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Effect of Intercropping with Soybean on Growth and Yield of Several Promising Lines of Black Rice in Aerobic Irrigation System

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Abstract**—*Rice is normally cultivated by the farmers under flooded conditions. This study aimed to examine the effect of additive intercropping with soybean on growth and yield of three promising lines of black rice grown on raised-beds under an aerobic irrigation system. The experiment was carried out on an irrigated rice growing area located in Dasan Tebu (-8.653912, 116.130813), West Lombok, Indonesia, from April to August 2021, which was arranged according to Split Plot design, with three blocks and two treatment factors: black-rice genotypes as the main plots (G3, G9, G4/15), and intercropping as the subplots (T0= monocrop and T1= rice-soybean-intercropping). On the intercropping beds, soybean of Dena-1 variety was relay-planted in additive series between double-rows of black-rice at two weeks after seeding of black-rice. Results indicated that intercropping with soybean increased growth and yield components of black rice with an average grain yield of 36.95 g/clump in T1 and 32.63 g/clump in T0. Grain yield was also different between genotypes with the highest grain yield of 39.32 g/clump in G4/15 line. However, the significant interaction between factors on biomass weight indicated that both G9 and G4/15 lines showed positive but G3 negative response to additive intercropping with soybean, which reasons are still unclear and need further investigation, although it seems that the G4/15 line was the most responsive to intercropping with soybean in increasing black-rice grain yield, with the highest grain yield was on G4/15 line intercropped with soybean (42.73 g/clump or 8.55 ton/ha).*

Keywords**—*Black rice, intercropping, additive series, soybean, aerobic irrigation system***

I. INTRODUCTION

Rice is an extremely versatile crop, which can grow in various different environmental conditions, i.e. from dry to flooded condition, and from low to high altitudes. Rice is grown in all the six continents of the world (Asia, Africa, Australia, Europe, North America, South America), and rice is the staple food for nearly half of the world's population [1]. However, rice is not just staple food. Rice has a lot of advantages for human health because rice contains various biomolecules capable of health-promotion and therapeutic activity, especially the colored grain rice [2].

Based on the color of the whole grains, there are white, brown, yellow (golden), red, purple and black rice, depending on the levels of its anthocyanin content. Colored rice, especially red, purple and black rice, possess unique color and flavor, as well as health benefits due to the presence of anthocyanins and other bioactive compounds, such as fat-soluble bioactive components, in particular, c-oryzanols, vitamin E isomers, and carotenoids [3].

In Indonesia, there are also many local cultivars of black rice grown across the country, and the cultivar names are region-specific depending on in which region the cultivars originate, and black rice in Indonesia is used as a functional food for improving and maintaining human health [4]. In Lombok, Indonesia, teaching staffs of the Faculty of Agriculture, University of Mataram, had produced some promising lines of black rice through crossbreeding and further selection, from which several promising lines of black rice had been developed, which are non-glutinous black rice genotypes [5], unlike the black glutinous rice cultivars that are commonly known and consumed by the community. Some of the promising lines had a relatively high yield potentials under irrigated growing conditions [5].

In Indonesia, rice crops in irrigated areas are grown under flooded irrigation systems, in which the soil is puddle and inundated with irrigation water from transplanting the seedlings until few weeks before harvest, and in most cases, irrigation water even flows between rice paddocks. This technique of rice cultivation is certainly wasting irrigation water. According to Yaligar et al. [6], the conventional techniques required irrigation water up to 20,260 m^3/ha, while dry seeded direct planting technique only required 4,260 m^3/ha. In more recently, there have been several water-efficient techniques of growing rice developed, such as the system of rice intensification (SRI) initially developed in Madagascar [7] and aerobic rice systems (ARS) [8] at IRRI, in the Philippines. By growing rice on raised-beds under aerobic irrigation systems, rice plants can be intercropped in an additive series with legume crops, such as soybean [9] or peanut [10], in which growth and yield of red rice were significantly higher in intercropping than in monocropped red rice, which indicates positive effects on intercropping red rice with legume crops on raised beds under an aerobic irrigation system.

This study aimed to examine the effect of additive intercropping with soybean on growth and yield of black rice grown on raised-beds under an aerobic irrigation system.

