RESEARCH ARTICLE

SCREENING OF MICROBIAL CONSORTIA ON SORGHUM CROP UNDER GREEN HOUSE CONDITIONS

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Received-05.05.2019, Revised-24.05.2019

Abstract: Screening of three different plant growth promoting microbial consortia was carried under green house conditions on sorghum (CSV-27). Different plant growth parameters like plant height, shoot weight, root weight, total dry weight and nutrient uptake were estimated during the screening. Microbial population was estimated at different intervals of crop growth. Microbial consortia-3 (*Azotobacter, Azospirillium,* P-solubilizer, K-releaser, Zn-solubilizer and PGP isolate) inoculated treatment T_3 performed better and improved all the plant growth parameters like plant height, shoot weight, root weight, total dry weight and nutrient uptake compared to the control and other two microbial consortia inoculated treatments.

Keywords: Microbial consortia, *Azotobacter, Azospirillium,* P-solubilizer, K-releaser, Zn-solubilizer

INTRODUCTION

Green revolution brought amazing consequences in food grain production but with insufficient concern for agricultural sustainability. Dependence on chemicals for future agricultural needs would result in further loss in soil health. Plant rhizosphere is a remarkable ecological zone in below ground, where myriad microorganisms colonize in, on, and around the roots of growing plants. Many microorganisms are highly dependent for their survival on preformed substrates exuded by plant roots (Khalid *et al*., 2006).

Voluminous research work has been carried out on the effect of N_2 fixers, P solubilizers as single and/or consortia on several crops. Simultaneous inoculation with different plant growth promoting rhizobacteria(PGPR) often resulted in increased growth and yield as compared to single inoculation through improved nutrient uptake (Amalraj *et al*., 2015).

In the present study different microbial consortia were developed for customized solution of soil health related problem including plant growth promoting properties.

MATERIALS AND METHODS

Pot experiment was conducted to study the effect of developed microbial consortia against host crop under green house conditions.

The pot culture experiment for screening of the microbial consortia was carried out at ARS, Amaravathi.

Viable population of *Azospirillum, Azotobacter*, Phosphate Solubilizing Bacteria, Potassium Releasing Bacteria, Zinc Solubilising Bacteria and PGP isolate were enumerated by the standard serial dilution plate count method (Vlassak *et al*., 1992).

Soil preparation and sowing

Soil was sterilized at 121^{o}C for 15 minutes at 15 lb pressure and about 7 kg of sterilized soil was filled into each pot. CSV-27 variety of sorghum was selected and sown at the rate of 6-8 seeds per pot then thinning was done and only 2 plants per pot were maintained.

Treatments

T_1: Control

T_2: Microbial consortium 1 (*Azotobacter*, P-solubilizer, K-releaser, Zn-solubilizer and PGP isolate)

T_3: Microbial consortium 2 (*Azospirillium*, P-solubilizer, K-releaser, Zn-solubilizer and PGP isolate).

T_4: Microbial consortium 3 (*Azotobacter, Azospirillium,* P-solubilizer, K-releaser, Zn-solubilizer and PGP isolate).

Microbial inoculation

Microbial consortia were prepared and added to the pots at the rate of 3ml/ pot according to the treatments.

RESULTS AND DISCUSSION

Effect of microbial consortia on plant height at different growth stages of sorghum

At 30DAS sorghum plant height was significantly highest in treatment T_4 (microbial consortia -3) 59.50 cm, which was significantly higher than T_3 (microbial consortia -2) 54.67 cm. At 120 DAS plant height was significantly highest in treatment T_4 (microbial consortia -3) 139.83 cm, which was

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significantly higher than T_3 (microbial consortia -2) 128.83 cm. (Table-1)

Plant height was highest in T_4 (microbial consortia -3) followed by T_3 (microbial consortia -2) compared to T_2 (microbial consortia -1) at all stages of plant growth. Microbial consortia -3 had dual effect of *Azotobacter* and *Azospirillium* which showed positive response on plant growth compared to the other two consortia. (Table-1)

Similar results were reported in the earlier studies with respect to plant height in different crops due to microbial inoculants application. Study by Burd *et al*. (2000) reported that *Pseudomonas*, *Azospirillium* and *Azotobacter* strains inoculation enhance the plant growth. Plant growth promoting rhizobacteria might enhance plant height and productivity by synthesizing phytohormones, increasing the local availability of nutrients, facilitating the uptake of plant nutrients by the plants and antagonizing plant pathogens (Hussain *et al*., 2013).

