IMPROVING SYNTHETIC FERTILIZER USE EFFICIENCY THROUGH BIO-FERTILIZER APPLICATION IN RICE

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ABSTRACT

Efficient plant nutrition management enhances and sustains agricultural production and safeguards the environment. The use of organic and inorganic fertilizer has its advantages and disadvantages in terms of nutrient supply, soil quality and crop growth. Developing a suitable nutrient management system that integrates use of these fertilizers may be a challenge to reach the goal of sustainable agriculture. An experiment to improve synthetic fertilizer efficiency through bio-fertilizer (BF) application in rice was conducted at the Agricultural Research Institute, Dera Ismail Khan, in 2009. The results showed that combination of bio-fertilizer, nitrogen and phosphorous (500: 120: 90 kg ha^{-1}) exceeded all other treatments in number of tillers m^{-2}, number of panicles m^{-2}, number of spikelets $panicles^{-1}$, percent normal kernels, 1000-grain weight (g) and paddy yield (t ha^{-1}). The results also showed that bio-fertilizer along with different levels of nitrogen and phosphorous significantly increased the growth and yield components of rice crop. The use of bio-fertilizer along with N and P was found better than N and P alone. This study suggests that bio-fertilizer along with different levels of nitrogen and phosphorous (BF: 500 kg, N: 120 kg, P: 90 kg ha^{-1}) should be used for maximizing rice productivity, reducing inputs of chemical fertilizers and sustaining soil fertility.

Keywords: Rice, Commercial Fertilizer, Bio Fertilizer, Pakistan

INTRODUCTION

Rice (*Oryza sativa* L.) is the 2nd most important cereal crop of Pakistan which brings economic prosperity for the growers as well as earns billions of rupees through its export for the country. The average yield of rice is 2079 kg ha^{-1} in Khyber Pakhtunkhwa (KPK), which is low as compare to national average yield of 2212 kg ha^{-1} (Anonymous, 2008). There are many factors affecting rice productivity in the country, however, nutrient availability is of prime importance because of its effect on key physiological and developmental processes that determine plant growth. For optimum plant growth, nutrients must be available in sufficient and balanced quantities. Soils contain natural reserves of plant nutrients, but these reserves are largely unavailable to plants, and only a minor portion is released each year through biological activity or chemical processes. This release is too slow to compensate for the removal of nutrients by agricultural production and to meet crop requirements. Therefore, fertilizers are designed to supplement the nutrients already present in the soil (Chen, 2008).

The consecutive use of fertilizers also disturbs the equilibrium of agro-systems and pollutes the environment. Over application of chemical fertilizers can result in negative effects such as leaching, pollution of water resources, destruction of micro-organism, crop susceptibility to diseases attack, acidification or alkalization of the soil or reduction in soil fertility, thus causing irreparable damage to the overall system (Anonymous, 2009a).

To overcome nutrients deficiency and adverse effects of chemical cultivation, efforts have been made to exploit all the available resources of nutrients under the theme of integrated nutrients management.

Under this approach the best available option lies in the complimentary use of bio-fertilizers, organic manure and chemical fertilizers. Bio-fertilizers are essential components of this approach which increase crop yield by 20-30 percent, replace chemical N and P by 25%, stimulate plant growth, activate soil biologically, restore natural fertility, provide protection against drought and some soil borne diseases (Anonymous, 2009b).

There is increased emphasis on the impact on environmental quality due to continuous use of chemical fertilizers. The integrated nutrient management system is an alternative and is characterized by reduced input of chemical fertilizers and combined use of chemical fertilizers with organic materials such as animal manures, crop residues, green manure and composts. Management systems that rely on organic inputs as plant nutrient sources have different dynamics of nutrient availability from those involving the use of chemical fertilizers. For sustainable crop production, integrated use of chemical and organic fertilizer proved to be highly beneficial (Malliga and Subramanian, 2002).

