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Microbial consortia enhance the yield of maize under sub-humid rainfed production system of India

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Plant beneficial microorganisms are being used to improve soil health and crop yield in different cropping systems. Maize is an important crop grown around the world for food, feed and raw material for various industries. The aim of the present study was to evaluate two microbial consortia *viz*., microbial consortia 1 (*Pseudomonas putida* P7 + *Paenibacillus favisporus* B30) and microbial consortia 2 (*Pseudomonas putida* P45 + *Bacillus amyloliquefaciens* B17) under field conditions for their suitability in improving maize yield under rainfed situations at Ballowal Saunkhri (Punjab) having sub-humid (Hot Dry) climatic conditions. Pooled analysis of three years field experiments data showed that, seed + soil application of microbial consortia 1 and 2 led to enhancement in grain yield of kharif maize by 27.78 and 23.21% respectively over uninoculated control. Likewise, significant increase in Benefit:Cost ratio as well as straw yield was also observed. The present investigation suggests that, microbial consortia would help in significantly improving the yield and economics of maize grown on inceptisols under rainfed conditions.

KEYWORDS
agricultural production, maize, microbial consortia, rainfed, yield

Introduction

Human population is expected to reach around 10 billion by 2050 and global food demand is projected to rise by 62% (van Dijk et al., 2021). It is estimated that, agricultural production needs to be increased by 60–70% to meet food demand of human population in 2050 (Silva, 2018). Maize is cultivated globally being the 3rd most important cereal crop after rice and wheat. Climate change significantly affects the crop production (Zhao et al., 2017). It is estimated that, climate change negatively affects maize production and decrease its yield by 24% (Jägermeyr et al., 2021). In India, it is being grown in about 9.3 m ha with a production of 30 m tons during the year 2020–21 (www.agricoop.nic.in). Kharif season accounts for about 83% of area under maize cultivation. Out of which more than 70% area is under rainfed condition.

Beneficial bacteria are extensively used to improve soil health, crop growth and yield (Srinivasarao and Manjunath, 2017; Efthimiadou et al., 2020). They extend necessary ecosystem services that help to enhance soil health and plant growth (Santos et al., 2019; Rouphael and Colla, 2020). The need for sustainable soil health and agricultural production worldwide led scientists to investigate different kinds of beneficial bacteria for their effectiveness. This has led to generation of lot of scientific evidence on beneficial interaction between plants and useful bacteria improving yield and productivity of cropping systems (Pereg and McMillan, 2015; Efthimiadou et al., 2020).

Nowadays, instead of single culture combination of two or more cultures as consortia are being used to improve plant growth and development (Olanrewaju and Babalola, 2019). Use of microbial consortia improved the plant growth and yield of various crops (Saikia et al., 2018; Silambarasan et al., 2019; Jain et al., 2021). Hence, we hypothesized that, microbial consortia increase crop growth and yield of maize. Since combination of microbial cultures carries out multiple functions, which are not possible for a single species. Further, consortia are not easily get affected by environmental alterations as individual microbial cultures (Brenner et al., 2008; Lindemann et al., 2016). *Bacillus* and *Pseudomonas* species have been reported to improve growth and yield crop plants (Radhakrishnan and Lee, 2016; Costa-Gutierrez et al., 2020). Application of microbial consortium comprising of *Rhizoglomus irregulare* and *Pseudomonas putida* increased P use efficiency and maize productivity (Pacheco et al., 2021). Use of beneficial microorganisms along with farm yard manure improved maize growth (Hussain et al., 2021). Consortia of beneficial bacteria stimulated maize growth and development (Walker et al., 2012; Olanrewaju and Babalola, 2019). The bacterial isolates used in the present study were tested individually for their ability improve plant growth under pot conditions (Sandhya et al., 2009, 2011; Ali et al., 2011). The *Bacillus amyloliquefaciens* B17 and *Paenibacillus favisporus* B30 were Gram positive with irregular margin, tested positive for citrate, catalase, and oxidase activity. The former was able to produce siderophores but not the latter. The *Pseudomonas putida* P7 and *Pseudomonas putida* P45 were Gram negative and posses the PGP characteristics such as P-solubilization, synthesis of indole acetic acid, gibberellins and siderophore. Further, they were also evaluated in pot experiments for plant growth promotion in maize, sunflower and wheat under moisture stress conditions. They have increased proline, sugar and protein contents in leaves, improved relative water content (RWC) and reduced leaf water loss (LWL) of inoculated plants under moisture stress conditions (Sandhya et al., 2009, 2011; Ali et al., 2011).

