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Full Length Research Paper

Improving planting pattern for intercropping in the whole production span of rubber tree

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A spatial arrangement for planting rubber was proposed in order to facilitate intercropping during the whole production span of rubber tree. A field experiment was established in the Experiment Farm, Chinese Academy of Tropical Agricultural Sciences, Danzhou, Hainan, China, with two planting patterns of rubber clone Reyan 7-20-59: (1) single row avenue planting pattern (SR) by 3 m × 7 m, and (2) double row avenue planting pattern (DR) by (2 m × 4 m) × 20 m. The experiment showed that the girth of rubber trees in the DR system at the first tapping year was slightly bigger than that in the SR system. Although rubber trees under tapping in per unit area in the DR system were relatively lesser, however, the yield per hectare with 98% of SR was not significantly affected due to its higher yield per tree. In addition, the DR system provided larger unshaded area of land and higher light penetration. Considering the overall performance of the two planting systems, the DR system proved to be a suitable planting system for long-term intercropping in rubber plantations.

Key words: *Hevea*, whole production span, intercropping system.

INTRODUCTION

The development of intercropping in rubber tree (*Hevea brasiliensis* Muell. Arg.) plantation began in the 1950s in China. In the 1950s, the expansion of rubber plantation area brought up issues of land use in immature rubber plantations, especially due to shortage of grain, so the main purpose of intercropping was to provide the rubber grower agricultural food products. During the 1970s-1980s, intercropping was put on the agenda due to damages of natural disasters such as typhoon, and the scale, efficiency and techniques of intercropping had been developed in an unprecedented way until the mid of 1980s. With the development of economic reform and opening up to the outside world, people's living standards have been greatly improved, and the productivity and product quality of intercrops in rubber plantations have been challenged or affected by other reasons, for instance, the lack of market of some intercrops such as tea, *Alphinia* in intercropping patterns rubber/tea and rubber/*Alpinia oxyphylla* which gradually lost their market (Lin et al., 1999).

In the past, intercrops were positioned as second-line crops to increase the land use capacity, yield per unit area, income and employment opportunities (Lin et al., 1999). However, with the increment of disastrous weather events due to global climate change and ecological awareness, and the decrement of land for growing other crops due to the fact that majority of lands have been covered with rubber tree, as well as the demand of agriculture industrialization due to marketization of products, it is also very important to stabilize income of farmers for whole production span, especially in the period after natural disaster or market stagnant, to produce food and vegetable for the people or to enrich biodiversity of rubber plantations in the area of hundred-miles rubber plantation in China so that intercrops are no longer as underpart and should be industrially planted as regular crops during the whole rubber production span of rubber tree. Nevertheless, most other crops generally do not grow as tall as rubber tree, and hence with the development of the rubber canopy, the practicality of inter-planting crops which demand fairly high amounts of radiation is not

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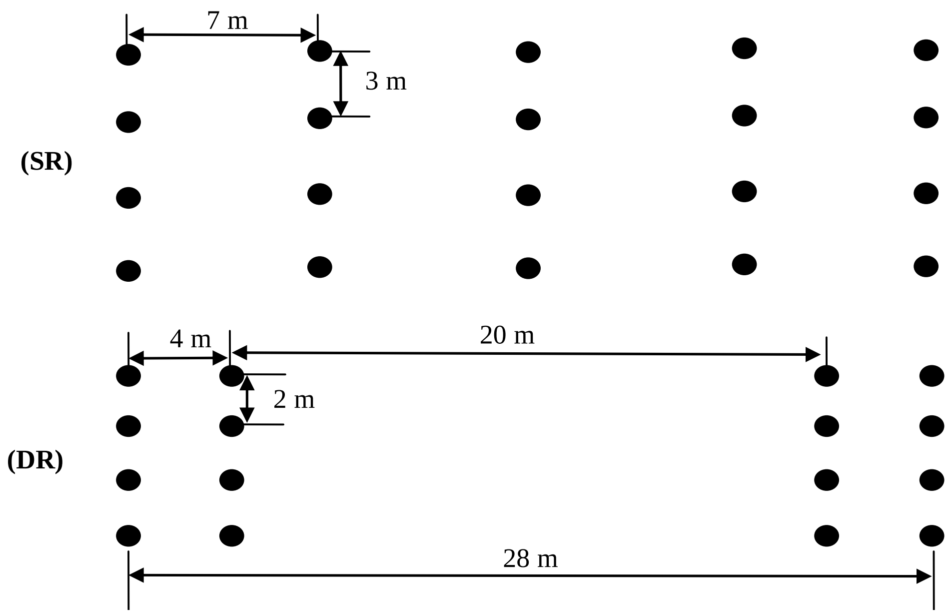