Several researchers have demonstrated the beneficial effect of combined use of chemical, organic and bio-fertilizer to mitigate the deficiency of many secondary and micronutrients in fields that continuously received only N, P and K fertilizer for a few years, without any micronutrients or organic fertilizer. Chand *et al*. (2006) indicated that integrated supply of plant nutrients through farmyard manure (FYM) and fertilizer (NPK), along with green manuring, played a significant role in sustaining soil fertility and crop productivity. Kaur *et al*. (2005) observed an increase in microbial biomass C and N in soils receiving organic manures only or with the combined application of organic manures and chemical fertilizers compared to soils receiving chemical fertilizers. This study showed that balanced fertilization using both organic and chemical fertilizers is important for maintenance of soil organic matter (OM) content and long-term soil productivity in the tropics where soil OM content is low. Hashem (2001) showed that bio-fertilizer may reclaim the problem soils such as acid soils and saline soils and improve the fertility status by supplementing 25-35% N for rice cultivation.

The effect of organic fertilization and combined use of chemical and organic fertilizer on crop growth and soil fertility depends on the application rates and the nature of fertilizers used. In general, the application rates of organic fertilizers mostly are based on crop N need and estimated rates of organic fertilizer N supply, but do not consider the amount of P and K provide with organic fertilizer. However, the N/P ratio of organic fertilizer usually is significantly lower than the N/P optic ratio of the crop. With this in view, the present research was planned to see the effect of synthetic N and P in combination with organic fertilizers on growth and yield of rice.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Institute, Dera Ismail Khan, in 2009. It was laid out in a randomized complete block design with four replications. The net plot size was $2x5m^2$ with 10 rows, 5 m long and 20cm apart. The land was prepared by giving 3-4 ploughings (including disc plough, cultivator and rotavator operation). Hand weeding was done twice after 25 and 50 days after transplanting. Variety IR-6 was transplanted in 1st week of June. Various doses of nitrogen and phosphorous were applied along with a constant dose of K (60 kg ha^{-1}) and bio-fertilizer (500 kg ha^{-1}) in their respective treatments. Commercially available bio-fertilizer (Zameen-Dost: 15% organic matter produced from the solid municipal waste) was purchased from the local market and then thoroughly incorporated in the soil at the time of seed bed preparation. The N, P and K fertilizers were applied in the form of Urea, Triple Super Phosphate and Potassium Sulphate, respectively. The detail of treatments is given as under:

Treatments	**Doses kg ha^{-1}**
T1:	N = 60 kg (30 kg at seed bed preparation + 30 kg after 25 and 45 DAT*) P = 45 kg (At seed bed preparation)
T2:	N = 60 kg (30 kg at seed bed preparation + 30 kg after 25 and 45 DAT) P = 90 kg (At seed bed preparation)
T3:	N = 120 kg (60 kg at seed bed preparation + 60 kg after 25 and 45 DAT) P = 90 kg (At seed bed preparation)
T4:	N = 60 kg (30 kg at seed bed preparation + 30 kg after 25 and 45 DAT) P = 45 kg (At seed bed preparation) Bio-fertilizer = 500 kg (At seed bed preparation)
T5:	N = 60 kg (30 kg at seed bed preparation + 30 kg after 25 and 45 DAT) P = 90 kg (At seed bed preparation) Bio-fertilizer = 500 kg (At seed bed preparation)
T6:	N = 120 kg (60 kg at seed bed preparation + 60 kg after 25 and 45 DAT) P = 90 kg (At seed bed preparation) Bio-fertilizer = 500 kg (At seed bed preparation)

* DAT = Days after transplanting

All phosphorus, potash and half nitrogen were applied at the time of transplanting while remaining nitrogen was applied after 25 and 45 days after transplanting (DAT). Furadon (3G) granules @ 30 kg ha^{-1} were applied to control rice stem borer. Soil analysis was done which showed that the experimental site was alkaline in nature with pH 7.81. The texture of soil was silty clay loam. It was deficient in organic matter, mineral nitrogen (N) and phosphorous (P), while adequate in potash (K) contents (Table-1).

Data were collected on number of tillers (m^{-2}), number of panicles (m^{-2}), number of spikelets (panicle^{-1}), normal kernel (%), 1000-grain weight (g) and paddy yield (t ha^{-1}). The data obtained were subjected to analysis of variance technique (Steel *et al*., 1997) by using MSTATC computer software (MSTATC, 1991) and means were separated by LSD test.