II. MATERIALS AND METHOD

The experiment in this study was carried out on an irrigated rice growing area located in Dasan Tebu, Ombe Baru village (-8.653912, 116.130813), South Kediri, West Lombok, Indonesia, from April to August 2021. There were three genotypes of black-rice planted on raised-beds under irrigated aerobic-system, with raised-bed design, planting geometry, and crop maintenance applied to the black-rice and soybean crops are as described by Wangiyana *et al.* [11], except for the type of rice was black rice in this study. In the intercropping treatments, soybean seeds of Dena-1 variety were relay-planted by dibbling them in additive series between double-rows of black-rice at two weeks after seeding of black-rice.

The field experiment was designed according to Split Plot design, consisting of three blocks and two treatment factors, namely black-rice genotypes (G) as the main plots (G3, G9, G4/15), and intercropping (T) as the subplots (T0= monocrop and T1= rice-soybean-intercropping).

The variables measured were growth and yield components, including height of rice plants and number of tillers at anthesis, dry straw weight, length and number of panicles, filled and %-unfilled grain number, 100-grain weight, and grain yield of black-rice per clump. ANOVA and Tukey's HSD at 5% level of significance were used to analyze the data using CoStat Windows 6.303.

III. RESULTS AND DISCUSSION

Results of data analysis summarized in Table 1 for growth related variables, and Table 2 for yield and yield components of those black rice genotypes indicated that in relation to growth related variables, intercropping with soybean significantly increased tiller number per clump, plant height, dry straw weight per clump, and percentage of panicle to tiller number while those genotypes were significantly different only in tiller number, which was the highest in G4/15 line and the lowest in G9 line (Table 1). In relation to yield components, intercropping with soybean significantly increased panicle number per clump and grain yield per clump, while the black rice genotypes were different only in panicle number per clump and grain yield per clump; panicle number was the highest in G4/15 line and the lowest in G9 line, which was similar to the number of tillers per clump and grain yield per clump, while grain yield per clump was the highest in G4/15 line and the lowest in G9 line (Table 2). Based on the results of correlation analysis, there were also different levels of significance between intercropping treatments (Table 3).

Table 1. Effects of treatments on growth related variables of black rice

Treatments	Tiller number per clump	Plant height (cm)	Dry straw weight (g/clump)	%-panicle/tiller number	Panicle length (cm)
T0: rice monocrop	17.78 b	78.22 b	21.30 b	89.44 b	21.94 a[1)]
T1:rice+soybean	19.44 a	91.89 a	27.62 a	92.85 a	22.28 a
HSD0.05	1.30	6.91	3.75	1.47	ns

G3 line	19.00 ab	83.08 a	27.76 a	91.09 a	22.02 a
G9 line	15.50 b	86.42 a	22.03 a	91.32 a	23.12 a
G4/15 line	21.33 a	85.67 a	23.58 a	91.03 a	21.20 a
HSD0.05	3.83	ns	ns	ns	ns
Interaction effect	ns	ns	ns	ns	ns

[1)] Remarks: Different number indicates significant different between levels of a treatment factor

Table 2. Effects of treatments on yield and yield components of black rice

Treatments	**Panicle number per clump**	**%-unfilled grains**	**Filled grains per clump**	**Above-ground biomass (g/clump)**	**Grain yield (g/clump)**	**Weight of 100 grains (g)**
T0: rice monocrop	15.89 b	14.49 a	88.62 a	58.97 a	32.63 b	2.24 a[1)]
T1:rice+soybean	18.06 a	15.34 a	91.01 a	59.52 a	36.95 a	2.22 a
HSD0.05	1.26	ns	ns	ns	3.39	ns
G3 line	17.33 ab	11.30 a	94.92 a	52.05 a	37.66 a	2.25 a
G9 line	14.17 b	16.33 a	86.10 a	63.18 a	27.48 b	2.21 a
G4/15 line	19.42 a	17.12 a	88.43 a	62.52 a	39.23 a	2.22 a
HSD0.05	3.46	ns	ns	ns	7.96	ns
Interaction effect	ns	ns	ns	s	ns	ns