Hence, the aim of the present study was to evaluate the open field effectiveness of two microbial consortia for improving yield of maize under rainfed conditions at Ballowal Saunkhri (Punjab) having sub-humid (Hot dry) climatic conditions.

Materials and methods

Experimental site

Starting from 2018–19 to 2020–21, 3 years consecutive field experiments were conducted at the research farm of All India Coordinated Research Project on Dryland Agriculture (AICRPDA) center, Ballowal Saunkhri (Punjab). A summary of geographic, edaphic and climatic characteristics of the site has been given in Table 1.

Microbial consortia

The microbial consortia developed by ICAR-Central Research Institute for Dryland Agriculture, Hyderabad were used for the evaluation. They include *Pseudomonas putida* P7 + *Paenibacillus favisporus* B30 (Microbial consortia 1) and *Pseudomonas putida* P45 + *Bacillus amyloliquefaciens* B17 (Microbial consortia 2).

TABLE 1 Geographic, climatic, and edaphic properties of the experimental site.

Particulars	Ballowal Saunkhri (Punjab)
Geographic location (latitude and longitude)	31° 5′ 53.19″ N and 76 °23′ 22.684″ E
Climate	Sub-humid (hot dry)
Soil type	Inceptisols
Crop	Maize
Variety	PMH-1
Spacing	20 × 60 cm
Plot size	5.4 × 6 m
Organic carbon (%)	0.49
pH	7.6
Available N (kg ha^{-1})	117
Available P (kg ha^{-1})	45.6
Available K (kg ha^{-1})	168
Mean annual rainfall (mm)	1,011
Mean annual temperature max. and min. (°C)	40.8 and 2.30

The bacteria used in the consortia development have been deposited at a national repository i.e., National Agriculturally Important Microbial Culture Collection (NAIMCC), Kushmaur, Mau Nath Bhanjan—275103, Uttar Pradesh (India) with the following accession numbers NAIMCC-B-00922 (*Pseudomonas putida* P7); NAIMCC-B-01801 (*Paenibacillus favisporus* B30); NAIMCC-B-00923 (*Pseudomonas putida* P45); and NAIMCC-B-00921 (*Bacillus amyloliquefaciens* B17). The isolates used in consortia development were tested for compatibility through confrontation studies. They were also tested for PGPR activities such as exopolysaccharide production, thermotolerance, ammonia production, P solubilization, synthesis of indole acetic acid, gibberellins, siderophore, and hydrogen cyanide (Sandhya et al., 2009, 2011; Ali et al., 2011).

Preparation of talc formulations

The Kings' B broth was used to grow *Pseudomonas putida* P7 and *Pseudomonas putida* P45 whereas, *Paenibacillus favisporus* B30 and *Bacillus amyloliquefaciens* B17 were grown in nutrient broth media. The cultures were kept on a shaker (120 rpm) at 28 ± 2°C for 48 h. The cell density of all the isolates was adjusted spectrophotometrically to 10^8 cells mL^{-1} by measuring optical density (0.8) at 600 nm. Talc formulations were made by mixing equal volumes of *Pseudomonas putida* P45 + *Bacillus amyloliquefaciens* B17 and *Pseudomonas putida* P7 + *Paenibacillus favisporus* B30 (Vidhyasekaran and Muthuamilan, 1995).