RESULTS AND DISCUSSION

Number of tillers (m^{-2})

Among yield components, tillers are very important because the final yield is mainly a function of the number of panicles bearing tillers. The data presented in Table-2 indicated that number of tillers was significantly influenced by added fertilizers. The maximum number of tillers (388.5) was obtained in T_6 which received 120 kg N, 90 kg P_2O_5 and 500 kg ha^{-1} bio-fertilizer. Treatments T_5 (N: 60 kg, P_2O_5: 90 kg, BF: 500 kg ha^{-1}) and T_2 (N: 60 kg, P_2O_5: 90 kg ha^{-1}) produced statistically at par number of tillers (372.3 and 368.5 m^{-2}). The minimum number of tillers (334.0) was noted in T_1 (N: 60 kg, P_2O_5: 45 kg ha^{-1}). These results indicated that number of tillers was significantly increased by the addition of bio-fertilizer along with N and P. Zahir *et al*. (2007) also reported that integrated effect of N, P and bio-fertilizer improved tiller production per unit area in rice.

Number of panicles (m^{-2})

The data pertaining to number of panicles are shown in Table-2, which revealed that number of panicles was significantly affected by the application of bio-fertilizer along with nitrogen and phosphorous. The maximum number of panicles (401.5) was recorded in T_6 (N: 120 kg, P_2O_5: 90 kg, BF: 500 kg ha^{-1}). It was statistically similar to T_5 (N: 60 kg, P_2O_5: 90 kg, BF: 500 kg ha^{-1}) and T_4 (N: 60 kg, P_2O_5: 45 kg, BF: 500 kg ha^{-1}) which resulted into 344.5 and 334.0 number of panicles. These treatments were significantly higher than rests of all treatments. Datta *et al.* (2001) stated that combined dose of chemical fertilizer with bio-fertilizer increased all the growth and yield attributes of rice significantly including number of panicles. Ahmed *et al.* (2004) also reported that combined use of bio-fertilizer and nitrogen produced higher number of panicles per unit area in rice.

Number of spikelets ($panicle^{-1}$)

The data on number of spikelets per panicle are presented in Table-2, which indicated significant differences among various treatments. The maximum number of spikelets (173.2) was obtained in T_6 (N: 120 kg, P_2O_5: 90 kg, BF: 500 kg ha^{-1}) whereas T_5 (N: 60 kg, P_2O_5: 90 kg, BF: 500 kg ha^{-1}), T_2 (N: 60 kg, P_2O_5: 90 kg ha^{-1}) and T_3 (N: 120 kg, P_2O_5: 90 kg ha^{-1}) had statistically similar number of spikelets per panicle. The maximum number of spikelets in T_6 might be due to availability of sufficient amount of nutrients on account of applying recommended doses of N and P along with bio-fertilizer as a supplement dose in rice.

Normal kernel (%)

The data revealed that combined use of chemical and bio-fertilizer significantly increased the normal kernel percentage (Table-3). The maximum (83.32 %) normal kernel were recorded in T_6 (N: 120 kg, P_2O_5: 90 kg, BF: 500 kg ha^{-1}). It was followed by T_3 (N: 120 kg, P_2O_5: 90 kg ha^{-1}) which had 78.37% normal kernel. Rests of the treatments produced statistically at par percent normal kernel. The higher percent normal kernel in T_6 again attributed to availability of sufficient amount of nutrients on account of applying recommended doses of N and P along with bio-fertilizer as a supplement dose. The results are supported by Ahmed *et al.* (2004) who recorded higher percent filled grain by using bio-fertilizer along with recommended NPK fertilizers.

1000-grain weight (g)

The data presented in Table-3 revealed significant variations among various treatments. The maximum grain weight (26.27g) was recorded in T_5 (N: 60 kg, P_2O_5: 90 kg, BF: 500 kg ha^{-1}) which was statistically at par with T_6 (N: 120 kg, P_2O_5: 90 kg, BF: 500 kg ha^{-1}) showing 25.75g weight of 1000-grains. The minimum and statistically similar grain weight was recorded in T_1 (N: 60 kg, P_2O_5: 45 kg ha^{-1}) and T_3 (N: 120 kg, P_2O_5: 90 kg ha^{-1}). Significantly heavier grains obtained in T_5 and T_6 were probably due to supply of adequate amount of nutrients at grain developmental stage. Moreover, the use of 50% recommended dose N in T_5 was equally effective as the 100% recommended dose in T_6, which ultimately saved 50% N fertilizer due to addition of bio-fertilizer. It means that less inorganic N fertilizer would be required for getting the same weight of seed, thereby potentially saving carbon emissions from fertilizer manufacture (Genxing *et al*., 2009). Zahir *et al*. (2007) also emphasized that addition of organic fertilizers is a cost effective approach for improving rice production, which reduces dependence on chemical fertilizers besides reducing their negative effects in the ecosystem.

