The Intercropping System of Rice and Soybean in Coastal Sand Area

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Abstract- Coastal sandy land is marginal land that has the potential for upland rice production but has low soil fertility. The insertion of soybean plants is considered to be able to increase the fertility of coastal sandy soil through the fixation of N_2 by the root nodules of soybean plants which can be used for the growth of upland rice plants. This study seeks to investigate the growth, crop yields, and land equity ratios of upland rice and soybean intercropping on sandy coastal land. The research was carried out in Bantul, Yogyakarta's Samas Coastal Sand. One factor, three replications, and a complete randomized block design (RAKL) were employed in this investigation. In this research, upland rice and soybeans were treated in six population proportions: 100:0, 80:20, 60:40, 40:60, and 20:80. According to the findings, upland rice and soybean had better total dry weights in the population ratios of 60:40 and 40:60 than did the other populations. The yields of upland rice with a population proportion of 60:40 gave the same yields as monoculture upland rice (100:0), but yields of soybean intercropping system were still lower than soybean monoculture systems (0:100). The population proportion of 60:40 gives a better land equity ratio (LER) compared to the other population proportions, namely 1.60.

Keywords: intercropping system, land equivalent ratio, replacement series, sand soil

I. Introduction

An archipelago nation called Indonesia has a potential area of 1,060,000 ha of coastal sand, which often includes marginal land [1]. Although coastal sandy soil has a relatively high coarseness, it has the capacity to sustain the growth of food crops such upland rice since it is supported by the availability of sufficient groundwater and sunlight. The high sand fraction (> 70%) causes more macro pores than micro pores so that the ability of the soil to hold nutrients and water is low. The low ability of sandy soil to bind nutrients and water has an impact on the easy loss of N nutrients due to leaching because N is easily soluble in water [2]. This causes the fertility of sandy soil to be low [3].

To overcome the low fertility of sandy soil can be done in various ways, namely by adding clay, adding organic matter, or other materials that can reduce water infiltration in the sandy soil. However, there are other biological ways that are thought to be able to provide N naturally in sandy soils, namely by planting soybeans between upland rice plants or using an intercropping system. A benefit of intercropping with soybean plants is that they can fix N_2 in the atmosphere through their root nodules, which have a symbiotic relationship with Rhizobium bacteria, and produce a nitrogen contribution of 65–115 kg N ha^{-1} [4][5]. For upland rice grown in low-fertility coastal sandy soils, this will assist deliver nitrogen.

Because it encourages niche complementarity and interspecific promotion among a variety of intercropping combinations, cereal and legume intercropping has been widely employed throughout the world [6]. When compared to the respective monocultures, almost all published reports on legume-cereal intercropping demonstrated yield benefits [7][8]. Additionally, compared to traditional monocultures, the intercropping agroecosystem offers higher output stability [9][10]. Studies on crop strip intercropping have shown that system production can be effectively increased since intercropping crops frequently require less input (such as fertilizer N and insecticides) [11].

Rice and soybean, which are tall and short plants, can be planted in alternate rows in order to generate an umbrella structure that is helpful for boosting light transmittance and light energy interception rates [12][13]. The functioning leaves accessible space, light intensity, and rate of photosynthetic development of the intercropped rice all increased considerably more than those of rice grown in a monoculture as the crops grew taller. However, the intercropping method causes crops to compete with one another for nutrients, water, and light. Crop production and stability are impacted by photosynthetic traits, which in turn are influenced by the model used for crop planting [14]. In order to reduce competition, it is crucial to manage the population proportion in the upland rice and soybean intercropping system. If the right population ratios are applied in the intercropping system to maximize growth space, light dispersion, and nutrient availability, upland rice can grow as well as soybeans. This study will look at the growth, crop yields, and land equity ratios of an intercropping system of upland rice and soybeans on sandy coastal locations.

II. Materials and Methods

2.1. Experimental Design and Crop Management

The research was carried out in the plant production management laboratory at Universitas Gadjah Mada and on the Samas coastal sand in Bantul, Yogyakarta, which is 10 meters above sea level. The research was conducted from December 2016 to March 2017. Materials utilized for upland rice and soybeans included the Segreng Handayani rice variety, the Anjasmoro soybean variety, 20 t. ha^{-1} of manure, 300 kg. ha^{-1} of urea, 200 kg. ha^{-1} of SP36, and 150 kg. ha^{-1} of KCl. The field experiment used a completely randomized block design with three replications. The percentage of treated plants consists of the following:

a. Rice Monoculture (100:0).
b. Rice 80% : Soybean 20% (80:20).
c. Rice 60% : Soybean 40% (60:40).
d. Rice 40% : Soybean 60% (40:60).
e. Rice 20% : Soyeban 80% (20:60).
f. Soybean Monoculture (0:100).

