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A Study of Negative Leaf Defoliation and Plant Population Density on Total Dry Matter Production and Yield in Soybean

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Abstract: ***Objectives of this research were to determine negative leaf defoliation and proper plant population density in order to increase productivity of the soybean. The research was conducted from June – August 2013 at the experiment field in Faculty of Agriculture, Brawijaya University. This research applied Split Plots Design in randomized complete block with three replications. Plant population as main plot in row spacing included J1= 20 x 15 cm (666,666 plant ha^{-1}), J2= 30 x 15 cm (444,444 plant ha^{-1}), J3= 40 x 15 cm (333,332 plant ha^{-1}), J4= 50 x 15 cm (266,666 plant ha^{-1}); and negative leaf defoliation (D) was placed as sub plot that included D0 = without defoliation, D1 = Defoliation of 2 trifoliate leaves at the bottom part, D2 = Defoliation of 4 trifoliate leaves at the bottom part. The harvest yield per area unit increases along with the increasing population of the plants. Treatment of low population of plants (266,666 plants ha^{-1}) has increased the harvest yield 22.75% in comparison with high population of the plants (666,666 plants ha^{-1}). Such defoliation of 4 trifoliate at the bottom part will increase the production as it compares with 2 trifoliate defoliations and without defoliation.***

Keywords: soybean, plant population, defoliation, negative leaf.

1. Introduction

High demand of soybean (*Glycine max* (L.) Merril) in Indonesia has not been able to be fulfilled by domestic production, therefore the domestic demand can only be fulfilled through import. This is due to national productivity of soybean has still lower ± 1.4 ton ha^{-1}. In 2012, total domestic production of soybean was 0.84 million ton and the imported soybean reached 2.4 million ton [2], [7].

The soybean productivity is affected by technical culture and agriclimate. One of the technical culture factors is planting space arrangement, which has close relation to population density of the plant in order to provide better growing space for individual plant. Denser population of the plant will make the plant's canopies shade to each other and it leads to competition in capturing the sun radiant. Lower yield during the harvest was caused by more negative leaves. Result of the research by Khorasani *et al*. [6] showed that defoliation 1/3 leaves at the bottom parts of the plant gave higher yield for about 587.50 kg ha^{-1} in comparison with defoliation of leaf at the top parts for about 514.06 kg ha^{-1}. The soybean plant have horizontal leaf canopy, therefore utilization of the radiant energy is not efficient. More downward, leaves growing in the shade is sunflecks, patches of full sunlight that pass through discontinuities of the canopy and travel along the shaded leaves as the sun moves. Leaves that are shaded by other leaves have much lower photosynthetic [11]. The lower the leaf, the lower intensity of light interception is, as well as reduced photosynthetic rate. Leaves at the bottom part of the plant are so-called negative leaves because they require carbohydrate, which is taken from leaves at the upper part, in order to keep alive and of course, they inflict and harm the main plant [10]. Therefore, in order to have maximum productivity, such negative leaves should be removed by manipulating the growth through defoliation. Leaf defoliation is an effort to manipulate the physiological function in absorbing light in order to increase the photosynthetic rate of the main leaves [4].

A research on negative leaf defoliation and plant population density has been conducted separately in soybean, but few research about combination between defoliation and plant population arrangement have been reported. Therefore, it is expected that such combination will be able to increase productivity of the soybean plant. Objectives of this research were to determine negative leaf defoliation and proper plant population density in order to increase productivity of the soybean. The proposed hypothesis in this research was negative leaf defoliation along with dense population of the plants could increase productivity of the soybean.

