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Growth, yield attributes and nutrient uptake of maize (*Zea mays* L.) as affected by balanced nutrition under western UP conditions

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Abstract
A field experiment was conducted during *Kharif* season 2016-17 at Crop Research Centre (Chirori) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) to study the effect of balanced fertilization on growth, yield attributes and nutrient uptake in maize. The nine treatments *viz*; T_1 (Control), T_2 (N), T_3 (NP), T_4 (Recommended NPK), T_5 (NPK + S), T_6 (NPK + S + Zn), T_7 (NPK + S + Zn + Fe), T_8 (NPK + S + Zn + Fe + B) and T_9 (NPK + FYM + PSB) were tested in Randomized Block Design with three replications. The maize variety K-25 (Kanchan) was grown and its performance in relation to growth and development, nutrient uptake, soil properties and nitrogen use efficiency as influenced by different treatments were assessed. Results obtained from the study revealed that plant height, number of functional leaves, chlorophyll content, dry matter accumulation, yield attributions and uptake of nutrients in maize were significantly superior with the application of NPK + S + Zn + Fe + B (T_8) as compared to rest of the treatments, except T_5 (NPK + Zn), T_6 (NPK + S + Zn), T_7 (NPK + S + Zn + Fe) and T_9 (NPK + FYM + PSB). However, the maize also accumulated significantly higher nitrogen, phosphorus, potassium and sulphur in grains, stover as well as total (189.48, 48.95, 178.36 and 61.24 kg/ha, respectively) as compared to T_1 (control), T_2 (N alone) and T_3 (NP).

Keywords: Maize, yield, balanced nutrition and nutrient uptake

Introduction
Maize (*Zea mays* L.) is one of the most important cereal crops next, only to wheat and rice in terms of total production in the world. Maize is grown throughout the world, under a wide range of climatic conditions. The major producers of the maize in the world are USA, China, Brazil, Mexico, Argentina and India. In the world, maize was grown in the area of 140 mha, with a production of 800 mt. In India, during 2014-15, maize was grown on an area of 9.43 mha, with a production of 24.35 mt and average productivity of 2583 kg ha^{-1}. In Uttar Pradesh, maize occupies an area of 0.7 mha, with a production of 1.23 mt and productivity of 1671 kg ha^{-1} (Anonymous, 2015) [1]. Despite, maize being predominantly a rainfed crop, its productivity is more than rice which is mainly grown under assured irrigated rainfed conditions. Maize contributes nearly 9% in the national food basket and more than 400 billion to the agricultural GDP at current prices. It is well known that maize is a heavy feeder of nutrients and because of its C_4 nature; it is very efficient in converting solar energy into production of dry matter. The crop has high genetic yield potential, hence it is called miracle crop and 'Queen of cereals'. There are several factors that affect the productivity of maize, however, the fertilizer management is one of the most important factors that affect the growth and yield of maize (Anonymous, 1979 and Duhan and Singh, 2002) [3]. In cereals, adequate nitrogen supply promotes vigorous vegetative growth and deep green color, increases the plumpness of grains and their protein content thus N has been recognized as one of the most limiting nutrient for these crops. NPK are among the most important nutrients for plant. Growth and their diverse concentrations have a significant influence on plant growth and soil-plant interactions (Xie *et al*., 2011) [21]. Growth and development of the crop plants are directly related to their genetic constitution, though environmental factors and cultural practices do influence it through their direct and indirect impact on different metabolic process of the plants. Among the various inputs, mineral nutrition of plants is the key input to making maximum contribution of crop productivity because nearly 55% of increase in food grain production during last two decades has come through increasing levels of fertilizer application.

However, total annual removal of nutrient by crop and cropping system being much higher than amount added through fertilizers has resulted in negative nutrient balance in the soil. Therefore, prompt effort is must, not only to increase and stabilize crop production but also to enhance the nutrient use efficiency, which shows great influence on crop production. The productivity of maize entirely depends on extent of successful completion of crop growth for exploiting their full genetic potential and properly integrated with environmental conditions in which it is grown. However, role of balanced and adequate nutrition is recognized as one of the important factors in realizing the maximum yield of maize. Role of nutrients for effective progression of plant ontogeny and crop yield as well as in quality improvement of crop has been well recognized. Besides, the major primary nutrients *i.e.* N, P and K, secondary nutrients like sulphur and micronutrients *i.e.* zinc, Iron and Boron has been recognized as essential inputs for sustained the maize productivity and enhancement in its quality.

