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Effect of soil and foliar application of micro nutrients (Zn, Fe & B) on field performance of Maize (*Zea mays* L.) in Northern Karnataka

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Abstract
Under rainfed conditions, farmers rarely use micro-nutrients for crop production, due to which soils become deficient especially in zinc (Zn), Iron (Fe) and boron (B). Secondly, farmers apply nutrients solely through soil application but scarcity/less availability of moisture makes the nutrients unavailable for crop plants. Under such circumstances, foliar application of micronutrients may play a key role for better crop growth and yield. Therefore, this on-farm testing was conducted to investigate the role of Zn, Fe and B application alone and in combination through soil and foliar application methods on growth, yield and net returns of maize grown under rainfed conditions. Results showed that combined application of Zn, Fe and B on foliage has improved the grain yield due to substantial expansion in entire yield related traits. Combined foliar application of Zn, Fe and B harvested 16.96 per cent and 25.27 per cent more grain yield (67.25 and 69.69 q ha^{-1} during 2016-17 and 2017-18, respectively) than farmers practice (57.50 and 55.63 q ha^{-1} during 2016-17 and 2017-18, respectively). Similar trend was observed in pooled data also [21.03 % higher grain yield (68.47 q ha^{-1}) than farmers practice (56.57 q ha^{-1})]. Higher gross return, net returns and benefit: cost ratio was also obtained by soil and foliar application of Zn, Fe and B. It has improved the gross income (Rs. 94822 and Rs. 99305 during 2016-17 and 2017-18, respectively), net income (Rs. 76622 and Rs. 81055 during 2016-17 and 2017-18, respectively) and benefit: cost ratio (BCR) (5.21 and 5.44 during 2016-17 and 2017-18, respectively) against farmers practice and similar trend was noticed in pooled data also (Rs. 97064, Rs. 78839 and 5.21 of gross return, net return and B:C ratio, respectively). In conclusion, application of RDF along with soil and foliar application of micronutrients has improved maize yield due to significant expansion in yield related traits and thus improved net returns of maize grown under rainfed conditions of Suttakote village of Hirekerur taluk, Haveri district.

Keywords: micronutrients, foliar application, grain yield, maize, on-farm testing

Introduction
Maize (*Zea mays* L.) is considered as leading cereals in the world as far as its production per unit area is concerned. In India, there was gradual increase in area (9.47 m ha), production (28.72 m t.) and productivity (3032 kg ha^{-1}) of maize during 2017-18 as compared to 1950-51 (3.16 m ha, 1.73 m t. and 547 kg ha^{-1} of area, production and productivity, respectively). In Karnataka it is cultivated over an area of 1.29 m ha with a production of 3.55 m t and productivity of 2755 kg ha^{-1} (Anon., 2018) [1]. However, the yield potential of maize under rainfed condition is very low as compared to irrigated condition. This might be due to low soil fertility and less availability of moisture at later crop growth stages. In addition to macronutrients like nitrogen (N), phosphorus (P), and potassium (K), most of the cereals mainly maize suffers from dearth of micronutrients *viz*., zinc (Zn), Iron (Fe) and boron (B) (Rashid and Rayan, 2004) [2]. Maize, being C_4 crop is responsive to nutrients at all the crop growth stages; and with adequate supply, it gives higher production (Song and Dia, 2000) [3]. Crops grown in arid or semi-arid regions are mostly exposed to low soil fertility and exhibit multiple nutrient deficiencies due to low organic matter and alkaline calcareous nature that limit the crop production (Rafique *et al*., 2006) [4]. The rainfed soils of Karnataka are deficient in Zn, Fe and B as compared to irrigated areas.

