RESPONSE OF BIO FERTILIZERS IN CONJUNCTION WITH INORGANIC FERTILIZERS IN *KHARIF* PADDY

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ABSTRACT

A field experiment was conducted during kharif season for two consecutive years during 2009-10 and 2010-11 at Instructional Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari to study the "Response of bio fertilizers in conjunction with inorganic fertilizers in kharif paddy". The results revealed that the treatment which received 100 per cent RDF (100 - 30 kg NP /ha) + $ZnSO_4$ @ 25 kg /ha+ Azospirillum as seedlings treatment +Azotobacter + PSB + Zn + Potassium solubilizer as soil application recorded significantly higher all growth and yield parameters such as plant height, number of tillers per plant, dry weight of shoot and root, number of panicles per hill, length of panicle, test weight and grain as well as straw yields of rice, while 100 per cent and 75 per cent RDF alone recorded the lowest value. The highest total uptake of N, P, K and Zn and residual available N, P, K and Zn in soil was also found highest in this treatment. Similarly, The highest gross returns, net returns and B:C ratio were recorded with 100 % RDF + $ZnSO_4$ @ 25 kg /ha + Azospirillum as seedlings treatment + Azotobacter + PSB + Zn + Potassium solubilizer, which is found to be promising for increased rice production.

KEY WORDS: Azospirillum, bio-fertilizer, inorganic fertilizer, nutrient uptake, PSB, RDF, rice

INRODUCTION

Rice is the major cereal crop of South Gujarat. The productivity of rice in coastal area is low due to heavy rainfall, inadequate and improper time of application of nutrients. The heavy rainfall results in leaching of nutrients like nitrogen, which leads to poor fertility condition of soil, high soil pH with salinity causing the main constraints for the low productivity of rice. The production potential of rice depends upon number of factors. Out of which, fertilizers is one of the most important factors to increase production potential. Though, the productivity of rice in coastal ecosystem is low which can be increased by proper and judicious use of fertilizers containing major and micronutrients. But the increasing costs of fertilizers particularly nitrogenous and phosphatic possess severe constraints to our farmers particularly on small and marginal farmers. Therefore, it is needed to search for alternative low cost resources to relieve the pressure on nitrogenous and phosphatic fertilizers. In this context, alternative low cost resources like bio fertilizers have gained prime importance in the recent decades.

Sustainable crop production is essential to conserve the natural resource base for future generations besides meeting out the different needs of the current population. The objectives of sustainable crop production can be achieved through the use of eco- friendly input technologies through use of bio- fertilizers. Bio-fertilizers have the potential to mitigate the ill effects of conventional eco- threatening crop production system. Recently, interest has aroused to produce liquid bio-fertilizers, which are special liquid formulations containing not only the desired microorganisms and their nutrients but also special cell protestants or chemicals that promote of resting spores or cysts for longer shelf life and tolerance to adverse condition (Bhattacharya and Kumar, 2002). Integration of inorganic fertilizer with bio fertilizer reduces the demand of inorganic fertilizer along with more fertilizer use efficiency and save the foreign exchange as well as improves the quality of product. Keeping to this fact in mind, an effort was made to find out the efficacy of different bio fertilizers on productivity of *kharif* paddy under high rainfall conditions of South Gujarat.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season for two consecutive years during 2009-10 and 2010-11 at Instructional Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari located at the 20^o 57' N Latitude and 72^o 54' E Longitude and has an altitude of 10 m above the mean sea level under Agro-Ecological Situation (AES)-III of South Gujarat Heavy Rainfall Zone. The soil was clayey in texture having medium availability of nitrogen (227 kg/ha) and phosphorus (48 kg/ha) and fairly rich in available potassium (360 kg/ha). The soil was slightly alkaline in reaction (pH 7.9) with normal electrical conductivity (0.58 dS m^{-1}). The eight treatments *viz*., $\mathbf{T_1}$: 100 % RDF (100 - 30 kg NP/ha) + $ZnSO_4$ @ 25 kg/ha, $\mathbf{T_2}$: 75 % RDF (75 - 22.5 kg NP/ha) + $ZnSO_4$ @ 18.75 kg/ha, $\mathbf{T_3}$: T_1 + *Azospirillum* as seedlings treatment + *Azotobactor* + PSB + Zn solubilizer as soil application), $\mathbf{T_4}$: T_2 + *Azospirillum* as seedlings treatment + *Azotobactor* + PSB + Zn solubilizer as soil application, $\mathbf{T_5}$: T_3 + potassium solubilizer as soil application, $\mathbf{T_6}$: T_4 + potassium solubilizer as soil application, $\mathbf{T_7}$: T_1 + Potassium solubilizer as soil application and $\mathbf{T_8}$ **:** T_2 + potassium solubilizer as soil application were evoluted with four replications in a randomized block design (RBD). Recommended dose of fertilizer (RDF) was applied as per treatment. Nitrogen was applied in form of urea in three split, half of the nitrogen was given at the time of transplanting and remaining half of the nitrogen in two equal splits at tillering and panicle initiation stage as top dressing. Entire quantity of phosphorous (in form of single super phosphate) was given as basal dose. *Azospirillum* applied as seedlings treatment @ rate of 100 ml/10 litre and *Azotobactor*, PSB, Zn and potassium solubilizer applied as soil application @ 2 litre/ha at the time of transplanting having minimum 10^8 CFU. Twenty five days old rice seedlings (during first year) and twenty seven days old rice seedlings (during second year) of variety 'NAU Rice – 1' were transplanted at 20 cm x 15 cm spacing. All cultural operations were carried out as when required.

