

Study of Intercropping System and *In Situ* Organic Matter Application on Coffee Agroforestry at Citarum Watershed, West Java, Indonesia

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Abstract

Agroforestry-based coffee is one of the conservation efforts to restore the damages at the Citarum watershed. Planting annual crops between coffee rows could potentially contribute income for the growers during the immature non-productive coffee growth. The aims of the research is to study the effect of various types of agroforestry models in the upstream Citarum watershed on the growth of coffee, and growth and yields of the intercrops. The research was conducted in September 2018 to June 2019 at the upstream Citarum watershed of Tarumajaya Subdistrict Kertasari, Bandung Regency, West Java, Indonesia. The research was arranged with a randomized block design with two factors. The first factor was the cropping system, i.e. coffee monoculture, coffee and corn, coffee and sweet corn, coffee and red beans, and coffee and habanero chili. The second factor was organic matter application, i.e. with and without application of *in situ* organic matter. The results of the research showed that coffee intercropped with habanero with application of *in situ* organic matter had the best vegetative growth, indicated by taller plants, more leaves, increased leaf P and Mg levels, and the maximum income from the intercrop. Coffee intercropped with corn with application of *in situ* organic matter had a maximum corn production but had the lowest income. Therefore, the model of coffee intercropped with habanero chili with application of *in situ* organic matter was the best model from several intercropping systems tested.

Keywords: Citarum, agroforestry, Arabica coffee, intercropping, organic matter

Introduction

The Citarum watershed is the main watershed in West Java, which has an area of 6 080 km² with ± 300 km long. The Citarum watershed is currently inhabited by about 10 million people; 6 million of which living at the upstream of the watershed, whereas the rest are scattered in the downstream watershed (Garno, 2011).

Citarum watershed was reported as one of the dirtiest rivers in the world (Vatvani, 2018). Imansyah (2012) stated that Citarum watershed problems, particularly in upstream area, was caused by the land clearing. Conversion of natural forests into agricultural land affects the watershed environment and reduce land fertility. Mulyono (2010) reported that 78% of Citarum watershed, or a total area of 560,095 ha had been damaged due to land conversion from the natural forest to agricultural production areas (Mulyono, 2010).

Agroforestry is one of conservation techniques than can prevent or potentially reduce damages in Citarum watershed. The coffee-based agroforestry has important roles in water conservation, soils, biodiversity, and the addition of nutrients. Water absorption of coffee-based agroforestry is higher than monoculture (Cannavo et al., 2011). N soil nutrient

content in coffee agroforestry is relatively high, i.e. 0.82% (Yamani, 2010).

The disadvantage of a coffee-based agroforestry system is that the farmers do not have income while the coffee trees have not reached productive stage. Coffee growers do not get revenues for at least the first 2.5 to 3 years after planting. One potential solution for these problems is by planting annual food crops between coffee rows. Planting annual crops between coffee rows are expected not to cause competition in water intake, nutrients, and light with the coffee trees. Turmudi (2002) reported that intercropping coffee with annual food crops can benefit farmers compared to coffee grown in monoculture, because of the increased land productivity, and more efficient uses of space.

Farmers in Citarum area have not explored the potential uses of the organic matters available from the remnants of plants that naturally grow in the area; some even see them as useless and burned them up, a practice that can decrease soil fertility. The remains of unharvestable crops and from plants that were naturally grown on the land is called *in situ* organic matter (Darwis and Rachman, 2013). The application of *in situ* organic matter to the soil can potentially improve soil chemical characteristics. This is particularly evident in the C-organic, N-Total and cation exchange capacity parameters which were significantly increased after application of organic matter to the soil (Ismail, 2011). Therefore, it is necessary to study the agroforestry model based coffee with various types of annual food crops and the uses of *in situ* organic matters, especially at the upper Citarum watershed.

The aim of the research is to study the effects of various types of agroforestry models in the upstream Citarum watershed on the growth of coffee, and yields from the intercrops. The annual food crops grown as coffee intercrops are corn, sweet corn, red beans and Habanero chilli.

Materials and Methods

This research was conducted in Tarumajaya Village, Kertasari District, Bandung Regency, West Java, Indonesia, in September 2018 until June 2019. The research was arranged in a randomized block design with two factors. The first factor was a the intercropping system, i.e. coffee-monoculture, coffee and corn, coffee and sweet corn, coffee and red beans, and coffee and habanero chili; the second factor was application of *in situ* organic matter, i.e. with and without application of organic matter. Each

combination was replicated three times, so in total there were 30 experimental units. Each unit consists of 50 coffee trees; 10 plants in the middle of the block were selected as samples. Each plot area measuring 300 m², so the total experimental area was ±9,000 m². Planting materials were 9-month-old coffee seedlings "Ateng Super", sweet corn seeds "SD3", seed corn hybrid variety "Pertiwi", red beans seed, and 2-week-old Habanero seedlings. Plant spacing was different for each type of crop; coffee plant spacing was 3 m x 2 m, Habanero chilli was 150 cm x 100 cm, corn and sweet corn was 100 cm x 25 cm, whereas red beans was 50 cm x 20 cm.

