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Effects of Biofertilizer on Growth and Yield of Rice

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ABSTRACT: The effect of biofertilizer (compound of microbial inoculants or groups of micro-organisms) on growth and yield of rice was investigated. The experiment was carried out in a randomized complete block design with 3 replications and 7 treatments namely: RF = N-P_2O_5-K_2O (11-5.5-4.8 kg $10a^{-1}$); half of the recommended fertilizer rate, HRF = N-P_2O_5-K_2O (5.5-2.75-2.4 kg $10a^{-1}$); HRF + Bio 250 = HRF combined with 250 kg biofertilizer $10a^{-1}$; HRF + Bio 500 = HRF combined with 500 kg biofertilizer $10a^{-1}$; Bio 250 = 250 kg biofertilizer $10a^{-1}$; Bio 500 = 500 kg biofertilizer $10a^{-1}$; and NF = No Fertilizer. Results showed that the recorded values of plant height, tiller number and chlorophyll content at 40 to 60 days after transplanting (DAT) in HRF + Bio 500 were significantly higher than those recorded in the RF treatment. Similar observations between these two treatments were only recorded from 60 DAT onwards. Yield components were also superior in HRF + Bio 500 treatment and comparable to that of RF. The highest grain yield obtained in HRF + Bio 500 treatment (785.8 kg $10a^{-1}$) was statistically similar to that of RF (739.8 kg $10a^{-1}$) but significantly higher than that of NF (506.7 kg $10a^{-1}$). Finally, head grain recovery (90.9) was low while chalkiness (0.03) was high at HRF + Bio 500 treatment as compared with RF, which were (96.1) and (0.3), respectively. Results showed that combined treatment of HRF and 500 kg biofertilizer $10a^{-1}$ has similar effects on the growth and yield of rice with that of RF.

Keywords: biofertilizer, yield, root activity, T/R ratio

The indiscriminate and excessive application of chemicals in crop production has been generally recognized as damaging to the environment in ways such as leaching out and polluting water basins, destroying micro-organisms and friendly insects, making the crops more susceptible to the attack of diseases, reducing the soil fertility and thus becoming an obstacle to soil productivity and causing irreparable damage to the overall system (Huang, 2000). The use of these agrochemicals can be expected to increase more in face of growing demands for agricultural produce driven by increasing population and continuous decline in land use devoted to agricultural production (Isherwood, 2000). Such scenario can most likely be expected in rice production as rice remains the staple food of much of world's population.

While agricultural chemicals have negative impacts to the environment, decreased dependence on these chemicals cannot be expected in the near future as it is impossible to sustain high agricultural yields without relying on them. However, effective alternative strategies that can significantly reduce inorganic chemicals without compromising yield and quality of agricultural produce can be explored. One such alternative that is worth investigating is the use of biofertilizers (Parr *et al.*, 2000). Presently, quite a number of studies on the efficiency of biofertilizers in rice production, and in agricultural production in general, are recorded; several formulations of biofertilizers developed by reputable research institutions especially in developing countries are available; and continuous search for effective microorganisms for biofertilizer formulation are existing (Dalmacio, 2006).

Biofertilizers are inoculants of live microorganisms capable of fixing atmospheric nitrogen, solubilizing phosphate, stimulating plant growth through synthesis of growth promoting substances, and adding considerable amount of organic matter to the soil increasing its fertility (Vessey, 2003). Thus, more farmers and scientists are recognizing the use of biofertilizer as effective for sustainable agriculture that can maintain an environment-friendly approach for nutrient management and ecosystem function (Sawar, 2005; Wu *et al.*, 2005).

In this study, the effect of biofertilizer on the growth, yield and quality of rice was investigated. The substrate of the biofertilizer used in this experiment was prepared from household waste materials and food residues. This investigation was carried with the aim of reducing the amount of mineral N fertilizer applied to the soil while maintaining healthy yield of rice.

