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PERFORMANCE OF PLANT GROWTH REGULATORS AND MICRONUTRIENT ON GROWTH AND YIELD OF MAIZE (*Zea mays* L.)

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Abstract–A field experiment was conducted during *kharif* 2020 at Crop Research Farm, SHUATS, Prayagraj (U.P) to study the performance of plant growth regulators and micronutrient on growth and yield of Maize (*Zea mays* L.). The experiment was laid out in Randomized Block Design with eight treatments each replicated thrice. It was observed that T_3 Superzyme 900 ml/ha foliar spray at 30 and 60 DAS was found to be the best treatment for obtaining growth and yield attributes such as plant height (196.20 cm), dry matter accumulation (573.07 g/m^2), Crop growth rate (2.42 g/m^2/day), cob length (18.77cm), cob girth (14.47 cm), No. cobs per plant (1.53), No. grains per cob (331.53), No. of grains per row (29.80), No. of rows per cob (11.36), seed index (29.00 g), grain yield (5.23 t/ha) while net returns (110770.78 INR/ha) and B:C ratio (2.40) were also recorded in application of Superzyme 900 ml/ha foliar spray at 30 and 60 DAS. From the above experiment, it was concluded that application of Superzyme 900 ml/ha foliar spray at 30 and 60 DAS was found to be more productive as well as economic.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crop after rice and wheat and occupies a prominent place in global agriculture. Maize is also called as corn, is one of the most crucial and strategic crops in the world. Its origin is in Mexico (Central America). It is called as "queen of cereals" because it has the highest genetic yield potential among cereals. The nutritional composition of maize (per 100g) is as follows protein 4g, 30g carbohydrate, 3.5g dietary fibre, 1.5g fat, 3.6g sugars, 4 mg calcium, 0.72 mg zinc etc. It efficiently utilizes solar energy and has immense potential for higher yield so called as miracle crop. It has the highest production potential among cereals. In India, maize is grown in 9.22 M ha area with a production and productivity of 28.72 million tonnes and 3,115 kg/ha respectively contributing 2.53% share over world's production (Directorate of Economics and Statistics, DAC&FW 2018). It occupies an important position in world economy and trade as a food, feed and industrial grain crop. However, lower maize harvest index has become an issue in means of meeting the food need of public and diversification of area under monoculture of maize. Hence, yield enhancing cultivation methods like usage of several Plant Growth Regulators (PGRs) need due attention. PGRs are being used intensively in agriculture. However, they have limited impact and application toward few yield and quality parameters (Pandey *et al*., 2001). Among various PGRs mepiquat chloride (MC) is water soluble plant growth regulators and when sprayed on the plant it acts systematically after its absorption by plant leaves. It acts as gibberellic acid inhibitor and inhibits cell elongation thereby reducing the longitudinal growth of the plant. Application of PGRs in the form of foliar spray at pre flowering stage helps in improving physiological efficiency along with crop productivity (Dashora and jain 1994). Micronutrients are trace elements which are barely needed by maize crop in small amounts and plays an active role in the plant metabolic functions in shortage of which show deficiency symptoms and crop yields are reduced. The application of

micronutrient fertilizer at basal dose may not reach the crop requirement for root growth and nutrient use. Foliar application is effective for micronutrient as 90% fertilizer utilized by plant when applied in foliar form (Manasa and Devaranavadagi, 2015). Therefore, In view of the above, the present investigation was undertaken with an aim to find out performances of plant growth regulators and micronutrient to maximize the growth and yield of Maize.

MATERIALS AND METHODS

This experiment was carried out during *Kharif* 2020 at Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology and Sciences (SHUATS), Prayagraj, (U.P.) which is located in at 25.28°N latitude, 81.54°E longitude (7.2), organic carbon (0.22%), available nitrogen (219 kg/ha), phosphorus (12.3 kg/ha) and potassium (235.7 kg/ha). The climate of the region is semi-arid subtropical.

