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Effect on various physiological and biological processes due to Microbial Consortium and their effect on growth and yield of maize (*Zea mays* L.) under dryland conditions of Southern Rajasthan

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ABSTRACT

Microbial consortium influences various physiological and biological processes in maize. The present study was aimed at growth and yield of maize affected by Microbial Consortium. An agronomic investigation was carried out at Dryland Farming Research Station, Arjiya, Bhilwara, MPUAT, Udaipur during *kharif* 2022. The experiment was laid out in a RBD with three replications. The experiment consisted of nine treatments and two different kinds microbial consortium was applied as soil application and seed inoculation or alone. Microbial connsortium-2 applied as soil application and seed inoculation recorded significantly higher growth parameters, yield attributing traits and yield *viz*, plant height, dry matter accumulation (g/plant), cob/plant, grain/cob, yield (q/ha), test weight (g), and yield over control. It was at par with Microbial consortium-1 as soil application and seed inoculation.

Key word: Kharif *maize, Microbial consortium and yield.*

Introduction

Maize (*Zea mays* L.) is a leading cereal crop of the world belonging to family Gramineae. '*Zea*' is a Greek word which means "sustaining life" and '*Mays*' is a word from Taino language which meaning "life giver". It is considered as a staple food in many parts of the world. It is cultivated in nearly 205 million hectare and production of 1210 million tonnes with the productivity of the world is 58.78 q/ha (FAOSTAT-2021). Due to its higher yield potential among the cereals it is known globally as "Queen of cereals". Maize is generally used forhuman and animal feed. It is widely processed

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into various types of products such as corn meal, snacks, grits, starch, flour, tortillas and breakfast cereals. Nutritionally maize contains 72 % carbohydrate, 10 % protein, 8.5 % fibre, 4.8 % oil and some vitamins and minerals. Maize kernel is an edible and nutritive part of the plant. Maize is third most important cereal crop after wheat and rice in India with a production of 33.62 million tonnes in 10.04 million hectare area and having average productivity of 3349 kg/ha. The major maize growing states are Karnataka (15.53 %), Madhya Pradesh (13.59 %), Maharashtra (10.50 %) (Anonymous, 2022).

Microbial consortium is typically defined as a collection of different microorganisms with the capacity to cooperate in a community. The combined inoculation of beneficial microorganisms increased germination, nutrient uptake, plant height, number of branches, yield, and total biomass of the crop in addition to growth and yield characteristics.

Azotobacter is a group of gram negative, free-living, nitrogen fixing aerobic bacteria inhabiting in the soil and non-symbiotic nitrogen fixerin nature.It leads to high level of nitrogen fixation due to its rapid growth. *Pseudomonas*, *Bacillus*, *Micrococcus*, *Aspergillus*, *Fusarium*, etc. are the major phosphate solubilizing bacteria (PSB) in soil. Phosphorus is one of the major essential macronutrient for plants and it is applied to soil in the form of phosphatic fertilizers. However, a large portion of soluble inorganic phosphate that is applied to the soil as chemical fertilizer is immobilized rapidly and becomes unavailable to the plants. Phosphate solubilizing bacteria (PSB) are beneficial bacteria that have capacity to solubilize inorganic phosphorus from insoluble compounds. P-solubilization ability of rhizosphere microorganisms is considered to be one of the most important traits associated with plant phosphate nutrition. KSM (Potassium-solubilizing microorganism) is the metal-mobilizing and plant growth–promoting bacterium living symbiotically in or on the root surface and it is helps in directly or indirectly promoting plant growth via solubilization of insoluble minerals (P and K). KSM such as *Bacillus* spp. and *Pseudomonas* spp. are the most dominant plant growth–promoting bacteria of rhizospheric soils.

ZSB (Zinc solubilizing bacteria) such as *Pseudomonas protegens*, *Bacillus megaterium*, *Bacillus altitudinis* is considered a promising approach for increasing zinc, phyto-availability and the enhancing crop growth and nutritional quality. Also it is necessary to understand the underlying bacterial solubilization processes to predict their repeatability in inoculation strategies.

