INTERCROPPING IN COFFEE FARMS, NEW TREND FOR SUSTAINABLE CULTIVATION IN THE CENTRAL HIGHLANDS

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Abstract

The results of survey on intercropping systems in coffee farms in the Central Highlands showed that there were 7 types of intercropping system in which the four most popular were: coffee with durian (*Durio zibethinus*); coffee with black pepper (*Piper nigrum* L.); coffee with avocado (*Persea nmericana*) and coffee with cashew (*Anacardium occidentale* L.). The high density of intercropping plant decreases coffee yield less than 3 tons per ha. Farmers used unbalanced fertilizer dose of N - P_2O_5 - K_2O ratio and the time of fertilizer application was not right. The amount of water irrigated for intercropping farm was quite reasonable, the average amount of water used for coffee was 400 liters per tree per time, durian of 250 liters per tree per time, pepper of 100 liters per plant per time, avocado of 300 liters per tree per time. Coffee productivity was less fluctuation over the years. Economic effects for intercropped farms increased from 1.5% to 300%.

Keywords: Intercrops, economic efficiency

INTRODUCTION

Coffee is one of the key export agricultural products of Vietnam, in 2017, the area coffee plants of total is about 643,000 hectares. The average yield of Robusta coffee is about 2.7 tons per hectare, higher than the world average yield 3 - 4 times (Department of Crop Production, 2018). Although there is a high production and export value but most of area is belongs to households, they produced monoculture and intensive cultivation unsustainability. Especially, affect of climate change for production like the Extreme weather phenomenon (drought, El nino…).

Therefore, intergrated cultivation by intercropping of economic value plants into coffee farms will be a solution for suitable production. The types of intercropping in coffee gardens will create diverse products, getting hight income, good biological and ecological interactions when agricultural market has many adverse changes (Thuong *et al*., 2001).

Currently, the intercropping of fruit plant with high economic value has not been evaluated in terms of science and economic efficiency. Therefore, it is necessary to study to determine intercropping models with economic efficiency on coffee production for ensure sustainability.

MATERIALS AND METHODS

Materials

Robusta coffee farms intercropping perennial cash crops such as durian, pepper, avocado and cashew; each farm has area larger than 0.5 ha.

Content

The investigation of coffee tree and kinds of intercroping plant: Area, type of land, slope, planting year, productivity and production. Management of varieties (types of variety, source variety). Irrigation (equipment for irrigate, time, number of watering times and amount of irrigation water). Fertilizer (dosage, type of fertilizer, method of fertilizer, time of use fertilizer). Selling product prices, labor cost, etc.

Methods

- Establishing questionnaires on the situation, application of technical measures, management of coffee and intercropping varieties, criteria to evaluate the economic efficiency of the model.

- Selecting the survey sample. In each province, choose 2 - 3 key districts had a intercropping in Robusta coffee plantations for economic efficiency. Interview face to face with 150 farmers per province to collected data and then recorded in the prepared form.

- Applying participatory assessment method (PRA) to provide two-way information exchange with cross-checking to collect accurate information.

- Using Excel and SPSS software to analysis data.

Time and place of the study

- Location: The study was conducted in the Central Highlands region including provinces Lam Dong, Dak Nong, Dak Lak, Gia Lai and Kon Tum.

- Duration: 2017 to 2018.

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RESULTS AND DISCUSSION

The type of intercropping in coffee plantations

The results of survey on 750 coffee farms in the Central Highlands showed that there were 7 types of intercropping system and divided into 2 groups, including: single intercropping (coffee and one industrial crop) and multiple intercropping (coffee and more than two industrial crop).

Single intercropping includes four most popular were coffee with durian (*Durio zibethinus*), black pepper (*Piper nigrum* L.), avocado (*Persea americana*) and cashew (*Anacardium occidentale* L.). There were 644 questionnaires per 750 total questionnaires (accounting for 85.8%). Multiple intercropping had 107 questionnaires per 750 total questionnaires (accounting for 14.2%).

