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A Sai Kiran
M.Sc. Agronomy (Water Management), Water Technology Centre, College of Agriculture, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad, Telangana, India

K Avil Kumar
Associate Director of Research, Regional Agricultural Research Station, PJTSAU, Palem, Nagarkurnool, Telangana, India

M Uma Devi
Director and Principal Scientist (SS&AC), Water Technology Centre, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, Telangana, India

B Balaji Naik
Senior Scientist (Agro.), Agro Climate Research Centre, ARI, Rajendranagar, Hyderabad, Telangana, India

S Triveni
Associate Professor & University Head, Dept. of Agricultural Microbiology & Bioenegry, PJTSAU, College of Agriculture, Rajendranagar , Hyderabad, Telangana, India

Correspondence
A Sai kiran
M.Sc. Agronomy (Water Management), Water Technology Centre, College of Agriculture, Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad, Telangana, India

Effect of drip fertigation of nitrogen, potassium and microbail consortium on growth and yield of *Rabi* maize (*Zea mays* L.)

A Sai Kiran, K Avil Kumar, M Uma Devi, B Balaji Naik and S Triveni

Abstract
A field experiment was conducted at Water Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, and Hyderabad during *Rabi* 2018-19 on "Drip fertigation of nitrogen, potassium and microbial consortium in *rabi* maize (*Zea mays* L.). The experiment was conducted (laid out) in randomized block design with DHM-117 and replicated thrice. The treatments comprises of drip fertigation of 100% RD N&K, drip fertigation of 100% RD N&K with soil application of microbial consortium (MC), drip fertigation of 100% RD N&K with biofertigation of MC three times, drip fertigation of 100% RD N&K with biofertigation of MC five times, drip fertigation of 75% RD N&K, drip fertigation of 75% RD N&K with soil application of MC, drip fertigation of 75% RD N&K with biofertigation of MC three times and drip fertigation of 75% RD N&K with biofertigation of MC five times. The interaction effect between RD N&K and biofertigation of MC was not significant on growth parameters and yield. Higher plant height, number of leaves plant^{-1} and DMP were recorded with fertigation of 100% RD N&K over 75% RD N&K at all growth stages except at 30 DAS. Significantly higher growth parameters *i.e.* height of plant, leaf number plant^{-1} and DMP at 60, 90 DAS and at harvest was observed among biofertigation of MC five times and three times compared to treatment where MC was not applied and was on par with soil application of MC. Similarly, yield (grain and stover) were recorded maximum with biofertigation of MC five times and three times which were on par with soil application of MC and superior to treatment where MC was not applied.

Keywords: Fertigation, biofertigation, microbial consortium

Introduction

Maize is grown almost all over the world in different agro-climatic conditions and in different seasons. It is the third most important food crop next to rice and wheat. It is also known as the miracle crop or queen of cereals due to its high productivity potential among the cereal crops of *Graminacea* family. In India, maize is not only grown for food and fodder but also for several industrial usage and acquired dominant role in the farming sector and macro-economy of the Asian region (Mauria *et al*., 1998) [13]. In India, *Rabi* maize is grown in an area of 1.19 M ha with a production of 5.90 M t and productivity of 4978 kg ha^{-1} (Does, 2016) [6]. In Telangana, it is cultivated in an area of 0.5 M ha with a production of 1.75 M t and productivity of 3057 kg ha^{-1} (Does, 2016) [6]. Maize is grown in *kharif, Rabi* and also during summer seasons, under irrigated conditions in entire plain region of the country. It is the most efficient field crop in producing higher dry matter per unit quantity of water applied.

Water and fertilizers are important production factors for improving maize production. In conventional method, application of water and fertilizers are not effective and wastage is high, whereas drip fertigation assures an effective and economical way to supply water and nutrients for the crops (Hanson *et al.,* 2006). Fertigation is used to supply water and fertilizer simultaneously (Castellanos *et al.*, 2012).

