

EFFECT OF PLANTING DENSITY ON GROWTH, YIELD, YIELD RELATED FACTORS AND PROFITABILITY OF RUBBER (HEVEA BRASILIENSIS MUELL. ARG.)

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ABSTRACT

Data available on an experiment on planting density of rubber in Kalutara region of Sri Lanka were analyzed in view of investigating how planting density affects yield, yield related factors and financial return. Experiment comprised six planting densities from 400 to 920 trees per hectare and three clones PB 86, RRIC 101 and RRIC 103. Planting density has affected plant girth of all clones from fourth year onwards. Density effect on girth of RRIC 101 was higher than that of other clones. With increasing planting density bark thickness and number of latex vessel rings declined in all clones and relatively more marked in clone RRIC 101. Similarly, yield per tree per tapping decreased, but yield per hectare per tapping and net present value increased with the increase in density. Nevertheless, with only two years of yield data and assuming a total healthy stand to calculate the yield per hectare per tapping and also without knowing number of tapping days for each density tested, it is not possible to arrive at definite conclusions. Less variation in girth increment among different densities towards later stage of plant growth indicates that apparent effect of density in this stage could be a cumulative effect over the period but not the effect of this stage. No density effect on canopy light interception was evident.

Available data justifies further investigations and it is suggested that more adoptability trials located in different agro-climatic regions are to be conducted using new clones before arriving at definite conclusions. In these studies due consideration should be given to tappable stand, incidence of tapping panel dryness and tapping days.

Key words: rubber, planting density, growth, Yield, Profitability

INTRODUCTION

Rubber (*Hevea brasiliensis* Muell. Arg.) plays an important role in Sri Lankan economy. It earns foreign exchange of more than 2000 million rupees annually, whilst providing raw material for the booming local rubber based industries (Central bank of Sri Lanka 1992). Also, a significant share of labour force of the island is engaged directly or indirectly in rubber industry. An increasing demand for this natural product exists in the local and international markets. Nevertheless, a continuous drop in production is evident depriving of valuable potential foreign exchange earnings to the country. From 1979 to 1992 the annual production has dropped from 150 to 105 million kg (Central bank of Sri Lanka 1979-1992).

Newly recommended high yielding clones have become popular among growers, and hence the drop in rubber production could be attributed to decline in area under rubber. From 1982 to 1992, total hectareage of rubber dropped by ca. 10 thousand (Plantation Sector Pocket Book 1994). This is caused mainly by urbanization and also by moving into other industries profitable than rubber.

As for any other crop, for rubber too, increase in productivity in an unit area is two dimensional, i.e. increase in yield per plant and increase in plant density. Under a specific management condition yield increase per tree basically depends on the clone, thus, requires introduction of high yielding clones.

In general, crop increases with the increase in plant density to a maximum which varies markedly with the crop type and the environment. Increase in plant density will narrow down the growing space available for a single plant. This results high competition for aerial and edaphic factors, which leads to less yield per tree. However, ultimate yield increase on the basis of the unit area is resulted in higher densities, as the increased number of plants compensate for decline in yield potential per tree.

Studies on density effect of annuals are many but less on perennial tree species particularly rubber. Also, for tree species it can be expected that density effect appears towards the latter part of the plant growth. An experiment in Malaysia revealed that increase in rubber planting density from 211 to 1067 trees per hectare caused drop in yield on per tree basis (Rubber Research Institute of Malaysia 1988). According to Westgarth and Battery (1965), at a density of 1075 trees per hectare, girthing has been poor and 35% of trees have never reached the tappable girth.

Density effect of rubber could vary in different environments. No comprehensive study has so far been made on density effect of rubber in Sri Lanka. The aim of this study was to investigate the effect of plating density on yield and other related parameters of rubber.

MATERIALS AND METHODS

Experimental area

The experiment was laid at Millawa Plantation in Kalutara District in Sri Lanka. Annual average rainfall of the area is ca. 4154 mm and altitude is between 30.48 m and 45.72 m from sea level. The mean daily maximum and minimum temperatures are approximately 31°C and 22°C respectively.

Experimental design

The experiment had been established in 1977 over an area of 8.22 ha by the Department of Plant Science of Rubber Research Institute in Sri Lanka and initially consisted of 3 rubber clones namely RRIC 101, RRIC 103 and PB 86. With the outbreak of *Corynespora* leaf spot disease RRIC 103 was uprooted in 1988. Experiment comprised 6 planting densities which varies from 400–920 trees per hectare as below with four replicates. Each plot accommodates about 64–154 plants depending on the density.

Spacing (m)	Density (Plants/ha.)
2.5 x 10	400
2.5 x 7.5	533
2.5 x 6.00	666
3.87 x 3.87 (triangular)	771
2.5 x 5	800
3.54 x 3.54 (triangular)	920

Measurements

In view of overcoming edge effects, all assessments had been made only in the centre part of the plot, keeping two rubber rows as guard rows.

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Girth

Plant girth at 1.5m above the bud grafted union had been measured annually from year one to year ten (except in years six and eight) after planting and then year 15. Calculation of annual girth increment was based on these girth measurements. As there was no girth measurement in year six and eight, it was assumed that girthings in subsequent years were equal to these particular years.