Paddy yield (t ha^{-1})

Paddy yield increased as a result of many factors, thus the crop production is most successful when all available factors are utilized favorably. The data regarding paddy yield are given in Table-3, which indicated that paddy yield was increased significantly by the addition of bio-fertilizer along with synthetic fertilizers. Application of 120 kg N and 90 kg P_2O_5 with 500 kg ha^{-1} of bio-fertilizer in T_6 substantially increased the paddy yield (9.23 t ha^{-1}). It was followed by T_5 (N: 60 kg, P_2O_5: 90 kg, BF: 500 kg ha^{-1}) which produced paddy yield of 8.32 t ha^{-1}. The minimum paddy yield (5.48 t ha^{-1}) was obtained in T_1 (N: 60 kg, P_2O_5: 45 kg ha^{-1}). The higher paddy yield in T_6 was attributed to increased number of tillers, panicles, spikelets, percent normal kernel and grain weight which boosted the yield in this treatment. It was due to the reasons that addition of organic nutrients brings positive changes in organic carbon and N content of the soil and increases tendency of available P and K contents (Dixit and Gupta, 2000). These results are supported by Gurung and Prasad (2005) who obtained 26% higher paddy yield by the application of bio-fertilizer along with recommended doses of NPK. Sengar *et al.* (2000) also found that the application of N fertilizer along with organic fertilizer significantly increased the yield and NPK uptake by rice over control and PK only.

REFERENCES

Ahmad A, Al-Noaim and Hamad S H. (2004). Effect of bio-fertilization along with different levels of nitrogen fertilizer application on the growth and grain yield of Hassawi rice (*Oryza sativa* L.). Sci. J. King Faisal Univ., (Basic and Appl. Sci), 5: 215-225.

Anonymous. (2008). Agriculture Statistics of Pakistan. Ministry of Food and Agriculture (Economic Wing), Govt. Pakistan, Islamabad.

Anonymous. (2009a). Utilization of Azolla as a bio-fertilizer. In: Bio-Fertilizer for Sustainable Agriculture (Jain, V. K eds.). p. 195-220.

Anonymous. (2009b). Bio-fertilizer and sustainable forming. In: Bio-Fertilizer for Sustainable Agriculture (Jain, V. K eds.). p. 149-179.

Chand S, Anwar M and Patra D D. (2006). Influence of long-term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint mustard cropping sequence. Comm. Soil Sci. & Pl. Ana., 37: 63-76.

Chen J H. (2008). The combined use of chemical and organic fertilizers and/or bio fertilizer for crop growth and soil fertility. National Chung hsing Univ., Taiwan.

Dixit K G and Gupta B R. (2000). Effect of farmyard manure, chemical and biofertilizers on yield and quality of rice and soil properties. J. Indian Soc. Soil Sci., 48: 619-638.

Datta J K, Banerjee A, Sikdar M S, Gupta S and Mondal N K. (2001). Impact of combined exposure of chemical, fertilizer, bio-fertilizer and compost on growth, physiology and productivity of *Brassica campestries* in old alluvial soil. J. Environ. Biol., 30: 797-800.

Gurung S and Prasad B N. (2005). Azolla and cyanobacteria (BGA): potential biofertilizers for rice. Scientific World, 3: 85-87.

Genxing P, Ping Z, Zhipeng L, Pete S, Lianqing L, Duosheng Q, Xuhu Z, Xiaobo

X, Shengyuan S and Xuemin C. (2009). Combined inorganic/organic fertilization enhances N efficiency and increases rice productivity through organic carbon accumulation in a rice paddy from the Tai Lake region. China Agric. Ecosys. & Environ., 131: 274-280.

