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Performance of *Azospirillium* and Phosphate solubilizing Bacteria on Growth and Yield of Sorghum

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ABSTRACT: In the present study, seven *Azospirillium* and eight Phosphate solubilizing bacteria (PSB) isolates were isolated from sorghum growing regions of Kolhapur District. All isolates were identified on the basis of morphological, microscopic features and different biochemical tests. The treatment T_{11}, (*Azospirillium* + PSB + 100 %N and P_2O_5+ RD of K_2O) showed the highest plant height at harvest (215.50 cm), number of tillers per plant (6.10) which was on par with treatment T_{10} (*Azospirillium* + PSB+ 75% N and P_2O_5+ RD of K_2O) *i.e.* plant height at harvest (213.40 cm) and number of tillers per plant (5.70). The results concern yield parameters revealed that the treatment T_{11}, (*Azospirillium* + PSB+ 100 %N and P_2O_5 + RD of K_2O) showed the highest 1000 grain weight (39.80 g), grain yield (44.33 q/ha) and fodder yield (15 t/ha) which was on par with treatment T_{10}, (*Azospirillium* + PSB+ 75 %N and P_2O_5+ RD of K_2O) *i.e.* test weight (38.50 g), grain weight (43.26 q/ha) and fodder yield (14.60 t/ha). Also highest available N (166.78 Kg/ha), P (42.36 Kg/ha) and K (143.22 Kg/ha) was showed by treatment T_{11}, (*Azospirillium* + PSB+ 100 %N and P_2O_5+ RD of K_2O) which was on par with treatment $T_{10,}$ (*Azospirillium* + PSB+ 75%N and P_2O_5 + RD of K_2O) available N (164.87 Kg/ha), P (41.16 Kg/ha) and K (142.63 Kg/ha) in soil after harvest.

Keywords: *Azospirillium*, Phosphate solubilizing bacteria, yield, Sorghum.

INTRODUCTION

Sorghum (*Sorghum bicolor*) is a member of Poaceae family that originated in Africa and is now widely grown in tropical and subtropical areas (Bibi *et al*., 2010). After rice, wheat, maize and barley sorghum is the world's fifth most significant cereal crop (FAO, 2010). Sorghum is a versatile grain that can be used for food, fuel and fodder (Bollam *et al.,* 2021). It is grass species grown for its grain which is used in human diet, animal feed and fuel manufacturing. Chemical fertilizers are now being used more frequently in order to complete the food requirement of the world's rising population. Chemical fertilizers enhance agricultural yield, but their excessive usage has hardened the soil, reduced fertility, strengthened pesticides, polluted the air, water, possess health and environmental risks. As a result, scientists and experts are advocating in favour of organic fertilizers and biofertilizers as the greatest alternative for avoiding soil degradation, other environmental and life dangers created by the overuse of chemical fertilizers. Biofertilizers are living microorganisms that colonize in the rhizosphere or the interior of the plant and encourage growth by increasing the supply or availability of major nutrients to the host plant when applied to seeds, plant surfaces or soil. Rhizosphere soil is a "hot-spot" for microbial growth and major microbial activities (Sachdev *et al.,* 2009). It is the narrow zone of soil specifically influenced by the root system (Dobbelaere *et al*., 2003). This zone is rich in nutrients when compared with the bulk soil due to the accumulation of a variety of plant exudates such as amino acids and sugars providing a rich source of energy and nutrients for bacteria (Gray and Smith 2005). Beneficial microorganisms that can solubilize organic nitrogen and phosphorus into inorganic form of nitrogen and phosphorus which made available to the plants. *Azospirillium* is one of the versatile non-symbiotic, free living diazotrophic bacteria which appears to have a world-wide distribution and occurs in large number in the rhizosphere soil of a variety of grasses and cereals. *Azospirillium* is a gram-negative, microaerophilic, non-fermentative, nitrogen-fixing bacterium belonging to the *Rhodospirillaceae* family. It is aerobic, but many of them can also function as microaerobic diazotrophs, meaning they can survive in low-oxygen environment. It may fix 20-40 kg of nitrogen per hectare per year. It promotes root propagation by secreting growth hormones (Van *et al*., 1997). Currently, the primary goal of soil phosphorus management is to maximize crop output while minimizing phosphorus loss from the soil (Bashan *et al*., 2013). The use of Phosphate solubilizing bacteria as inoculants increases phosphate uptake by plants while also increasing crop production. The formation of organic acid is the primary mechanism for mineral phosphate solubilization and enzyme phosphatases play an important role in the mineralization of organic phosphorus in soil (Rechardson and Simpson 2011). For sustainable crop production, we are now attempting to limit the usage of chemical fertilizers by increasing the use of biofertilizers. Keeping this in mind, an appropriate balance of biofertilizers and chemical fertilizers should be used to optimise crop growth and quality.

