The Growth and Production of Coffee in Different Shade, Pruning and Fertilizing Conditions

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Abstract: Coffee plants (*Coffea* sp.) are C3 plant groups, with characteristic of low photosynthetic efficiency, which is due to the occurance of photorespiration. In simple agroforestry systems, legumesare commonly used as shade trees. In addition, pruning and fertilizing are also very important cultivation techniques incoffee plantation business. This study was aimed toto obtain the maximum potential of coffee production at a certain height in Humbahas Regency with a package treatment of pruning, fertilizing and shade technology. Plant experiments were carried out at an altitude zone of 1200-1300 meters above sea level(masl) which was designed in the form of Splits plot design. There are three factors tested, the main plot is shade with a levelof without shade (N0) and shade (N1); the main subplots are pruning, namely pruning with the farmer system (P1) and pruning recommendations (P2); while thesubplots are fertilization methods consisting of: farmers' fertilizing level (O0), giving organic fertilizer from coffee pulp at a level of 10 kg / tree (O1), giving organic fertilizer from manure at a level of 10 kg / tree (O2), giving phosphate fertilizer (SP36) 150 g/ tree. The growth and production of coffee plants are influenced by the interaction between shade plants, pruning and fertilization. On all altitudes level in this experiment, vegetative growth in plants were improvedin not shaded by pruning conditionsand application oforganic fertilizer, both with manure and coffee pulp compost. However, the best yield production was obtained at under shaded conditions in which the plants were cut according to theprune recommendations.

1 INTRODUCTION

Coffee plants (*Coffea* sp.) are C3 plants, with low photosynthetic efficiency characteristic, because the photorespiration occurs. However, the low photosynthetic efficiency makes the growth rate of coffee plants themselves not optimal (Mawardi, 2008). Coffee is grown in mixed systems (agroforestry), ranging from simple to complex (multistrata) mixed systems that resemble forests (Hairiah & Rahayu, 2010). Coffee gardens can be cultivated through farming systems that lead to agroforestry (Dariah et al., 2005). In simple agroforestry systems, the common shade is legume trees such as dadap (*Erythrina sububrams*), gamal (*Gliricidia sepium*), and lamtoro (*Leucaena glauca*) which are useful for feed and as soil fertilizers, so that the use of chemical fertilizers decreases (Hairiah & Rahayu, 2010). However, there are several shade-free coffee cultivations such as in Hawaii, Brazil and Kenya (Prawoto et al., 2006; Panggabean, 2011).

Pruning is one of the most important cultivation techniques business of coffee planting, because pruning is related to the supply of fruit branches which are the main organ producing in coffee fruit. The production of coffee plants is largely determined by the number of productive fruit branches during a conception season. Irregular and narrow spacing causes crop canopies to overlap with plant aging, therefore, pruning is an effective solution to reduce the effects of excessive initial constriction on the plantation. Pruning is a technology that has been associated with higher yields due to the promotion of reproductive output in different plant species (Bilir et al., 2006; Dutkuner et al., 2008).

Coffee plants are are best cultivated at soil conditions with high organic matter content, becausethe productivity of coffee plants is directly

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related to the level of organic matter in the soil. The optimal level of organic ingredients for coffee plants ranges from 2-5%, depending on the soil texture class. Organic matter plays an important role in plant productivity because of its influence on the physiological, chemical and biological characteristics of the soil. In this case it is also related to soil air, supports water infiltration, reduces erosion and activates the life of soil organisms (Wintgens, 2012). In addition, organic matter also greatly increases cation exchange capacity (CEC) in tropical soils. Organic materials also help to resist acidity caused by certain nitrogen fertilizers. This is very important because high acidity levels in the soil reduce microbial activity, and further develop toxicity caused by the presence of aluminum and manganese.

Coffee is an important commodity in Indonesia as an agent of development that provides income, jobs for2.3 million farmers, the formation of growth centers, encouraging coffee agribusiness and agro-industry (GAEKI ICEA, 2015; ICO, 2009; Marsh, 2005; Roldán-Pérez et al., 2009). In 2010, Indonesia became the third major coffee producer in the world after Brazil and Vietnam, while in fourth place was Colombia. These four countries produce 63.48% of world coffee production (ICO, 2014). At the national level, North Sumatra Province is in fourth place in the total production of arabica and robusta coffee, contributing 8% of national coffee production. Humbang Hasundutan Regency has a type of coffee called "Lintong coffee" or Sigarar Utang coffee. The area of coffee plantations in the Regency is about 9,246 ha and with production of 6,461 tons. Coffee plantations consist of 48.45% of agricultural and plantation land area (Humbahas in 2011). In Humbang area, there are also several other varieties such as Onan Ganjang, Jember and Lasuna, but the production of these three varieties have been very small at only 5%.

