The Growth of Arabica Coffee (*Coffea arabica* L.) Seedling on Combination of Inorganic-organic Fertilizers and Shading Level

Ade Astri Muliasari[1*], Ade Wachjar[2], Supijatno[3]

[1]Graduate School of Agronomy and Horticulture, Bogor Agricultural University, Bogor 16680, Indonesia
[2]Department of Agronomy and Horticulture, Bogor Agricultural University, Bogor 16680, Indonesia
[3]Department of Agronomy and Horticulture, Bogor Agricultural University, Bogor 16680, Indonesia

[*]*Corresponding author's email: adeastri07 [AT] gmail.com*

ABSTRACT— ***Coffea arabica* L. grows naturally under shading with low intensity of sunlight, but optimum growth of coffee is not only determined by shading levels but also by nutrient availability. The objective of this research is to know the effect on the combination of inorganic-organic fertilizers and shading levels on growth of coffee seedling. The research was conducted in Bogor Agricultural University Experimental Station, Cikabayan, Darmaga-Bogor, from May 2013 to February 2014. The experiment was arranged in a split plot design with three replications. The main plots were four shading levels, i.e. 25%, 50%, 75% and 95%, while subplots were five combinations of inorganic-organic fertilizers: inorganic, coffee pulp compost and organic manure. The best combination inorganic-organic fertilizer for coffee seedling growth was 25% inorganic fertilizer+75% organic manure. The optimum shading level to support optimum growth of arabica coffee seedling was 62%. Interaction between shading levels and combination of inorganic-organic fertilizers significantly affected leaf number, stem diameter, leaf area and leaf thickness. The best combination treatment was 75% shading intensity with 25 % inorganic fertilizer + 75% organic manure.***

Keywords— Coffee pulp compost, arabica coffee, organic manure, light intensity

1. INTRODUCTION

Indonesia is the third biggest coffee producer in the world after Brazil and Vietnam. In 2014, the productivity of Arabica coffee in Indonesia was about 920 kg ha^{-1}year. This number is still far from the optimum yield of the variety can produce, more than 1 500 kg ha^{-1}year [1]. Low productivity is caused by several factors such as non-homogeneous seeds variety, bad maintenance of cultivation, non-optimal fertilization and shade intensity management. Improper application of fertilizer is one of the examples of disorientation of fertilization management which causes low yield of coffee. Application of shade intensities with plastic light intensity, natural shade or trees shade should be well managed for optimum coffee growing.

Nursery is the first step of coffee seedling production. Nutrient availability in nursery is one of the factors that determine the successful of high quality of coffee seedling production. Sources of nutrients can be supplied from organic and inorganic fertilizer. The combination of both organic and inorganic fertilizer is able to provide sufficient nutrients and reduce the cost of inorganic fertilizers [2]. Generally, the source of organic materials comes from decompotion of plant tissue and animal waste. According to Abdoellah [3], returning of coffee pulp will help in reducing the use of inorganic fertilizer. Beside nutrients, shade intensity also affects the growth of coffee seedlings. Shade intensity protects coffee plants against adverse environmental stress such as high soil temperatures and low relative humidit [4]. Bote and Struik noted, application of shade intensities may reduce the excessive of light, mulch the soil with their litter, create hostile conditions for pest and diseases, and harbour a variety of predatory animals [5].

The information of organic and inorganic fertilizer combination and level of shade intensities studied in this research is expected to be very useful to support folksy coffee plantation. The objectives of this study are:

(1) to find out the best proportion of organic and inorganic fertilizer combination for Arabica seedling.
(2) to find out the optimum shade intensity for Arabica seedling growth
(3) to study the interaction between shading and organic-inorganic fertilizer combination to the growth of Arabica seedling.

2. MATERIAL AND METHODS

2.1 Study site and treatments

The experiment was carried out at Bogor Agricultural University Experimental Station, Cikabayan, Darmaga, Bogor. Two month-old healthy Arabica coffee seedlings (Catimor variety) were tested. The plants were transplanted into polybags in nursery stage. The seedlings were transplanted from nursery beds into polybags with treated growing media; inorganic fertilizer (P1) and inorganic-organic fertilizer combination (P2, P3, P4 and P5). Those treatments refer to fertilizer management.

