Ilmu Pertanian (Agricultural Science)
Vol. 2 No. 3 December, 2017 :130–136
Available online at http://journal.ugm.ac.id/jip
DOI: doi.org/10.22146/ipas.25215

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(Agricultural Science)

Growth and Yield of Upland Rice Under Intercropping System with Soybean in Sandy Coastal Area

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Received: 23rd May 2017; Revised: 22nd August 2017; Accepted: 29th December 2017

ABSTRACT

Sandy coastal area in Indonesia is potential for upland rice cultivation, but it has constraints low of nutrient availability such as nitrogen. To solve the low fertility of the sandy land can be done by planting soybean between upland rice under intercropping system due to the soybean is able to provide nitrogen in soil through fixation of N_2 in the air by root nodules. Intercropping is an alternative cropping system to increase land productivity, but there is competition between crops under an intercropping system. Reducing of the competition on the system is needed by crops proportion adjustment. The objective of the study is to examine growth and yield component of upland rice at different crops proportion under an intercropping system with soybean in the sandy coastal area. The research was conducted in Samas sandy coastal area, Bantul, Yogyakarta. This research used randomized complete block design (RCBD) with one factor and three blocks. The treatment of this research was five level crops proportion between upland rice and soybean under intercropping system, namely: 100:0; 80:20; 60:40; 40:60; and 20:80, respectively. The results showed that crop growth rate and yield per clump of upland rice increased on crops proportion adjustment under intercropping system with soybean. The crops proportion of 60:40 and 40:60 gave higher crop growth rates that were 1.45 $g.dm^{-2}.wk^{-1}$ and 1.44 1.45 $g.dm^{-2}.wk^{-1}$ than upland rice under monoculture (100:0) that was 1.09 $g.dm^{-2}.wk^{-1}$. The higher crop growth rates in crops proportion of 60:40 and 40:60 were able to give better yield per clump than other that were 17.17 g and 16.46 g, respectively. The yield of upland rice was not different under crops proportion of 100:0, 80:20, and 60:40 and decreased of upland rice proportion until ≤ 40% affected the low yield of upland rice.

Keyword: Crop growth rate, crops proportion, intercropping, yield

INTRODUCTION

Rice is one of the essential food crops for the people of Indonesia. One of the types of rice cultivated in Indonesia is upland rice. Upland rice is cultivated on dry land that is not watered throughout its lifetime and water source comes from soil moisture derived from rainfall (Sumarno and Hidayat, 2007). The contribution of upland rice production is still 5% of the total rice production in Indonesia (Kementan, 2016). The role of upland rice to provide food and national grain supply is going to become important in the future. This is due to the decreasing of wetland and the indication of the rice production rate does not increase, while the increase of population rate continues to increase at an average rate of 1.17% per year (BPS, 2016).

National issues about low grain productions can be solved by cultivating upland rice in the sandy coastal area. Indonesia has a long coastline of 106.000 km and the land area of 1.060.000 ha, generally including marginal land (Saparso *et al.*, 2009). Sandy coastal area has a potential for the development of food crops such as upland rice. Sandy coastal area is supported by soil water availability that is relatively shallow and abundant sunshine (Wibowo, 2006). However, the sandy coastal area is marginal land that has limiting factors such as the ability to save water which is low, high infiltration, organic matter and soil fertility are very low (Al-Omran *et al*., 2004).

Management of sandy coastal area can be done with the soil enhancers material in the form of clay and manure (Rajiman *et al*., 2008). To solve the low fertility of the sandy land can be done by planting soybeans between upland rice or intercropping system. Intercropped with soybean can provide many benefits in nitrogen contribution through fixation of N_2 in the air by root nodules which are symbiotic with Rhizobium bacteria.

