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Effect of foliar application of zinc, boron and iron on seed yield and quality of sweet corn cv. Madhuri

Jolli RB, Nayak VH, Boranayaka MB and Latha HC

Abstract
The experiment was carried out in the field of Regional Agricultural Research Station, Vijayapur during *kharif* 2018 to evaluate the effect of foliar application of zinc, boron and iron on growth, seed yield and quality parameters of sweet corn (cv. Madhuri). The experiment was planned with eight treatments *viz.*, T_1: Zinc 0.2%, T_2: Boron 0.1%, T_3: Iron 0.1%, T_4: Zinc 0.2% + Boron 0.1%, T_5: Zinc 0.2% + Iron 0.1%, T_6: Boron 0.1% + Iron 0.1%, T_7: Zinc 0.2% + Boron 0.1% + Iron 0.1%, T_8: Control (No treatment) during *Kharif* 2017 at MARS, University of Agricultural Sciences, Dharwad with three replications in RBD. The results revealed that, the foliar application of zinc 0.2% + boron 0.1% + iron 0.1% + RDF (100 kg N, 50 kg P_2O_5, 25 kg K_2O, 10 kg SO_4 and FYM 7.5 t ha^{-1} has recorded higher plant height (200.6 cm), cob weight (102.0 g), seeds per cob (590.7), 100 seed weight (12.03 g) and seed yield (31.79 q/ha) and seed quality traits like germination (99.30 %), seedling vigour index (4210) and seedling dry weight (2.50 g) as compared to other treatments. It was revealed from the present investigation that the application of RDF in combination with the foliar application of zinc @ 0.2%, boron @ 0.1% and iron @ 0.1% recorded significantly higher seed yield, fodder yield and shelling percentage followed by the foliar spray of zinc @ 0.2% and boron @ 0.1% as this treatment recorded higher seed yield, fodder yield and shelling percentage over other combinations of major and micronutrients application in sweet corn.

Keywords: Sweet corn, zink, boron and iron, foliar application, seed quality and yield attributes

Introduction
Sweet corn (Zea mays ssp. saccharata) is an important vegetable which produced kernels consisting mostly sugar rather than starch, it became more valued in recent years, it is consumed as fresh, frozen or conserved and also used in the salads. The nutrient composition of sweet corn is very important for human health and diet. Among the various factors affecting the growth, yield and quality of sweet corn, nutrient management plays a vital role. It is desired that the soil should have the required nutrients in sufficient quantities and in optimum proportion to meet the nutritional requirement of the crop. Hence, soil fertility plays an important role in sustaining the crop productivity and seed yield. Presently, the chemical fertilizers are considered as the major source of nutrients. However, apart from major nutrients, micronutrients also play an important role in quality seed production. The dire need for intensive land use drew attention for applying micronutrients to maize.
Among the micronutrients, zinc is one of the micronutrients recognized as an essential for the plants. It is a micronutrient most commonly limiting crop yields in Indian soils. Some crops are more responsive to Zn than others. Zinc is transported to plant root surface through diffusion. It helps in the synthesis of plant growth substances and enzyme systems and is essential for promoting certain metabolic reactions. It is also necessary for production of chlorophyll and carbohydrates. Zinc is not translocated within the plant, so symptoms first appear on the younger leaves. Boron (B) is required for proper growth and yield of crop plants (Tariq and Mott, 2006; Kakar *et al.*, 2000) [26, 9]. It plays important role in water relations, cell wall formation; cations and anions absorption, Boron deficiency in the plants results in terminal bud growth stoppage and death of young leaves. Sugar transport, pollen formation, pollen germination and development of nodules are also affected in its absence. Seed and grain production are also reduced with low boron supply (Sillanpae, 1982) [23]. Iron plays an important role in the synthesis of chlorophyll and prosthetic group, also helps in the absorption of other nutrients. As a constituent of chlorophyll, it regulates respiration, photosynthesis, reduction of nitrates and sulphates. Though the role of micronutrients, like Zn, B and Fe application in improving maize performance is well documented; however very little is known about the effect of combined application of Zn, B and Fe through different combinations on sweet corn yield and quality.