Yield

Yield data was available only in year seven and ten of the experiment. Average annual yield (Y) per tree per tapping (g/t/t) had been estimated from monthly test tappings in these two years. Latex from each tree in effective area was pooled and volume measured. A 100ml sample was taken for the measurement of dry rubber content. Sample was coagulated using 1% formic acid; washed thoroughly to remove all acid; milled with horizontally grooved roller to facilitate drying; dried at 80°C for ca. 24 hrs. for a constant weight. The latex volume and dry rubber content were taken for the calculation of yield. Though the planting density could affect number of tappable trees (Westgarth and Battery 1965), it had not been recorded in this experiment. However, no significant difference ($P < 0.05$) between number of tappable trees in different densities was found in year 15. Thus estimation of yield per hectare per tapping (YH) was based on total number of plants per unit area.

Bark thickness

This was done during the year 15 of the experiment. The thickness of the virgin bark was measured in three points selected randomly at 150 cm from the union, and the thickness of renewed bark was measured at a point 5 cm below the initial cut of panel BO-1, by using a bark gauge.

Number of latex vessel rings

In the year 15 of the experiment, bark samples from the virgin and renewed bark were taken at the same height used for bark thickness measurements by using cork remover. Samples were preserved in a Formalin-Aceto-Alcohol (FAA) mixture containing 5% of formic acid, 5% of acetic acid and 90% of 50% alcohol (Corn Mary & Victor, 1960). Three transverse sections from each bark sample were taken

and were stained in Sudan III. The latex vessel rings were counted using a light microscope and the average of the three values were taken.

Light interception

Measurements of photosynthetic active radiation (PAR) were made in the year 15 of the experiment using two quantum sensors (LI 90 SR, LI COR Ltd., Lincoln, Nebraska, U.S.A.). PAR under the rubber canopy was measured at 12 randomly selected points in each plot repeated 4 times at different times of day. Corresponding light measurements from open area were also taken for the calculation of light interception.

Economic evaluation

Cost analysis of the experiment for the particular years of which yield data are available (i.e. year 7 and 10) was carried out. Neither over head charges which markedly varies from plantation to plantation nor subsidy payments were considered. Costs were based on the estimation of State Plantation Corporation (SPC) of Sri Lanka. For some management practices cost depends on number of plants per unit area and for some it does not. Based on that, cost per hectare of each year in immature period (i.e. year one to year five) for each density was calculated and then the present value was estimated using the discount rate of 18%. Similarly, present values of costs of the 7th and 10th years in which yield data are available, of the plantation were calculated. The cost for immature period is generally considered as a capital investment, thus present value of it was divided by 24 which is the mature period of rubber, in view of estimating the share of the capital for a year in mature phase. Present values of the total cost of 7th and 10th year were estimated by adding this component to the present value of the cost of the particular year.

The income of the 7th and 10th years were calculated with estimated yield per hectare of the experiment and assuming the rubber price as Rs.40/= per kilogram. For both cost and income, 280 tapping days per year (i.e. 140 days per each tree on d/2 system) were assumed. Income was also discounted as done for the cost and then net present value of 7th and 10th year for each density was estimated from the difference between present values of income and cost.

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RESULTS

Girth Development

Plant growth has followed the normally expected pattern, i.e. rate of increase is higher initially and then become less (Fig.1,2,3). Density effect on plant girthing has become apparent from the 4th year onwards in all clones. The widest range of distribution of girth among different densities was shown by the clone RRIC 101.

Yield

In general, yield per tree per tapping (Y) tends to decrease with the increase in plant density both in the 7th and 10th year after planting (Fig. 4). General decrease was 0.0096 in year 7 and 0.015 in year 10 (g/t) per unit increase in plant density. However, Y of clone PB 86 was highest at 771 trees/ha in year 7 and at 533 trees/ha in year 10.

In contrast to the Y, yield per hectare per tapping (YH) increases with the increase in plant density (Fig.5). General increase was 0.011 in year 7 and 0.015 in year 10 (kg/ha) per unit increase in plant density. Highest YH of all clones except RRIC 101 were achieved in both years at the highest density of 920 trees/ha. YH of RRIC 101 in year 7 was highest at 666, but comparable with that of 771 trees/ha.

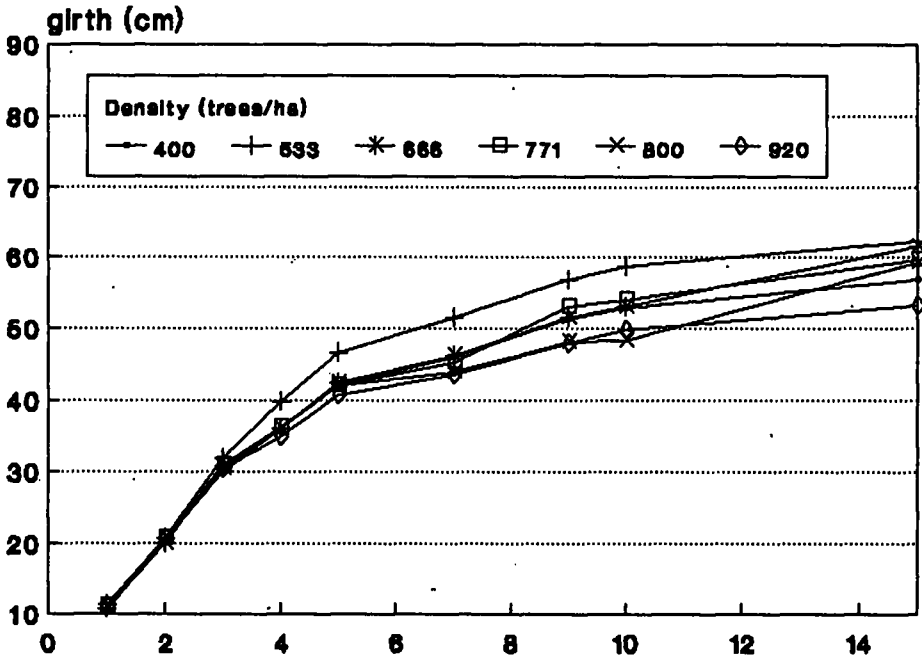
Bark thickness

Since clone RRIC 103 was uprooted, other two clones were used for this assessment. Irrespective of the clone, thickness of renewed bark (ca. 8 years of renewal) was less than that of virgin bark. Bark thickness of both virgin and renewed barks of both clones tends to decrease marginally with the increase in plant density (Fig.6). This decrease in clone RRIC 101 was higher than that of PB 86.