[1)] Remarks: Different number indicates significant different between levels of a treatment factor

Table 3. Correlation coefficients and their p-values between variables

Yield components:	**Plant height**	**Tiller number**	**Dry straw weight**	**Panicle length**	**Panicle number**	**Filled grain number**	**100-grain weight**	**Biomass weight**
	------------------------------------- Under black rice monocrop (T0) -------------------------------------							
Panicle number/clump	-0.310	0.996	0.472	-0.528				
p-value	0.417	**0.000**	0.200	0.144				
Filled grains/panicle	-0.026	-0.140	0.368	-0.139	-0.152			
p-value	0.948	0.719	0.329	0.722	0.697			
Weight of 100 grains	0.007	0.102	-0.048	-0.128	0.094	0.360		
p-value	0.985	0.794	0.902	0.743	0.810	0.341		
Above-ground biomass	-0.072	0.674	0.913	-0.572	0.664	0.484	0.183	
p-value	0.854	**0.046**	**0.001**	0.108	0.051	0.187	0.638	
Dry grain yield/clump	-0.219	0.737	0.748	-0.573	0.732	0.516	0.332	0.954
p-value	0.572	**0.024**	**0.020**	0.106	**0.025**	0.155	0.382	**0.000**
	---------------------------------- Under rice + soybean intercropping (T1) ------------------------------							
Panicle number/clump	0.068	0.999	0.177	-0.125				
p-value	0.862	**0.000**	0.648	0.748				
Filled grains/panicle	0.797	0.113	0.647	0.643	0.132			
p-value	**0.010**	0.773	0.060	0.062	0.736			

Weight of 100 grains	0.765	0.370	0.776	0.177	0.394	0.574		
p-value	**0.016**	0.327	**0.014**	0.648	0.294	0.106		
Above-ground biomass	0.587	0.678	0.786	0.335	0.694	0.709	0.787	
p-value	0.097	**0.045**	**0.012**	0.378	**0.038**	**0.033**	**0.012**	
Dry grain yield/clump	0.417	0.889	0.371	0.119	0.899	0.541	0.554	0.865
p-value	0.265	**0.001**	0.326	0.759	**0.001**	0.133	0.122	**0.003**

Based on the results of correlation analysis in Table 3, plant height shows different levels of significance between monocropping and intercropping systems, in which under monocropped black rice, there was no significant correlation, but under rice+soybean intercropping system, plant height shows significant correlation with filled grain number per panicle and weight of 100 grains. From Table 1 it can be seen that plant height is significantly higher on black rice intercropped with soybean than on monocropped black rice. However, filled grain number per panicle and weight of 100 grains are not significantly higher on intercropped than on monocropped black rice plants (Table 2).

Nevertheless, grain yield per clump is significantly higher on the intercropped than on monocropped black rice plants (Table 2). Based on best subset regression (BSR) analysis, grain yield per clump is most related to above-ground biomass weight per clump, with the highest R^2 of 82.56% (p-value <0.001), but by excluding biomass weight in the BSR analysis, the most related variable to grain yield is panicle number per clump, with an R^2 of 69.74% (p-value <0.001), followed by tiller number per clump with an R^2 of 67.57% (p-value <0.001). When two X-variables are included in the BSR analysis, the two most related variables to grain yield are biomass weight (X1) and dry straw weight per clump (X2), with the highest R^2 close to 100.0% (p-value<0.001), which means that grain yield of the black rice per clump was mostly determined by these two variables. When biomass weight is excluded from the BSR analysis, the two most related variables to grain yield are panicle number (X1) and filled grain number per clump (X2), with an R^2 of 95.94% (p-value <0.001), followed by tiller number (X1) and filled grain number per clump (X2), with an R^2 of 95.52% (p-value <0.001).

From Table 1, it can be seen that tiller number and dry biomass weight per clump are significantly higher on the intercropped than monocropped black rice plants, and Table 2 shows that panicle number per clump is significantly higher on the intercropped than monocropped black rice plants. Therefore, although filled grain number per clump was not significantly higher on the intercropped than monocropped black rice plants, grain yield per clump could be significantly higher on the intercropped than monocropped black rice plants, due to the significant and positive correlation of grain yield with the determining variables such as panicle number, tiller number, biomass weight, and dry straw weight per clump.

