The Growth of Arabica Coffee Seedling (*Coffea arabica Linn.*) on Various Watering Time Intervals and Shade Intensities

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ABSTRACT---- ***The purpose of this research is to get the parameter of plant coefficient and water fraction availability that needed in order to calculate the accurate watering time interval, to get the optimum shade intensity, also the combination of watering time interval and the optimum shade intensity for the growth of coffee seedling. The experiment conducted at IPB Experimental Station, Dramaga, Bogor from May 2013 until April 2014, using split plot design with two factors. Main plot is shade intensity with some levels: 0, 25, 50, 75, 100%, and the sub plot is watering time interval, once in 2, 4, 6 and 8 days. The interaction between shade intensity treatments, and watering intervals result significantly towards leaf thickness, stomata density, chlorophyll content, wet weight of root, evapotranspiration, plant coefficient and available water fraction. The treatment combination that suggested is 75% shade treatment with watering time interval once in 4 days with the value of available water fraction that can be absorbed 15.56% and plant coefficient is 0.87. The optimum shade for the growth of coffee seed is 77%.***

Keywords--- biomass, evapotranspiration, plant coefficient, water fraction.

1. INTRODUCTION

Coffee is one of the commodities that play an important role in the Indonesian economy. This is supported by the government's efforts to improve Indonesia's coffee production. Indonesia's coffee production over the last 5 years has decreased by 0.98 %. Coffee production in 2009 reached an amount of 682 591 tonnes and decreased to 675 881 tonnes in 2013 (Ditjenbun, 2015).

The cause of decline in coffee production in Indonesia is the seeds used by coffee farmers are not superior clones. Even if superior clones are used, but if the management of the seed including the maintenance of seedlings is not optimum, then the produced quality will remain low. Therefore, an optimized maintenance of coffee seedlings in nurseries is very important, among others; fertilization, weed control, pest and disease control, as well as watering and shade intensity settings. Coffee nursery is usually carried out under the stands of shade plants which are planted one year earlier. Although seeding is done under the stands of shade plants, the level of intensity of light received by the coffee seeds does not always meet the standard requirement. This is caused by the population of shade plants grown are not in accordance with the standards of the intensity of the shade. The intensity of the shade for the coffee plant nursery is 60-75 % (PTPN XII, 2013).

Shade is needed not only because coffee seeds are not resistant to excessive sunlight flogging but also because of the root system that is not yet well developed, and is unable to absorb water in a sufficient amount to compensate for evapotranspiration. Low shade intensity often result in plant seedlings to wilt or even die. Delvian research results (2005) showed that the shade with an intensity of 25 to 75 % can improve seedling growth of cinnamon well.

The sensitivity of the coffee seeds towards light will increase due to water shortage. The provision of water in the nursery phase is done to maintain soil moisture and availability of water for the plants. Plants that lack of water can hamper its growth, either in its anatomy, morphology, physiology, and biochemistry. Low water availability can cause a decrease in evapotranspiration. According Sulistyono *et al.* (2007) the availability of ground water located between the groundwater voltage and field capacity point (0.3 bars) and permanent wilting point (15 bars).

The intensity of the shade combined with watering intervals is expected to produce optimal growth of coffee seedlings. Therefore, research is needed to determine the effect of the intensity of the shade and watering intervals. This research is also expected to obtain the parameters value of the available water fraction and the plant coefficients that can be used as a basis for making recommendations for the coffee farmers in determining the time interval of watering coffee seedlings and optimum shade intensity.

2. MATERIALS AND METHODS

This research was conducted at the experimental station of IPB Cikabayan, Dramaga, Bogor, West Java, starting in July 2013 until April 2014. Analysis of leaf thickness, stomata density, and analysis of the chlorophyll content was conducted at the Ecophysiology Laboratory, Department of Agronomy and Horticulture, Bogor Agricultural University.

