ESTABLISHING PERENNIAL INTERCROPS IN RUBBER PLANTATIONS AFTER REMOVAL OF PINEAPPLE: EFFECT ON GROWTH AND YIELD OF RUBBER, SOIL MOISTURE AND NUTRIENT STATUS

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Though diverse food crops are cultivated with rubber as intercrops during the initial 3 to 4 years of the plantation cycle, in the later phase, other crops are seldom cultivated due to the limited light availability. Two varieties of coffee (Robusta and C x R) and cocoa were established in a three year old rubber plantation in Central Kerala after removal of pineapple. The experiment was laid out in RBD with three replications. Both coffee and cocoa established well after removal of pineapple. Growth and yield of rubber were not influenced by intercropping with these crops. Soil moisture status during summer was higher in the presence of intercrops and soil nutrient status was not influenced. There were other facilitative interactions in terms of higher earthworm castings and rhizosphere alkalinization under mixed planting system. Yield of coffee was poor, but that of cocoa was comparatively better. Crop diversification in rubber plantations without adverse impact on the performance of rubber is important in the current scenario of price uncertainties, increasing environmental concerns about monoculture plantations and as a low input strategy to mitigate drought, which is also a growing concern.

Keywords: Cocoa, Coffee, Intercropping, Pineapple, Rubber plantations, Soil moisture, Soil nutrients

INTRODUCTION

In India, the planting system adopted for rubber allows sufficient sun light between rows for cultivation of a variety of annual and short term crops during the initial 3 to 4 years. As the rubber trees develop their canopy, the light availability within the plantation decreases and during the remaining period of the plantation cycle, rubber is predominantly grown as monoculture plantations. Apart from the limited light availability, concern of negative effect of other perennial crops on the growth and yield of rubber is also a deterrent for integrating these crops with rubber.

There is growing concern about the biodiversity of monoculture plantations of Western Ghats, where agriculture is dominated by spices and plantation crops. By superimposing rubber distribution map over Ecologically Sensitive Zones (ESZ) of Western Ghats, Thomas and Jacob (2013) observed that about 2,78,000 ha of natural

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rubber cultivated in Kerala, Karnataka and Tamil Nadu fall under one of the three ESZs identified by Western Ghats Ecology Expert Panel (WGEEP) and crop diversification in these plantations is crucial for the continued sustainability of Western Ghats Ecosystem. Price volatility of agricultural commodities is beyond the control of domestic markets and policies in the current era of market liberalization and appropriate cropping systems with shade tolerant crops should be developed as a long term strategy for risk distribution.

In the warm humid tropics where rubber is widely cultivated, shade tolerant crops like coffee and cocoa are cultivated in mixed stands with comparatively tall crops like coconut, arecanut *etc*. or as understorey crops in homesteads. Both these crops are recommended suitable for agroforestry systems because of their ability to adapt morphologically to severely reduced radiation availability (Righi *et al*., 2013; Koko *et al*., 2013).

Pineapple is a very popular intercrop in young rubber plantations since it gives early and good income. Along with pineapple, no other crops are usually cultivated as intercrops and after the removal of pineapple also, rubber is grown as monoculture plantations. In this context, the effect of establishing coffee and cocoa in rubber plantations after the removal of pineapple on the growth and yield of rubber was studied. The effects of cultivating these crops in rubber plantations on soil moisture and nutrient status were also studied.

MATERIALS AND METHODS

The experiment was conducted in a small holding at Kanjirappally (9^0 35' N, 76^0 47'E). This region experiences warm humid tropical climate with an average annual rainfall of 3500 mm. Soil of the experiment area was medium in organic carbon status (1.45%), medium in available P (1.28 mg 100 g soil^{-1}), low in available K (4.14 mg 100 g soil^{-1}), medium in available Ca (13.10 mg 100 g soil^{-1}) and low in available Mg (0.67 mg 100 g soil^{-1}) with a pH of 4.57. There were 11 treatments *viz*., control (rubber alone), cocoa, two varieties of coffee (robusta and C x R) and 50 and 100 per cent fertilizer doses with and without intercrops. Rubber (polybag plants of clone RRII 105) was planted at a spacing of 6.7 x 3.4 m during June in 1997 and short term intercrop, pineapple was cultivated between rubber rows for three years. Coffee and cocoa were planted during September in 2000, after the removal of pineapple. The spacing adopted for coffee and cocoa was also 6.7 x 3.4 m, so that there was one intercrop at the centre of four rubber plants (density of rubber and intercrops- 445 each). The design of the experiment was RBD with three replications. Gross plot size was 30 and net plot size was 12. All the cultural operations for rubber were done as per the recommendation of the Rubber Board and for the intercrops, the package of practices recommendations of Kerala Agricultural University (KAU, 1989) was followed.