The organic treatment consisted of composted coffee pulp (P2, P3) and organic manure (P4, P5). The polybags used 40 cm x 30 cm in size containing top soil and several levels of inorganic-organic fertilizer combination. Levels of fertilizer treatments refer to dosage of recommendation. The amount of organic fertilizer per polybag was about 10 882.28 $cm^{3.}$ Organic fertilizer application was done together with growing media application. First application of inorganic fertilizer was given when the seedlings had been transplanted into the polybags and the following application was given gradually every eight weeks. It was ended when the seedling reached 24 weeks of age.

The application of inorganic fertilizer (P1 was done by sowing them 2 cm away from the lower part of the stem. Dosage and time of inorganic fertilizers are listed in Table 1.

Table 1. Dosage and time of inorganic fertilizers application

age of seedlings (MAT)	Urea	SP-36	KCl
	.....(g seedlings^{-1}).....		
0	0.50	0.25	0.25
8	1.00	0.50	0.50
16	2.00	1.00	1.00
24	2.50	1.50	1.50
Amount	6.00	3.25	3.25

Description : MAT= month after transplanting
Sources : [6]

2.2 Trial Set Up

Split plot design with two factor of treatments was used in this experiment. Shade intensity was placed as the main plot. It consist of 4 standard shade intensities, four level of shade intensity were used 25 % (N1), 50 % (N2), 75 % (N3), and 95 % (N4). Light intensity was measured by using Lux meter. The combination of organic and inorganic Fertilizer was placed as sub-plot. It consist of 5 levels of fertilizers ratio sub-plot; 100% inorganic fertilizer (P1), 50% inorganic fertilizer + 50% coffee pulp compost (P2), 25% inorganic fertilizer + 75% coffee pulp compost (P3), 50% inorganic fertilizer + 50% cow manure (P4), and 25% inorganic fertilizer + 75% cow manure (P5). Therefore, there were 20 treatment combinations and each combination consists of 3 replicates, so that, there were 60 units of trial. Each units of trial consisted of 11 seedlings of coffee. They were arranged 30 cm x 30 cm away among the polybags . Three seedlings out of eleven were set as the sampling.

The first data collection was collected one month after transplanting (MAT). The parameters obserbed were plant height, stem diameter, and the number number of leaves until they reach seven months old of age. The number of leaves was collected monthly. The destructive measurements such as: stomatal density, leaf thickness, fresh weight and dry weight of canopy, fresh weight and dry weight of roots , chlorophyll content, and the content N, P and K of leaf were done at the end of experiment .

The statistical analysis used was ANOVA with split plot design model. Orthogonal Contrasts was test to fertilizer combination (kode) when the results showed 5% of significant test level If the results of variance is significant effect on the test level 5% then further test of Orthogonal Contrasts for both combination treatment inorganic-organic fertilizers. Contrast polynomial was used as the advanced test for shade intensity treatment [7].

3. RESULT AND DISCUSSION

3.1. Response of coffee seedling growth to inorganic-organic fertilizers combination

Application of a combination of inorganic-organic fertilizer was very significant affect on plant height at the age of 1-7 MAT coffee seedlings. Combination treatment inorganic-organic fertilizer produced higher plants compared with inorganic fertilizer treatment from age 1-7 MAT. Combination of of 25% inorganic fertilizer dose + 75% cow manure (P5) produced the highest plant although not significantly different combination of 50% inorganic fertilizer dose + 50% cow manure (P4).

Application of inorganic fertilizer (P1) produced the lowest plant height. Based on the research results, coffee seedling growth response to various combinations of inorganic-organic fertilizers has fulfilled the standard criteria for seedlings which ready for distribution following the regulation of ministry of agriculture of Indonesia. The seedling reached 5 months old of age with height between 25-30 cm, 5 pairs of leaves, fresh green leaf color, stem diameter ≥ 8 mm, and free of plant pests [8]. Tabel 2 shows the response of coffee seedlings to several levels of fertilizer combination.

