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Effect of inorganic and bio-fertilizers on growth and yield of rice in New Alluvial Zone of West Bengal

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Abstract
A field experiment was conducted during *kharif*, 2016 in the experimental farm of Bidhan Chandra Krishi Viswavidyalaya to assess the effect of inorganic and bio-fertilizers on growth and yield of rice. The results revealed that the highest plant height, leaf area index, dry matter accumulation and crop growth rate were observed in 100% RDF (T_2) which was statistically at par with 75% recommended dose of NP + 100% RDK + *Azotobacter chroococcum* @ 5 kg ha^{-1} (T_4). Similarly, T_2 treatment recorded the maximum panicle length (24.50 cm), number of panicles/hill (14.90), filled grains/panicle (127.00), test weight (20.10 g), grain and straw yield (5.66 t ha^{-1} and 6.99 t ha^{-1}) and all these were at par with T_4. The benefit cost ratio (2.42) was same in T_2 and T_4 treatments, exhibiting better potential in improving crop growth and yield parameters of rice in new alluvial zone of West Bengal.

Keywords: Chemical fertilizer, Crop growth, Yield attributes, Bio-fertilizer, Rice

Introduction
Sustainable development in agriculture and yield maximization of crops can be achieved through restoration and scientific management of land productivity. For yield maximization in intensive cropping, supply of appropriate source and amount of nutrients are indispensable. In conventional practice, improved cropping system involving high value crops rely on the use of inorganic fertilizers due to its immediate availability of nutrients. Though chemical fertilizers nourish plants, they also jeopardize the environment through nitrate pollution and create adverse effects on the fragile ecosystem with elimination of beneficial soil organisms and deterioration of physical and chemical properties of soil. A growing consciousness of such overdependence on synthetic chemicals and the associated degradation in product and environmental quality led to the emergence of a new concept called ‘integrated nutrient management’. For restoration and augmentation of soil fertility and improvement of crop yield and quality in intensive cropping system, INM can be an option. Integrated nutrient management practices such as the use of bio-fertilizers along with chemical fertilizers would solve these issues and make the ecosystem healthier. Bio-fertilizers are defined as the products containing active or latent strains of soil microorganisms, either bacteria alone or in combination with algae or fungi that increase the availability and uptake of mineral nutrients by the plants (Vessey, 2003) [7]. The bio-fertilizer includes mainly the nitrogen fixing, phosphate solubilizing and plant growth promoting microorganisms (Goel *et al*., 1999) [1]. Rice (*Oryza sativa* L.) is an important cereal crop in the developing world and meets the dietary energy requirements for almost half of the world’s population. It is primarily a high energy or high caloric food containing around 78.2% carbohydrate, 6.8% protein, 0.5% fat and 0.6% mineral matter. It accounts for 45-70% of the total calorie intake in many rice consuming countries. UN’s FAO has forecasted global rice production of 2014-2015 at around 494.4 Mt slightly lower from an estimated 496.6 Mt in 2013-2014. Among the rice producing states, West Bengal ranks the leading position which occupies the acreage of 5.80 m ha with the largest production to the tune of 15.5 Mt among the states in the country while the productivity attained to be 2.79 t/ha. Among the various factors responsible for high productivity and quality of rice, fertilizer management is considered to be an important one. Nutritional status is an important factor in case of quality at harvest and post harvest life of crops. Fertilizer application schedules vary widely among growers which depends upon soil type, cropping history and soil test results. Deficiencies, excesses or imbalances of various nutrients are known to result in disorders that can limit the quality of the crops. Quite a large number of farmers are growing rice and they are mostly taking two cereal crops like rice-rice, rice-wheat, or maize-rice in a year where there are irrigation facilities and they obtain at least 10-12 tonnes of food grains/ha by using N:P:K as 160:80:80 kg/ha annum.

But the cost of fertilizers has gone higher and their availability may be limited at some places. In such situation there is scope for thinking as to how far available bio-fertilizers can partly be substituted for the inorganic fertilizers. So, there is an urgent need to study the role of bio-fertilizers in partially compensating the higher demand of fertilizers for growing rice varieties to maximize food production. Considering all the available meteorological information, rice crop can be grown successfully with minimum risk factor. Therefore, the present investigation was carried out to assess the effect of integrated nutrient management practices on growth and yield parameters of rice under influence of chemical and different bio-fertilizer based nutrient sources.