Light interception by rubber was measured by PAR Ceptometer (Decagon) and the light availability was expressed as percentage of the open. Soil samples (0-30 cm) were collected five years after commencement of the experiment and were analysed for pH (1:2.5 soil: water ratio), organic carbon (Walkely and Black's method as described by Jackson, (1973), available phosphorus (Bray and Kurtz, 1945), available potassium (Morgan, 1941) and available magnesium (Vogel, 1969). Observations on rhizosphere pH, fine roots and number of earthworms were collected six years after commencement of experiment. Rhizosphere pH of rubber and intercrops was measured during January and October as per the method suggested by Bagayako *et al*. (2000) from the treatments which received 50 per cent of the recommended levels of fertilizers. To measure the area of fine roots in top 10 cm soil, soil samples were collected by a core sampler from the center of rubber and intercrops and 30 cm away from the base of intercrop. The fine roots were seperated by washing and area of fine roots was determined using a root scanner (HP ScanJet 6300 C). Soil moisture was recorded during January from rubber alone, coffee and cocoa established plots ignoring the fertilizer treatments gravimetrically and expressed as percentage. Number of earthworm castings was also recorded from control, coffee and cocoa established plots at a distance of 45 cm from the base of plants three months after fertilizer application from the treatments which received 50 per cent of the recommended levels of fertilizers. The nutrient content of earthworm castings was determined following the standard analytical protocols.

Girth of rubber was recorded at 125 cm from the bud union annually. The exploitation of the trees for latex commenced during 2004. The tapping system followed was S/2 d3. Yield of rubber trees was recorded at monthly intervals and was expressed as gram tree^{-1} tap^{-1}. Yield of coffee was recorded. Since squirrels were common in the area and fed on the cocoa pods, plot wise yield was not recorded, yield was extrapolated based on the average number of cocoa pods in each treatment. The data were subjected to statistical analysis, either analysis of variance or independent t-test.

RESULTS AND DISCUSSION

PAR availability within the plantation

PAR availability in the plantation gradually decreased from 52.4 per cent of the open at the time of planting of intercrops (2000) to 21.6 in 2002, 6.0 in 2004 and then gradually increased to 8.9 in 2005, 12.72 in 2006 and 16.9 per cent in 2007. Interception of light by the canopy of cocoa was 16.3 per cent and that by coffee was 15.4 per cent.

Soil moisture status

Soil moisture status during January was significantly higher near intercrops (Table 1). Rubber trees shed their leaves during wintering in December- January and sunlight falls directly on the ground increasing evaporation from the soil surface and reducing soil moisture content. Coffee and cocoa prevent the direct incidence of solar radiation on the soil surface leading to less evaporative loss of moisture and hence higher soil moisture content (15.6 and 17.7 per cent respectively). Presence of undergrowth of plants, either intercrops or weeds has been reported to increase soil moisture content in rubber plantations during summer and has been suggested as a drought mitigation strategy (Jessy *et al*., 2010).

Table 1. **Influence of intercropping coffee and cocoa on soil moisture status (%)**

Situation	Depth of soil (cm)	
	0-30	30-60
45 cm from the base of coffee	15.61 **	17.53 **
45 cm from the base of cocoa	17.67 **	19.41 **
Control (Rubber alone)	9.91	12.11

** significant at 0.01

Soil nutrient status

There was no significant difference between treatments in the soil nutrient status near rubber and intercrops (Table 2). Compared to pre-treatment values, available P and K status showed an increasing trend both in the control and in the intercropped