Maintenance of the intercrops and coffee trees included fertilization, watering and weeding. For sweet corn and corn 300 kg Urea, 200 kg SP-36, and 100 kg KCl.ha⁻¹ were applied at two stages, half of the Urea (150 kg), 200 kg SP-36, and 100 kg KCl.ha⁻¹ at two weeks after planting (WAP), the second fertilization was 150 kg of Urea.ha⁻¹ applied at 5 WAP. Fertilization for red beans and Habanero was 100 kg Urea, 200 kg SP-36, and 150 kg KCl.ha⁻¹, applied at two WAP. Fertilization for the coffee was applied in two stages, which is at 4 WAP and 24 WAP at 25 g of Urea, 25 g SP-36 and 20 g KCl per plant. Weeding was carried out twice during the course of the experiment, at 4 and 6 weeks after planting (WAP). Pest and disease was controlled when required.

Organic matter was spread at 4 kg per plot in the rows of the intercrops. The organic matter were derived from weeds and crop remnants previously growing on the test plot.

The chemical properties of the soil were analyzed prior to and after the experiment. Parameters measured on coffee were the plant height, the number of leaf, leaf stomatal density, leaf chlorophyll levels (chlorophyll a, chlorophyll b, carotene, anthocyanin), and the coffee leaf nutrient levels (N, P, K, Mg). While parameters measured on intercrop were plant height, the number of leaf, leaf stomatal density, levels of chlorophyll a, chlorophyll b, carotene, anthocyanin at 8 WAP, and yield. Data was analyzed using ANOVA using Statistical Tool for Agricultural Research (STAR) Nebula 2.0.1. Significant treatments were further analyzed using Duncan's Multiple Range Test (DMRT) at $\alpha=5\%$.

Results and Discussion

General Environmental Condition

The research site was located at Citarum watershed area is geographically located between 7° 12' 15" and

107° 39 ' 24", with an altitude of 1,598 meter above sea level. The soil at the research site is andosol. Based on the results of soil analysis shows that pH (H₂O) soil in the research site is somewhat acidic (5.68), C-Organic of 5.01%, N-total is classified as high (0.62%), available P is a very high (228.51 ppm), K is relatively high (0.75 c.mol kg⁻¹). The research was conducted in September 2018 until June 2019. During the research, rainfall was quite varied; at the beginning of the coffee planting in October 2018, the rainfall was 124.8 mm per month with 15 low days of low rain. Planting of the intercrops was conducted in November 2018 with the precipitation of 48.3 mm/month with 22 rainy days. Both Arabica coffee and the intercrop grew well. Pests attacked the intercrop were boar (*Sus scrofa*), caterpillars (*Agrotis ipsilon*) and grasshoppers (*Caelifera* sp.), but all could be controlled manually.

The Coffee Growth in Different Cropping Systems *Coffee height*

The types of intercrop had significant effect on the coffee plant height at 20 and 24 WAP only (Table 1). Coffee intercropped by habanero chili were taller than those grown in monoculture, whereas the choice of intercrop effects were not significantly different. Habanero chili had a positive effect on the coffee plant height, with an increased of 24.21% than monoculture and 21.36% compared to those intercropped with red beans.

Coffee plants with Habanero chili had a positive impact on coffee plant growth was possibly because coffee also absorb the overflow of nutrients from the fertilizer that was applied to the Habanero. Ferry et al. (2013) reported that the growth of rubber trees intercropped with the annual food crops was better than rubber tree monoculture, due to additional nutrients from fertilization applied to the intercrop. In addition, habanero chili roots also helped maintain soil moisture, and the availability of water was beneficial for the growth of coffee plants.

Coffee leaf number

The types of intercrop affected the number of coffee leaf at 12 to 24 WAP (Table 1). The leaves of the coffee plant intercropped with habanero chili were 90.89% more than those in monoculture, whereas intercropping with the other annual crops had no significant effects. The positive effect of intercropping was possibly through the roots of trees that recycled the nutrients, particularly nitrogen that were available from the intercrops. In addition, intercropping suppress weed population, and help to maintain soil moisture levels. Handayani (2011) reported that the right combination of intercropping could create biological stability, suppress pest and disease, and maintain soil fertility.