Figure 1. Schematic diagram showing the layout of different spatial arrangements of planting rubber. SR: Single row avenue planting pattern; DR: double row avenue planting pattern.

feasible (Rodrigo, 2001). Due to most economically important crops, most of which are heliophilous plants of which the photosynthetic characteristics are difficult to improve, cannot be grown under the heavy shade of a mature rubber tree, should rubber-based cropping systems be improved into rubber-intercrops commensal cropping systems, which are most feasible to form a new planting system and allow greater light penetration for intercrops, to instead of the traditional planting systems of rubber

In this context, a new planting pattern in which more space and light would be provided to facilitate inter-cropping during the whole production span of rubber tree based on a new clone of rubber tree was studied.

MATERIALS AND METHODS

Eighteen-month-old seedling plants were bud-grafted with one of the fast-growing high-yielding clones bred and selected by Rubber Research Institute of Chinese Academy of Tropical Agricultural Sciences (RRI of CATAS), Reyan7-20-59. Successfully grafted plants were then transferred into poly bags and raised, and then transplanted in the field when they grew with two stable whorls of leaves.

Experimental layout

The experiment was established in 2002 in the District 3 of the CATAS Experiment Farm situated in Danzhou, Hainan, China. Treatments comprised two spatial arrangements of planting rubber (Figure 1): (1) single row avenue planting pattern (SR, CK) with a row spacing of 7 m and plant spacing of 3 m; (2) double row avenue planting pattern (DR) with a plant spacing of 2 m and a double row spacing of 4 m and 20 m gap between double rows. The planting density was 480 trees/ha in SR and 420 in DR. In row planting arrangements, crops could be planted in between the rows or in the gap. Treatments were laid out in three randomized blocks in an area of ca.2.1 ha. Each block comprised one set of all five treatments in an area of ca. 0.7 ha.

Crop husbandry

Rubber plants were fertilized with about 10 to 20 kg per plant of organic fertilizers-based and 0.8 to 1.5 kg per plant of chemical fertilizers for all the treatments. Chemical fertilizer application was implemented in April, June and September each year and mulching was done once or twice per year in fertilizer hole. The fertilizer holes (0.6 m wide 0.6 m deep and 2 m long), were dug by one side of planting hole once a year for 4 year after planting, and dug at the middle of row space by one hole for 4 plants in SR plots, while only a ditch (1 m wide and 1 m deep) along the middle of double row space in treatment plots was used instead of fertilizer hole in DR plots. The fertilizer application for rubber trees is shown in Table 1.

Measurements

All measurements were confined to the center part of the plots, and plants at the boundaries were disregarded in assessments. Considering the nature of the spatial arrangement and the plot size of each treatment, the number of plants could not be fixed. For instance, the plots of DR systems were larger and had more plants in order to maintain a reasonable number of effective trees in addition to boundary rows. Plant girth at the height of 100 cm from the bud-grafted union was measured at 1, 8 and 9 years after planting (YAP). Bark thickness at the height of 100 cm was measured in 2011 with a standard bark gauge. Canopy spread along the gap between the row systems was assessed in 2011. The distance of the spread of branches of rubber trees was determined using a pole placed vertically touching the end of the branches and taken as the canopy width.

The rate of light penetration of undergrowth was calculated by

Table 1. The fertilizer applied to rubber trees.