Table 2. **Effect of intercropping coffee and cocoa on soil nutrient status**

Treatment	Org C (%)		Av.P (mg 100 g soil^{-1})		Av.K (mg 100 g soil^{-1})	
	I	II	I	II	I	II
Rubber alone	1.35	1.39	3.96	2.37	5.66	7.01
Rubber + coffee R (RDF)	1.50	1.48	5.83	4.23	6.97	6.29
Rubber + coffee C x R (RDF)	1.50	1.39	3.47	4.40	5.73	6.42
Rubber + cocoa (RDF)	1.29	1.43	5.13	4.80	5.67	13.10
Rubber with RDF of coffee without coffee	1.33	1.26	4.54	4.13	7.24	5.73
Rubber with RDF of cocoa without cocoa	1.62	1.46	4.00	4.50	6.24	6.56
Rubber + coffee R (50% of RDF)	1.51	1.57	5.41	4.11	8.00	7.52
Rubber + coffee C x R (50 % of RDF)	1.34	1.45	3.83	4.73	5.90	7.94
Rubber + cocoa (50 % of RDF)	1.41	1.49	4.48	4.33	6.89	8.17
Rubber with 50 % RDF of coffee without coffee	1.44	1.49	5.0	4.12	5.98	7.18
Rubber with 50 % RDF of cocoa without cocoa	1.30	1.26	4.09	4.66	5.62	5.87
SE	0.10	0.12	1.53	0.76	0.57	1.55
CD (P = 0.05)	NS	NS	NS	NS	NS	NS

R- Robusta I - near rubber II - near intercrop
RDF- recommended dose of fertilizers

Table 3. **Rhizosphere soil pH of rubber and intercrops**

Bulk soil	Rhizosphere of rubber	Rhizosphere of intercrops
4.35	4.59*	4.79** (Coffee)
4.31	4.57**	4.75** (Cocoa)

*Significant at 0.05; * *Significant at 0.01

plots. Jessy *et al*. (2013a) also reported an increase in available P status under intercropping and suggested to reduce P fertilizers under intercropped conditions.

All the crops alkalinized their rhizosphere, but the extent of alkalinization of rhizosphere was significantly higher near intercrops compared to rubber (Table 3). Rhizosphere alkalinization might be an adaptation to enhance nutrient acquisition under acidic soil pH conditions as reported in other crops also (Hinsinger, 2001). Rhizosphere alkalinization may also decrease the release of Al from the solid phase in to the rhizosphere soil solution (George *et al*., 2012a) thus reducing Al toxicity under acidic soil conditions. Rhizosphere alkalinization, though localized will be beneficial to all the component crops.

More number of earthworm castings was observed near cocoa (Table 4). This might be due to the litter addition through cocoa, in addition to the litter addition from rubber trees. Compared to cocoa, canopy

Table 4. **Number of earthworm castings in the plantation**

Situation	Number m^{-2}
45 cm from the base of coffee	20.9 **
45 cm from the base of cocoa	30.4 **
Control	17.9