Biofertilizers can partially replace chemical fertilizers. There is a need to search for alternative strategies to improve soil health without causing damage to environment as well as soil. Therefore biofertilizers are gaining importance as they are ecofriendly, non-hazardous and non-toxic products. Biofertilizers include mainly the nitrogen fixing, phosphate solubilizing and plant growth promoting microorganisms. Biofertilizers benefiting the crop production are *Azatobacter, Azospirillum, blue green algae, Azolla, P-solubulizing microorganisms, mycorrhizae and sinorhizobium* (Selvakumar *et al.*, 2009) [19].

However it was reported that survival of microbes is difficult under moisture deficit conditions of traditional methods of irrigation and rainfed conditions. Drip irrigation facilitates moisture at field capacity. Beneficial bacteria such as *Azospirillum*, *Phosphobacteria* and *Methylotroph* colonizing in the rhizosphere region have the ability to fix nitrogen, solubilize phosphorus and stimulate plant growth. The biofertigation, that is application of liquid biofertilizers or microbial consortium along with drip irrigation can precisely deliver the bio inoculants in the root zone. However this technology needs to be standardized as the literature availability related to biofertigation is very scarce. Drip irrigation is the fastest growing segment of micro irrigation in the state of Telangana and its benefits are many and these days, it is used on a wide variety of crops with the increasing shortage of water. Keeping in view of the above, the present study entitled Effect of drip fertigation of nitrogen, potassium and microbial consortium on growth and yield of maize" was planned to evaluate the performance of biofertigation under field condition along with fertigation of inorganic fertilizers on *Rabi* maize.

Material and Methods

A field experiment was conducted at Water Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, and Hyderabad during *Rabi* 2018-19 on "Drip fertigation of nitrogen, potassium and microbial consortium in *rabi* maize (*Zea mays* L.)". The experiment was conducted (laid out) in randomized block design with DHM-117 and replicated thrice. The treatments comprises of drip fertigation of 100% RD N&K, drip fertigation of 100% RD N&K with soil application of microbial consortium (MC), drip fertigation of 100% RD N&K with biofertigation of MC three times, drip fertigation of 100% RD N&K with biofertigation of MC five times, drip fertigation of 75% RD N&K, drip fertigation of 75% RD N&K with soil application of MC, drip fertigation of 75% RD N&K with biofertigation of MC three times and drip fertigation of 75% RD N&K with biofertigation of MC five times. The recommended dose of (RD) nutrients were 240:80:80 kg N: P_2O_5:K_2O ha^{-1}. The spacing adopted for sowing was 80 cm × 15 cm, experimental soil was loamy in texture, slightly alkaline in reaction, non-saline, low in available nitrogen, medium in available phosphorous and high in available potassium, medium in organic carbon content. N & K was applied in different doses (75% & 100% RDF) through fertigation at an interval of 3 days in the form of urea and SOP (white) and drip irrigation was scheduled at 1.2 Epan during the entire crop growth period. The recommended dose of fertilizers *i.e.*, 240:80:80 kg of N: P2O5:K2O ha^{-1} were applied during fertigation treatments. The entire dose of phosphorus was applied to soil as basal whereas nitrogen and potassium were applied through fertigation at 3 days interval by dissolving the required quantity of fertilizer as per the crop need $plot^{-1}$ and applied through venturi system. The liquid Microbial consortium consisted of *Azotobacter* (Non-symbiotic heterotrophic N_2 fixing bacterium), P solubulizing bacteria, K releasing bacteria and Zn solubulizing bacteria. It was applied through drip irrigation system @ 1.5 L (with microbial count of 10^{12} cell ml^{-1}) diluted in 500 L of water for one hectare (except for soil application). Fertigation of microbial consortium was started from 10 days after sowing (DAS) at 10 days interval. In three times application the scheduling was at 20, 30 and 40 DAS and in 5 times application it was extended up to 60 DAS. Soil application of microbial consortium was done at 10 DAS @ 1.5 L (with microbial count 10^{12} cell ml^{-1}) mixed with 150 kg of varmam post for one hectare and applied along the plant rows. The data generated in this study were analyzed using standard statistical methods through factorial concept as there was significant variation among the treatments was observed.