The prime reason of this deficiency is the unavailability of irrigation water to apply the nutrients to crop plants under field conditions in rainfed regions. Secondly, most of the farmers in Karnataka do not apply micronutrient especially Zn, Fe and B that lead to their deficiency in soil and causes yield reduction. Zinc being essential nutrient plays a significant role in stomatal regulation and reducing the tensions of less water by creating ionic balance in plant system (Baybordi, 2006) [5] and is involved in various physiological processes such as synthesis of protein and carbohydrates (Yadavi *et al*., 2014) [6]. In addition, iron is involved in chlorophyll synthesis and it is essential for the maintenance of chloroplast structure and function. Similarly, B application improves growth, and enhances stress tolerance in plants and improves grain production (Hussain *et al*., 2012) [7]. These micronutrients play an important role in the basic plant functions like photosynthesis, protein and chlorophyll synthesis (Cakmak, 2008) [8]. These nutrients are also involved in root growth, synthesis of proteins and carbohydrates, increase flower setting (Moeinian *et al*., 2011) [9] and reduce kernel abortion (Wahid *et al*., 2011) [10]. The nutrient deficiency can be corrected by applying micronutrient containing fertilizers. The nutrients can be applied to crop plants in a variety of ways like soil application and foliar spray. Every method has its advantages and disadvantages (Rehim *et al*., 2012) [11], depending upon the soil and climatic conditions of the area. Soil application of Zn, Fe and B is highly helpful in improving the maize productivity (Kanwal *et al*., 2010) [12]. However, from economic point of view foliar application along with soil application are better options because these are economical than soil application.

Foliar application of micronutrients is 6 to 20 times more useful than the soil application and improves the nutrition (Arif *et al*., 2006) [13]. Foliar application of Zn reduces the micronutrient deficiencies and it is an efficient method because nutrients are easily absorbed through leaves and is best option to compensate micronutrient deficiencies in shorter period of time under rainfed regions (Nasiri *et al*., 2010) [14]. Foliar application of B at earlier, middle and later growth stages along with recommended dose of NPK resulted in higher maize grain and fodder yield (Soomro *et al*., 2011) [15]. Similarly, in B and Zn deficient soils, their combined soil application significantly increased the plant height, root length, leaf area index, shoot and root dry weight and chlorophyll content (Panhwar *et al*., 2011) [16]. Though the role of micronutrients, like Zn and B application in improving maize performance is well documented; however very little is known about the effect of combined application of Zn, Fe and B through different methods on maize performance grown under rainfed conditions. Therefore, ICAR- Krishi Vigyan Kendra, Haveri has conducted On-farm testing (OFT) in maize growing farmers field on the effect of soil and foliar application of micronutrients on growth and yield of maize. Through On-Farm Testing Krishi Vigyan Kendra does comparative studies in farmers' fields to come to conclusion that which of the technologies tested is more suitable to the resources available in the district and is cost effective. This is a form of participatory study where farmers' perspective is given more importance. On-Farm Testing is aimed at testing the proven technologies evolved at Research Stations on farmers' field with their farming system perspective in view under their management and their active participation so as to convince them the relevance and viability of the new technology.

Material and Methods

On-farm testing (OFT) was conducted to assess the impact of soil and foliar application of micronutrients *viz*., Zn, Fe and B on the yield and economics of maize over farmers' practice. An attempt to test the technology through participatory approach on the economics of the district was made. The study was conducted in Haveri district of Karnataka, which comes under Agro-climatic Zone – 8 *i.e.* Northern Transitional Zone. This on-farm testing was conducted by Krishi Vigyan Kendra, Haveri during *kharif* season of 2016-17 and 2017-18 in maize growing farmer's field in Suttakote village of Hirekeruru taluk, Haveri district. The on-farm testing was conducted in an area of 1.2 ha in two farmers' field under rainfed condition. Soil and foliar application of micronutrients were compared with farmers practice *i.e.* treated as a control. Totally three technology options were tested *viz*., TO_1 (Farmers' practice), TO_2 (RDF + (Soil application of $ZnSO_4$+ $FeSO_4$ + FYM)) and TO_3 (RDF + Soil application of 0.8 kg /ac borax + Foliar application of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.1 % solubor @ 30 & 45 DAS). Before start of the trial composite soil samples were collected at 0 to 30 cm depth of soil from the study area by using screw auger. The soil topography was fairly uniform with a slope of one per cent in one direction in both the farmers' field. The composite soil samples of about 250 g was collected and mixed thoroughly, air dried and passed through a 2.0 mm sieve and used for physical and chemical analysis as per standard procedures. The results of soil analysis are furnished in Table 1.