Materials and Methods

A field experiment was conducted during the *kharif* season of 2016 at 'C' block farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal. The experimental farm was situated at 22.5°N latitude and 89.0°E longitude and at an elevation of 9.75 m above mean sea level. The soil of the experimental field was new alluvial (type – Entisol) and sandy loam in texture with pH 6.81 and had good water holding capacity and moderate fertility. The sand, silt and clay content of the soil were 54.8%, 21.8% and 23.1% respectively and the bulk density was 1.31 g cc^{-1}. On the other hand, the organic carbon, available nitrogen, phosphorus and potassium content were 0.30%, 320.52 kg ha^{-1}, 35.6 kg ha^{-1} and 106.2 kg ha^{-1} respectively. The experiment consisted of seven treatments *viz.* T_1: control, T_2: chemical fertilizer at 100% recommended dose of NPK, T_3: 50 % recommended dose of NP + 100% RDK + *Bacillus polymyxa* @ 5 kg ha^{-1}, T_4: 75% recommended dose of NP + 100% RDK + *Azotobacter chroococcum* @ 5 kg ha^{-1}, T_5: 75 % recommended dose of NP + 100% RDK + *Bacillus polymyxa* @ 5 kg ha^{-1}, T_6: 50 % recommended dose of NP + 100% RDK + *Pseudomonas fluorescence* @ 5 kg ha^{-1} and T_7: 50 % recommended dose of NPK + *Bacillus polymyxa* @ 5 kg ha^{-1}. The experiment was conducted in randomized block design with 3 replications. The size of each plot was 5 m x 3 m. Rice cultivar 'IET-4786 (Shatabdi)' was sown. The recommended dose of N: P_2O_5: K_2O for rice was 60:30:30 kg ha^{-1} and the chemical fertilizer in the form of urea, single super phosphate (SSP) and muriate of potash (MOP) were broadcasted and incorporated into 15 cm depth of soil. Half dose of nitrogen and full dose of P_2O_5 and K_2O were applied as basal and remaining half nitrogen was top dressed at 30 days after transplanting (DAT). All the bio-fertilizers were applied @ 5 kg/ha as seed treatment. For raising of seedlings about 50 kg seeds of rice were broadcasted in the 4^{th} week of June in nursery bed for transplanting and about 21 days old seedlings were transplanted in 3^{rd} week of July at a spacing of 20 cm × 15 cm. 2-3 seedlings per hill were transplanted. Weeding was done manually at 30 and 50 DAT to keep the plot weed free. The seedbed was prepared with irrigation and the water soaked seeds were sown in seedbed provided continuous submergence with water. About 2 cm water depth was maintained through the nursery period. After transplanting in the main field 2-3 cm water depth and at tillering and panicle initiation stage, alternate wet and dry soil condition was maintained as far as possible. The irrigation was stopped at 15 days before harvesting of the crop. Ten plants were selected randomly from the each plot and plant height, leaf area index, dry matter accumulation, crop growth rate (CGR), panicle length, number of panicles/hill, number of filled grains per panicle, test weight of grains, grain and straw yield, biological yield and harvest index were recorded. Benefit: cost ratio was worked out by dividing gross return with cost of cultivation. The data obtained were subjected to statistical investigation following the analysis of variance technique by using software packages of MS Excel and OPSTAT. Statistical significance between means of individual treatments was assessed using Fisher's Least Significant Difference (LSD) at 5% level of probability.