Results and Discussion

Growth parameters

The crop growth characters of plants are manifested in many ways. The important among them are plant height, number of leaves, LAI and DMP. The source-sink relationship mainly depends on these important crop growth characters. Hence, the observations on above traits at various crop growth stages were recorded in the current investigation and the results are detailed below.

Plant height (cm)

The plant height of maize increased from 30 DAS to harvest and was significantly influenced by fertigation of RD N&K and biofertigation of MC at 60, 90 DAS and at harvest except with 30 DAS and their interaction effect at any growth stage was not significant (Table 1).

Significantly higher plant height at 60, 90 DAS and at harvest (192.5, 236.5 and 241.5 cm, respectively) was observed with fertigation of 100% RD N&K (240:80 kg N: K_2O ha^{-1}) over 75% RD N&K *i.e.*160:60 kg N: K_2O ha^{-1} (177.7, 223.8 and 229.3 cm, respectively).

The plant height increased with increasing fertigation level RD N&K *i.e*, from 75 to 100%. This might be due to increased availability of nutrients better uptake by the roots and increased in the number of nodes and inter nodal distance. These results are in accordance with Himaja (2014), Bibe *et al.* (2017) [5] and Ramdas (2018) [17] who has reported increasing fertigation level increased the plant height.

Among biofertigation of MC, at 60, 90 DAS and at harvest significantly higher plant height was recorded with the biofertigation of MC five times (190.6, 234.9 and 241.2 cm, respectively) and three times (188.8, 233.4 and 238.4 cm) over without application of MC (185.0, 229.4 and 234.0 cm) and was on par with the soil application of MC (176.1, 222.9 and 227.9 cm). Significantly lower plant height at all growth stages was recorded under in treatment where MC was not applied and was on par with the soil application of MC.

Plant height of maize was significantly increased with biofertigation of MC either soil applied or biofertigated over the treatment without application of MC. This indicates the higher performance of biofertigation of MC which contains nitrogen fixers (*Azotobacter*), phosphorus solubulizer, and potassium releasing and zinc solubulizing bacteria. *Azatobacter* fixes atmospheric nitrogen, produces plant growth promoters which increases the plant growth and the number of hair roots, root absorptive surface which in turn increase the nutrient availability and uptake by the plant Phophorus solubulizing bacteria (PSB), Potassium releasing bacteria (KRB) and zinc solubulizing bacteria produces organic acids which plays a major role in mineralization of phosphorus, potassium and zinc in soil besides releasing plant growth promoting substances such as IAA, Auxins, Gibberilins which increases the plant height. Similar results *i.e.* biofertigation increased the plant height were found by Obid *et al.* (2016) [14] and Viana *et al.* (2014) [22] in maize, Ahmed *et al.* (2000) [2] and Gomathy *et al.* (2008) [7] in cotton.

Table 1: Plant height (cm) of *Rabi* maize as influenced by nitrogen, potassium and microbial consortium drip fertigation.

Treatment	30 DAS	60 DAS	90 DAS	At Harvest
RD N&K				
100% RD N&K	46.5	192.5	236.5	241.5
75% RD N&K	43.9	177.7	223.8	229.3
SE. m ±	1.0	2.2	1.9	1.8
CD (P=0.05)	NS	6.5	5.7	5.6
biofertigation				
MC_0	44.6	176.1	222.9	227.9
SMC	44.4	185.0	229.4	234.0
MC_3	45.6	188.8	233.4	238.4
MC_5	46.2	190.6	234.9	241.2
SE. m ±	1.5	3.0	2.7	2.6
CD (P=0.05)	NS	9.2	8.1	7.9
Interaction between RD N&K and biofertigation				
SE. m ±	2.1	4.3	3.8	3.7
CD (P=0.05)	NS	NS	NS	11.2

RD N&K 100% RD (240:80 kg N: K_2O ha^{-1}); 75%RD (180:60 kg N: K_2O ha^{1}).
Biofertigation MC_0-Without Microbial Consortium (MC); SMC-Soil application of MC;
MC_3-Biofertigation of MC three times; MC_5-Biofertigation of MC five times.

