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Effect of Zn, Fe and B on yield, nutrient uptake and quality of *kharif* maize in Marathwada region of Maharashtra

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Abstract
The experiment was conducted during *Kharif* 2017-18 to study the effect of Zn, Fe and B on yield, nutrient uptake and quality of *kharif* maize at the research farm, Department of Soil Science and Agricultural Chemistry, College of Agriculture Badnapur. The experiment was planned in randomized block design with nine treatments with three replications in randomized block design. The treatment consists of T_1 RDF (150:75:75 NPK kg ha^{-1}), T_2 (RDF + $ZnSO_4$), T_3 (RDF + $FeSO_4$), T_4 (RDF + Borax), T_5 (RDF + $ZnSO_4$ + $FeSO_4$), T_6 (RDF + $ZnSO_4$ + Borax), T_7 (RDF + $FeSO_4$+ Borax), T_8 (RDF + $ZnSO_4$ + $FeSO_4$ + Borax), T_9 (RDF + Foliar application of grade II micronutrient application at 45 DAS). The results emerged out clearly indicated that yield, nutrient uptake and quality was increased due to application of micronutrients. It was inferred from the results that application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1}+ Borax @ 10 kg ha^{-1} found superior over only N P and K application i.e. RDF (150:75:75 N, P_2O_5 and K_2O kg ha^{-1}).

Keywords: Effect, Zn, Fe, B on yield, nutrient uptake, quality, *kharif* maize

Introduction

Maize is an important cereal crop of the world as well as of India. Maize crop grown next to wheat and rice in the world. In India, it is cultivated over an area of 92.32 lakh hectares with an annual production of 236.73 lakh tonnes having an average productivity of more than 2564 kg ha^{-1}. In Maharashtra it occupies an area of 10.59 lakh hectares with total production of 22.03 lakh tonnes having an average productivity of more than 2080 kg ha^{-1}

Micronutrients are essential for crop production in the present situation of soil fertility and their deficiency drastically affects the growth, metabolism and reproductive phase of crop plants, animal and human beings. Micronutrient deficiencies in crop plants are widespread because of increased micronutrient demand from intensive cropping practices and adaptation of high-yielding crop cultivars, enhanced crop production on marginal soils that contain low levels of essential micronutrients, increased use of high analysis fertilizers with low amounts of micronutrients, decreased use of animal manures, composts and crop residues, use of soils low in micronutrient reserves, use of liming in acid soils, involvement of natural and anthropogenic factors that limit adequate supplies and create elemental imbalance in soil (Fageria *et al.* 2002) [3]. Shukla and Behera (2011) [16] reported that as much as 48, 12, 5, 4, 33, 13 and 41 per cent soils in India are affected with deficiency of Zn, Fe, Mn, Cu, B, Mo and S respectively. In India, the trends of micronutrient deficiencies are now changing. Instead of single nutrient deficiency, cluster of micronutrient deficiencies are emerging fast in vast areas. This suggests that increasing multi-micronutrients deficiencies in soil and crops not only affect the crop productivity, but also create malnutrition and health problems. In experiments with rice-wheat, sesame-wheat, pigeon pea-wheat, maize-wheat, groundnut-wheat and sorghum (Fodder)wheat cropping systems, the addition of S + Zn + B in balanced fertilization schedule increased N,P and K utilization efficiency which highlights the role of micronutrients in enhancing macronutrient use efficiency. Based on the results of large number of field trials (4144), Katyal (1985) [10] concluded that at least in two out of three experiments, treatment with Zn fertilizer was necessary to derive optimum benefit from NPK fertilizers.