MATERIAL AND METHODS

The experiment was conducted during *Rabi* at Plant Pathology and Agricultural Microbiology Department, R.C.S. M. College of Agriculture, Kolhapur during the year 2021-22. Seven *Azospirillium* isolates and eight phosphate solubilizing bacterial isolates were isolated from roots and rhizospheric soil of sorghum from Kolhapur district. All isolates were identified and selected efficient strains on the basis of morphological (cell morphology, colony shape, colony colour, stain colour, gram reaction) microscopic observations and different biochemical tests *viz.* methyl red test, catalase test, starch hydrolase test, gelatine hydrolase test, nitrate reductase test, indol test, N fixing and P solubilizing ability respectively. The efficient strains of *Azospirillium* and Phosphate solubilizing bacteria were selected for field studies.

RESULTS AND DISCUSSION

The co-inoculation of efficient *Azospirillum* and Phosphate solubilizing bacteria along with 100 % recommended dose of chemical fertilizers showed significant increase in growth and yield parameters of sorghum as compared to other treatments.

Germination percentage. The data represented in Table 1 specified that, the germination percentage, plant height, number of tillers per plant and number of leaves per plant were significantly increased when seedlings were treated with *Azospirillium* and phosphate solubilizing bacteria as compared to single inoculation and uninoculated control. The treatment $T_{11,}$ *Azospirillium*+ PSB+ 100%N and P_2O_5+ RD of K_2O observed highest germination per cent (89.22%) which was found statistically at par with treatments T_{10}, *Azospirillium*+ PSB+ 75%N and P_2O_5+ RD of K_2O (87.12 %); T_5, *Azospirillium*+ RDF (85.39 %) and treatment T_8, PSB+ RDF (83.00 %). The treatment T_{12}, Control (RDF) (81.30%) was found statistically at par with treatments T_4, *Azospirillium* + 75%N + RD of P_2O_5 and K_2O (80.00%); T_7, PSB+ 75% P_2O_5+ RD of N and K_2O (78.76%); T_9, *Azospirillium*+ PSB+ 50%N and P_2O_5+ RD of K_2O (76.88); T_3, *Azospirillium* +50% N +RD of P_2O_5 and K_2O (75.00%); T_6, PSB+ 50% P_2O_5+ RD of N and K_2O (74.41%). Lowest germination percentage was observed in treatment T_2, PSB (67.00 %). The results are in support with the Cassana *et al.* (2009); Anjali *et al.* (2013), noticed high germination percentage of maize seeds inoculated with *Azospirillum brasilense* than uninoculated seeds.

Plant height. Plant height at harvest, the results showed that highest plant height (215.50 cm) was found in treatment T_{11}, *Azospirillium*+ PSB+ 100%N and P_2O_5+ RD of K_2O which was found statisticallyat par with the treatments T_{10}, *Azospirillium* + PSB+ 75%N and P_2O_5+ RD of K_2O. (213.40 cm) and the treatment T_5, *Azospirillium* + RDF (209.99 cm). The treatment T_8, PSB+ RDF (206.77 cm) was found statistically at par with the treatments T_{12}, Control (RDF) (205.80 cm); treatment T_4, *Azospirillium* + 75% N+ RD of P_2O_5 and K_2O (204.87 cm) and treatment T_7, PSB+ 75% P205+ RD of N and K_2O (203.60 cm). Rest of the treatments showed the plant height between 199.77 to 201.10 cm. The treatment T_2, PSB showed lowest height (198.43 cm).