2. Materials and Methods

The research was conducted from June – August 2013 at the experiment field in Faculty of Agriculture, Brawijaya University. Equipments used in this research include analytic scales, oven, Luxmeter, Leaf Area Meter (LAM), chlorophyl meter Minolta SPAD (Soil Plant Analysis Development) 502 and knapsack sprayer. Materials of the research include soybean seeds of *Anjasmoro* variety, Carbofurane, Urea (46% N) 50 kg ha^{-1}, SP-36 (36% P_2O_5) 100 kg ha^{-1}, and KCl (60% K_2O) 50 kg ha^{-1} and pesticide. This research applied Split Plots Design (SPD) in randomized complete block with three replications. Plant population as main plot in row spacing included J1= 20 x 15 cm (666,666 plant ha^{-1}), J2= 30 x 15 cm (444,444 plant ha^{-1}), J3= 40 x 15 cm (333,332 plant ha^{-1}), J4= 50 x 15 cm (266,666 plant ha^{-1}); and negative

leaf defoliation (D) was placed as sub plot that included D0 = without defoliation, D1 = Defoliation of 2 trifoliate leaves at the bottom part, D2 = Defoliation of 4 trifoliate leaves at the bottom part. Defoliation was done at 35 dap, due to the plant has maximum vegetative growth at that time. Observation on the plant growth was done at the age of 40 to 70 days after planting (dap) and during the harvest time (85 dap). Observation on the plant growth included total dry matter of the plant, leaf area index (LAI), interception efficiency (IE), chlorophyll index and specific leaf area (SLA). For observation on yield component, it was done at 85 dap, which included numbers of pod per plant, numbers of seed per plant, weight of seed per plant, yield of seeds (ton ha^{-1}) and the harvest index. The obtained data was analyzed using analysis of variance (F-test) in 5% level. If result of the testing showed significant difference, it will be followed by comparative test among treatments by using the Least Significant Difference (LSD) in 5% level.

3. Result and Discussion

3.1 Leaf area index and Interception Efficiency

Results of the research due to the influence of plant density and trifoliate leaf defoliation have significant influence on leaf area index (LAI) in level 5% (Table 1). Treatment of plant population density has affected on each age of observation. Maximum LAI occurred at 60 dap (days after planting) and had the highest value of 2.46 on high population (666,666 plants ha^{-1}) and had significant value along with LAI on low population (266,666 plants ha^{-1}). The result meant that LAI increased along with the increasing population. LAI > 1 described mutual shade among leaves, which caused the sheltered leaves below the canopy could not capture the radiant completely, therefore the photosynthetic rate is lower than the unsheltered leaves [1].

Table 1: Mean of leaf area index due to the influence of plant density and trifoliate leaf defoliation

Treatment	*Mean leaf area index at the age of observation (dap)*			
	40	50	60	70
Population density (plant per ha):				
666,666	1.63 b	2.25 b	2.46 c	2.31 b
444,444	1.32	1.57 a	1.73 b	1.45 a
333,332	1.07 a	1.18 a	1.30 a	1.05 a
266,666	0.82 a	1.09 a	1.15 a	0.87 a
LSD 5%	0.5	0.57	0.37	0.45
Trifoliate defoliation				
0	1.3	1.66 b	1.78	1.5
2	1.2	1.54 ab	1.65	1.37
4	1.13	1.37 a	1.55	1.45
LSD 5%	ns	0.26	ns	ns

Notes: Similar letters in each column show non-significant difference, according to LSD tests at the 5 % level; ns = non-significant; dap = days after planting.

The significant influence of trifoliate leaf defoliation on LAI was seen at 50 dap. Result of the observation showed that high LAI was found on treatment without defoliation for about 1.66 and had significant difference by treatment of 4 trifoliate defoliation. The result meant that soybean without defoliation has higher LAI than soybean, which has trifoliate defoliation. This was due to treatment without defoliation has higher LAI as having higher leaf area and more numbers of leaves in comparison with treatment by trifoliate defoliation. LAI relates to interception efficiency. The increasing LAI will increase the interception efficiency. Data of the interception efficiency has increased along with the increasing age of the plant (data not shown).