Results and Discussion

The soil chemical characteristics of the study area indicated that there was slight increase in pH level of the soil in all the technology options after harvest of the crop as compared to initial status (7.50 and 7.40 during 2016-17 and 2017-18, respectively) during both the years of study as well as in pooled data (7.45). Among different technology options, TO_3 i.e. RDF + soil application of 0.8 kg ac^{-1} borax + foliar application of 0.5 % $ZnSO_4$ + 0.5% $FeSO_4$ + 0.1 % solubor @ 30 & 45 DAS has recorded higher pH value of 7.62 and 7.52 during 2016-17 and 2017-18, respectively as compared to rest of the technology options. Similar trend was noticed in pooled data (7.57). In addition, there was increase in the quantity of soil available nutrients after harvest of the crop as compared to initial nutrient status of the soil. Among different technology options, TO_3 has recorded higher quantity of soil available N (292 and 280 kg ha^{-1} during 2016-17 and 2017-18, respectively), P (26.2 and 26.6 kg ha^{-1} during 2016-17 and 2017-18, respectively), K (180 and 178 kg ha^{-1} during 2016-17 and 2017-18, respectively), Zn (0.82 and 0.82 ppm during 2016-17 and 2017-18, respectively), Fe (1.82 and 1.68 ppm during 2016-17 and 2017-18, respectively) and B (0.76 and 0.70 ppm during 2016-17 and 2017-18, respectively) as compared to rest of the technology options during both the years of study as well as in pooled data (286, 26.4, 179 kg ha^{-1} of N, P and K, respectively and 0.82, 1.75 and 0.73 ppm of Zn, Fe and B, respectively) (Table 1).

Table 1a: Soil chemical characteristics of study area (pH and primary nutrients)

Status	Technology options	pH			N			P			K		
					Kg ha^{-1}								
		2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Initial	-	7.50	7.40	7.45	286	242	264	25.5	23.4	24.5	175	155	165
Final (After harvest of the crop)	TO_1	7.65	7.65	7.65	268	259	264	22.6	21.6	22.1	168	162	165
	TO_2	7.58	7.58	7.58	288	268	278	25.0	25.8	25.4	182	173	178
	TO_3	7.62	7.52	7.57	292	280	286	26.2	26.6	26.4	180	178	179

Table 1 b: Soil chemical characteristics of study area (micronutrients)

Status	Technology options	Zn			Fe			B		
		ppm								
		2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Initial	-	0.52	0.48	0.50	1.56	1.37	1.47	0.60	0.54	0.57
Final (After harvest of the crop)	TO_1	0.43	0.41	0.42	1.25	1.28	1.27	0.52	0.51	0.52
	TO_2	0.75	0.75	0.75	1.65	1.54	1.60	0.72	0.62	0.67
	TO_3	0.82	0.82	0.82	1.82	1.68	1.75	0.76	0.70	0.73

Among different technology options, TO_3 has recorded higher number of grains per cob (474 and 489.5 during 2016-17 and 2017-18, respectively), cob length (14.8 cm and 14.6 cm during 2016-17 and 2017-18, respectively) and cob girth (4.7 cm and 11.2 cm during 2016-17 and 2017-18, respectively) as compared to the rest of the technology options during both the years of study as well as in pooled data (481.75, 14.7 cm and 8.0 cm of no. of grains cob^{-1}, cob length and cob girth, respectively). However, maize produced less number of grains per cob (308 and 299.5 during 2016-17 and 2017-18, respectively), cob length (11.2 cm and 11.3 cm during 2016-17 and 2017-18, respectively) and cob girth (3.8 cm and 8.8 cm during 2016-17 and 2017-18, respectively) in farmers practice during both the years of study as well as in pooled data (303.75, 11.3 cm and 6.3 cm of no. of grains cob^{-1}, cob length and cob girth, respectively) (Table 2). Increase in yield parameters through soil and foliar application of Zn, Fe and B mixture might be attributed higher crop growth rate. It is the fact that B application enhanced the pollen tube germination, grain setting which is involved in metabolism, increased root growth, synthesis of proteins carbohydrates (Moeinian *et al*., 2011) [17] which improved the yield related traits by the application of B and other micronutrients (Tabrizi *et al.*, 2009) [18].