The results are in accordance with the scientists Widada *et al.* (2003), observed increase in plant height by inoculated seeds over uninoculated seeds. Seeds inoculated with *Azospirillium lipoferum* showed more plant height than inoculated with PSB *Pseudomonas* spp .sorghum seed inoculated with the N_2 fixing bacteria *Azospirillium lipoferum* and PSB *Pseudomonas* spp. observed highest plant height.

Number of tillers per plant

Number of tillers per plant 30 DAS, the results indicated that that maximum number of tillers per plant plant (6.10) was observed in the treatment T_{11}, *Azospirillium* + PSB + 100%N and P_2O_5+ RD of K_2O which was found statistically at par with the treatment T_{10}, *Azospirillium* + PSB+ 75%N and P_2O_5+ RD of K_2O (5.70). The treatment T_5, *Azospirillium*+ RDF (4.73) was found statistically at par with the treatment T_8, PSB+ RDF (4.43) and the treatment T_{12}, Control (RDF) (4.40). Rest of the treatments showed number of tillers per plant in the range of 2.73 to 3.77. The treatment T_2, PSB showed lowest number of tillers per plant (2.47). The results are in support with the Kapulnik *et al.* (1984), noticed significant increases in the number of fertile tillers per unit area and in the nitrogen yield in two cultivars of *Triticum aestivum* and *T. turgidum* inoculated with bacteria of the genus *Azospirillum,* the field.

Number of leaves. Number of leaves per plant of sorghum, the results noticed that maximum number of leaves per plant (13.43) observed in the treatment T_{11}, *Azospirillium* + PSB+ 100%N and P_2O_5+ RD of K_2O which was found statistically at par with the treatment T_{10}, *Azospirillium* + PSB+ 75%N and P_2O_5+ RD of K_2O (12.80). The treatment T_5, *Azospirillium* + RDF (10.60) was found statistically at par with the treatment T_8, PSB+ RDF (10.47) and treatment T_{12}, Control (RDF) (10.17).

Rest of the treatments showed number of leaves per plant in the range of 7.76 to 9.63. The treatment T_2, PSB showed lowest number of leaves per plant (7.30). The present findings are in accordance with the scientists, Sunita *et al.* (2018); Fikrettin *et al.* (2004).

Table 1: Effect of efficient strain of *Azospirillium* and phosphate solubilizing bacteria on growth and yield parameters of Sorghum.

Tr. No.	Treatment details	Germination %	Plant Height (cm)				No. of tillers per Plant (30 DAS)	No. of Leaves per Plant	1000 grain weight (g)	Grain yield (q/ha)	Fodder yield (t/ha)
			30 DAS	45 DAS	60 DAS	At harvest					
T_1	*Azospirillium*	70.50	18.10	33.50	62.80	199.77	2.73	7.76	30.45	29.55	8.00
T_2	PSB	67.00	17.23	32.70	61.40	198.43	2.47	7.30	30.86	30.53	8.10
T_3	*Azospirillium* +50% N + RD of P_2O_5 and K_2O	75.00	19.80	35.30	64.50	200.54	3.27	8.52	31.94	32.11	9.10
T_4	*Azospirillium* + 75% N+ RD of P_2O_5 and K_2O	80.00	23.40	39.10	67.60	204.87	3.77	9.63	33.82	36.73	10.00
T_5	*Azospirillium* + RDF	85.39	26.60	42.03	73.50	209.99	4.73	10.60	36.63	40.78	11.40
T_6	PSB+ 50% P_2O_5+ RD of N and K_2O	74.41	19.10	34.50	62.80	202.40	3.10	8.49	32.08	33.16	9.20
T_7	PSB+ 75% P_2O_5+ RD of N and K_2O	78.76	21.73	38.57	65.43	203.60	3.47	9.33	34.75	37.63	10.40
T_8	PSB+ RDF	83.00	25.00	40.70	69.80	206.77	4.43	10.47	37.89	42.21	12.00
T_9	*Azospirillium* + PSB + 50%N and P_2O_5+ RD of K_2O	76.88	20.30	35.90	65.10	201.10	3.30	8.83	32.65	34.82	9.37
T_{10}	*Azospirillium*+ PSB+ 75%N and P_2O_5+ RD of K_2O	87.12	28.50	44.50	75.00	213.40	5.70	12.80	38.50	43.26	14.60
T_{11}	*Azospirillium* + PSB+ 100% N and P_2O_5 + RD of K_2O	89.22	30.10	46.00	76.87	215.50	6.10	13.43	39.87	44.78	15.00
T_{12}	Control (RDF)	81.30	23.80	40.10	69.40	205.80	4.40	10.17	35.97	39.22	11.00
	S.E.±	**2.48**	**1.12**	**1.17**	**2.54**	**1.88**	**0.25**	**0.32**	**1.31**	**1.89**	**0.89**
	C.D. at 5%	**7.28**	**3.29**	**3.45**	**7.47**	**5.52**	**0.73**	**0.95**	**3.85**	**5.57**	**2.62**