Therefore, this field study was designed to evaluate the effect of foliar application of zinc, boron and iron on seed yield and quality of sweet corn.

Materials and Methods

The field experiment was carried out to know the effect of foliar application of micronutrients like Zn, B and Fe either alone or in combination on quantitative and qualitative parameters of sweet corn at Regional Agricultural Research Station, Vijayapur during *kharif* 2018. It comprised of eight treatments *viz*., T_1: Zinc 0.2%, T_2: Boron 0.1%, T_3: Iron 0.1%, T_4: Zinc 0.2% + Boron 0.1%, T_5: Zinc 0.2% + Iron 0.1%, T_6: Boron 0.1% + Iron 0.1%, T_7: Zinc 0.2% + Boron 0.1% + Iron 0.1%, T_8: Control (No treatment). RDF (100:50:25:10 N, P_2O_5, K_2O and SO_4 per ha and FYM @ 7.5 t/ha, respectively) as a basal dose is common for all the treatments. The cultural operations were followed as per the package of practice and treatments were imposed as per the treatments of the experiment. The regular crop protection measures were taken care during the crop growth period. All observations were recorded on five randomly selected plants which were tagged at early stage of the crop within the net plot area for the parametrs *viz*., *Crop growth parameters:* Plant height (cm), Days to 50 per cent tasseling, Days to 50 per cent silking, Days to maturity, Cob length (cm) and Cob girth (cm); *Yield and yield components:* Cob weight (g), Number of seed rows per cob, Number of seeds per rows, Number of seeds per cob, Seed yield per plant (g), Seed yield per plot (kg), Seed yield per hectare (q), Stover yield per hectare (t/ha), Shelling percentage and 100 seed weight (g); *Seed quality parameters:* Seed germination (%),Root length (cm), Shoot length (cm), Seedling dry weight (g), Vigour index and Electrical conductivity (dSm^{-1}) of seed leachate.

Statistical analysis

The data collected from the experiment was analyzed statistically by adopting the procedures as described by Sundarajan *et al*. (1972) [25] and critical differences were calculated at one per cent level, wherever, 'F' test was significant. The data on germination percentage was transformed into Arcsine square root percentage values (Snedecor and Cochran, 1967) [24].

Results and Discussion

Maize belongs to the family Poaceae and is one of the major food and industrial crops of the world. Indian economy continued to receive great support through this commercial crop known as "The King of crops" worldwide. Sweet corn is one of the specialty corns which are coming up in recent years. Few composite varieties and hybrids have been released for cultivation. Since the growth habit, cob and seeds of sweet corn is varied with the commercial corn. The quality of sweet corn depends upon the mother plant nutrition. In the present investigation it is evident from the data that, there was an increase in the seed yield due to influence of foliar spray of zinc, boron and iron along with soil application of major nutrients as compared to only major nutrients.

Growth parameters

The Effect of foliar spray of zinc boron and iron on plant growth parameters *viz*., plant height at different growth stages, days to 50 % tasseling and silking, tassel length and days to maturity of sweet corn cv. Madhuri was presented in Table 1. Higher plant height (200.6 cm) was observed with foliar spray of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% at harvest. The increased plant height was mainly attributed to high level of auxin production such as indoleacetic acid (IAA). Besides, zinc involved in the synthesis of tryptophan, plays an important role in catalytic part of several enzymes. Tryptophan is precursor for synthesis of IAA. IAA involved in the process of cell differentiation and elongation. In the absence of IAA plant growth was stunted and reduced leaf size with mottled appearance. These results are in agreement with the findings of Verma *et al.* (2006) [28] in maize, Negm *et al.* (2001) [15] in wheat.