Results and Discussion

a) Effect on growth parameters

The effect of inorganic fertilizer and different bio-fertilizers on plant height, leaf area index, dry matter accumulation and crop growth rate of rice are given in Table 1 and Table 2. The plant height increased gradually with increase in age of the crop. Among different fertilizer sources, T_2 treatment *i.e.* application of inorganic fertilizer at 100% recommended dose recorded significantly highest plant height at all growth stages. At 30 DAT, the highest plant height (80.66 cm) was observed in case of T_2 which was at par with T_4 and T_5 treatments (80.46 cm and 80.26 cm respectively). As expected the control treatment (T_1) recorded lowest plant height (66.23 cm). Similarly at 60 DAT and 90 DAT, the highest plant height (88.52 cm and 105.60 cm respectively) were observed in T_2 and the lowest plant height (77.78 cm and 93.67cm respectively) were recorded in T_1. At 60 DAT, T_2 was statistically at par with T_4 (86.69 cm) and at 90 DAT, T_2 was at par with T_4 and T_5 treatments (103.93 cm and 102.60 cm respectively). The addition of macronutrients N, P and K through full dose of inorganic fertilizer in soil resulted in increased plant height. Bio-fertilizer sources supply plant nutrients as well as plant growth regulators and humic acid and they have additive effect on plant growth (Tomati *et al*., 1988) [5]. Although plant height is the genetic character but it is largely influenced by the availability of nitrogen in soil. Nitrogen plays an important role in overall growth of the crop. Any restriction in the supply of this mineral element, particularly at early growth stage, may limit the crop growth. The highest leaf area index at 25 DAT was noted in T_2 (0.79) followed by T_4, T_5 and T_6 treatments and T_1 recorded the lowest LAI (0.66). At 50 DAT and 75 DAT, the highest LAI values (2.72 and 3.81 respectively) were also observed in case of T_2 which were statistically at par with T_4 treatment (2.62 and 3.67 respectively). Leaf area index is directly related with the vegetative growth of the crop which is influenced by the availability of plant nutrient in soil (De Datta, 1981) [2]. *Azotobacter* also influences LAI positively particularly at later growth stage by supplying nitrogen to the plant. Kader *et al.* (2000) [3] also reported similar growth trend of LAI due to *Azotobacter* inoculation. Venkataraman (1982) [6] stated that *Azotobacter* accelerated the growth of crops by supplying nitrogen and growth stimulating substances. It is observed from this experiment that reduction of NPK fertilizer by 25 % did not reduce LAI significantly at all growth stage and it was at par with maximum doses of NPK fertilizer. This amount of chemical fertilizer was supplemented from bio-fertilizer.

Dry matter accumulation gradually increased with the advancement of growth stages and reached their maximum values towards maturity. Full recommended dose of inorganic fertilizer recorded maximum dry matter accumulation at 30 DAT, 60 DAT, 90 DAT and at harvest (155.17 g m^{-2}, 398.53 g m^{-2}, 478.36 g m^{-2} and 622.52 g m^{-2} respectively) which were significantly superior to rest of the treatments except treatment T_4. At all growth stages, the dry matter accumulation in T_4 (154.51 g m^{-2}, 395.74 g m^{-2}, 469.97 g m^{-2} and 614.14 g m^{-2} respectively) was at par with T_2. On the other hand, the lowest dry matter accumulation at 30 DAT, 60 DAT, 90 DAT and at harvest were recorded in T_1 (123.33 g m^{-2}, 230.12 g m^{-2}, 358.04 g m^{-2} and 454.19 g m^{-2} respectively). Both inorganic and bio-fertilizers or their combinations when supplied at recommended dose increased nutrient supply and enhanced absorption of nutrients by the crop. However, the rate of mineralization differed between inorganic and bio-fertilizer sources. In inorganic fertilizer, mineralization process was faster and thereby showed immediate release of nutrient elements like N, P and K with their quick availability. The effects of *Azotobacter* application either individually or in combination with the use of organic and chemical fertilizers on the growth and yield of transplanted *aman* rice and nutrient status of soil were evaluated (Kader *et al*., 2000) [3].

The crop growth rate of rice at 30-60 DAT and 60-90 DAT changed significantly with different fertilizer treatments. At 30-60 DAT, the maximum crop growth rate (14.79 g m^{-2} day^{-1}) was recorded in T_2 treatment which was statistically at par with T_4 (14.42 g m^{-2} day^{-1}) but significantly superior to rest of the treatments and the lowest CGR (7.94 g m^{-2} day^{-1}) was recorded in case of control treatment. Similarly, at 60-90 DAT maximum crop growth rate (10.42 g m^{-2} day^{-1}) was observed in T_2, at par with T_4 (9.98 g m^{-2} day^{-1}) and the lowest CGR (5.93 g m^{-2} day^{-1}) was found in T_1.