Latex vessel rings

Number of latex vessel rings (LVR) in both virgin and renewed barks of clone RRIC 101 decreases with the increase in plant density (Fig.7). This decrease is less prominent in clone PB 86 compared to clone RRIC 101, but both clones show lowest value at the highest density of 920 trees/ha.

(a)



(b)

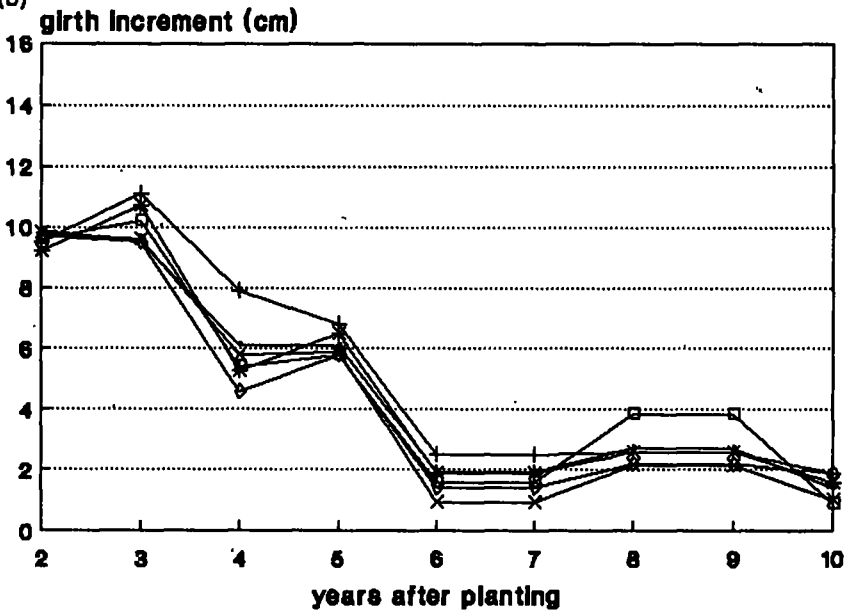


Fig. 1. Cumulative girth development (a) and annual girth increment (b) of clone PB 86 in different densities

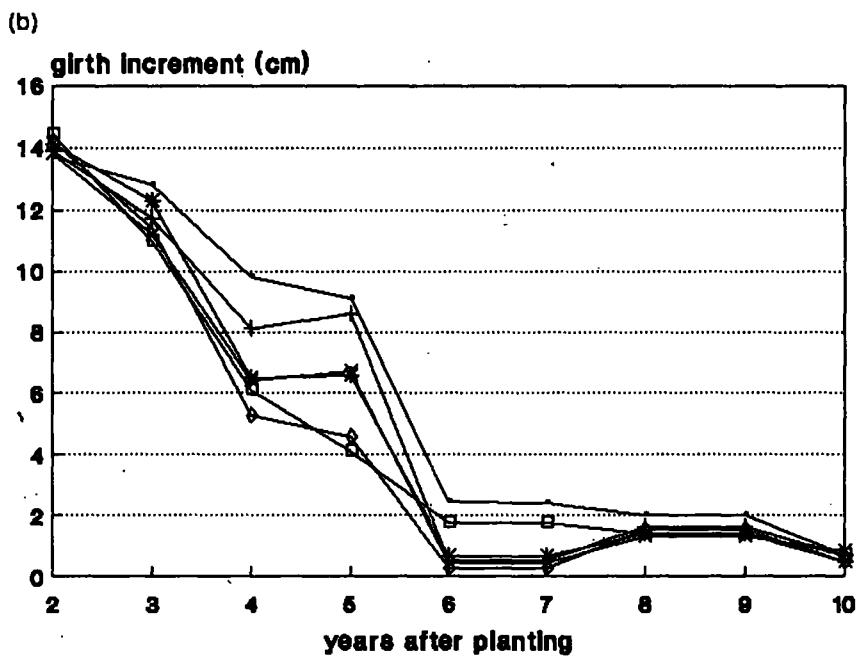
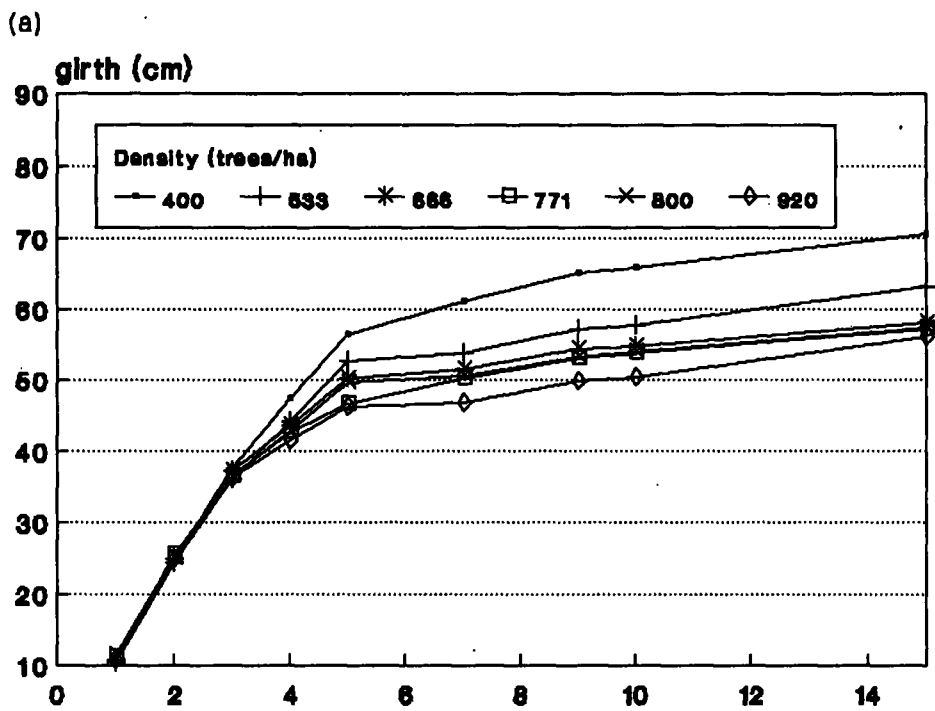