Table 2. Effect of inorganic-organic fertilizer combination to the height of the Arabica coffee seedlings

Combination of fertilizers	Age (month after planting)							
	0	1	2	3	4	5	6	7
	.....(cm).....							
P1	5.39	6.71b	8.61c	10.05c	13.79c	18.22c	24.92b	27.44c
P2	5.35	6.54b	7.68cd	8.42c	12.42c	19.26c	28.94b	31.25c
P3	5.68	6.89b	7.59d	8.08c	11.57c	19.86c	29.56b	31.14c
P4	5.43	7.88a	12.43b	18.81b	27.18b	36.25b	45.57a	45.61ab
P5	5.58	7.64a	13.76a	21.37a	31.96a	41.11a	49.58a	50.63a

Description: Different letters in the same column indicate statistically significant difference ($p<0.05$) according to Duncan multiple range test
P1 : inorganic seedlings 100%, P2 : 50% inorganik + 50% skin coffee compost, P3: 25% inorganik + 75% skin coffee compost, P4 :50% inorganik +50% cow manure, P5: 25% inorganik + 75% cow manure. Descriptions of fertilizer combinations apply also to other variables.

Application of combination of inorganic-organic fertilizers impact on chlorophyll a, chlorophyll b, total chlorophyll, chlorophyll ratio b / a, SPAD value and stomatal density on coffee seedlings at the age of 7 MAT (Table 3).

Table 3. Effect of inorganic-organic fertilizer Combination on the content of chlorophyll a, chlorophyll b, total chlorophyll, chlorophyll ratio b / a, SPAD value and stomatal density Arabica coffee seedlings

Combination of fertilizers	chlorophyll a (mg g^{-1})	chlorophyll b (mg g^{-1})	Total chlorophyll (mg g^{-1})	Chlorophyll ratio b/a	SPAD values	Stomatal density (stomata mm^{-2})
P1	1.70b	0.74c	0.54bc	0.44ab	54.40cd	157.113c
P2	1.66b	0.71c	0.52c	0.43ab	50.97d	165.182bc
P3	1.80b	0.76bc	0.56bc	0.42b	58.27bc	184.289ab
P4	1.89b	0.84b	0.61b	0.45a	62.74ab	193.206a
P5	2.14a	0.942a	0.70a	0.44ab	64.95a	178.769ab

Descriptions: Different letters in the same column indicate statistically significant difference ($p<0.05$) according to Duncan multiple range test

The application of fertilizer combinations were 25% inorganic dose + 75% cow manure (P5) affected chlorophyll a, chlorophyll b, total chlorophyll, and SPAD value. It showed highest value among the others compared to other treatments. On the other side, fertilizer combinations of 50% inorganic dose + 50% cow manure (P4) affected the values of chlorophyll ratio b/a and stomata density densest but statistically not different toP5. SPAD meter can be used to estimate the chlorophyll content using the scale shown. The value showed positive correlation to total chlorophyll content (R^2=0.744). The value of SPAD meter cannot show chlorophyll content in specific units.

Inorganic-organic fertilizers combination showed significant on the nutrient content of coffee seedling leaf age of 7 MAT. The values can be seen in Table 4.

Table 4. Response of various combinations of inorganic-organic fertilizer on nutrient content of Arabica coffee seedling leaves

Combination of Fertilizer	Nutrient content of leaves (%)					
	N	Status	P	Status	K	Status
P1	2.05ab	Deficiency	0.19d	Sufficient	2.61a	High
P2	1.94ab	Deficiency	0.21cd	High	2.31abc	Sufficient
P3	2.11a	Deficiency	0.210c	High	2.01c	Sufficient
P4	1.90b	Deficiency	0.22b	High	2.09bc	Sufficient
P5	2.12a	Deficiency	0.23a	High	2.45ab	High

Descriptions: Different letters in the same column indicate statistically significant difference ($p<0.05$) according to Duncan multiple range test

N and P content are higher in P5 treatment among the other. Malavolta (1990) noted, in coffee leaf , N deficiency is considered when amount of N is <2.2%, P is relatively high between 0:21 to 0:23%, and K is quite enough between 1.9-2.4%. Cai et al. noted, the higher of fertilizer dose that given to the Arabica coffee plant then the nutrient content in the leaves also increased and is marked with a better vegetative growth [9]. This is beneficial also in terms of plant adaptation mechanisms to the intensity of the low shade.

