Environment & Ecology 35 (2A) : 900—905, April—June 2017
Website: environmentandecology.com ISSN 0970-0420

Effect of *Azospirillum* and Phospho-Solubilizing Bacterial Isolates on Yield and Nutrient Uptake of Rice in Salt Affected Soil

Pawan Kumar Srivastwa, Nishi Kumari, Ruby Chandra, Suman Klayani, Kanhaiyaji Verma, Radhey Shyam, S. K. Singh, Ranvir Kumar

Received 25 June 2016 ; Accepted 23 July 2016 ; Published online 16 August 2016

Abstract A pot experiment was conducted to investigate the effect of soil microbes (*Azospirillum* and phospho-solubilizing bacteria) with different dose of NPK on soil properties, grain yield, straw yield, nutrient content (%) and uptake in salt affected soil. The experiment was carried out in randomized block design (RBD) with 21 treatments i.e. three levels of fertilizer (50, 75 and 100% recommended dose of NPK ha^{-1}) with and without microbial isolates along with control and replicated thrice. The result indicated that addition of microbial isolates to salt affected soil not only increase the yield of rice, but also reduced use of fertilizer. It also improved the soil physico-chemical properties like pH, EC, organic carbon, available N, available P and available K in the post-harvest soil.

Keywords *Azospirillum*, Phosphate solubilizing bacteria, Microbial isolate, Rice.

P. K. Srivastwa, Nishi Kumari[1]*, Ruby Chandra, S. Klayani[2], K. Verma, R. Shyam[2], S. K. Singh[2], Ranvir Kumar[2]
[1]Research Scholar, [2]Assistant Professor
University Department of Botany, J. P. University, Chapra, Bihar, India
e-mail: pawan.raj61@gmail.com
*Correspondence

Introduction

Rice (*Oryza sativa* L.) is a stable food in India, providing 43% of calorie requirement for more than 70% of the Indian population. Self-sufficiency and sustainability in rice production could be achieved only by maintaining a balance between demand and supply of nutrients by integration of inorganic and organic sources like bio-fertilizer, vermicompost, biocompost. Integrated nutrition techniques with inorganic and bio-fertilizers increase the yield and yield components as well as nutrient content, uptake and use efficiency of rice [1, 2]. *Azospirillum* sp. strain B510 enhances rice growth and yield [3].

In the light of above facts this study was conducted with two objectives:

Isolation and characterization of microorganisms (*Azospirillum* and PSB) to increase the yield of rice.

Effect on soil physico-chemical properties like pH, EC, OC, Available N, Available P, Available K in the post-harvest soil.

Materials and Methods

The pot experiment with rice variety '*Usar dhan*–3' was conducted in *kharif* 2012 with 21 (12 *Azospirillum* and 05 phospho-solubilizing bacteria) treatment in salt-affected soil. The treatments consist of control,

full dose of fertilizer, 3/4th dose of NP+K 1/2th dose of NP+K with twelve isolates of *Azospirillum* and five isolates of phospho-solubilizing bacteria (PSB) tested with 1/2 NP+K fertilizer dose. The soil samples were collected from (0–15 cm soil depth) from the salt-affected soil of zone-1. The experimental soil was Texture -Sandy loam, Bulk density–1.58 Mg M^{-3}, Organic matter–0.27%, pH (1:2.5::Soil: Water suspension at 25°)–8.72, EC (1:2.5::Soil: Water suspension at 25°)–1.23 dSm^{-1}, ESP-32%, Available nitrogen, Available P_2O_5, and Available K_2O were low. The experiment was laid out with randomized block design (RBD) having 3 replication. Thirty five days old three seedlings per hill and three hills per pot were used for transplanting purpose. The recommended dose of fertilizer (120:60:40 kg NPK/ha) were applied to rice crop. Half dose nitrogen (60 kg ha^{-1}) through urea (0.58 g pot^{-1}) and full dose of P_2O_5 (tricalcium phosphate 0.54 g pot^{-1}) and K_2O (muriate of potash 0.29 g pot^{-1}) were applied at the time of transplantation of rice seedlings. Remaining half amount of nitrogen was applied in two equal instalments after 20 days and 45 days after transplanting (DAT). The crop was harvested on physiological maturity and yield of grain and straw were recorded. At the same time, post harvest soil samples were collected and processed for further chemical analysis following standard procedure. The grain and straw samples were also analyzed for total N, P, and K contain by digestion with sulfuric acid and diacid procedure and uptake were calculated.