2.2. Measurement

The data observed in this study included plant growth and yield variables including plant height (cm), plant dry weight (g. $crop^{-1}$), and plant yield (t. ha^{-1}). Then to determine the level of efficiency and land productivity of rice and soybean intercropping systems, the value of the land equivalent ratio (LER) is calculated:

$$LER = (Y_{ir}/Y_{sr}) + (Y_{is}/Y_{ss})$$

where Yir and Yis stand for the respective actual yields of intercropped rice and soybean. The yields of sole rice and sole soybean are Ysr and Yss, respectively. If the LER value is greater than 1, intercropping is advantageous and if it is lower than 1, intercropping is a disadvantage.

With a 5% error rate and a fully randomized block design, the collected observational data were then subjected to Analysis of Variance (ANOVA) using Microsoft Excel macro add-ins (DSAASTAT version 1.101). If the analysis of variance revealed significant differences, the collected observational data were then further investigated using the least significant difference test (LSD) [15].

III. Result and Discussion

As a result of genetic, environmental, and cultivation management factors, plant height growth is a growth indicator variable that is easily observed in plants. According to the variance findings, both upland rice and soybeans experienced a significant effect ($\alpha = 0.05$) from the intercropping system with varying crops proportions on plant height growth.

Table 1. Plant height of upland rice and soybeans in crop proportions in the intercropping system

Crops proportion	**Plant height (cm)**	
	Rice	**Soybean**
Rice : Soybean		
100 : 0	102.11 b	-
80 : 20	103.89 b	88.22 bc
60 : 40	111.56 a	82.22 c
40 : 60	112.00 a	82.44 c
20 : 80	103.33 b	90.89 ab
0 : 100	-	96.67 a
Average	106.58	88.09
CV (%)	3.23	4.18

Note: the numbers in the column followed by the same letter show no significant difference based on the 5% LSD test.

When compared to other crop proportions, such as 111.56 cm and 112.00 cm or with an average rice plant height of 111.78 cm, the crop proportions of 60:40 and 40:60 provide the optimum height growth. The plant height dropped by 7.56% when the population of rice fell below 40%. The plant height will then fall by 7.06% to 8.65% if the rice population rises by more than 60% or becomes more dominant than the soybean population.

According to the description of the anjasmoro soybean plant variety, the height of the anjasmoro soybean plant was in the range of 64-68 cm, however soybean plant height in the monoculture system (0:100) exhibited high growth reaching 96.67 cm. This is predictable given that soybean plants' height elongation results from their leaves' mutual shading of one another. This is a result of the constrained room for expansion that results from a population ratio of 0:100 (soybean monoculture). Low light conditions cause auxin to be accumulated by soybean plants more than usual, which results in a 2.1% increase in plant height [16]. But in general the enhanced assimilate translocation is also a sort of accelerated cell division that contributes to the growth in plant height. This has to do with how well plants can do photosynthesis since the assimilate produced as a result of photosynthesis is transferred to the many plant organs that require it afterwards. A source of energy for cell proliferation and enlargement that increases plant height is the dry matter produced by photosynthesis [17].

Based on the variance of total plant dry weight data, it was demonstrated that changing the proportions of plant populations in the intercropping system significantly affected the total dry weight of upland rice and soybean plants (Table 2). The upland rice and soybean plants may grow their dry weights the fastest when the population ratios are set at 60:40 and 40:60, respectively (Table 2). The population ratio of 80:20 also gives soybeans plenty of room to expand, resulting in ideal dry matter formation because plant leaves do not obscure one another due to the considerably broader growth area. In order for plants to successfully acquire light energy for photosynthesis, which often occurs under low light intensity circumstances, shade causes an increase in leaf area [6]. The amount of photosynthate stored in the receiving organs falls as a result of a reduction in net assimilation, which in turn causes a reduction in plant dry weight. Shade can also reduce the main light radiation that is active in photosynthesis. The ability of legume plants to provide nitrogen elements around the plants through N_2 fixation by their root nodules explains how management of intercropping cultivation systems by controlling the ideal population of legume plants can increase the accumulated dry weight of the surrounding plants [18]. In order for the assimilate to result in an increase in dry weight, photosynthesis must be functioning properly for there to be an increase in dry weight [19].