RESULTS AND DISCUSSION

Growth and yield attributes

The data presented in Table 1 revealed that the effect of different nutrient management treatments was found significant on plant height, number of tillers per plant, dry weight of shoot and root, number of panicles per hill, length of panicle and test weight at harvest of rice crop. The application of 100 % RDF (100 + 30 kg NP/ha) + $ZnSO_4$ @ 25 kg/ha + *Azospirillum* as seedlings treatment **+** *Azotobactor* **+** PSB **+** Zn + potassium solubilizer as a soil application (T_5) was recorded significantly higher plant height (122.58 cm), number of tillers per plant (12.92), dry weight of shoot (190.10 g) and root (28.86 g), number of panicles per hill (10.71), length of panicle (25.70 cm) and test weight (22.95) as compared to 75 % RDF (75 + 22.5 kg NP /ha) + $ZnSO_4$ @ 18.75 kg /ha in pooeld analysis. But it was at par with T_3 in all growth and yield characters, while with T_6 in number of panicles per hill, length of panicle and test weight, T_7 for test weight, and with T_4 for length of panicle and test weight. In this experiment, application of 100 % RDF with biofertilizers inoculated treatments recorded significantly higher growth and yield attributes because of higher fertilizer dose and continuous supply of additional amount of nutrients throughout its growth stage as a result of inoculation of bio fertilizers (*Azospirillum*, *Azotobacter*, PSB, Zn and Potassium solubilizer). Leaching loss of nutrients must have been minimized by the use of bio fertilizers because these are the products containing living cells which have an ability to bind with the nutrients temporarily.

According to Tien *et al*. (1979), in addition to its high nitrogen fixation, *Azospirillum* can synthesis growth substances such as IAA and other auxins and Vitamin B, which might have helped in increasing the plant height. Higher dose of phosphorus enhanced the root development. Inoculation of phosphobacteria converted insoluble forms of phosphorus into soluble forms and make them available to plants, which resulted in increased plant height. Higher levels of potassium also influenced the plant height. Inoculation of potassium solubilizers converted insoluble forms of K into soluble forms and make available to plants. Even though potassium was not considered to be necessary for promoting the vegetative growth it might be possible that this nutrient had an indirect effect in increasing the uptake of nitrogen which in turn might have increased the plant height (Halvin *et al.*, 1956). Inoculation of Zn solubilizers converted insoluble forms of Zn into soluble forms and make them available to plants which enhanced the plant height. The favourable effect of zinc might be due to its direct influence on the quantity of auxin production which in turn enables the plants to growth better. These findings were in accordance with the findings of Srinivasan and Naidu (1998). Increased plant height owing to zinc takes place in metabolism of plant, as zinc is an activator of several enzymes which in turn directly or indirectly affect the synthesis of carbohydrates and proteins (Narwal *et al*., 1995).