Micronutrients are trace elements which are needed by the maize crop in small amounts and play an active role in the plant metabolic functions in shortage of which show deficiency symptoms and crop yields are reduced, they are therefore to be added into the soil before crop planting or applied directly to the crop to increase maize productivity. Adhikari *et al.* (2010) revealed in order to evaluate the effects of micronutrients (B, Zn, Mo, S and Mn) on the grain production of maize (var. Rampur Composite), series of field experiments were conducted during the winter season of three consecutive years (2007 to 2009) in the acidic soil condition

(5.1 pH) at National Maize Research Programme (NMRP), Rampur. The highest grain yield (5.99 t ha^{-1}) was recorded with the crop which was supplied with all micronutrients (B, Zn, S, Mn and Mo applied in combination with NPK fertilizers at 120:60:40 kg ha^{-1} which produced almost 171 % higher grain yield than those with control plot (2.21 t ha^{-1}) and 3.78 t ha^{-1} of additional grains over NPK treated crop.

Material and methods

The experiment was conducted during *Kharif* 2017-18 at the research farm, Department of Soil Science and Agricultural Chemistry, College of Agriculture Badnapur. The experiment was conducted to study the effect of Zn, Fe and B on yield, nutrient uptake and quality of *kharif* maize planned in randomized block design with nine treatments with three replications. The chemical composition of experimental plots indicated that the soil was low in available nitrogen (126 kg ha^{-1}), high in available phosphorus (26.40 kg ha^{-1}), very high in available potassium (540.26 kg ha^{-1}) and alkaline having pH 8.1. The concentration of zinc, iron and B in experimental plots was 0.3 ppm, 2.3 ppm and 0.7 ppm respectively. The dose of the NPK along with Zn, Fe and B for maize was worked out according to the present recommendation of maize hybrids in Marathwada region. The 100% NPK dose in kg ha^{-1} worked out was 100:75:75 NPK kg/ha for maize crop. The doses for zinc, iron and boron were framed by applying $ZnSO_4$ @25 kg ha^{-1}, $FeSO_4$ @ 25 kg ha^{-1} and borax @ 10 kg ha^{-1}, respectively. Fertilizer application was made as per the treatments. Full dose of phosphorus, potash and half dose of nitrogen were applied at sowing as basal application. The remaining dose of nitrogen was top dressed at 30 DAS depending upon the occurrence of rains. Full dose of zinc, iron and boron were applied at sowing.

Maize variety Markiv-6202 was sown at the seed rate of 15 kg ha^{-1} at uniform row of 60 cm × 20 cm. Shallow furrows were opened and seeds were sown manually by using dibbling method at the depth of 5cm. Plants selected for analysis were uprooted from net plot, washed in distilled water, dried at 70 °C in oven and powdered. The powdered samples were stored in plastic bags for further analysis. Total nitrogen in plant was estimated by Micro-Kjeldahls methods total phosphorous in plant was estimated by Vanadomolybdeate yellow colour Colorimetric method total potassium in plant was estimated by Flame photometer, total Zn and Fe were determined by DTPA extraction method boron was determined by procedure given by J.T. Hatcher and L.V. Wilcox, crude protein estimated by micro kjeldals method and crude fat estimated by soxhlet method.

Result and discussion

Yield of maize

Grain yield and stover yield

The significantly highest grain yield was recorded by T_8 ($RDF+ZnSO_4+ FeSO_4$+Borax) (4890 kg ha^{-1},) which was at par with T_5, T_6 and T_9. The lowest grain yield was recorded by T_1 (RDF).The interaction effect between NPK and micronutrients were significant and the highest grain yield registered in the application of $RDF+ZnSO_4+ FeSO_4$+Borax.Gowthami and Rama (2014) conducted a field experiment at Agricultural College Farm, Bapatla during *Kharif* 2013-14 to study the effect of foliar application of potassium, boron and zinc on growth and seed yield of soybean. The results revealed that foliar application of potassium nitrate @ 2 % + boric acid @ 50 ppm + zinc sulphate @ 1 % at 30 and 60 DAS was found to be superior in increasing plant height, number of branches, number of leaves, leaf area, total drymatter, number of pods per plant, test weight and seed yield followed by potassium nitrate @ 2 % + boric acid @ 50 ppm at 30 and 60 DAS.