Table 2. Total dry weight of upland rice and soybean in crop proportions in the intercropping system

Crops proportion	Crop dry weight (g)	
	Rice	Soybean
Rice : Soybean		
100 : 0	28.43 b	-
80 : 20	28.48 b	25.67 a
60 : 40	37.44 a	27.60 a
40 : 60	37.19 a	25.41 a
20 : 80	25.27 b	16.71 b
0 : 100	-	16.97 b
Average	31.36	22.47
CV (%)	13.89	9.30

Note: the numbers in the column followed by the same letter show no significant difference based on the 5% LSD test.

Crop proportions had a substantial impact on the yield of upland rice and soybeans, according to the results of crop yield variance (Table 3). According to upland rice population ratios of 100:0 (upland rice monoculture), 80:20, and 60:40, upland rice yield was better in these proportions than in the proportions of 40:60 and 20:80. It is intriguing that the upland rice monoculture system (100:0) and the 60:40 population ratio both produce high-quality results. This shows that when upland rice is intercropped with soybeans and managed by the population ratio (60:40), it can yield the same outcomes as a monoculture system.

Table 3. Upland rice and soybean yields in the intercropping system at varied population densities

Crops proportion	Yield (ton .ha^{-1})	
	Rice	Soybean
Rice : Soybean		
100 : 0	3.24 a	-
80 : 20	3.15 a	0.99 e
60 : 40	3.09 a	2.08 d
40 : 60	1.98 b	2.41 c
20 : 80	0.76 b	2.85 b
0 : 100	-	3.24 a
Average	2.44	2.31
CV (%)	8.85	5.72

Note: the numbers in the column followed by the same letter show no significant difference based on the 5% LSD test.

With regard to soybeans, as opposed to upland rice, the monoculture system had the maximum yield when compared to the intercropping system. Soybeans grown in monoculture (0:100) do have a bigger population than those grown in intercropping systems, where the population is controlled, and as a result, the yields from the monoculture system are also high.

A crop growing management that can raise the productivity of the land is intercropping. Utilizing indices of land use efficiency or the land equivalent ratio (LER), one can compare the level of land efficiency. The productivity of land used for intercropping and monoculture can be determined by the LER value. The value of LER is determined in order to assess whether the intercropping system under study is effective in terms of land usage or not. The intercropping cropping plan is more productive than monoculture if the analysis's findings reveal that the LER value is larger than 1 (> 1) [5]. Additionally, the productivity and composition of plant communities influence a variety of ecological processes, including crop intercropping system competition [20]. According to the LER calculation results, the highest LER value was achieved at a crop proportion of 60:40 of 1.60 (Table 4). This has to do with the amount of grain and soybean seeds generated per crop hectare. A high LER in the population proportion setting of 60:40 indicates that, especially with the monoculture system, this crop proportion's land usage is more productive and efficient than the others.

Table 4. Land equity ratios in crop proportions in the intercropping system

Crops proportion	**LER of Rice**	**LER of Soybean**	**Total of LER**
Rice : Soybean			
100 : 0	1.00	-	1.00
80 : 20	0.97	0.31	1.28
60 : 40	0.95	0.65	1.60
40 : 60	0.61	0.75	1.36
20 : 80	0.23	0.88	1.12
0 : 100	-	1.00	1.00

IV. CONCLUSION

In comparison to other crop proportions, the 60:40 and 40:60 crop ratios produced superior growth in the rice and soybean crops. The production of rice and soybeans, however, responded differently; high yields of rice were discovered in plant ratios of 60:40 and 40:60, but the maximum yields of soybeans were found in monocultures. However, the intercropping system with a population ratio of 60:40 produces the highest LER compared to the other population ratios, namely 1.60, depending on the effectiveness and productivity of the land used. This suggests that compared to other population arrangements, especially monoculture systems for both upland rice and soybeans, land utilization at a crop percentage of 60:40 is more effective and productive.

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