The experimental design used in the study is a split plot design with a factorial treatment arrangement. The treatment consists of two factors; the intensity of the shade as the main plot, and the time interval watering as subplots. The intensity of the shade consists of 5 levels, namely 0, 25, 50, 75, and 100 %. While watering time interval consists of 4 levels, namely watering every 2, 4, 6, and 8 days. Watering is done according to the field capacity. Thus there are 20 combinations of treatment and every combination treatment was repeated three times so that there are 60 units of the experiment.

The statistical analysis used was variance analysis with split plot design. If the results of variance showed significant effect on the F test level α of 5%, then further testing will be done using *Duncan Multiple Range Test* (DMRT) at 5% level and polynomial contrast test to determine the optimum shade intensity.

A map is created to put 11 polybags of coffee seedlings with 3 polybags of coffee seedlings as a sample placed in the middle for each experimental unit. Shade making is done by using bamboo and paranet as the roof in accordance with the treatment used. Shade is made horizontally with paranet of 1.5 m high. The Polybags used are black measuring of 30 cm x 40 cm, with a thickness of 0.2 mm. At the top of the entire shade, transparent plastic is used to prevent rain water geting into the polybag. Seedling maintenance includes weeding, fertilizing as well as pest and disease control.

Watering is done until percolation. As a preventive measure from pests, diseases, and weeds, spraying is done by using fungicides, insecticides and herbicides. Fertilization is done with Urea, SP - 36 and KCl with each dose according to the age of the seedlings. At age 0 Months After Treatment (BSP) dose of 0.5 g seeds^{-1} Urea, SP36 0.25g seeds^{-1} and KCl 0.25 g seed^{-1}, 2 and 4 BSP dose of 1 g seeds^{-1} Urea, SP36 0.5 g seeds^{-1} and 0.5 g KCl seed^{-1}, as well as the age of 6 BSP dose of 2 g seeds^{-1} Urea, SP36 1 g seeds^{-1} and KCl 1 g seed^{-1} (Puslitkoka, 2006) .

Observations began when the coffee plant seedlings were aged 1 BSP and the number of samples observed 3 seed plants per experimental unit. Changes observed were the growth of plants (plant height, stem diameter, and number of leaves) per month. At the end of the experiment, the changes observed includes stomata density, leaf thickness, wet and dry weight of canopy, wet and dry roots weight, chlorophyll content and the daily evapotranspiration.

Daily evapotranspiration observations was conducted on experimental unit with the principles of the water balance. Water balance in the polybag is I = E + Pk + ΔM, I is irrigation, E = evapotranspiration , Pk = percolation and ΔM = change in soil water content. All units of the water balance is expressed in units of mm. Irrigation is measured by measuring the volume of water per unit of time. Dosing percolation is done with a dosing percolation placed at a depth of 50 cm.

3. RESULTS AND DISCUSSION

3.1. The growth response of plants towards water watering interval

The watering interval has a significant effect on the diameter of the stem at 2, 3 and 5 BSP, stomata density, wet weight of root, wet weight of canopy, total chlorophyll, daily evapotranspiration, plant coefficient and water fractions. Watering intervals of once every four days resulted in stem diameter becoming greater than the diameter of the stem at watering intervals of once every 8 days but not significantly different with watering intervals of once every 2 and 6 days at 5 BSP (Table 1).

Table 1: Response of coffee seedling stem diameter at various watering intervals

Watering interval (day time)	Age of seeds (BSP)						
	0	1	2	3	4	5	6
	.....(mm).....						
2	1.62	1.69	2.02a	2.79a	2.94	3.08a	4.04
4	1.63	1.75	1.94a	2.82a	2.91	3.26a	4.08
6	1.61	1.74	1.79b	2.66b	2.85	3.20a	3.90
8	1.58	1.68	1.77b	2.54b	2.65	2.61b	3.62

Description: The numbers followed by the same letter in the same column are not significantly different on DMRT test at the level α 5%.