N fixation ability to convert N_2 into organic N often reach 100 kg.ha^{-1}.yr^{-1} is more than enough to sustain the needs of N and replace the missing N (Vitousek *et al*., 2002). On the environmental conditions which are favorable to good root nodules, soybean plants can obtain a contribution of N results of N_2 fixation by Rhizobium bacteria equivalent to 65–115 kg N ha.yr^{-1} (Alexander, 1977). It will help the availability of nitrogen to upland rice in the sandy coastal land with low fertility levels.

According to Inal *et al*. (2007) intercropping system is effective to increase mobilization and absorption of nutrients in the soil. The intercropping system can increase absorption of nutrients N, P, K in maize and peanuts on land that is not fertile. Increased absorption of nutrients in the intercropping system is described by Inal *et al*. (2007), that increasing the concentration and activity of acid phosphatase, phytosiderophore, and ferric reductase in the root area help to absorb the macro and micronutrients in the less fertile land.

However, the intercropping system has problems such as light, water, and nutrients competition between crops constituent. Reducing of the competition on the system is needed by crops density adjustment. Under standing of crops density (population) is the total crop population includes all kinds of components with the population of each species of crop components (Pasau *et al*., 2008). The population is the number of the crop in a particular area. In determining the population of each component uses replacement series and additive series. Replacement series is a combination of species in a state of pure components and mixtures with proportions substitute an equivalent proportion of species with other species, usually a percentage of 50: 50. While the definition of additive series is a combination of several species of crops by maintaining the main component remains in optimal condition 100 %, subsequently added component to the two types of plants by 25%, 50%, 75% of the optimal proportion of the main components, thus forming new combinations of 100:25, 100:50, 100:75 (Shokati and Zehtab-Salmasi, 2014).

The arrangement of crops proportion in the intercropping system can optimize the utilization of growing space, distribution of light and nutrients for upland rice so that the growth of upland rice will be optimal. This study aims to know of the growth and yield of upland rice intercropped with soybeans at different crops proportion in the sandy coastal area.

MATERIALS AND METHODS

The study was conducted in Samas sandy coastal area, Bantul, Yogyakarta with an altitude of 10 m above sea level and laboratory of crop production management Faculty of Agriculture, Universitas Gadjah Mada. An experiment was conducted in December 2016 to March 2017. The materials that are used such as upland rice Segreng Handayani, soybean Anjasmoro, manure 20.000 kg.ha^{-1}, Urea (300 kg.ha^{-1} for upland rice and 50 kg.ha^{-1} for soybeans), SP36 (150 kg.ha^{-1} for upland rice and 200 kg.ha^{-1} for soybean), and KCl (150 kg.ha^{-1} for upland rice and 100 kg.ha^{-1} for soybean).

The field experiments used a randomized complete block design with three replications. The crops proportion included: a). Upland rice monoculture (100:0), b). Intercropping 80% of upland rice + 20% soybean (80:20), c). Intercropping 60% of upland rice + 40% soybean (60:40), d). Intercropping 40% of upland rice + 60% soybean (40:60), e). Intercropping 20% of upland rice + 80% soybean (20:80).

Observations were done on: leaf area (cm^2), number of tillers, specific leaf area (m^2.g^{-1}), root-shoot ratio, net assimilation rate (g.dm^{-2}.wk^{-1}), crop growth rate (g.dm^{-2}.wk^{-1}), number of panicles per clump, percentage of productive tillers (%), yield per clump (g), and yield (ton.ha^{-1}).

Specific leaf area (SLA) was calculated as (Amanullah, 2015):

$$SLA = \frac{LA}{WL} (m^2.g^{-1}) \quad (1)$$

Where LA and WL were leaf area (m^2) and leaf dry weight (g), respectively.

Net assimilation rate (NAR) was calculated as (Ghost *et al*., 2006):

$$NAR = \frac{W2-W1}{T2-T1} \times \frac{\text{Ln LA2-Ln LA1}}{La2-La1} (g.dm^{-2}.week^{-1}) \quad (2)$$

Where W1 and W2 were the total plant dry weight (g) at time T1 and T2, respectively. LA1 and LA2 were leaf area (dm^2) at time T1 and T2, respectively.