Fertilizer type	Amount of fertilizer (Kg/tree/year) applied to rubber trees		
	Before four years after planting	**Five years after planting to period before tapping**	**Tapping period**
Organic fertilizer	>10.00	>15.00	>20.00
Ammonium sulfate	0.50-1.20	1.00-1.50	0.80-1.50
Super phosphate	0.30-0.50	0.20-0.30	0.40-0.50
Potassium chloride	0.05-0.10	0.05-0.10	0.15-0.25
Green manure	>30.00	>30.00	>30.00

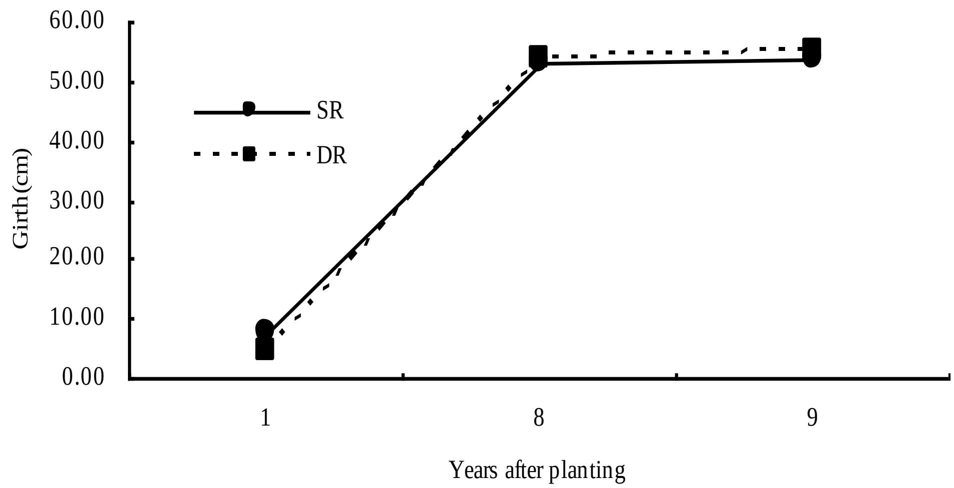

Figure 2. Effect of planting patterns on rubber tree girth. Error bars represent the standard error of means for three replicate plots. SR: Single row avenue planting pattern; DR: Double row avenue planting pattern.

dividing illumination measured in undergrowth from illumination measured in open ground. Illumination across a horizontal profile of each treatment (at a 2 m interval) was measured together with three measurements (east-west direction at 0.3 m intervals) under the open condition using a digital light meter (TES -1336A, Taiwan) for 3 days at 12:00-14:00 h. The number of trees that survived and were tapped for latex (that is the trees with a girth of 50 cm or above at 100 cm height) were assessed at 8 years after planting (YAP). A tapping system of half spiral cut every 3 days during the first year of tapping (that is 1/2S D/3) was practiced for latex harvest. Latex yield of each treatment was measured as the actual latex yield collected at three cuts per month from individual treatment plots for a full year at 8 YAP.

Data analysis

Data sets were subjected to analysis of variance of randomized blocks using the Proc. ANOVA procedure of the SAS statistical package (SAS Institute, Cary, NC).

RESULTS

Plant girth

In general, girth increase of rubber plants in all treatments was biphasic with initial rapid linear increase before tapping, and thereafter marginal increases approaching a plateau (Figure 2). Mean rate of girth increase during tapping period in 8 years after planting (YAP) and 9 YAP was 54.42 and 53.62 cm for double row (DR) and Single row (SR) systems, respectively. Mean girth of the DR system was slightly better than that of the traditional SR and was 0.8 cm at 9YAP. However, the difference was not statistically significant (P = 0.353).

Bark thickness

The mean rate of increase in bark thickness was similar among treatments with an average of 0.805 cm at 9 YAP. Similar to the girth values, bark thickness was slightly lower in the SR systems with an average of 0.80 cm at 9 YAP, but the difference was not statistically significant (Figure 3).