Treatment details

T1: Uninoculated control, T2: Seed treatment of microbial consortia 1 (@30 g/kg seeds), T3: Soil application of microbial consortia 1 [@2.5 kg of talc formulation mixed with 50 kg of well-decomposed Farmyard manure (FYM)/ha], T4: Seed + Soil application of microbial consortia1 (T1 + T2), T5: Seed treatment of microbial consortia 2 (@30 g/kg seeds) T6: Soil application of microbial consortia 2 (@2.5 kg of talc formulation mixed with 50 kg of well-decomposed FYM/ha), T7: Seed + Soil application of microbial consortia 2 (T4 + T5). For seed treatment, a slurry of talc formulation was prepared with 1% carboxy methyl cellulose, the slurry was coated onto the surface of seeds, shade dried for 30 min and used for sowing. For soil application, the dosage used was 2.5 kg of talc formulation was mixed with 50 kg of well-decomposed FYM/ha. The talc formulation was properly mixed with FYM and kept overnight, applied to soil by broadcasting before sowing. The experiment was conducted by following randomized block design with three replications. The crop was raised by following recommended agronomic practices and fertilizer doses. Maize variety, PMH-1 was sown on 7th July in 2018 and 2019 and on 6th July in 2020 after the onset on monsoon rains entirely as a rainfed crop. The crop was sown at a spacing of 60 × 20 cm by using 20 kg seeds ha^{-1}. The sowing was done by dibbling seeds 3–5 cm deep. The size of each plot was 5.4 × 6 m with a buffer zone of 1 m between the plots with 120 plants in net plot area (4 × 3.6 m). The recommended dose of 80 kg N ha^{-1} was applied through urea (180 kg ha^{-1}), 40 kg P_2O_5 through single superphosphate (250 kg ha^{-1}) and 20 kg K_2O through muriate of potash (37.5 kg ha^{-1}). The half of N (90 kg urea per hectare) and entire doses of P_2O_5 and K_2O were applied as basal and remaining half dose of N was top dressed uniformly at knee high stage in all the treatments. It was on done 3rd October, 27th and 22nd September in 2018, 2019, and 2020, respectively. All other cultural operations were followed as per the package of practices of Punjab Agricultural University (Anonymous, 2018). The crop was harvested manually and grain yield was calculated on 14% moisture basis. The rows of maize from the net plot and border strips (14.4 m^2) were harvested separately to record the grain and straw yield. Ten cobs were randomly selected from each net plot area to evaluate cob length, and number of grains per cob. For 1,000-grain weight, all the cobs from each net plot were thrashed and one thousand grains were counted from the yield of each net plot and then weighed. Cost of cultivation, net monetary returns and benefit: cost ratio were calculated on the basis of prevailing market price of inputs and outputs.

Soil sampling and analysis

Before sowing of maize crop, three random soil samples were collected 0–15 cm depth (from top surface) and composited. The soil samples were hand crushed and passed through 2 mm sieve and used for the analysis. The available nitrogen (Subhiah and Asija, 1956), available phosphorus (Olsen et al., 1954), available potassium (Piper, 1966) and soil organic carbon (Walkley and Black, 1934) contents were determined. Soil moisture was measured by following gravimetric method at sowing, flowering and harvest stages (Black, 1965). Net Returns, Benefit: Cost and Rain Water Use Efficiency (RWUE) were calculated by following formulae *viz.*

$$\begin{aligned} Net\ Returns &= Gross\ returns - Gross\ expenditure \\ B:C &= \frac{Gross\ returns}{Gross\ expenditure} \\ RWUE &= \frac{Grain\ yield\ (kg/ha)}{Rainfall\ (mm)\ during\ the\ cropping\ season} \end{aligned} \quad (1)$$

respectively.

Statistical analysis

Each year data was analyzed using triplicate sets of data, by ANOVA using the Statistical Package for Social Sciences 16.0 (SPSS, 2016) for windows. The pooled data analysis was done by taking mean value of each year for the parameters analyzed. The *p*-value of each parameter obtained through the analysis is given in Table 3 and Supplementary Tables S1–S3.

Results

Rainfall received and dryspells occurred during the cropping season

An amount of 894.5, 732.4, and 493.9 mm of rainfall received at Ballowal Saunkhri during the cropping seasons of 2018, 2019, and 2020, respectively. Year wise rainfall received during the cropping season has been presented as Supplementary Figure 1. During the year 2018, two dryspells of 09 days each occurred at tasselling and silking stage as well as dough stage, respectively. One dryspell of 10 days occurred at dough stage during the year 2019. In the year, 2020 two dryspells of 11 and 19 days occurred at grain filling and dough stage, respectively (Table 2).

TABLE 2 Dryspells observed during three cropping seasons (2018–20) at Ballowal Saunkhri (Punjab).

