Effort in Increasing the Conversion Efficiency of Solar Radiation Energy on Intercropped Maize (*Zea mays*) and Soybean (*Glycine max* (L.) Merr)

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Abstract*: One of the efforts to increase conversion efficiency of radiation energy is by increasing plant population through intercropping system. The aim of this study is to determine the variety and planting density of soybean in intercropping system with maize which can increase conversion efficiency of radiation energy. This research used two varieties of soybean, Pangrango and Wilis, and four planting densities of soybean; 266,666, 133,332, 88,888, 66,666 plants ha^{-1}. The results indicated that intercropped maize with the high population densities of soybean, 266,666 and 133,332 plants ha^{-1}, can increase the value of conversion efficiency of radiation energy in intercropped maize and soybean. Maize yield components were not affected by varying planting densities of soybean.*

Keywords: conversion, radiation, intercropping, population

1. Introduction

Radiation is one of the environmental components, which is highly influential on crop productivity. Through photosynthesis, the crops produce photosynthates, which are useful for growth and development of the crops. Almost 80 – 90% of dry matters are the products of photosynthesis. However, efficiency of the radiation energy intercepted by the crops is very low. Such conversion efficiency of radiation energy on crops just ranges between 1 – 2 % [1], [2].

Many factors cause low conversion efficiency of radiation energy. One of them is vacant space between crops, which causes the radiation could not be utilized completely by the canopy due to a part of the radiation falls on the soil surface. Therefore, further effort is required to increase radiation use efficiency. [3] suggested how to improve crop breeding to reduce the escaped radiation energy and optimize the radiation use, which has been intercepted by the canopy by increasing the crops population. One of efforts in increasing population of the crops can be done by intercropping system.

Planting maize (*Zea mays*) and soybean (*Glycine max* (L.) Merr) in intercropping system is a potential model to be developed. It is due to both maize and soybean are the superior foodstuff commodity that pose an important position in Indonesia and have higher economic values. Intercropping system between maize and soybean has been frequently done, but information about optimal population density of the soybean in intercropped maize is very limited. [4] had a research on soybean population density in intercropping system with sorghum. Results of the research showed that population of the soybean, which 333,000 plants per hectare yielded the highest return in comparison with population densities of 200,000 and 400,000 plants per hectare, respectively.

Other problem emerges from the application of intercropping system between maize and soybean is low radiation intensity, which is intercepted by the crop due to the shade of maize crops. Radiation intensity, which was intercepted by the soybeans in intercropping system with maize, has decreased for about 33% [5]. The decreasing radiation intensity has affected on the soybean yields. Therefore, it requires selecting variety of soybean, which could adapt and produce higher yield in intercropping system with maize. The tolerant varieties of soybean include Wilis and Pangrango [6], [7]. Objectives of the research were to determine population density of the soybean and select the tolerant varieties of soybean along with the appropriate shade in intercropping system with maize in order to increase conversion efficiency of radiation energy.

2. Materials and Methods

The research was conducted from from May to August 2013 in Singosari, Malang, Indonesia. The geographic location of the experiment is at the latitude of 7.5º South Latitude and 137.5º East Longitude at the altitude of 491 meter above the sea level (asl). Daily average temperature ranges 24.4 ºC – 29 ºC. Type of the soil is Andosol. Equipments used in this research include analytic scales, oven, Luxmeter, Leaf Area Meter (LAM) and knapsack sprayer. Materials of the research include maize (Pioneer 21 variety), soybean (Pangrango and Wilis varieties), Urea (46% N), SP-36 (36% P_2O_5) and KCl (60% K_2O) and insecticide with active substrate was deltamethrin 0,5 l ha^{-1}.