The differences in stover yield due to different treatments were found to be significant. The mean stover yield per hectare was 4863.66 kg. The significantly higher stover yield was recorded by T_8 (5390 kg ha^{-1}) which was as par with T_6, T_7 and T_9.Lowest stover yield was found in T_1 which receive RDF alone. Ashoka *et al*., (2008) [2] conducted a field experiment to study, the effect of micronutrients with or without organic manures on yield of baby corn - chick pea cropping sequence. The results revealed that, the application of RDF (150:75:40 kg N, P_2O_5, K_2O ha^{-1}) + 25 kg $ZnSO_4$ + 10 kg $FeSO_4$ + 35 kg vermicompost ha^{-1} recorded significantly higher yield components i.e. ear length (7.40 cm), ear weight (17.40 g), yield (64.43 q ha^{-1}), green fodder yield (232 q ha^{-1}) and pod plant-1 (100.33).

Total uptake of N

Data revealed that the uptake of N at tasseling stage, cob initiation stage and harvesting stage significantly highest total N uptake 98.33kg ha^{-1},190.79 kg ha^{-1}and238.33 kg ha^{-1}respectively, which was found in treatment T_8 which was at par with T_6, T_7 and T_9. Increased uptake of N at higher doses might have resulted in initial build up of plants due to vigorous growth and higher photosynthetic rate which led to better uptake throughout the crop growth period. The results in the present study indicates when a considerable amount of N is applied at or near anthesis (taselling stage), there is greater possibility of its accumulation in sink rather than other vegetative parts, as found in maize by Parthipan (2000) [14]. Gupta and Patalia (1993) [7] reported the combined application of Zn and B recorded the highest N and P uptake while the lowest amount was in the application of Zn and B at zero level.

Total uptake of P

The data furnished in Table:1 revealed that significantly highest P uptakeat tasselling stage 21.71 kg ha^{-1}, cob initiation stage 32.73 kg $ha^{-1}$and harvesting stage 47.33 kg ha^{-1} found by inT_8 which is highest than other treatments. During the growth period, the highest P uptake was observed at harvest stage due to combined application of RDF + $ZnSO_4$ + $FeSO_4$ + Borax. Zinc iron and B fertilization had slight but significant effects on P uptake. Increments in B addition significantly decreased the concentration of P and the reduction in concentration of P could be attributed to a dilution effect (Ziaeyan and Rajaie 2009) [19]. Nuttal *et al*. (1987) [13] reported that application of micronutrients (B) registered the maximum N and P uptake of 150.8 and 29.13 kg ha-1 while the control registered the N and P uptake of only 129.1 and 24.2 kg ha^{-1} respectively.

Total uptake of K

The data furnished in Tables 1 show that the application of 100 % RDF + $ZnSO_4$ + $FeSO_4$ + Borax (T_8) registered the significantly highest K uptake of maize during the tasselling 71.10 kg ha^{-1}, cob initiation stage 138.54 kg ha^{-1} and harvesting stage 174.13 kg ha^{-1} which was at par with T_7 and T_9.Mandal *et al.* (1992) [12] reported that the effect of Zn and B interaction and found that increased K uptake with the combined application of 3 kg B + 16 kg Zn ha^{-1} whereas the B application alone registered the lowest K uptake.

Total uptake of Zn

The experimental results in Tables 2 showed that the significantly higher Zn uptake of maize during the tasselling 42.51mg kg^{-1},cob initiation stage 46.57 mg $kg^{-1}$and harvesting stage 58.34 mg $kg^{-1}$was found in treatment T_8which was at par with treatmentT_9.Synergism was observed when bothB and Zn were in excess together as excess B accelerated the effects of high Zn by lowering reduced biomass, economic yield and carbonic anhydrase activity and increased concentration of B and Zn in leaves and seeds (Sinha *et al.* 2000; Hosseini *et al.* 2007) [9].