The productivity of maize is low because mostly it is grown under rainfed conditions in *kharif* season without assured irrigation in addition to lack of suitable varieties, poor weed management, improper time of harvesting and poor soil health. Another factor contributing to low productivity of maize is use of suitable biofertilizer in terms of Microbial consortium. Lack of suitable Microbial consortium particularly for essential nutrient management may be one of them. Microbial consortium designed to reduce the problem, like fixation and immobilization of nutrients. It helpsin utilization of applied nutrients more efficiently and correcting deficiencies rapidly especially for short duration crops. Hence, optimum mineral nutrient management through Microbial consortium application is basic requirement to realize potential yield of crops and maize as well.

Matrials and Method

The experimental trial was conducted in the Dry Land Farming Research Station, Arjia, Bhilwara, Instructional Farm (Agronomy) during *Kharif* 2022, which is located in the Southern region of Rajasthan at 24° 24' N latitude, 74° 40' E longitude, and an altitude of about 432 meters above mean sea level. This area is part of Rajasthan's Agro-climatic ZoneI Va(Sub-Humid Southern Plain and Aravalli Hills). The investigation was done to assess the effect of Microbial consortium and inorganic fertilizers on growth and yield of maize under dryland condition of southern Rajasthan using randomized block design, experiment was laid out with nine treatments *viz*., T_1 (control – RDF), T_2 (RDF + microbial consortium – 1 as soil application), T_3 (RDF + microbial consortium – 1 as seed inoculation), T_4 (RDF + microbial consortium – 1 as soil application and seed inoculation), T_5 (RDF + microbial consortium – 2 as soil application), T_6 (RDF + Microbial consortium-2 as seed inoculation), T_7 (RDF + Microbial consortium-2 as soil application and seed inoculation), T_8 (75 % RDF + Microbial consortium-1 as soil application and seed inoculation) and T_9 (75 % RDF + Microbial consortium-2 as soil application and seed inoculation) and was replicated three times. Where, microbial consortium-1 contains *Azotobacter* + PSB + KSB and microbial consortium-2 contains *Azotobacter* + PSB + KSB + ZMB.

The dose of microbial inoculants as per treatment was applied as soil application before sowing and seed treatment at the time of sowing. The microbial inoculants were applied to the soil through mixing with 50 kg FYM with dose @ 3 l/ha. The seed inoculation was done as seed treatment @ 4 ml/kg seed at the time of sowing. The fertilizer application was done @ 60 kg N and 30 kg $P_2O_{5/}$ha as recommended dose.

Results and Discussion

Effect of microbial consortia on growth attributes of maize

The data presented in Table 1 exhibit that the application of RDF along with microbial consortium significantly impacted the various growth parameters *viz.*, plant height, dry matter accumulation and leaf area index.

The significantly higher plant height, dry matter accumulation at 60 DAS and at harvest, and leaf area index at 30 and 60 DAS observed under RDF + microbial consortium-2 as soil application and seed inoculation which was significantly higher over control at 60 DAS and at harvest by 30.60% and 27.81%, respectively, however remained at par with treatment T_4 (application of RDF + microbial consortium-1 as soil application and seed inoculation) and treatment T_5(RDF + microbial consortium -2 as soil application). However, plant height and dry matter accumulation at 30 DAS failed to show significant effect. The faster availability of nutrients due to microbial consortium inoculation throughout the cropping period enhances the nutrient requirement of the crop and production of greater number of photosynthetically active leaves which might have lead to higher production of carbohydrates and phytohormones which resulted in increased plant height and dry matter accumulation of maize. Nitrogen plays important role in the plant's growth above ground. Phosphorous promotes strong root system development, cell division, flower and seed production in plants. Potassium improves the plant's immunity to fight against diseases. Zinc is a crucial micronutrient plays a critical and major role in optimizing growth of plant due to its involvement in many enzymes and protein. All these beneficial effect improved growth and development of the plant and the results are in accordance with the findings of Khandare *et al.* (2019), Kakde *et al.* (2020), Fitriatin *et al*. (2021) and Jain *et al.* (2021).