Materials and Methods

A field experiment in Randomized Block Design which consists of 9 treatments with three replications were as follows: T_1 (control), T_2 (N), T_3 (NP), T_4 (NPK), T_5 (NPK + S), T_6 (NPK + S + Zn), T_7 (NPK + S + Zn + Fe), T_8 (NPK + S + Zn + Fe + B), T_9 (NPK + FYM + PSB), was conducted during *Kharif* season of 2016-17 at Crop Research Centre (Chirori) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) The experimental site was located at 29^0 4' N latitudes and 77^0 46' E longitudes with an altitude of 237 m above the mean sea level the area lies at, an average annual rainfall of 520 mm. The soil of experimental field was deep sandy loam in texture, slightly alkaline pH (8.03) in reaction, low in organic carbon (0.47%) and available (193.3 kg N/ha) but medium available (15.8 kg P_2O_5/ha), (218.3 kg K_2O/ha). Maize hybrid 'K 25' was sown at second fortnight of July 2016 on flat bed at the spacing of 60cm x 20cm with a seed rate of 20 kg/ha. Different treatments of application of inorganic sources of nutrients (*viz.* recommended dose of fertilizers (RDF) and organic sources of nutrients (*viz.* application of FYM, bio-fertilizer) and their combinations with each other were arranged (Table-1). Recommended dose of nutrients used in the treatment were 120 kg N + 60 kg P_2O_5 + 40 kg K_2O + 20 kg S + 8 kg Zn + 4 kg Fe +1 kg B/ha. Out of which all the nutrients, except N were applied at the time of sowing and N was applied in three splits as; 50% at the time of sowing, 25% at knee high stage and remaining 25% at the time of tasseling (i.e. at 60 DAS). Well decomposed FYM was applied at the rate of 5 t/ha before sowing the crop as per treatment. Bio fertilizers inoculants of phosphate solubilizing bacteria were used @20g/kg of maize seed as seed treatment before sowing. Plant protection measures and irrigations whenever required were provided in same manner for all the treatments. Regular biometric observations were recorded at specific time intervals by selecting randomly five plants in each plot. Crop was harvested at 90 days after sowing and observations were recorded from net plots. Randomly soil samples from each plot were taken and examined for Physico-chemical properties and nutrient status of soil after harvest of maize crop.

All necessary management practices were carried out as per standard recommendation for maize crop. All vegetative and reproductive parameters were recorded. Plant height, number of functional leaves plant^{-1}, dry matter accumulation plant^{-1} were measured during vegetative period. Data on different yield parameters such as cob length, was measured with measuring scale, and counted the grains rows^{-1}, grains row cob^{-1}, and grains cob^{-1} and finally 1000 grain weight were weighed with electrical balance. The crop was harvested manually at full maturity. The harvested crop of the plot was bundled separately, tagged properly and bring to the clean threshing floor. The seeds and straw weight for each plot were recorded after sun drying and weighed. Cobs were de-husked, dried, shelled and weighed with electric balance. The data were analyzed statistically using the analysis of variance (ANOVA) technique with the help of MSTAT-C (Gomez & Gomez, 1984) [5] However, total annual removal of and Microsoft excel program, and mean differences were adjusted by using F test.

