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Effect of Inoculation of Microbial Consortia on Soil Physicochemical and Nutrient Status

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Authors' contributions

This work was carried out in collaboration among all authors. Author YK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NT and AVG managed the analyses of the study. Author AVG managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted in *kharif*, 2018 at ARS, Amaravathi, Guntur district, to find the efficiency of carrier based microbial consortia. In sorghum carrier based microbial consortia was applied along with different doses of chemical fertilizers. Microbial consortium-1 (*Azospirillium*, P-solubilizer, K-releaser, Zn-solubilizer and PGPR isolate), Microbial consortium-2 (*Azotobacter*, *Azospirillium,* P-solubilizer, K-releaser, Zn-solubilizer and PGPR isolate) were used in the study. Soil pH, electrical conductivity (EC), organic carbon, available nitrogen, phosphorus, potassium were recorded during different intervals of crop growth. The treatments with microbial consortia and

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75% Recommended Dose of Fertilizers (RDF) showed increased available nutrients content. Soil pH was neutralized in the microbial consortia added treatments, while in treatments with RDF alone the pH was more. There was a significant increase in organic carbon content in treatments with microbial consortia and 75% RDF. Highest available nutrients and organic carbon content was observed in T_{10} (75% RDF+ Microbial consortium-2). The organic carbon content improved gradually during the crop period and highest was at harvesting stage. All the soil physicochemical properties were improved by the microbial consortia with decreased doses of chemical fertilizers compared to the treatments added with chemical fertilizers alone.

Keywords: Available nutrients; organic carbon; soil pH; microbial consortia.

1. INTRODUCTION

There are several soil and environmental problems which are the major areas of research. Availability of nutrients for the plant growth is one of the important factor that is under research. The microbial consortium is developed for customized solution of soil health related problems, with plant growth promoting properties including root and shoot length elongation, early and high germination rate, high yield, decrease in soil pathogenic load and increase soil micro and macronutrient status. These specifically designed polymicrobial formulations would further provide protection against plant pathogens lowering the need for nitrogen containing fertilizers, solubilize minerals, protect plants against pathogens, and make available to the plant valuable nutrients, such as phosphate, thus reducing and eliminating the need for using chemical fertilizers and chemical pesticides [1].

All over India variety of crops were grown depending on the area, native soil texture and weather. Sorghum is one of the usual grown crop, it is vital life sustaining crop in many parts of the world, ranking fifth after wheat, rice, maize and barley [2]. There is a ranking in grain producing country among them India ranks second after USA. In India it is the third important crop after rice and wheat. Sorghum is primarily used for the food in the different area of India Importance states producing sorghum crop are Maharashtra, Karnataka, Andhra Pradesh and Madhya Pradesh. Nutritionally sorghum is superior to all other cereals and therefore it requires to improve the crop yield [2].

2. MATERIALS AND METHODS

A pot experiment was conducted to investigate the effect of efficient microbial consortia on soil health, growth of sorghum crop in pot experiment under green house conditions.

2.1 Experiment Site

The pot experiment was carried out in green house, ARS, Amaravathi. The soil of the experiment was vertisols. Representative soil sample to fill the pots was collected from the field prior to processing and analysed for the physical, chemical and biological properties by adopting standard procedures at Department of Agricultural Microbiology, APGC, Lam and Department of Soil Science (RRU Chemistry), RARS, Lam, Guntur.

2.2 Experimental Setup

The soil used in this experiment was black soil and sand mixture in the ratio of 2:1. Soil mixture was weighed and 7 kg was filled into each pot. CSV-27 variety of sorghum was sown at the rate of 6-8 seeds/pot then thinned out to maintain only 2 plants per pot.