Cropping season	Dryspells		Phenological stage of the crop	Date of harvesting
	Duration	Dates and month		
2018–19	9 days	14th to 22nd August	Tasselling and silking	03.10.2018
	9 days	13th to 21st September	Dough stage	
2019–20	10 days	12th to 21st September	Dough stage	27.09.2019
2020–21	11 days	22nd August to 1st September	Grain filling	22.09.2020
	19 days	4th to 23rd September	Dough stage	

TABLE 3 Influence of seed and soil application of microbial consortia on yield attributes, yield, and economics of maize.

Treatments	Cob length (cm)	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Net returns (Rs/ha)	B:C ratio
Uninoculated control	15.25^{b} ± 0.71	192.84^{f} ± 7.89	3,019.67^{c} ± 123.79	6,934.33^{e} ± 58.61	27,480.33^{e} ± 2,614.23	1.79^{e} ± 0.06
Seed treatment (microbial consortia 1)	16.68^{ab} ± 0.17	212.03^{bc} ± 9.15	3,500.33^{b} ± 41.07	8,632.33^{abc} ± 345.95	37,291.33^{bc} ± 4,651.93	2.06^{bc} ± 0.11
Soil application (microbial consortia 1)	16.08^{ab} ± 0.44	206.45^{de} ± 7.50	3,346.33^{b} ± 40.48	8,070.00^{cd} ± 510.07	33,992.00^{cd} ± 4,467.73	1.96^{cd} ± 0.11
Seed treatment + soil application (microbial consortia 1)	17.37^{a} ± 0.30	221.26^{a} ± 9.76	3,858.67^{a} ± 134.60	9,110.00^{a} ± 435.47	43,743.33^{a} ± 4,256.95	2.22^{a} ± 0.10
Seed treatment (microbial consortia 2)	16.29^{ab} ± 0.40	209.90^{cd} ± 9.47	3,443.67^{b} ± 40.14	8,311.33^{bcd} ± 308.20	35,861.00^{cd} ± 4,487.16	2.02^{cd} ± 0.11
Soil application (microbial consortia 2)	15.80^{ab} ± 0.31	205.11^{e} ± 7.02	3,295.00^{b} ± 50.27	7,857.67^{d} ± 482.11	32,879.67^{d} ± 4,278.26	1.93^{d} ± 0.10
Seed treatment + soil application (microbial consortia 2)	16.66^{ab} ± 0.53	215.52^{b} ± 8.60	3,720.67^{a} ± 127.66	8,827.33^{ab} ± 457.16	40,913.00^{ab} ± 3,651.00	2.15^{ab} ± 0.08
Mean	16.48	211.71	3,527.44	8,468.11	37,446.72	2.06
SEm	0.46	1.26	62.68	189.93	1,281.32	0.03
p-value	0.12	<0.001	<0.001	<0.001	<0.001	<0.001

Microbial consortia 1 (*Pseudomonas putida* P7 + *Paenibacillus favisporus* B30); microbial consortia 2 (*Pseudomonas putida* P45 + *Bacillus amyloliquefaciens* B17); dosage: seed treatment (@30 g/kg seeds); soil application [@2.5 kg of talc formulation mixed with 50 kg of well-decomposed Farmyard manure (FYM)/ha].
Different alphabets within the column indicates significant difference.

Effect of seed and soil application of microbial consortia on grain and straw yield of maize

Three years of field experiments have showed that, the treatments with seed + soil application of microbial consortia 1 (3,858.66 kg/ha) and microbial consortia 2 (3,720.66 kg/ha) significantly increased maize grain yield as compared to uninoculated control (3,019.66 kg/ha). The straw yield was also significantly improved due to seed + soil application of microbial consortia 1 (9,110 kg/ha) as well as microbial consortia 2 (8,827.33 kg/ha) compared to uninoculated control which recorded lowest straw yield of 6,934.33 (Table 3). Year wise data on the influence of microbial consortia on grain and straw yield of maize has been provided in Supplementary Tables S1–S3.

Effect of microbial consortia on net returns and Benefit:Cost ratio

Significant increase in net returns was observed due to the use of microbial consortia. The treatments with seed + soil application of microbial consortia 1 (Rs. 43,743.33) and microbial consortia 2 (Rs.40,913.00) recorded significantly higher net returns ($p < 0.001$) as compared to uninoculated control (Rs. 27,480.33). Likewise, significantly ($p < 0.001$) higher B:C ratios were also recorded due to the use of microbial consortia 1 (2.22) and microbial consortia 2 (2.14) vis-a-vis uninoculated control, which recorded lowest B:C ratio of 1.79 (Table 3). Year wise data on net returns and B:C ratio has been given as Supplementary Tables S1–S3.