The most popular of current intercropping plants were the durian and pepper, accounting for 72.5% of the interviews households. The type of intercropping avocado has only recently developing, accounting for more than 8.5% of the interviews households. The type of intercropping cashew type accounts for nearly 6% of the interviews households. The multiple intercropping had 13.1% of the interviews households.

Lam Dong province had more types of intercropping than other provinces in the Central Highlands.

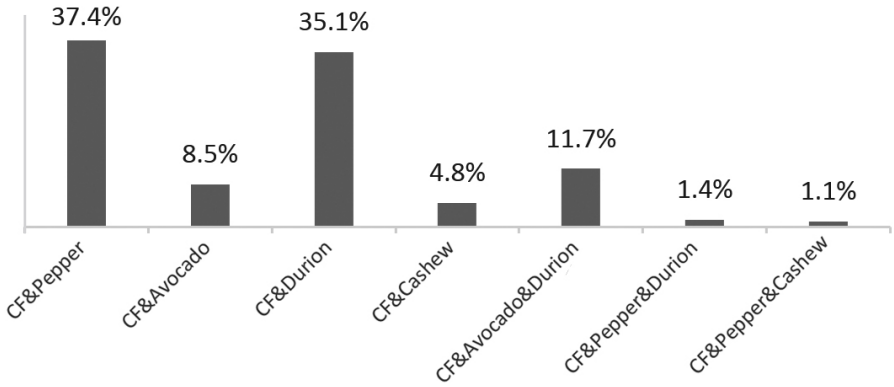

Figure 1. Ratio of types plant of intercropping in the Central Highlands

Technical management method of intercropping

Table 1 showed that production practice had two main method of intercropping, including: replacing into coffee tree position follow fixed spacing and planted between four coffee trees with fixed spacing were applied by most farmers, with over 90% of the interviews households.

The data at table 2 showed that growing coffee with 3 × 3 m spacing was still dominant with more than 69.3% of the households, other distances account for over 30.7% of the households.

Table 1. The methods of intercropping popular (% households applied)

Intercropping crops	Replace into coffee holes with fixed spacing	Planted between four coffee plants with fixed spacing	Planted with none spacing
Durian	46.3	46.3	7.4
Pepper	-	97.4	2.6
Avocado	33.3	55.6	11.1
Cashew	60.0	40.0	-

In general, some distances popular was planted according to results of survey: durian and avocado grown with 2 main spacing were 9 × 9 m and 12 × 12 m, respectively 33.0%, 14.7% for durian trees and 21.6%, 20.5% for avocado trees . The main plant spacing of black pepper was still mainly 3 × 3 m (between four coffee trees with fixed spacing, intercropping between the two coffee lines) with more than 78.1% of the survey households. The main tree spacing of cashew was 6 × 6 m and 15 × 15 m.

The survey results of fertilizer at table 3 used by farmers for Robusta coffee plantations were quite high, unbalanced fertilizer dosage of N - P_2O_5 - K_2O ratio and the time of fertilizer application was not right, the lowest level of fertilizer used by farmers for coffee was 273 kg N + 130 kg P_2O_5 + 280 kg K_2O per hectare, the productivity achieved was 3.1 tons per ha. Higher amounts of fertilizer at other plant spacing had not difference in productivity. However, the trends of coffee productivity were inversely proportional to the density of intercropping. This showed that interactions of intercropped crops had created shade to limit forming coffee flower, so coffee could not maximize the potential yield as pure plantation.

Table 2. The spacing between crops (% households)