Location: ARS, Amaravathi
Design: CRD (pot culture)
Variety: CSV-27

2.3 Treatments

Microbial consortia preparation: Microbial consortia were prepared and mixed with the carrier material in 2:3 ratio (consortial broth: carrier material). These are microbial consortium 1 (*Azospirillium*, P-solubilizer, K-releaser, Zn-solubilizer and PGP isolate) and microbial consortium 2 (*Azotobacter*, *Azospirillium,* P-solubilizer, K-releaser, Zn-solubilizer and PGPR isolate). The prepared mixture was added to the pot experiment according to the treatments. The treatments are T_1 : Microbial consortium 1, T_2 : Microbial consortium 2, T_3: 50% RDF + Microbial consortium 1, T_4: 50% RDF + Microbial consortium 2, T_5: 50% RDF + FYM + Microbial consortium 1, T_6: 50% RDF + FYM + Microbial consortium 2, T_7: 75% RDF + Microbial consortium 1, T_8: 75% RDF + Microbial consortium 2, T_9: 75% RDF + FYM + Microbial consortium 1, T_{10}: 75% RDF + FYM +Microbial consortium 2, T_{11}: 100% RDF and T_{12}: 100% RDF + FYM.

Then after, CSV-27 sorghum variety was sown at a rate of 6-8 seeds/pot and thinned out to maintain only 2 plants per pot at 10 days after sowing. The experiment was arranged in complete randomized design and replicated Soil samples were collected from the field prior to processing and analysed for the physical, chemical and biological properties by adopting standard procedures at Department of Agricultural Microbiology, APGC, Lam and Department of Soil Science (RRU Chemistry), RARS, Lam, Guntur. pH of the samples was determined in 1:2.5 substrate water suspension by using digital pH meter (Systronics µ pH system 361) [3]. The electrical conductivity of slurry samples was determined in saturation extract by using Elico CM 180 conductivity meter [3]. Soil organic-carbon was estimated following the method described by Walkley and Black [4]. Soil organic carbon was calculated as given below and expressed in per cent.

Organic carbon per cent:

$$\frac{10\ (\mathrm{B}-\mathrm{S})\times\ 0.003}{\mathrm{B}}\times\frac{100}{\text{wt of the sample taken (g)}}$$

Titre value of the blank in ml = B
Titre value of the sample in ml = S

The alkaline potassium permangante method of Subbiaiah and Asija (1956) was followed for the estimation of available N content in soil. Available P in soil was determined by Olsen's method described by Olsen et al. [5]. Available P was expressed in Kg ha^{-1}. Available potassium content from soil was extracted by using 1 N neutral normal ammonium acetate as described by Jackson [3]. The concentration of potassium in the extractant was determined by flame photometer and expressed in Kg ha^{-1}.

3. RESULTS AND DISCUSSION

3.1 Soil pH

Initial pH of the soil used for the experiment was 7.5 (Table 1) while at 45 Days after Sowing (DAS) pH was high in T_{11} (100% RDF) 8.2, which was significantly different with T_8 (75% RDF + MC_2) 8.1. At 90 DAS significantly high pH was observed in T_{11} (100% RDF) 7.4, when compared to T_9 (75% RDF + MC_1 + FYM) 7.3. At 120 DAS significantly high pH was observed in T_5, (50% RDF + MC_1+ FYM) 7.9, when compared to T_{10} (75% RDF + MC_2 + FYM) 7.8 (Table 1). pH varied among the treatments at different stages of crop growth. Application of microbial consortia along with chemical fertilizers increased the pH from near neutral to alkaline at 45 DAS, while at 90DAS increased microbial activity lead to decrease in pH near to neutral and at the end the pH of soil increased to alkaline state, which is due to the buffering nature of the soil and more organic matter accumulation. The results showed that application of microbial consortia cause relative decrease in pH at 90 DAS, which was optimum for solubilization of bound elements and it may be attributed to the production of organic acids (glycine, cystein and humic acid) during mineralization of organic materials by heterotrophs. These results were accordance to Patel et al. [6] and Lin et al. [7] where the microbes lowered the soil pH by releasing of organic acids.

3.2 Electrical Conductivity

Initial electrical conductivity (EC) was 0.23 dSm^{-1} (Table 1). At 45 DAS EC of all the treatments increased significantly compared to the initial and highest EC was observed in T_2 (MC_2) 0.91 dSm^{-1}, which was higher than T_6 (50% RDF+ MC_2+FYM) 0.79 dSm^{-1}. At 90 DAS high EC was observed in T_2 (MC_2) 0.97 dSm^{-1}, which was significantly higher than T_6 (50% RDF + MC_2 + FYM) 0.84 dSm^{-1}. At 120 DAS highest EC was observed in T_2 (MC_2) 0.19 dSm^{-1}, which was significantly higher than T_1 (MC_1) and T_5 (50% RDF + MC_1 + FYM) 0.17 dSm^{-1} (Table1).