Crop growth rate (CGR) was calculated as (Ghost *et al*., 2006):

$$CGR = \frac{1}{GA} \times \frac{W2-W1}{T2-T1} (g.dm^{-2}.week^{-1}) \quad (3)$$

Where GA was ground area (dm^2).

Data from observations were analyzed by Analysis of Variance (ANOVA) according to a randomized complete block design using SAS for windows release 9.1(SAS Institute, 2004). Where analysis of variance significant differences, it means were compared using the least significant difference (LSD) at 5% level.

RESULT AND DISCUSSION

Growth componentsof upland rice

The result of variance analysis on several growth variables showed in Table 1. The number of tillers and leaf area of upland rice showed a significant difference, but the specific leaf area showed no significant difference.

The crops proportion between rice and soybean of 80:20, 60:40, and 40:60 were an able high of tillers number more than the crops proportion of 100:0 and 20:80. And then the crops proportion of 60:40 and 40:60 gave higher leaf area than other. Leaf area on the crops proportion of 60:40 and 40:60 increase that was 28.76% and 34.69% from the leaf area of monoculture system (100:0), respectively. It was predicted that the increase of soybean proportion under intercropping system gave a positive impact that was the availability of nitrogen for upland rice from the N_2 fixation by soybean nodule. However, the crops proportion of 20:80 gave a negative impact to decrease the leaf area of upland rice. At the crops proportion of 20:80, the supply of nitrogen by soybeans was not matched by the availability of growing space for upland rice because the growth of upland rice will be hampered by competing with soybeans to obtain the growing space and light.

Ilkaee *et al.* (2011) stated that the growth of leaf area was very important for the crop because it became the center of energy transfer and the process of forming dry matter in the canopy. The growth of leaf area was large, it formed the high specific leaf area. Specific leaf area was thickness or large of leaf to show the ability of leaves to produce biomass or dry matter or leaf effectiveness in producing dry matter (Amanullah, 2015). Although it was not significantly different, specific leaf area increased with increasing crops proportion of soybean.

The crops proportion between upland rice and soybean under intercropping system could significantly increase the net assimilation rate in upland rice. The net assimilation rate was the ability of crops to produce dry matter per unit of leaf area per time (Taufiq and Kristiono, 2016). With the equation $Y = 0.0002X - 0.0018$ ($R^2 = 0.693$), it was clear that higher leaf area will be affected the net assimilation rate to increase (Figure

Table 1. Growth component of upland rice under different crops proportion on intercropping system with soybean

Treatment	Number of tillers	Leaf area (cm^2)	Specific leaf area ($m^2.g^{-1}$)
Upland rice : Soybean			
100:0	18.78 b	1.601.84 b	0.029 a
80:20	20.33 a	1.598.01 b	0.026 a
60:40	21.11 a	2.062.06 a	0.028 a
40:60	21.00 a	2.157.51 a	0.030 a
20:80	18.22 b	1.584.14 b	0.026 a
Mean	19.89	1.800.71	0.028
CV (%)	2.33	4.04	18.62

Note: number followed by the same letter in the column indicates not significantly different according to LSD at 5% levels.

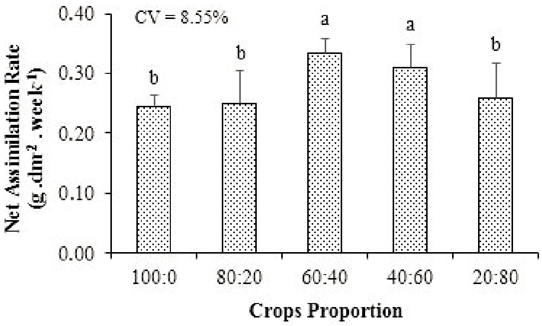

Figure 1. Net assimilation rate of upland rice on various crops proportion under intercroping system with soybean.