Effect of microbial consortia on shoot dry weight of sorghum

Shoot dry weight was significantly highest in treatment T_4 (microbial consortia -3) 20.43 g plant^{-1}, which was significantly higher than T_3 (microbial consortia -2) 18.23 g plant^{-1} and comparitively lowest shoot dry weight was recorded in T_1 (control) 10.74 g plant^{-}1. Shoot dry weight was highest in T_4 (microbial consortia -3) followed by T_3 (microbial consortia -2) compared to T_2 (microbial consortia -1) (Table-2). Microbial consortia -3 had dual effect of *Azotobacter* and *Azospirillium* which showed positive response on shoot dry weight compared to the other two consortia.

Effect of microbial consortia on root dry weight of sorghum

Root dry weight was significantly highest in treatment T_4 (microbial consortia -3) 28.33 g plant^{-1}, which was significantly higher than T_3 (microbial consortia -2) 25.38 g plant^{-1} and comparitively lowest root dry was recorded in T_1 (control) 13.44 g plant^{-1}. Root dry weight was highest in T_4 (microbial consortia -3) followed by T_3 (microbial consortia -2) compared to T_2 (microbial consortia -1) (Table-2). Microbial consortia -3 had dual effect of *Azotobacter* and *Azospirillium* which showed positive response on root dry weight compared to the other two consortia. Root weight was generally more responsive to microbial inoculation. Mane *et al*., 2000 reported that dual inoculation with *Azospirillum* and PSB increased the dry weight of roots in pearl millet.

Effect of microbial consortia on total dry weight of sorghum

Total dry weight was significantly highest in treatment T_4 (microbial consortia -3) 48.76 g plant^{-1}, followed by T_3 (microbial consortia -2) 43.61 g plant^{-1} and comparitively lowest total dry was recorded in T_1 (control) 24.18g plant^{-1}. Total dry weight was highest in T_4 (microbial consortia -3) followed by T_3 (microbial consortia -2) compared to T_2 (microbial consortia -1) (Table-2). Microbial consortia -3 had dual effect of *Azotobacter* and *Azospirillium* which showed positive response on total dry weight compared to the other two consortia.

Results were accordance to Kannan and Ponmurugan (2010), who stated that application of *Azospirillum* and other PGPR had increased the fresh and dry weight of rice plants.

Effect of microbial consortia on PGPR population at different stages of sorghum

***Azotobacter* population at different intervals of sorghum crop**

Azotobacter population at the initial was significantly highest in treatment T_4 (microbial consortia -3) log 8.46 which was on par with T_2 (microbial consortia -1) log 8.44 and comparitively lowest *Azotobacter* population was found in T_1 (control) log 5.16 (Table-4)

Azotobacter population at 120 DAS was significantly highest in treatment T_4 (microbial consortia -3) log 7.71 which was on par with T_2 (microbial consortia -1) log 7.45 and comparitively lowest *Azotobacter* population was found in T_1 (control) log 4.72. (Table-4)

The microbial counts increased initially during crop growth and reduced substantially at harvest. The less microbial counts at harvest stage might be due to reduction in root exudates at that stage as compared to peak at vegetative or flowering stage. In the study statistical analysis revealed that *Azotobacter* population was significantly declined at time of harvest as compared to other time intervals. This may be due to availability of root exudates and nutrients level in rhizospheric soil were decreased at crop maturity stage. The similar results were also observed by Soleimanzadeh and Gooshchi (2013).

***Azospirillium* population at different intervals of sorghum crop**

Azospirillium population at the initial was significantly highest in treatment T_4 (microbial consortia -3) log 8.34 which was on par with T_3 (microbial consortia -2) log 8.32 and comparitively lowest *Azospirillium* population was found in T_2 (microbial consortia -2) log 5.19. (Table-5)

Azospirillium population at the 120 DAS was significantly highest in treatment T_3 (microbial consortia -2) log 7.91 which was significantly different with T_4 (microbial consortia -3) log 7.69 and comparitively lowest *Azospirillium* population was found in T_1 (control) log 4.56. (Table-5)

The difference in the survival efficiency among the isolates was due to the amount of root exudates produced by plants. These exudates affect growth rates and metabolism of bacteria. This study clearly showed a significant decrease in *Azospirillum* population at time of harvest as compared to other time intervals. Availability of root exudates and nutrients at higher level in rhizospheric soil get decreased at crop maturity stage (Raul *et al*., 2009).

Phosphorus solubilizing bacteria population at different intervals of sorghum crop

Phosphorus solubilizing bacteria population at the initial was significantly highest in treatment T_2 (microbial consortia-1) log 8.37 which was statistically on par with T_3 (microbial consortia -2) log 8.32 and comparitively lowest PSB population was found in T_1 (control) log 5.25. (Table-6)

Phosphorus solubilizing bacteria population at 120 DAS was significantly highest in treatment T_3 (microbial consortia -2) log 6.61 which was statistically on par with T_4 (microbial consortia -3) log 6.59 and comparitively lowest PSB population was found in T_1 (control) log 3.16. (Table-6)

A considerably higher concentration of phosphate solubilizing bacteria was commonly found in the rhizosphere in comparison with non-rhizosphere soil (Katznelson *et al*., 1962) which was significantly affected by the crop growth stage.