3.2. Plant growth response towards the intensity of the shade

The shade intensity has a significant effect on height and diameter of the stems of the coffee seedlings at the age of 2-6 BSP, the number of leaves at the age of 1-6 BSP, the total of chlorophyll and leaf thickness, stomata density, wet and dry weight of canopy, wet and dry root weight, root length at the end of the study as well as evapotranspiration, plant coefficient and water fraction at the age of 1-6 BSP. The intensity shade of 75 % produces higher coffee seedlings, more numbers of leaves, significantly larger stem diameter than the intensity of the shade of 0, 25, 50 and 100 % at age 6 BSP (Table 2).

Table 2: The influence of shade intensity of the morphological variables Arabica coffee seedlings at 6 BSP (end of research)

Shade intensity (%)	Seed height (cm)	Number of leaves (leaf)	Stem diameter (mm)	Weight of canopy (g)		Dry weight of root (g)	Root length (cm)
				Wet	Dry		
0	13.58c	8d	2.72b	2.17c	0.65c	0.41c	13.54c
25	15.21c	14c	3.26b	1.39c	0.46c	0.33c	16.17bc
50	25.17ab	15c	4.19a	5.43b	1.86b	0.85b	19.25ab
75	27.42a	24a	4.92a	11.57a	3.16a	1.56a	24.5a
100	22.50b	18b	4.46a	7.22b	2.33ab	1.04ab	24.17a

Description: The numbers followed by the same letter in the same column are not significantly different on DMRT test at the level α 5%.

Coffee plant is a C3 plant which in the process of its growth will grow better if given shade. Giving shade has an effect on the intensity of sunlight, temperature and water availability received by the seedlings. If in the process of the coffee seedlings growth do not get shelter and has low water availability, the growth of coffee seedlings will be inhibited which will then lead to death. The temperature at the research on coffee seedlings without shade measured at sunny weather which is 38 ^{0}C, while the intensity of 75% shade temperature is 33 ^{0}C. According to Wahid *et al* (2007) high temperatures can cause damage such as the burning of leaves, branches and stem, senesen, leaf abscission, inhibition of growth, discoloration and reduction in yield. Coffee seedlings can grow optimum in temperature of 15-25 ^{0}C (Puslitkoka, 2006), though the growth of coffee seedlings at the age of 6 BSP shade intensity 75% had met the criteria of seedlings that are ready to be distributed. Criteria of coffee seedlings that is ready are seeds of at least 5 months of age, 25-30 cm plant height, leaf number at least 5 pairs of leaves, wet green leaf color, stem diameter ≥ 8 mm and free from Plant Pest Organisms (OPT) (Permentan, 2013).

3.3. The growth response of plants towards watering intervals and shade intensity

The intensity of the shade and watering intervals significantly affect the thickness of the leaf, wet weight of root, stomata density, total leaf chlorophyll, and evapotranspiration, plant coefficient and water fraction at 1-6 BSP. 100 % intensity shade and watering intervals of every 2 days produce thinner leaf thickness by 22% compared to 0 % shade intensity interval watering of every 2 days (Table 3).

The response of plants towards the shade intensity of 100 % and watering intervals of every 2 days produces thinner leaves shows the adaptation of plants towards the shade of high intensity. This is consistent with Pompelli's research *et al* (2010) that low intensity shade will cause the leaves to modify their growth so that the leaves are thicker but smaller. According to Taiz and Zeger (2002) changes in leaf anatomy becoming thicker in a low shade intensity is a quality control mechanism and the amount of light that can be utilized by chloroplasts.

The shade intensity of 0 % and every 4 days watering intervals yield in more dense stomata density 147 % compared with 100 % intensity shade and watering intervals of every 4 days (Table 3). Stomata density will affect the rate of photosynthesis. The density of stomata were higher in the condition with no shade at watering intervals of every 4 days in accordance to the research results of Morais *et al* (2004) in the conditions of lack of water and high light intensity, the plants will make modifications to the anatomy of the leaves in the form of the higher density of stomata, and the leaves become more thick. Water loss reduction mechanisms are generally implicated with reduced CO_2 fixation.