Table 2. Root-shoot ratio of upland rice under different crops proportion on intercropping system with soybean

Treatment	Root-shoot ratio		
	21 das	42 das	63 das
Upland rice : Soybean			
100:0	0.266 a	0.156 a	0.074 a
80:20	0.262 a	0.101 a	0.063 a
60:40	0.233 a	0.075 a	0.068 a
40:60	0.246 a	0.095 a	0.064 a
20:80	0.238 a	0.093 a	0.093 a
Mean	0.249	0.104	0.072
CV (%)	15.40	33.31	23.20

Note: number followed by the same letter in the column indicates not significantly different according to LSD at 5% levels.

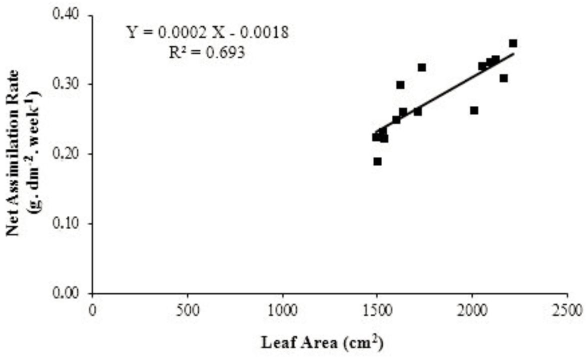

Figure 2. Relationship of leaf area and net assimilation rate

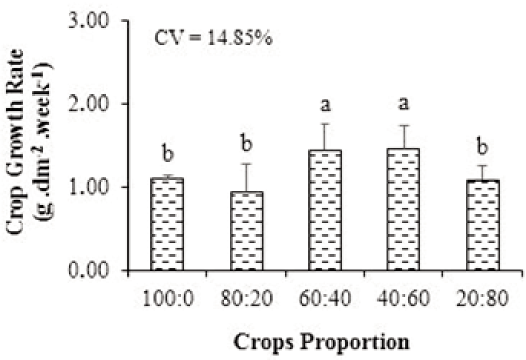

Figure 3. Crop growth rate of upland rice on various crops proportion under intercroping system with soybean.

2).Dry matter was a source of energy that will be distributed to parts of the crop as a support plant growth. The increase of soybean proportion became 80% (20:80), it decreased in net assimilation rate in upland rice. It happened because of the growing space, nutrients, and water competition between upland rice and soybeans affected the growth of upland rice.Decreased of leaf area on upland rice is one of the factors of decreasing the net assimilation rate in upland rice crops.

The distribution of dry matter between the canopy and the root was indicated by the root-shoot ratio value. The root-shoot ratios of 21 das, 42 das, and 63 das were not significant differences between treatments (Table 2). Although it was not significantly different, the root-shoot ratio value in all treatments showed to decrease in the increase of crop age. When the age of upland rice was 21 das, the distribution of dry matters to the roots was higher than the age of upland rice was 42 das and 63 das. It was related to the early growth of crops, so the plant tried to form the root more for absorbing water and nutrients in the soil. While the age of the crop entered 42 das to 63 das, the root-shoot ratio decreased from an average of 0.072. That was affected by upland rice to focus on forming the shoot to generate energy through the mechanism of photosynthesis. The energy will be used to support the growth of the crop. The energy will be used to support the growth of the crop.

The crops proportion of 60:40 and 40:60 increased the crop growth rate of 33.26% and 31.66% than upland rice under monoculture. But the crop growth rate (CGR) decreased in the crops population was 20:80 (Figure 3). It was thought to be due to the high population of soybean, causing the upland rice to have inadequate growing space and less competition in obtaining light, water, and nutrients so that the materials needed for the dry matter forming process were limited. The leaf of soybean was wide, caused upland rice difficult on getting light. The production of dry matter was limited due to the low light received by upland rice due to the shade of soybean leaf. It is resulting in lower carbohydrate supply and the proportion of the distribution of dry matter throughout the crop growth rate (CGR) (Adeniyan *et al*., 2014). The low supply of dry matter is caused by the absorption of light energy for photosynthesis process is hampered by shading of soybean canopy. Light energy is absorbed by chlorophyll which located