Potassium releasing bacteria population at different intervals of sorghum crop

Potassium releasing bacteria population at the initial was significantly highest in treatment T_4 (microbial consortia -3) log 7.35 which was statistically on par with T_3 (microbial consortia -2) and T_2 (microbial consortia -1) log 7.32 and comparitively lowest KRB population was found in T_1 (control) log 4.20. (Table-7)

Potassium releasing bacteria population at 120 DAS was significantly highest in treatment T_3 (microbial consortia -2) log 6.84 which was statistically on par with T_2 (microbial consortia -1) log 6.83 and comparitively lowest KRB population was found in T_1 (control) log 3.56. (Table-7)

The difference in the survival efficiency among the isolates was due to the amount of root exudates produced by plants. These exudates affect growth rates and metabolism of bacteria.

Zinc solubilizing bacteria population at different intervals of sorghum crop

Zinc solubilizing bacteria population at the initial was significantly highest in treatment T_4 (microbial consortia -3) log 7.23 which was statistically on par with T_2 (microbial consortia -1) log 7.13 and comparitively lowest ZnSB population was found in T_1 (control) log 4.20. (Table-8)

Zinc solubilizing bacteria population at 120 DAS was significantly highest in treatment T_4 (microbial consortia -3) log 6.83 which was significantly different with T_3 (microbial consortia -2) log 6.62 and comparitively lowest ZnSB population was found in T_1 (control) log 3.15. (Table-8)

Other special PGPR population at different intervals of sorghum crop

Other special PGPR population at the initial was significantly highest in treatment T_4 (microbial consortia -3) log 8.00 which was statistically on par with T_3 (microbial consortia -2) log 7.99 and T_2 (microbial consortia -1) log 7.96, while comparitively lowest population was found in T_1 (control) log 5.26. (Table-9)

Other special PGPR population at 120 DAS was significantly highest in treatment T_4 (microbial consortia -3) log 6.96 which was significantly different with T_3 (microbial consortia -2) log 6.84, while comparitively lowest population was found in T_1 (control) log 3.55. (Table-9)

Effect of microbial consortia on nutrient uptake of sorghum

Nitrogen uptake

Nitrogen uptake was significantly highest in treatment T_4 (microbial consortia -3) 1.41% which was significantly different with T_3 (microbial consortia -2) 1.27% and lowest nitrogen uptake was found in T_1 (control) 0.89%. (Table-3)

Co-inoculation of *Bacillus polymyxa* and *Pseudomonas striata* strains showing phosphate-solubilizing ability along with a strain of *Azospirillium brasilense* resulted in significant increase in N and P uptake as compared to individual inoculations in sorghum was reported by Alagawadi and Gour (1992).

Phosphorus uptake

Phosphorus uptake was significantly highest in treatment T_4 (microbial consortia -3) 0.17% which was significantly different with T_3 (microbial consortia -2) 0.16% and lowest phosphorus uptake was found in T_1 (control) 0.12%. (Table-3)

Potassium uptake

Potassium uptake was significantly highest in treatment T_4 (microbial consortia -3) 1.60% which was significantly different with T_3 (microbial consortia -2) 1.54% and lowest potassium uptake was found in T_1 (control) 0.81%. (Table-3)

All most all the nutrients uptake was highest in T_4 (microbial consortia -3) followed by T_3 (microbial consortia -2) compared to T_2 (microbial consortia -1). Microbial consortia -3 had dual effect of *Azotobacter* and *Azospirillium* which showed positive response on plant nutrient uptake compared to the other two consortia.

Ramakrishnan and Bhuvaneswari (2014) found that finger millet treated with *Azospirillium* + PSB increased the plant growth and N, P uptake.