1000 grain weight. The results revealed that, highest 1000 grain weight (39.87 g) which was found statistically at par with the treatment T_{10}, *Azospirillium* + PSB+ 75%N and P_2O_5+ RD of K_2O (38.50 g); treatment T_8, PSB+ RDF (37.89 g) and treatment T_5, *Azospirillium* + RDF (36.63 g). The treatment T_{12}, Control (RDF) (35.97 g) was found statistically at par with the treatments T_7, PSB+ 75% P_2O_5+ RD of N and K_2O (34.75 g) T_4, *Azospirillium* + 75% N+ RD of P and K_2O (33.82 g) T_9, *Azospirillium* + PSB+ 50% N and P_2O_5+ RD of K_2O (32.65 g). Rest of the treatments exhibited 1000 grain weight in the range of 30.86 to 32.08 g. T_1, *Azospirillum* showed lowest 1000 grain weight (30.45 g). The results are in accordance with following researchers Mokula Md. Rafia and Charyulu (2016); Ghodpage and Datke (2005), found increase in germination percentage, growth, yield (1000 grain weight) nutrient uptake by sorghum when seeds were treated with *Azospirillum* and PSB. The treatment 60:30:30 kg NPK per ha + FYM @ 5 tonnes per ha + *Azospirillum* + PSB showed maximum yield.

Grain yield. The results indicated that the maximum (44.78 q/ha) yield of sorghum was observed in treatment T_{11}, *Azospirillium* + PSB+ 100%N and P_2O_5+ RD of K_2O which was found statistically at par with the treatment T_{10}, *Azospirillium* + PSB+ 75%N and P_2O_5+ RD of K_2O (43.26 t/ha); T_8, PSB+ RDF (42.21 q/ha); T_5, *Azospirillium* + RDF (40.78 q/ha).

The treatment T_{12}, Control (RDF) (39.22 q/ha) was found statistically at par with the treatment T_7, PSB+ 75% P205+ RD of N and K_2O (37.63 q/ha); T_4, *Azospirillium* + 75% N + RD of P and K_2O (36.73 q/ha); T_9, *Azospirillium* + PSB+ 50%N and P_2O_5 + RD of K_2O (34.82 q/ha). Rest of the treatments showed the grain yield between 30.53 to 33.16 q/ha. The treatment T_1, *Azospirillum* showed lowest grain yield (29.55 q/ha). The results of present investigation are in support with Sarig *et al.* (1990), studied the effect of inoculation with *Azospirillum brasilense* on growth and yield of *Sorghum bicolor* and Jat *et al.* (2013).

Fodder yield. Fodder yield (t/ha), the results stated that, highest fodder yield (15.00 t/ha) was observed in treatment T_{11}, *Azospirillium* + PSB+ 100% N and P_2O_5+ RD of K_2O which was found statistically at par with the treatment T_{10}, *Azospirillium* + PSB+ 75%N and P_2O_5+ RD of K_2O (14.60 t/ha). The treatment T_8, PSB+ RDF (12.00 t/ha) was found statistically at par with the treatments T_5, *Azospirillium* + RDF (11.40 t/ha); T_{12}, Control (RDF) (11.00 t/ha); T_7, PSB+ 75% P_2O_5+ RD of N and K_2O (10.40 t/ha) and treatment T_4, *Azospirillium* + 75%N+ RD of P_2O_5 and K_2O (10 t/ha).