Fig. 2. Cumulative girth development (a) and annual girth increment (b) of clone RRIC 101 in different densities

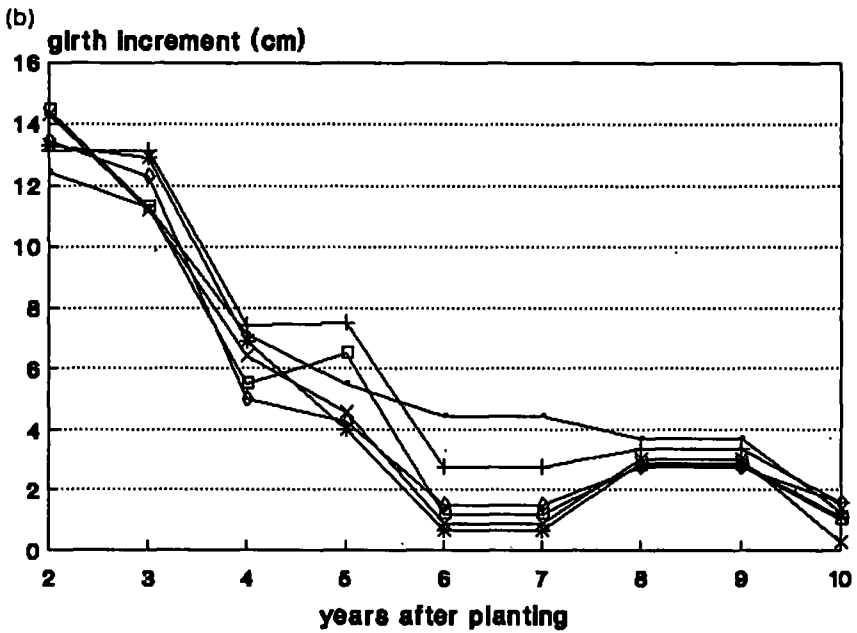
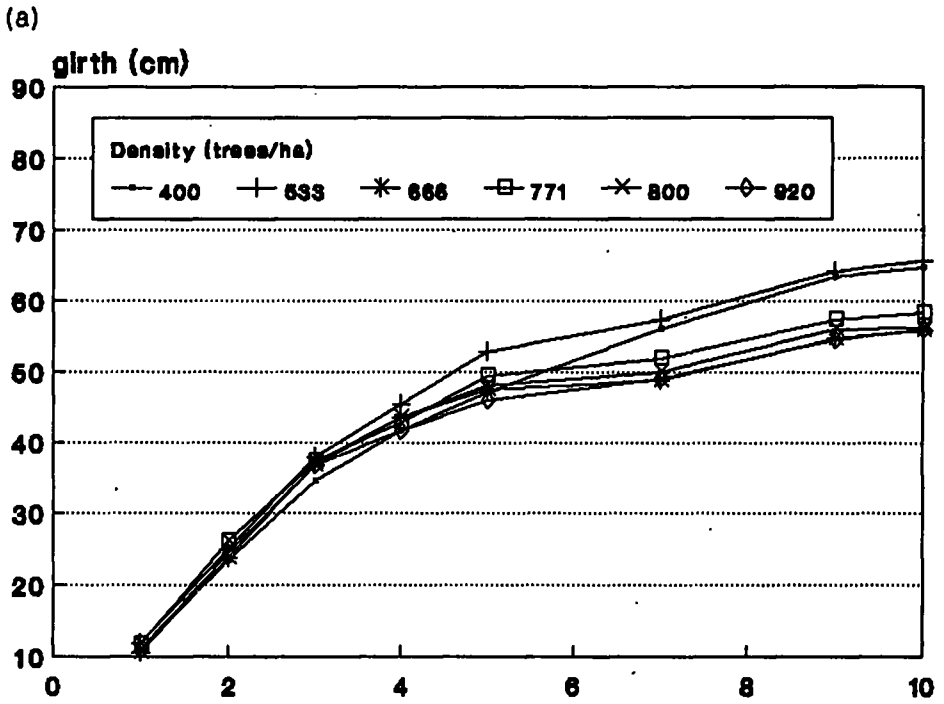


Fig. 3. Cumulative girth development (a) and annual girth increment (b) of clone RRIC 103 in different densities