Effect of microbial consortia on soil moisture content and rain water use efficiency

Soil moisture content was measured at sowing, flowering and harvest stages. Relatively higher soil moisture content was observed at flowering stage between uninoculated control and microbial consortia 1 and 2 (Figure 1). Year wise soil moisture content data has been provided as Supplementary Figures S2, S4, S6. Use of microbial consortia particularly seed + soil application of microbial consortia 1 (5.73 kg/ha/mm) and microbial consortia 2 (5.53 kg/ha/mm) significantly enhanced the rain water use efficiency of maize compared to uninoculated control (4.52 kg/ha/mm) (Figure 2). Year wise data on rain water use efficiency has been presented in Supplementary Figures S3, S5, S7.

Discussion

Beneficial microorganisms have been used to improve growth and yield of wheat (Kumar et al., 2014), sunflower (Alami et al., 2000), chickpea (Ogola et al., 2021), maize (Chahal et al., 2022), okra (Manjunath et al., 2016), and many other crops. The microbial technologies offer ecofriendly and affordable means for sustainable soil health and crop production (Kumar et al., 2014; Manjunath et al., 2016). Plant associated microorganisms help to improve plant growth and development through mobilization, solubilization and transformation of plant nutrients, production of plant hormones, exopolysaccharides and regulation of biochemical compounds like sugars and proline.

In the present investigation, seed + soil application of microbial consortia 1 and 2 recorded significantly higher grain as well as straw yield of maize as compared to uninoculated control (Table 3). This may be due to beneficial effects exerted by the microbial

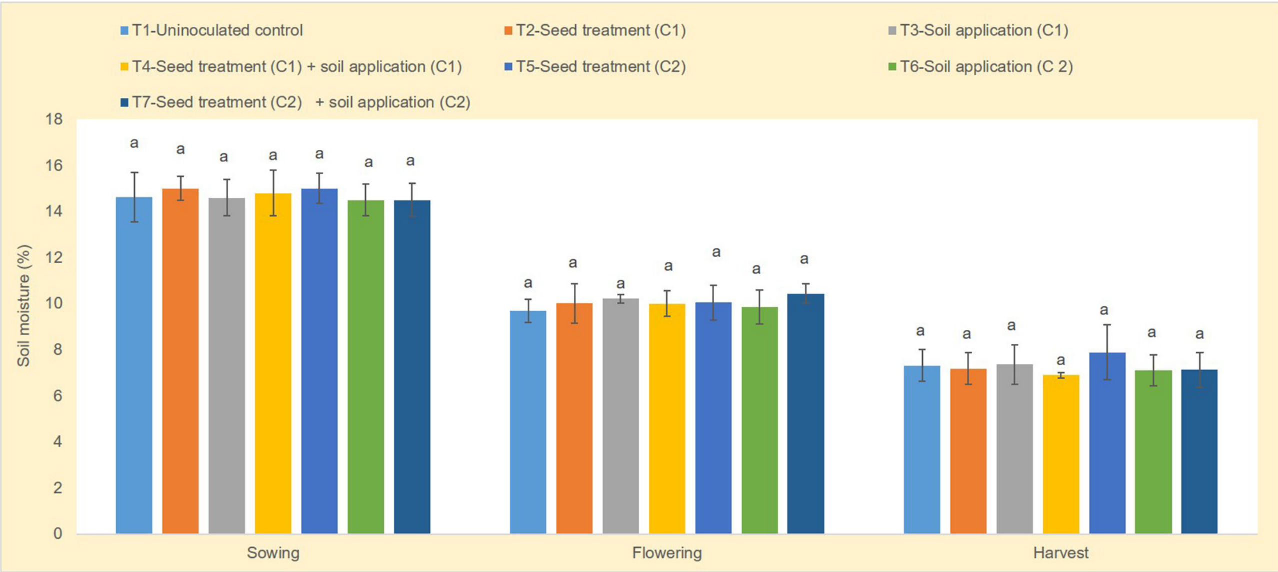

FIGURE 1
Soil moisture (%) at different stages of crop growth at Ballowal Saunkhri (Punjab). Sowing ($p = 0.92$), flowering ($p = 0.53$), and harvest ($p = 0.67$); error bars indicate standard error. The different alphabets on the top of error bars indicate the significant difference.