However, the level of coffee productivity in Indonesia is still relatively lower, which is 700 kg / ha. The productivity in North Sumatra isabove the national average, 1,022 kg / ha / year, occupying the second position after Aceh with a productivity of 1,158 kg / ha / year. However, at the local level, the productivity of Arabica coffee in Humbang Hasundutan Regency is still low at 867.35 kg / ha / year. This production is still far from the potential of similar Arabica coffee production which can reach 1.50 - 2.0 tons / ha / year (Disbun Province of North Sumatra, 2013).

This study was aimedto obtain the maximum potential of coffee production at a certain height in Humbahas Regency with a package treatment of pruning, fertilizing and shade technology.

2 RESEARCH METHODHOLOGY

Plant experiments were carried out at an altitude zone of 1200-1300 meters above sea level(masl) which was designed in the form of Splits plot design. Plant trials will be carried out for 1 year. There are three factors tested, the main plot is shade with a level without shade (N0) and shade (N1); subplots are pruning, namely pruning with the farmer system (P1) and pruning recommendations (P2); while the subplots are fertilization methods consisting of: farmers' fertilizing dose (O0), giving organic fertilizer from coffee pulp at a dose of 10 kg / tree (O1), giving organic fertilizer from manure at a dose of 10 kg / tree (O2) , giving phosphate fertilizer (SP36) 150 g / tree.

$$Y_{ijk} = \mu + K_l + A_i + Y_{il} + B_j + (AB)_{ij} + \delta_{ijl} + C_k + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + \varepsilon_{ijkl}$$

$$i = 1, 2..., a;\ j = 1, 2...b;\ k = 1, 2...c;\ l = 1, 2...r$$

Description:

- Y_{ijk} : Observation in the first experimental unit that obtained a combinationtreatment of the i-level of factor A, the j-level of factor B, and the k-level of factor C
- μ : Population average Value
- K_l : The effect of additive from group I
- A_i : The effect of additive to i-level from A factor (Main plot)
- Y_{il} : Random effect of the main plot, which appears at the first level of A factor in the first group.
- B_j : The effect of additive j-level from B factor (subplot)
- $(AB)_j$: The effect of additive level A factor and the j-level of B factor
- δ_{ijl} : Random effects from the first experimental unit that obtain an ij treatment combination (Plot of b errors)
- C_k : Random effects from the first experimental unit that obtain an ij treatment combination (Plot of b error)
- $(AC)_j$: The effect of additive level –i of A factorandk-level of C factor
- $(BC)_j$ The effect of additive level j of B factorand k-level of factor C

ε_{ijkl} : Random effects of the first experimental unit that obtain an ijk treatment combination (plot of c errors)

This observation was carried out using 10 sample plants from each sample plot and each sample plot was repeated three times. The parameters of growth and production of coffee plants observed were: 1) number of productive branches, 2) number of bunches / branches, 3) number of fruit / bunches, 4) total fruit / trees, 5) diameter of canopy, 6) wet weight of coffee beans, and 7) dry water content of 14%.

3 RESULT AND DISCUSSION

Generally, shade as the main plot does not have a significant effect on the growth and production of coffee in the altitude region 1200-1300 m above sea level, but it only significantly affects the number of productive branches. Likewise, pruning and fertilizing as subplots do not have a significant effect on all parameters (Table 1). The significant interaction effect is found at the treatment of Shade x Pruning x Fertilization (NPO) interaction, which resulted insignificant effect on all parameters.