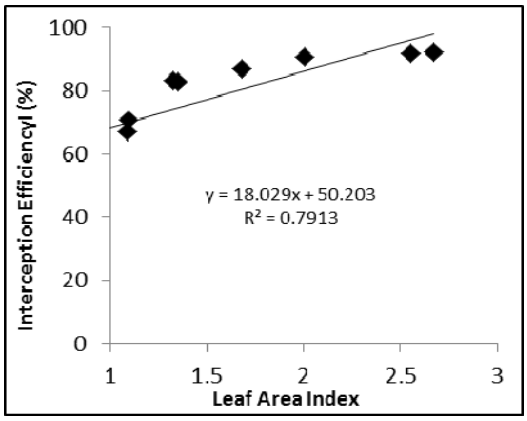

Figure 1: Relation between LAI and Interception Efficiency

Result of the regression analysis showed that 79.13% variance of interception efficiency was affected by leaf area index (Figure 1). Higher leaf area index will increase the interception efficiency. Plant that having high LAI has multi-layered leaves, so that the intercepted radiant on the upper canopy would be transferred to the lower leaves, and so forth. Plants that having dense population and without defoliation, have high LAI value and high radiant interception, but it doesn't mean that the plants would be more efficient in utilizing the radiant.

3.2 SLA and Chlorophyll Index (SPAD value)

Result of the research due to the effect of plant density and trifoliate defoliation has significant influence on chlorophyll index (SPAD value) in 5% level (Table 2). Treatment on plant population density has its effect at 60 dap. Treatment of population density of 333,333 plants ha^{-1} has high chlorophyll index, 41.57, and has significant difference by the treatment of population density 666,666 plants ha^{-1}. It means that the chlorophyll keeps decreasing by the increasing population of the plants. The significant influence of the trifoliate defoliation treatment on chlorophyll of the leaf was at 50 - 60 dap. Result of the observation showed that 2 trifoliate defoliation treatments has high chlorophyll for about 42.05 and 41.82 and has significant difference by the treatment without trifoliate defoliation. The result means that the plant, which having trifoliate defoliation, has higher chlorophyll level than without defoliation. The chlorophyll level relates to specific leaf area (SLA). The data shows that SLA increases along with the increasing aged of the plant (data not shown).

Table 2: Mean of chlorophyll index due to the effect of plant density and trifoliate defoliation

Treatment	*Mean chlorophyll index (SPAD value) at the age of observation (dap)*			
	40	50	60	70
Population density (plant per ha):				
666,666	38.92	40.92	40.37 a	31.24
444,444	40.71	40.88	40.82 ab	31.41
333,332	41.02	41.19	41.57 b	28.01
266,666	41.67	41.41	41.44 b	30.03
LSD 5%	ns	ns	0.9	ns
Trifoliate defoliation				
0	39.17 a	39.23 a	39.75 a	30.74
2	41.27 b	42.05 b	41.82 b	29.94
4	41.30 ab	41.94 b	41.58 b	29.83
LSD 5%	3	1.81	1.8	ns

Notes: Similar letters in each column show non-significant difference, according to LSD tests at the 5 % level; ns = non-significant; dap = days after planting.

Tendency of the increasing LAI and SLA, under the treatment of high population density and without trifoliate defoliation, has reduced the chlorophyll index. It occurs due to the leaf has high SLA value, which means that the leaf is thin and the chlorophyll is low. The leaves become thin due to the leaves shade to each other, therefore, the lower leaves have less radiant interception and of course, it would reduce the chlorophyll level.

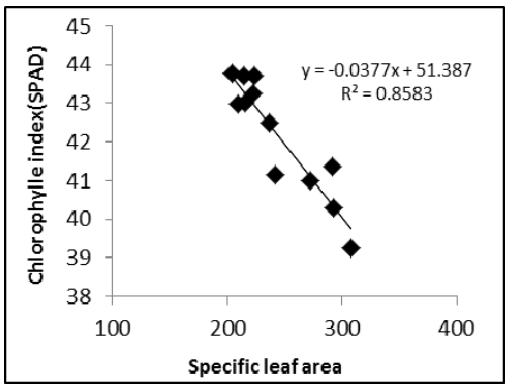

Figure 2: Relation between SLA and Chlorophyll Index

Chlorophyll relates to specific leaf area value. Result of the regression analysis showed that 85.8% variance of chlorophyll has been affected by specific leaf area (Figure 2). The higher value of the specific leaf area, it will reduce the chlorophyll level. Higher SLA shows that the leaf is thin and has low chlorophyll content.