The Effect of Organic Matter Application on Coffee Growth in Different Cropping Systems

The organic matter (OM) affected the number of coffee leaves on 8 to 24 WAP. Coffee leaf number with organic matter application was 30.98% more than without organic matter at 24 WAP (Table 2).

The organic matter applied to the coffee trees positively affected of the number of coffee leaf. Activities of soil microorganisms in the organic matter resulted in macro and micronutrient availability for the roots and increase crop growth (Pertiwi and Adrian, 2016).

Effect of Intercrops and Organic Matter Application on Coffee Leaf Water Content, Leaf Nutrient, and Leaf Stomatal Density

The results showed the types of intercrop and organic matter application significantly affected the coffee leaf water content, leaf nutrients, and stomatal leaf density. Monoculture coffee applied with organic matter had a higher leaf water content compared to the other treatment combinations (Table 3).

Table 1. The height and leaf number of coffee in different intercropping systems

Intercropping system	Plant height (cm) at week		Coffee leaf number at week			
	20	24	12	16	20	24
Monoculture	44.48c	47.49c	21.15b	22.87b	24.51b	25.81b
Corn	51.88abc	56.13ab	29.36ab	34.69a	39.93a	43.93a
Sweet corn	53.02ab	57.12ab	25.15ab	28.76ab	32.29ab	34.99ab
Red bean	46.20bc	49.32bc	26.05ab	30.15ab	34.16ab	37.22ab
Habanero chili	54.51a	58.99a	32.93a	38.97a	44.75a	49.27a

Table 2. Number of coffee leaf with and without application of organic matter

Treatment	Coffee leaf number at week				
	8	12	16	20	24
Without OM	20.72b	24.07b	27.39b	30.63b	33.11b
With OM	24.80a	29.79a	34.78a	39.63a	43.37a

Note: values followed by the same letter in the same column do not differ according to DMRT at $\alpha=5\%$

Coffee monoculture with organic matter application had a 1.95% higher leaf water content than without organic matter. The leaf water content of coffee intercropped with corn with organic matter application decreased to 53% compared to monoculture without organic matter (Table 3).

Coffee intercropped with red bean had a higher leaf N than those intercropped with habanero chili, and it was 30.95% higher in intercropping system when organic matter was applied. However, the coffee leaf N was 5.5% lower when intercropped with Habanero chilli (Table 3).

Coffee leaf N nutrient was the highest when intercropped with red beans; it is possible that this is related to interactions between legume and *Rhizobium sp.*, a soil microbial capable of binding of free nitrogen (N_2) from the air (Sari and Prayudyaningsih, 2015). *Rhizobium* in the legume crop roots converts air nitrogen to ammonium (NH_4), then by nitric bacteria further converted into nitrite (NO_2^-) and nitrate (NO_3^-).

The coffee leaf P nutrient content was the highest when intercropped with habanero chilli without application of organic matter. The content of P on

coffee leaves in intercropping coffee-habanero chili without organic matter increased by 53.84% compared to coffee-monoculture without organic matter. Intercropping of coffee with habanero chilli with organic matter decreased the leaf P by 7.69% compared to monoculture without organic matter (Table 3). It is possible that this occurred due to less decomposition and mineralization organic matter. The process of organic matter mineralization would take place if the content of P organic matter was high. Harsono (2012) explained that if the content of P organic matter is high, or C/P ratio is low less than 200, there would be mineralization or released P into the soil, but if the higher C/P ratio is more than 300 it will occur P immobilization or loss P available.

The coffee and corn with organic matter application increased coffee leaf potassium compared to the other treatment combinations, while the coffee intercropped with red beans with organic matter decreased it. Coffee intercropped with corn with organic matter had leaf potassium of 23.10% higher compared with coffee monoculture without organic matter, and it was 7.93% lower when coffee was intercropped with red beans (Table 3).

