Physiology Response of Soybean Variety to Various Types of Shading in Agroforestry System

Muhammad Rizwan[1], Abdul Rauf[2], Rahmawaty[3], Erwin Nyak Akub[2]
[1]*Doctoral Student in Agricultural Science, Sumatera Utara University*
[1]*Department of Agrotechnology, University Islamic Sumatera Utara*
[2]*Agricultural Science, Sumatera Utara University*
[3]*Faculty of Forestry, Sumatera Utara University*

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Abstract: In mixed cropping patterns as in agroforestry systems, competition between crops and trees will occur. It willspecifically occur for nutrient absorption and light for photosynthetic process, which often has a negative impact on crop productivity. Field trial approach was used to examine adaptation of soybean varieties to shade in each tree, namely: rubber, *mindi*, white teak, *jabon*, *sentang*. The test is done with a Split plot design. The main plot is type of shading while subplots are soybean varieties. Treatment composition in the first experiment on each factor (main plot and subplot) and type of plant is consisted of: Main plot: P1 = Rubber shading, P2 = Mindi shading, P3 = *Jabon*shading, P4 = White Teak shading. Subplot: V1 = *Anjasmoro* variety; V2 = *Burangrang*variety, V3 = Dena-1 variety, V4 = Dena-2variety. The finding of the research were: 1) Shading as the main plot have very significant effect on plant high except at 3 weeks after planting (MST), has very significant effect on flowering age of soybean; 2) The effect of shading types on leaf chlorophyll parameters, both in the leaf tip, middle leaf, base leaf and total chlorophyll is identical. *Mindi, Jabon* and white teak stands did not have significant effect each other, but all three stands affect the chlorophyll content of soybean leaves compared to rubber stands, where the levels of soy chlorophyll under this stand were the lowest.

1 INTRODUCTION

Indonesia has around 148 million ha (78%) dry land and around 40.20 million ha wet lands (22%) of 188.20 million ha of total land area. However, suitable land for agricultural purpose is only 76.22 million ha (52%) and most of such land is located in lowlands (70.71 million ha or 93%) and the rest is in highlands. In lowland areas, flat to wavy land (slope <15%) that suitable for crop farming covers 23.26 million ha while on more sloping land (15−30%) is 47.45 million ha. In highlands, suitable land for crops is only about 2.07 million ha and annual crops are 3.44 million ha. Most of the dry land is scattered in lowlands, namely area at an altitude of 0 - 700 m above sea level (60.65%) and highlands located at an altitude > 700 m above sea level (39.35%) (Hidayat and Mulyani, 2002; Adimihardja et al. 2005; Notohadiprawiro, 2006; Minardi, 2009).

Crops commodities development can also be carried out on forestry land with technical requirements and applicable policies. Forest area in Indonesia reaches 180 million hectares, but most of the area has experienced deforestation (forest damage) due to ex-HPH (forest tenure rights) areas. Of the total forest area in Indonesia, only 23 percent or equivalent to 43 million hectares is still free from deforestation, still maintained and as primary forests (BPS Kehutanan, 2010). Forest areas and/or land overgrown with trees, both forest and industrial trees and fruits, are still widely available, especially in residential areas and buffer zones as well as forest areas. Inter-cropping areas is needed for land use efficiency.

One of alternative for sustainable agricultural development is to develop agroforestry systems. Agroforestry is defined broadly as a farming or land use system that integrates spatially and temporally both tree and annual crops on an area. Agroforestry is a type of land use that can maintain and increase land productivity as a wholethat is a mixed activity between forestry and agricultural activities, either

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jointly or in rotation, which is adjusted to cultivation patterns of local communities (King and Chandler,1978;Wijayanto, 2002). Dry land management, especially in watersheds, with agroforestry systems is very necessary as a strategic development resource, including: 1) dry land is the largest cultivation area, 2) dry land can supply most of the major commodities, and 3) dry land has diverse commodities for agro-industry development (Widaningsih, 1991; Suhara, 1991; Badrun, 1998).

In general, there are many obstacles in developing agroforestry, among other low productivity, due to lack of knowledge in the selection of plant species and cropping patterns management. According to Beets (Beets,1982), in mixed cropping patterns as in agroforestry systems, competition between crops and trees will occur, especially for nutrient absorption, which often has a negative impact on crop productivity. For this reason, selection of plant species and cropping patterns management in agroforestry must consider physical, socio-economic, existing opportunities, and farmer’s involvement in design and assessment of cropping patterns to expedite the technology adoption process. According to Thakur et al. (Thakur et al.2005), farmers should choose annual crops that have high economic value (cash crops), food crops, medicines, herbs and even animal feed. In addition, low productivity can also be caused by radiation intensity stress due to canopy closure. Several studies on ecophysiology of shading have been carried out on upland rice (Chozin et al. 2000), soybean (Sopandie et al. 2007), taro (Djukri, 2003) and pepper (Wahid, 1984). The research shows that the impact of light intensity stress is disruption of photosynthesis rate which decrease plant metabolic processes.