Results and Discussion

Effect of bacterial isolates on yield and nutrient content (per cent) of rice grain and straw

The grain straw yield/pot were significantly increased by full dose, $^3/_4$ dose, and ½ dose of fertilizer and ½ dose of fertilizer with different isolates of *Azospirillum* and PSB over control [4]. $PsbVA_{15B}$ isolates of PSB increased in grain and straw yield 50.0% and 34.70%, respectively over without isolates. However in grain yield was recorded with $AzsMUZ_8$ (72.50%) and straw yield with $AzsEC_{11}$ (40.63%) over without isolates this study was also confirmed by Das et al. [5] and reported that combined application of bio-fertilizers which caused maximum fixation of atmospheric nitrogen, increased uptake of soil phosphorus and potassium by the stevia plant as compared to their respective sole applications (Table 1).

The nutrient content in grain and straw of rice were influenced by application of fertilizer with microbial isolates [6]. Nitrogen and phosphorus content in grain straw have higher in $N_{½}P½K + AzsMUZ_7$ (1.18% and 0.33%, respectively) but straw have higher in $N½ P_{½} K + AzsNUZ_{8B}$ (0.53% and 0.14% respectively). However these treatments were at par to each other. The potassium containt in rice grain and straw indicates that the effect of different fertilizer dose with inoculation of selected *Azospirillum* and PSB isolates were found non-significant.

Effect of Bacterial isolates on Nitrogen, Phosphorus and Potassium (mg pot^{-1}) uptake in grain and straw

Uptake of nitrogen

Nitrogen uptake (mg/pot) by grain, straw and total, increases significantly (Table 2). The highest N uptake by grain was recorded in *Azospirillum* treatment (T_{10}) $AzsMUZ_8$. In case of N uptake in grain with *Azospirillum* and PSB all inoculants increase significantly except treatment (T_6) with $AzsVA_1$. The effect of different fertilizer dose with *Azospirillum* and PSB inoculants on nitrogen uptake by straw was increase significantly. The highest N uptake by straw was recorded in *Azospirillum* treatment (T_{15}) with $AzsEC_{11}$. Total uptake of nitrogen under different dose of fertilizers and microbial inoculants was significant. The effect of *Azospirillum* and PSB treatment all 17 inoculants was increase significantly. The highest total N uptake was recorded in treatment (T_{10}) with inoculant $AzsMUZ_8$.

Uptake of phosphorus

Phosphorus uptake (mg/pot) by grain, straw and total increases significantly. The highest grain, straw and total P uptake was recorded in *Azospirillum* treatment (T_{10}) with inoculant $AzsMUZ_8$. In case of P uptake in grain the effect of *Azospirillum* and PSB all

Table 1. Effect of *Azospirillum* and phosphate solubilizing bacterial isolates on yield and nutrient content of rice grain and straw.