Table 1: Recapitulation of analysis of varianceof growth and production of coffee plants on shade, pruning and fertilization at an altitude of 1200-1300 masl

Variable	Shade	Pruning	Fertilization	Interaction			
	(N)	(P)	(O)	NP	NO	PO	NPO
Canopy Diameter	ns	Ns	ns	ns	ns	ns	**
Number of Poductive Branches	*	Ns	ns	ns	ns	ns	**
Number of bunches	ns	Ns	ns	ns	ns	ns	**
Total of Fruit / Away	ns	Ns	ns	ns	ns	ns	**
Wet Fruit Weight	ns	Ns	ns	ns	ns	ns	**
Dry Fruit Weight	ns	Ns	ns	ns	ns	ns	**

Description: (ns): not significantly different, (*): significantly different from the Duncan test 5%, (**): very significantly different in the Duncan test 1%.

The absence of beneficial effects from the presence of shade trees on a plot scale can occur because coffee itself also produces a lot of litter which contributes greatly to the formation of soil organic matter, regardless of the presence of protective trees. Coffee litter at this height has organic C content of 20.43% and N of 0.89, so C / N is 22.7. The contribution of C organic from litter can increase soil fertility

Table 2: The Effect of shade, pruning and fertilization interaction on the growth and production of coffee plants in altitude of 1200-1300 m.asl

Kombinations	Parameter					
	JCP	DKnp	JTd	JBh_td	BBsh	BKr
N0P1O0	37.67d	203.3a	15.3b	13.0b	430.0b	156.0b
N0P1O1	37.67d	178.3a	22.3c	13.7b	363.3b	118.3b
N0P1O2	33.00c	193.3a	11.0a	13.3b	931.3c	159.8b
N0P1O3	34.00c	164.0a	16.3b	8.7a	202.5a	62.3a
N0P2O0	32.00c	156.0a	7.0a	7.0a	177.7a	85.4b
N0P2O1	31.67c	173.0a	16.7b	6.0a	246.0a	89.1b
N0P2O2	36.00c	176.0a	20.0c	10.0b	279.1b	101.8b
N0P2O3	41.67e	150.0a	10.0a	12.7b	173.4a	85.5b
N1P1O0	22.33b	185.7a	32.3c	14.0b	689.8b	205.5b
N1P1O1	22.67b	200.0a	32.0c	16.3b	599.3b	228.9c
N1P1O2	19.67b	198.3a	61.3d	22.7c	423.6b	156.1b
N1P1O3	20.00b	166.7a	21.7c	13.7b	590.0b	138.9b
N1P2O0	29.67c	193.3a	58.7d	20.3c	784.6bc	253.5c
N1P2O1	18.00a	197.7a	23.0c	15.3b	387.3b	139.1b
N1P2O2	32.33c	154.7a	22.3c	10.7b	169.0a	81.4b

N1P2O3	23.00b	171.7a	11.0a	17.0b	221.1a	104.6b

Description: numbers followed by different letter notations in the same column are significantly different in Duncan's 5% test. JCP = number of productive branches / plants; DKnp = diameter of plant canopy; JTd= number of bunches / plants; JBh= number of fruits / bunches; BBsh = fruit / plant wet weight; Bkr = dry weight of fruit / plant (weight of water content is 12%).

In the single factor, shade does not generally affect coffee growth and production. It means that the shade system of coffee plants, which correspondingly provides several ecosystem services, also does not reduce coffee production. However, there is one growth parameter that is influenced by coffee shade, namely the number of branches productivity (Graph 1), where the number of productive branches coffee is not shaded by 33.8% more than shaded coffee. These results contradict with the findings of Siles et al. (2010), where shading of coffee plants in intercropping systems plays an important role in productivity

Number of productive branches

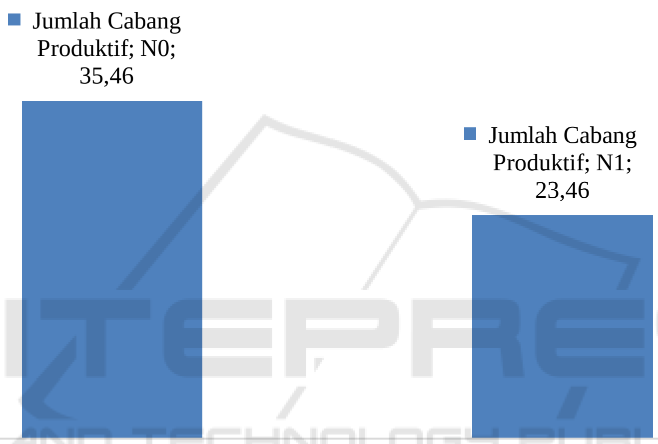

Figure 1: Number of branches productivity in shaded and non-shaded conditions (N0: non-shaded; N1: shaded)