Table 3. Coffee leaf water content, nutrient, and stomatal density in various intercropping systems

Treatment	Coffee leaf nutrients					Coffee stomatal density mm^{-2}
	LWC ²⁾	N	P	K	Mg	
Monoculture	6.65b	2.52f	0.1300ef	2.90f	0.2100b	255.10a
Monoculture + OM	6.78a	2.44i	0.1700b	3.15c	0.2000b	187.08bc
Corn	3.11i	2.69d	0.1200f	3.01d	0.2000b	158.16c
Corn + OM	4.33f	2.79b	0.1700b	3.57a	0.1700c	222.79ab
Sweet corn	4.83d	2.50g	0.1600bc	2.99e	0.2000b	151.36c
Sweet corn + OM	4.56e	2.75c	0.1500cd	3.25b	0.1700c	173.47bc
Red bean	3.94g	2.64e	0.1400de	2.82g	0.2100b	153.06c
Red bean + OM	6.33c	3.30a	0.1567bc	2.67i	0.2267a	205.78abc
Habanero chili	3.59h	2.46h	0.2000a	2.79h	0.1700c	224.49ab
Habanero chili + OM	6.65b	2.38j	0.1200f	2.79h	0.1200d	209.18abc
CV (%)	0.17	0.32	5.73	0.29	4.61	16.04

Note: ¹⁾ mg per g dry weight; ²⁾ leaf water content; values followed by the same letter in the same

Potassium in plant is mobile, and could move depends on the affinity and the plant requirements. The decrease in coffee leaf potassium when intercropped with red bean and organic matter was possibly because the red bean took up more potassium for seed formation. Potassium has significant roles in seed formation (Haridi and Zuhidiani 2009; Sitepu et al., 2014), whereas coffee requires more nitrogen for vegetative growth (Kadarwati, 2006).

Coffee intercropped with red beans with organic matter application had a higher leaf Mg than those with other treatment combinations, whereas intercropping with habanero chili decreased it. The coffee leaf Mg in coffee and red bean intercropping increased by 7.95% compared to coffee monoculture without organic matter, whereas coffee intercropped with habanero chili with organic matter application decreased leaf Mg coffee by 40% compared with coffee monoculture without organic matter (Table 3). The increase in Mg of coffee leaves was possibly related to the low absorbed potassium. The weak bound of potassium makes it easily replaced by other cations such as Ca and Mg (Subandi, 2013). Magnesium is a major constituent of the chlorophyll and is required for sugar and starch formation; Mg also functions in the translocation of phosphorus (Wirawan et al., 2016).

Stomatal density in coffee leaf grown in monoculture without organic matter was significantly higher than the other intercropping systems (Table 3). The monoculture coffee received plenty of sunlight without any shade influence from the annual crops. In Suherman and Kurniawan study (2015) coffee plantation without shade had a higher stomatal density than those that were shaded.

Growth of the Intercrops

Intercrop plant height

The intercrops growth with organic matter were better than without organic matter (Figure 1). The corns with organic matter 0.49% were taller than without organic matter, similarly with sweet corn (18.24%), red beans (11.58%), and habanero chili (0.2%) with organic matter. Therefore the effect of organic matter was the largest on the height of the sweet corn. Sweet corn has been reported to be very responsive to nutrient application (Kresnatita et al., 2013). The provision of organic matter had provided more nutrients for the crops. Akasah et al. (2018) reported an increase in the soil pH, C-Organic, P, crop growth, shoot and root dry weight of the crop.

Intercrop leaf number

Application of organic matter demonstrated positive impacts on the number of leaves of each crop (Figure 2). The corn number of leaf with organic matter was 1.25% more than without application of organic matter whereas in sweet corn, red bean and habanero chilli it was 3.18%, 52.8% and 27.9% more, respectively. Therefore, the effects of organic matter application was the highest on red beans.

Intercrop production

Yield of the intercrop was affected by the intercrop, but not by organic matter application (Table 4). Corn had the highest yield per hectare but had a lower income than the habanero chili. Habanero chili crops produced the lowest yield per hectare but had the highest income compared to other crops.

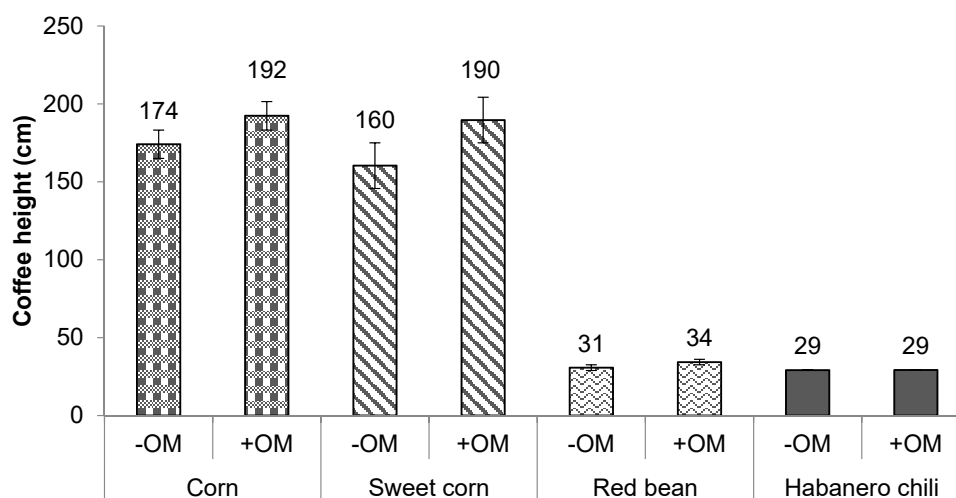


Figure 1. Height of corn, sweet corn, red bean and habanero chili as intercrops with coffee; WOM= without application of organic matter; OM= with application of organic matter