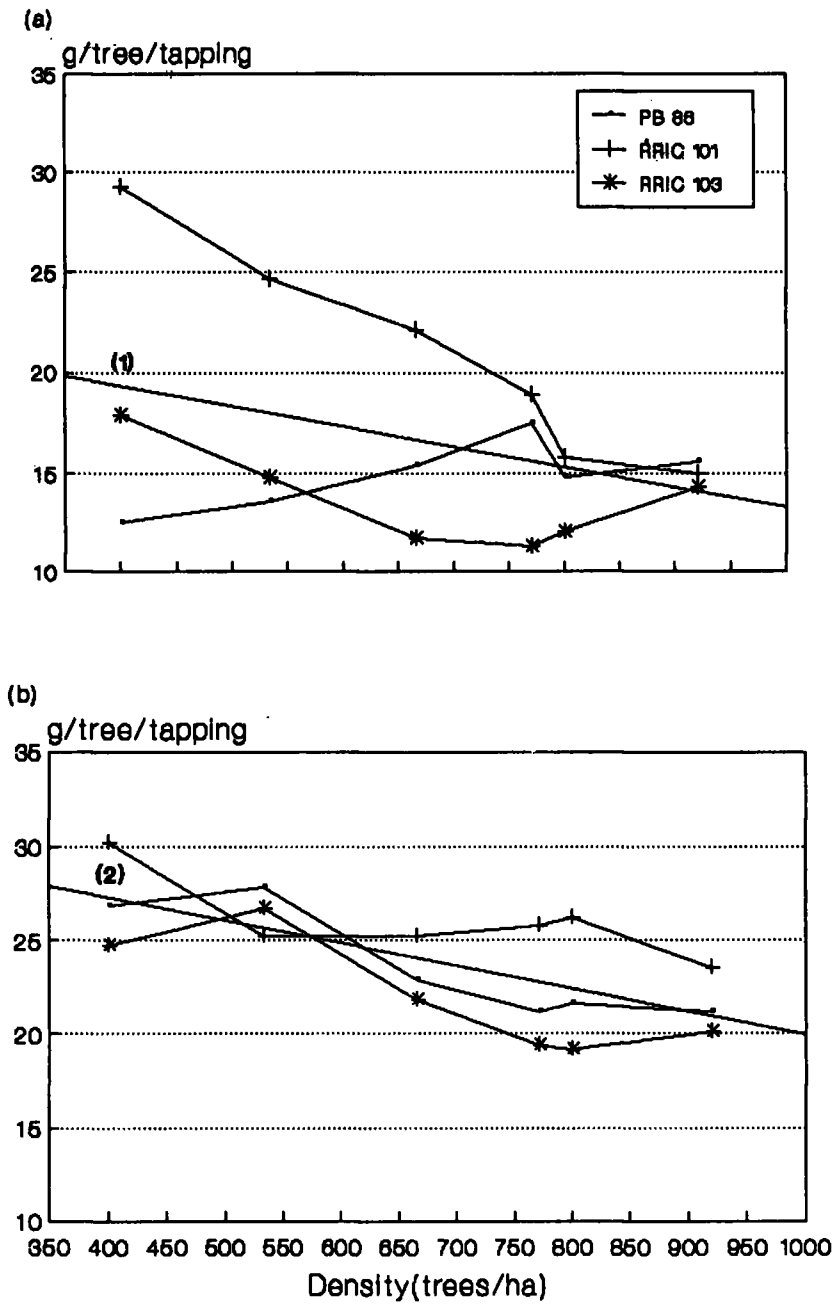


Fig. 4. Effect of planting density on mean annual dry rubber yield (g/t/t) of clones PB 86, RRIC 101 and RRIC 103 in the 7th (a) and 10th (b) year after planting

Regression equations (\pm Standard error) fitted for all clones;
 (1) Yield = $23.07(\pm 4.54) - 0.0096(\pm 0.0062) \cdot \text{Density}$ $r^2=0.13$
 (2) Yield = $34.12(\pm 2.24) - 0.0150(\pm 0.0030) \cdot \text{Density}$ $r^2=0.60$