According to Sopandie (2014), the plant will demonstrate a variety of mechanisms to survive in conditions of high light intensity by means of long-term penology and morphology adaptations, short-term avoidance mechanism and the mechanisms of acclimatization such as changing the orientation of the leaves, drop in temperature through transpiration, or changes in the composition of the membrane lipids. Plants can grow optimally at high light intensity by maintaining turgor pressure of the leaf, transpiration rate, and net CO_2 exchange.

Intensity of 75 % shade and watering intervals of every 4 days yields 157 % greater wet weight of root compared to 0 % shade intensity and watering interval of every two days (Table 3). The response of plants experiencing water shortages are also indicated by a decrease in the weight of biomass root. Water needs of plants can be met in the presence of water uptake by the roots. The amount of water absorbed by the roots are very dependent on soil water content, soil particle's ability to retain water as well as the ability of the roots to absorb water (Ai *et al*., 2010). Reduced productivity (biomass) of plants during water shortage is caused by a decrease in the activity of the primary metabolism including photosynthesis and leaf area shrinkage (Solichatun *et al*., 2005).

100 % shade intensity with every 2 days watering interval resulted in 164% greater content of total of chlorophyll greater than 0% shade intensity with every 2 days watering interval (Table 3). One of the physiological responses of plants to the water shortage is a drop in chlorophyll content of the leaves which can be caused by inhibition of the formation of chlorophyll, a decrease in Rubisco enzyme, and inhibition of absorption of nutrients, particularly nitrogen and magnesium that plays an important role in the synthesis of chlorophyll (Ai and Banyo, 2011). The same thing happened on the spacial plants, namely the decrease in water content in the growing Jatropha (*Jatropha curcas* L.) from 40 to 32% decreasing the chlorophyll content up to 0.004 mg g^{-1} leaf (Syafi, 2008) .

Further test results of intensity of shade and watering intervals showed that the intensity of 0% shade with irrigation of once every 2 days generates evapotranspiration, plant coefficient and higher fraction of available water than the intensity of the shade of 25-100% with irrigation level of once every 2-8 days (Table 3). This is consistent with the Sulistyono's statement (2006), in general, the availability of high water by high levels of irrigation will lead to higher evapotranspiration. Plant coefficients depend on the nature of the plant, time of planting, growth stage and climatic conditions. The plant coefficient will affect the efficiency of water use by plants. According to Sezen *et al*. (2005), water usage efficiency is influenced by the irrigation water interval and plant coefficient. Water fraction is the proportion of water that can be absorbed by plants. According to Allen *et al*. (1998), the water fraction that is getting lower showed that irrigation is needed more frequently with the increasing age of the plant.

Table 3: Leaf thickness, stomata density, wet weight of root, total leaf chlorophyll, daily evapotranspiration, plant coefficient and water fractions in various intensities of shade and watering intervals