Effect of microbial consortia on yield of maize

Significantly higher grain, stover and biological yields were observed in the treatment T_7 (RDF + microbial consortium-2 as soil application and seed inoculation) and wasat par with (T_4) application of RDF + microbial consortium -1 as soil application and seed inoculation and (T_5) RDF + microbial consortium -2 as soil application and significantly higher over rest of the treatments. While the harvest index was found non-significant. The extent of increase in yield due to a positive effect of microbial

Table 1. Mean weekly weather parameters during crop growing season (kharif-2022-23)

Week No.	Duration	Temperature (ºC)		Relative Humidity (%)		Sunshine (hrs)	Rain (mm)	Evaporation (mm/day)
		Max.	Min.	Max.	Min.			
27	7 July–8 July., 2022	32.5	25.1	84.0	47.5	1.9	2.5	0.7
28	9 July–15 July., 2022	32.5	23.7	78.3	47.6	2.8	47.8	0.2
29	16 July–22 July., 2022	30.5	21.6	83.9	56.9	0.5	90.8	0.7
30	23 July –29 July., 2022	28.9	22.8	85.7	68.6	0.2	255.4	1.2
31	30 July–5 Aug., 2022	30.1	24.5	83.4	66.4	1.1	41.6	0.5
32	6 Aug–12 Aug., 2022	31.5	23.7	84.9	70.6	1.2	20.0	0.8
33	13 Aug–19 Aug., 2022	29.8	22.9	83.1	71.7	0.3	98.6	2.9
34	20 Aug–26 Aug., 2022	28.9	24.3	86.4	80.9	1.0	80.0	5.8
35	27 Aug–2 Sept., 2022	32.8	22.3	73.9	61.3	2.5	13.0	5.7
36	3 Sep–9 Sept., 2022	33.8	22.6	69.3	42.4	5.7	00.0	4.7
37	10 Sep–16 Sept., 2022	31.5	23.1	68.7	56.0	6.2	11.2	6.2
38	17 Sep–23 Sep., 2022	32.4	21.0	69.3	55.7	5.1	26.4	8.7
39	24 Sep–30 Sep., 2022	31.1	20.4	65.3	41.4	6.1	9.8	5.3
40	1 Oct–7 Oct., 2022	34.5	21.4	70.4	38.0	8.4	0.0	7.6

Source: DFRS Agro Meteorological Observatory, Arjia, Bhilwara, Rajasthan.

consortium inoculation might be due to more population of *Azotobacter*, phosphate, potassium and zinc solubilizing bacteria, better survival of inoculated microorganisms in the rhizosphere and seed surface due to presence of cell protectant chemicals such as PVP and trehalose. Application of microbial consortium enhanced high number of cells in the rhizosphere, multiplication and survival of cells due to availability of carbon and energy sources. Microbial consortium inoculation might improve nutritional environment. Hence, increased the supply of N, P, K and Zn as evidenced by the higher uptake of nutrients by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters consequently resulted in increased grain and stover yield of the crop. These results are in the line with the findings of Khandare *et al.* (2015), Bhavya *et al.* (2017), Gautam *et al.* (2017) and Mohanta *et al.* (2020).

Conclusion

Application of Microbial Consortium as soil and

Table 2. Physical, biological and chemical properties of the soil of the experimental field before the sowing of the crop