Hashem M A. (2001). Problems and prospects of cyanobacterial biofertilizer for rice cultivation. Aust. J. Pl. Physiol., 28: 881-888.

Kaur K, Kapoor K K and Gupta A P. (2005). Impact of organic manures with and without mineral. Soil Sci., 168: 117 122.

Malliga P and Subramanian G. (2002). Cyanobacterial bio-fertilizer for sustainable agriculture. Bioinoculants for Sustainable Agric. & Forestry, p. 99-106.

MSTATC. (1991). MSTATC package, version 1. Michigan State Univ. USA.

Sengar S S, Wade L J, Baghel S S, Singh R K Singh G. (2000). Effect of nutrient management on rice (*Oryza sativa*) in rainfed lowland of Southeast Madhya Pradesh. Indian J. Agron., 45: 315-322.

Steel R G D, Torrie J H and Dicky D A. (1997). Principles and Procedures of Statistics, a Biometrical Approach. 3rd Ed. McGraw Hill, Inc. Book Co. N.Y. (USA.) pp. 352-358.

Zahir Z A, Naveed M, Zobair M, Khalid A and Arshad M. (2007). Enrichment of composted organic wastes for improvement in rice production. J. Chem. Soc. Pak., 29: 514-519.

Table-1. Physico-chemical characteristics of soil of the experimental site.

Parameters	**Unit**	**Pre-sowing**	**Post-harvesting**
pH	-	7.81	7.80
Electrical conductivity	ds/m	0.35	0.20
Ca + Mg	mg/l	3.10	2.50
HCO_3	mg/l	1.20	1.60
Cl	mg/l	1.02	1.34
Organic matter	%	0.64	0.70
Nitrogen	%	0.032	0.035
Sand	%	16.2	16.4
Silt	%	47.8	47.2
Clay	%	36.0	36.4
Texture class	-	Silty clay loam	Silty clay loam
Phosphorous	mg/kg	3.2	3.5
Potassium	mg/kg	128	132

Source: Soil Chemistry Laboratory, Agricultural Research Institute, Dera Ismail Khan

Table-2. Number of tillers (m^{-2}), panicles (m^{-2}) and spikelets ($panicle^{-1}$) as affected by N, P_2O_5 and bio-fertilizer application in rice.

Treatments	N, P_2O_5 and bio-fertilizer (kg ha^{-1})	Number of tillers (m^{-2})	Number of panicles (m^{-2})	Number of spikel (panicles^{-1})
T_1: N+P	60+45	334.0 d	272.5 b	143.2 b
T_2: N+P	60+90	368.5 ab	280.5 b	155.1 ab
T_3: N+P	120+90	337.0 cd	296.8 b	153.3 ab
T_4: N+P+BF	60+45+500	361.0 bc	334.0 ab	152.5 b
T_5: N+P+BF	60+90+500	372.3 ab	344.5 ab	160.8 ab
T_6: N+P+BF	120+90+500	388.5 a	401.5 a	173.2 a
$LSD_{0.05}$	---	26.51	81.58	20.64

* BF=Bio-fertilizer
Means followed by different letter(s) in a column are statistically significant at 5% level of probability.

Table-3. Normal kernel (%), 1000-grain weight and paddy yield (t ha^{-1}) as affected by N, P_2O_5 and bio-fertilizer application in rice.

Treatments	N, P_2O_5 and bio-fertilizer (kg ha^{-1})	Normal kernel (%)	1000-grain weight (g)	Paddy yield (t ha
T_1: N+P	60+45	74.50 c	23.00 d	5.48 e
T_2: N+P	60+90	73.72 c	24.40 c	6.27 cd
T_3: N+P	120+90	78.37 b	22.85 d	6.65 c
T_4: N+P+BF	60+45+500	73.41 c	24.98 bc	6.07 d
T_5: N+P+BF	60+90+500	74.62 c	26.27 a	8.32 b
T_6: N+P+BF	120+90+500	83.06 a	25.75 ab	9.23 a
$LSD_{0.05}$	---	2.922	1.236	0.423

* BF=Bio-fertilizer
Means followed by different letter(s) in a column are statistically significant at 5% level of probability.