Types	Spacing	Kon Tum	Gia Lai	Dak Lak	Dak Nong	Lam Dong	Average
Coffee	3 × 3 m	57.7	72.9	69.9	70.2	75.7	*69.3*
	Other	42.3	27.1	30.1	29.8	24.3	*30.7*
Durian	9 × 9 m	21.1	-	71.8	12.8	26.6	*33.0*
	9 × 12 m	15.8	-	2.6	10.3	6.1	*8.7*
	12 × 12 m	10.5	-	-	35.9	12.2	*14.7*
	12 × 15m	-	-	-	10.3	10.5	*5.2*
	Other	52.6	-	25.6	30.7	44.6	*38.4*
Pepper	3 × 3 m	100.0	60.0	80.3	62.5	87.5	*78.1*
	3 × 6 m	-	-	3.3	6.3	-	*1.9*
	6 × 6 m	-	6.7	1.6	3.1	12.5	*4.8*
	Other	-	33.3	14.8	28.1	-	*15.2*
Avocado	9 × 9 m	-	-	50.0	25.0	11.2	*21.6*
	9 × 12 m	20.0	-	12.5	0.0	11.1	*10.9*
	12 × 12 m	40.0	-	12.5	18.6	11.1	*20.5*
	12 × 15 m	0.0	-	-	25.0	-	*6.2*
	Other	40.0	-	25.0	31.4	66.6	*40.8*
Cashew	6 × 6 m	-	23.1	-	-	-	*23.1*
	12 × 12 m	-	7.7	-	-	-	*7.7*
	15 × 15 m	-	15.4	-	-	-	*15.4*
	Other	-	53.8	-	-	-	*53.8*

Table 3. The amount of fertilizer used for coffee tree and intercropping plants

Model	Distance	Coffee			Intercropping plant			Mean coffee yield (tonsha^{-1})
		N (kgha^{-1})	*P_2O_5 (kgha^{-1})*	*K_2O (kgha^{-1})*	*N (kg plant^{-1})*	*P_2O_5 (kg plant^{-1})*	*K_2O (kg plant^{-1})*	
Mono coffee crop		276	160	420				3.9
Coffee and Durian	9 × 9	383	267	272	*0.71*	*0.60*	*0.64*	3.1
	9 × 12	316	205	259	0.50	0.34	0.39	3.4
	12 × 12	389	260	300	0.54	0.44	0.44	3.5
	12 × 15	377	254	303	0.48	0.35	0.30	3.2
Coffee and Pepper	3 × 3	364	224	268	0.19	0.13	0.14	3.2
	3 × 6	*273*	*130*	*280*	0.14	0.12	0.12	3.1
	6 × 6	354	237	127	*0.21*	*0.15*	*0.20*	3.4
Coffee and Avocado	9 × 9	310	218	209	0.24	0.18	0.11	3.0
	9 × 12	595	217	402	0.72	0.95	0.20	3.3
	12 × 12	309	163	326	0.49	0.25	0.12	3.1
	12 × 15	370	248	250	*0.30*	*0.17*	*0.18*	3.3
Coffee and Cashew	6 × 6	424	242	193	0.19	0.23	0.15	2.1
	12 × 12	376	200	261	0.33	0.33	0.14	2.8
	15 × 15	348	97	159	*0.30*	*0.30*	*0.14*	3.2

Note: N - Nitrogen; P_2O_5 - Phosphorus; K_2O - Potassium

Coffee plant were irrigated on average from 2.7 to 4.0 times each dry season with the cycle from 21.7 to 31.8 days, the average amount of irrigation water from 350 to 533 liters per tree per time, the amount of irrigation water for coffee on intercropping cashew was higher than other types of intercropping. In general, comparing with advisory irrigation for pure coffee plantation (520 liters per tree per time), the amount of irrigation water for intercropping coffee garden had decreased significantly. Depending on each type of intercropping plants, there were differences in the number of irrigation times, irrigation cycles, and irrigation water. Average intercropping durian were irrigated 3.8 times per dry season, about 20 days per time and an average water volume 250 liters per tree per time and there were not much difference for amount of irrigation water in planting spacing. The average intercropping pepper was irrigated 5 times per dry season, cycle of 16 days and average water volume of 110 liters per pole per time. The average intercropping avocado was irrigated 3 times per dry season, cycle of 22 days, the average water volume 290 liters per tree per time. Cashew plant was less irrigated or not watered.

