**GROWTH AND YIELD OF UPLAND RICE UNDER INTERCROPPING SYSTEM WITH SOYBEAN IN SANDY COASTAL AREA**

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**ABSTRACT**

Sandy coastal area in indonesia has a potential for upland rice cultivation, but it has constraints low of nutrient availability such us nitrogen availability. In addition 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 N2 in the air by root nodules. Intercropping is an alternative cropping system to increase land productivity, but there is competition between crops under 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 of upland rice at different crops proportion under intercropping system with soybean in 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 block. The treatment on this research was 5 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 and yield of upland rice increased with the crops proportion between upland rice and soybean under intercropping system. The crops proportion of 60:40 and 40:60 gave higher crop growth rates that were 1,45 g dm-2 week-1 and 1,44 g dm-2 week-1 than upland rice under monoculture (100:0). The higher crop growth rates in crops proportion of 60:40 and 40:60 were able to give better grain yields than other crops proportion that were 17,17 g and 16,46 g, respectively.

Keyword: upland rice, sandy coastal area, intercropping, crops proportion

**INTRODUCTION**

Upland rice is one of crop that has the potential to future the staple food beside the lowland rice in Indonesia. The contribution of upland rice production still reaches 5% of the total rice production in Indonesia (Kementan, 2016). The role of upland rice to provide food and national grain supply are 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 increasing of population rate continues to increase at an average rate of 1,17% per year (BPS, 2016).

National issues about fewer grain productions can be solved by cultivating upland rice on sandy coastal area. Indonesia has a long coastline with a potential reach 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. It 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).

Sandy coastal area management for the cultivation can be done with the soil enhancers material in the form of clay and manure (Rajiman *et al.*, 2008). In addition to solve the low fertility of the sandy land can be done by planting soybeans between upland rice crop or intercropping system. Intercropped with soybean can provide much benefits in nitrogen contribution through fixation of N2 in the air by root nodules which are symbiotic with Rhizobium bacteria.

N fixation ability to convert N2 into organic N often reach 100 kg ha-1 year-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 N2 fixation by Rhizobium bacteria equivalent to 65-115 kg N ha-1 year-1 (Alexander, 1977). It will help the availability of nitrogen to upland rice in 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. By using 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) increasing the concentration and activity of acid phosphatase, phytosiderophore, and ferric reductase in the root area helping in the absorption of macro and micro nutrients in the less fertile land.

However, the intercropping system has problems such as light, water, and nutrients competition between plants constituent. Reducing of the competition on the system is needed by crops density adjustment. Understanding 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 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 grain yield of upland rice intercropped with soybeans at different crops population in sandy coastal area.

**MATERIALS AND METHODS**

The study was conducted in Samas sandy coastal area, Bantul, Yogyakarta with a 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 proportion population of crops included:

a. Upland rice monoculture (100:0)

b. Intercropping upland rice and soybeans, 80% of upland rice + 20% soybean (80:20)

c. Intercropping upland rice and soybeans, 60% of upland rice + 40% soybean (60:40)

d. Intercropping upland rice and soybeans, 40% of upland rice + 60% soybean (40:60)

e. Intercropping upland rice and soybeans, 20% of upland rice + 80% soybean (20:80).

Observations were done on: leave area (cm2), number of tillers, specific leaf area (m2 g-1), root-shoot ratio, net assimilation rate (g dm-2 week-1), crop growth rate (g dm-2 week-1), number of panicles per hill, percentage of productive tillers (%), and yield per hill (g).

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

SLA = $\frac{LA}{WL}$ (m2 g-1) (1)

Where LA and WL were leaf area (m2) and leaf dry weight (g), respectively.

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

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

Where W1 and W2 were the total plant dry weight (g) at time T1 and T2, respectively. LA1 and LA2 were leaf area (dm2) at time T1 and T2, respectively.

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

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

Where GA was ground area (dm2)

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

**RESULT AND DISCUSSION**

**Growth components** **of upland rice**

The result of variance analysis on several growth variables showed in Table 1. The number of tillers, leaf area, net assimilation rate, and crop growth rate of upland rice showed significantly different, but the specific leaf area showed no significant different.