The optimal intensity of sunlight for coffee plant growth as a result of the use of various types of shade something that is specific and cannot be generalized to different growing environments, varieties, and management. The interaction between the growing environment, varieties, and crop management is a factor that can be a differentiator in the use of various types of shade plants. Beer et al. (1988) suggested that the influence of shade on the coffee crop results many contradictions due to differences in biophysical environment, plant material, evaluation criteria, and duration of study. Beer et al. (1988) and Dossa et al. (2008) suggested that the interaction between coffee plantations and species of shade plants is strongly influenced by differences in the growing environment, characteristics and or differences in plant varieties, and differences in management of garden management.

In the generative phase, increasing shade can reduce productivity. This is due to excessive shade, the assimilation of carbon becomes lower so that vegetative growth becomes more dominant than the appearance of flower buds (DaMatta, 2004), and fewer flower buds per branch (Wintgens, 2014).

The effect of the best shade, pruning and fertilizing interactions on the parameters of the number of productive branches was obtained in N0P2O3 (without shade, trimming recommendations and giving 150 gr phosphate fertilizer / tree), as many as 41.67 branches. While the lowest productive branch growth was obtained at N1P2O1 (with shade, trimming recommendations and giving compost from 10 kg of coffee pulp / tree).

The canopy diameter parameters, although further test analysis did not show significant differences, the best effect of interaction of shade, pruning and fertilization was obtained on N0P1O0 (without shade, cropping of farmers 'systems and farmers' dosing) and N1P1O1 (with shade, pruning of farmer systems and compost fertilizer) from 10 kg of coffee pulp / tree) with a canopy diameter of

203.3 cm, while the smallest canopy diameter at N0P2O3 (without shade, trimming recommendations and giving 150 gr phosphate fertilizer / tree) was 150 cm.

The parameters of the number bunches of tree, the best interaction effect of shade, pruning and fertilization was obtained on N1P1O2 (with shade, pruning the farmer system and 10 kg manure / tree) and N1P1O1 (with shade, pruning the farmer system and compost from 10 kg coffee pulp / tree) with a number of bunches of 61.3, while the number of bunches was at least in N0P2O0 (without shade, pruning recommendations and fertilizing at a farmer's dose) as many as 7 bunches per tree.

The parameters number of fruits per bunch per tree, the best interaction effect of shade, pruning and fertilization was obtained on N1P1O2 (with shade, pruning the farmer system and 10 kg of manure / tree) with a bunch of 61.3, while the number of bunches was at least N0P2O1 (without shade, pruning recommendations and fertilizing with compost from 10 kg of coffee pulp / tree) as much as 6 pieces per bunch per tree.

The parameters of wet seed weight, the best interaction effect of shade, pruning and fertilization was obtained on N0P1O2 (without shade, pruning the farmer system and 10 kg of manure / tree) with a wet seed weight of 931.3 gr, while the lowest wet seed weight was N1P2O2 (with shade, pruning recommendations and fertilizing with 10 kg of manure / tree) weighing 169 gr.

The parameters of dry seed weight, the best effect of interaction of shade, pruning and fertilization was obtained on N1P2O0 (with shade, pruning recommendations and fertilizer for farmers) with dry seed weight 253.3 gr, while the lowest dry seed weight on N0P1O3 (without shade, trimming system farmers and fertilization with SP36 150 g / tree) weighing 62.3 gr. However, when viewed from the percentage of heavy shrinkage from wet-dry, the best interactions are found in N1P2O3 (with shade, cropping of farmer's recommendations and fertilizing with SP36 150 g / tree), with shrinkage of 52%. This shrinkage value is much lower than N0P1O2 (without shade, cropping the farmer's system and 10 kg of manure / tree) with a wet seed weight of 931.3 gr and shrinking by 82% (159.2 gr) on the dry weight of the seeds.

In locations without shade, with a spacing of 2.5 x 2.5 m wide, it is not possible for coffee plants to grow and develop properly. The absence of shade trees causes the distribution of sunlight that can be absorbed by coffee plants is relatively large. Such as conditions cause the growth of the main coffee plants to be disrupted. At high light intensity causes the air temperature to rise and these conditions tend to cause plants to suffer from lack of water due to increased evapotranspiration and reduce the flow of CO2 into the leaves so that the assimilation process becomes reduced. If this condition continues, the plant growth will be hampered. Plants will be more disturbed if the leaves are burned by the sun's heat and increased leaf miscarriages will reduce the ability of the leaves to produce assimilates for their growth.