Table 4. Number of irigation times, cycle and amount of irrigation water

Type of intercropping *Coffee*		Irrigation times (times)		Irrigation cycle (daytime^{-1})		Amount of irrigation water (litterplant^{-1}time^{-1}	
		Coffee	*Intercropping tree*	*Coffee*	*Intercropping tree*	*Coffee*	*Intercropping tree*
Coffee and Durian	9 × 9	2.9	4.6	24.1	17.0	434.9	231.1
	9 × 12	3.1	3.8	25.5	20.8	429.5	261.4
	12 × 12	2.9	3.4	26.7	23.2	404.3	246.0
	12 × 15	2.9	3.4	21.7	18.7	357.1	252.9
	Aver	3.0	3.8	24.5	19.9	406.5	247.9
Coffee and Pepper	3 × 3	3.4	5.2	27.0	16.7	425.2	90.2
	3 × 6	3.3	4.5	23.3	16.7	337.5	103.8
	6 × 6	3.3	5.3	24.1	14.1	436.7	130.0
	Aver	3.3	5.0	24.8	15.8	399.8	108.0
Coffee and Avocado	9 × 9	2.9	3.0	31.8	27.1	395.8	241.7
	9 × 12	3.3	3.3	25.0	18.0	407.1	235.7
	12 × 12	3.0	3.1	21.7	21.4	381.3	318.8
	12 × 15	2.7	2.7	20.0	20.0	416.7	358.3
	Aver	3.0	3.0	24.6	21.6	400.2	288.6
Coffee and Cashew	6 × 6	4.0	1.7	21.3	22.0	350.0	100.0
	12 × 12	3.3	0.7	30.0	0.0	533.3	66.7
	15 × 15	3.5	0.0	25.0	0.0	475.0	0.0
	Aver	3.6	0.8	25.4	7.3	452.8	55.6

Productivity and economic efficiency of intercropping crops

According to survey data in table 5, in areas with long-time durian intercropping in Robusta coffee gardens, the effects of planting distance on coffee yield. These spacing of 6 × 6 m, 9 × 9 m, 9 × 12 m, coffee yield did not reach 3 tons per ha. Therefore, it is not recommended to grow these spacing so as not to affect the development of the coffee industry.

According to table 6 showed that, intercropping durian with 9 × 9 m and 9 × 12 m distances were higher economic efficiency than two spacing 12 × 12 m and 12 × 15 m. According results table 5 with high density intercroping had coffee yield not reach 3 tons/ha, with low productivity negatively affects sustainable coffee production. Spacing of intercropping durian with 12 × 12 m and 12 × 15 m had coffee yield from 3.2 to 3.5 tons per ha, economic efficiency was higher than pure coffee plantation from 75.89 - 96.85%.

Table 5. Average productivity of durian intercropping in key areas

Intercropping distance of durian	Krong Pak district, Dak Lak province		Dak Mil district, Dak Nong province	
	Coffee beans (tonsha^{-1})	*Durian (kgplant^{-1})*	*Coffee beans (tonsha^{-1})*	Durian (kgplant^{-1})
6 × 6	2.5	21.5	2.7	51.7
9 × 9	2.6	126.4	2.9	43.2
9 × 12	2.8	57.5	2.6	57.3
12 × 12	3.2	67.5	3.2	44.1
12 × 15	-	-	3.0	61.3

Table 6. Economic efficiency of intercropping models (Million VND per ha)

Model	Distance (meter)	Yield		Total income	Total cost	Benefit	(%) increase compare to pure plantation
		Coffee (tonsha^{-1})	Intercropping plant (kgplant^{-1})				
Mono coffee crop		3.9		86.30	144.70	58.30	
Coffee and Durian	9 × 9	3.1	86.2	126.56	361.23	233.03	299.71
	9 × 12	3.4	77.9	111.58	310.83	199.24	241.75
	12 × 12	3.5	59.6	121.01	235.78	114.77	96.85
	12 × 15	3.2	95.8	129.42	231.97	102.54	75.89
Coffee and Pepper	3 × 3	3.2	2.1	144.92	306.82	161.90	177.70
	3 × 6	3.1	2.7	119.80	248.32	128.52	120.45
	6 × 6	3.4	3.3	141.42	258.16	116.75	100.25
Coffee and Avocado	9 × 9	3.35	55.70	118.62	269.23	150.61	158.33
	9 × 12	3.3	31.6	126.30	222.60	96.30	65.19
	12 × 12	3.1	42.8	97.52	204.35	106.83	83.24
	12 × 15	3.3	44.3	110.24	191.62	81.38	39.58
Coffee and Cashew	6 × 6	2.1	10.5	83.68	120.70	63.50	-36.50
	12 × 12	2.8	21.3	97.70	156.88	101.51	1.51
	15 × 15	3.2	34.3	96.09	175.33	135.92	35.92