Grain and straw yield

The grain and straw yield differed significantly due to different treatments during both the years as well as in pooled analysis (Table 1). The linearly response was sown with increasing application of chemical fertilizers in combined with bio fertilizers. The perusal of data presented in Table 1 revealed that the highest grain yield (4.97 and 4.91 t/ha) and straw yield (7.35 and 7.12 t/ha) was recorded with T_5 (100 % RDF + $ZnSO_4$ @ 25 kg /ha + *Azospirillum* Seedlings treatment + *Azotobacter* + PSB + Zn + Potassium solubilizer as soil application during first year and in pooled analysis, respectively. But, it was followed by T_3 and T_6. However, during second year, application of T_1 + *Azospirillum* Seedlings treatment + *Azotobacter* + PSB + Zn solubilizer as soil application (T_3) gave significantly higher seed and straw yields, which was followed by T_5 and T_6. Significantly lowest seed and straw yields were recorded in T_8, T_2, and T_1 during both years and in pooled analysis. The 100 % RDF or 75 % RDF alone can fail to exhibit significant improvement in yield due to short supply of available nutrients in early stage which significantly reduced tillering capacity of rice which might be affected to yield. An evidence from initial soil status, the amount of available N, P as well as Zn comes under low to medium categories which could not fulfill the nutrient requirement of the rice thereby resulted in less number of tillers per plant as well as panicles. The treatments T_5 and T_3 was equally effective and tended to increase seed yield to the tune of 15.9 and 13.8 per cent, 16.2 and 16.5 per cent and 16.1 and 15.4 per cent over control during I and II year and in pooled analysis, respectively. Similar trend was also observed in case of straw yield. The increased yield was due to the higher magnitude of yield components *i.e.* maximum number of tillers (12.92), higher panicle length (25.70 cm), more number of panicles per hill (10.71) and test weight (22.95 g). The increase in yield due to biofertilizer inoculation may not be solely due to nitrogen fixation or phosphate solubilization, but because of several other factors such as release of growth promoting substances, control of plant pathogens, and proliferation of beneficial organisms in the rhizosphere. These findings were in accordance with Kundu and Gaur (1984). PSB solubilizer act on inorganic phosphates in the soil and make it available to the crop, which resulted in better yield. It also produces a phytohormone, indole 3-acetic acid, which increases its capacity of nutrient extraction from the soil. The response due to mixed culture inoculation was more than single culture, synergistic effect of the two types of organisms. The significant response may be mainly due to the supply of two major nutrients, nitrogen and phosphorus.

In this experiment, potassium solubilizer did not affect any significant variation than the control because high initial status of potassium (360 kg/ha). It was observed that combined application of inorganic fertilizers, ZnSO4 and bio fertilizers including Zn solubilizer recorded the highest yield. The yield obtained by the combined application of Zn solubilizer or K solubilizer was significantly superior over their individual application indicating the synergistic effect of Zn on the activity of microorganisms. Biofertilizers inoculated treatments found superior as compared to RDF alone in case of straw yield. Nitrogen is known to promote tillering, improve length and width of leaves which in turn increases the plant height and dry matter which are responsible for increase in straw yield.

