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Effect of Biofertigation and Chemical Fertilizers on Yield Attributes and Yield of *Rabi* Maize (*Zea mays* L.)

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Abstract

A field experiment was conducted on maize (*Zea mays* L.) during *rabi* (November - February), 2018–19 to study the effect of drip fertigation of Nitrogen (N), Potassium(K) and microbial consortium (MC) at Water Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad. The experiment was laid out in randomized block design and replicated thrice. The treatments, comprising of two fertility levels viz., 75% and 100% recommended dose (RD) of N&K as first factor and biofertigation of MC as second factor. The interaction effect between RD of N, K and biofertigation of MC was not significant. Significantly higher cob length, cob girth, number of rows cob^{-1}, cob weight, number of grains cob^{-1} and grain weight cob^{-1} were recorded with fertigation of 100% RD of N&Kcompared to 75% RD of N&K and five MC biofertigation recorded significantly higher cob length, cob girth, number of rows cob^{-1}, cob weight , number of grains cob^{-1} and grain weight cob^{-1} than that of treatment without application of MC and was on par with biofertigation of MC three times. Maize grain and stover yield recorded with 100% RD of N&K were significantly higher compared to 75% RD of N&K. Biofertigation of MC five times and three times were on par and recorded significantly higher grain and stover yield compared to treatment without application of MC. Significantly lower grain and stover yield were observed under treatment without application of MC

Keywords: Biofertilizers, biofertigation, fertigation, maize, yield and microbial consortium, yield attributes

1. Introduction

Maize is the third most important food crop next to rice and wheat. Maize plays a vital role in ensuring food security as well as nutritional security through quality protein (Manan et al., 2013). In India it is cultivated in an area of 9.8 M ha with an average production of 30.2 M t and productivity of 3057 kg ha^{-1} (Anonymous, 2020). Adoption of drip system can improve the water use efficiency and water saving of more than 50% (Rai et al., 2011). Drip irrigation can save water as well as increase the crop production to the extent of 20 to 100% (Reddi and Reddy, 2017). In drip fertigation, nutrient use efficiency could be as high as 90% compared to 40 to 60% in conventional methods (Solaimalai et al., 2005). Fertigation of nutrients significantly increased saving of fertilizer nutrients up to 40% without affecting the yield of crops (Sathya et al., 2008).

According to Tiwari (2002) there is a need for integrating application for alternate sources of nutrient for sustaining the crop productivity. The application of organic source of nutrients, make soil micro flora and fauna more active that result in an increase of the biomass carbon (Kumar et al., 2017). Present microbial inoculant technology ensures 25% reduction of chemical N and P fertilizers in India. Biofertilizers include mainly the nitrogen fixing, phosphate solubilizing and plant growth promoting microorganisms. According to Tiwari et al. (1993), among the inoculants, *Azospirillum*, *Bacillus megaterium* and *Pseudomonas fluorescens* are the potential candidates used in India.Application of *Azotobacter*+PSB+KSB+ZnSB+75% NPK & Zn exhibited highest grain yield and straw yield of oat grain production (Jena et al., 2017). Kumar et al. (2015) revealed that farm yard manure incorporated along with green manure and biofertilizers substantially improved the yield of rice and wheat system. Kalhapure et al. (2013) concluded that application of 25% RDF in combination with biofertilizers to maize seed as seed treatment, green manuring with sunhemp and incorporation of compost increased the maize grain yield by 252.4%. Combined application of biofertilizers along with 100% RDF of NPK and enriched compost has resulted in higher grain yield of maize compared to application of biofertilizers alone (Umesha et al., 2014). Maize seeds treated with PSB before sowing produced higher grain yield than untreated seeds (Khalid and Amanullah, 2016).Preetham et al. (2020) reported that higher yield attributes, cob yield and stover yield of baby corn were achieved under application of 25% N through vermicompost in conjunction with 75% RDF and bio-fertilizers.

The biofertigation i.e., application of liquid biofertilizers or microbial consortium along with drip irrigation can precisely deliver the bioinoculants in the root zone and maintain a proper moisture content for their survival and action. Abdelhamid et al. (2011) stated that use of 50% RDF along with humic substance and bio-fertigation of liquid formulation of N-fixers and P-solubulizers has recorded higher seed and straw yield of cowpea over control (100% RDF). Drip fertigation of 150% RDF along with biofertilizers recorded higher seed yield of cotton over soil application of 100% RDF alone (Jayakumar, 2014). Shravani (2018) revealed significantly higher yield and yield attributes of green gram were recorded with application of liquid based biofertilizers (LBBF) over control i.e., only biofertilizers. Keeping in view of the above, the present study was planned to evaluate the performance of biofertigation under field condition along with fertigation of inorganic fertilizers on *rabi* maize.

