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Morpho-physiological impact of growth indices to iron and zinc Biofortification on growth and yield of sweet corn (*Zea mays* L. *Saccharata*)

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ABSTRACT
Field experiment was carried out during kharif 2017 and 2018 in black soil at farmer field at Kumarnahally village, Huvina hadagali Tq, the experiment was laid out in a randomized block design (RCBD) comprising 13 treatments replicated thrice. Bellary District representing the Northern Dry Zone (Zone-II) which is located at latitude of 15.04' N, longitude of 75.94' E and 561 meters which is above mean sea level to study the Morpho-physiological impact of growth indices to iron and zinc biofortification on growth, yield and quality of sweet corn (Zea mays L. Saccharata) to evaluate and analysis of sweet corn through biofortification to achieve higher growth, yield and quality parameters. The results of pooled data revealed that seed treatment by $ZnSO_4$ @ 0.5 % & $FeSO_4$ @ 0.5 % and foliar spray of $ZnSO_4$ @ 1.0 % & $FeSO_4$ @1.0 % which was on par with seed treatment with $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded significantly higher plant height, number of leaves, leaf dry weight, stem dry matter, cob dry weight and total dry matter by enhancing LA (Leaf area), TDM (Total dry matter), LAI (Leaf area index), LAD (Leaf area duration), AGR (Absolute growth rate), CGR (Crop growth rate), NAR (Net assimilation rate), RGR (Relative growth rate), SLW (Specific leaf weight), SLA (Specific leaf area) and yield parameters like number of seeds per row, number of seed rows per cob, cob length, cob girth, cob weight and fresh cob yield and also quality parameter like protein content, reducing sugar, non reducing sugar, zinc concentration in grain and iron concentration in grain.
Keywords: *Sweet corn, yield parameters, zinc and iron concentration*

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INTRODUCTION

Sweet corn (*Zea mays* L. *saccharata*) is a vegetable crop grown for human consumption throughout the world. The U.S, Mexico, Nigeria, Indonesia, Hungary, South Africa, Peru, Guinea, France and Thailand were the top ten sweet corn producing countries [3]. The U.S. was the highest sweet corn producer by mass produced, 4.09 million metric tons, and by area harvested, 243,790 ha [3]. Maize is called "Queen of Cereals" because of its productive potential compared to any other cereal crop. In India, maize occupies an area of 9.2 m ha, production of 23.6 million tonnes with the productivity of 2564 kg ha^{-1}. Among all the cereals, maize in general and hybrids in particular are responsive to nutrients, and water management practices. Maize being a C_4 plant has more photosynthetic efficiency than other cereals. It is an exhaustive crop which consumes large quantity of nutrients for growth and development. Under the present trend of exploitive agriculture in India, inherent soil fertility can no longer support for the sustainable yields. It is said that nutrient supplying capacity of soil declines steadily under continuous and intensive cropping system. The intensive crop rotation and imbalance fertilizer use have resulted in a wide range of nutrient deficiencies in field. Further, about 50 per cent of applied N and 70 per cent of applied potassium to the soil remain unavailable to a crop due to a combination of leaching, fixation and volatilization

Sweet corn (*Zea mays* L. *saccharata*) also known as sugar corn, is a hybridized variety of maize (*Zea mays* L.) specifically bred to increase the sugar content. Sweet corn is introduced to India from United States of America. It has a sugary rather than a starchy endosperm with a creamy texture. The low starch level makes the kernel wrinkled rather than plumpy. The modern sweet corn varieties are classified as "normal sugary" (Su); "sugary enhanced" (Se) and "shrunken" (Sh_2), which are also called as "super sweet". These differ in sweetness and ratio of conversion of sugar to starch. All these varieties are most popular while "super sweet" is commercially used because it is very sweet with minimum conversion of sugar to starch. The sweet corn contains relatively good amount of calcium (Ca), phosphorus (P), iron (Fe) and potassium (k). It contains a higher proportion of sitosterol (47%). Due to high oil content, flavor and color develop in processed sweet corn. Sweet corn is rich in thiamine, riboflavin, niacin, vitamin B_6 and vitamin A as major vitamins. Lipoxygenase and peroxidase enzymes are directly associated with off-flavor and other quality deteriorations. In sweet corn, aroma develops due to dimethyl sulphide (DMS) and hydrogen sulphide (H_2S).

Biofortification can be achieved by two approaches; conventional breeding and agronomic biofortication. In conventional breeding method locally adopted high yielding varieties are cross breed with the variety with naturally rich in nutrients to produce high yielding and nutritious plants. Agronomic biofortication involves application of micronutrients in fertilizers Zn and Fe to the soil or through foliar feeding. Genetic biofortification offers a sustainable and low cost way to provide essential micronutrients to people but it is a long term process. Whereas, agronomic biofortification is a short term solution to the problem but this involves some technology and costs. Hence, it is necessary to combine both the strategies to maximize the enrichment of food crop with micronutrients. Micronutrient deficiency is the fifth major global challenge to human health. Iron and zinc deficiency the most common and widespread, afflicting more than half of the human population [8].