Watering interval (day time)	Shade intensity (%)				
	0	25	50	75	100
	Leaf thickness (mm)				
2	0.239bcdef	0.248bcd	0.210efgh	0.249bcd	0.223defg
4	0.272b	0.232cdef	0.237bcdef	0.181h	0.199gh
6	0.237cde	0.305a	0.206fgh	0.272b	0.186h
8	0.223defg	0.256bc	0.202gh	0.239bcdef	0.24cde
	Stomata density (mm^{-2})				
2	32.00cdef	35.67cde	35.67cde	26.33f	27.33ef
4	65.00a	33.67cdef	33.67cdef	30.67def	26.33f
6	45.00b	41.00bc	37.33bcd	39.33bcd	33.00cdef
8	45.00b	39.00bcd	37.67bcd	33.67cdef	41.00bc
	Wet weight of root (g $seed^{-1}$)				
2	3.57bcde	3.38bcde	5.37bcd	4.96bcde	5.41bc
4	2.92cde	2.64de	5.20bcde	9.18a	4.43bcde
6	3.00cde	2.55e	2.96cde	6.00b	4.29bcde
8	2.78cde	3.03cde	2.81cde	3.84bcde	3.81bcde
	Total leaf chlorophyll (mg g^{-1} leaf)				
2	1.45fghij	1.02ijk	2.49bcd	2.31cde	3.83a
4	2.32cde	1.61fghij	1.77efgh	3.04b	1.98def
6	1.17hijk	0.65k	2.71bc	1.87defg	1.60fghij
8	0.95jk	1.04ijk	1.57fghij	1.23ghijk	1.64fghi
	Evapotranspiration (mm day^{-1})				
2	6.95a	6.19b	3.53d	2.57ef	2.05g
4	6.73a	4.05c	3.66cd	2.63e	1.99g
6	6.76a	3.88cd	2.76e	2.44efg	1.97g
8	6.09b	3.95cd	2.61e	2.24efg	2.07g
	Plant coefficient				
2	2.48a	2.23bc	1.17d	0.86ef	0.69f
4	2.41ab	1.35d	1.22d	0.87ef	0.67f
6	2.42ab	1.29d	0.92e	0.81ef	0.66f
8	2.20c	1.32d	0.87ef	0.75ef	0.69f

	Water fraction (%)				
2	39.92a	35.39b	20.83d	15.23ef	12.16g
4	38.63a	23.97c	21.64cd	15.56ef	12.16g
6	38.79a	22.98cd	16.31e	14.48efg	11.68g
8	34.85b	23.41cd	15.46ef	13.28fg	12.26g

Description: The numbers followed by the same letter on the same variables showed no significantly different at the level 5% Duncan test.

3.4. Determination of Optimum Shade

The determination of the optimum shade requirement for the growth of coffee seedlings using common curve plant growth response towards the intensity of the shade. The determination of optimum shade is done by lowering the regression equation variable response curves that were patterned quadratic growth in the intensity of the shade. Shade intensity has significant quadratic effects towards the number of leaves of coffee seedlings at the age of 1 BSP, leaf thickness, stomata density, wet weight of canopy, wet and dry roots weight. The quadratic relationship of shade intensity pattern towards the number of leaves at age 1 BSP is illustrated with line equation Y = -0.00006 x2 + 0.0116x + 2.1414 with R2 which is 37.44% (Figure 1a). The quadratic relationship of shade intensity pattern to coffee leaf thickness is indicated by line equation Y = 0.000004x2 - 0.0005x + 0.2377 with R2 33.49% (Figure 1b), while the relationship of shade intensity to the stomata density is described by the line equation Y = 0.0089x2 - 1.5962x + R2 234.43 with 95.6% (Figure 2a). Quadratic relationship shade intensity pattern to wet weight of canopy is indicated by line equation Y = -0.0006x2 0.1387x + R2 + 0.78 by 63.36% (Figure 2b), while the intensity of the shade to the wet weight of root is indicated by line equation Y = -0.0007x2 + 0.1102x + 2.0497 with R2 35.91% (Figure 3a) and the intensity of the shade to the dry root weight is indicated by the equation Y = -0.00008x2 + 0.0178x + 0.2414 with R2 65.17% (Figure 3b). The optimum shade intensity is 76.59% or 77%.