The less number of days to 50% tasseling and silking (46.67 and 51.33, respectively) were noticed with the foliar spray zinc @ 0.2% + boron @ 0.1% + iron @ 0.1%. This may be due to increased pollen formation and pollen grain germination. On the other hand, auxin indirectly controlled ethylene activity there by early flowering was induced. Zinc also contributed to increased flower retention by preventing abscission layer formation in flowers. At the same time it also increased the sink demand as well as translocation of photosynthates from source to sink. This might be due to transportation of the current photosynthates being accumulated in leaf and stem, which took place for prolonged period towards flowering. These results are in conformity with the results of Tekale *et al*. (2009) [27] in pigeon pea.

Among the treatments there was no significant difference in days to maturity. However foliar spray zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% hasten the maturity. It may be due to adequate nutrient supply which might have helped in increased root growth to extract nutrients and moisture more efficiently from deeper soil layers. Thus improving all the growth and yield attributing characters as a result of increased activity of many enzymes and photosynthesis leading to early maturity, this is in agreement with the findings of Gawade (1998) [8] in sweet corn.

Yield parameters

The results of foliar spray of zinc, boron and iron on yield components of sweet corn cv. Madhuri were represented in Table 2. The cob length and cob girth were higher (Plate 1) with foliar spray of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% (16.64 cm and 4.1 cm, respectively) which was attributed to increased synthesis of starch, nitrogen, soluble proteins and specific activity of carbonic anhydrase, acid phosphatase and ribonuclease resulted in higher cob length over control (12.9 cm and 3.1 cm, respectively). Similarly, increased cob weight per plant (102.0 g) was due to increased photosynthetic activity, its assimilation that led to the increased sink size (seeds). These results are in agreement with the reports of Verma *et al.* (2006) [28] in maize.

Higher number of seed rows per cob was recorded with the foliar spray of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% (14.67) over control (11.96) (Table 2). The increased number of seed rows per cob may be due to the beneficial effect of zinc and boron could be attributed to its role in metabolic activity mainly protein synthesis as well as nitrogen fixation pollen viability and metabolism of N and P, carbohydrate synthesis and fats in the plant (Oyinlola, 2007) [17] in sunflower. Similarly Yield improvement in any crop could be attributed to the higher production of assimilates and better partitioning of photo synthates towards reproductive and economic sinks (seeds). Boron is an essential element in pollen germination and pollen tube growth and fertilization which might have increased sweet corn seed yield. This can also be attributed to transportation of higher amount of assimilates into seed tissues. Boron involved in a number of metabolic pathways and can act in the regulation of metabolic processes, similar to plant hormones which resulted in higher dry matter production. Chaudry *et al*. (2007) [6] reported that use of iron either only or combination with zinc and boron increased the wheat seed yield. Abdul-Wahab (2008) [1] reported micronutrients, especially iron and zinc which act as metal components of various enzymes and are also associated with photosynthesis and protein synthesis and iron has important functions in plant metabolism, such as activating catalase enzymes. So, iron, boron and zinc have important roles in growth and yield of plants.

Likewise, higher number of seeds per row and number of seeds per cob was recorded with foliar spray of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% (590.76 and 40.27, respectively) over control (379.85 and 31.76), due to the beneficial effects on chlorophyll content and indirectly influenced the more photosynthesis and higher reproduction. The channelization of photosynthates during reproductive stages might have influenced by zinc, by way of its involvement in electron transport chain system. Siam *et al*. (2008) [22] in maize reported that application of boron increased the number of grains per cob as grains number are direct index of pollen viability and where boron is proved to be increased fruit set and pollen viability, and significant affect on pollen formation. Choudhary *et al.* (2000) [7] in cowpea and Pathak and Pandey (2010) [18] in maize reported that zinc and boron deficient plants showed a decreased pollen receptive area and a persistent cuticle over the stigmatic surface which affected the germinability of the pollen grains, seed abortion with poor seed setting in maize. The zinc and boron fertilized sweet corn reversed the effects.