Experimental design and treatment combinations

The experiment was laid out in Randomized Block Design. The treatments consists of six plant growth regulators (Superzyme gold, root master, superzyme, Boost, Americana, Sea bomb) and one micronutrient (Microl-F), where three treatments are applied as soil application (Superzyme gold, Root master, Americana) and four treatments were applied as a foliar spray at 30 and 60 DAS interval (superzyme, Boost, Sea bomb, Microl- F) and one respective control was used. The treatments comprised T1- Superzyme gold- 12.5 kg/ha- it is combination of gibberellic acid and seaweed extracts. Chemical composition- (liquid seaweed extracts- 4.0% + calcinite bentonite granules- to make 100%). Mode of action: Activate key metabolic activities i.e photosynthesis, restoration and pollination resulting in increased vegetative and reproductive growth. Benefits: Builds comparatively better robust root system and leads to improve effective translocation of nutrients. T2- Rootmaster 13 kg/ha- it is mycorrhizal biofertilizer Mode of Action: Containing beneficial fungi Mycorrhiza which helps root growth of crops. Method of: Rootmaster can be used at the time of sowing of Application seeds or mixing with seeds. Benefits: It helps overall root and plant growth. It also helps to improves plants health by developing roots and health of crops. T_3- Superzyme-900 ml/ha- Chemical composition: Gibberellic acid- 0.001% + protein hydrolysed- 2.5% + seaweeds – 3.0%+ $FeSo_4.7H_2O$-2.3% + $MnSo_4.3H_2O$- 1.4% + $ZnSo_4.7H_2O$- 3.9%+ $MgSo_4.7H_2O$-4.3% + emulsifier- 1.0%, Water- 81.59%. Mode of Action: Superzyme acts by deactivating repressors, resulting in increase in cell elongation. Method of: Use superzyme at recommended dose in Application 450-500 lite water and sprayed the crop at flowering stage and second spray at 30-40 days after first spraying. Benefits: Increases yield, quality, Resistance to pests. T4- Boost- 600 ml/ha Combination of ATCA (N-Acetyl Thiazolidine Carboxylic Acid) and folic acid.

Mode of Action: Nutracitical plant growth regulator. Method of: Use Boost at 75ml -100ml in 250 litre water Application and sprayed the crop at flowering and fruit setting stage of crops. Benefits: Effective Bio stimulant Nutrient Solution. T5- Americana-7.5 kg/ha -it is composition of Sea weed extracts, enzymes and organic matter. Mode of Action: Robust root development, better movement of nutrient from soil, increase in metabolic activities, vegetative & reproductive phase booster. Yield parameter significantly enhances, leading to better economic growth. Method of: Americana can be used in soil at the time of Application seed sowing mixing with fertilizers or broadcast at soil at first or second irrigation. Benefits: Especially designed for yield booster for all agronomic and horticultural crops. It is significantly superior and unique over others. T6- Seabomb-500ml/ha-plant growth stimulant. Mode of Action: Accelerate the plant growth and development. Method of: Can be used for foliar spray. Can be mixed Application with fertilizer for broadcasting. Seeds can be soaked in solution for increasing the quality of produce. Benefits: It induces physiological process such as photosynthesis and nutrient & carbohydrate translocation. As a result of these changes, flowering and yield is increased and the quality of the produce is improved. T7- Microl-F- 300 ml/ha- mixed micronutrients- chemical composition- Fe – 2.0%, Mn – 0.5%, Zn – 4.0%, Cu – 0.5%. T_8- Control (RDF-120:80:60 NPK kg/ha). There are eight treatments replicated thrice during *kharif* season 2020.

Crop management

Maize variety (Shivani KSMH-1980) sown at the rate of 20 kg/ha. This variety is resistant to drought. Seed of this variety are golden yellow in colour and are resistant to insects and pests. It is 90-110 days

duration crop. It is non- lodging with high yielding potential. The recommended dose of fertilizer 120:80:60 NPK kg/ha. The nutrient sources were Urea, DAP, MoP to fulfill the requirement of nitrogen, phosphorus and potassium. Two irrigations were given first at post sowing, second irrigation before grain filling stage. One hand weeding was done manually with *khurpi* at 20 DAS followed by second manual weeding was done at 40 DAS. This was done at grass as well as broad leaf weeds.

Statistical Analysis

The data recorded were different characteristics were subjected to statistical analysis by adopting Fishers the method of Analysis of Variance (ANOVA) as described by Gomez and Gomez (2010). Critical Difference (CD) values were calculated the F test was found significant at 5% level.

Plant Sampling

Growth attributes

The height of the plants was measured from the base of the plant up to the last leaf. Five randomly selected plants were recorded at 20, 40, 60 and 80 Days after Sowing from each plot.

Dry matter of plants were recorded without root at intervals of 20, 40, 60 and 80 DAS by uprooting of plants from border row of each plot.

Yield attributes

After harvest, cobs are selected randomly according to treatment wise from harvested plants then cob length, cob girth, no. of cobs/plant, no. of grains/cob, no. of grains/row, seed index (g) were recorded randomly from five tagged plants and their averages were recorded. Cobs from harvest area (1.0 m^2) were dried in sun and grains were removed after that they are weighed separately from each plot for calculating grain yield. For stover yield, plants from harvest area (1.0 m^2) were dried in sun after that they are weighed separately from each plot.