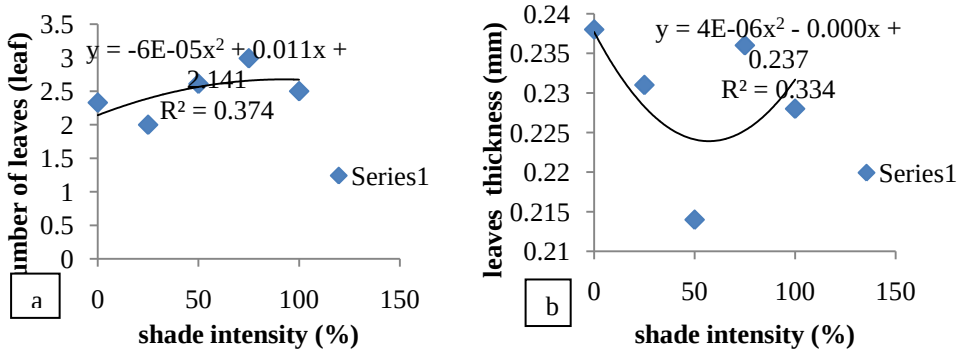

Figure 1. The pattern of the relations between shade intensity with the number of leaves (a), shade intensity with leaves thickness (b)

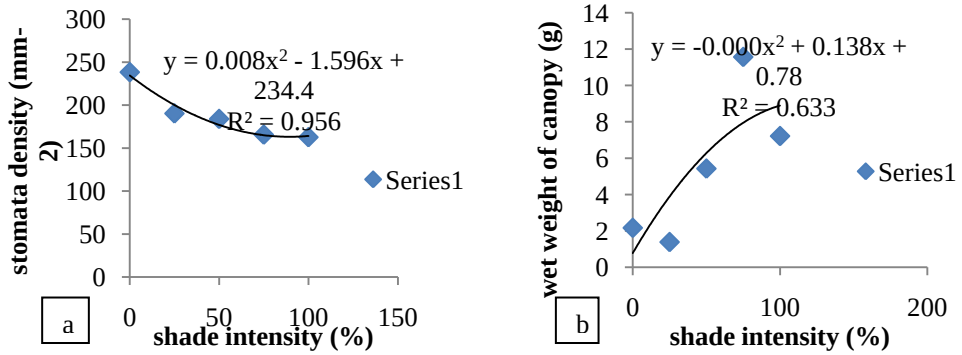

Figure 2. The pattern of the relations between shade intensity with stomata density (a), shade intensity with wet weight of canopy (b)

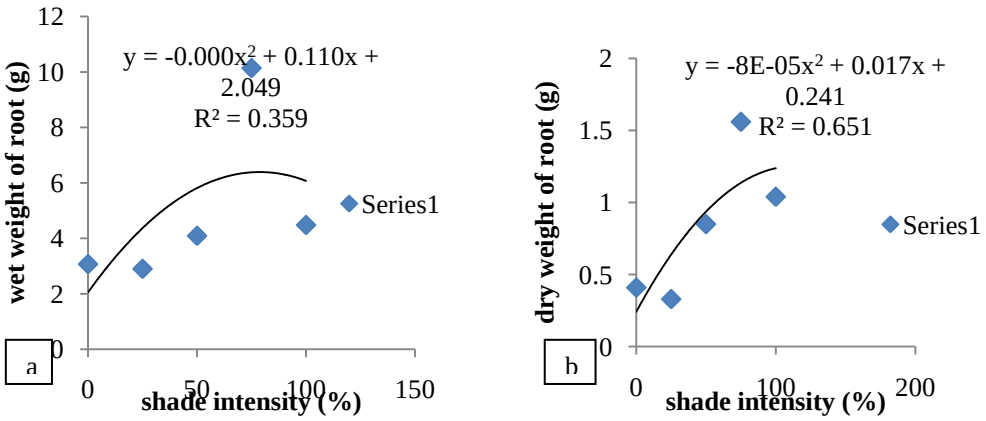

Figure 3. The pattern of the relations between shade intensity with wet weight of root (a), shade intensity with dry weight of root (b)

4. CONCLUSION

The shade intensity and watering intervals significantly affect leaf thickness, stomata density, chlorophyll analysis, wet weight of root, evapotranspiration, plant coefficient and fraction of available water. Combination of treatments that produce the best coffee seedling growth is the shade intensity of 75 % with water watering intervals of once every 4 days with a fraction of the value of available water that can be absorbed by 15.56 % and the plant coefficient is 0.87. The optimum shade intensity for coffee seedling growth is 76.59 % or 77 %.

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