b) Effect on yield attributes

Yield attributes of rice such as panicle length (cm), number of panicles/hill, filled grains/panicle, 1000 grain weight (g), grain and straw yield (kg/ha), biological yield and harvest index are presented in Table 3 and Table 4. Applications of different fertilizers have shown significant improvement in all yield parameters than control. The highest panicle length (24.50 cm), number of panicles/hill (14.90), filled grains/panicle (127.00) and 1000 grain weight (20.10 g) were recorded in case of T_2 treatment. The lowest panicle length (21.80 cm), number of panicles/hill (10.06), filled grains/panicle (116.61) and test weight (17.40 g) were observed in T_1 treatment. In case of panicle length and test weight, T_2 treatment was statistically at par with T_4 (24.30 cm and 19.83 g respectively) and T_5 (24.26 cm and 19.66 g respectively) treatments. It was found that T_4 (14.17 and 126.70 respectively) was at par with T_2 treatment while considering number of panicles/ hill and filled grains/ panicle. In the present study, number of panicles/hill and filled grains/panicle increased with the increasing amount of inorganic fertilizer and reached maximum where full recommended dose of inorganic fertilizer were applied. Along with NPK fertilizer, bio-fertilizer played a significant role in these parameters.

Grain yield and straw yield were significantly influenced by different fertilizer sources. The grain yield was maximized in T_2 treatment (5.66 t ha^{-1}) which was at par with T_4 (5.48 t ha^{-1}) and significantly superior to rest of the treatments. The lowest grain yield (4.72 t ha^{-1}) was observed in case of control treatment (T_1). The grain yield is the product of yield attributes like panicle length, number of panicles/hill, filled grains/panicle, test weight etc. In our present investigation, application of full recommended dose of inorganic fertilizer produced highest yield attributes. Reduction of the dose of nitrogen and phosphorus fertilizer up to 25 % of recommended dose was supplemented by bio-fertilizer. But almost all the yield attributes in this study was drastically reduced when half of the recommended doses of NPK fertilizer were curtailed. On the other hand, application of 100% recommended dose of inorganic fertilizer resulted the maximum straw yield (6.99 t ha^{-1}) and it was also statistically at par with T_4 treatment (6.93 t ha^{-1}). A field experiment was conducted with rice variety ADT-31 where foliar spray of *Azotobacter chroococcum* was applied on 15th, 30th and 45th day after transplanting of rice crop. They observed that the foliar spray of *Azotobacter* culture significantly increased the grain and straw yield of rice crop (Kannaiyan *et al*., 1980) [4]. The lowest 5.88 t ha^{-1} straw yield was observed in control. Satisfying the nutrient requirement of plants through combined application of inorganic fertilizer and bio-fertilizers was also found equally promising in supplying nutrient elements in available form due to rapid release from chemical source as well as slow and steady release from bio-fertilizers in the soil along with essential micronutrients and growth promoting substances which results in higher growth and yield of crops. Similarly, the maximum and minimum biological yield (12.65 t ha^{-1} and 10.60 t ha^{-1} respectively) were recorded in T_2 and T_1 treatments respectively. The highest harvest index was noted in T_3 (45.08%) treatment and statistically at par HI was recorded in T_1, T_2, T_4, T_5, T_6 and T_7 treatments.

c) Economics

The highest gross return (Rs. 80145.00/ha), net return (Rs. 47020.00/ha) and benefit: cost ratio (2.42) were recorded in T_2 followed by T_4 treatment (75% recommended dose of NP + 100% RDK + *Azotobacter chroococcum* @ 5 kg ha^{-1}). Similar trend was also found in T_4 treatment in case of benefit: cost ratio (2.42). T_1 treatment recorded the lowest gross return (Rs. 52800.00/ha), net return (Rs. 20800.00/ha) and benefit: cost ratio (1.65). Hence, the economics play an important role in adoption of new technology by farming community.

Table 1: Effect of inorganic and bio-fertilizers on plant height and leaf area index of rice.

Treatments	Plant height (cm)			Leaf Area Index		
	30 DAT	60 DAT	90 DAT	25 DAT	50 DAT	75 DAT
T_1	66.23	77.78	93.67	0.66	2.02	2.89
T_2	80.66	88.52	105.60	0.79	2.72	3.81
T_3	79.03	83.88	100.03	0.67	2.38	3.59
T_4	80.46	86.69	103.93	0.76	2.62	3.67
T_5	80.26	85.88	102.60	0.75	2.40	3.21
T_6	78.33	83.19	100.13	0.70	2.45	3.28
T_7	78.16	80.45	98.76	0.65	2.13	3.02
SEm ±	0.49	0.79	1.62	0.05	0.13	0.09
CD (P= 0.05)	1.53	2.45	5.00	0.10	0.24	0.19

Table 2: Effect of inorganic and bio-fertilizers on dry matter accumulation and crop growth rate of rice.