3.2. The Response of Coffee Seedling Growth to Shade Intensity

The shade intensity is very significant affect on height of coffee seedlings plant aged 1-7 MAT. The effect of shade intensity to the height of Arabica coffee seedlings are presented in Table 5.

Table 5. The Effect of shade intensity to the height of Arabica coffee seedling

Shade intensities (%)	Ages (month after transplanting)							
	0	1	2	3	4	5	6	7
	..... (cm).....							
25	5.53	6.79b	9.24b	11.10b	15.53c	20.08b	27.64b	29.21b
50	5.33	7.02ab	10.02ab	13.46a	18.97b	29.01a	37.12a	38.41a
75	5.44	7.33a	10.31a	14.98a	23.10a	30.13a	40.22a	42.10a
95	5.64	7.38a	10.49a	13.84a	19.95b	28.53a	37.87a	39.14a

Descriptions: Different letters in the same column indicate statistically significant difference ($p<0.05$) according to Duncan multiple range test

The plants placed in 50-95% of shade intensities were higher than in 25%. The highest plants were found in the 75 % of shade treatment, about 42.10 cm. Quadratic influence of the shade intensity to plant height age 7 MAT descripted by the line equation $Y = -0.0053x^2 + 0.7864x + 12.78$ R^2 is 0.9968%.

The Applications of shade intensities were highly significant to chlorophyll a, chlorophyll b, total chlorophyll, SPAD value, and stomatal density unless ratio b/a is presented in Table 6. Low light intensity caused the increasing of chlorophyll a, chlorophyll b, total chlorophyll, and SPAD value higher than other levels. Levitt states that, the plant will adapt to shade intensity by increasing light capture efficiency per unit area of photosynthetic namely by increasing the amount of chlorophyll per unit leaf area [10].

Stomata density is highest in the low shade intensity treatment (25%), but not significantly different with the shade intensity of 50% and 95% (Figure 1). In high light intensity plant will modify leaves anatomy by increasing the stomatal density. It aims to enhance CO_2 fixation in the photosynthesis process. High light intensity and temperature may reduce 20% of CO_2 fixation by oxygenation process [11].

Table 6. The effect of shade intensity to the content of chlorophyll a, chlorophyll b, total chlorophyll, chlorophyll ratio b/a, SPAD values and stomatal density of Arabica coffee seedlings

Shade intensities (%)	chlorophyll a (mg g^{-1})	chlorophyll b (mg g^{-1})	Total chlorophyll (mg g^{-1})	Klorofil ratio b/a	SPAD value	Stomatal density (stomata/mm^{-2})
25	1.30c	0.58c	3.77a	0.44	54.24b	193.631a
50	1.39c	0.62c	2.05b	0.44	56.93ab	185.139a
75	2.02b	0.88b	2.89c	0.43	60.68a	145.053b
95	2.64a	1.12a	3.77a	0.43	61.21a	179.024a

Descriptions: Different letters in the same column indicate statistically significant difference ($p<0.05$) according to Duncan multiple range test

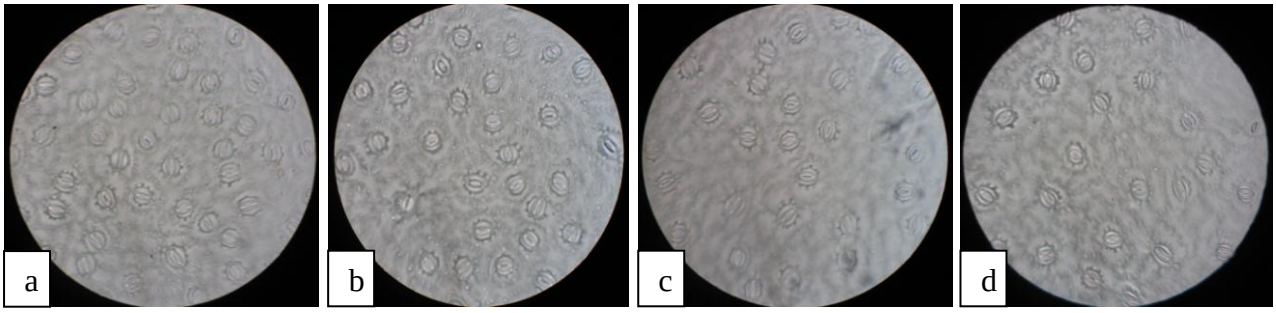

Figure 1. Effect of shade intensity to the stomatal density of Arabica coffea seedlings. Shade intensity [a] 25%, [b] 50%, [c] 75%, [d] 95%