3.3 Total Dry Matter

Result of the research due to the effect of plant density and trifoliate defoliation has significant influence on total dry matter of the plant in 5% level (Table 3). Table 3 presents that total dry matter of plant, under the treatment of row spacing and trifoliate defoliation, has increased along with the increasing aged of the plant. Result of the observation showed that at 40 – 60 dap, higher total dry matter of the plant was on lower population treatment and it has significant difference with higher population. Total dry matter of the plant will reduce along with denser population of the plants.

Table 3: Mean of total dry matter of plant due to the influence of plant density and trifoliate leaf defoliation

Treatment	*Mean of total dry matter (g) at the age of observation (dap)*			
	40	50	60	70
Population density (plant per ha):				
666,666	5.34 a	7.46 a	10.92 a	16.14
444,444	6.57 ab	7.47 a	11.37 a	17.25
333,332	6.28 ab	7.48 a	11.74 a	17.12
266,666	7.16 b	9.03 b	12.89 b	17.96
LSD 5%	1.53	1.42	1.74	ns
Trifoliate defoliation :				
0	6.80	7.90	11.28	15.48 a
2	5.93	7.85	12.08	17.27 ab
4	6.20	7.80	11.83	18.60 b
LSD 5%	ns	ns	ns	1,97

Notes: Similar letters in each column show non-significant difference, according to LSD tests at the 5 % level; ns = non-significant; dap = days after planting.

Defoliation affected at the end of observation, 70 dap, in which the plant that having trifoliate defoliation showed higher total dry matter in comparison with the plant without defoliation. This was due to the remaining leaves become the essential part in photosynthetic activity, so that the resulted carbohydrate can be stored in the generative parts (pod and seed). Result of the research by Mondal *et al.* [8] showed that 25% defoliation of leaves at the lower part of mungbean have higher yield for total dry matter of the plant than the control treatment. After defoliation, when the bottom leaf stories were removed, the top-story leaves started supplying assimilates downward to defoliate inter node and the grape brunch [5].

3.4 Distribution of biomass in trifoliate defoliation treatment

Distribution of biomass is important in determining final yield of the plants. The amount of biomass resulted by the plants can be measured indirectly by measuring dry weight as final yield of assimilate accumulation in an organ. In this research, trifoliate defoliation is done by removing lower leaves so that the remaining upper leaves will become the essential part in photosynthesis, which is so-called source.

Result of the research showed that at the end of observation, 70 dap (Figure 3), for 4 trifoliate defoliation treatment has allocated 55% of total biomass to pod (sink), 26% to stem, and 19% to leaf. Meanwhile, distribution of biomass for 2 trifoliate defoliation treatments has allocated 52% to pod, 28% to stem, and 20% to leaf. For control treatment (without defoliation), it has allocated 47% to pod, 31% to stem, and 22% to leaf. It can be seen that plant, in which the lower leaves have been removed, produces more pods and they will determine the final yield. In accordance with research by Mondal *et al.* [8], which showed that 25% defoliation of leaves at the lower part of mungbean have pod weight per plant, 100 seeds weight, and higher seed yield per plant in

comparison with the control treatment and 50% defoliation of the lower leaves.

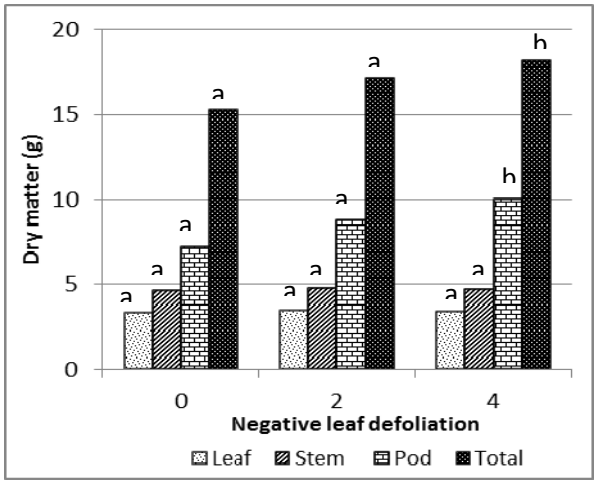

Figure 3: Distribution of biomass on trifoliate defoliation treatment at the age of 70 dap