Nutrient uptake by plant

The nutrient removal by rice plant were computed using content of seed and straw separately with its dry yield and finally make their total uptake. The result recorded in Table 2 and 3 revealed that the effect of bio fertilizers inoculated treatments gave significant differences on uptake of N, P, K and Zn by seed, straw as well as their total during both the years. The treatment T_5 (100 % RDF + $ZnSO_4$ @ 25 kg /ha+ *Azospirillum* + *Azotobacter* + PSB + Zn + Potassium solubilizer) recorded significantly higher uptake of N (58.37, 46.99 and 105.36 kg/ha) and (62.60, 47.98 and 110.58 kg/ha), P (6.12, 5.93 and 12.05 kg/ha) and (6.32,5.80 and 12.11 kg/ha), K_2O (18.12, 100.82 and 118.94 kg/ha) and (18.30, 93.40 and 111.69 kg/ha) and Zn (419.44, 449.09 and 869.09 g/ha) and (444.54, 451.10 and 895.63 g/ha) than the control and T_2 by grain, straw and their total during the first and second year, respectively, which was at par with T_3, T_6 and T_7 in K uptake, while for P uptake, T_3 and T_6, for N and Zn uptake T_3. The increase in dry matter accounted for the increased uptake. Application of nitrogenous fertilizers along with *Azospirillum* resulted in higher dry matter production. Inoculation of PSB also increased the uptake of nitrogen. PSB inoculation enhanced the P uptake due to the solubilization of insoluble phosphate. A variety of mechanisms are ascribed in the solubilization and mineralization of insoluble and organic phosphorus sources such as production of aliphatic, aromatic acids, phytases and phospholipases. Combined application bio fertilizers increased the K uptake than the single application mainly due to higher dry matter accumulation. This is may be due to effect of bio fertilizers and $ZnSO_4$ on dry matter production. Zinc uptake was also found highest in combined application of bio fertilizers and $ZnSO_4$ @ 25 kg/ha than their single application mainly due to increase in dry matter, yield and zinc concentration.

Nutrient availability in the soil

The available N, P_2O_5, K_2O and Zn content in soil was significantly differed due to different treatments (Table 4). Treatment T_5 recorded the highest available N (295.9 and 297.28 kg/ha) and treatment T_2 recorded the lowest available N (235.3 and 229.5 kg/ha) during both the years, respectively. The nitrogen content at harvest was more than the initial status in treatments T_3, T_4, T_6 and T_7. This was due to the enhanced microbial activity due to inoculation of Azospirillum and *Azotobacter*. Depletion of nitrogen was found in T_1 and T_2 due to lack of sufficient nitrogen to crop. After harvest, the available phosphorus content in soil increased from its initial status in all the treatments except T_1 and T_2 which accounted for a slightly lower P content than initial status. The available phosphorus content varied form 51.21 and 53.37 kg/ha in T_2 to 69.03 and 72.39 kg/ha in T_3 during both the years, respectively. Application of higher doses of phosphatic fertilizers along with PSB resulted in higher available phosphorus in the soil. PSB inoculation resulted in greater mobilisation of insoluble inorganic phosphate and mineralization of organic phosphorus. These findings were in accordance with Mohod *et al*. (1989). The available potassium content in soil increased from its initial status in all the treatments except T_1 and T_2, since T_1 and T_2 did not receive potassium application and resulted in its depletion. The available K content varied from 373.2 and 375.8 kg/ha (T_5) to 315.0 and 282.8 kg/ha (T_2) during both the years, respectively. The increase in available K was due to inoculation of potassium solubilizer. The available Zn content in soil varied from 0.488 and 0.586 ppm (T_5) to 0.402 to 0.399 ppm (T_2) during both the years. After harvest, the available zinc content in soil increased from its initial status in all the treatments except T_2 and T_1. This is because of antagonistic relationship between zinc and phosphorus. Higher doses of phosphorus must have reduced the availability of zinc. Lower Zn concentration in T_2 may also be due to greater removal because of higher dry matter production.

Economics

The benefit cost analysis of rice cultivation showed that the treatment T_5 (1.72) recorded the highest benefit cost ratio in pooled analysis; however it was followed by T_3 (1.69). This is because T_5 and T_3 gave the maximum gross returns and net returns due to higher grain and straw yields due to combined application of 100 % RDF+ $ZnSO_4$ @ 25 kg/ha in conjunction with bio fertilizers.