T_1, *Azospirillum* showed lowest fodder yield (8 t/ha). Rest of the treatments exhibited fodder yield in the range of 8.10 to 9.37 t/ha. The results are in support with the scientist Sarig *et al.* (1984), inoculated *sorghum bicolor* seeds with bacteria of the genus *Azospirillum* resulted in significant increases over controls of 17% in grain yield and of 19% in the forage yield. In addition, significant increases over controls in plant dry weight, mineral content (N, P and K) and panicle number were obtained by inoculation and Tandel *et al.* (2020).

Table 2: Effect of efficient *Azospirillum* and Phosphate solubilizing bacteria on available N,P, K status of soil

after harvesting and Microbial Population at 50% flowering stage of sorghum.

Treatment No.	Treatment details	Available N (Kg/ha)	Available P (Kg/ha)	Available K (Kg/ha)	Microbial Population	
					Azospirillium (10^6cfu/g)	PSB (10^6cfu/g)
T_1	*Azospirillium*	151.44	33.75	131.35	4.70	1.98
T_2	PSB	148.61	34.15	130.78	3.20	2.70
T_3	*Azospirillium* + 50% N + RD of P2O5 and K2O	155.67	34.86	132.38	4.90	2.00
T_4	*Azospirillium* + 75% N+ RD of P2O5 and K2O	159.34	37.13	136.12	5.36	2.10
T_5	*Azospirillium*+ RDF	163.76	39.13	140.76	5.90	2.20
T_6	PSB+ 50% P2O5+ RD of N and K2O	152.32	35.18	131.92	3.50	3.00
T_7	PSB+ 75% P2O5+ RD of N and K2O	158.55	37.96	135.23	3.70	3.26
T_8	PSB+ RDF	162.36	40.00	138.00	4.00	3.50
T_9	*Azospirillium* + PSB+ 50%N and P2O5+ RD of K2O	156.54	36.88	134.63	5.10	3.10
T_{10}	*Azospirillium* + PSB+ 75%N and P2O5+ RD of K2O	164.87	41.16	142.63	6.20	3.70
T_{11}	*Azospirillium* + PSB+ 100%N and P2O5+ RD of K2O	166.78	42.78	143.22	6.60	3.80
T_{12}	Control (RDF)	161.88	38.95	137.94	2.90	1.92
	S.E.±	**2.09**	**1.26**	**1.83**	**0.41**	**0.17**
	C.D. at 5%	**6.16**	**3.71**	**5.38**	**1.21**	**0.53**

The analysed results from Table 2 stated that, the combine use of *Azospirillium* and PSB significantly increases available N, P and K.

Available N. The results concluded that the maximum available N after harvesting of sorghum (166.78 Kg/ha) was observed in treatment T11, *Azospirillium*+ PSB+ 100%N and P2O5+ RD of K2O which was found statistically at par with the treatment T10, *Azospirillium* + PSB+ 75% N and P2O5+ RD of K2O (164.87 Kg/ha); T5, *Azospirillium* + RDF (163.76 Kg/ha) and T8, PSB+ RDF (162.36 Kg/ha).The treatment T12, Control (RDF) (161.88 Kg/ha) was found statistically at par with the treatment T4, *Azospirillium* + 75% N + RD of P2O5 and K2O (159.34 Kg/ha) T7, PSB + 75% P2O5+ RD of N and K2O (158.55 Kg/ha) T9, *Azospirillium*+ PSB+ 50%N and P2O5+ RD of K2O (156.54 Kg/ha). Rest of the treatments showed the available N in the range of 151.44 Kg/ha to 155.67 Kg/ha. T2, PSB showed minimum available N *i.e.* 148.61 Kg/ha