RESULTS AND DISCUSSION

Performance of plant growth regulators and micronutrient on Plant height (cm) of Maize

Observations regarding the plant height of maize are given in the Table 1. There was an increasing in crop age plant height which was progressively

Table 1. Performance of plant growth regulators and micronutrient on Growth attributes of Maize at different day intervals

Treatments	Plant height (cm)				Dry matter accumulation (g/m^2)				Crop Growth Rate (g/m^2/day)		
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	20-40 DAS	40-60 DAS	60-80 DAS
Superzyme gold- 12.5 kg/ha	18.47	82.40	165.26	167.33	61.87	345.60	547.20	564.80	14.19	10.08	1.96
Root master- 13 kg/ha	15.90	82.01	179.46	181.47	69.07	333.07	531.47	547.20	13.20	9.92	1.02
Superzyme- 900 ml/ha	19.33	86.40	181.73	196.20	60.27	339.20	541.87	573.07	13.95	10.13	2.42
Boost-600 ml/ha	18.13	84.30	187.83	190.60	70.93	341.33	505.60	522.40	13.52	8.21	2.34
Americana- 7.5 kg/ha	18.00	82.80	173.53	180.73	73.60	349.87	523.47	539.20	13.81	8.68	1.29
Sea bomb- 500 ml/ha	17.40	85.73	192.00	194.13	77.07	324.27	544.80	571.47	12.36	11.03	1.41
Microl- F- 300 ml/ha	17.33	82.80	188.66	190.53	73.33	318.93	518.67	533.87	12.28	9.99	1.01
Control (RDF-120:80:60 NPK kg/ha)	17.13	81.73	169.13	171.40	63.73	316.80	533.87	545.33	12.65	10.85	1.40
SEm (±)	0.56	0.98	5.72	4.54	8.76	17.52	14.67	10.81	0.91	1.29	0.32
CD (P=0.05)	1.71	2.98	17.35	13.78	NS	NS	NS	32.81	NS	NS	0.98

Note- Blanket application of RDF (120:80:60 NPK kg/ha)

increased with the advancement of crop during the experimentation. The analysis on plant height was found to be significantly higher in all the different growth intervals with the application of plant growth regulators and micronutrient. At harvest, highest and significant plant height (196.20 cm) was recorded with application of superzyme 900 ml/ha which was significantly superior over all other treatments except Sea bomb- 500 ml/ha (194.13 cm), boost-600 ml/ha (190.60 cm) and Microl-F -300 ml/ha (190.53 cm) was found to be statistically at par with Superzyme-900 ml/ha. (Narendra *et al.* 2018) explained that application of different doses of gibberellic acid leads to an increase of plant height as compared to control in both seasons i.e. *kharif* and *rabi*. The increase in plant height is due to plant hormones promoted vegetative growth by active cell division, cell enlargement and cell elongation and thus helped in improving growth characteristics and also facilitated reproductive growth. The results demonstrated that foliar application of magnesium sulphate ($MgSO4.7H_2O$) had significant superior effect on plant height (El-Dissoky *et al.* 2017), similar results was reported by (Altarugio *et al*. 2017) (Basavaraja *et al.* 2018) explained that foliar application of *Kappaphycus alvarezii* (K sap) and *Gracilaria edulis* (G sap) leads to an increase in plant height of maize. Similar results were obtained by Islam *et al.* 2014.

Performance of plant growth regulators and micronutrient on Dry matter accumulation (g/m²) of Maize

Observations regarding the dry matter accumulation (g/m²) of maize are given in the Table 1 and data showed an increasing tendency from 20 DAS to at harvest. At harvest, maximum dry matter accumulation (573.07 g/m²) was recorded with application of superzyme 900 ml/ha which was significantly superior over all other treatments except with application of sea bomb-500 ml/ha (571.47 g/m²), superzyme gold- 12.5 kg/ha (564.80 g/m²), Root master- 13 kg/ha (547.20 g/m²) and control-RDF- 120:80:60 NPK kg/ha- (545.33 g/m²) which are statistically at par with Superzyme - 900 ml/ha. Maize dry matter accumulation significantly increased by increasing concentration of *Kappaphycus alvarezii* (K- sap) and *Gracilaria edulis* (G-sap) extract (Singh *et al.* 2015). Application of Zinc by foliar spray significantly increases the dry matter accumulation as compared to control treatments. It might due to application of Zn which