MATERIALS AND METHODS

The experiment was conducted in 2004 at the experimen-

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tal field of Agricultural Research & Extension Services in Chilgok, Kyungpook. Rice variety Junambyeo was provided by the Rural Development Administration (RDA), Kyungbook Province while biofertilizer was obtained from the Korean Forest Research Institute (KFRI). All management practices in rice cultivation recommended by RDA were employed. The experiment was laid out in a randomized complete block design with 7 treatments and 3 replicates. The treatments were as follows: recommended fertilizer rate, RF = N-P_2O_5-K_2O (11-5.5-4.8 kg $10a^{-1}$); half of the recommended fertilizer rate, HRF = N-P_2O_5-K_2O (5.5-2.75-2.4 kg $10a^{-1}$); HRF + Bio 250 = HRF combined with 250 kg biofertilizer $10a^{-1}$; HRF + Bio 500 = HRF combined with 500 kg biofertilizer $10a^{-1}$; Bio 250 = 250 kg biofertilizer $10a^{-1}$; Bio 500 = 500 kg biofertilizer $10a^{-1}$; and NF = No Fertilizer. The experimental plots had a dimension of 5.6 m $\times$ 2 m (11.2 m^2) and a strip of 1 m was left to separate each plot.

Parameters investigated were agronomic characters, yield and yield components, and rice quality. The agronomic characters included plant height, tiller number, leaf area index, T/R ratio, root activity, chlorophyll content. Chlorophyll content was measured in mid-portion of the uppermost fully expanded leaf using chlorophyll meter (SPAD-502, Minolta, Ramsey, NJ). Plant height and tiller number were measured from 40 to 80 days after transplanting (DAT) at 10-day interval. Yield components included panicle length, number of panicles $hill^{-1}$, ripening ratio, number of spikelets $panicle^{-1}$, 1000 grain weight and total yield were all recorded after harvesting. Leaf area index was determined at 30 DAT by measuring from a 1 meter row of plants using LI 3100 (Glen Spectra UK) leaf area meter. Top to root ratio (T/R Ratio) was computed from the dry weights of tillers and roots.

The rice plant root oxidizing activity was measured using the methods modified by Ota (1970). Fresh roots (1 g) of the rice plants were taken 30 DAT and transferred into a 150 mL flask containing 50 mL of 20 mg L^{-1} α-naphthylamine. The flasks were incubated for 3 h at room temperature in a HB-201SF shaker. The solution was then filtered and 2 mL filtrate was mixed with 1 mL of 100 mg L^{-1} $NaNO_2$ and 1 mL sulphanilic acid. The color developed in 30 to 60 min was read at 510 nm using a spectrophotometer (U-2001).

Rice grain quality characteristics such as head, broken, chalky, damaged, colored and cracked grains were analyzed using grain analyzer (Cervitec 1625 Grain Inspector, Foss Tecator, Sweden).

All statistical analysis of data was done using SAS program (SAS Institute, Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

Effect of biofertilizer on agronomic characters of rice

The effects of different levels of chemical, biofertilizer and mixtures of biofertilizer and chemical fertilizer on agronomic characteristics of rice plants were presented in Table 1. Plant height, number of tillers and chlorophyll contents were recorded from 40 to 80 DAT at 10-day interval. For all agronomic characters observed, data shows (Table 1) that the values obtained at HRF + Bio 500 treatment from 40 to 80 DAT were significantly higher than the other treatments. It can be noted that plant height of RF treatments became statistically similar with that of HRF + Bio 500 treatment at 60 DAT only.

Leaf greenness is a measure of chlorophyll content and is used as an important indicator of growth as it determines the photosynthetic of the plant. It can be directly related to the availability of nitrogen supply since nitrogen is necessary

Table 1. Effects of different levels of bio-and chemical fertilizers on the agronomic characters of rice plant.