Model of pepper intercroping with a spacing of 3 × 3 m was still coffee yield over 3 tons per ha, but pepper yield per plant was the lowest among the pepper intercropping spacing. Pepper with a high density in coffee gardens have shown to be less sustainable. There were many pepper gardens in Lam Dong, Dak Nong, Gia Lai province effected quick wilt disease and slow decline. The intercropping pepper spacing of 3 × 6 m and 6 × 6 m gave the coffee yield from 3.1 to 3.4 tons per ha, economic efficiency was higher than pure coffee planting from 100.25 to 120.45%.

For intercropping avocado, all intercropping spacing have reached coffee yield of 3 tons. However, as analyzed above, the thick density in the long term will affect coffee yield. Therefore, it is not recommended to maintain the thick planting spacing. Decrease coffee productivity due to increased the density of intercropping have also been reported (Hoa *et al.*, 2016). So appropriate intercropping spacing for avocado tree should be 12 ×12 m and 12 ×15 m, coffee yield and avocado yield were quite good, economic efficiency was higher than pure coffee planting from 39.58 - 83.24%.

All intercropping cashew spacing had low coffee yield and economic efficiency was not significantly increased comparing to pure coffee planting. Therefore it is not recommended to intercropping this type.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- The most popular of current intercropping plants was single durian and single pepper in coffee gardens,

accounting for 72.3% of the households. The type of intercropping avocado has only recently developed, accounting for more than 8% of the households. Multiple intercropping model had above 11.7% of the households.

- Type of intercropping durian with a spacing of 12 × 12 m and 12 × 15 m for coffee yield of over 3 tons/ha and durian productivity of over 60 kg per tree, economic efficiency higher than pure coffee planting from 75.89 to 96.85%.

- Type of intercropping pepper with spacing of 3 × 6 m, 6 × 6 m for coffee yield of 3 tons/ha and pepper yield of 2.7 kg per plant, economic efficiency higher than pure planting from 100.25 to 120.45%.

- Type of intercropping avocado with all spacing had coffee yield over 3 tons/ha and the productivity of avocado over 30 kg per tree, economic efficiency increased from 39.58 to 83.24%.

- Type of intercropping cashew with all spacing had low coffee yield and economic efficiency was not significantly increased comparing to pure coffee planting.

Recommendations

- On the basis of coffee as the main crop, to increase income per area unit and ensure sustainable coffee cultivation, recommending reasonable intercropping, ensuring the harmonious development of crops, the average coffee yield is over 3 tons per ha and the economic efficiency is higher than that of pure coffee planting.

- Recommending durian and avocado intercroping with the spacing of 12 × 12 m and 12 × 15 m; pepper intercroping with the spacing of 3 × 6 m and 6 × 6 m. The recommended density was the same as in the intercropping process. It is not recommended to develop cashew intercroping.

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FLOWER BIOLOGY OF BLACK PEPPER (PIPER NIGRUM) IN VIETNAM

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Abstract

A study on flower biology of black pepper (*Piper nigrum*) was carried out to provide important understanding in flower biology which is vital to breeding and hybridization studies in Vietnam. Three varieties namely Vinh Linh, Phu Quoc and SRLK have been used for this study. The results showed that it takes about 242 days to 270 days from spike appearance to fruit ripening. The longest period is fruit development and fruit maturity. Anther dehiscence of Vinh Linh and Phu Quoc occurs at around 7:00 pm to 8:00 pm. However, SRLK is earlier at 4:00 pm to 5:00 pm. Sigma receptivity happens 1.8 days to 2.8 days after anther dehiscence. Stigma remains receptive from 4 days to 6 days and up to 10 days.

Keywords: *Piper nigrum*, flower biology, anther dehiscence, stigma receptivity

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