The present results showed that electrical conductivity increased in the treatments having MC along with inorganic fertilizers. This may be due to increase in solubility of many nutrients and thus providing optimum conditions for better plant growth. The increase of soil EC might occur due to production of acids or acid forming compounds that reacted with the sparingly soluble salts already present in the soil and increased their solubility. Hence, the EC of soil may be increased e.g., $CaCO_3$ (ever present in the soils of arid and semi-arid regions) may be converted to $CaHCO_3$ or even to Na_2CO_3 which are more soluble forms. The Similar results had been reported by Sarwar et al. [8].

3.3 Soil Organic Carbon

Initial organic carbon was 0.36% (Table 1). At 45 DAS increase in organic carbon content was

Table 1. Effect of microbial consortia on soil physico- chemical properties of sorghum under green house conditions

Treatments	Soil pH			EC (dSm^{-1})			Organic carbon (%)		
	45 DAS	90 DAS	120 DAS	45 DAS	90 DAS	120 DAS	45 DAS	90 DAS	120 DAS
T_1	7.8	7.1	7.7	0.53	0.64	0.17	1.02	1.05	1.06
T_2	7.3	7.1	7.5	0.91	0.97	0.19	0.64	0.66	0.84
T_3	7.1	7.2	7.7	0.67	0.62	0.12	1.01	1.06	1.06
T_4	7.4	7.2	7.7	0.06	0.13	0.16	0.65	0.68	0.86
T_5	7.9	7.2	7.9	0.52	0.65	0.17	0.65	0.70	0.87
T_6	7.6	7.2	7.7	0.79	0.84	0.16	0.68	0.72	0.92
T_7	7.8	7.2	7.6	0.55	0.55	0.11	0.96	1.03	1.06
T_8	8.1	7.1	7.7	0.52	0.57	0.11	0.97	1.02	1.08
T_9	8.0	7.3	7.4	0.44	0.46	0.14	0.94	1.03	1.12
T_{10}	7.9	7.1	7.8	0.60	0.62	0.12	0.85	1.02	1.16
T_{11}	8.2	7.4	7.7	0.43	0.44	0.11	0.31	0.60	0.86
T_{12}	7.9	7.1	7.3	0.42	0.46	0.11	0.34	0.68	0.89
SE(m)	0.01	0.01	0.01	0.01	0.01	0.003	0.004	0.01	0.01
CD (P=0.05)	0.04	0.04	0.03	0.03	0.03	0.01	0.01	0.02	0.03
CV	0.28	0.33	0.22	2.56	2.01	3.77	0.83	1.12	0.59

T_1: MC_1; T_2: MC_2; T_3: 50% RDF + MC_1; T_4: 50% RDF + MC_2; T_5: 50% RDF + FYM + MC_1; T_6: 50% RDF + FYM + MC_2; T_7: 75% RDF + MC_1; T_8: 75% RDF + MC_2; T_9: 75% RDF + FYM + MC_1; T_{10}: 75% RDF + FYM + MC_2; T_{11}: 100% RDF; T_{12}: 100% RDF + FYM

MC_1: (Microbial consortium 1: Azospirillium + PSB + KRB + ZnSB + PGPR Isolate)

MC_2: (Microbial consortium 2: Azotobacter + Azospirillium+ PSB + KRB + ZnSB + PGPR Isolate)

Table 2. Effect of microbial consortia on available nutrients in soil of sorghum under green house conditions