Treatment	Agronomic Characters														
	40 DAT			50 DAT			60 DAT			70 DAT			80 DAT		
	H	TN	C	H	TN	C	H	TN	C	H	TN	C	H	TN	C
RF	65.7ab	20.8a	33.9cd	70.9ab	18.3a	33.8b	80.9a	16.5ab	32.2bc	92.0a	16.1a	36.8ab	96.9a	15.0a	37.4ab
HRF	61.6c	18.3bc	32.4de	67.3c	18.7a	29.8c	74.5bc	15.5b	30.3cd	86.7bc	15.1ab	34.8c	90.8bc	14.5a	35.0cd
HRF + Bio 250	66.4ab	18.6ab	35.2bc	71.6ab	17.5ab	35.2ab	77.8ab	16.7ab	33.2ab	89.5ab	16.0a	36.0b	97.2a	15.4a	36.7abc
HRF + Bio 500	67.5a	19.0ab	38.4a	73.5a	17.5ab	35.6ab	80.3a	17.4a	34.9a	91.9a	15.9a	37.7a	98.2a	15.5a	38.2a
Bio 250	63.7bc	17.7bc	33.9cd	68.8bc	16.4b	31.0c	73.3c	13.8c	32.5bc	83.6c	15.2ab	33.7c	88.5cd	14.1a	35.2cd
Bio 500	64.2bc	17.5bc	37.2ab	71.1ab	17.9ab	35.7a	75.4bc	16.8ab	35.2a	85.4c	15.0ab	36.2b	92.4b	14.8a	35.9bcd
No fertilizer	58.2d	16.0c	31.2e	63.8d	12.9c	28.5d	68.3d	13.4c	29.1d	77.4d	13.3b	34.1c	85.3d	11.3b	34.1d

RF: recommended fertilizer rate; HRF: half recommended fertilizer rate; Bio 250: biofertilizer 250 kg $10a^{-1}$; Bio 500: biofertilizer 500 kg $10a^{-1}$; DAT: days after transplanting; H: plant height, TN: tiller number, C: chlorophyll content. The same letters in each column are not significantly different at 5% level by DMRT.

for cellular synthesis of chlorophyll. The chlorophyll content of the rice plant was consistently high in the HRF + Bio 500 from 40 to 80 DAT as compared to the other treatments (Table 1). The chlorophyll content of RF treatment became statistically similar with that of HRF + Bio 500 treatment only after 60 DAT. It is also interesting to note that observed chlorophyll content of Bio 500 treatment was statistically similar with that of the HRF + 500 treatment. Haroun and Hussein (2003) reported that seed pretreatment of biofertilizer resulted in increased chl a, chl b, total chlorophyll and total pigment contents of the plant. Also, Biswas *et al.* (2000) reported an increase in leaf greenness of rice inoculated with rhizobium.

Table 1 also shows that on all agronomic characters, values obtained between the HRF and biofertilizer treatments were statistically similar. Wu *et al.*(2005) reported that biofertilizer application significantly increased growth of *Zea mays* and had similar effects compared with half the amount of organic fertilizer or chemical fertilizer treatments.

The relative growth rate (growth rate per unit leaf) of the leaves determines the rate with which leaves grow in area in the early stages of crop growth. It is an important factor in predicting crop growth and yield (Yin, 2003; Yoshida, 1986) and biomass production. Figure 1 shows similar effect of biofertilizer on the leaf area index (LAI) and T/R ratio as was observed in the other agronomic characters. The HRF + Bio 500 (7.3 and 6.1 for LAI and T/R ratio, respectively) treatment gave a statistically similar value with the other treatments except NF (4.4 and 4.8 for LAI and T/R ratio, respectively) while the biofertilizer treatments alone gave a statistically similar value with the NF treatment. LAI and biomass increased with increasing soil fertility. The results showed that the biofertilizer brought about a comparable LAI and T/R ratio with that of the RF. Furthermore, it can be observed from Fig. 1 that the effect of biofertilizer alone on both LAI and T/R ratio are statistically similar with that of the HRF as was observed in plant height, tiller number and chlorophyll content.

Sawar (2005) stated that due to the high organic matter content of these fertilizers, soil remains loose and dry, holds more moisture and nutrients, fosters growth of soil organisms, increases water infiltration rate, and promotes plant root development. Consistent with these observations, Fig. 2 shows that Bio 500 treatment had the highest root activity, which is statistically higher than the other treatments, followed by HRF+500 treatment while the lowest was obtained in HRF treatment. The result might have been resulted from that biofertilizer enhanced microbial activity around the root system which significantly increased root mass and improved nutrient uptake and plant health.