Hundred seed weight was influenced by foliar spray of zinc, boron and iron. Higher hundred seed weight (12.03 g) was recorded with foliar spray of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% over only major nutrients, as zinc is a constituent of number proteins, which form a structural modification of DNA binding regions of the transcriptional regulatory protein and play an important role in increasing the seed weight. These results are in agreement with those of Siam *et al.* (2008) [22] in maize. Boron increases the sugar transport, pollen formation, seed germination and development of nodules. Seed and grain production are also increased with boron supply (Sillanpae, 1982) [23].

Among the treatments, significantly higher seed yield (31.79 q /ha) and fodder yield (4.23 t/ha) was recorded with foliar spray of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% followed by zinc @ 0.2% + boron @ 0.1% (29.86 q/ha of seed and 3.86 t/ha of fodder yield), which were on par with the application of boron @ 0.1% + iron @ 0.1% (28.16 q/ha of seed and 3.98 t/ha of fodder yield). The increased seed and fodder yields were to an extent of 47.1 and 48.9 per cent respectively over RDF (100:50:25:10, N: P_2O_5:K_2O:SO_4 kg/ha and 7.5 ton FYM/ha) (Table 2). The increased seed yield may be due to improved yield components like higher cob length, cob girth, cob weight, number of seed rows per cob, number of seeds per row ant total number of seeds per cob and hundred seed weight. The difference in fodder yield was ascribed to the profuse growth of plant and higher total dry matter accumulation. This was mainly due to increased metabolic rate which resulted in more number of leaves per plant throughout growing period. Ali *et al.* (2008) [2] and Welch (2003) [29] who has stated that application of micronutrient combinations gave the highest biological yield and grain yield was also influenced which might be attributed to the additional availability of nutrients. Similar pattern in response to mix fertilization of micronutrients in maize was also given by Lana *et al*. (2007) [12].

Shelling percentage (77.59) was significantly higher with foliar spray of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% due to greater proportion of seed and biological yields as compared to control (64.86) (Table 2). Babu *et al.* (2012) [3] reported that application of 20 kg $ZnSO_4$ and 5 kg $FeSO_4$ per ha recorded higher harvest index (37.9%) over control in pigeon pea. These results are in agreement with the findings of Ram *et al.* (2008) [20] in mungbean; Shanti *et al.* (2008) [21] in rice and Valenciano *et al.* (2011) in chickpea.

Seed quality parameters

In the present investigation, results of foliar spray of zinc, boron and iron on resultant seed quality parameters of sweet corn cv. Madhuri were presented in Table 3. The average germination percentage of sweet corn seeds were 97.90 (Table 3). There was significant difference among the treatments in germination percentage. Higher germination percentage (99.30) was observed with the foliar spray of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1%.Whereas, the lowest germination percentage (98.75) was observed in the control. The higher germination may be due to the higher catalytic activity of zinc, boron and iron in enzyme systems which are involved in the pre and post-germination events, leading to better and higher seed germination. These results are in agreement with the findings of Biradar *et al*. (2001) [5] in sorghum seeds.

Increase in shoot length, root length and seedling dry weight (20.02 cm, 22.50 cm and 1.18 g, respectively) with foliar spray of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% over control (15.74 cm, 18.7 cm and 0.85 g, respectively) (Table 3). Many researchers observed that iron and zinc is closely related to nitrogen metabolism pathway of plants, thus caused increase in protein synthesis. Zinc deficiency significantly affected the seedling growth including root and shoot development. Further, plant enzymes were activated by zinc and iron which was involved in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, and regulation of auxin synthesis which increased the root and shoot growth and development. These results are in agreement with the reports of Kakar *et al.* (2000) [9] in wheat and Lukaszewski and Blevins (1996) [14] in wheat.