Results and Discussion

Growth parameters

All the growth characters at harvest were significantly affected by different treatments. The application of (NPK + S + Zn + Fe + B) T_8, being *at par* with the NPK + S (T_5), NPK + S + Zn (T_6), NPK + S + Zn + Fe (T_7) and NPK + PSB + FYM (T_9), resulted into significantly tallest plants (188.1 cm) as compared to rest of the treatments. Though, the shortest plants (164.8 cm) were recorded under control (T_1). At harvest stage, T_8 (NPK + S + Zn + Fe + B), being *at par* with NPK + S (T_5), NPK + S + Zn (T_6), NPK + S + Zn (T_7) and NPK + PSB + FYN (T_9) resulted into significantly maximum number of functional leaves/plant (10.6) followed by NPK + S + Zn + Fe (T_7), NPK + S + Zn (T_6), NPK + PSB + FYM (T_9) and NPK + S (T_5). Though, the minimum number of functional leaves (5.3/plant) was recorded under control (T_1). At harvest stage, maximum dry matter accumulation (246.7g plant^{-1}) was observed under the treatment T_8 (NPK + S + Zn + Fe + B) followed by NPK + S + Zn + Fe (T_7), and NPK + PSB + FYM (T_9). Although, these treatments remained *at par* to each other, produces significantly more dry matter plant^{-1} as compared to rest of the treatments. However, the significantly lowest dry matter accumulation plant^{-1} was recorded in control treatment followed by T_2 (N), T_3 (NP) and T_4 (NPK). Further, the application of NPK + S + Zn + Fe + B (T_8) accumulated 32.2% more dry matter plant^{-1} at harvest as compared to recommended NPK. Sujatha *et al.* (2008) [19] has been also reported similar results of positive effects of combination of macro, and micro fertilizer, use of biofertilizers and FYM on growth characters of rainfed maize. At harvest stage, T_8 (NPK + S + Zn + Fe + B), being *at par* with T_9 resulted into significantly maximum chlorophyll content (23.2) than rest of the treatments. Though, the minimum chlorophyll content of 9.5 was recorded under control (T_1). Sobhana *et al.*, (2012) [18] conducted a field experiment at IARI New Delhi during *Kharif* season of 2010 to assess the nutrient requirements of baby corn hybrid HM-4 and noticed that each increase in NPK level from control to N-150 P-32.75 K-62.5 recorded significantly taller plants and higher dry weight plant-1 but LAI improved only up to application of N120 P60K40.

Table 1: Growth parameters as affected by balanced nutrition at successive stage of crop growth

Treatments	At harvest			
	Plant height (cm)	No. of functional leaves plant^{-1}	Dry matter accumulation	Chlorophyll content (SPAD value)
T_1- Control	164.8	5.3	125.0	9.5
T_2- N	170.9	8.8	156.0	20.7
T_3- NP	175.0	8.9	175.0	20.0
T_4- NPK	181.1	9.5	186.6	21.1
T_5- NPK + S	182.7	9.8	201.7	21.2
T_6- NPK + S + Zn	183.4	9.9	216.7	21.3
T_7- NPK + S + Zn + Fe	186.1	10.3	236.6	21.8
T_8- NPK + S + Zn + Fe + B	188.1	10.6	246.7	23.2
T_9- NPK + FYM + PSB	187.3	10.4	243.3	23.0
S.Em±	2.2	0.3	5.0	0.5
CD (P= 0.05)	6.4	1.0	14.7	1.4

Yield attributes

Different yield attributing characters at harvest were significantly affected by different treatments. The application of NPK + S + Zn + Fe + B (T_8), being *at par* with the (NPK + FYM + PSB) (T_9), NPK + S + Zn + Fe (T_7), NPK + S + Zn (T_6) and NPK + S (T_5) resulted into significantly higher cob length (17.5 cm) as compared to rest of the treatments. Though, the shortest cob length (13.50 cm) were recorded under control (T_1). At harvest stage, T_8 (NPK + S + Zn + Fe + B), being *at par* with NPK + S (T_5), NPK + S + Zn (T_6), NPK + S + Zn (T_7) and NPK + PSB + FYN (T_9) resulted into significantly maximum grains row/cob (13.7) as compared to rest of the treatments. Though, the minimum grains row/cob (10.0) was recorded under control (T_1). At harvest stage, maximum grains/row (28.0) was observed under the treatment T_8 (NPK + S + Zn + Fe + B) followed by NPK + S + Zn + Fe (T_7) and NPK + PSB + FYM (T_9). Although, these treatments remained *at par* to each other, produces significantly more grains/row as compared to rest of the treatments. However, the significantly minimum grains/row was recorded under control treatment followed by T_2 (N), T_3 (NP) and T_4 (NPK). Further, the application of NPK + S + Zn + Fe + B (T_8) accumulated more grains/row at harvest as compared to recommended NPK. Sujatha *et al.* (2008) [19] has been also reported similar results of positive effects of combination of macro, and micro fertilizer, use of bio fertilizers and FYM on yield attributing characters of rainfed maize. At harvest stage, T_8 (NPK + S + Zn + Fe + B), being *at par* with T_9, T_7, T_6 resulted into significantly greater test weight (226.7) than rest of the treatments. Though, the minimum test weight of 190.30 was recorded under control (T_1). Singh *et al.* (2016) [17] studies the response of baby corn to integrated nutrient management results revealed that maximum baby corn length, baby corn girth, green cob weight, baby cob weight, number of cobs, baby corn yield and green fodder yield were recorded with application of 5 t FYM + 120 kg N K 60 kg ha^{-1} followed by 100% recommended dose of nitrogen.