2. Materials and Methods

2.1. Study site

A field experiment was conducted at Water Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, Telengana state, India during *rabi* (November - February), 2018–19 maize (*Zea mays* L.). The farm is geographically situated at 17032°37' N Latitude, 78040°88' E Longitude and altitude of 534 m above mean sea level. The experimental soil was loamy in texture, moderate in infiltration rate, slightly alkaline and non-saline in reaction. The fertility status of the experimental soil was low in organic carbon, low in available N, medium in phosphorus, high in available potassium contents and sufficient in available Zn status.

2. 2. Details of experiment

The treatments, comprising of two fertility levels *viz.,* 75% and 100% recommended dose (RD) of nitrogen and potassium (N&K) as first factor and biofertigation of Microbial consortium (MC) *viz*., soil application of MC (SMC), biofertigation of MC three times (MC_3), biofertigation of MC five times (MC_5) and without application of MC (MC_0) as second factor. 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 80×15 cm^2. N & K was applied in different doses (75% & 100% RDF) through fertigation with 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 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 chrococcum* (Non symbiotic heterotrophic N_2 fixing bacterium), P solubilizing bacteria (*Pseudomonas flourescens*), K releasing bacteria (*Bacillus mucilaginaceous*) and Zn solubilizing bacteria (*Bacillus edapicus*). 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 vermicompost for one hectare and applied along the plant rows.

2. 3. Method of data collection

2. 3. 1. Yield attributes

Cobs from five randomly selected maize plants in each net plot were taken for data collection *i.e.,* cob length and girth (cm), number of rows cob^{-1}, cob weight plant^{-1} (g), number of grains cob^{-1}, grain weight cob^{-1}(g), shelling percentage and test weight (g) were measured and the mean value was computed.

2. 3. 2. Grain and straw yield (kg ha^{-1})

The grain yield was recorded at 14 % moisture from net plot area including the yield obtained from selected five plants and expressed as kg ha^{-1}. The straw harvested from the net plot area including the straw yield from selected five plants was thoroughly sun dried and weight was presented as kg ha^{-1}

2. 3. 3. Harvest index (%)

Harvest index is defined as the ratio of economic yield to the biological yield and expressed in percentage. It was calculated by using the formula suggested by Donald (1962) given below;

Harvest index (%) = (Grain yield (kg ha^{-1}) / Biological yield (kg ha^{-1})) X 100………. (1)

2. 4. Statistical design and analysis

The experiment was laid out in randomized block design with maize hybrid DHM-117 and replicated thrice. 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.

3. Results and Discussion

The data collected on yield attributes was presented in Table 1. and the perusal of data indicated that there was significant difference due to drip fertigation of 75% or 100% RD N&K and due to biofertigation of MC and the interaction effect between RD N&K and biofertigation of MC on yield attributes was not significant.

3.1. Yield attributes

3.1.1. Number of cobs plant^{-1}

Number of cobs plant^{-1} was not significantly influenced either with drip fertigation of RD N&K or biofertigation of MC (Table 1).

3.1.2. Cob length (cm)

The results on cob length (cm) indicated that significantly higher mean cob length (18.0 cm) was recorded with drip fertigation of 100% RD N&K than 75% RD N&K (16.9 cm). Maximum mean cob length (17.9 cm) was recorded with biofertigation of MC five times which was significantly superior to the treatment without MC (17.0 cm) and was on par with the biofertigation of MC three times (17.5 cm) and soil application of MC (17.3 cm). However, cob length observed in treatment where MC was not applied and was on par with the application of MC through biofertigation three times and soil application (Table 1).

The increase in mean cob length may be due to positive effect of inorganic and biofertilizers (*Azotobacter*, PSB, KRB and ZnSB) on better root development which resulted in increase in nitrogen, phosphorus, potassium and other nutrient availability besides producing vitamins and plant growth promoting substances for better plant growth. These results obtained i.e. increase in cob length with increased fertigation level and use of biofertilizers are in accordance with Khalid and Amanullah (2016) through seed treatment (PSB) in maize and Mishra et al. (2010) through seed treatment in dwarf field pea and Preetham et al. (2020) in baby corn through seed treatment.