Treatments	Available nitrogen (Kg ha^{-1})			Available phosphorus (Kg ha^{-1})			Available potassium (Kg ha^{-1})		
	45 DAS	**90 DAS**	**120 DAS**	**45 DAS**	**90 DAS**	**120 DAS**	**45 DAS**	**90 DAS**	**120 DAS**
T_1	75.60	144.90	114.03	20.65	42.64	26.23	252.93	307.07	224.93
T_2	81.90	149.62	107.73	21.70	49.39	27.01	258.53	312.67	228.67
T_3	87.57	158.02	120.75	22.78	51.54	27.67	265.07	337.87	237.07
T_4	93.87	159.07	108.35	25.83	61.00	28.09	269.73	342.53	233.33
T_5	97.02	164.32	114.66	24.59	72.15	28.87	273.47	348.13	241.73
T_6	98.49	165.31	101.43	26.39	74.69	30.51	278.13	354.67	244.53
T_7	100.59	167.83	95.55	29.65	75.57	32.02	281.87	381.73	256.67
T_8	103.01	173.25	101.43	33.68	76.50	33.35	287.47	384.53	259.47
T_9	107.63	182.49	114.66	35.44	77.10	35.22	292.13	390.13	272.53
T_{10}	113.19	185.85	114.66	36.21	77.89	36.85	300.53	396.67	278.13
T_{11}	95.43	161.28	107.73	26.59	57.15	26.47	275.33	362.13	266.67
T_{12}	97.02	163.17	108.15	26.80	61.52	26.88	288.40	374.27	269.73
SE(m)	0.459	0.400	0.545	0.135	0.257	0.226	0.894	0.933	0.914
CD (P=0.05)	1.347	1.173	1.600	0.396	0.756	0.664	2.624	2.740	2.684
CV	0.828	0.421	0.865	0.849	0.688	1.308	0.559	0.452	0.630

T_1: MC_1; T_2: MC_2; T_3: 50% RDF + MC_1; T_4: 50% RDF + MC_2; T_5: 50% RDF + FYM + MC_1; T_6: 50% RDF + FYM + MC_2; T_7: 75% RDF + MC_1; T_8: 75% RDF + MC_2;
T_9: 75% RDF + FYM + MC_1; T_{10}: 75% RDF + FYM + MC_2; T_{11}: 100% RDF; T_{12}: 100% RDF + FYM
MC_1: (Microbial consortium 1: Azospirillium + PSB + KRB + ZnSB + PGPR Isolate)
MC_2: (Microbial consortium 2: Azotobacter + Azospirillium+ PSB + KRB + ZnSB + PGPR Isolate)

observed in all the treatments and highest was observed in T_1 (MC_1) 1.02%, which was significantly higher than T_3 (50% RDF + MC_1) 1.01%. At 90 DAS increase in organic carbon content was observed in all the treatments and highest organic carbon was observed in T_3 (50% RDF + MC_1) 1.06%, which was significantly higher than T_1 (MC_1) 1.05%. At 120 DAS organic carbon increase was observed in all the treatments and highest organic carbon was observed in T_{10} (75% RDF + MC_2 + FYM) 1.16%, which was significantly higher than T_9 (75% RDF + MC_1 + FYM) 1.12% (Table 1).The present results indicated that application of MC that contain living microorganisms was one of the management practices that can help to maintain or increase the content of organic carbon and improve soil fertility. This was probably due to the rapid decomposition of fresh or immature organic material and the intensive polymerization process (humification) of organic matter as influenced by the microbial consortia. These results were in accordance to Bozena et al. (2016).

3.4 Availability of Macro Nutrients in the Soil

Nitrogen: Available nitrogen content was 72.27 Kg ha^{-1} (Table 2) in the initial soil sample. At 45 DAS all the treatments showed increased available nitrogen content compared to initial. High available nitrogen was observed in T_{10} (75% RDF + MC_2 + FYM) 113.19 Kg ha^{-1} which was significantly higher than T_9 (75% RDF + MC_1 + FYM) 107.627 Kg ha^{-1}. At 90 DAS all the treatments showed increased available nitrogen content compared to initial and 45DAS and highest available nitrogen was observed in T_{10} (75% RDF + MC_2 + FYM) 185.85 Kg ha^{-1}, which was significantly higher than T_9 (75% RDF + MC_1 + FYM) 182.49 Kg ha^{-1}. At 120 DAS available nitrogen content decreased in all treatments compared to 90DAS and highest available nitrogen content was observed in T_3 (50% RDF + MC_1) 120.75 Kg ha^{-1} which was significantly higher than T_5 (50% RDF + MC_1 +FYM), T_9 (75% RDF + MC_1 + FYM) and T_{10} (75% RDF + MC_2 + FYM) 114.66 Kg ha^{-1} (Table 2).

In present study, combined application of inorganic fertilizers and MC increased the availabllity of nitrogen in soil at 45 DAS and 90 DAS. The important characteristic of *Azospirillum* and *Azotobacter* was that they excrete ammonia in the rhizosphere in the presence of root exudates. The combined treatments of inorganic fertilizers and biofertilizer in the present study resulted in a higher available N content in the soil. These similar results were found earlier by Narula and Gupta [9] and Wu et al. [10].