Number of leaves plant^{-1}

Fertigation with RD N&K and biofertigation of MC significantly influenced number leaves plant^{-1} at all growth stages except at 30 DAS and their interaction effect was not significant at all growth stages. The number of leaves plant^{-1} of *rabi* maize were increased with the age of the plant till 90 DAS after that no more increase in number of leaves plant^{-1} was observed and decreased at harvest due to senescence of lower leaves (Table 2)

There was no significant difference in number of leaves plant^{-1} was observed with biofertigation of MC, fertigation of RD N&K and by their interactions at 30 DAS. However, number of leaves plant^{-1} ranged from 8.6 to 9.1 at 30 DAS (Table 2).

Fertigation with 100% RD N&K recorded significantly maximum number of leaves plant^{-1} (15.1, 15.3 and 14.9) compared to 75% RD N&K (14.3, 14.9 and 14.4) at 60, 90 DAS and at harvest, respectively.

The number of leaves plant^{-1} were increased with increase in fertigation dose due to better availability and uptake of nutrients resulting in better growth and development in terms of plant height resulting in more number of leaves. Reduction (lesser leaves) in number of leaves plant^{-1} at harvest compared to 90 DAS was mainly due to the reason of senescence of fully matured and ripened lower (1-2) leaves at harvestable maturity. Similar results *i.e.* increase in fertilizer dose increased number of leaves plant^{-1} was found by Himaja (2014), Pal (2016) [15] and Ramdas (2018) [17].

biofertigation of MC five times (15.0 and 15.4) and three times (14.9 and 15.2) recorded significantly higher number of leaves plant^{-1} at 60 and 90 DAS, respectively than the treatment where MC was not applied (14.2 and 14.7) and was on par with soil application of MC (14.6 15.0). Significantly lower number of leaves plant^{-1} was recorded in treatment without application of MC and was on par with soil application of MC.

There was no significant difference in number of leaves plant^{-1} at harvest among biofertigation of MC five times (15.0), three times (14.8) and soil application of MC (14.7) and were significantly superior over the treatment without application of MC (14.1).

The number of leaves were increased with increasing biofertigation of MC, soil application of MC compared to treatment where MC was not applied. This promoting effect of bio fertilizers is due better better performance of biofertilizers with fertigation and biologically active substance produced by these microorganism such as auxins, Gibberilins, amino acids and vitamins resulting in better growth and development in terms of plant height which resulting in more number of leaves. These results in maize *i.e.* increasing number of leaves plant^{-1} through biofertilizers are in accordance with sughra *et al*. (2010) [21] through seed inoculation of *Azospirillum* and Viana *et al.* (2014) [22] through biofertigation and number of branches plant^{-1} in cotton by Jaya kumar (2014) [11].

Table 2: Number of leaves plant^{-1} of *Rabi* maize as influenced by nitrogen, potassium and microbial consortium drip fertigation.

Treatment	30 DAS	60 DAS	90 DAS	At Harvest
RD N&K				
100% RD N&K	9.0	15.1	15.3	14.9
75% RD N&K	8.8	14.3	14.9	14.4
SE. m ±	0.1	0.1	0.1	0.1
CD (P=0.05)	NS	0.3	0.3	0.4
biofertigation				
MC_0	8.7	14.2	14.7	14.1
SMC	8.8	14.6	15.0	14.7
MC_3	8.9	14.9	15.2	14.8
MC_5	9.0	15.0	15.4	15.0
SE. m ±	0.1	0.1	0.1	0.2
CD (P=0.05)	NS	0.4	0.4	0.5
Interaction between RD N&K and Biofertigation				
SE. m ±	0.1	0.2	0.2	0.2
CD (P=0.05)	NS	NS	NS	NS

RD N&K 100% RD (240:80 kg N: K_2O ha^{-1}); 75%RD (180:60 kg N: K_2O ha^{-1}).
Biofertigation MC_0-Without Microbial Consortium (MC); SMC-Soil application of MC;
MC_3-Biofertigation of MC three times; MC_5-Biofertigation of MC five times.