CONCLUSION

It can be concluded that application of 100 % RDF (100 - 30 kg NP/ha) + $ZnSO_4$ @ 25 kg/ha in conjunction with bio fertilizers (Especially mixed culture inoculation *viz*., *Azospirillum* as seedling + *Azotobacter* + PSB + Zn + K solubilizer as soil application) to *kharif* rice effectively increased the yield, nutrient uptake and economics. Same time it sustain nutrient status as well as saved 25 % inorganic fertilizers.

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Table 1: Growth parameters, yield attributes and yield of paddy as influenced by different bio fertilizer treatments (Pooled over 2 years)

Treatment	Plant Height (cm)	Number of Tillers	Dry Weight of Shoot (g)	Dry Weight of Root (g)	Number of Panicles per Hill	Length of Panicle (cm)	Test Weight (g)	Seed Yield (t/ha)			Straw Yield (t/ha)		
								I Year	II Year	Pooled	I Year	II Year	Pooled
T_1	98.98	10.19	158.80	21.90	8.41	24.85	21.48	4.29	4.18	4.23	6.64	5.82	6.23
T_2	90.53	9.59	141.96	17.90	7.41	23.57	20.33	3.70	4.10	3.90	5.97	5.67	5.82
T_3	122.18	12.75	187.10	27.35	10.16	25.25	22.77	4.88	4.87	4.88	7.32	6.92	7.12
T_4	105.73	10.91	165.03	23.13	8.80	24.75	21.68	4.31	4.20	4.26	6.65	6.12	6.39
T_5	122.58	12.92	190.10	28.86	10.71	25.70	22.95	4.97	4.86	4.91	7.35	6.89	7.12
T_6	109.63	11.25	172.16	25.25	10.02	24.89	22.33	4.40	4.56	4.48	6.66	6.33	6.49
T_7	106.40	11.08	165.96	23.65	9.08	25.25	21.96	4.33	4.18	4.25	6.67	6.13	6.40
T_8	92.00	10.00	15.19	17.9	7.16	22.63	19.50	3.75	3.83	3.79	6.01	5.57	5.79
SEm ±	3.77	0.42	5.61	0.70	0.53	0.40	0.48	0.20	0.22	0.14	0.21	0.30	0.17
CD (P=0.05)	10.71	1.19	15.97	1.98	1.78	1.14	1.35	0.57	0.64	0.40	0.82	0.88	0.49

Table 2: Total uptake of N (kg/ha) and P_2O_5 (kg/ha) as influenced by different bio fertilizer treatments

Treatment	N uptake						P uptake					
	I Year			II Year			I Year			II Year		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	43.49	36.68	80.17	46.92	37.26	84.18	5.25	4.98	10.23	5.14	4.51	9.65
T_2	37.18	33.43	70.61	47.63	36.39	84.02	4.48	4.41	8.89	5.19	4.19	9.37
T_3	55.04	44.33	99.37	61.16	47.63	108.79	5.90	5.78	11.68	6.31	5.66	11.97
T_4	47.39	39.79	87.18	51.32	41.35	92.67	5.11	5.04	10.15	5.18	4.80	9.99
T_5	58.37	46.99	105.36	62.60	47.98	110.58	6.12	5.93	12.05	6.32	5.80	12.11
T_6	49.23	40.32	89.55	55.93	42.39	98.32	5.30	5.32	10.62	5.66	5.39	11.04
T_7	47.16	37.27	84.43	50.46	37.88	88.34	5.25	5.36	10.60	5.07	4.88	9.95
T_8	38.07	33.05	71.12	42.35	34.65	77.01	4.64	4.23	8.87	4.59	4.20	8.79
SEm ±	3.93	2.55	5.24	2.08	2.75	3.55	0.30	0.35	0.55	0.41	0.34	0.49
CD (P=0.05)	11.56	7.51	15.40	6.12	8.07	10.43	0.90	1.03	1.62	1.22	1.00	1.43