Table 2. Performance of plant growth regulators and micronutrient on yield attributes, yield and Economics of Maize:

Treatments	Cob length (cm)	Cob girth (cm)	Cobs/ plant (No.)	Grains/ cob (No.)	Grains/ row (No.)	Rows/ cob (No.)	Seed index (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Net returns (INR/ha)	B:C ratio
Superzyme gold-12.5 kg/ha	17.70	13.83	1.13	270.60	28.83	9.38	25.67	3.96	13.67	22.54	71520.78	1.51
Root master- 13 kg/ha	15.50	13.43	1.20	255.80	26.67	9.61	23.67	4.08	13.33	23.51	76320.78	1.66
Superzyme – 900 ml/ha	18.77	14.47	1.53	331.53	29.80	11.36	29.00	5.23	15.33	29.70	110770.78	2.40
Boost- 600 ml/ha	16.07	13.30	1.13	251.13	26.20	9.58	25.00	4.58	12.67	26.28	90955.78	1.96
Americana- 7.5 kg/ha	17.07	14.37	1.13	295.93	29.13	9.93	27.67	4.98	12.33	28.88	103495.78	2.25
Sea bomb- 500 ml/ha	16.87	13.83	1.20	245.33	28.47	8.59	28.00	4.73	12.00	29.43	96295.78	2.11
Microl-F-300 ml/ha	15.17	13.67	1.53	255.33	27.13	9.39	28.33	4.84	13.33	27.53	98440.78	2.11
Control-(RDF-120:80:60 NPK kg/ha)	15.47	13.30	1.00	242.00	25.53	9.21	24.33	3.70	11.67	23.89	66220.78	1.48
SEm (±)	0.96	0.94	0.07	15.17	1.47	0.45	1.19	0.31	0.86	1.66	-	-
CD (P=0.05)	2.84	2.81	0.33	46.04	4.41	1.44	3.54	0.96	2.62	5.05	-	-

Note- Blanket application of RDF- 120:80:60 NPK kg/ha

induces systemic and positive response on shoot and root growth. The results are in good agreement with findings of Zhang *et al.* (2013).

Performance of plant growth regulators and micronutrient on Crop Growth Rate (g/m^2/day) of Maize

Observations regarding the Crop Growth Rate (g/m^2/day) of Maize are given in the Table 1 and data showed an increasing tendency from 20-40 and 40-60 DAS and thereafter, it was decreased. At 60-80 DAS, maximum crop growth rate (2.42 g/m^2/day) was recorded in superzyme 900 ml/ha which is significantly superior over all other treatments except with the application of Boost 600 ml/ha (2.34 g/m^2/day) and superzyme gold (1.96 g/m^2/day) which are statistically at par with Superzyme 900ml/ha. Crop growth rate was gradually increased from 20-40 DAS and thereafter decreased in advanced growth stages. The highest CGR was registered for application of gibberelic acid at stage when 4-6 leaves had emerged. By the application of plant growth regulators it has increased the power of source and thus increased the transport of assimilates to the sink including roots and young leaves. The results are in good agreement with findings of Ghodrat *et al*. (2013).

Performance of plant growth regulators and micronutrients on Yield attributes and yield of Maize