Yield

Percentage of trees under tapping was calculated by

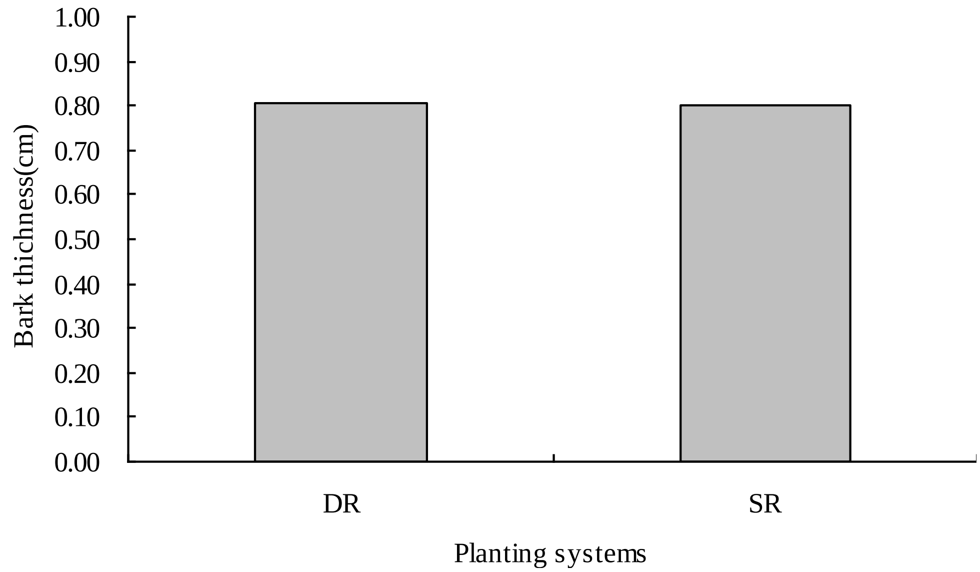

Figure 3. Effect of planting systems on bark thickness. Error bars represent the standard error of means for three replicate plots. SR: Single row avenue planting pattern; DR: Double row avenue planting pattern.

Table 2. Effect of planting systems on rubber yield.

Planting patterns	Trees in tapping (%)	Yield per hectare(kg/ha)	Yield per tree(g/t/t)
SR	88.5	1113.0	26.2
DR	77.8	1097.9	29.4

SR: Single row avenue planting pattern; DR: Double row avenue planting pattern.

subtracting the percentages of dead, weak and TPD plants. Though not statistically different, a higher value was recorded in the SR system followed by that in the DR (88.5 and 77.8%, respectively). However, the mean yield per tree (g/t/t) was lower (26.2g/t/t) than that of the DR system (29.4g/t/t), and the mean yield per hectare in the SR system was similar to that in the DR system (1113.0 and 1097.9 kg/ha, respectively), equivalent to 98% of that of the SR system (Table 2).

Canopy spread

Canopy spread of rubber tree towards the space available between rows was observed, and a significantly (P = 0.0080) greater spread was recorded in the DR system, while a smaller spread in SR system (Figure 4). At 9YAP, the canopy of the DR system spread to about 4.58 m, while the SR system was 2.80 m. As shown by the unshaded distance, at 9 YAP, the gap without any canopy cover was found nearly 11 m in the DR system, while in the traditional SR system; only ca. 1.4 m was available. Overall, the unshaded area (%) with respect to total land area was 45 and 20% in the TR and DR systems, respectively.

Light penetration

Continuous clear sky conditions could not be obtained when the radiation was measured due to moving clouds. This, together with variation in solar angle to the row position of treatment plots, resulted in increased standard error of means for percentage light penetration (Figures 5 and 6). The overall light penetration in the SR system was extremely poor, with similar value to that in the narrow row in the DR system. As determined over the different positions in each treatment, the mean percentage light penetration was 17.8 and 45.3% in the SR and DR treatments, respectively. Mean percentage of light penetration did not exceed 50% at any point measured in the SR, whilst it was always above 80% beyond 4.0 m from the rubber rows in the DR system.

DISCUSSION

Rubber is taller than most of other economical crops grown under similar conditions. Therefore, success of intercropping in rubber plantation with other sun semi-perennials or perennials depends mostly on the amount of radiation penetrating the rubber canopy. In general, the