Total uptake of B

The data furnished in Table 2 revealed that the significantly highest B uptake of maize during the tasselling 31.44 mg kg^{-1}, cob initiation stage 37.07 mg $kg^{-1}$and harvesting stage 48.15 mg $kg^{-1}$was found in treatment T_8 which was at par with treatment T_7 and T_9. Tripathy *et al.* (1999) [7] reported that application of major and micronutrients significantly enhanced the uptake of nutrients viz., nitrogen, phosphorus, potassium, zinc and boron. Experiments were conducted on farm during two seasons (2003-04) by Sahrawat *et al.* (2008) [15] and reported that soil application of sulphur, boron, zinc, nitrogen and phosphorus @ 30, 5, 10, 60 and 30 kg ha-1, respectively recorded significantly higher N, S, Zn and B content in sorghum over control.

Total uptake of Fe

The data furnished in Table 2revealed that significantly highest uptake of Feat tasseling stage 45.86 mg kg^{-1}, cob initiation 56.06 mg kg^{-1} and harvesting stage 61.32 mg kg^{-1}which was at par with treatments T_7 and T_9.The better iron uptake was due to readily absorbed nutrients by leaves and trans located within the plant leading to the synergistic action between zinc and iron. Similar results were also found by Farshid Aref (2012) that soil application of different levels of Zn showed no significant effect on the leaf Fe content relative to the zero Zn level ($p<0.05$), but Zn spray increased the leaf Fe content relative to the application of Zn to the soil.

Quality parameter

Crude protein

The data furnished in Table 3revealed that the significantly highest crude protein concentration(11.03%) was found by T_8which was at par withT_3, T_4, T_5, T_6, T_7 and T_9.With regard to the interaction between macro and micronutrients, the combined application of RDF + $ZnSO_4$ + $FeSO_4$ + Borax recorded the highest crude protein. This might be due the role of Zn on the enzymatic activity in plants which could bring about significant changes in the protein content in the grain. Gayathri (2010) [5] observed that combined application of the recommended dose of 150:50:50 kg N, P2O5 and K2O kg ha^{-1} along with soil application of ZnSO4 @ 25 kg ha^{-1} increased the maximum true protein content of 6.62 % in rice grain of all the treatments where the control showed the lowest value of 6.31 %. Hemantaranjan and Gray (1988) [8] observed that individual foliar spraying of B and Zn significantly increased grain protein content to the tune of 8 and 10 per cent respectively in corn while the highest grain protein content (11.3%) was obtained when these two nutrients were applied in a combined spray.

Crude Fat

The data furnished in Table 3revealed that the significantly highest crude fat percentage (4.40 %) found by T_8which was at par with T_5, T_6, T_7 and T_9. According to Malakouti (2008) [11] and Wang *et al.* (2015) [18] micronutrients and the interactions between them have a positive effect on the physiological processes of plants, which is reflected in improved grain yield and quality.

Table 1: Effect of Zn, Fe, B applications on uptake N, P and K at critical growth stages of maize