The data presented on yield attributes and yield of Maize were statistically analyzed and have been presented in Table 2. The maximum length of cob (18.77cm) was recorded with application of Superzyme 900 ml/ha which was significantly superior over all other treatments except with application of superzyme gold- 12.5 kg/ha (17.70cm), Americana 7.5 kg/ha (17.07cm), sea bomb 500 ml/ha (16.87cm) and boost 600 ml/ha (16.07cm) which was statistically at par with superzyme 900 ml/ha. Maximum cob girth (14.47cm) was recorded with application of Superzyme 900 ml/ha which was statistically significantly over all other treatments. Maximum number of cobs per plant (1.53) was recorded with application of superzyme 900 ml/ha and Microl-F 300 ml/ha which was significantly superior over all other treatments except with the application of root master 13 kg/ha (1.20) and sea bomb 500 ml/ha (1.20) which were statistically at par with superzyme 900 ml/ha. Maximum number of grains per cob (331.53) was recorded with application of Superzyme 900 ml/ha which was significantly superior over all other treatments except with application of Americana 7.5 kg/ha (295.93) which was statistically at par with superzyme 900 ml/ha. Maximum no. of grains per row (29.80) was recorded with application of Superzyme 900 ml/ha which was statistically significant over all other treatments. Maximum number of rows per cob (11.36) was recorded with application of Superzyme 900 ml/ha which was significantly superior over all other treatments except with application of Americana 7.5 kg/ha (9.93) which was statistically at par with superzyme 900 ml/ha. Maximum seed index (29.00g) was recorded with application of Superzyme 900 ml/ha which was significantly superior over all other treatments except with application of Microl-F 300 ml/ha (28.33 g), Sea bomb 500 ml/ha (28.00 g), Americana 7.5 kg/ha (27.67 g) and superzyme gold 12.5 kg/ha (25.67 g) which were statistically at par with superyme 900 ml/ha. Maximum grain yield (5.23 t/ha) was recorded with application of Superzyme 900 ml/ha which was significantly superior over all other treatments except with application of Americana 7.5 kg/ha (4.98 t/ha), microl- F 300 ml/ha (4.84 t/ha), sea bomb 500 ml/ha (4.73 t/ha) and boost (4.58 t/ha) which were statistically at par with superzyme 900 ml/ha. It might be due to application of $ZnSo_4$ and $MgSo_4$ nevertheless significantly increased grain yield, as zinc plays major role in pollination process which leads to increase the yield of crop. Magnesium and zinc interaction shows synergetic effect on maize grain production (Abunyewa and Mercer 2004.).

Maximum stover yield (15.33 t/ha) was recorded with application of superzyme 900 ml/ha which was significantly superior over all other treatments except with application of superzyme gold 12.5 kg/ha (13.67 t/ha), root master 13 kg/ha (13.33 t/ha) and Microl- F 300 ml/ha (13.33 t/ha) which were statistically at par with superzyme 900 ml/ha. Maximum harvest index (29.70 %) was recorded with application of Superzyme 900 ml/ha which was significantly superior over all other treatments except with application of Sea bomb 500 ml/ha (29.43 %), Americana 7.5 kg/ha (28.88 %), Microl- F 300 ml/ha (27.51 %) and boost 600 ml/ha (26.28 %) which were statistically at par with superzyme 900 ml/ha. The results demonstate that application of Magnesium sulphate by foliar spray has positive response on maize which has significantly superior effect on 100 grain weight, grain yield, stover yield

as application of Mg rates as a magnesium sulphate had a significant effect on the uptake of N, P, K, Ca, Mg, Zn, Fe and Mn by grain. With increasing yield, more Fe would be needed, not only during vegetative stages, but also reproductive stages for maximum yields. Mn should be applied before silking stage. These results are in accordance with earlier findings of (El-Dissoky *et al.* 2017) and (Xue *et al*. 2014) Zinc combined with iron significantly increased maize grain yield, as these are effective for enhancing growth, grain yield and grain nutrient concentarion as they are extensively used to increase yield and their concentration as well as quality of crops (Mugenzi *et al.* 2018) . Gibberellic acid can stimulate rapid stem and root growth, induce mitotic division in the leaves of some plants, and increase seed germination and ultimately crop production. Crop yields depends on the accumulation of photo-assimilates during the growing period and the way they are partitioned between desired storage organs of plants. Similar results are reported by (Narendra *et al*. 2018) that significantly higher cobs/plant, con length, cob girth, and grains/cob were recorded with gibberellic acid, higher grain yield and stover yield were recorded under gibberellic acid respectively. Ghassan *et al.* (2015) gibberellic acid treatment at 100 ppm demonstrated a positive impact on plant cells compared with the other treatments. The seed weight per plant under treatment with 100 ppm gibberellic acid recorded significantly higher than sprayed with 50 ppm gibberellic acid leading to seed weight per plant.

Performance of plant growth regulators and micronutrient on economics of Maize

The data pertaining to economics of growing as influenced by performance of plant growth regulators and micronutrient on growth and yield of maize has been exhibited and presented in Table 2. Maximum net returns (1,10,770.78 INR/ha) and B:C ratio (2.40) were obtained with the application of Superzyme 900 ml/ha which was superior over rest of all treatments.

Application of gibberellic acid fetched the maximum gross returns, net returns and B:C ratio respectively. Integrated application of seaweed extracts and RDF increased the gross and net returns as compared to sole RDF application of control (T_1). These results are in accordance with earlier findings of (Narendra *et al.,* 2018) and (Nayak *et al.,* 2020)

CONCLUSION

On the basis of one season experimentation, it is concluded that treatment with application of Superzyme-900 ml/ha was found to be more productive (5.23 t/ha) as well as economically (1,10,770.78 INR/ha) viable.

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