The provision of shade intensity significantly affect to N content and highly significant to P content of Arabica coffee seedling leaf age of 7 MAT (Table 7). High shade intensity (95%) showed highest leaf N. 75% of shade intensity showed highest leaf P content. 95% of shade intensity has highest leaf K content not significantly different from 25% and 75% of shade treatments. The higher of shade intensity, higher nutrients contained in leaf. Plants which grow under low light intensity had high amount of leaf nitrate concentration due to the reduction of leaf photosynthesis rate.

Nitrogen is a precursor of chlorophyll work as the antenna pigment for capturing of light for photosynthesis. Nitrogen is also a component RuBP carboxylase enzymes that work to reducing CO2 into carbohydrates in the dark reaction [11]. Bote and Struik reported that, The coffee plants grow under low light intensity showed higher value of leaf N content and leaf greenness Than high light intensity and fully expose to sun light [12]. Quadratic correlation of the shade intensity to the content of leaf nutrient at the age of 7 MAT is illustrated by line equation $Y = 0.0002x^2 - 0.0135x + 2.1341$ with R^2 is 0.9042 for nutrient N and line equation $Y = -000008x^2 + 0.0011x + 0.1854$ with R^2 is 0.3429 for P leaf content.

Table 7. The effect of shade intensities to nutrient content of Arabica coffee seedling leaves

Shade Intensities (%)	Leaves nutrient content (%)					
	N	Status	P	Status	K	Status
25	1.92c	Deficiency	0.21b	High	2.22ab	Sufficient
50	1.79c	Deficiency	0.21b	High	2.12b	Sufficient
75	2.11b	Deficiency	0.23a	High	2.32ab	Sufficient
95	2.27a	Disturbed	0.21b	High	2.51a	High

Descriptions: Different letters in the same column indicate statistically significant difference ($p<0.05$) according to Duncan multiple range test

3.3. Response of coffee seedling growth to various combinations of inorganic-organic fertilizers and shade intensities

Application of various combinations of organic and inorganic fertilizers and shade intensity significantly affect the number leaf sheet of six-month old plants (Figure 2) and stem diameter of seven-month old Arabica coffee seedlings (Figure 3).

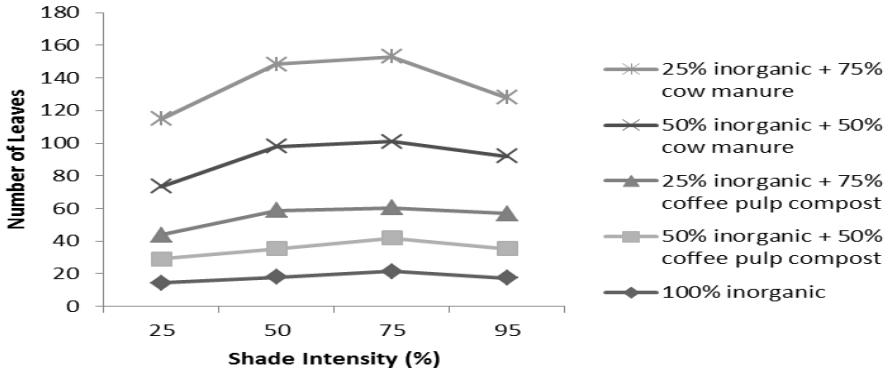

Figure 2. The combination effect of inorganic-organic fertilizers and shade intensity to the number of leaves of six-month old Arabica Of six-month old Arabica