In the present study, it was observed that foliar application of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1% resulted in a higher seedling vigour index (4210) of sweet corn as compared to control (3161) (Table 3). Radpoor and Rimaz (2007) [19] in their study on priming of maize seeds with iron, zinc, and boron solutions, came to the same conclusion. Furthermore, Louzada and Vieira (2005) [13] verified that the application of very high doses of micronutrients to bean seeds, due to their toxic effects, caused an increase of abnormal and dead seedlings. Significant differences have been observed in the dry matter accumulation and seedling vigour index of red periwinkle (*Catharanthus roseus* L.) between primed and unprimed seeds with zinc and boron (Karthikeyan *et al.*, 2007) [11].

Electrical conductivity of seed leachate varied significantly due to different treatments. Significantly lowest electrical conductivity was recorded (0.141 dSm^{-1}) with foliar application of zinc @ 0.2% + boron @ 0.1% + iron @ 0.1%. Whereas, the highest electrical conductivity of seed leachate (0.231 dSm^{-1}) was recorded in the control. It may be due to the role of supply of macro nutrients that led to the proper development of seed and seed coat which resulted in prevention of leaching of nutrients from the seed. This statement is also in accordance with the reports of Badiyala and Verma (1991) [4] and Okon *et al*. (1981) [16] in maize, Similarly by Kale and Bano (1986) [10] in rice and wheat.

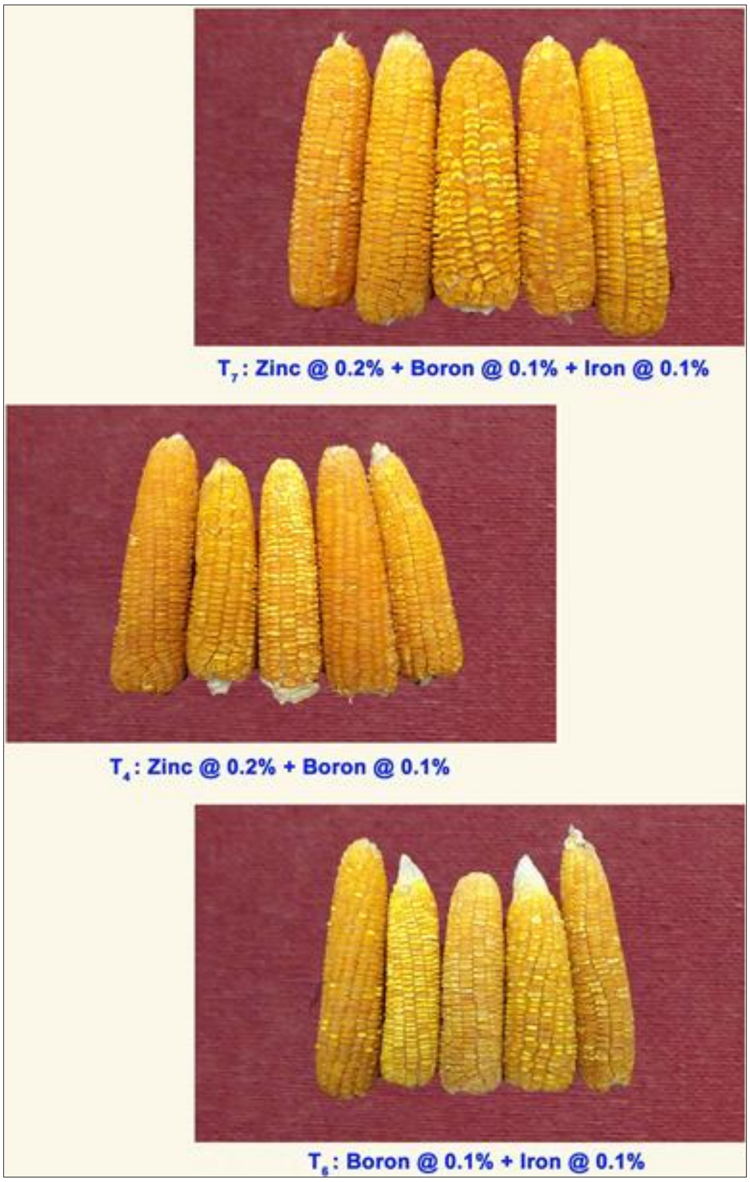

Plate 1: Effect of foliar application of zinc, boron and iron on sweet corn (cv. Madhuri) cobs