Dry matter production (DMP, kg ha^{-1})

Dry matter of *Rabi* maize increased progressively with advance in age of crop up to harvest. DMP was significantly influenced by fertigation of RD N&K and biofertigation of MC. The interaction effect between RD N&K and biofertigation of MC was not significant at all growth stages *i.e.* 30, 60, 90 DAS and at harvest (Table 3)

There was no significant difference in DMP was recorded with fertigation of RD N&K and biofertigation of MC at 30 DAS. However, it ranged from 579.2 to 593.1 kg ha^{-1}.

Fertigation with 100% RD N&K recorded significantly higher dry matter at 60, 90 DAS and at harvest (8563, 17604 and 19081 kg ha^{-1}) compared to 75% RD N&K (7540, 16256 and 18145 kg ha^{-1}).

Increase in dry matter was observed due to increase in fertigation of RD N&K from 75 to 100% and it might be due to higher availability and uptake of nutrients and there was a significant and positive correlation between uptake of N, P and K and DMP which resulting in higher plant height, number of leaves and leaf area plant^{-1} and there was a significant and positive correlation between growth parameters *viz.*, plant height, number of leaves plant^{-1} at harvest and LAI at 90 DAS and DMP at harvest resulting in higher DMP with higher fertigation level and these results of increasing DMP with increasing fertigation levels are in agreement with the findings of Pal (2016) [15], Bibe *et al.*

(2017) [5], Patel *et al.* (2017) [16] and Ramdas (2018) [17] in maize.

Among biofertigation of MC, significantly higher DMP at 60, 90 DAS and at harvest was observed in biofertigation of MC five times (8567, 17555 and 19180 kg ha^{-1}) and three times (8389, 17347 and 18957 kg ha^{-1}) than the treatment in which MC was not applied (7693, 16481 and 17785 kg ha^{-1}) and was on par with soil application of MC (8165, 17194 and 18529 kg ha^{-1}). Significantly lower DMP was observed in treatment without application of MC at 60 DAS and at harvest and was on par with the soil application of MC at 90 DAS.

DMP, which reflects the total plant growth, increased with increase in plant height and LAI which might be due to rapid release of nutrients in soil through organic and inorganic resources by *Azatobacter,* PSB, KRB and Zn SB microorganism in microbial consortium. Besides these, they also releases biologically active substances such as auxins, cytokinins, amino acids and vitamis which coulb be attributed to increased root growth which in turn enhances the nutrient and water uptakes from soil and there was a significant and positive correlation between uptake of N, P and K and DMP which contributes to more buildup of DMP by plant These results *i.e.* increase in DMP through biofertigation are in agreement with the findings of Viana *et al.* (2014) [22] in maize, Janat *et al.* (2016) [10] in soybean and Bharathi *et al.* (2017) [4] in bhendi.

Table 3: Plant dry matter production (kg ha^{-1}) by *Rabi* maize as influenced by nitrogen, potassium and microbial consortium drip fertigation.

Treatment	30 DAS	60 DAS	90 DAS	At Harvest
RD N&K				
100% RD N&K	591	8563	17604	19081
75% RD N&K	582	7540	16256	18145
SE. m ±	4	185	244	166
CD (P=0.05)	NS	563.0	740	504
Biofertigation				
MC_0	584	7443	16124	17785
SMC	587	7807	16694	18529
MC_3	588	8388	17347	18957
MC_5	588	8566	17555	19180
SE. m ±	6	262	345	235
CD (P=0.05)	NS	796	1046	713
Interaction between RD N&K and biofertigation				
SE. m ±	8	371	488	332
CD (P=0.05)	NS	NS	NS	NS

RD N&K 100% RD (240:80 kg N: K_2O ha^{-1}); 75%RD (180:60 kg N: K_2O ha^{-1}).