The research applied a Randomized Complete Block Design (RCBD) that comprised of 9 treatments and 3 replications. The treatments included : T0 = Sole maize, T1 = maize + soybean var Pangrango 266,666 plants ha^{-1}, T2 = maize + soybean var. Pangrango 133,332 plants ha^{-1}, T3 = maize + soybean var. Pangrango 88,888 plants ha^{-1}, T4 = maize +

soybean var. Pangrango 66,666 plants ha^{-1}, T5 = maize + soybean var Wilis 266,666 plants ha^{-1}, T6 = maize + soybean var. Wilis 133,332 plants ha^{-1}, T7 = maize + soybean var. Wilis 88,888 plants ha^{-1}, and T8 = maize + soybean var Wilis 66,666 plants ha^{-1}. Observation on the plant growth was done at the age of 30, 45, 60, 75 days after planting (DAP) and during the harvest time. Observation on the plant growth on soybean included leaf area index (LAI), specific leaf area (SLA), unit leaf rate (ULR). Observation on yield component of the maize yield included seeds weight per crop, 100 seeds weight per crop and the yield. Conversion efficiency of radiation energy is counted by equation as follows [1] ;

$$\text{conversion efficiency of rad.energy: } \frac{\Delta W.k}{I.t.PAR} \text{ x } 100\%$$

in which ΔW = difference of dry weight of the crops in a period of time (g), K = Coefficient of burning heat (4,000 kal g^{-1}), I = Intensity of daily radiant (kal m^{-2} day^{-1}), t = a given period of time (day), PAR = Photosyntetic Active Radiation is counted as 50% of the intercepted radiation [8]. 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 LSD in 5% level.

3. Result

3.1 Maize Yield Component

Planting soybean in diverse population has no significant effect on seed yields of the maize. Observation on the maize seeds, which includes the seeds weight per plant, 100 seeds weight, and the maize yield, did not show significant difference among treatments.

Table 1: Yield component of maize due to the soybean planting in diverse population

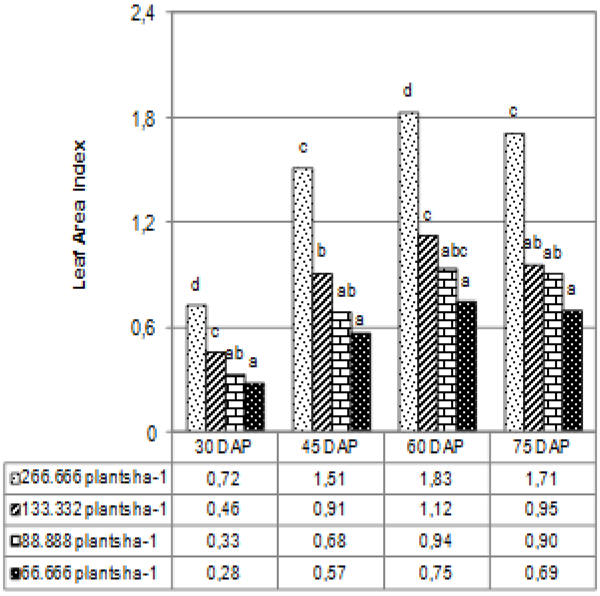
Treatment	*Seed weight per plant (g)*	*Yield (ton ha^{-1})*	*100 seeds weight (g)*
T0	177.89	10.38	41.03
T1	168.76	9.84	40.93
T2	172.56	10.07	40.30
T3	174.94	10.21	39.90
T4	176.07	10.27	41.23
T5	167.86	9.79	40.53
T6	170.64	9.95	40.57
T7	173.38	10.11	40.03
T8	174.58	10.18	40.90
LSD 5%	ns	ns	ns