Intercropping is possible especially for food crops such as sweet potatoes, corn, soybeans, and upland rice, and horticultural crops such as vegetables, flowers and fruits, as well as medicinal plants such as turmeric, galangal, galingale, etc. According to Asanawi and Ratna (Asanawi and Ratna,2010), land use efficiency through intercroping is very likely to be carried out as long as fulfill plant growing requirements.

One of the cash crop commodities that require intensive and important development is soybeans. Soybeans have important role as source of vegetable protein to improve nutritional level of the community (Jufri, 2006). However, the community's soybean needs cannot be fully met. Soybeans supply tends to decrease in the period 2003-2007 (PDSIP Ministry of Agriculture, 2016). In this period, the availability rate decreased by an average of 3.37% on annually basis. In the following year, it increased again until 2011 to be 10.91 kg/capita/year or an increase of 11.78% compared to the previous year of 9.76 kg/capita/ ear. The decline in availability was occurred again in 2012, and continuing to 2014.

National strategy to increase soybean production is formulated in the Source of Production Growth which consists of five opportunities, namely: a) expansion of harvest area, b) increasing productivity, c) increasing yield uniformity and stability, d) emphasis on yield gaps, and e) emphasis on yield loss. In this strategy, increasing harvested area is carried out by new land clearing, increasing cropping index (IP), and soybean intercropping with plantation and forestry crops (Adisarwanto et.al. 1997). However, efforts to increase production have constrained by decreasing harvested area. In 2012-2016, the average national harvest area decreases to 1.68% (PDSIP Ministry of Agriculture. 2016). Therefore, research has been carried out to obtain the best fertilizing dose for inter-cropping soybeans grown along with forest tree.

2 METHODOLOGY

This research has been carried out in Arboretum of USU KwalaBekala from January to December 2015. Field trial approach was used to examine adaptation of soybean varieties to shade in each tree, namely: rubber, *mindi*, white teak, *jabon, sentang*. The test is done with a Split plot design. The main plot is stands while subplots are soybean varieties.

Treatment composition in the first experiment on each factor (main plot and subplot) and type of plant is consisted of: Main plot: P1 = Rubber shading, P2 = Mindi shading, P3 = *Jabon*shading, P4 = White Teak shading. Subplot: V1 = *Anjasmoro* variety; V2 = *Burangrang* variety, V3 = Dena-1 variety, V4 = Dena-2variety.

The linear additive model of the plan is used as follows:

$$Y_{ij} = \mu + K_l + A_i + Y_{il} + B_j + (AB)_{ij} + \delta_{ijl} \quad (1)$$

Y_{ijk} = the observational response of the experimental unit that receive the Shading factors, and j is the observational response of the experimental unit that receive the treatment on variety of soybean.

μ = general average

A_i = the effect of the i-shading

β_j = influence of the j-Variety of soybean

$(AB)_{ij}$ = the interaction effect of shading and variety of soybean
ε_{ijk} = random effects of the i-shading and the j-group

The data that obtained are analyzed by variance in the level α = 0.05.If there is a significant effect, then followed by the test of LSD for each treatment group, the data analysis is performed with Microsoft Office Excel program.

2.1 Observation

Observations were made on all intercrops and main crops, which include growth, yield and production of intercrops. The data was analyzed by analysis of variance and then means difference will be tested with Least Significant Differences test.

Observations made include the phase of plant growth. Observation of the vegetative phase was carried out by observing plant growth in each experimental unit. Observations were carried out on 10 sample plants in each experimental unit. The variables observed are as follows:

1. Plant height, observed once a week since 3 weeks after planting to flowering using meter
2. Flowering age (days), observed the first flower formation
3. Leaf chlorophyll content

3 RESULT AND DISCUSSION

3.1. Effect of Shading

3.1.1 Growth Parameters

Shading as the main plot have very significant effect on plant high except at 3 weeks after planting (MST), has very significant effect on flowering age of soybean (Table 1).

At 6 and 9 MST, the highest plant height found in *Jabon* shading followed by Mindi, compared to other stands. Both types of shading has significant effect on plant height than Rubber and White teak stand.

Board (Board,2000) states that in vegetative growth, light quality and quantity can affect the length, stem diameter and stem density of soybean. Without considering photosynthesis, these two factors affect plant development and morphology, known as photomorphogenesis. For example, in the same photosynthetic capacity, stem part that receives more light will experience shorter elongation.