Finally, results showed that the biofertilizer used in this experiment has positive effects on the agronomic characters of rice plants which agrees with previously reported studies (Vessey, 2003; Matiru and Dakora, 2004; Wu *et al.*, 2005; Haroun and Hussein, 2003; Rodriguez and Reynaldo, 1999). These beneficial effects to plants can be attributed to the microorganism inoculants that enhance soil fertility and sufficiently make available plant nutrients and other growth promoting substances during the early stage of rice plant development. This study showed that biofertilizer can meet the nutrient demands of the plant that even reducing the RF to HRF and substituting biofertilizer, the plants can still

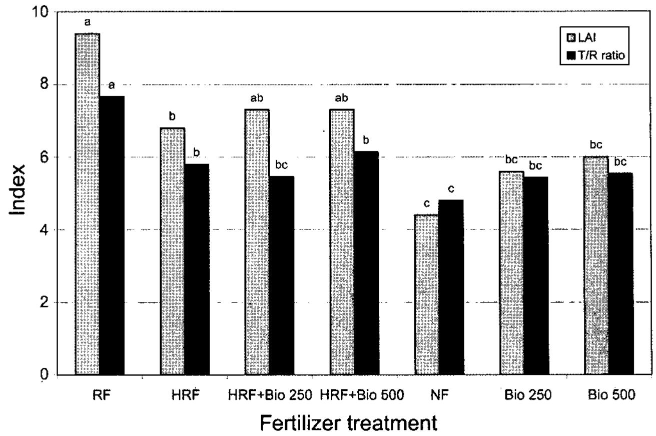

Fig. 1. Effects of the levels of bio-and chemical fertilizers on leaf area index and T/R ratio.
RF: recommended fertilizer rate; HRF: half recommended fertilizer rate; Bio 250: biofertilizer 250 kg $10a^{-1}$; Bio 500: biofertilizer 500 kg $10a^{-1}$; DAT: days after transplanting. The same letters in each column are not significantly different at 5% level by DMRT.

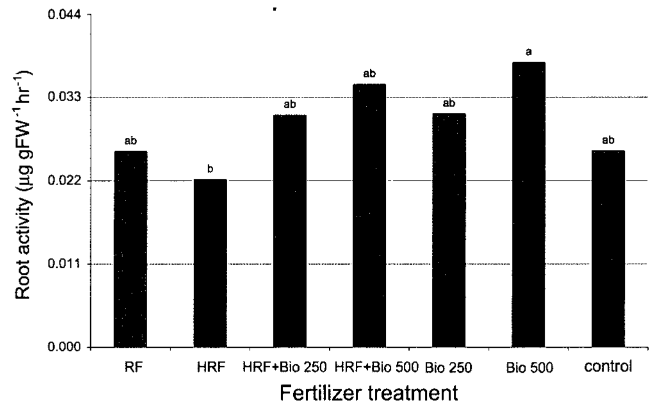

Fig. 2. Effects of the levels of bio-and chemical fertilizers on root activity.
RF: recommended fertilizer rate; HRF: half recommended fertilizer rate; Bio 250: biofertilizer 250 kg $10a^{-1}$; Bio 500: biofertilizer 500 kg $10a^{-1}$; DAT: days after transplanting. The same letters in each column are not significantly different at 5% level by DMRT.

grow and function comparable with those grown in RF.

Effect of biofertilizer on yield and yield components of rice

The effects of mixture of inorganic fertilizer and biofertilizer on the yield and yield components of rice were investigated and presented in Table 2. For the panicle length, the highest value was obtained in HRF + Bio 500 treatment but was not statistically different from the rest of the treatments except that in NF. In the case of thousand grain weight, no significant difference among treatments was observed. The major determinants of increased grain yield are the number of panicle, ripening ratio and number of spikelets. In these yield components, except for number of panicle per hill, the highest values obtained were in HRF + Bio 500 which were statistically similar with those obtained in RF and higher than those in NF. The values obtained in the yield components of biofertilizer alone treatment were comparable or similar with those recorded in either HRF or NF. Due to increased performance in the yield components, yield in HRF + Bio 500 treatment was the highest and was similar with that obtained in RF. Comparing the values obtained in HRF and Bio 500 treatments with that of HRF + Bio 250 shows that biofertilizer was effective in increasing the yield of rice. The lowest grain yield was obtained in the NF treatment.