Ns = non-significant

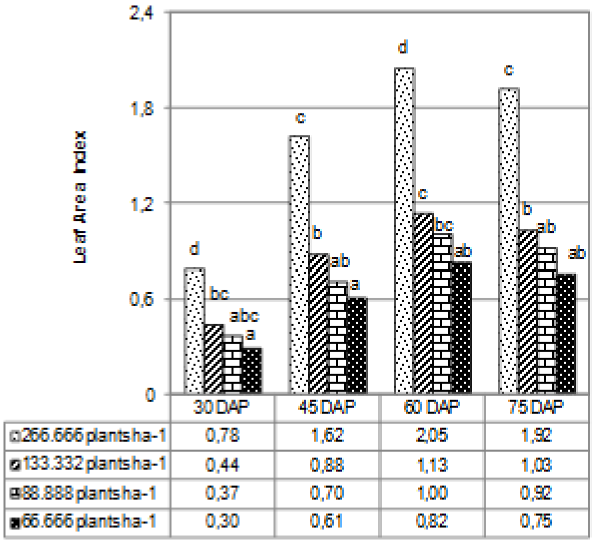
3.2 Soybean Growth and Yield

3.2.1 Leaf area index (LAI)

Planting soybean in diverse populations by intercropping system with maize showed significant effect on LAI of the soybeans at the age of 30, 45, 60 and 75 DAP. LAI of soybean increased up to 60 DAP and declined thereafter (Figure 1). The general trend for LAI was the increasing planting density associated with increasing LAI. LAI of soybean was greatest when planted at 266.666 plants ha^{-1}.



(a)

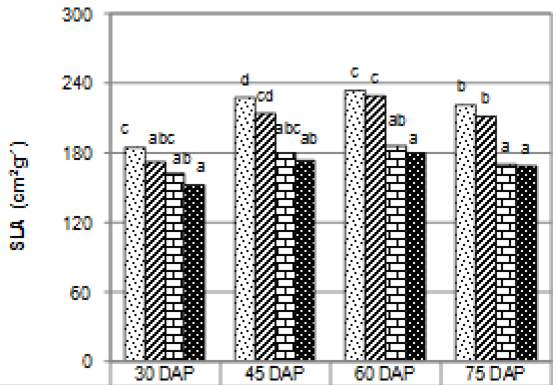


(b)

Figure 1: Graphic for mean LAI of the soybean in diverse population by intercropping system with maize of (a) Pangrango variety, (b) Wilis variety

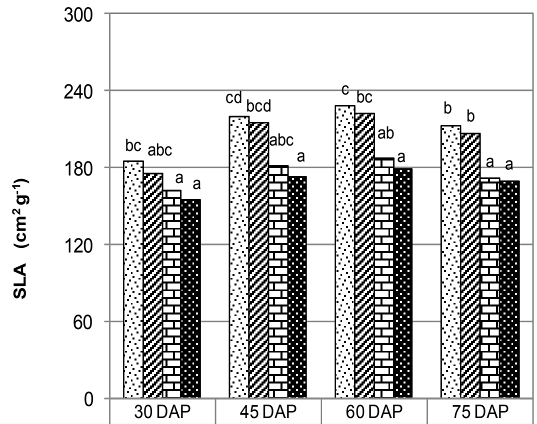
3.2.2 Specific leaf area (SLA)

Planting soybean in diverse populations by intercropping system with maize showed significant effect on SLA of the soybeans at the age of 30, 45, 60 and 75 DAP. SLA of the soybean, which was planted in high population, has produced higher SLA in comparison with in low population. The declining value of SLA had been followed by the decreasing population of the soybean (Figure 2).



	30 DAP	45 DAP	60 DAP	75 DAP
266.666 plants ha-1	186,18	228,23	233,79	221,62
133.332 plants ha-1	173,31	214,13	229,59	212,13
88.888 plants ha-1	162,69	180,31	186,63	171,07
66.666 plants ha-1	153,33	174,33	180,48	169,08

(a)



	30 DAP	45 DAP	60 DAP	75 DAP
266.666 plants ha-1	184,61	219,01	227,29	212,22
133.332 plants ha-1	174,85	213,79	220,89	206,00
88.888 plants ha-1	161,45	180,94	186,72	170,58
66.666 plants ha-1	153,59	172,24	177,65	168,68

(b)

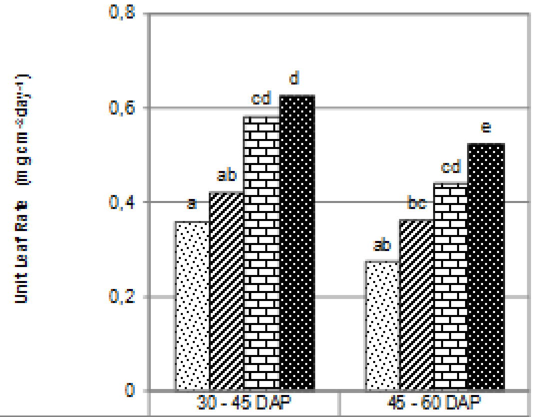
Figure 2: Graphic for mean SLA of the soybean in diverse population by intercropping system with maize of (a) Pangrango variety, (b) Wilis variety