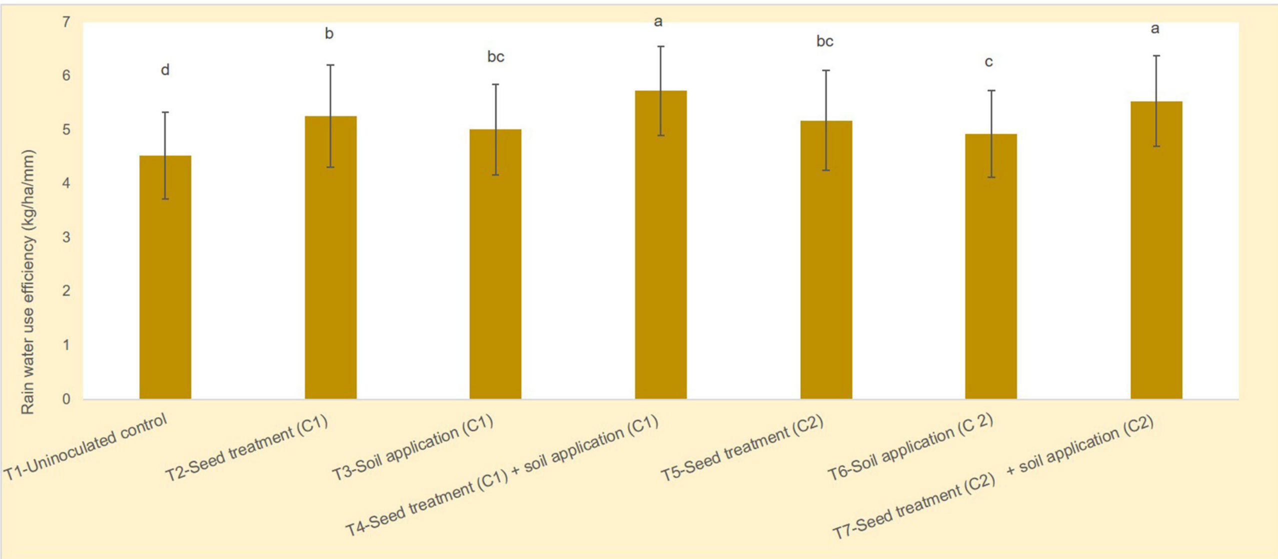

FIGURE 2
Effect of microbial consortia on rain water use efficiency of maize. $p = 0.00$; error bars indicate standard error. The different alphabets on the top of error bars indicate the significant difference.

consortia on maize plants. The bacteria used in the present study *viz.*, *Pseudomonas putida* P7 + *Paenibacillus favisporus* B30 (Microbial consortia 1) and *Pseudomonas putida* P45 + *Bacillus amyloliquefaciens* B17 (Microbial consortia 2) were previously tested for plant growth promoting characteristics. They were able to produce phytohormones such as IAA, solubilize phosphorus, synthesize exopolysaccharides (EPS) and increased proline, sugar and protein contents in leaves under moisture stress conditions. Also improved relative water content (RWC) and reduced leaf water loss (LWL) of inoculated plants (Sandhya et al., 2009, 2010, 2011; Ali et al., 2011). Both seed as well as soil application might have resulted in providing more inoculum for improved colonization as compared to seed or soil application alone. Fitriatin et al. (2021) reported that, seed and soil application of biofertilizers improved growth of maize compared to single method of application.