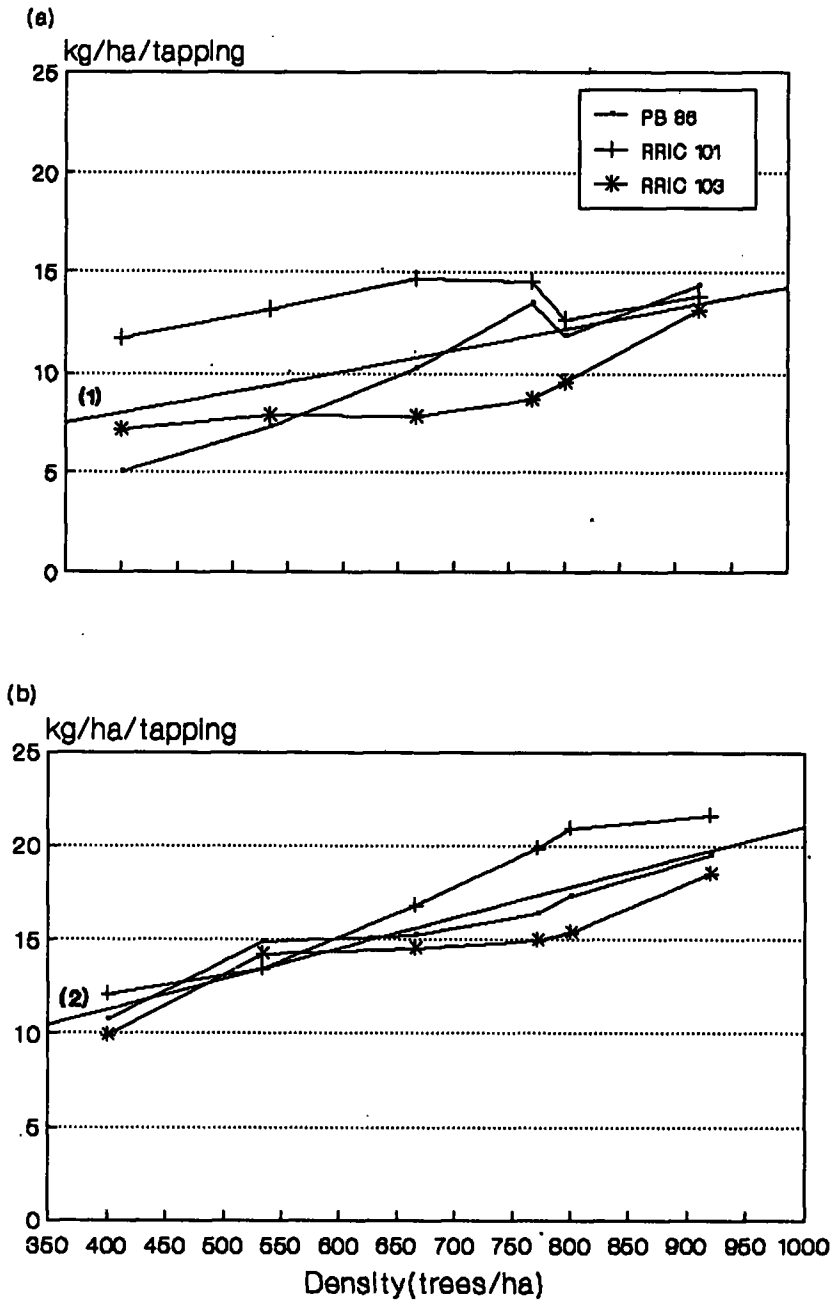


Fig. 5. Effect of planting density on dry rubber yield (kg/ha/t) of clones PB 86, RRIC 101 and RRIC 103 in the 7th (a) and 10th (b) year after planting

Regression equations (\pm Standard error) fitted for all clones;
 (1) Yield = $3.52(\pm 2.45) + 0.011(\pm 0.0033) \cdot \text{Density}$ $r^2=0.40$
 (2) Yield = $5.36(\pm 1.60) + 0.015(\pm 0.0020) \cdot \text{Density}$ $r^2=0.75$

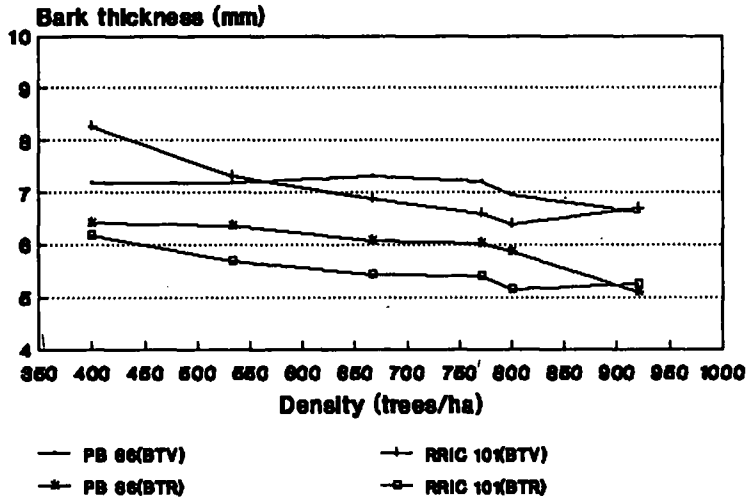


Fig. 6. Effect of planting density on the virgin and renewed bark thickness of clones PB 86 and RRIC 101 at 15 years after planting

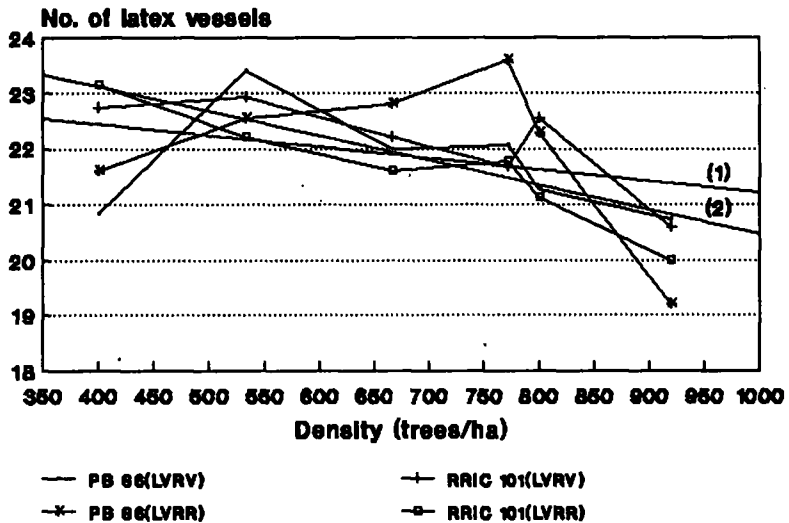


Fig. 7. Effect of planting density on number of latex vessel rings in both virgin (LVRV) and renewed (LVRR) barks of clones PB 86 and RRIC 101 at 15 years after planting

Regression equations (\pm Standard error) fitted

(1) for clone PB 86;

$$\text{LVR} = 23.13(\pm 1.25) - 0.0019(\pm 0.0021) \cdot \text{Density} \quad r^2 = 0.07$$

(2) for clone RRIC 101;

$$\text{LVR} = 24.89(\pm 0.53) - 0.0044(\pm 0.0009) \cdot \text{Density} \quad r^2 = 0.71$$

Light interception

Light interception has shown no distinct pattern with respect to change in density (Fig.8). Variation in light interception of clone RRIC 101 is higher compared to the clone PB 86.