Characteristics	Content	Methodofanalysis	Reference
Mechanicalcomposition			
Sand (%)	34.40	International pipettemethod	Bouyoucos (1962)
Silt (%)	30.30		
Clay(%)	35.70		
Texture	Clayloam	Texturetriangle	Piper (1950)
Physicalproperties			
Bulkdensity (g/cc)	1.39	Coresampler method	Black (1965)
Particledensity (g/cc)	2.56		Black (1965)
Porosity (%)	48.20		Black (1965)
Chemicalproperties			
Organiccarbon (%)	0.46	Rapid titrationmethod	Walkley and Black (1934)
Available nitrogen (kg/ha)	252.50	Alkaline KMnO4 method	Subbiah and Asija (1956)
Available phosphorus (kg/ha)	15.70	Olsen'smethod	Olsen *et al.* (1954)
Available potassium (kg/ha)	362.60	Flame photometer	Flame photometer
Available zinc (mg/kg)	0.62	DTPA/extract method	Lindsay and Norvell (1978)
Electrical conductivity(dSm^{-1}at 25 ^{o}C)	0.828	Conductivitybridge	Richard (1968)
pH (1:2.5 soil water ratio)	7.32	pHmeter	Richard(1968)

Table 3. Plant height, dry matter accumulation, and LAI of maize as influenced by Microbial Consortium

Treatments	Plant height (cm)			Dry matter accumulation ($g\ plant^{-1}$)			LAI	
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS
T1 : Control (RDF - 60:30:0)	42.5	139.2	164.3	17.4	46.2	133.7	1.65	2.15
T2 : RDF + Microbial consortium-1 as soil application	44.2	162.5	188.0	17.2	55.1	153.1	1.83	2.35
T3 : RDF + Microbial consortium-1 as seed inoculation	42.7	145.1	179.4	17.8	50.4	142.6	1.68	2.17
T4 : RDF + Microbial consortium-1 as soil application and seed inoculation	50.1	178.4	209.0	17.5	62.4	170.7	2.05	2.73
T5 : RDF + Microbial consortium-2 as soil application	46.2	172.1	205.3	18.2	60.9	166.2	1.93	2.66
T6 : RDF + Microbial consortium-2 as seed inoculation	43.1	146.4	182.6	18.4	52.9	147.8	1.83	2.21
T7 : RDF + Microbial consortium-2 as soil application and seed inoculation	50.7	181.8	210.0	18.6	63.0	173.9	2.08	2.79
T8 : 75 % RDF + Microbial consortium-1 as soil application and seed inoculation	43.3	149.2	184.4	18.3	54.5	150.5	1.81	2.22
T9 : 75 % RDF + Microbial consortium-2 as soil application and seed inoculation	44.0	155.6	187.5	18.2	54.6	152.7	1.83	2.31
SEm ±	2.0	5.7	7.3	0.9	2.3	6.3	0.06	0.09
CD at 5%	NS	17.0	22.0	NS	7.0	19.0	0.19	0.26

Table 4. Grain yield, stover yield and harvest index as influenced by Microbial Consortium of maize

Treatments	Grain yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	HI (%)
T1 : Control (RDF - 60:30:0)	34	44	78	43.14
T2 : RDF + Microbial consortium-1 as soil application	40	51	91	43.46
T3 : RDF + Microbial consortium-1 as seed inoculation	35	46	82	43.38
T4 : RDF + Microbial consortium-1 as soil application and seed inoculation	45	58	103	43.92
T5 : RDF + Microbial consortium-2 as soil application	44	56	99	43.89
T6 : RDF + Microbial consortium-2 as seed inoculation	36	48	84	43.42
T7 : RDF + Microbial consortium-2 as soil application and seed inoculation	46	58	104	43.80
T8 : 75 % RDF + Microbial consortium-1 as soil application and seed inoculation	37	49	86	43.34
T9 : 75 % RDF + Microbial consortium-2 as soil application and seed inoculation	38	50	88	43.43
SEm ±	1.69	1.96	3.05	1.20
CD at 5%	5.06	5.89	9.14	NS

seed inoculation along with RDF showed better performance with respect to growth and yield of maize in southern Rajasthan.

To boost the productivity of maize, application of sufficient quantity of Microbial consortium specially in the form of soil application and seed inoculation has distinct advantage of quick and efficient utilization of nutrients and reduced losses through leaching, fixation and regular uptake of nutrients by plant.

Conflict of Interest: None

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