Available P. The results specified that, the maximum available P in soil after harvesting of sorghum was observed in treatment T11, *Azospirillium* + PSB+ 100% N and P2O5+ RD of K2O. (42.78 Kg/ha) which was found statistically at par with the treatment T10, *Azospirillium* + PSB + 75%N and P2O5+RD of K2O (41.16 Kg/ha); T8, PSB+ RDF (40.00 Kg/ha) and T5, *Azospirillium* + RDF (39.13 Kg/ha. The treatment T12, Control (RDF) (38.95 Kg/ha) was found statistically at par with the treatment T7, PSB+ 75% P2O5+ RD of N and K2O (37.96 Kg/ha); T4, *Azospirillium* + 75%N+ RD of P2O5 and K2O (37.13 Kg/ha) and treatment T9, *Azospirillium*+ PSB+ 50%N and P2O5+ RD of K2O (36.88 Kg/ha). Rest of the treatments showed the available P in the range of 34.15 Kg/ha to 35.18 Kg/ha. T1, *Azospirillum* showed minimum available P *i.e.* 33.75 Kg/ha.

Available K. The results indicated that, the maximum available K in soil after harvesting of sorghum was observed in treatment T_{11}, *Azospirillium* + PSB+ 100% N and P_2O_5+ RD of K_2O (143.22 Kg/ha) which was statistically at par with the treatment T_{10}, *Azospirillium* + PSB+ 75% N and P_2O_5 + RD of K_2O, T5, *Azospirillium* + RDF (140.76 Kg/ha) and T8, PSB+ RDF (162.36 Kg/ha). The treatment T12, Control (RDF) (137.94 Kg/ha) was found statistically at par with the treatment T_4, *Azospirillium* + 75% N+ RD of P205 and K2O (136.12 Kg/ha) T7, PSB+ 75% P2O5+ RD of N and K2O (135.23 Kg/ha) T9, *Azospirillium*+ PSB+ 50%N and P2O5+ RD of K2O (134.63Kg/ha). Rest of the treatments showed the available K in the range of 131.35 Kg/ha to 132.38 Kg/ha. T2, PSB showed minimum available K *i.e.* 130.78 Kg/ha.

The maximum Available N (166.78 Kg/ha), P (42.36 Kg/ha) and K (143.22 Kg/ha) in soil after harvesting of sorghum was observed in treatment T_{11}, *Azospirillium* + PSB+ 100%N and P_2O_5+ RD of K_2O which was found statistically at par with the treatment T_{10}, *Azospirillium* + PSB+ 75%N and P_2O_5 + RD of K_2O, Available N (164.87 Kg/ha), P (41.16 Kg/ha) and K (142.63 Kg/ha). It is in accordance with the obtained results of scientists Pacovsky *et al.* (1985) in which sorghum plants were inoculated with *Azospirillium brasilense*. *Azospirillium* inoculation increased plant dry weight and nitrogen assimilation by 25%. The inoculated plants showed increased dry weight, grain yield, available N, P and K content in soil.

Microbial population. The results indicated that, the maximum population count of *Azospirillum* at 50% flowering stage of sorghum was observed in treatment T11, *Azospirillium*+ PSB + 100%N and P2O5+ RD of K2O (6.60 × 10^6cfu/g) which was found statistically at par with the treatment T10, *Azospirillium*+ PSB+ 75%N and P2O5+ RD of K2O (6.20×10^6cfu/g) and the treatment T5,*Azospirillium* + RDF (5.90×10^6cfu/g). The treatment T4, *Azospirillum* + 75%N + RD of P2O5 and K2O (5.36×10^6cfu/g) was found statistically at par with the treatments T9, *Azospirillum* + PSB+ 50%N and P2O5+ RD of K2O (5.10×10^6cfu/g); T3, *Azospirillium* +50% N +RD of P2O5 and K2O (4.90×10^6cfu/g); T1, *Azospirillium* (4.70×10^6 cfu/g). Rest of the treatments showed the population count of *Azospirillum* in the range of 3.20 × 10^6cfu/g to 4.00 × 10^6cfu/g. The treatment T12, Control (RDF) showed (2.90×10^6 cfu/g) showed lowest *Azospirillum* population at 50% flowering stage of sorghum.