Table 1. Effect of microbial consortia on plant height at different intervals of sorghum crop

	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**
T_1	37.83	74.83	81.83	86.17
T_2	49.33	100.93	108.77	112.77

T_3	54.67	119.93	124.63	128.83
T_4	59.50	130.73	135.60	139.83
SE(m)	0.250	0.117	0.178	0.162
CD (P=0.05)	0.828	0.368	0.589	0.535
CV	0.860	0.190	0.273	0.239

Table 2. Effect of microbial consortia on different growth parameters of sorghum crop

	Shoot fresh weight (g plant^{-1})	Shoot dry weight (g plant^{-1})	Root fresh weight (g plant^{-1})	Root dry weight (g plant^{-1})	Total dry weight (g plant^{-1})
T_1	80.42	10.74	69.58	13.44	24.18
T_2	99.23	16.51	82.32	20.64	37.16
T_3	114.02	18.23	89.23	25.38	43.61
T_4	132.12	20.43	105.09	28.33	48.76
SE(m)	0.324	0.104	0.168	0.224	0.230
CD (P=0.05)	1.074	0.344	0.556	0.743	0.762
CV	0.528	1.091	0.336	1.771	1.037

Table 3. Effect of microbial consortia on nutrient uptake sorghum

	N uptake (%)	P uptake (%)	K uptake (%)
T_1	0.89	0.12	0.81
T_2	1.09	0.15	1.47
T_3	1.27	0.16	1.54
T_4	1.41	0.17	1.60
SE(m)	0.019	0.002	0.012
CD (P=0.05)	0.062	0.005	0.039
CV	2.787	1.789	1.521

Table 4. *Azotobacter* population at different intervals of sorghum crop

Treatments	**log CFU g^{-1}**				
	Zero day	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**
T_1	5.16	5.53	6.27	6.34	4.72
T_2	8.44	8.71	9.47	9.84	7.45
T_3	5.39	5.65	6.40	6.74	4.98
T_4	8.46	8.78	9.47	9.93	7.71
SE(m)	0.051	0.018	0.028	0.013	0.009
CD (P=0.05)	0.168	0.061	0.092	0.042	0.030
CV	1.277	0.442	0.610	0.266	0.249

Table 5. *Azospirillium* population at different intervals of sorghum

Treatments	**log CFU g^{-1}**				
	Zero day	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**
T_1	5.33	5.58	6.34	6.63	4.56
T_2	5.19	5.68	6.39	6.75	4.66
T_3	8.32	8.40	9.39	9.41	7.91
T_4	8.34	8.48	9.45	9.47	7.69
SE(m)	0.023	0.011	0.031	0.015	0.015
CD (P=0.05)	0.076	0.036	0.104	0.050	0.049
CV	0.584	0.265	0.690	0.322	0.415

Table 6. PSB population at different intervals of sorghum crop

Treatments	log CFU g^{-1}				
	Zero day	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**
T_1	5.25	5.55	6.46	6.65	3.16
T_2	8.37	8.64	9.10	9.46	6.47
T_3	8.32	8.58	9.16	9.39	6.61
T_4	8.26	8.81	9.09	9.45	6.59
SE(m)	0.020	0.018	0.016	0.013	0.034
CD (P=0.05)	0.066	0.060	0.052	0.042	0.114
CV	0.454	0.395	0.321	0.253	1.042

Table 7. KRB population at different intervals of sorghum crop

Treatments	log CFU g^{-1}				
	Zero day	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**
T_1	4.20	5.64	6.56	6.93	3.56
T_2	7.32	8.45	9.39	9.69	6.83
T_3	7.32	8.45	9.43	9.77	6.84
T_4	7.35	8.47	9.46	9.84	6.72
SE(m)	0.021	0.013	0.013	0.006	0.013
CD (P=0.05)	0.068	0.043	0.045	0.020	0.043
CV	0.546	0.289	0.268	0.116	0.372

Table 8. ZnSB population at different intervals of sorghum crop

Treatments	log CFU g^{-1}				
	Zero day	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**
T_1	4.20	5.58	6.28	6.75	3.15
T_2	7.13	8.22	9.38	9.84	6.40
T_3	6.99	8.16	9.42	9.96	6.62
T_4	7.23	8.32	9.43	10.04	6.83
SE(m)	0.033	0.010	0.037	0.007	0.028
CD (P=0.05)	0.108	0.034	0.121	0.024	0.093
CV	0.884	0.237	0.736	0.137	0.847

Table 9. Other special PGP organisms population at different intervals of sorghum crop

Treatments	log CFU g^{-1}				
	Zero day	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**
T_1	5.26	5.64	5.93	6.36	3.55
T_2	7.96	8.30	8.80	9.08	6.82
T_3	7.99	8.33	8.92	9.46	6.84
T_4	8.00	8.38	8.95	9.70	6.96
SE(m)	0.015	0.013	0.005	0.022	0.012
CD (P=0.05)	0.049	0.044	0.017	0.074	0.041
CV	0.349	0.301	0.111	0.449	0.356

CONCLUSION

Microbial consortia -3 showed increase in all the plant growth parameters like plant height, shoot dry weight, root dry weight, total dry weight, N, P and K uptake and microbial population survival, compared to microbial consortia -2. While comparitively low response was shown by microbial consortia -1. So Microbial consortia 3 and Microbial consortia 2 were recommended for further research.

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