** significant at 0.01

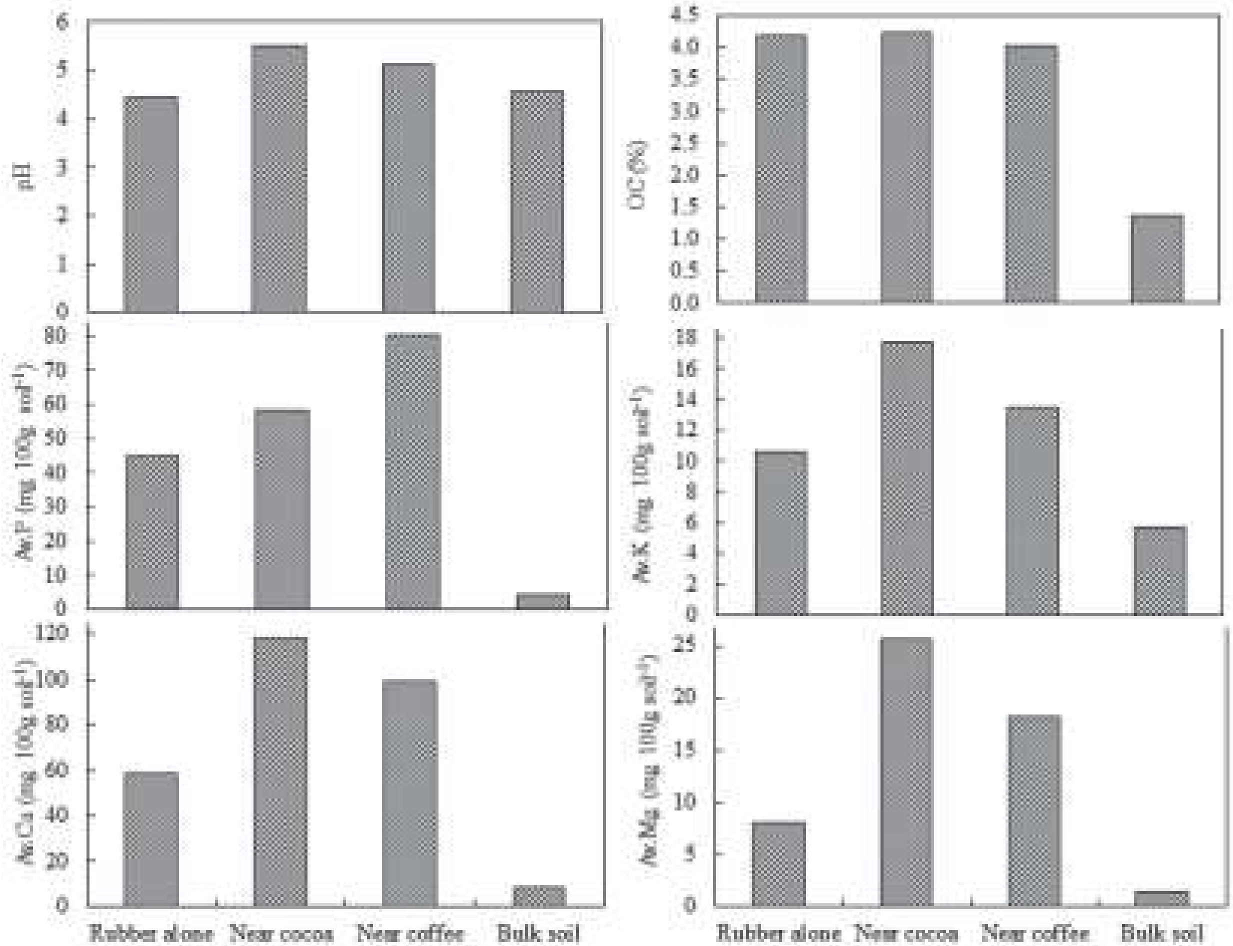

Fig. 1. Soil pH, organic carbon and available nutrient status of earthworm castings

development of coffee was poor and hence litter addition also will be less for coffee. The earthworm castings were rich in available nutrients, particularly Ca (Fig. 1). Certain earthworms are reported to synthesize calcite granules and increase soil pH and Ca levels (Garcia-Montero *et al*., 2013).

Effect of intercropping on fine root development

Considerable variation was observed in the area of fine roots of rubber and intercrops in different treatments, which might be due to the high spatial heterogeneity in fine root observations (Jessy *et al*., 2013b), rather than any treatment effect, but it was clearly observed that rubber roots explored the entire inter-row area including the basin area of intercrops (Fig. 2 and 3), which is of competitive advantage for rubber, since it will provide access to the fertilizers added to the intercrops also.

Growth and yield of rubber

Growth of rubber was not influenced by intercropping with coffee and cocoa (Table 5), indicating that planting these crops in rubber plantations did not have an adverse effect on growth of rubber. Yield of rubber was also not influenced by