3.5 Yield component

Result of the observation on yield component of the harvest yield showed no significant interaction between population arrangement and trifoliate defoliation (Table 4). Table 4 shows that low population (266,666 plants ha^{-1}) have numbers of filled pod per plant, numbers of seed per plant, and high seed weight per plant and have significant difference with high population treatment (666,666 plants ha^{-1}). The yield of harvest relates to numbers of seed and seed weight per plant, even in dense spacing results lower yield per plant but the yield per hectare during harvest time increases due to greater numbers of population than in distantly spacing. Population in distantly spacing has higher values for SLA and chlorophyll index; therefore photosynthetic process will be optimal. Different numbers of filled pod, seeds per plant, and seed weight per plant due to dense population are caused by competition among plants. Competition among individual plant in high population could be caused by some factors, such as light, nutrients, and water that could reduce the pod development in soybean of Enrei cultivar [12]. In low population, competition among plants is low and, of course, each plant will be able to produce more seeds [9].

Numbers of the filled pod per plant, numbers of seed per plant and seed weight per plant have increased along with the increasing defoliated leaves. Higher yield at the harvest time is as a result of 4 trifoliate defoliation treatments and has significant difference with trifoliate leaf without defoliation. Numbers of filled pod per plant, numbers of seed per plant, and seed weight per plant are found in 4 trifoliate defoliation treatments. It shows that the soybean yield will be higher by the increasing numbers of seed per plant and seed weight per plant. The increasing yield, as a result of 4 trifoliate defoliation, is due to each plant has low SLA value (thick leaf) and high chlorophyll level.

Table 4: Mean of harvest yield component and harvest index due to the influence of plant density and trifoliate leaf defoliation

Treatment	*Numbers of pod per plant*	*Numbers of seed per plant*	*Weight of seed per plant (g)*	*Yield (ton ha^{-1})*	*Index of harvest*
Density of population (plant per ha):					
666,666	22.37 a	44.74 a	5.55 a	2.32 b	0.45 a
444,444	22.38 a	50.95 ab	8.91 b	2.28 a	0.60 ab
333,332	23.05 ab	50.13 ab	9.21 b	2.22 a	0.69 b
266,666	25.61 b	54.31 b	10.63 b	189 a	0.76 b
LSD 5%	3.20	9.33	2.20	0.40	0.22
Trifoliate of defoliation					
0	21.14 a	44.66 a	7.30 a	1.85 a	0.58
2	23.95 ab	50.45 ab	8.99 ab	2.30 b	0.66
4	24.96 b	54.98 b	9.44 b	2.39 b	0.64
LSD 5%	3.57	10.19	1.80	0.36	ns

Notes: Similar letters in each column show non-significant difference, according to LSD tests at the 5 % level; ns = non-significant; dap = days after planting.

Other factors that affect the final yield were LAI and interception efficiency. Radiant interception was high in high population and without defoliation. Even though it has higher interception but the yield is still lower. This is due to dense population and without defoliation treatment of the lower leaves; therefore it is not efficient for photosynthesis as the leaves shade one to another. In accordance Mondal *et al.* [8], due to defoliation treatment, the remaining leaves have higher net photosynthetic rate than the intact ones (without defoliation), and in other word, the remaining leaves could replace the loss as a result of defoliation. This may cause the yield has not reduced by the reducing leaves in soybean.

The yield of soybean has been controlled by total accumulated dry matters of the plant and partition of dry matters to the seed as reflected by harvest index. Population density has significant influence on harvest index. In lower population density (266,666 plants ha^{-1}), it has higher harvest index in comparison with higher population density (666,666 plants ha^{-1}). In higher population, the harvest index is lower because numbers of pod per plant and seed weight per plant are lower. However, due to higher population per hectare, the yield is higher than for lower population. In lower population (266,666 plants ha^{-1}), it has high harvest index by the increasing production of dry matters per plant, which could increase the production of pod per plant. Result of the research by Board and Maricherla [3], showed a contrast relationship between harvest yield and harvest index, in which the harvest yield is restricted by production of dry matter. Greater yields were associated with lower harvest index and lower yields with greater harvest index.