Table 1: Effect of shading types on soybean growth.

Shading Type	Plant High (cm)			Flowering (DAP)
	3 MST	6 MST	9 MST	
Rubber (T1)	22,35	33,34^{b}	48,30^{a}	72,59^{b}
Mindi (T2)	23,68	36,49^{c}	53,42^{b}	47,57^{a}
Jabon (T3)	23,41	38,16^{d}	54,81^{b}	72,88^{b}
White Teak (T4)	23,89	29,05^{a}	46,71^{a}	83,43^{c}
LSD 5%		2,26	4,82	6,22

Note: numbers followed by the same letter in the same column are not significant different in the 5% LSD test.

Light quality is determined by the ratio between red light (R) and far red (FR) and blue light radiation which in this case also affects the process of elongation. This is due to etiolation process that occurs during the stem elongation. It is suspected that etiolation process that occur in shaded plants is a way to capture light more efficiently. According to Chairuddin etal. (Chairuddin etal.2015), increasing plant height is an attempt to increase light absorption because the plants are not able to raise the leaves above the canopy.

With respect to production parameters, shading has very significant effect on flowering age of soybean. Soybean under Mindi shading (T2) show faster flowering than other shading, on the other hand, soybeans under white teak shading are the slowest. Ballare (Ballare,1999), Morelli and Ruberti (Morelli and Ruberti,2002), and Handayani (Handayani,2003) stated that shading triggers morphological and anatomical changes such as stimulating hypocotyl growth and petiole lengths, decreasing and developing leaves, reduce branching, flowering acceleration and reduce reserves for storage and reproduction. As a result, soybeans under shading become more mature. Karamoy (Karamoy,2009) stated that soybean grown in low light conditions generally have faster flowering age. Flowering process occurs due to presence of easily soluble proteins (phytochrome). High light intensity converts pigment into a form that initiates flowering induction.

Such different result is thought due to differences in shading intensity and microclimate conditions such as air temperature and humidity at the study site. According to Susanto and Adie (2006), differences in climate and elevation have different affect in plant life.

3.1.2 Physiology Parameters

In general, shading as the main plot and varieties as subplots has different effects on physiological responses (Table 2).

The effect of shading types (Table 2) on leaf chlorophyll parameters, both in the leaf tip, middle leaf, base leaf and total chlorophyll is identical. *Mindi, Jabon* and white teak stands did not have significant effect each other, but all three stands affect the chlorophyll content of soybean leaves compared to rubber stands, where the levels of soy chlorophyll under this stand were the lowest.

Table 2: Effect of shading types on chlorophyll content of soybean leaves (unit / mm2).

Variable	Shading (T)				LSD
	Rubber (T1)	Mindi (T2)	Jabon (T3)	White Teak (T4)	
Leaf tip chlorophyll	31,16^{a}	35,65^{b}	35,69^{b}	34,34^{b}	2,04
Middle leaf chlorophyll	27,89^{a}	35,91^{b}	35,53^{b}	33,88^{b}	2,59
Base lea chlorophyll	26,42^{a}	32,74^{b}	35,38^{b}	33,58^{b}	4,11
Total chlorophyll	85,47^{a}	104,30^{b}	106,61^{b}	100,04^{b}	8,80

Note: numbers followed by the same letter in the same column are not significant different in the 5% LSD test.

Plant adjustments to low radiation are characterized by enlarged antennas for photosystem II. The enlargement of the antenna for photosystem II will increase the efficiency of light harvesting (Hidema et al. 1992). Kisman (Kisman,2008) stated tht chlorophyll *a* content is affected by light factors, plastid inhibitors, and interactions between light and inhibitors. While the content of chlorophyll b and hypocotyl length is only influenced by light factors. This shows that light factor has very dominant role for chlorophyll content and hypocotyl length at early growth of soybean. In soybean, leaves photosynthetic character such as chlorophyll content, ratio of chlorophyll a/b, and leaf area are important characteristics for adaptation to shade (Khumaida, 2002;Handayani, 2003;Jufri, 2006).

3.2 Effect of Varieties

3.2.1 Growth Parameters

Varieties have significant effect on plant height at all observation time, namely 3 MST, 6 MST, and 9 MST (Table 3). The effect of different varieties varies each week. The more age of soybeans is the wider the difference in height for each variety.