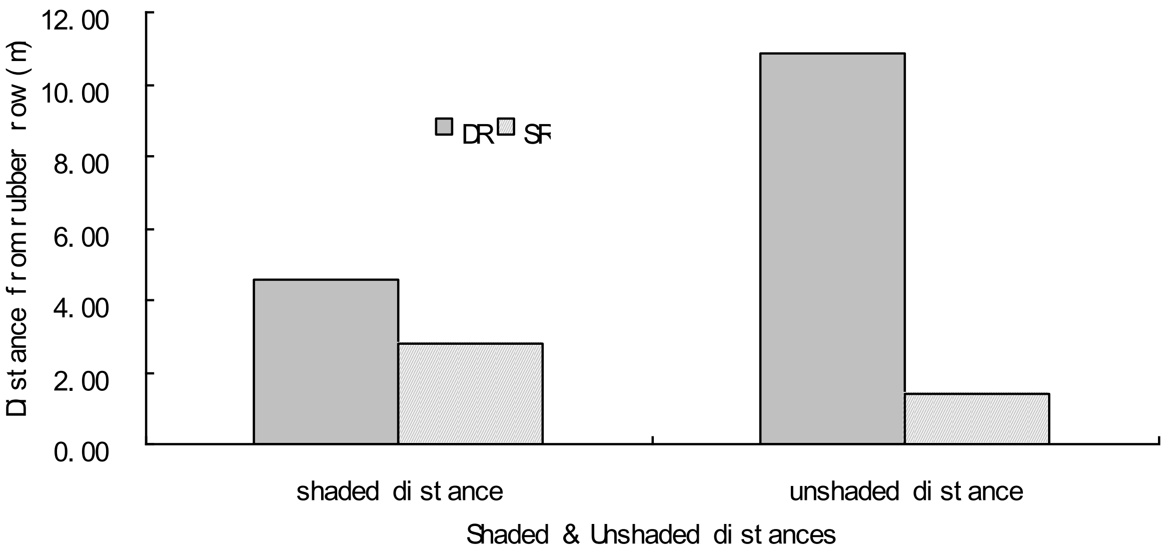

Figure 4. Effect of planting patterns on canopy spread. SR: Single row avenue planting pattern; DR: Double row avenue planting pattern.

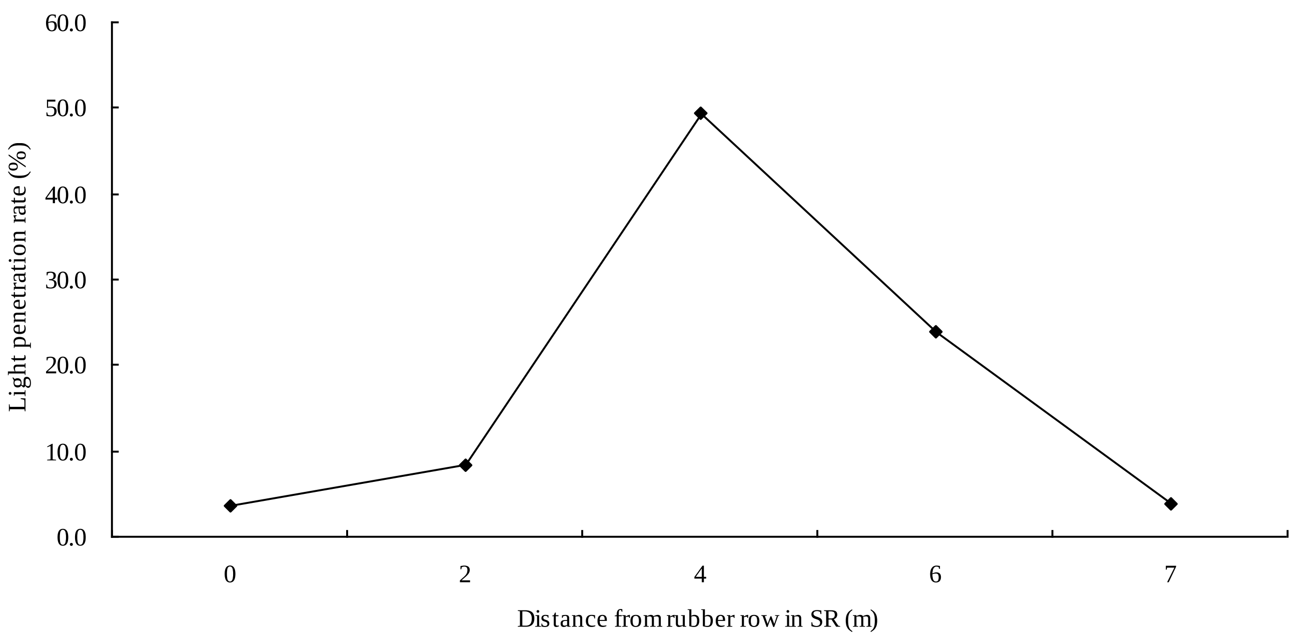

Figure 5. Radiation profile across the gap available for intercropping between rubber rows in SR system 9 years after planting. SR: Single row avenue planting pattern.