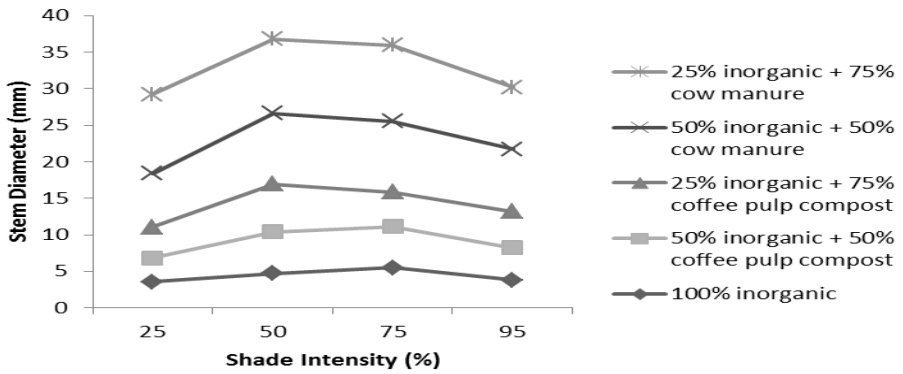

Figure 3. The combination affect of inorganic-organic fertilizers and shade intensity to stem diameter of seven-month old Arabica coffee seedlings

The combination of inorganic-organic fertilizer and shade intensity yield a number of leaf the most. The number of leaf in combination 25% of inorganic fertilizer dose + 75% of cow manure (P5) and 50-75% of the shade intensity. This is in contrast with the results from Chemura reported that inorganic fertilizer induced leaf growth higher than inorganic fertilizer with the same light intensity treated [13]. The highest value of stem diameter of seven-month seedling is on 25% inorganic fertilizer combined with 75% cow manure (P5) with 25% and 75% of shade intensities. Whereas, the value is not significantly different with 50% of shade intensity. Kadir and Kanro reported that organic fertilizer derived from livestock waste produces stem diameter larger than coffee waste or a mixture of both under the shade intensity in the form of shade trees [14]. The treatment combination of organic and inorganic fertilizers low light intensity (25%) caused the reduction of stem diameter value and the number of leaves.

Combination of inorganic-organic fertilizer showed proportional growth, this suggests that the use of organic fertilizers for coffee seedling can provide nutrient balance. Application of organic fertilizers can improve the growth component of coffee seedling. Quadratic influence the shade intensity to the number of leaves at the age of 5 MAT) illustrated by line equation $Y= -0.0034x^2 + 0.4616x + 4.4246$ with R^2 is 0.9986%. Quadratic influence the shade intensity to diameter stem at the age of 6 MAT is described by the line equation $Y= -0.0014x^2 + 0.1834x + 1.0432$ with R^2 is 0.9881%. The highest value of leaf thickness and leaf area were found P5 with 25% of shade intensity (Figure 4).

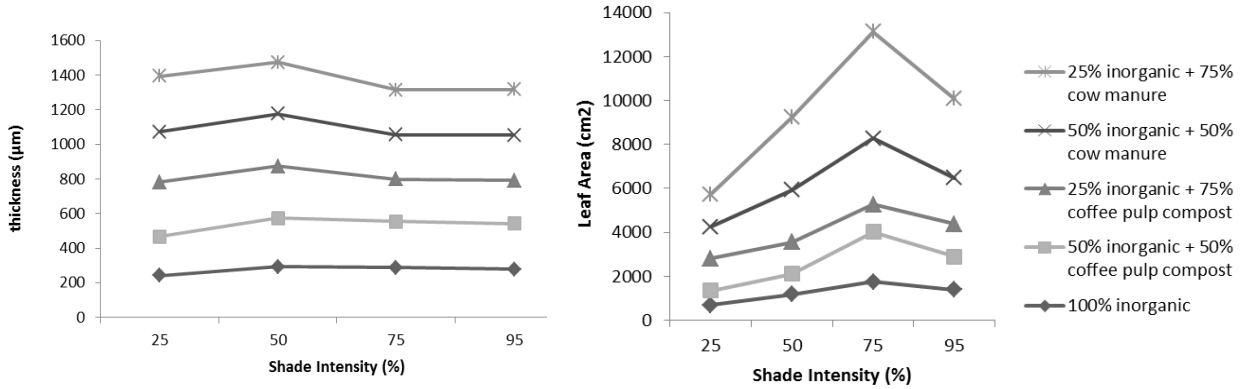

Figure 4. Effect of inorganic-organic fertilizer combinations and shade intensities to leaf thickness (a) and leaf area (b) of Arabica coffee seedlings at the age of 7 MAT