3.2.3 Unit Leaf Rate (ULR)

Observation on ULR values at the age of 45 – 60 DAP showed that in Pangarango variety, planting the soybeans of 266,666 plants ha^{-1} produced LUP for about 0.27 mg cm^{-2} day^{-1} (Figure 3). The value was lower and had significant difference with population of 133,332, 88,888, and 66,666 plants ha^{-1} by the values of 0.36, 0.44 and 0.52 mg cm^{-2} day^{-1}, respectively. ULR values increased along with the decreasing population of the soybean.

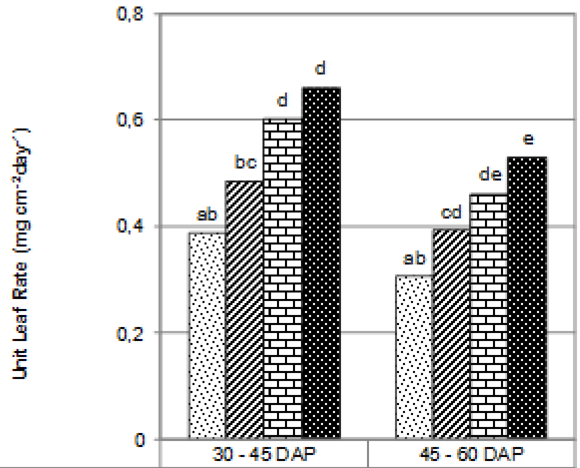
3.2.4 Yield of Soybean

The treatment maize + Wilis variety 266,666 plants ha^{-1} produced the highest grain yield, 6,87 quintal ha^{-1}, followed by the treatment of maize + soybean of Pangrango variety 266,666 plants ha^{-1} and maize + soybean, 6.60 quintal ha^{-1}. The treatments of maize + soybean of Pangrango variety 66,666 plants ha^{-1} and maize + soybean of Wilis variety 66,666 plants ha^{-1}, which only could produce 2.23 and 2.37 quintal ha^{-1} (Figure 4).



	30 - 45 DAP	45 - 60 DAP
266.666 plants ha-1	0,36	0,27
133.332 plants ha-1	0,42	0,36
88.888 plants ha-1	0,58	0,44
66.666 plants ha-1	0,62	0,52

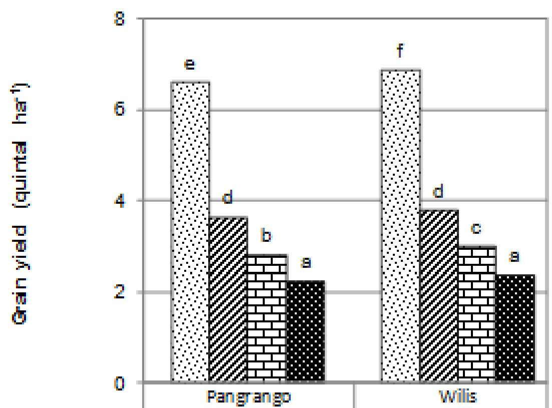
(a)



	30 - 45 DAP	45 - 60 DAP
266.666 plants ha-1	0,39	0,30
133.332 plants ha-1	0,49	0,39
88.888 plants ha-1	0,60	0,46
66.666 plants ha-1	0,66	0,53

(b)

Figure 3: Graphic for mean ULR of the soybean in diverse population by intercropping system with maize of (a) Pangrango variety, (b) Wilis variety



	Pangrango	Wilis
266.666 plants ha-1	6,60	6,87
133.332 plants ha-1	3,63	3,79
88.888 plants ha-1	2,79	2,99
66.666 plants ha-1	2,23	2,37

Figure 4: Graphic for mean grain yield of the soybean in diverse population by intercropping system with maize

3.3 Conversion Efficiency of Radiation Energy

Intercropped maize and soybean on varying population densities has significant effect on the conversion efficiency of radiation energy values. The treatment of maize + soybean of Pangrango variety 266,666 plants ha^{-1}, maize + soybean of Wilis variety 266,666 plants ha^{-1}, maize + soybean of Pangrango variety 133,332 plants ha^{-1}, and maize + soybean of Wilis variety 133,332 plants ha^{-1} produced higher conversion efficiency of radiation energy in comparison with monoculture of maize by the values of 1.56%; 1.60%; 1.51% and 1.51%, respectively.