rubber canopy is quite dense allowing little radiation through to the understorey. According to Ibrahim (1991), only about 20% of incoming solar radiation is available under a 4 to 5-year-old rubber canopy. In intercropping systems, the heterogeneous nature of the canopy improves light use efficiency in the system (Rodrigo et al., 2001). However, if the understorey crop does not receive sufficient radiation, its agronomic performance and hence the financial viability of the return, is dubious. For example, in the case of rubber, pepper did not provide sufficient yield under mature rubber canopies (Rodrigo, 2001). Considering the poor light penetration through the rubber canopy, rubber/tea intercropping system was designed with ca. 30% reduction of the standard density of rubber in order to provide improved light penetration. However, dramatic yield decline in tea was found after the sixth year of growth of rubber plants (Rodrigo, 2001).

The planting density recommended for the rubber crop

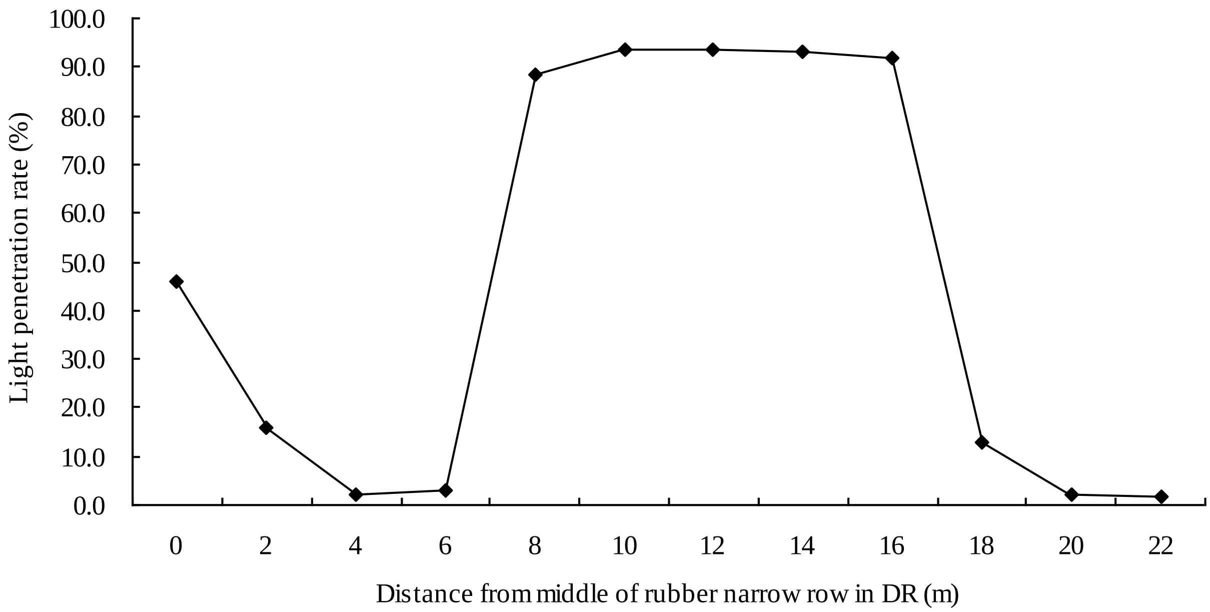

Figure 6. Radiation profile across the gap available for intercropping between rubber rows in DR 9 years after planting. DR: Double row avenue planting pattern.

in China is 480 to 500 trees/ha. The present study was aimed to find suitable spatial arrangements for planting rubber to improve light penetration in order to facilitate long-term rubber-based intercropping systems without compromising the planting density of rubber. Obviously, the DR system provided the highest unshaded area and hence the highest light penetration, allowing the largest area for intercropping. As indicated by girth development and bark thickness, the DR system did not affect growth of rubber and gave good yield equivalent to 98.6% of that of the SR system.