P5 treatment with 25% of shade intensity shows the highest value of leaf thickness eventough statistically not significant different with other inorganic- organic combination. The highest value of leaf area was found in P5 treatment with 75% of shade intensity This result is in line with a study by Huawei reported that the provision of the shade intensity can reduce the thickness of the leaves but tends to increase leaf area [15]. Leaf thinning occurs because of the reduction in the number of network layers palisade and mesophyll cells. Increased of leaf area is effort of plants in efficiently capturing of light energy for photosynthesis normally in the high shade intensity condition. This is function to increase light capture area [16].

Quadratic influence the shade intensity of the leaf area at the age of 7 MAT illustrated with line equation $Y= -0.5548x^2 + 81.425x - 612.36$ with R^2 is 0.8828%.

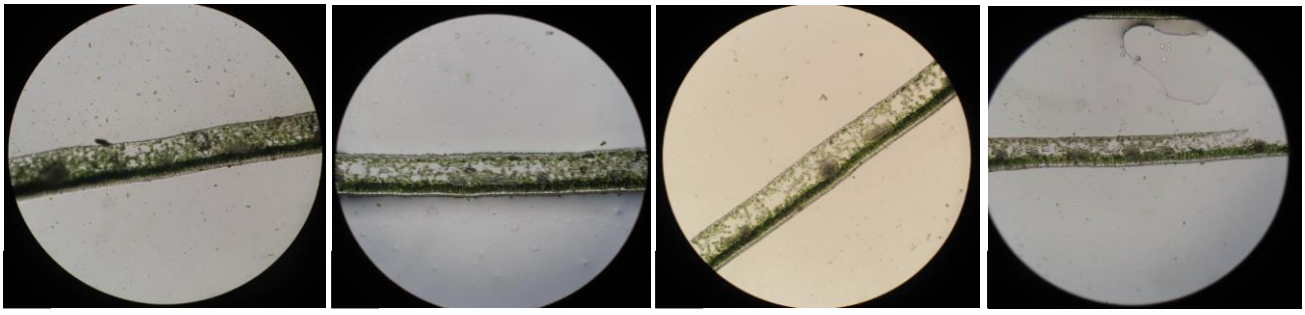

Figure 4. The effect of shade intensities to the thickness of leaf. Shade intensities [a] 25%, [b] 50%, [c] 75%, [d] 95%

The determination of optimum shade intensity for the growth of coffee seedlings can use a common response curve of plant growth to the shade intensity. The determination of the optimum shade intensity was done by lowering the regression equation variable response curve of growth that patterned quadratic in shade intensity treatment. The optimum shade obtained was 62.26%. The optimum of shade intensities interval ranges from 40-70% [17]. The determination of optimum shade intensity can be seen in Table 8.

Table 8. The Determination of optimum shade intensity Arabica coffee seedlings

Variables	Regression equations	R^2	Optimum shade intensity (%)
Plant height (7 MAT)	$Y = -0.0053x^2 + 0.7864x + 12.78$	0.9968	74.19
The number of leaves (5 MAT)	$Y = -0.0034x^2 + 0.4616x + 4.4246$	0.9986	67.88
Stem diameter (6 MAT)	$Y = -0.0014x^2 + 0.1834x + 1.0432$	0.9881	65.50
Leaf area (7 MAT)	$Y = -0.5548x^2 + 81.425x - 612.36$	0.8828	73.38
Wet weight root	$Y = -0.0176x^2 + 2.0504x - 14.699$	0.8428	58.25
Wet weight canopy	$Y = -0.0235x^2 + 3.1221x - 5.0219$	0.8479	66.43
Root dry weight	$Y = -0.0083x^2 + 0.9744x - 6.5738$	0.8287	58.70
N content in leaves	$Y = 0.0002x^2 - 0.0135x + 2.1341$	0.9042	33.75
Average			62.26

4. CONCLUSION

According to the data recorded, there are several conclusion as follows:

1. P5 (combination of 25% of inorganic fertilizer doses + 75% organic fertilizer of cow manure) with 75% of shade intensity has the highest values of all parameters tested.
2. The optimum shade intensity for the growth of coffee seedlings is 62.26% or 62%.
3. The interaction between organic and inorganic fertilizers combination and shade intensity significantly affected the leaf 6 MAT, stem diameter (6-7 MAT), leaf thickness and leaf area of Arabica coffee seedlings.