Table 2: The conversion efficiency of radiant energy on intercropped maize and soybean in varying population

Treatment	*Conversion Efficiency of Radiation Energy (%)*
T0	1.32 a
T1	1.56 c
T2	1.51 bc
T3	1.37 ab
T4	1.40 ab
T5	1.60 c
T6	1.51 bc
T7	1.39 ab
T8	1.39 ab
LSD 5%	0.14

Numbers followed by the same letter show no significant difference based on LSD test 5%.

4. Discussion

Planting the soybean in varying population densities on intercropping system with maize has not shown significant effect on all yield components of maize. Observation on yield of maize includes diameter of ear, length of ear, weight of ear, and weight of seed, have not shown significant difference among treatments. The yield components of maize have no significant difference among treatments, which mean that the existence of soybean as intercrop in varying population densities has no significant effect on the yield of maize. Planting the soybean, 266,666 plants ha^{-1}, has not affected the yields of maize. It shows that maize crop is the most dominant component in intercropping with soybean [9]. Dominance of maize crops could win the competition interspecies with the soybean toward in obtaining the growing factor.

High level of the maize dominance in intercropped with soybean has also been obtained on research by [10]. Result of the research showed that some varieties of soybean intercropped with maize have no significant effect on yield component of the maize. The maize domination level may reduce the yield per individual soybean crop due to competition in obtaining of growing factor [11]. The yield per individual soybean crop keeps declining along with the increasing population densities of the soybean crops.

Results of the observation on LAI of the soybean intercropped with maize showed that soybeans, which are planted in population density of 266,666 plants ha^{-1}, have higher LAI than in population densities of 133,332 plants ha^{-1}, 88,888 plants ha^{-1}, and 66,666 plants ha^{-1}. Crops that are planted in high population densities, have high LAI as well, and in contrast, crops that are planted in low population densities, have low LAI as well [12], [13].

SLA values of the soybean have increased along with the increasing population of soybeans. Higher value of the SLA shows that the leaf tends to thinner than in population of 88,888 plants ha^{-1} and 66,666 plants ha^{-1} that have lower value for SLA. Relationship between crop population and SLA was reported in the research by [14]. Results of the research stated that the higher population of the crops, they will tend to reduce the leaf thickness.

Observation on ULR showed that soybeans, which are planted in high population, 266,666 plants ha^{-1}, have lower ULR values in comparison with in low population. [15] had a research that concerning with the effect of soybean population on the soybean growth. Results of the research showed that ULR values are affected by population of the soybeans. ULR value increased along with the reducing population of soybeans.

Observation on yield of the soybean showed that high population result higher yields in comparison with in low population densities. [16] described that the increasing population could reduce the yield per individual crop, but it could increase the yield per unit area.

Conversion efficiency of radiant energy shows how much the intercepted energy could be changed into dry matter. Results of the research showed that the soybean population addition as intercrop in intercropping system with maize, 133,332 plants ha^{-1} to 266,666 plants ha^{-1}, could increase the conversion efficiency of radiation energy. Meanwhile, additional population of soybean 66,666 plants ha^{-1} and 88,888 plants ha^{-1} showed no significant difference for values of the conversion efficiency of radiant energy with monoculture of maize. It showed that additional population of soybean 88,888 plants ha^{-1} and 66,666 plants ha^{-1} in intercropped with maize has not been able to increase the conversion efficiency of radiation energy.

5. Conclusion

1. The treatments of high planting population of soybean, 266,666 and 133,332 plants ha^{-1}, intercrop with maize could increase the value of conversion efficiency of radiation energy.
2. The value of conversion efficiency of radiation energy on intercropped maize with Pangrango variety at 266,666 and 133,332 plants ha^{-1} increased 13.83% and 17.94%, on Wilis variety at 266,666 and 133,332 plants ha^{-1} increased 14.28% and 20.57% in comparison with sole maize.

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