The highest yield of corn may be because there was less competition between the coffee and the corn plants. Corn height was taller than coffee so the corn intercepted more light, resulting in promoted photosynthesis. The income from corn, however, was lower than habanero chili because the selling price per kilogram of corn is lower than that of habanero chili.

Habanero chili had the lowest production per hectare compared to the other intercrops, and this was possibly due to low chili plant population. The planting distance used in this study was wider (1.5 x 1 m) than it was in monoculture, meaning in one row of

Conclusion

The intercropping of habanero chili with coffee with application of the *in situ* organic matters resulted in the best vegetative growth of coffee, demonstrated by taller trees, more leaves, and higher leaf P and Mg content. The highest income from the intercropping was from the coffee with habanero chili with the application of organic matter. Coffee intercropped with corn with organic matter application had a maximum yield from the intercrop, but had the least income. Therefore, intercropping of coffee with habanero chili with organic matter application is the best model from several intercropping models tested in this study.

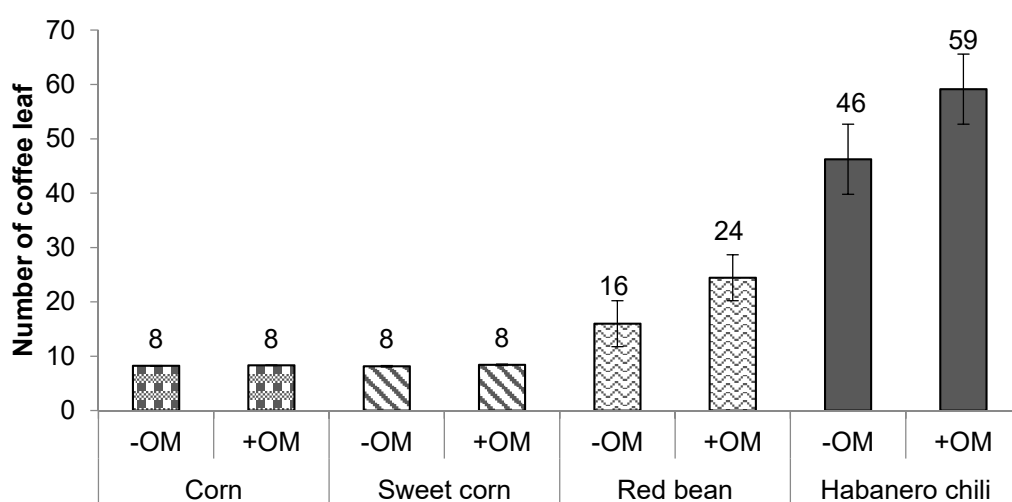


Figure 2. Number of leaf of corn, sweet corn, red bean and habanero chilli as coffee intercrop; WOM= without application of organic matter; OM= with application of organic matter.

Table 4. Production and income of various coffee intercropping systems

Intercrops	Yield per plant (kg)	Yield per plot (kg per 300 m ²)	Yield (ton/ha)	Selling price (IDR per kg)	Lowest income (IDRx1000)	Highest income (IDRx1000)	Average income (IDRx1000)	
Corn	0.29b	93.08a	3.07a	3,500	6,000	9,080.48a	16,759.40 b	12,909.94ab
Sweet corn	0.28b	90.21a	3.03a	2,000	6,000	7,214.57b	16,145.51b	11,679.86b
Red bean	0.12c	76.80b	2.53b	2,000	3,000	3,497.50c	6,082.15c	4,789.77c
Habanero chilli	1.15a	46.14c	1.48c	6,000	15,000	7,419.92b	21,124.50a	14,789.77a
CV	24.41	6.91	7.95			13.29	14.77	14.30

Notes: values followed by the same letter in the same column do not differ according to DMRT at $\alpha=5\%$

coffee there was only one row of habanero chili, while on a corn and sweet corn plant it was two rows, and with red beans it was three rows. According to Basuki (2009) the correct plant spacing is important for optimal growth and yields. Nevertheless, habanero chili intercrop had the highest income compared to other treatments because of its high selling price.

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