4 CONCLUSIONS

The growth and production of coffee plants is influenced by the interaction of shade plants, pruning and fertilization. In all altitudes, vegetative growth in plants tends is enhanced in conditions of not shaded by pruning and giving organic fertilizer, both with manure and coffee pulp compost. However, the best yield production parameters was obtained under shaded conditions which are pruned according to the recommendations.

REFERENCES

BPS. 2011. Humbahas in Numbers, Central Bureau of Statistic. Humbang Hasundutan district, Sumatera Utara. [Indonesian]

Beer, J., Muschler, R., Kass, D., Somarriba, E. 1997. Shade management in coffee and cacao plantations. *Agroforestry systems*, 38(1-3), 139-164.

Bilir, N., Prescher, F., Ayan, S., Lindgren, D. 2006. Growth characters and number of strobili in clonal seed orchards of Pinus sylvestris. *Euphytica*, 152(2): 1-9.

Dariah. A., Agus. F., maswar, 2005. Soil quality on farming land coffe plant based (Case Ctudy on Sumber Jaya, Lampung Barat). Soil and climate Journal. 23.48-57

DaMatta, F. M. 2004. Ecophysiological constraints on the production of shaded and unshaded coffee: a review. *Field crops research*, 86(2-3), 99-114.

Dishutbun. 2013. Annual report plantation estate, 2013. Forestry and estate service Humbang Hasanudin District, North Sumatera.

Dossa, E. L., Fernandes, E. C. M., Reid, W. S., Ezui, K. 2008. Above-and belowground biomass, nutrient and carbon stocks contrasting an open-grown and a shaded coffee plantation. *Agroforestry Systems*, 72(2), 103-115

Dutkuner, I., Bilir, N., Ulusan, M. D. 2008. Influence of growth on reproductive traits and its effect on fertility and gene diversity in a clonal seed orchard of scots pine, *Pinus Sylvestris* L. *Journal of environmental biology*, 29(3), 349.

[GAEKI] Indonesian coffee exporter association. 2015. Production and area [internet]. [downloaded at 2018 maret 01] available at http://gaeki.or.id/areal-dan-produksi/

Hairiah k., Rahayu. S. 2010. Climate change mitigation (coffee agroforestry to sustain carbon stock landscape). Coffee Prosiding Symposium.

[ICO] International Coffee Organization. 2009. Opportunities and challenges for the world coffee sector, Multi-stakeholder Consultation on Coffee of the Secretary- General of UNCTAD, Geneva: International Coffee Organisation.

ICO, 2014. International Coffee Organization statistical database ICO. (accessed 20.1.2019) http://www.ico.org.

Marsh, Antony. 2005. A review of Aceh coffee industry. *UNDP ERTR Livelihood Component*.

Mawardi, S., Yusianto, R. H. 2008. Khalid, dan A. Marsh. 2008. Flavor Evaluation of Several Arabica Coffee Varieties in different altitude and different processing methods in the Gayo Highlands (NAD). In Aceh Coffee Forum Workshop. Takengon (Vol. 25).. In *Workshop Forum Kopi Aceh. Takengon* (Vol. 25).

Panggabean. E. 2011. Coffee Smart Book. Agromedia Pustaka. Jakarta.

Prawoto, A., Nur, A. M., Soebagiyo, S. W. A., Zaubin, M. 2006. Alelopathy test for several species of shade plants for arabica coffee (*Coffea arabica* L.) seeds. Pelita Perkebunan*22*(1), 1-12.

Roldán-Pérez, Adriana; Maria-Alejandra Gonzalez-Perez, Pham Thu Huong, and Dao Ngoc Tien (2009). *Coffee, cooperation and competition: A comparative study of Colombia and Vietnam*, UNCTAD Virtual Institute. http://www.vi.unctad.org/resources-mainmenu-64/digital-library?coffee.

Wintgens, J. N. (2004). *Coffee: growing, processing, sustainable production. A guidebook for growers, processors, traders, and researchers*. 2nd Edition. WILEY-VCH Verlag GmbH & Co. KGaA. http://dx.doi.org/10.1002/9783527619627