Table 2: Yield attributes as affected by balanced nutrition at successive stage of crop growth

Treatments	Cob length (cm)	Grain rows cob^{-1}	Grains row^{-1}	Test weight
T_1- Control	13.5	10.0	13.5	190.3
T_2- N	15.5	11.3	16.5	223.5
T_3- NP	16.2	12.4	17.2	224.4
T_4- NPK	16.2	12.8	20.0	224.7
T_5- NPK + S	16.5	13.4	24.3	225.9
T_6- NPK + S + Zn	16.8	13.5	24.8	226.0
T_7- NPK + S + Zn + Fe	16.9	13.6	26.6	226.5
T_8- NPK + S + Zn + Fe + B	17.5	13.7	28.0	226.7
T_9- NPK + FYM + PSB	16.9	13.6	26.9	226.6
S.Em±	0.4	0.2	0.5	0.3
CD (P= 0.05)	1.1	0.6	1.5	0.7

Nutrient uptake

The statistical data revealed that, there was significant effect of various sources of nutrients over control on the nutrient uptake of maize. Highest uptake of N, P_2O_5 and K_2O was observed during application of NPK + S + Zn + Fe + B (T_8). In case of N uptake treatment NPK + FYM + PSB (T_9) with NPK + S + Zn + Fe (T_7) were found to being at par with each other. The uptake of N, P_2O_5 and K_2O was found higher to the tune of 189.48, 48.94 and 178.36 in application of NPK + S + Zn + Fe + B (T_8) over control. This might be due to the combined effect of rapid release of nutrients in plant and also due to the increased availability of N and P_2O_5 which added in the soil through organic and inorganic resources by phosphate solubilizing bacteria. Satish *et al.* (2011) has been also reported that the combination of organic and inorganic fertilizer showed higher uptake values of all the three nutrients, which is in close conformity with the results obtained in present investigation. Grain yield increased with increasing levels of nitrogen and maximum grain yield 68.7 q ha^{-1} was obtained by use of 120 kg N ha^{-1} with FYM @ 5t ha^{-1} and PSB inoculation. Significant uptake of nitrogen, phosphorus and potassium was recorded under application of 120 N kg ha^{-1} over the control. Protein content in maize grain increased significantly by conjoint use of organic manure and bio fertilizers with each level of nitrogen application, over application of each nitrogen level alone (Meena *et al.*, 2013) [11]. It was influenced by releasing nutrients from sources and biological activity which resulted in more nutrient uptake (Mankinde *et al.*, 2011) [10]. From result, it can be concluded that different types organic manures and fertilizers

combination recorded significantly higher yield and nutrient concentration in maize which resulting higher nutrient uptake.

Table 3: Nutrient uptake as affected by balanced nutrition at successive stage of crop growth

Treatments	N	P_2O_5	K_2O
T_1- Control	43.25	9.33	50.13
T_2- N	75.53	16.55	79.89
T_3- NP	91.61	22.08	90.60
T_4- NPK	113.63	26.83	108.64
T_5- NPK + S	150.45	36.19	144.75
T_6- NPK + S + Zn	157.82	38.45	153.23
T_7- NPK + S + Zn + Fe	172.91	43.07	168.61
T_8- NPK + S + Zn + Fe + B	189.48	47.15	178.36
T_9- NPK + FYM + PSB	178.61	48.94	175.28
S.Em±	6.43	1.22	4.55
CD (P= 0.05)	18.69	3.55	13.31

Conclusion

To the experimentation it can be concluded that, application of NPK + S + Zn + Fe + B RDF is the best combination of inorganic (macro and micro) fertilizers for increasing productivity of hybrid maize.

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