The results recorded that, the maximum population count of PSB at 50% flowering stage of sorghum was observed in treatment T11, *Azospirillium* + PSB+ 100% N and P2O5+ RD of K2O (3.80 × 10^6cfu/g) which was found statistically at par with the treatments T10, *Azospirillium*+ PSB+ 75% N and P2O5+ RD of K2O (3.70×10^6cfu/g) and treatment T8, PSB + RDF (3.50 × 10^6cfu/g). The treatment T7, PSB+ 75% P2O5+ RD of N and K2O (3.26×10^6cfu/g) was found statistically at par with the treatments T9, *Azospirillium* + PSB+ 50% N and P2O5+ RD of K2O (3.10×10^6cfu/g), T6, PSB+ 50% P2O5 + RD of N and K2O (3.00 ×10^6cfu/g). Rest of the treatments showed PSB population count in the range of 1.98 × 10^6cfu/g to 2.70 × 10^6cfu/g. The treatment T12, Control (RDF) (1.92×10^6cfu/g) showed lowest PSB population at 50% flowering stage of sorghum.

The results of present investigation are in support with Alagawadi and Gaur (1994), studied effect of combined inoculation of *Azospirillum brasilense* and *Pseudomonas striata* or *Bacillus polymyxa* (with and without fertilizer nitrogen and rock Phosphorus) on the yield and nutrient uptake of sorghum. Noticed increase in population counts of *Azospirillum* and PSB in the rhizosphere of sorghum in the respective inoculation treatments than in uninoculated treatments and Sawicka and Swędrzyńska (2001).

CONCLUSIONS

Results revealed that, the treatment $T_{11,}$ *Azospirillium* + PSB+ 100%N and P_2O_5+ RD of K_2O, showed highest growth parameters, yield parameters and high available N, P, K followed by the treatment T_{10} , *Azospirillium* + PSB + 75% N and P_2O_5 + RD of K_2O.

Also it was noticed that the combine use of *Azospirillum* and phosphate solubilizing bacteria had better effect on growth and yield of sorghum than single. Use of *Azospirillium* and Phosphate solubilizing bacteria saves 25% dose of nitrogenous and phosphatic chemical fertilizers. Additionally efficient strains of *Azospirillium* and PSB could be increase nitrogen fixing and phosphorus solubilizing ability which indirectly increases yield.

Integrated use of inorganic N, P, K and efficient strains of biofertilizers is most efficient way of saving the chemical fertilizers.

REFERENCES

Alagawadi, A. R. and Gaur, A. C. (1994). Inoculation of *Azospirillium brasilense* and phosphate-solubilizing bacteria on yield of sorghum [*Sorghum bicolor* (L.) Moench] in dry land. *Tropical Agriculture*, *69*(4), 347-350.

Anjali, S., Sejal, R. and Preeti, S. (2013). Screening of efficient halotolerant phosphate solubilizing bacteria and their effect on seed germination under saline conditions. *Journal of Scientific and Innovative Research*, *2*(5), 932-937.

Bashan, Y. Kamnev, A. A. and Bashan, D. (2013). Tricalcium phosphate is inappropriate as a universal selection factor for isolating and testing phosphate solubilizing bacteria that enhance plant growth: a proposal for an alternative procedure. *Biology and Fertility of Soils*, *49*, 465-479.

Bibi, A., Sadaqat, H. A., Akram, H. M. and Mohammed, M. I. (2010). Physiological markers for screening sorghum (*Sorghum bicolor*) germplasm under stress condition. *International Journal of Agriculture and Biological Sciences*, *12*(3), 451-455.

Bollam, S., Romana, K. K., Rayaprolu, L., Vemula, A., Das, R. R., Rathore, A., Gandham, P., Chander, C., Deshpande, S. and Gupta, R. (2021) Nitrogen use efficiency in sorghum: Exploring native variability for Traits under variable N-regimes. *Front. Plant Sci., 12*.

Cassana, F., Diego, P., Veronica, S., Virginia, L., Departamento, D. Ciencias, N., and Facultad, D. (2009). *Azospirillium brasilense* Az39 and *Bradyrhizobium japonicum* E109, inoculated singly or in combination, promote seed germination and early seedling growth in corn (*Zea mays* L.) and soybean (*Glycine max* L.). *European journal of soil biology*, *45,* 28–35.