Economic evaluation

Calculated net present values (NPV) in both years tend to increase with increase in density (Fig.9). However this is more prominent with less variation in year ten compared to year seven. Though no overall increase of NPV of clone RRIC 101 was found in year seven, its increase in year ten was clear.

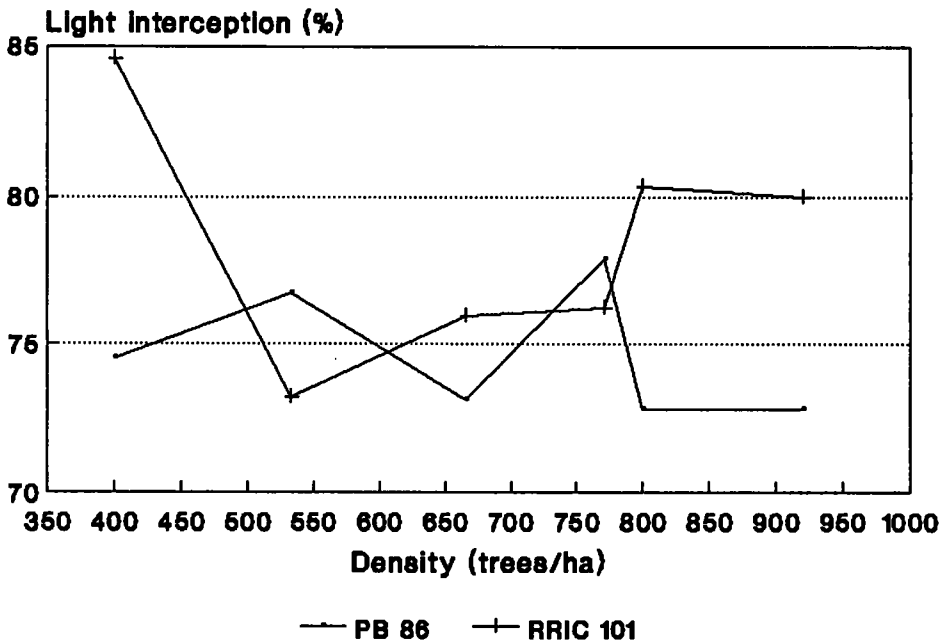


Fig. 8. Effect of planting density on light interception (%) of clones PB 86 and RRIC 101 at 15 years after planting

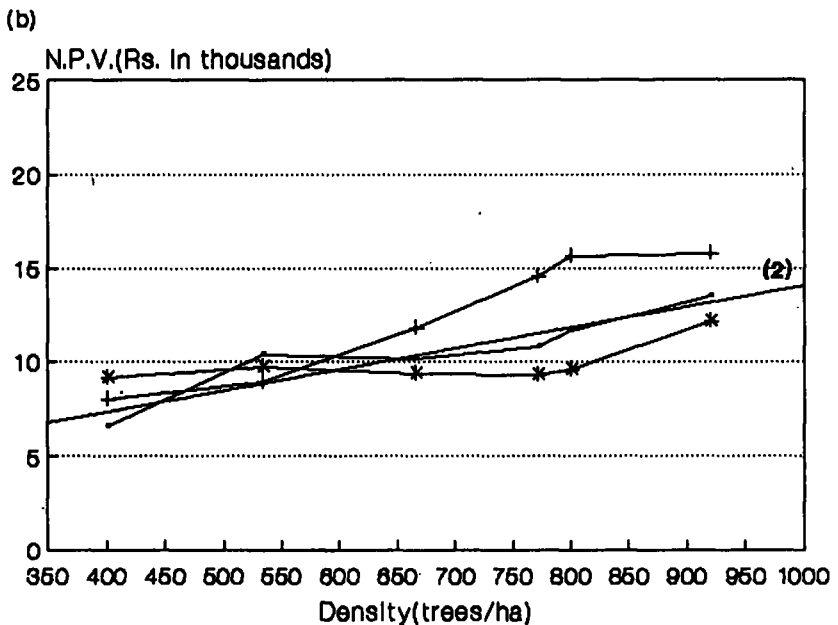
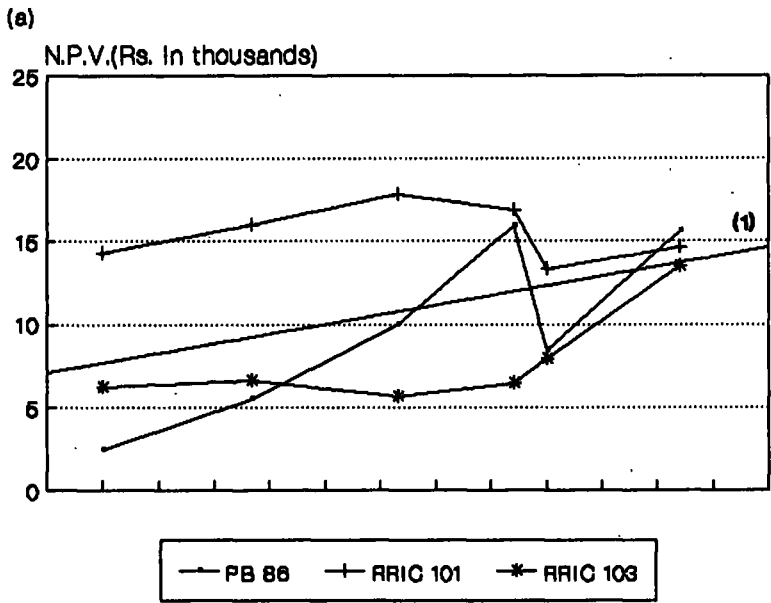