Similarly, plants fertilized with RDF and soil and foliar application of micronutrients produced 16.96 per cent and 25.27 per cent more grain yield (67.25 and 69.69 q ha^{-1}during 2016-17 and 2017-18, respectively) than farmers practice (57.50 and 55.63 q ha^{-1}during 2016-17 and 2017-18, respectively). Similar trend was observed in pooled data also [21.03 % higher grain yield (68.47 q ha^{-1}) than farmers practice (56.57 q ha^{-1})]. Grain yield is the combined effect of different yield related traits. Increase in grain yield under combined application of soil and foliar applied Zn, Fe and B mixture might be attributed to notable expansion in entire yield related traits (Table 2). Similarly, it might be due to higher translocation of carbohydrates to grains (Rajaie and Ziaeyan, 2009) [19], which ultimately resulted in higher grain yield under foliar application of micronutrients. Similar results were reported by Parasuraman *et al.* (2008) [20], Paramasivan *et al.* (2010) [21], Soomro *et al.* (2011) [22] and Mohsin *et al.* (2014) [23].

Table 2: Yield parameters and yield of maize under on-farm testing

Technology Options	No. of grains/cob			Cob Length(cm)			Cob Girth(cm)			Yield (q/ha)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
TO_1	308	299.5	303.75	11.2	11.3	11.3	3.8	8.8	6.3	57.50	55.63	56.57
TO_2	412	417.0	414.50	13.2	13.9	13.6	4.2	9.2	6.7	61.50	62.19	61.85
TO_3	474	489.5	481.75	14.8	14.6	14.7	4.7	11.2	8.0	67.25	69.69	68.47

Economic analysis of the on-farm testing indicated that application of RDF + Soil application of 0.8 kg /ac borax + foliar application of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.1 % solubor @ 30 & 45 DAS has improved the gross income (Rs. 94822 and Rs. 99305 during 2016-17 and 2017-18, respectively), net income (Rs. 76622 and Rs. 81055 during 2016-17 and 2017-18, respectively) and benefit: cost ratio (BCR) (5.21 and 5.44 during 2016-17 and 2017-18, respectively) against farmers practice during both the years of study and similar trend was noticed in pooled data also (Rs. 97064, Rs. 78839 and 5.21 of gross return, net return and B:C ratio, respectively) (Table 3). Farmers adopt any technology by considering its economic feasibility in terms of cost and profit involved for growing any crop (Khan *et al*., 2012)[24]. Economic analysis of the current study showed that combined soil and foliar application of Zn, Fe and B found superior over other nutrient treatments and application methods to achieve maximum net income and BCR (Table 3) due to increased maize yield, which is main concern of the farmers.

Table 3: Economics of maize under on-farm testing

Technology Options	Cost of Cultivation (Rs. ha^{-1})			Gross Return (Rs. ha^{-1})			Net Return (Rs. ha^{-1})			B:C ratio		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
TO_1	16900	16330	16615	81075	79266	80171	64175	62936	63556	4.79	4.85	4.82
TO_2	17500	17580	17540	86715	88617	87666	69215	71037	70126	4.95	5.04	5.00
TO_3	18200	18250	18225	94822	99305	97064	76622	81055	78839	5.21	5.44	5.21

*Market rate of produce: Rs. 1410 q^{-1} and Rs. 1425 q^{-1} during 2016-17 and 2017-18, respectively.

Conclusion

Through On-Farm Testing Krishi Vigyan Kendra does comparative studies in farmers' fields to know that which of the technologies tested is more suitable to the resources available in the farmers field is cost effective. This is a form of participatory study where farmers' perspective is given more importance. In the above study combined application of Zn, Fe and B on foliage has improved the grain yield due to substantial expansion in entire yield related traits and also it has improved the economic level of the farming community.

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