Treatments	Grain yield (g/pot)	Straw yield (g/pot)	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
			Grain	Straw	Grain	Straw	Grain	Straw
T_1 (N_0 P_0 K_0) (control)	8.6	20.3	1.01	0.45	0.27	0.11	0.26	1.37
T_2 (N P K) (full dose)	12.6	22.6	1.19	0.52	0.35	0.14	0.35	1.44
T_3 ($N_{¾}P_{¾}$ K)	12.3	22.9	1.16	0.48	0.33	0.13	0.32	1.40
T_4 ($N_½P_½$ K)	12.0	21.9	1.12	0.47	0.28	0.11	0.30	1.39
T_5 ($N_½$ $P_½$ K+ $AzsSI_4$)	14.6	24.6	1.15	0.48	0.31	0.12	0.32	1.42
T_6 ($N_½$ $P_½$ K+ $AzsVA_1$)	13.0	22.0	1.14	0.50	0.31	0.12	0.31	1.42
T_7 ($N_½$ $P_½$ K+ $AzsVA_{15}$)	13.6	25.8	1.14	0.48	0.31	0.12	0.32	1.42
T_8 ($N_½$ $P_½$ K+ $AzsMUZ_6$)	17.1	28.6	1.15	0.48	0.31	0.12	0.32	1.43
T_9 ($N_½$ $P_½$ K+ $AzsMUZ_7$)	19.0	29.5	1.18	0.52	0.33	0.13	0.33	1.43
T_{10} ($N_½$ $P_½$ K+ $AzsMUZ_8$)	20.7	29.2	1.17	0.53	0.32	0.14	0.32	1.42
T_{11} ($N_½$ $P_½$ K+ $AzsMUZ_{8B}$)	18.8	30.2	1.16	0.48	0.32	0.12	0.33	1.42
T_{12} ($N_½$ $P_½$ K+ $AzsMUZ_9$)	13.6	25.8	1.14	0.49	0.32	0.12	0.31	1.41
T_{13} ($N_½$ $P_½$ K+ $AzsMUZ_{13}$)	15.0	27.2	1.16	0.48	0.31	0.12	0.31	1.41
T_{14} ($N_½$ $P_½$ K+ $AzsMUZ_{13B}$)	17.8	30.2	1.15	0.48	0.31	0.12	0.31	1.41
T_{15} ($N_½$ $P_½$ K+ $AzsEC_{11}$)	19.8	30.8	1.17	0.52	0.32	0.13	0.33	1.42
T_{16} ($N_½$ $P_½$ K+ $AzsEC_{11B}$)	13.0	25.2	1.14	0.48	0.31	0.12	0.32	1.41
T_{17} ($N_½$ $P_½$ K+ $PsbSI_4$)	13.0	25.6	1.14	0.48	0.32	0.12	0.31	1.41
T_{18} ($N_½$ $P_½$ K+ $PsbVA_{15B}$)	18.0	29.5	1.13	0.51	0.33	0.13	0.31	1.43
T_{19} ($N_½$ $P_½$ K+ $PsbMUZ_{8B}$)	13.6	25.8	1.14	0.49	0.31	0.12	0.31	1.41
T_{20} ($N_½$ $P_½$ K+ $PsbEC_{11B}$)	17.0	27.0	1.13	0.48	0.31	0.12	0.31	1.41
T_{21} ($N_½$ $P_½$ K+ $PsbWC_{15}$)	14.6	24.9	1.12	0.48	0.31	0.11	0.31	1.41
CD at (0.05)	1.09	1.77	0.04	0.04	0.03	0.01		
CD at (0.01)	1.41	2.28	0.05	0.05	0.04	0.02	NS	NS
CV	6.75	6.44	3.58	8.27	10.22	12.48		

treatment was significant except treatment (T_6) $AzsVA_1$, but in case of P uptake in straw the effect of *Azospirillum* and PSB all treatment was significant except treatment (T_6) $AzsVA_1$ and (T_{21}) $PsbWC_{15}$.

Uptake of potassium

Potassium uptake (mg/pot) by grain, straw and total with microbial inoculants of *Azospirillum* and PSB significantly increased. The highest K uptake by grain was recorded in *Azospirillum* treatment (T_{10}) with inoculant $AzsMUZ_8$. The effect of different fertilizer dose with *Azospirillum* and PSB inoculant on P uptake by straw was significant with all inoculant except treatment (T_6) with inoculant $AzsVA_1$ and the highest K uptake by straw was recorded in *Azospirillum* treatment (T_{15}) $AzsEC_{11}$. Similarly in case of total uptake of potassium by different dose of fertilizers and microbial inoculant *Azospirillum* and PSB was significant. The highest total uptake of P was recorded in treatment (T_{15}) with $AzsEC_{11}$.

