature period of growth of rubber may encourage farmers to replant their old rubber plantations, which could possibly benefit the country as a whole by increasing rubber production at the national level.

Although only the growth of rubber was assessed in this study, improved growth in the intercrops over the sole crop had three major implications for rubber plantations. Firstly, the evaluation index for latex exploitation of rubber is the girth dimension at 0.9 m height (Liyanage & Peries 1984), and it may be that the increase in girth in the high density intercrops would have the effect of shortening the immature growth period, with obvious benefits to farmers' income. Indeed, the number of tappable trees (*i.e.* number of trees ready to be exploited for latex) increased with planting density of banana. Secondly, the close correlation between girth and latex yield (Thattil *et al.*, 1991; Napitupulu, 1973) suggests that improved yields may be obtained from rubber in the high density banana systems. However, the early onset of tapping may limit further girth expansion (Jayasekera *et al.*, 1994) and hence the capacity for latex production in later years, with the result that farmers may have to make a compromise between the early return and the higher yield from their mature rubber plantations. Finally, in addition to early latex production, increased girth dimension and tree height may result in an increase in timber production by the time of uprooting and so provide a better incentive for replanting senile rubber.

The greater LAI in high density banana intercrops led to an increase in fractional light interception and ground cover, which would be useful to farmers in intercultivation practices as it may reduce weed growth (Jama *et al.*, 1991) and the need for a cover crop. Increased ground cover is also likely to decrease soil erosion (Meyer & Harmon 1992) thereby protecting the long term sustainability of farm lands.

In the absence of any yield returns during the long immature period of rubber, farmers tend to pay little attention to the rubber crop. When banana is grown, however, the farmers' visits to the crop may increase in frequency and subsequently so too would care of the rubber crop (Yogaratnam, 1991).

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