In general, latex yield at individual tree level tends to decrease with increased planting density (Westgarth and Buttery, 1965; Rodrigo et al., 1995). In the present study, the SR system with 480 rubber trees per hectare might have resulted in lower g/t/t than the DR system with 420 rubber trees per hectare. Under the same tapping days, rubber yield per hectare depended on latex yield per tapping at individual level and number of trees being tapped. Traditional single row avenue planting systems have minimum effect on rubber growth, and the mean percentage of tappable trees was greater in the SR system. However, the lower latex yield at individual tree level results in decline of rubber yield per hectare. In contrast, the interplant competition within the double row system was higher, but did not affect the growth of rubber trees, and the yield of rubber tree decreased slightly but not significantly.

In addition, since the canopy of the SR system almost fully spread out, light penetration of these systems was extremely poor (less than 20%) and more or less the same across the gap between alleys. Light penetration improved dramatically between 8 to 16 m in the DR system, similar in canopy spread to the SR system, indicating that the area could be utilized in long-term intercropping. The distance covered by the rubber canopy across this transect in the DR system was ca. 4.6 m at the same age (9 YAP), which may be related to the characters of rubber clones. However, light transmission in the present study was measured in the middle of the day and particularly at times when direct-light dominates the defused light. Light penetration through the canopy is stronger under the defused- than the direct-light. The fraction of defused-light is high under overcast conditions and at lower solar elevations (Monteith and Unsworth, 1990), and hence overall percentage of light penetration is expected to be greater than the values recorded in the present study. Moreover, according to the spatial distribution of light penetration across the transect of the DR system, it could be appropriate to plant other crops in avenues leaving a gap of 10.84 m on either side of the rubber alley (double rows). However, it is only 1.4 m in the SR system. The results showed that 45% of the land in mature rubber plantation in the DR system was available for growing other crops if output value of crop is similar to that of single crop rubber, which means that the output rate of land per unit is expected to be 143%.

For a given density, if the gap between rows is increased by reducing the gap between trees within alleys, there will be more trees within a row resulting in a lower number of rows in the field planting. Undoubtedly, this will reduce the overall distance of travel required to be covered in a given area, hence the time taken for tapping (Nugawela, 1991). Therefore, despite the difficulties in field establishment, the systems with wider gaps are advantageous over those with narrower gaps with respect to tapping. Also in the case of sloped terrain, the systems with wider gaps (avenue systems) require fewer terraces, reducing the cost for land preparation. In addition, other agronomic advantages such as the feasibility of practicing intensive cultural methods for component crops in intercropping systems, acting as windbreaks and decrease in panel diseases of rubber with improved air circulation have been recorded in avenue planting (Dijkman, 1951).

As a whole, the DR offers a practically feasible spatial system for incorporating perennials as rubber-based intercrops, provided the space within the double rows is increased. The gap between rubber rows (the avenue) in the presently recommended planting system for rubber/tea intercropping is 11 -18 m (Feng, 1986; Zheng and He, 1991; Zhimei et al., 2006) which is sufficient to provide required light for long-term tea cultivation. Similarly, some studies have also suggested that the double staggered row system with an plant spacing gap of 2.4 and 14.1 m between double rows used in rubber-banana intercropping provided the highest unshaded area and hence light penetration than traditional single row system with an row spacing of 8.1 m and a plant spacing of 2.4 m, but performed poor growth and yield of rubber trees (Rodrigo et al., 2004). Therefore, it is necessary to reduce the planting density of rubber trees. In this regard, the density of planting rubber in the present system would not have to be compromised. So far, the factors affecting the success of application of the DR system include: upright rubber tree species, sufficient spacing and relatively flat terrain. In addition, steep area could be suitable for promotion and any other clones of rubber tree could be used for the DR system, although more studies are needed to verify this.

The DR system, an intercropping pattern in the whole rubber production period which provides more land and space available for crop intercropping without significant effect on rubber production, can effectively solve the issues of current intercropping systems, example short period, scattered distribution and competition with light, nutrients and space. As the gap between rows is wider,
eople can engage in various agricultural activities of long-term crop production and normalize agricultural production, and thus attract planters to invest in rubber plantation, to improve production levels and to promote the standardization and industrial development of rubber plantation.

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