Central Statistical Agency, CAS (2017). Report on area and production of crops. *Statistical Bulletin* 584, Volume I.

Dobbelaere, S., Vanderleyden, J. and Okon, Y. (2003). Plant growth-promoting effects of diazotrophs in the rhizosphere. *Critical Reviews in Plant Sciences, 22,* 107-149.

Gray, E. J. and Smith, D. L. (2005). Intracellular and extracellular PGPR: Commonalities and distinctions in the plant-bacterium signaling processes. *Soil Biology and Biochemistry, 37,* 395-412.

FAO (2010). FAOSTAT. Retrieved December 23, 2012. From http://www.faostat.fao.org

Fikrettin, S., Ramazan, C. and Faik, K. (2004). Sugarbeet and barley yields in relation to inoculation with nitrogen fixing and phosphate solubilizing bacteria. *Plant and Soil*, *265,* 123-129.

Jat, M. K., Purohit, H. S., Singh B., Garhwal, R. S. and Choudhary, M. (2013). Effect of integrated nutrient management on yield and nutrient uptake in sorghum (*Sorghum bicolor*). *Indian Journal of Agronomy*, *58*(4), 543-547.

Kapulnik, Y. Sarig S., Nur, I. and Okon, Y. (1984). Response of non-irrigated *sorghum bicolor* to *Azospirillium* inoculation. *Experimental Agriculture, 20*(1), 59-66.

Mokula Md Rafi and Charyulu, P. B. (2016). Synergistic effect of *Azospirillium* and Phosphate solubilizing bacteria (PSB) inoculation on growth and yield of foxtail millet. *International Journal of Plant, Animal and Environmental Sciences*, *6*(1), 138-147.

Pacovsky, G., Fuller, E. A. and Paul (1985). Influence of soil on the interactions between endomycorrhizae and *Azospirillium* in sorghum. *Soil Biology and Biochemistry, 17*(4), 525-531.

Rechardson, A. E. and Simpson, R. J. (2011). Soil microorganisms mediating phosphorus availability update on microbial phosphorus. *Plant Physiol, 156,* 989-996.

Sarig, S., Kapulnik, Y., Nur, I. and Okon, Y. (1984). Response of non irrigated sorghum bicolor to *Azospirillum* inoculation. *Experimental Agriculture, 20*(1), 59-66.

Sarig, S., Yaacov, O. and Blum (1990). Promotion of leaf area development and yield in *sorghum bicolor* inoculated with *Azospirillium hrasilense*. *Symbiosis, 9,* 235-245.

Sachdev, D., Chaudhari, H. G., Kasture, V. M., Dhavale, D. D. and Chopade, B. A. (2009). Isolation and characterization of indole acetic acid (IAA) producing *Klebsiella pneumoniae* strains from rhizosphere of wheat (*Triticum aestivum*) and their effect on plant growth. *Indian Journal of Experimental Biology, 47*, 993-1000

Sawicka, A. and Swędrzyńska, D. (2001). Effect of inoculation on population numbers of *Azospirillium* bacteria under winter wheat, oat and maize. *Journal of Environmental studies*, *10*(1), 1230-1485.

Sunita, R., Kandpal, G., Jatana, M. S. and Singh, G. (2018). Effect of different fertilizers on growth parameters of sorghum (*Sorghum bicolor) International Journal of Current Microbiology and Applied Sciences, 7*(6), 2086-2091.

Tandel, B. B., Pankhaniya, R. M. and Thanki, J. D. (2020). Response of fodder sorghum (*Sorghum bicolor* L. Moench) varieties to biofertilizer and nitrogen levels. *Journal of Pharmacology and Phytochemistry*, *6*, 49-52.

Van tran Van, Suong, N., Odile, B., Prakash, H., Thierry, H., Denis, F., Rene, B. (1997). Isolation of *Azospirillium lipoferum* from the rhizosphere of rice by a new, simple method. *Canadian Journal of Microbiology*, *43*(5), 486-490.

Widada, Damarjaya D. I., Kabirun, D. (2003). The interactive effects of arbuscular mycorrhizal fungi and rhizobacteria on the growth and nutrients uptake of sorghum in acid soil. www.researchgate.net

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