Treatments	Uptake of N (Kg/ha)			Uptake of P (Kg/ha)			Uptake of K (Kg/ha)		
	At Tasseling	At Cob initiation	At harvesting	At Tasseling	At Cob initiation	At harvesting	At Tasseling	At Cob initiation	At harvesting
T_1- RDF	72.26	152.30	185	11.63	17.41	27.43	51.16	108.02	146
T_2- RDF+$ZnSO_4$	72.86	174.32	213.38	14.91	20.33	34.30	53.50	115.41	151.96
T_3- RDF+$FeSO_4$	74.60	167.25	215	13.14	20.09	27.81	56.90	114.31	156.50
T_4- RDF + Borax	74.50	175.31	225	13.10	19.17	37.30	54.73	119	158.90
T_5- RDF+$ZnSO_4$+$FeSO_4$	72.36	177	223.33	18.32	25.38	39.30	65.93	124.61	163.56
T_6- RDF+$ZnSO_4$+Borax	90.53	180.24	226.66	18.59	27.98	40.53	67.06	127.24	163.91
T_7- RDF+$FeSO_4$+Borax	86.80	179.32	231.33	18.25	26.44	33.13	63.54	124.25	163.40
T_8- RDF+$ZnSO_4$+$FeSO_4$+Borax	98.33	190.79	238.33	21.71	32.73	47.33	73.13	138.54	174.13
T_9- RDF + Foliar application of Micronutrients	93.33	183.64	232.30	19.13	28.04	42.63	71.10	132	164.96
SE ±	4.10	5.64	7.20	0.57	0.96	2.32	3.46	4.23	4.73
CD at 5%	12.34	17	21.69	1.74	1.36	6.98	10.43	12.75	14.25

Table 2: Effect of Zn, Fe, B applications on uptake Zn, B and Fe at critical growth stages of maize

Treatments	Uptake of Zn (mg/kg)			Uptake of B (mg/kg)			Uptake of Fe (mg/kg)		
	At Tasseling	At Cob initiation	At harvesting	At Tasseling	At Cob initiation	At harvesting	At Tasseling	At Cob initiation	At harvesting
T_1- RDF	30.26	35.12	43.35	10.31	14.97	22.38	38.80	44.20	51.46
T_2- RDF+$ZnSO_4$	36.31	42.12	51.61	12.41	16.17	24.31	40.67	48.03	54.39
T_3- RDF+$FeSO_4$	32.30	40.01	47.29	12.72	16.40	27.14	41.80	48.67	55.34
T_4- RDF + Borax	28.14	37.80	44.73	26.23	31.53	43.23	35.81	46.03	53.17
T_5- RDF+$ZnSO_4$+$FeSO_4$	38.02	41.63	53.62	24.31	30.57	43.31	43.61	50.81	58.32
T_6- RDF+$ZnSO_4$+Borax	37.43	41.02	52.36	25.43	31.80	44.18	42.81	48.04	57.01
T_7- RDF+$FeSO_4$+Borax	35.49	39.12	49.20	26.41	35.09	44.47	43.38	50.91	58.47
T_8- RDF+$ZnSO_4$+$FeSO_4$+Borax	42.51	46.57	58.34	31.44	37.03	48.15	45.86	56.06	61.32
T_9- RDF + Foliar application of Micronutrients	40.38	44.38	55.12	27.63	36.84	46.62	43.87	51.13	58.47
SE ±	1.30	1.30	1.55	0.64	0.90	1.40	1.29	1.45	1.64
CD at 5%	3.93	3.93	4.69	1.94	2.73	4.24	3.88	4.37	4.95

Table 3: Effect of Zn, Fe and B on Grain yield, Stover yield, crude protein and crude fat concentration

Treatments	Grain yield (Kg/ha.)	Stover yield (Kg/ha.)	Crude Protein (%)	Crude fat (%)
T_1- RDF	3862	4267	9.87	3.52
T_2- RDF+$ZnSO_4$	4201	4672	10.24	3.68
T_3- RDF+$FeSO_4$	4065	4470	10.39	3.62
T_4- RDF + Borax	4103	4653	10.57	3.57
T_5- RDF+$ZnSO_4$+$FeSO_4$	4456	4951	10.55	3.63
T_6- RDF+$ZnSO_4$+Borax	4549	5037	10.81	3.91
T_7- RDF+$FeSO_4$+Borax	4497	5026	10.86	4.11
T_8- RDF+$ZnSO_4$+$FeSO_4$+Borax	4890	5390	11.03	4.40
T_9- RDF+ Foliar application of Micronutrients	4791	5307	10.96	4.36
SE ±	151.47	143.77	0.22	0.11
CD at 5 %	455.98	432.81	0.68	0.35

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