Effect of use of bacterial inoculants on physico-chemical properties of soil

Soil reaction (pH)

The soil reaction in terms of pH (1:2.5::soil: water extract) of post-harvest soil presented in Table 3. The effect of different *Azospirillum* and PSB treatments on soil reaction was insignificant. Inoculation of phosphate solubilizing bacteria with half dose of N, P and full dose of K decrease the soil pH after harvest of paddy but the effect was not significant. The decrease in soil pH in treatment with PSB isolates may be due to production of weak organic acids by PSB in the rhizosphere of rice crop.

Electrical conductivity

The electrical conductivity (dSm^{-1}) of post-harvest soil presented in Table 3 clearly indicates that the effect of different fertilizer dose alone and in combination with inoculation of selected *Azospirillum* and

Table 2. Effect of *Azospirillum* and phosphate solubilizing bacterial isolates on nitrogen, phosphorus and potassium uptake (mg pot^{-1}) in rice.

Treatments	Nitrogen			Phosphorus			Potassium		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1 (N_0 P_0 K_0) (control)	0.087	0.091	0.178	0.023	0.022	0.045	0.022	0.278	0.301
T_2 (NPK) (Full dose)	0.150	0.118	0.268	0.044	0.032	0.076	0.044	0.325	0.370
T_3 ($N_{¾}$ $P_{¾}$ K)	0.143	0.110	0.253	0.041	0.030	0.070	0.039	0.321	0.360
T_4 ($N_{½}$ $P_{½}$ K)	0.134	0.103	0.237	0.034	0.024	0.058	0.036	0.304	0.340
T_5 ($N_{½}$ $P_{½}$ K+$AzsSI_4$)	0.168	0.117	0.285	0.046	0.030	0.075	0.047	0.350	0.396
T_6 ($N_{½}$ $P_{½}$ K+$AzsVA_1$)	0.148	0.110	0.258	0.040	0.026	0.067	0.040	0.312	0.353
T_7 ($N_{½}$ $P_{½}$ K+$AzsVA_{13}$)	0.155	0.124	0.279	0.042	0.031	0.073	0.043	0.367	0.410
T_8 ($N_{½}$ $P_{½}$ K+$AzsMUZ_6$)	0.197	0.138	0.335	0.053	0.034	0.087	0.054	0.407	0.462
T_9 ($N_{½}$ $P_{½}$ K+$AzsMUZ_7$)	0.224	0.154	0.379	0.063	0.039	0.102	0.063	0.422	0.485
T_{10} ($N_{½}$ $P_{½}$ K+$AzsMUZ_8$)	0.242	0.155	0.397	0.066	0.041	0.107	0.066	0.414	0.481
T_{11} ($N_{½}$ $P_{½}$ K+$AzsMUZ_{8B}$)	0.218	0.145	0.363	0.060	0.036	0.096	0.062	0.429	0.491
T_{12} ($N_{½}$ $P_{½}$ K+$AzsMUZ_9$)	0.155	0.126	0.281	0.043	0.031	0.074	0.042	0.364	0.406
T_{13} ($N_{½}$ $P_{½}$ K+$AzsMUZ_{13}$)	0.174	0.130	0.305	0.047	0.033	0.079	0.046	0.384	0.430
T_{14} ($N_{½}$ $P_{½}$ K+$AzsMUZ_{13B}$)	0.205	0.145	0.350	0.055	0.036	0.091	0.055	0.426	0.481
T_{15} ($N_{½}$ $P_{½}$ K+$AzsEC_{11}$)	0.232	0.160	0.392	0.063	0.040	0.103	0.065	0.437	0.503
T_{16} ($N_{½}$ $P_{½}$ K+$AzsEC_{11B}$)	0.227	0.121	0.348	0.062	0.030	0.092	0.064	0.355	0.419
T_{17} ($N_{½}$ $P_{½}$ K+$PsbSI_4$)	0.148	0.123	0.271	0.042	0.031	0.072	0.040	0.361	0.402
T_{18} ($N_{½}$ $P_{½}$ K+$PsbVA_{15B}$)	0.203	0.150	0.354	0.059	0.038	0.098	0.056	0.422	0.478
T_{19} ($N_{½}$ $P_{½}$ K+$PsbMUZ_{8B}$)	0.155	0.126	0.281	0.042	0.031	0.073	0.042	0.364	0.406
T_{20} ($N_{½}$ $P_{½}$ K+$PsbEC_{11B}$)	0.192	0.129	0.321	0.053	0.032	0.085	0.053	0.381	0.433
T_{21} ($N_{½}$ $P_{½}$ K+$PsbWC_{15}$)	0.163	0.118	0.281	0.045	0.028	0.073	0.045	0.352	0.397
CD (p = 0.05)	0.014	0.010	0.020	0.006	0.005	0.008	0.005	0.027	0.027
CD (p = 0.01)	0.018	0.016	0.025	0.008	0.007	0.011	0.006	0.035	0.035
CV	7.671	9.761	6.255	12.253	16.386	10.323	9.769	7.000	6.212