Phosphorus: Available phosphorus content was 18.32 Kg ha^{-1} (Table 2) in the initial soil sample. At 45 DAS all the treatments showed increased available phosphorus content compared to initial. Highest available phosphorus content was observed in T_{10} (75% RDF + MC_2 + FYM) 36.21 Kg ha^{-1} which was significantly higher than T_9 (75% RDF + MC_1 + FYM) 35.44 Kg ha^{-1}. At 90 DAS all the treatments showed increased available phosphorus content compared to initial and 45 DAS. Highest available phosphorus was observed in T_{10} (75% RDF + MC_2+ FYM) 77.89 Kg ha^{-1} which was statistically on par with T_9 (75% RDF + MC_1 + FYM) 77.10 Kg ha^{-1}. At 120 DAS available phosphorus content decreased in all treatments compared to 90 DAS and significantly high available phosphorus content was observed in T_{10} (75% RDF + MC_2 + FYM) 36.84 Kg ha^{-1} which was significantly higher than T_9 (75% RDF + MC_1 + FYM) 35.21 Kg ha^{-1} (Table 2).

The findings revealed that available soil phosphorus significantly increased with dual application of microbial consortia and inorganic fertilizers. Therefore, use of microbial consortia with chemical fertilizer can play an important role in improving P bioavailability. The increase in soil P content might be due to the P-solubilizing potential of the isolates used in microbial consortia. This may be attributed to the production of organic acids, chelating oxo-acids and solubilization of inorganic insoluble phosphates by microorganisms. Application of phosphate fertilizers with PSB enriched the rhizosphere with soil available P resulting in improved yield of rice crop. The potential role of soil microorganisms for increasing the amount of available P from phytase activity has also been reported by Richardson [11]. Sundara et al. [12] found that the application of PSB, *Bacillus megatherium* var. *phosphaticum*, increased the Phosphate Solubilizing Bacteria (PSB) population in the rhizosphere and hence increment in P availability in the soil.

Potassium: Available potassium content was 229.85 Kg ha^{-1} (Table 2) in the initial soil. At 45 DAS all the treatments showed increased available potassium content compared to initial. Highest available potassium content was observed in T_{10} (75% RDF + MC_2 + FYM) 300.53

Kg ha^{-1} was significantly higher than T_9 (75% RDF + MC_1 + FYM) 292.13 Kg ha^{-1}. At 90 DAS all the treatments showed increased available potassium content compared to initial and 45 DAS. Highest available potassium was observed in T_{10} (75% RDF + MC_2 + FYM) 396.66 Kg ha^{-1} was significantly higher than T_9 (75% RDF + MC_1 + FYM) 390.13 Kg ha^{-1}. At 120 DAS available potassium content decreased in all treatments compared to 90 DAS and highest available potassium content was observed in T_{10} (75% RDF + MC_2 + FYM) 278.13 Kg ha^{-1} was significantly higher than T_9 (75% RDF + MC_1+ FYM) 272.53 Kg ha^{-1} (Table 2).

The results indicated that application of M.C along with inorganic fertilizers increase the available potassium content in soil. This may be due to variety of soil microbes which can release soluble potassium from potassium-bearing minerals. These microbes release organic acid, which quickly dissolves rock and chelate silicon ions, releasing K ions into the soil [13,14].

4. CONCLUSION

The treatments with microbial consortia and 75% RDF showed increased available nutrients content and also enzymatic activities. Soil pH was neutralized in the microbial consortia added treatments, while in treatments with RDF alone the pH increased. There was a significant increase in organic carbon content in treatments with microbial consortia and 75% RDF. Highest available nutrients and organic carbon content was observed in T_{10} (75% RDF+ Microbial consortium-2). The organic carbon content improved gradually during the crop period and highest was at harvesting stage. All the soil physicochemical and nutrient status was improved by the microbial consortia with decreased doses of chemical fertilizers compared to the treatments added with chemical fertilizers alone. So the use of microbial consortia helps in minimizing the use of chemical fertilizers and reduce the cost of cultivation which inturn reduces the environmental pollution.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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