The crops proportion between rice and soybean of 60:40 was able to produce the higher number of tillers than other crops proportion and it was not significantly different from the crops proportion of 80:20 and 40:60. The decreasing number of tillers occurred under crops population of 20:80. And then the crops population of 60:40 and 40:60 gave higher leaf area than other proportion population. Leaf area on the proportion population of 60:40 and 40:60 increased that were 28,76% and 34,69% from the leaf area of monoculture system (100:0), respectively. It was predicted that the increased of soybean proportion under intercropping system gave a positive impact that was the availability of nitrogen for upland rice from the N2 fixation by soybean nodule. However, the crops proportion of 20:80 gave a negative impact to decrease the leaf area of upland rice. At 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 when competing to obtain the growing space and light.

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Treatment** | **Number of tillers** | **Leaf area** | **SLA** | **NAR** | **CGR** |
| **Upland rice : Soybean** |  | ...cm2... | ..m2 g-1.. | ..g dm-2 week-1.. | ..g dm-2 week-1.. |
| **100:0** | 18,78 b | 1601,84 b | 0,029 a | 0,245 b | 1,09 b |
| **80:20** | 20,33 a | 1598,01 b | 0,026 a | 0,260 b | 1,07 b |
| **60:40** | 21,11 a | 2062,06 a | 0,028 a | 0,309 a | 1,45 a |
| **40:60** | 21,00 a | 2157,51 a | 0,030 a | 0,334 a | 1,44 a |
| **20:80** | 18,22 b | 1584,14 b | 0,026 a | 0,250 b | 0,93 b |
| **Mean** | 19,89 | 1800,71 | 0,028 | 0,280 | 1,20 |
| **CV (%)** | 2,33 | 4,04 | 18,62 | 8,55 | 14,86 |

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

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 (R2 = 0,6933), it was clear that higher leaf area will be affected the net assimilation rate to increase (Figure 1). Dry matter was a source of energy that will be distributed to parts of the crop as a support plant growth. The increased 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. In addition to the decreased of leaf area of the upland rice in the crops proportion of 20:80 has been 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 increased 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 crop began 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.

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: das is day after showing. Number followed by the same letter in the column indicates not significantly different according to LSD at 5% levels.

Figure 1. Relationship of leaf area and net assimilation rate

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 (Table 1). 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 shaded 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 in photosystem I and II on thylakoid membranes. In addition, 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 dan NADPH digunakan dalam proses reaksi gelap sebagai energi. Pada reaksi gelap, 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 would result the lower of ATP and NADPH in light reactions which 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 hill, but was not significant different on 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.

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 hills** |
| **Upland rice : Soybean** | ...%... |  | ...g... |
| **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: Note: number followed by the same letter in the column indicates not significantly different according to LSD at 5% levels.

The grain yield per hill was shown (Table 3) that the crops proportion of 60:40 and 40:60 gave yield per hill that was 17,17 g and 16,46 g, respectively. These were 69,50% and 62,55% of grain yield per hill 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 = 4,2636x2 - 3,2292x + 11,289 (R2 = 0,5483) (Figure 2), 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 was shown that the relationship between the number of panicles with the grain yield was the form of quadratic curve where y = -0,1378x2 + 5,296x – 34,934 (R2 = 0,3731) (Figure 2). 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 2). An increase in the number of panicles exceeding the optimum point was not able to increase grain yield.

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 higher growth and grain yield were influenced by the increasing soybean proportion. The increasing of soybean proportion was able to provide nitrogen supply from N2 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-1. While the research Vitousek *et al*. (2002) explained that the ability of legume crops fixes N that was 100 kg N ha-1 season-1 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. The narrow spaces affected to higher competition between crops. It could be seen in the 20:80 crops proportion treatment which has less yield (12,63 g) compared to the 60:40 and 40:60. The more soybean proportion (80%) resulted competition in getting light due to the growth fast of soybean and occupy the space. It was shown that the crop growth at 20:80 treatment became to obstruct (Table 1) and the lower yield (Table 3) than the other treatments.

Figure 2. Relationship of crop growth rate with yield per hill (A) and number of panicles with yield per hill (B).

**CONCLUSION**

The crops proportion of 60:40 and 40:60 in upland rice and soybean under intercropping systems are yielding 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 were able to increase the panicles and yields.

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