Dena-1 variety has the lowest height, while *anjasmoro* is the highest genotype. At 9 MST, plant height of *Anjasmoro, Burangrang*, Dena-1, and Dena-2 were 56.06 cm, 53.38 cm, 46.61 cm and 47.19 cm respectively. According to Balitkabi, (Balitkabi,2012), plant height description of *Anjasmoro, Burangrang*, Dena-1 and Dena-2 are ± 64-68 cm, ± 60-70 cm, ± 59 cm, and ± 40 respectively. The results of this study are close to the description range of each variety, even the Dena-2 variety has exceeding the description. This shows that such variety has an adaptation mechanism in shaded conditions by increasing plant height. Williams et al. (Williams et al.1976) stated that reduced light received by plants will reduce root growth, and plants exhibit etiolation symptoms by increasing stem length at low light intensity. Elfarisna (Elfarisna,2000) states that heavy shading conditions (shade level50%) can increase plant height, leaf area, and the amount of chlorophyll of soybean, but reduce the number of branches, leaf thickness, stomata density, filled pods, empty pods, seed size and seeds weight per plant.

Table 3: Effect of varieties on soybean growth.

Varieties	Plant Height (cm)			flowering (DAP)
	3 MST	6 MST	9 MST	
Anjasmoro(V1)	23,89^{b}	36,38^{b}	56,06^{b}	72,37
Burangrang(V2)	24,46^{b}	36,59^{b}	53,38^{b}	71,56
Dena-1 (V3)	21,88^{a}	31,81^{a}	46,61^{a}	67,13
Dena-2 (V4)	23,10^{ab}	32,27^{a}	47,19^{a}	65,42
LSD 5%	1,51	2,20	3,22	4,07

Note: numbers followed by the same letter in the same column are not significant different in the 5% LSD test.

Each variety has different flowering age. The fastest flowering ages are Dena-2, Dena-1, *Burangrang,* and *Anjasmoro*, namely 65.42 DAP (days after planting), 67.13 DAP, 71.56 DAP and 72.37 DAPrespectively. When compared with flowering age description of each variety from Balitkabi (2012), the results indicate that there is a delay in flowering. Based on varieties description, flowering ages for Dena-2, Dena-1, *Burangrang*, and *Anjasmoro* are 35 days, 33 days, 35 days and 35-39 days respectively. This means that under shaded conditions, all varieties experience delayed flowering 2 times than normal flowering period. Difference in flowering age of various varieties is related to genetic diversity factors. Similar results were also reported by Soverda et al. (2012) which states that flowering age character of several soybean genotypes is different.

3.2.2 Physiology Parameters

There is a significant difference of leaf chlorophyll parameters among four varieties tested in the adaptation mechanism to shade (Table 4).

Table 4. Effect of varieties on chlorophyll content of soybean leaves (unit / mm2).

Variables	Varieties (V)				LSD
	Anjasmoro(V1)	*Burangrang*(V2)	Dena-1 (V3)	Dena-2 (V4)	
Tip chlorophyll	34,08^{ab}	32,65^{a}	34,80^{b}	35,31^{b}	1,45
Midle leaf chlorophyll	33,17^{ab}	32,03^{a}	34,45^{b}	33,57^{b}	1,39
Base leaf chlorophyll	32,63^{a}	31,05^{a}	32,99^{a}	31,45^{a}	2,11
Total chlorophyll	99,51^{b}	94,53^{a}	102,05^{b}	100,33^{b}	4,48

Note: numbers followed by the same letter in the same column are not significant different in the 5% LSD test.

One important strategy in improving the efficiency of light use as an energy source is increasing of leaf chlorophyll levels. Table 4 shows that Dena-1 and Dena-2 have the highest chlorophyll content compared to other varieties. Higher increased chlorophyll in Dena varieties compared to other varieties shows that this variety is more effective in capturing limited light in shaded environments. The higher Chlorophyll content in shaded conditions is more optimal growth and production potential, because 50% of light energy can be transferred to the reaction centre through chlorophyll (Croce et al. 2001). This is confirmed by DjukriandPurwoko(DjukriandPurwoko,2003); Soepandi (Soepandi,2013);Chairudin etal (Chairudin etal.2015) that stated leaves formed at low light intensity show an increase in the amount of chlorophyll and contain chlorophyll a and b per unit volume of chloroplast four to five times more and have lower chlorophyll a/b ratio and decreasing non-chloroplast pigment content such as anthocyanin compared to full light because it has increased light harvesting complex which increases light capture efficiency for photosynthesis.

In high light intensity, the presence of photons is abundant, thus affecting leaves ability to process the light. In full light conditions, leaves ability to process light must be greater than in low light, consequently optimization of leaf function is more to harvest light than to process energy (Atwell etal. 1999).

4 CONCLUSIONS

Tolerant Soybean (Dena-1 and Dena-2) and sensitive soybeans (*Anjasmoro* and *Burangrang*) has made adaptations to low light intensity under tree stands (shading) by improve light capture capability and use. Such adaptation is through anatomical-physiological changes such as plant height, chlorophyll content and flowering.

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