Table 1: Effect of foliar spray of zinc boron and iron on plant height at different growth stages, days to 50 % tasseling and silking, tassel length and days to maturity of sweet corn cv. Madhuri

Treatments	Plant height (cm)			Days to 50% tasseling	Days to 50% silking	Tassel length (cm)	Days to maturity
	30 DAS	60 DAS	At maturity				
T_1: Zinc @ 0.2%	41.8	174.9	188.6	52.00	57.13	33.22	91.58
T_2: Boron @ 0.1%	42.0	170.2	184.9	50.00	55.17	35.00	93.00
T_3: Iron @ 0.1%	42.4	172.8	186.7	53.67	58.67	32.62	92.00
T_4: Zinc @ 0.2% + Boron @ 0.1%	42.9	180.0	194.2	48.67	52.67	37.50	89.86
T_5: Zinc @ 0.2% + Iron @ 0.1%	44.1	181.4	196.0	51.33	55.93	34.39	90.50
T_6: Boron @ 0.1% + Iron @ 0.1%	42.0	177.8	190.0	49.33	55.17	36.19	91.00
T_7: Zinc @ 0.2% + Boron @ 0.1% + Iron @ 0.1%	44.5	186.4	200.6	46.67	51.33	39.00	90.00
T_8: Control (No spray)	41.6	165.7	181.0	56.67	61.45	30.37	92.64
Mean	42.7	176	190	51.04	55.94	34.79	91.32
S.Em±	0.97	2.20	3.33	0.34	0.46	0.68	2.13
CD (P=0.05)	NS	6.66	10.10	1.04	1.40	2.07	NS

* NS - Non significant, DAS – Days after sowing

1. RDF (100:50:25:10, N: P_2O_5:K_2O:SO_4 kg/ha and 7.5 ton FYM/ha) is common for all treatments.
2. Spraying was done at 30 and 45 DAS.
3. Sources of micronutrients spray.

Zinc spray = $ZnSO_4$@ 0.2% (chelated zinc sulphate)
Iron spray = $FeSO_4$ @ 0.1% (ferrous suplhate)
Boron spray = Boron @ 0.1% (solubor)

Table 2: Effect of foliar spray of zinc, boron and iron on yield components of sweet corn cv. Madhuri

Treatments	Cob length (cm)	Cob girth (cm)	Cob weight (g)	Seed rows per cob	Seeds per row	Seeds per cob	100 seed weight (g)	Seed yield (g/plant)	Seed yield (kg/plot)	Seed yield (q/ha)	Shelling percentage	Stover yield (t/ha)
T_1: Zinc @ 0.2%	13.99	3.6	74.3	13.00	35.44	460.72	10.79	49.7	3.14	24.23	71.12	3.38
T_2: Boron @ 0.1%	14.53	3.7	85.8	13.42	37.51	503.38	11.45	57.6	3.52	27.16	74.56	3.16
T_3: Iron @ 0.1%	13.57	3.4	69.0	12.87	34.63	445.69	10.41	46.4	2.98	22.99	68.40	3.42
T_4: Zinc @ 0.2% + Boron @ 0.1%	16.00	3.8	96.7	14.00	38.67	541.38	11.78	63.8	3.87	29.86	75.45	3.86
T_5: Zinc @ 0.2% + Iron @ 0.1%	14.40	3.6	81.6	13.30	36.60	486.78	11.07	53.9	3.29	25.39	72.98	3.98
T_6: Boron @ 0.1% + Iron @ 0.1%	15.00	3.9	91.7	13.67	38.08	520.55	11.61	60.4	3.65	28.16	74.23	3.62
T_7: Zinc @ 0.2% + Boron @ 0.1% + Iron @ 0.1%	16.64	4.1	102.0	14.67	40.27	590.76	12.03	71.1	4.12	31.79	77.59	4.23
T_8: Control (No spray)	12.90	3.1	61.4	11.96	31.76	379.85	9.60	36.5	2.80	21.60	64.86	2.84
Mean	14.63	3.6	82.8	13.36	36.62	489.24	11.09	54.9	3.42	26.40	72.40	3.56
S.Em±	0.24	0.1	1.7	0.19	0.63	12.00	0.07	1.5	0.08	0.63	1.70	0.08
CD (P=0.05)	0.74	0.3	5.3	0.58	1.91	36.40	0.21	4.6	0.25	1.92	5.16	0.26