Table 3: Total uptake of K (kg/ha) and Zn (g/ha) as influenced by different bio fertilizer treatments

Treatment	K uptake						Zn uptake					
	I Year			II Year			I Year			II Year		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	14.92	87.43	102.35	14.92	76.37	91.29	334.19	339.86	674.05	351.50	319.30	670.79
T_2	12.44	72.97	85.41	14.15	70.02	84.17	256.06	287.97	544.03	312.56	295.29	607.84
T_3	16.68	96.88	113.56	17.04	93.61	110.65	406.40	443.94	850.33	420.10	440.80	860.90
T_4	14.61	86.59	101.21	14.69	84.07	98.76	323.50	386.11	709.61	347.24	374.80	722.04
T_5	18.12	100.82	118.94	18.30	93.40	111.69	419.44	449.65	869.09	444.54	451.10	895.63
T_6	16.00	90.96	106.96	16.96	86.75	103.71	342.44	366.71	709.15	394.82	370.73	765.55
T_7	15.69	90.23	105.92	15.57	81.91	97.48	328.29	343.73	672.02	358.86	345.36	704.21
T_8	13.523	81.43	94.96	14.27	74.47	88.73	275.14	300.83	575.97	323.82	300.85	624.67
SEm ±	0.81	5.49	5.68	0.82	4.98	5.11	18.57	20.34	29.91	24.36	26.90	35.21
CD (P=0.05)	2.37	16.15	16.69	2.40	14.65	15.02	54.61	59.82	87.97	71.63	79.12	103.55

Table 4: Available N (kg/ha), P_2O_5 (kg/ha), K_2O (kg/ha) and Zn (ppm) as influenced by different bio fertilizer treatments

Treatments	N		P_2O_5		K_2O		Zn	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
T_1	243.0	234.52	53.21	54.23	318.6	287.30	0.416	0.424
T_2	235.3	229.52	51.21	53.37	315.0	282.82	0.402	0.399
T_3	282.2	262.60	69.03	72.28	334.5	321.31	0.458	0.582
T_4	270.4	257.40	66.64	58.16	328.8	318.62	0.440	0.549
T_5	295.9	297.28	61.47	72.39	373.2	375.75	0.488	0.586
T_6	286.2	289.25	60.08	70.84	368.3	353.53	0.476	0.557
T_7	256.7	254.15	57.39	58.80	358.9	342.79	0.439	0.521
T_8	254.7	235.30	55.60	57.87	342.7	323.10	0.429	0.464
Initial	227		48		360		0.334	
SEm ±	13.46	15.35	3.77	3.60	13.78	12.57	0.018	0.027
CD (P=0.05)	NS	NS	11.08	10.59	40.52	36.96	0.053	0.078

Table 5: Economics of different bio fertilizer treatments

Treatment	Gross realization (₹ /ha)		Cost of cultivation (₹ /ha)		Net realization (₹ /ha)			Benefit: Cost Ratio		
	I Year	II Year	I Year	II Year	I Year	II Year	Pooled	I Year	II Year	Pooled
T_1	53440	54728	21847	22716	31593	32011	31802	1.45	1.41	1.43
T_2	46496	47606	21418	22287	25078	25318	25198	1.17	1.14	1.15
T_3	60312	61775	22247	23116	38065	38659	38362	1.71	1.67	1.69
T_4	53584	54875	21818	22687	31766	32188	31977	1.46	1.42	1.44
T_5	61314	62806	22347	23216	38967	39590	39278	1.74	1.71	1.72
T_6	54482	55801	21818	22687	32664	33113	32889	1.50	1.46	1.48
T_7	53863	55162	21947	22816	31916	32346	32131	1.45	1.42	1.44
T_8	47030	48154	21418	22287	25612	25866	25739	1.20	1.16	1.18

Selling price : Seed - ₹ 9.79/kg and ₹ 10.09/kg during first and second year, respectively.
Straw - ₹ 1.72/kg during both the year

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