3.1.3. Cob girth (cm)

Drip fertigation with 100% RD N&K (240:80 kg N: K_2O ha^{-1}) recorded significantly higher cob girth (4.84 cm) over 75% RD N&K (4.65 cm).There was no significant difference in cob girth between biofertigation of MC five times and three times (4.80 and 4.78 cm) which were on par with soil application of MC (4.72 cm) and significantly superior to treatment without MC (4.66 cm). Inturn, there was no significant difference in cob girth between soil application of MC and without application of MC (Table 1).

The increase in cob girth with biofertigation was due to positive effect of inorganic and biofertilizers (*Azotobacter*,

Table 1: influence on Yield attributes of *rabi* maize

Treatment	Cob length (cm)	Cob girth (cm)	Rows cob^{-1} (No.)	Cob weight plant^{-1} (g)	Grains cob^{-1} (No.)	Grain weight cob^{-1} (g)	Test weight (100 grain) (g)	Shell-ing (%)	Harvest index (%)
RD N&K									
100% RD N&K	18.0	4.84	14.9	240.3	479	149.8	31.15	62.4	38.0
75% RD N&K	16.9	4.65	14.5	230.1	449	137.2	30.91	59.6	38.4
SEm±	0.1	0.02	0.1	1.3	5	2.2	0.08	1.1	0.3
CD (*p*=0.05)	0.4	0.06	0.2	3.9	17	6.8	NS	NS	NS
Biofertigation									
MC_0	17.0	4.66	14.3	226.3	442	134.5	30.93	59.4	38.0
SMC	17.3	4.72	14.6	233.5	458	141.2	31.00	60.5	38.4
MC_3	17.5	4.78	14.8	238.8	474	147.5	31.05	61.7	38.2
MC_5	17.9	4.80	15.0	242.2	482	151.0	31.14	62.4	38.1
SEm±	0.2	0.03	0.1	1.8	8	3.2	0.11	1.6	0.4
CD (*p*=0.05)	0.6	0.08	0.3	5.5	25	9.7	NS	NS	NS
Interaction between RD N&K and biofertigation									
SEm±	0.2	0.03	0.1	1.84	8	3.2	0.16	1.6	0.6
CD (*p*=0.05)	NS	NS	NS	NS	NS	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

PSB, KRB and ZnSB) on better root development which resulted in increase in nitrogen, phosphorus, potassium and other nutrient availability in soil and their uptakes besides producing vitamins and plant growth promoting substances for better of plant growth in terms of increased plant height, leaf number plant^{-1} and LAI which resulted in higher photosynthesis and translocation of photosynthates. Similar results of increased cob girth with increased fertigation level and use of biofertilizers were observed by Preetham et al. (2020) in baby corn through seed treatment.

3.1.4. Number of rows cob^{-1}

Higher number of rows cob^{-1} of 14.9 was observed with fertigation of 100% RD N&K and was significantly superior over 75% RD N&K (14.5). There was no significant difference in number of rows cob^{-1} between biofertigation of MC five times (15.0) and three times (14.8) and both were significantly superior to soil application of MC (14.6) and without application of MC (14.3). Biofertigation of MC three times and soil application of MC was on par with other. However number of rows cob^{-1} observed with soil application of MC was on par with the treatment where no MC was applied (Table 1).

Similar results of higher row number were found by Naseri et al. (2013) in maize.

3.1.5. Cob weight plant^{-1}

Significantly superior cob weight plant^{-1} (240.3 g) was recorded with fertigation of 100% RD N&K (240:80 kg N:K_2O ha^{-1}) compared to 75% RD N&K (230.1 g). Biofertigation of MC five times recorded maximum cob weight plant^{-1} (242.2 g) which was on par with the biofertigation of MC three times (238.8 g) and was significantly superior to soil application of MC (233.50 g) and without application of MC (226.3 g). However biofertigation of MC three times was on par with soil application of MC (Table 1).

The increased nutrient uptake due to fertigation of RD N&K and biofertigation of MC resulted more photosynthetic area, photosynthesis and translocation of photosynthates increased the cob length, cob girth and number of rows cob^{-1}, this contributed to the increasing the cob weight plant^{-1}. The similar results of increased cob weight due to increase in fertilizer level and use of biofertilizers were found by Naveen et al. (2008), , Umesha et al. (2014) in maize and Preetham et al. (2020) in baby corn.

3.1.6. Grain number cob^{-1}

Drip fertigation with 100% RD N&K (240:80 kg N:K_2O ha^{-1}) recorded significantly higher number of grains cob^{-1} (479) than that of 75% RD N&K (449). Maximum number of grains cob^{-1} (482) was observed with biofertigation of MC five times which was on par with the biofertigation of MC three times (474) and soil application of MC (458) and significantly superior over without MC (442). The treatment without MC recorded significantly lower grain number cob^{-1} than biofertigation of MC five and three times and was on par with the soil application of MC (Table 1).