The significantly higher tiller and panicle number of black rice per clump on the intercropped than monocropped black rice plants most probably related to the nutrition of the black rice plants, which could be better on the intercropped than monocropped black rice plants. Previous studies have reported that intercropped maize and peanut showed higher contents of various nutrients compared with their monocrops due to higher availability of various nutrients in the rhizosphere of maize-peanut intercrops than in that of their monocrops [12]. Since legume crops such as soybean and others have the ability to fix atmospheric nitrogen and deposit the fixed N to the soil [13], better nutrition of the intercropped black rice could also because of some N transfer from the legume plants to rice plants, such as from peanut to rice plants in aerobic system [14] and from soybean to sorghum plants [15]. Wangiyana *et al*. [10] also found that red rice plants intercropped with peanut in additive series showed greener leaves with up to one or two levels higher green color measured using the IRRI leaf color chart, which also indicated better N nutrition (higher N content) in leaves of the intercropped than the monocropped red rice plants.

In relation to the effect of different genotypes on grain yield of the black rice, it can be seen from Table 2 that G4/15 line shows the highest grain yield of 39.23 g/clump and the lowest grain yield of 27.48 g/clump is shown by the G9 line. These mean values of grain yield could be related to panicle number per clump which is also the highest on G4/15 line and the lowest on G9 line. In addition, BSR analysis indicated that grain yield per clump was most closely related to panicle number per clump.

Although the interaction effect between the treatment factor was not significant on grain yield per clump, based on their individual mean and standard error, it can be seen from Fig. 1 that the response of the three genotypes to intercropping in relation to grain yield was different between genotypes, in which both G9 and G4/15 lines shows positive and significant response to intercropping with soybean unlike the G3 line. However, the interaction effect was significant on the above-ground biomass weight (Table 2), in which both G9 and G4/15 lines shows positive and significant response to intercropping with soybean but G3 shows negative response to intercropping (Fig. 2). The reasons for this response need to be investigated further in further research projects.

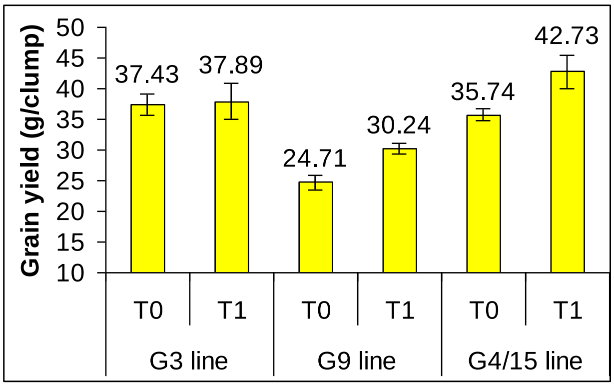

Fig. 1. Different responses of genotypes to intercropping with soybean in relation to grain yield of black rice

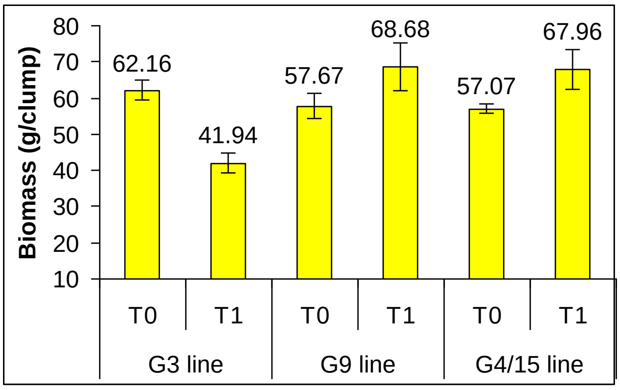

Fig. 2. Different responses of genotypes to intercropping with soybean in relation to biomass weight of black rice

IV. CONCLUSION

It can be concluded that additive intercropping with soybean can increase yield of black rice grown raised beds under an aerobic irrigation system, mainly due to an increase in tiller and panicle number per clump. Although different genotypes showed different responses to additive intercropping with soybean, there was no clear determining factors, and still need to be investigated further.

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