Biofertigation MC_0-Without Microbial Consortium (MC); SMC-Soil application of MC;

MC_3-Biofertigation of MC three times; MC_5-Biofertigation of MC five times.

Yield Attributes

Grain yield (kg ha^{-1})

Significantly higher grain yield (7254 kg ha^{-1}) was recorded with fertigation of 100% RD N&K than that of 75% RD N&K (6951 kg ha^{-1}) (Table 4).

Among the biofertigation treatments, maximum grain yield (7304 kg ha^{-1}) was achieved with biofertigation of MC five times which was on par with the biofertigation of MC three times (7230 kg ha^{-1}), soil application of MC (7118 kg ha^{-1}) and was significantly superior to without MC (6758 kg ha^{-1}).

The higher grain yield in drip fartigation of RD N&K and biofertigation of MC might be due to combined effect of biofertilizer microbial consortium with conventional N&K fertilizers which increases the availability of nutrients and transport major nutrients like N, P and K and there was a significant and positive correlation between uptake of N, P and K and grain yield, besides secreating plant growth promoting substances such as Indole acetic acid, Gibberilins and Abscisic acid for maize which resulted in increase the plant height, number of leaves and leaf area in turn leaded to higher production and translocation of photosynthates and yield attributes like cob length (cm), cob girth (cm), number of rows cob^{-1}, cob weight (g), grain weight (g) and there was a significant and positive correlation between yield attributes *viz.*, cob length, cob girth, number of rows cob^{-1}, cob weight, grain weight and grain yield which resulted in increased grain yield due to higher production and translocation of photosynthates. The results were in similar trend with the results reported by Obid *et al.* (2016) [14] in maize, Bharathi *et al.* (2017) [4] in bhendi and Shravani (2018) [18] in greengram.

Stover yield (kg ha^{-1})

Significantly higher stover yield (9471 kg ha^{-1}) was recorded with 100% RD N&K over 75% RD N&K (8907 kg ha^{-1}). Stover yield recorded with biofertigation of MC five times (9496 kg ha^{-1}) and three times (9397 kg ha^{-1}) was significantly higher than that recorded without applivation of MC (8752 kg ha^{-1}) and was on par with soil application of MC (9111 kg ha^{-1}). The lower stover yield was recorded with without MC and was on par with soil application of MC.

The increase in stover yield might be due to combined effect of biofertilizer microbial consortium with conventional N&K fertilizers which increases the availability of nutrients and transport major nutrients like N, P and K and there was a significant and positive correlation between uptake of N, P and K and stover yield, besides secreting plant growth promoting substances which resulted in increase the plant height, number of leaves and leaf area in turn leaded to higher production and translocation of photosynthates and more dry matter production plant^{-1}. The results are in similar trend with the results of increase stover yield due to biofertigation of microbes as reported by Abdel Hamid *et al.* (2011) [1] through biofertigation, through seed inoculation in maize by Baral and Adhikari (2013) [3] and Meena *et al*. (2013) [12].

Table 4: Grain and stover yield (kg ha^{-1}) of *Rabi* maize as influenced by nitrogen, potassium and microbial consortium drip fertigation.

Treatment	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
RD N&K		
100% RD N&K	7254	9471
75% RD N&K	6951	8907
SE. m ±	73	119
CD (P=0.05)	222	362
Biofertigation		
MC_0	6758	8752
SMC	7118	9111
MC_3	7230	9397
MC_5	7304	9496
SE. m ±	103	169
CD (P=0.05)	314	511
Interaction between RD N&K and biofertigation		
SE. m ±	146	238
CD (P=0.05)	NS	NS

RD N&K 100% RD (240:80 kg N: K_2O ha^{-1}); 75%RD (180:60 kg N: K_2O ha^{-1}).

Biofertigation MC_0-Without Microbial Consortium (MC); SMC-Soil application of MC;

MC_3-Biofertigation of MC three times; MC_5-Biofertigation of MC five times.

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