ISSN 0126-4214 (print) ISSN 2527-7162 (online)

Table 3. Yield component of upland rice under different crops proportion on intercropping system with soybean

Treatment	Persentage of productive tillers (%)	Number of panicles	Yield per clump
Upland rice : Soybean			
100:0	73.99 a	13.89 b	10.13 b
80:20	80.92 a	16.44 a	13.11 b
60:40	83.41 a	17.56 a	17.17 a
40:60	80.93 a	17.00 a	16.46 a
20:80	77.38 a	14.11 b	12.63 b
Mean	79.33	15.80	13.90
CV (%)	6.84	5.27	11.42

Note: number followed by the same letter in the column indicates not significantly different according to LSD at 5% levels.

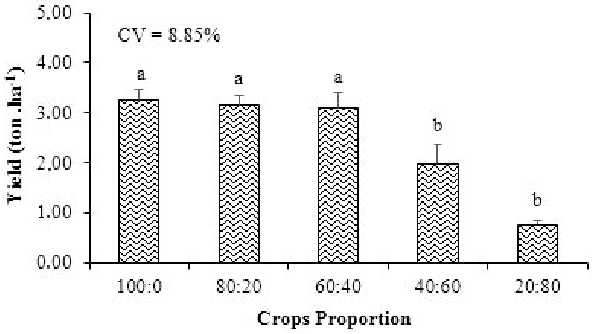

Figure 4. Yield of upland rice on various crops proportion under intercropping system with soybean

in photosystem I and II on thylakoid membranes. The light energy is used as regeneration of electrons in the process of water photolysis and the transport of electrons in the light reactions. The electron transport chain may contribute to the domination of the cyclic electron transport activity for ATP and NADPH production in the chloroplast (Munekage, 2016). ATP and NADPH are used by energy in dark reaction. In the dark reaction, 3-phosphoglycerate is phosphorylated by the enzyme phosphoglycerate kinase, forming 1,3-bisphosphoglycerate, which is then reduced by glyceraldehyde 3-phosphate dehydrogenase to glyceraldehyde 3-phosphate before starch biosynthesis, consuming ATP and NADPH (Sharwood *et al*., 2016). The low light energy will result in the low of ATP and NADPH in light reactions followed by decreasing starch or dry matter through dark reaction.

Yield components of upland rice

The result of variance analysis on several upland rice yields component showed in Table 3. The crops proportion under intercropping system was significant on the number of panicles and the yield per clump but was not significantly different from the percentage of productive tillers.

In the crops proportion of 60:40 was able to increase higher the number of panicles than other treatments. But the number of panicles at 60:40 population density was not significantly different from the population densities of 80:20 and 40:60. The number of panicles increased with the addition of soybean population density in this intercropping system. With the crops proportion of 80:20, 60:40, and 40:60 were able to increase the panicles as 18.4%; 26.4%; and 22.4%, respectively.

The yield per clump was shown (Table 3) that the crops proportion of 60:40 and 40:60 gave yield per clump that was 17.7 g and 16.46 g, respectively. These were 69.50% and 62.55% of grain yield per clump higher than the crops population of upland rice under monoculture (100:0). Putra (2011) explained that the increase in the yield was related to the number of panicles that could be formed by upland rice. In addition to the dry matter produced was also effected on the grain yield. Through the equation Y = 4.2636 X2 - 3.2292 X + 11.289 (R^2 = 0.548) (Figure 5A), it could be seen that was the higher the rate of plant growth, the grain yield which would be more produced. In addition, the grain yield was also influenced by the number of panicles that are formed. The regression analysis results showed that the relationship between the number of panicles with