The effect of biofertilizer in combination with inorganic fertilizer on the yield of rice cultivated alone or intercropped with other crops like soybean and *Vigna radiata*, is already well documented (Sawar, 2005; van Quyen and Sharma, 2003; Wu *et al.*, 2005; Matiru and Dakora 2004; Jha and Prasad, 2006; Singh *et al.*, 2001; Hashem, 2001; Kamaru *et al.*, 1998). The comparable performance of mixture of chemical fertilizer and biofertilizer can be attributed to the ability of microorganisms to maintain nitrogen supply all throughout the vegetative and reproductive growth of the plants. The N supply from soil and fertilizer adequately maintained at key growth stages is a very important factor for yield (Kropff *et al.*, 1993; Asif *et al.*, 1999). The superior yield and yield components observed in the HRF + 500 treatment can be correlated with the healthy growing plants

Table 2. Effects of mixtures of bio and chemical fertilizers on yield components of rice.

Treatment	Yield components					
	Number of panicle	Panicle length (cm)	Thousand grain wt.(g)	Ripening ratio (%)	Spikelets panicle^{-1}	Yield (kg 10a^{-1})
RF	15.4a	20.1abc	26.1a	85.1a	131.0a	738.9ab
HRF	13.5b	19.9bc	26.4a	79.6abc	115.9ab	602.4c
HRF + Bio 250	14.2ab	20.6ab	26.1a	82.1ab	122.1a	761.9ab
HRF + Bio 500	14.5ab	20.8a	26.1a	86.1a	133.7a	785.8a
Bio 250	13.3b	20.0abc	25.9a	75.9bc	120.0ab	612.4c
Bio 500	13.8ab	20.2abc	25.8a	78.3abc	119.7ab	719.5b
No fertilizer	11.7c	19.5c	26.0a	71.4c	103.3b	506.7d

RF: recommended fertilizer rate; HRF: half recommended fertilizer rate; Bio 250: biofertilizer 250 kg 10a^{-1}; Bio 500: biofertilizer 500 kg 10a^{-1}; DAT: days after transplanting. The same letters in each column are not significantly different at 5% level by DMRT.

Table 3. Effects of the levels of bio-and chemical fertilizers on appearance quality of white rice.

Treatment	Head	Broken	Cracked	Chalky	Coloured
			(%)		
RF	96.1a	1.2b	2.3cd	0.3a	0.0b
HRF	96.2a	0.5c	2.3cd	0.3ab	0.7ab
HRF + Bio 250	93.0b	1.1bc	4.5bc	0.2ab	1.2a
HRF + Bio 500	90.9b	2.0a	6.9a	0.03b	0.2ab
Bio 250	96.4a	0.8bc	2.6cd	0.2ab	0.2ab
Bio 500	91.3b	2.0a	6.4ab	0.2ab	0.03b
No fertilizer	97.2a	1.0bc	1.4d	0.2ab	0.2ab

RF: recommended fertilizer rate; HRF: half recommended fertilizer rate; Bio 250: biofertilizer 250 kg 10a^{-1}; Bio 500: biofertilizer 500 kg 10a^{-1}; DAT: days after transplanting. The same letters in each column are not significantly different at 5% level by DMRT.

as was shown by the agronomic characters. In general, results of this study showed the effectiveness of biofertilizer applied in supplement with HRF in increasing grain yields.

Effect of biofertilizer on rice grain quality

Table 3 shows the effects of biofertilizer and inorganic fertilizer on grain appearance. Comparing with the RF treatment, data showed that HRF + Bio 500 treatment both significantly decreased head and chalky rice recovery. In a study conducted at the International Rice Research Institute, it was shown that late N fertilizer application improved milling of rice grain (Perez *et al.*, 1996) while Leesawatwong *et al.*(2005) showed that added application of N fertilizer may increase hardness in rice grain and thus could make it more resistant to breakage during milling.

Results showed that the use of biofertilizer can decrease to half the amount of recommended inorganic fertilizer with effects on growth and yield similar to using recommended fertilizer alone. Now that the environment is facing problems on tremendous overloads of inorganic fertilizer detrimental to soil health and sustainable production, this study showed that biofertilizer, being an environment-friendly material, offers a viable alternative not just in maintaining high yield but also in protecting and conserving the environment. Furthermore, continuous search for biofertilizer and environment-friendly materials for crop production should be undertaken.

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