Treatments	Dry matter accumulation (g m^{-2})				Crop growth rate (g m^{-2} day^{-1})	
	30 DAT	60 DAT	90 DAT	At harvest	30-60 DAT	60-90 DAT
T_1	123.33	230.12	358.04	454.19	7.94	5.93
T_2	155.17	398.53	478.36	622.52	14.79	10.42
T_3	146.23	295.05	378.05	503.56	11.63	9.89
T_4	154.51	395.74	469.97	614.14	14.42	9.98
T_5	151.82	310.23	429.06	523.75	11.67	9.85
T_6	145.62	301.06	409.07	517.58	11.32	8.30
T_7	133.90	279.73	373.11	498.52	11.26	7.96
SEm ±	0.73	0.86	3.24	3.28	0.15	0.18
CD (P= 0.05)	2.26	2.97	10.09	10.77	0.46	0.56

Table 3: Effect of inorganic and bio-fertilizers on yield attributes of rice

Treatments	Panicle length (cm)	No. of panicles/hill	Filled grains/ panicle	1000 grain weight (g)
T_1	21.80	10.06	116.61	17.40
T_2	24.50	14.90	127.00	20.10
T_3	22.96	12.00	124.02	19.53
T_4	24.30	14.17	126.70	19.83
T_5	24.26	13.77	125.59	19.66
T_6	23.33	11.60	123.82	18.93
T_7	20.96	10.23	122.70	18.60
SEm ±	0.22	0.33	0.32	0.17
CD (P= 0.05)	0.68	1.03	0.98	0.52

Table 4: Effect of inorganic and bio-fertilizers on yields of rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
T_1	4.72	5.88	10.60	44.53
T_2	5.66	6.99	12.65	44.74
T_3	5.32	6.48	11.80	45.08
T_4	5.48	6.93	12.41	44.12
T_5	5.40	6.62	12.02	44.92
T_6	5.12	6.29	11.41	44.87
T_7	4.98	6.12	11.10	44.86
SEm ±	0.89	0.11	0.13	0.67
CD (P= 0.05)	0.20	0.24	0.29	1.45

Table 5: Effect of inorganic and bio-fertilizers on economics of rice cultivation

Treatments	Cost of cultivation (Rs./ha)	Gross return(Rs./ha)	Net return(Rs./ha)	B:C ratio
T_1	32000.00	52800.00	20800.00	1.65
T_2	33125.00	80145.00	47020.00	2.42
T_3	33612.50	77415.00	43802.50	2.30
T_4	33006.25	79810.00	40963.75	2.42
T_5	33837.50	67410.00	33572.50	1.99
T_6	34756.25	66789.00	32032.75	1.92
T_7	34037.50	64188.00	30150.50	1.89

Conclusion

In India in the history of past 50 years, the inorganic fertilizers have played a crucial role in increasing the agricultural productivity. Increasing the productivity and profitability in an economically sustainable manner is the most effective step for reducing poverty and hunger in our country. A judicious use of organic amendment and bio-fertilizers may be effective not only in sustaining crop productivity and soil health but also in supplementing a part of inorganic fertilizer requirement of crops. Based on the findings of the experiment, it is observed that application of full dose of fertilizer through inorganic sources or their combination resulted higher growth and yield of rice as compared to control. It is clearly observed from the present study that the reduction of the dose of nitrogen and phosphorus of chemical fertilizer by 25% did not restrict the growth and yield attributes when it is substituted by the *Azotobacter chroococcum*. Therefore it can be concluded that combined application of bio-fertilizer and inorganic fertilizer *i.e.* treatment T_4 (75% recommended dose of NP + 100% RDK + *Azotobacter chroococcum* @ 5 kg ha^{-1}) can be recommended for achieving higher rice yield in a cost effective manner and also for sustaining soil health and reducing environmental pollution.

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