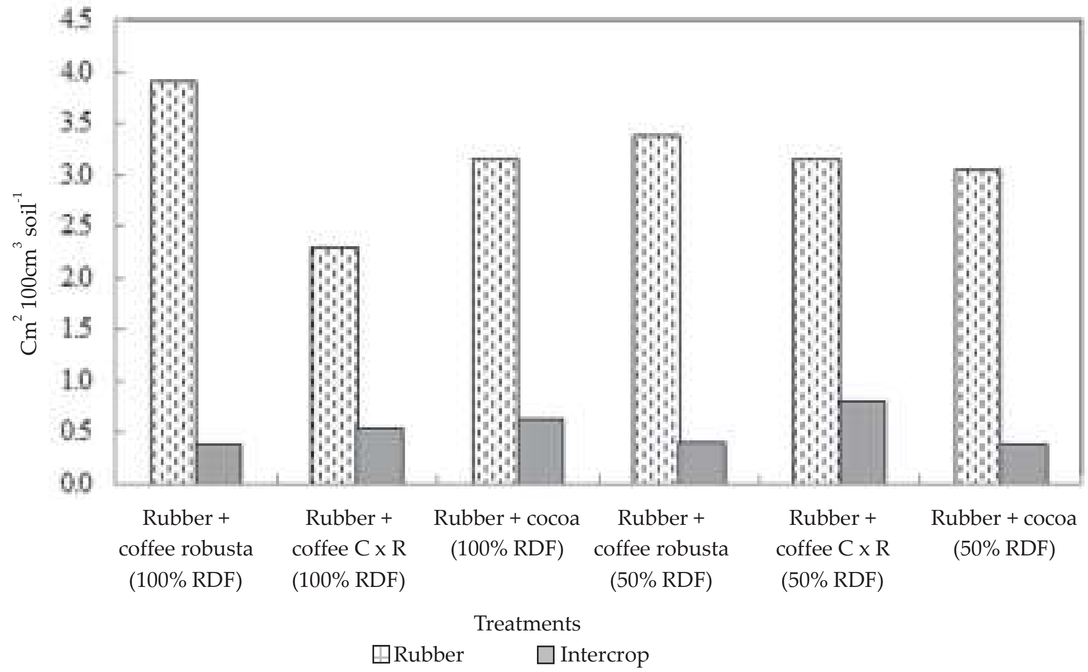

Fig. 2. Area of fine roots of rubber and intercrops (cm^2 100 cm^{-3} of soil) in the middle of rubber and intercrops rows

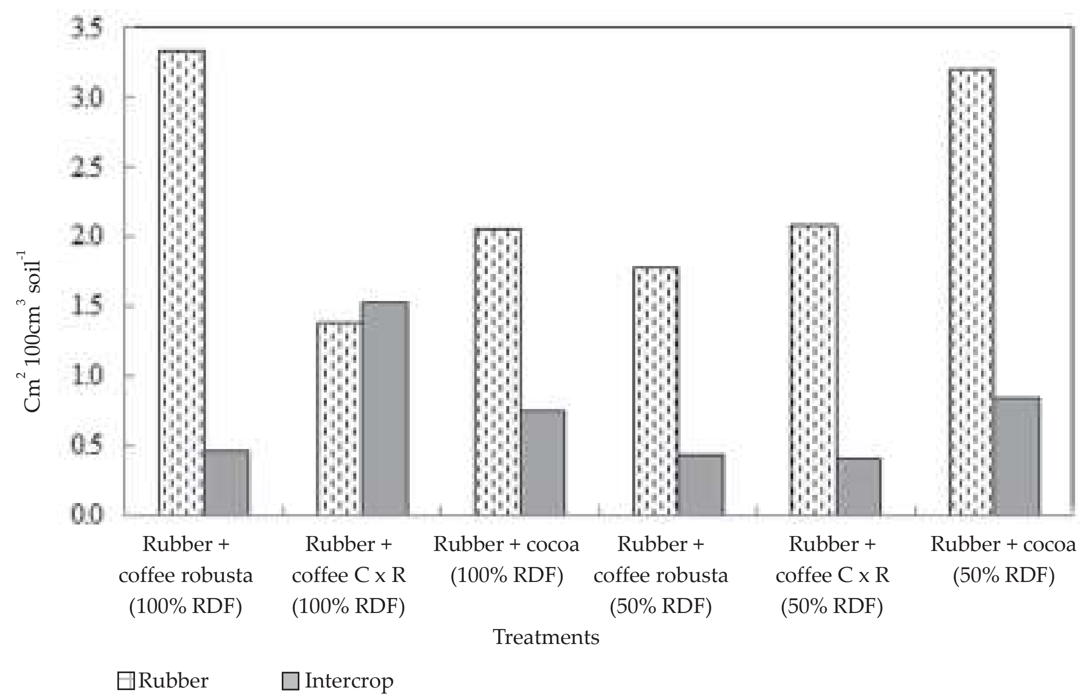

Fig. 3. Area of fine roots of rubber and intercrops (cm^2 100 cm^{-3} $soil^{-1}$) 30 cm from the base of intercrops