4. Conclusion

1. The harvest yield per area unit increases along with the increasing population of the plants. Treatment of low population of plants (266,666 plants ha^{-1}) has increased

the harvest yield 22.75% in comparison with high population of the plants (666,666 plants ha^{-1}).

2. The remaining leaves as a result of defoliation at the bottom part have become the sources that produce assimilate to supply the generative parts (pod and seed). Optimal biomass distribution to the pod is due to 4 trifoliate defoliation for about 55% in which 26% is distributed to the stem, and 19% to the leaves of total biomass of the plants.
3. Such defoliation of 4 trifoliate at the bottom part will increase the production as it compares with 2 trifoliate defoliations and without defoliation.

References

[1] H. Abdullah, Radiation Use Efficiency on Three Varieties of Paddy (*Oryza sativa* L.) in Different Density of Plant, Thesis, Faculty of Agriculture, Brawijaya University, Malang, Indonesia, 2010. (Unpublished).
[2] Statistic of Indonesia, "Food Crops," Table of Harvested Area- Productivity- Production Soybean in Indonesia Province [Online]. Available: http://www.bps.go.id/tnmn_pgn.php?kat=3&id_subyek=53&notab=0. [Accessed: March 10, 2013].
[3] J.E. Board and D. Maricherla, "Explanation for Decreased Harvest Index with Increased Yield in Soybean". Crop Science, XLVIII, pp. 1995 – 2002, 2008.
[4] D.D. Briske and J.H. Richards, Plant Responses to Defoliation: A Physiological, Morphological and Demographic Evaluation Society for Range Management, Deenver. CO, pp. 59-167, 1995.
[5] S.S. Chanishvili, G.Sh. Badridze, T.F. Barblishvili, M.D. Dolidze, "Defoliation, Photosynthetic Rates, and Assimilate Transport in Grapvine Plants", Russian Journal of Plant Physiology, LII (4), pp. 507 – 512. 2005.
[6] S.E. Khorasani, F. Paknejad, B. Delkosh, V. Ardalan, S.M. Mirtaheri, "An Evaluation of Effects of Source – Sink Limitation on Yield and Yield Components in Two Soybean Varieties", Journal of Basic and Applied Scientific Research, II (9), pp. 9049 – 9055, 2012.
[7] Kompas, "The Difference between Local and Imported Soybean," August 13, 2008. [Online]. Available: http://bisniskeuangan.kompas.com/read/2012/08/13. [Accessed: March 20, 2013].
[8] M.M.A. Mondal, M.S.A. Fakir, M.R. Ismail, M. Ashrafuzzaman. "Effect of Defoliation on Growth, Reproductive Characters and Yield in Mungbean (*Vigna radiata* (L.) Wilczek)," Australian Journal of Crop Science, V (8), pp. 987 – 992, 2011.
[9] P. Pedersen, "Soybean plant population," [Online]. Available: http://extension.agron.iastate.edu/soybean/production_plantpopulation.html. [Accessed: April 16, 2013].
[10] Y. Sugito, Plant Ecology, UB Press, Malang, 2009.
[11] L. Taiz and E. Zeiger, Plant Physiology, The Benjamin / Cummings. Pub. Co., Inc. California, 565 p. 1995.
[12] K. Yamada, A. Sasakura, K. Nishiwaki, H.A. El-Shemy, P.K. Mohapatra, N.T. Nguyen, H. Kurosaki, S. Kanai, J. Ito, K. Fujita, "Effect of Terminal Locations of Pods on Biomass Production and 13C Partitioning in a Fascinated Stem Soybean Shakujo." J Zhejiang Univ-Sci B (Biomed & Biotechnol), XII (1), pp. 72 – 82, 2011.

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