5. ACKNOWLEDMENT

Thank you very much to Dr Ir Bagus P Purwanto, MAgr, The Director of Diploma Program, Bogor Agricultural University as the sponsor of this research.

6. REFERENCES

[1] Directorate General of Plantation, Plantation Statistics Indonesia, Coffee Comodities 2013-2015, Jakarta. 2014
[2] Chemura A, Mahoya C, Kutywayo D, Chidoko P. The growth response of coffee plants to organic manure, inorganic fertilizer and integrated soil fertility management under different irrigation levels, *International Journal Recycl Org Waste Agriculture* 2014, 3:59.
[3] Abdoellah S. Integrated plant nutrition management in coffee plantations, *Indonesia Coffee and Cacao Research Center*, 2013, 1 (1) 24-39.
[4] Bote AD, Struik PC, Effect Shade on growth, production and quality of coffee (*Coffea arabica* L.) in Ethiopia, *International Journal of Roots and Tubers* 2014, Vol. 1 (1) 007-011.
[5] Beer J, Muschler R, Kass D, Somarriba E, Shade management in coffee and cacao plantations, *Agroforestry system* 1998, 38: 139-164.
[6] *Indonesia Coffee and Cacao Research Center*. Technical guidelines for the cultivation of the coffee plant, Jember, 2006, 96p.
[7] Mattjik AA, Sumertajaya IM, Design Applications with SAS and Minitab, IPB Press, Bogor, 2006.
[8] Regulation of Agriculture Minister Number 89 of 2013. http://perundangan.pertanian.go.id/admin/file/Permentan%2089-2013%20SOP%20 Kopi%20 (total).pdf. [1 September 2014]
[9] Malavolta E., Nutricao mineral e adubacao do cafeeiro. Associacao Brasileira para Pesquisa da Potassa e do Fosfato (Piracicaba), *Editora Agronomica Ceres Ltd*, Sao Paulo, Brazil, 1990.
[10] Cai C-T, Cai Z-Q, Yao T-Q, Qi X, Vegetatif growth and photosynthesis in coffee plant under differrent watering and fertilization managements in Yunan, SW China, *Photosynthetica* 2007, 45(3):455-461.
[11] Levitt J, Responses of plants to environmental stress: Water, radiation, salt adn other stress, Voll II, Academic Press. 1980, 283-303p.
[12] Morais H, Medri ME, Marur CJ, Caramori PH, Riberio AMDA dan Gomes JC, Modifications on leaf anatomy of *Coffea arabica* caused by shade of Pigeonpea (*Cajanus cajan*), Brazilian Archives of Biology and Technology, 2004, 47 (6):863-871
[13] Bote AD, Struik PC, Effect Shade on growth, production and quality of coffee (*Coffea arabica* L.) in Ethiopia, *International Journal of Roots and Tubers* 2014, Vol. 1 (1) 007-011.
[14] Kadir S, Kanro MZ, The effect of organic fertilizer on the growth and production of Arabica coffee , *J. Agrivigor* 2006, 6 (1):85-92
[15] Huawei L, Dong J, Wollenweber B, Tingbo D, Weixing C, Effects of shading on morphology, physiology and garin yield of winter wheat, Europ. *J. Agronomy* 2010, 33:267-275.

[16] Hale MG, Orcutt DM, The Physiology of Plant Under Stress, John Wiley and Sons.,Canada, 206 p. 1987.
[17] Kumar D, Tieszen LL, Photosynthesis in *Coffea arabica* L, Efects of light and temperature, Exp. *Agric* 1980,16:13-19