Kaur and Reddy (2014) evaluated phosphate-solubilizing bacteria such as *Pantoea cypripedii* and *Pseudomonas plecoglossicida* at three different agroclimatic regions and reported that, these two bacteria significantly improved the phosphorous (P) uptake, soil organic carbon, activity of soil enzymes, grain yield of maize and wheat at three agroclimatic regions. Notable increase in maize productivity under field conditions was observed due to the use of microbial consortium which resulted in improved phosphorus use efficiency (Pacheco et al., 2021). Likewise, IAA producing bacteria promoted plant growth through improved root growth leading to increased water and nutrient uptake (Mantelin and Touraine, 2004; Myo et al., 2019). Inoculation of plant growth promoting bacteria *viz*., *Pseudomonas* spp. and *Azotobacter* spp. in maize significantly improved leaf area and relative water content as compared to uninoculated control under moisture stress conditions (Osama et al., 2020). Seed treatment of maize with *Pseudomonas fluorescens* strain 153 caused enhancement in proline content and improved the tolerance of plants to water deficit stress conditions (Ansary et al., 2012). Proline helps to maintain osmotic potential of cell, scavenge reactive oxygen species, stabilizes proteins and cell membrane leading to prevention of electrolytes leakage (Chun et al., 2018). EPS producing *Pantoea aglomerans* NAS206 improved root colonization, soil aggregation and thereby moisture stress tolerance of wheat (Amellal et al., 1998). In the present study, dryspells of 09–19 days duration were observed during the cropping seasons. Application of microbial consortia 1 and 2 resulted in relatively higher soil moisture content at flowering stage as compared to uninoculated control (Figure 1). This may be attributed to improved water holding capacity as a consequence of increased soil aggregation due to exopolysaccharide synthesis ability of bacteria used in the consortia. Inoculation of wheat with EPS producing microbial consortia consisting of *Planomicrobium chinense* strain P1 and *Bacillus cereus* strain P2 significantly improved the soil moisture availability as well as chlorophyll, sugar and leaf protein contents under rainfed conditions at different locations (Khan and Bano, 2019). Further, significant increase in rain water use efficiency was recorded due to seed + soil application of microbial consortia 1 and 2 as compared uninoculated control (Figure 2).

Conclusions

Evaluation of microbial consortia under field conditions for 3 years suggested that, both microbial consortia 1 (*Pseudomonas putida* P7 + *Paenibacillus favisporus* B30) and microbial consortia 2 (*Pseudomonas putida* P45 + *Bacillus amyloliquefaciens* B17) significantly increased yield and economics of kharif maize under rainfed conditions at Ballowal Saunkhri (Punjab) having sub-humid (Hot Dry) climatic conditions. Since microbial consortia are ecofriendly and affordable, they can be conveniently used to improve maize production under rainfed farming.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MM, GC, SY, and KG: designed research. AK: performed research. MM and AK: analyzed data. MM, NJ, and KS: wrote the manuscript. VS, MS, and MP: resources. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1108492/full#supplementary-material

SUPPLEMENTARY FIGURE 1
Rainfall received during the cropping seasons 2018 **(a)**, 2019 **(b)**, and 2020 **(c)**.

SUPPLEMENTARY FIGURE 2
Soil moisture (%) at different stages of maize growth during the year 2018. Sowing ($p = 0.07$), flowering ($p = 0.73$), and harvest ($p = 0.85$); error bars indicate standard error.

SUPPLEMENTARY FIGURE 3
Effect of microbial consortia on rain water use efficiency of maize during the year 2018. $p = 0.05$; error bars indicate standard error.

SUPPLEMENTARY FIGURE 4
Soil moisture (%) at different stages of maize growth during the year 2019. Sowing ($p = 0.20$), flowering ($p = 0.94$), and Harvest ($p = 0.11$); error bars indicate standard error.

SUPPLEMENTARY FIGURE 5
Effect of microbial consortia on rain water use efficiency of maize during the year 2019. $p = 0.04$; error bars indicate standard error.

SUPPLEMENTARY FIGURE 6
Soil moisture (%) at different stages of maize growth during the year 2020. Sowing ($p = 0.92$), flowering ($p = 0.15$), and Harvest ($p = 0.75$); error bars indicate standard error.

SUPPLEMENTARY FIGURE 7
Effect of microbial consortia on rain water use efficiency of maize during the year 2020 $p = 0.02$; error bars indicate standard error.

SUPPLEMENTARY TABLE 1
Influence of seed and soil application of microbial consortia on yield attributes, yield and economics of maize during the year 2018 under rainfed conditions of India.

SUPPLEMENTARY TABLE 2
Influence of seed and soil application of microbial consortia on yield attributes, yield and economics of maize during the year 2019 under rainfed conditions of India.

SUPPLEMENTARY TABLE 3
Influence of seed and soil application of microbial consortia on yield attributes, yield and economics of maize during the year 2020 under rainfed conditions of India.

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