PSB at half dose of N, P and full dose of K was insignificant. However, the value varied from 1.23 to 1.24 dSm^{-1} in different treatments.

Available N (mg/kg)

Available nitrogen (mg/kg) of post harvest soil analyzed and presented in Table 3. The available nitrogen varied from 54.55 to 64.50 mg/kg due to different treatment. The effect of fertilizer dose alone and half dose of N, P and full dose of K with microbial inoculant of either *Azospirillum* or PSB significantly improved the available nitrogen content of the post-harvest soil. The highest available N was recorded in ½ dose of fertilizer with inoculant $AzsMUZ_8$. Increasing dose of fertilizer from control to ½ dose, ½ dose to 3/4th and 3/4th to full dose of fertilizer have significantly increased the available nitrogen in post harvest soil. The effects of selected *Azospirillum* inoculants at half dose of N, P and full dose of K have significantly improved the available nitrogen of post-harvest soil. This may be due to the fact that *Azospirillum* may fix atmospheric nitrogen in the rhizosphere and increased the available N significantly. The available nitrogen in post-harvest soil after the treatment with *Azospirillum* inoculant $AzsMUZ_7$, $AzsMUZ_8$, $AzsMUZ_{8B}$, $AzsMUZ_{13}$, $AzsMUZ_{13B}$ and $AzsEC_{11}$ were found to be almost equivalent to 3/4th dose of fertilizer. It means if these inoculants of *Azospirillum* are used in farm field, it may save 1/4th dose of nitrogen of paddy cultivation in salt-affected soil.

Available P (mg/kg)

Available phosphorus (P_2O_5 mg/kg) of post-harvest soil presented in Table 3, the available phosphorus varied from 6.30 to 7.37 mg/kg due to different treatment in control and ½ dose of fertilizer with inoculant $PsbVA_{15B}$ inoculant, respectively. The effect of fertilizer dose alone and half dose of N, P and full dose of K with microbial inoculant of either *Azospirillum* or PSB significantly improved the available phosphorus of the post-harvest soil. Increasing dose of fertil-

Table 3. Effect of *Azospirillum* and phosphate solubilizing bacterial isolates on physico-chemical properties of the post-harvest soil of the rice crop.