Increased LAI facilitated more synthesis and translocation of photosynthates to sink due to more uptake of nutrients besides producing vitamins and plant growth promoting substances which increased the cob length, cob girth and number of rows cob^{-1}, this contributed to the increasing the number of grains cob^{-1}. These results i.e.increase in grain number with increase in fertigation level and use of biofertilizers are in accordance with the results of Gholami et al. (2009) and Khalid and Amanullah (2016) in maize.

3.1.7. Grain weight cob^{-1}

Drip fertigation of 100% RD N&K (240:80 kg N:K_2O ha^{-1}) recorded higher grain weight cob^{-1} (149.9 g) and was significantly superior to 75% RD N&K (137.2 g). Among biofertigation, significantly maximum grain weight cob^{-1} (151.0 g) was recorded with biofertigation of MC five times compared to soil application of MC (141.2 g) and without application of MC (134.5 g) and was on par with biofertigation of MC three times (147.5 g). There was no significant difference between soil application of MC and biofertigation of MC three times. Significantly lower grain weight cob^{-1} was recorded without application of MC than biofertigation of MC five and three times and was on par with the soil application of MC (Table 1.).

This might be due to positive effect of inorganic fertilizers (N&K) and biofertilizers (*Azotobacter*, PSB, KRB and ZnSB) on better root development which resulted in increase in nitrogen, phosphorus, potassium and other nutrient availability and their uptakes which resulted in higher plant height, increased LAI there by synthesis and translocation of photosynthates to sink besides producing vitamins and plant growth promoting substances which increased the cob length, cob girth and number of rows cob^{-1}, this contributed to the increasing the number of grains cob^{-1} and finally the grain weight cob^{-1}. These results i.e. increase in grain weight with increasing fertigation level and biofertilizers are in accordance with the results of Preetham et al. (2020) in baby cornand Umesha et al. (2014) in maize.

3.1.8. Shelling percentage

Shelling percentage was not significantly influenced by fertigation with RD N&K and biofertigation of MC, however it was ranged from 58.3 to 62.4 % (Table 1).

3.1.9. Test weight (100 grain)

There was no significant difference on test weight of maize grains was recorded with fertigation of RD N&K and biofertigation of MC. However, the test weight was ranged from 29.70 to 31.35 g (Table 1).

3.2. Yield (kg ha^{-1})

The grain and stover yield of *rabi* maize was significantly influenced by fertigation with RD N&K and biofertigation of MC and there was no significant influence by their interaction (Table 2).

Table 2: Effect of treatments on grain and stover (kg ha^{-1}) of *rabi* maize

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
SEm±	73	119
CD (*p*=0.05)	222	362
MC_0	6758	8752
SMC	7118	9111
MC_3	7230	9397
MC_5	7304	9496
SEm±	103	169
CD (*p*=0.05)	314	511
Interaction between RD N&K and biofertigation		
SEm±	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

3.2.1. 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}).

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 over the treatment without application of MC (6758 kg ha^{-1}).

The higher grain yield in drip fertigation 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 of major nutrients like N, P and K besides secreting plant growth promoting substances such as Indole acetic acid, gibberilins and abscisic acid for maize which resulted in increase in plant height, number of leaves and leaf area which in turn lead 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). The results were in similar trend with the results reported by Preetham et al. (2020) in baby corn and Shravani (2018) in greengram.

3.2.2. 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 application 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 treatment without application of 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, besides secreting plant growth promoting substances which resulted in increase the plant height, number of leaves and leaf area which in turn lead 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 of stover yield due to biofertigation of microbes as reported by Abdelhamid et al. (2011) through biofertigationand through seed inoculation in baby corn by Preetham et al. (2020

3.2.3. Harvest index (%)

The RD N&K levels and biofertigation of MC and their interactions did not record any significant influence on harvest index. However higher harvest index of 38.4% was recorded with 100% RD N&K and biofertigation of MC five times (38.1%) (Table 1).

4. Conclusion

Among different treatment combination, application of 75% RD N&K with biofertigation of MC either three times or five times recorded significant higher yield attributes and yield over 100% RD N&K and soil application of biofertilizers. Use of liquid biofertilizers helped in reducing recommended doses of chemical fertilizers without compromising the yield and also achieves sustainable soil health in long run.

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