Table 5. **Effect of intercropping coffee and cocoa on growth of rubber**

Treatment	Girth (cm)				
	2003	2004	2005	2006	2007
Rubber alone	41.5	52.3	54.7	57.3	60.4
Rubber + coffee R (RDF)	43.3	52.0	54.2	56.6	60.4
Rubber + coffee C x R (RDF)	44.3	52.1	54.5	56.7	60.4
Rubber + cocoa (RDF)	43.1	51.4	53.8	56.3	59.5
Rubber with RDF of coffee without coffee	43.2	50.8	53.1	54.4	58.8
Rubber with RDF of cocoa without cocoa	43.2	52.0	52.5	55.5	60.0
Rubber + coffee R (50% of RDF)	40.5	50.0	51.9	54.3	57.4
Rubber + coffee CxR (50 %of RDF)	42.3	51.2	54.1	55.6	58.8
Rubber + cocoa (50 % of RDF)	41.6	50.9	53.3	55.3	58.7
Rubber with 50 % RDF of coffee without coffee	43.3	51.3	53.6	56.0	59.6
Rubber with 50 % RDF of cocoa without cocoa	43.4	50.8	53.7	56.0	55.8
SE	1.1	1.2	1.2	1.2	1.3
CD (P = 0.05)	NS	NS	NS	NS	NS

R- Robusta RDF- recommended dose of fertilizers

intercropping with coffee and cocoa (Table 6). When coffee and cocoa were planted during mature phase also, there was no adverse effect on the growth and yield of rubber (George *et al.*, 2008). However, when perennial intercrops like coffee, vanilla (on *Gliricidia* standards) and *Garcinea* were planted along with rubber, growth of rubber was significantly improved compared to monoculture of rubber. Yield was not adversely affected by intercropping these crops (RRII, 2012).

Table 6. **Effect of intercropping with coffee and cocoa on yield of rubber**

Treatment	Yield (g $t^{-1}t^{-1}$)			
	2004-05	2005-06	2006-07	2007-08
Rubber alone	35.0	40.9	62.4	74.7
Rubber + coffee R (RDF)	33.7	42.9	63.5	83.6
Rubber + coffee C x R (RDF)	33.0	44.4	63.9	89.1
Rubber + cocoa (RDF)	36.0	42.6	62.8	83.7
Rubber with RDF of coffee without coffee	31.0	43.8	64.9	79.7
Rubber with RDF of cocoa without cocoa	32.1	41.1	47.7	63.6
Rubber + coffee R (50% of RDF)	28.6	42.2	56.2	72.0
Rubber + coffee CxR (50 % of RDF)	31.5	40.5	64.5	71.3
Rubber + cocoa (50 % of RDF)	29.6	40.2	61.7	72.5
Rubber with 50 % RDF of coffee without coffee	31.7	43.4	77.2	87.0
Rubber with 50 % RDF of cocoa without cocoa	30.1	40.4	56.7	83.2
SE	2.2	3.33	7.72	12.23
CD (P = 0.05)	NS	NS	NS	NS

R- Robusta RDF- recommended dose of fertilizers

Performance of intercrops

Both coffee and cocoa established well after the removal of pineapple in rubber plantation. However, the canopy development and yield of coffee was poor. By the time coffee established, shade within the plantation intensified, thus adversely affecting the canopy development and yield of coffee. However, canopy development of cocoa was comparatively better even under intense shade and average yield ranged 25-30 pods year^{-1} plant^{-1}. No difference was observed between treatments receiving 100 and 50 per cent of the recommended levels of fertilizers for cocoa. George *et al*. (2008; 2012) reported that when planted in mature rubber plantation, the yield of coffee ranged from 30 to 35 per cent of that of monoculture and that of cocoa from 40 to 60 per cent without any difference between 50 and 100 per cent of the recommended doses of fertilizers. In another experiment in the same region, canopy development of coffee was good when planted along with rubber and coffee continued to yield well under shaded condition in mature rubber plantation (RRII, 2012).

CONCLUSION

Cocoa and coffee established well in rubber plantation after the removal of pineapple. Intercropping rubber with these crops after removal of pineapple did not adversely affect growth and yield of rubber. There were facilitative interactions in terms of higher soil moisture status during summer, earthworm castings and rhizosphere pH of coffee and cocoa under mixed planting system. Canopy development and yield of coffee was poor when established three years after planting with rubber, whereas performance of cocoa was better. Intercropping in rubber plantations without adverse impact on the performance of rubber is beneficial in the current scenario of price uncertainties, increasing environmental concerns about monoculture plantations and as a drought mitigation strategy.

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