Fig. 9. Effect of planting density on Net Present Value (NPV) of clones PB 86, RRIC 101 and RRIC 103 in the 7th (a) and 10th (b) year after planting

Regression equations (\pm Standard error) fitted for all clones;

(1) $NPV = 3090.87(\pm 4490) + 11.50(\pm 6.10) \cdot \text{Density}$ $r^2=0.18$

(2) $NPV = 3570.64(\pm 1742) + 10.81(\pm 2.37) \cdot \text{Density}$ $r^2=0.56$

DISCUSSION

Among the growth and yield related parameters, light interception has followed no distinct pattern of variation with respect to the change in density or yield. High variation in light interception of this study could have been resulted by instantaneous measurements instead of continuous recording of data. However, no difference in light interception among different densities indicates a similar leaf area index or otherwise leaf distribution pattern within the canopy. An increase in light conversion efficiency or harvest index in higher densities is apparent since yield per hectare increases with no change of light interception.

Bark thickness of clone PB 86 has remained unchanged to some extent to the increase in plant density compared to that of clone RRIC 101. Generally, density effect on perennial appears later. Therefore, in rubber, effect on renewed bark could be higher than that of virgin bark. However, in this study both virgin and renewed barks have been affected more or less similarly irrespective of the clone. Similar to the bark thickness, number of latex vessel rings (LVR) tends to decrease with the increase in plant density. This effect is more marked in clone RRIC 101 when compared to the clone PB 86. Bark thickness and LVR are reported to be correlated with yield (Gomez 1979). This is further confirmed by the clone RRIC 101 of this study.

Girth measurements indicate a density effect on growth in all clones tested 4 years after planting. As similar quantities of manure were given per plant, it is likely that competition would have been for light. Canopy closure may have occurred at high densities 4 years after planting. From this stage up to commencement of tapping, i.e. 6 years after planting, girthing is clearly negatively associated with the density in all clones tested. Girth measurements made after commencement of tapping has not followed the same pattern as in immature period. Trees falling dry after commencement of tapping, i.e. tapping panel dryness, commonly shows anomalous growth resulting higher girths. If such trees are not avoided during girth measurements the true density effect on girthing could be easily masked. However, the girth increment in mature stage has been less irrespective to the clone and the density (Fig 1b, 2b, 3b). This indicates apparent density effect on different parameters at this stage could be a cumulative effect over the period of plant growth.

In general, yield per tree per tapping (Y) tends to decrease with the increase in density (Fig 4). This may be attributed to decreasing, a) girth b) bark thickness and c) latex vessel rings with the increasing plant density. Nevertheless, clone PB 86 has behaved differently (Fig 4) and justifies further investigation.

PLANTING DENSITY ON GROWTH, YIELD

Irrespective of the clone, yield per hectare (YH) increases with increasing density in both year 7 and 10. Moreover, it has not leveled off indicating density could be further increased to achieve maximum yield per hectare per tapping. An increase, similar to that of yield is also observed in net present value (NPV) except in clone RRIC 101 in year 7. Therefore it may be that the optimum density which is financially most profitable is beyond the maximum density tested. Nevertheless, when calculating the YH, it was assumed that all trees remain tappable in all densities, which may need to be further confirmed. Also, these yield data were based only on early stages of tapping, i.e. tapping on virgin bark.

Yield per hectare per year depends on yield per hectare per tapping and number of tappable days per year. With increasing plant density, it is possible to get relatively less number of normal tappings and more late tappings affecting the YPH and profitability. Further, if rain guards are used to overcome this problem, more number of extra tapping days will be needed to cover the cost of the rain guard due to low yield per tree per tapping at high densities.

Economic analysis indicates that density may be increased further than the presently recommended levels by the Rubber Research Institute of Sri Lanka i.e. 500 trees/ha. Nevertheless, the analysis was based only on yields on virgin bark and due consideration has not been given to tappable stand, incidence of tapping panel dryness and number of tapping days in different densities tested. Data on these aspects are lacking, thus in future studies, these should be looked into. Density effect may vary with environmental conditions and clones. The plot size in this study is also not sufficient to come into definite conclusions. Thus, it is advisable to have further adoptability trials on planting density in different agro-climatic regions where rubber is grown.

More recent clones with different canopy architecture should be tested in these trials and due consideration should be given to study on disease aspects and rooting pattern.

CONCLUSIONS

Yield per hectare per tapping and net present value increase with increasing density. Nevertheless, in addition to yield per tree per tapping, number of healthy trees per hectare and number of tapping days per annum affect yield per hectare. These factors may be affected by the density and demand detailed investigations. Also, indications are that a) girth b) bark thickness c) number of latex vessel rings and

hence the yield per tree per tapping decreases with increasing density. Agro-management may need changes to overcome these undesirable effects of increasing density. Controlling canopy architecture by suitable pruning programme to minimize competition for light and a manuring programme to limit competition for nutrients, i.e. split doses, are aspects need to be looked into.

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