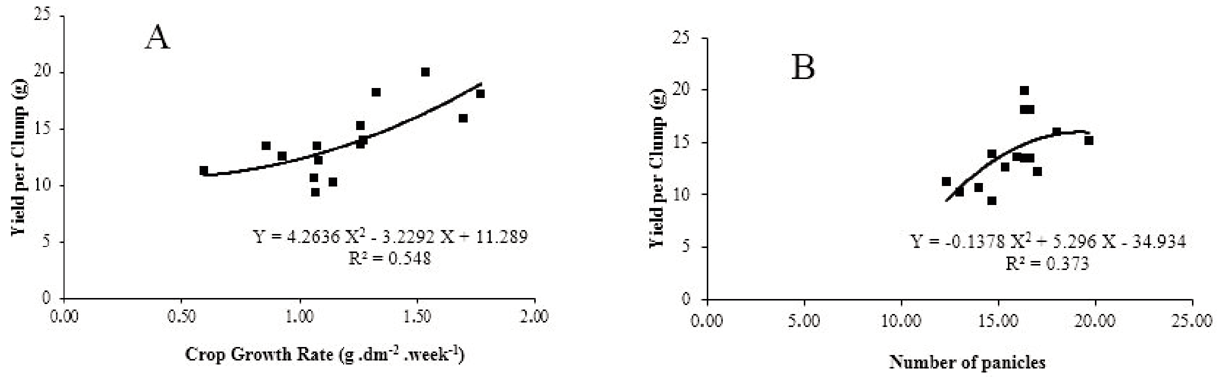

Figure 5. Relationship of crop growth rate with yield per clump (A) and number of panicles with yield per clump (B).

the grain yield was the form of a quadratic curve where Y = -0.1378 X2 + 5.296 X – 34.934 (R^2 = 0.373) (Figure 5B). From the curve could be explained that the grain yield would reach 19.98 g (optimum point) when the number of panicles was at the number 16.33 (Figure 5). An increase in the number of panicles exceeding the optimum point was not able to increase yield per clump.

Ghosh *et al.* (2006) explained that high crop growth rate gave a high yield. The crop growth rate was influenced by an adequate supply of nitrogen. Nitrogen was used crops for metabolic processes in crop cell division and enlargement. The increased of crop growth rate and yield per clump were influenced by the increased soybean proportion. The increasing of soybean proportion was able to provide nitrogen supply from N_2 fixation to be utilized by upland rice. Through this explanation, it could be assumed that the presence of soybean in upland rice crops has a positive effect on nitrogen supply. Peoples *et al.* (1995) explained that the amount of nitrogen is fixed by legume ranges from 1 to 80 kg N/ha. While the research Vitousek *et al.* (2002) explained that the ability of legume crops fixes N that was 100 kg N /ha/year sufficient to maintain N requirements in crops.

Moreover, the role of appropriate space availability in crops proportion of 60:40 and 40:60 was a key factor for increasing yield per clump. The narrow spaces affected by higher competition between crops. It could be seen in the 20:80 crop proportion treatment which has less yield per clump (12.63 g) compared to the 60:40 and 40:60. The more soybean proportion (80%) resulted in competition in getting light due to the growth fast of soybean and occupy the area. It was shown that the crop growth rate at crops proportion of 20:80 became to obstruct (Figure 3) and the lower yield per clump (Table 3). Figure 4 explained that the crops proportion under intercropping system was significantly different under least significant difference (LSD) test with $\alpha = 5\%$. But The high of yield per clump was not simultaneously to increase the yield per hectare. The decreased of upland rice proportion affected the low of upland rice yield per hectare. It was affected by the number of populations of upland rice which decreased in the area. However, the crops proportion of 100:0, 80:20, and 60:40 showed the yield was same (Figure 4). The high yield of upland rice under crop proportion of 60:40 is the impact of the high crop growth rate of upland rice in the proportion. High growth rates will produce the high dry weight of plants followed by the high grain formation (Ghosh *et al.*, 2006).