1 RDF (100:50:25:10, N: P_2O_5:K_2O:SO_4 kg/ha and 7.5 ton FYM/ha) is common for all treatments.
2 Spraying was done at 30 and 45 DAS.
3 Sources of micronutrients spray.
Zinc spray = $ZnSO_4$@ 0.2% (chelated zinc sulphate)
Iron spray = $FeSO_4$ @ 0.1% (ferrous suplhate)
Boron spray = Boron @ 0.1% (solubor)

Table 3: Effect of foliar spray of zinc, boron and iron on resultant seed quality parameters of sweet corn cv. Madhuri

Treatments	Germination percentage	Shoot length (cm)	Root length (cm)	Seedling vigour index	Seedling dry weight (g)	Electrical conductivity of seed leachates (dSm^{-1})
T_1: Zinc @ 0.2%	97.56 (81.05)*	17.03	20.19	3558	2.07	0.186
T_2: Boron @ 0.1%	97.69 (81.30)	18.12	21.00	3820	2.27	0.160
T_3: Iron @ 0.1%	97.19 (80.39)	17.29	19.80	3523	2.05	0.207
T_4: Zinc @ 0.2% + Boron @ 0.1%	98.75 (83.67)	19.48	21.97	4075	2.39	0.156
T_5: Zinc @ 0.2% + Iron @ 0.1%	97.71 (81.33)	17.81	20.33	3748	2.19	0.178
T_6: Boron @ 0.1% + Iron @ 0.1%	98.00 (81.92)	18.86	21.67	3945	2.29	0.162
T_7: Zinc @ 0.2% + Boron @ 0.1% + Iron @ 0.1%	99.30 (85.28)	20.02	22.50	4210	2.50	0.141
T_8: Control (No spray)	96.98 (80.04)	15.74	18.17	3161	1.94	0.231
Mean	97.90 (81.87)	18.04	20.70	3755	2.21	0.17
S.Em±	0.28	0.38	0.37	75.31	0.05	0.01
CD (P=0.05)	0.85	1.18	1.13	228.41	0.15	0.02

* Figures in the parenthesis indicate arcsine root transformed values and without parenthesis indicate the original values.
1. RDF (100:50:25:10, N: P_2O_5:K_2O:SO_4 kg/ha and 7.5 ton FYM/ha) is common for all treatments.
2. Spraying was done at 30 and 45 DAS.
3. Sources of micronutrients spray.
Zinc spray = $ZnSO_4$@ 0.2% (chelated zinc sulphate)
Iron spray = $FeSO_4$ @ 0.1% (ferrous suplhate)
Boron spray = Boron @ 0.1% (solubor)

Conclusion

Based on the present study, it can be concluded that the application of RDF(100:50:25:10, N: P_2O_5:K_2O:SO_4 kg/ha and 7.5 ton of FYM/ha) in combination with the foliar application of zinc @ 0.2%, boron @ 0.1% and iron @ 0.1% recorded significantly higher seed yield (31.79 q /ha), fodder yield (4.23 t/ha) and shelling percentage (77.59). It was followed by the foliar spray of zinc @ 0.2% and boron @ 0.1% as this treatment recorded seed yield (29.86 q/ha), fodder yield (3.86 t/ha) and shelling percentage (75.45) over other combinations of major and micronutrients application in sweet corn. These will improve the crop allometry, yield components and productivity of sweet corn.

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