	Treatments	pH	EC	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
T_1	(N_0 P_0 K_0) (control)	8.72	1.23	54.55	6.30	50.27
T_2	(N P K) (Full dose)	8.70	1.24	64.50	7.20	54.73
T_3	($N_{¾}$ $P_{¾}$ K)	8.72	1.24	62.76	6.97	52.90
T_4	($N_½$ $P_½$ K)	8.71	1.24	58.52	6.74	51.96
T_5	($N_½$ $P_½$ +$AzsSI_4$)	8.71	1.23	60.44	6.93	52.41
T_6	($N_½$ $P_½$ K+$AzsVA_1$)	8.71	1.24	60.08	6.90	52.37
T_7	($N_½$ $P_½$ K+$AzsVA_{15}$)	8.71	1.24	60.93	6.94	52.77
T_8	($N_½$ $P_½$ K+$AzsMUZ_6$)	8.72	1.23	61.74	6.97	52.81
T_9	($N_½$ $P_½$ K+$AzsMUZ_7$)	8.71	1.23	62.58	6.97	52.90
T_{10}	($N_½$ $P_½$ K+$AzsMUZ_8$)	8.71	1.23	63.52	7.03	53.71
T_{11}	($N_½$ $P_½$ K+$AzsMUZ_{8B}$)	8.72	1.23	63.12	7.02	53.26
T_{12}	($N_½$ $P_½$ K+$AzsMUZ_9$)	8.72	1.23	61.87	6.95	52.81
T_{13}	($N_½$ $P_½$ K+$AzsMUZ_{13}$)	8.72	1.24	62.00	6.94	52.86
T_{14}	($N_½$ $P_½$ K+$AzsMUZ_{13B}$)	8.71	1.23	62.76	6.99	52.95
T_{15}	($N_½$ $P_½$ K+$AzsEC_{11}$)	8.71	1.23	62.72	7.00	53.71
T_{16}	($N_½$ $P_½$ K+$AzsEC_{11B}$)	8.71	1.23	60.89	6.92	52.95
T_{17}	($N_½$ $P_½$ K+$PsbSI_4$)	8.62	1.23	59.06	7.34	52.81
T_{18}	($N_½$ $P_½$ K+$PsbVA_{15B}$)	8.21	1.23	60.08	7.37	52.50
T_{19}	($N_½$ $P_½$ K+$PsbMUZ_{8B}$)	8.51	1.23	60.13	7.33	50.71
T_{20}	($N_½$ $P_½$ K+$PsbEC_{11B}$)	8.32	1.23	60.17	7.28	52.86
T_{21}	($N_½$ $P_½$ K+$PsbWC_{15}$)	8.60	1.23	59.10	6.83	51.92
	CD at (0.05)			0.47	0.38	3.29
	CD at (0.01)	NS	NS	0.60	0.50	4.25
	CV			0.73	5.29	5.95

izer from control to 1/2 dose, 1/2 to 3/4th dose and 3/4th to full dose of N and P has significantly increased the available phosphorus of the post-harvest soil. The effect of selected *Azospirillum* inoculants at half dose of N, P and full dose of K has increased positively, but the available phosphorus due to *Azospirillum* inoculant was insignificant. All *Azospirillum* inoculants recorded available P at par with 3/4th dose of N, P and full dose of K. The effect of different isolates of PSB significantly increase the available phosphorus in post-harvest soil except the treatment with PSB inoculant $PsbWC_{15}$.

Available K (mg/kg)

The available potassium (K_2O mg/kg) of post-harvest soil presented in Table 3 clearly indicated that the effect of different fertilizer dose and inoculation of selected *Azospirillum* and PSB at half dose of N, P and full dose of K were non-significant and they varied from 50.27 to 54.73 mg/kg in treatment control and full dose of NPK fertilizer respectively.

Conclusion

It can be inferred that different dose of NPK with or without bacterial strain (*Azospirillum* and PSB) to salt affected soil not only increase the yield of rice also improve the soil physico-chemical properties like pH, EC, organic carbon, available N, available P, available K in the post harvest soil.

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