CONCLUSIONS

The crops proportion of 60:40 and 40:60 in upland rice and soybean under intercropping systems had the better growth to compare other crops proportion. The number of tillers and leaf area of upland rice at the population density of 60:40 and 40:60 showed to increase the net assimilation rate (NAR) and crop growth rates (CGR) of upland rice. The higher rate of net assimilation and crop growth of upland rice wereable to increasethe panicles and yieldper clump.The yield of upland rice under crops proportion of 100:0, 80:20, and 60:40 was not different. The yield was low if the upland rice proportion was decreased until ≤ 40%.

REFERENCES

Adeniyan, O. N., O. A. Aluko, S. O. Olanipekum, J. O. Olasoji, and V. O. Aduramigba-Modupe. 2014. Growth and yield performance of cassava/maize intercrop under different plant population density of maize. Journal of Agricultural Science 6 (8): 35–40. http:// dx.doi.org/ 10.5539/ jas.v6n8p35.

Amanullah. 2015. Specific leaf area and specific leaf weight in small grain crops wheat, rye, barley, and oats differ at various growth stages and NPK Source. Journal of Plant Nutrition 38 (11): 1694–1708.

Alexander, M. 1977. Introduction to Soil Microbiology. 2nd Edition. John Wiley and Sons; New York Chichaster-Brisbane-Toronto-Singapore. 472 pp.

Al-Omran, A.M., A.M. Falatah, A.S. Sheta, and A.R. Al-Harbi. 2004. Clay deposits for water management of sandy soils. Arid Land Research and Management 1: 171–183.

Badan Pusat Statistik. 2016. Penduduk Indonesia menurut Provinsi 1971, 1980, 1990, 1995, 2000 dan 2010. [On line] Available at: https://www.bps.go.id/linkTabelStatis/view/id/1267 [Accessed 13 Apr. 2017].

Ghosh, P. K., M. Mohanty, K. K. Bandyopadhyay, D. K. Painuli, and A. K. Misra. 2006. Growth, competition, yield advantage and economics in soybean/pigeonpea intercropping system in semi-arid tropics of India I. Effect of subsoiling. Field Crops Research 96: 80–89.

Ilkaee, M. N., F. Paknejad, and M. Zavareh. 2011. Prediction model of leaf area in soybean (*Glycine max* L.). American Journal of Agricultural and Biological Sciences 6 (1): 110–113.

Inal, A., A. Gunes, F. Zhang, and I. Chakmak. 2007. Peanut/maize intercropping induced changes in rhizosphere and nutrient concentrations in shoots. Plant physiology and biochemistry 45: 350–356.

Kementrian Pertanian. 2016. Basis data statistik pertanian. [online] Available at: http://aplikasi.pertanian.go.id/bdsp/newkom.asp [Accessed 13 Apr. 2017].

Munekage, Y. N. 2016. Light harvesting and chloroplast electron transport in NADP-malic enzyme type C4 plants. Current Opinion in Plant Biology 3: 9–15. http://dx.doi.org/10.1016/j.pbi.2016.03.001

Pasau, P., P. Yudono, dan A. Syukur. 2008. Pergeseran komposisi gulma pada perbedaan proporsi populasi jagung dan kacang tanah dalam tumpang sari pada regosol Sleman. Ilmu Pertanian 16 (2): 60–78.

Peoples, M. B., D. F. Herridge and J. K. Ladha. 1995. Biological nitrogen fixation: An efficient source of nitrogen for sustainable agriculture production. Plant and Soil 174: 3–28.

Putra, S. 2011. Pengaruh jarak tanam terhadap peningkatan hasil padi gogo verietas Situ Patenggang. Agrin. 15 (1): 54–63.

Rajiman, P. Yudono., E. Sulistyaningsih, and E. Hanudin. 2008. Pengaruh pembenah tanah terhadap sifat fisik tanah dan hasil bawang merah pada lahan pasir pantai Bugel Kabupaten Kulon Progo. Agrin. 12 (1): 67–77.