Higher yield and profits can be obtained by supplying the nutrients to the plant at critical stages of development. The yield of maize is based on the number of kernels per ear and kernel weight. These factors are predetermined at the particular leaf stage and are influenced by the availability of nutrients and environmental conditions. Timing of nutrient demand and acquisition by maize is nutrient specific and associated with key vegetative or reproductive growth stages. Knowledge of the dynamics of nutrient accumulation to sink organs and the fate of foliar-applied nutrients at specific growth stages would provide a useful tool to deliver nutrients more efficiently to meet nutrient requirement, thus improving nutrient management and sustainable intensification and obtaining greater yield.

To alleviate iron and zinc deficiency, it is required to increase iron and zinc concentration in the endosperm. Currently, there is growing concern to address micronutrient malnutrition through different interventions. Typically, these interventions are categorized into 4 major groups: pharmaceutical supplementation, industrial fortification, dietary diversification, and biofortification [6]. Generally, food fortification and supplementation strategies have been followed across world to alleviate malnutrition. However, such method has not been successful because they are neither sustainable nor cost effective for treatment of large population. Recently new approach called biofortification has been developed for alleviating malnutrition problem. Biofortification strategy involves developing crop varieties with superior nutrient qualities and it includes both increasing nutrient levels in the edible parts of fruit crops as well as their bioavailability.

The malnutrition problem is expected to increase further with the increase of population as the poor masses in the developing countries like India only depends on cereal meals *i.e.*, rice and it cannot afford to balance their diet with vegetables, milk, meat and fruit supplements [7].

MATERIAL AND METHODS

Field experiment was carried out during *kharif* 2017 and 2018 in black soil at farmer field at Kumarnahally village, Huvina hadagali Tq, Bellary District representing the Northern Dry Zone (Zone-II) which is located at latitude of 15.04' N, longitude of 75.94' E and 561 meters above mean sea level. Laboratory studies were carried out in the Department of Crop Physiology, College of Agriculture, University of Agricultural Sciences, Raichur. The experiment was laid out in randomized block design and comprised three replication and of thirteen treatments for study *viz.,* T_1: Seed treatment with $ZnSO_4$ @ 0.5 %, T_2: Seed treatment with $FeSO_4$ @ 0.5%, T_3: Foliar application of $ZnSO_4$ @ 1.0 %, T_4: Foliar application of $FeSO_4$ @ 1.0%, T_5: Seed treatment with $ZnSO_4$ @ 0.5 % + Seed treatment with $FeSO_4$ @ 0.5 %, T_6: Seed treatment with $ZnSO_4$ @ 0.5 % + foliar application of $ZnSO_4$ @ 1.0 %, T_7: Seed treatment with $ZnSO_4$ @ 0.5 % + foliar application of $FeSO_4$ @ 1.0 %, T_8: Seed treatment with $FeSO_4$ @ 0.5 % + foliar application of $ZnSO_4$ @ 1.0 %, T_9: Seed treatment with $FeSO_4$ @ 0.5 % + foliar application of $FeSO_4$ @ 1.0%, T_{10}: Seed treatment with $ZnSO_4$ @ 0.5 % + foliar application of $ZnSO_4$ @ 1.0 % + foliar application of $FeSO_4$ @ 1.0%, T_{11}: Seed treatment with $FeSO_4$ @ 0.5 % + foliar application of $ZnSO_4$ @ 1.0 % + foliar application of $FeSO_4$ @ 1.0%, T_{12}: Seed treatment with $ZnSO_4$ 0.5 % + Seed treatment with $FeSO_4$ 0.5 % + foliar application of $ZnSO_4$ 1.0 % + foliar application of $FeSO_4$ 1.0% and T_{13}:Control. The soils of the experimental site belong to black soil with optimum pH (8.34) and electrical conductivity was normal (0.108 dsm^{-1}). The nitrogen content in the soil was low (248.0 kg ha^{-1}), whereas the phosphorous was medium (43.0 kg ha^{-1}) and the potash was high (386.0 kg ha^{-1}). The organic carbon content was medium (0.45 %) besides, zinc (0.85 mg/kg^{-1}) content found to be slightly below the normal, iron (0.87 mg/kg^{-1}).

TSS was analyzed by taking 1.0 ml alcoholic aliquot, 1.0 ml 1N H_2SO_4 was added and heated at 49°C in water bath for 30 minutes for hydrolysis of the mixture. 1-2 drop of methyl red indicator was added. 1N NaOH was added drop wise for the neutralization (color was to yellow from pink). 1.0 ml Nelson Somogyi's reagent was added to it and the tube was kept in boiling water bath for 20 minutes. After cooling of the test tube, 1 ml arsenomolybdate was added and final volume was made up to 20 ml with distilled water. OD (Optical density) was noted at 540 nm. Blank was prepared in the same manner.

Extraction of protein

- Take 500 mg of seed sample and grind well in 10 ml of phosphate buffer with a pestle and mortar.
- Centrifuge at 5000 x g for 15 minutes.
- Take the supernatant for protein estimation and discard pallets.
- Take 0.1 ml of the above extract in the test tube
- Add 1 ml of alkaline copper reagent to it
- Stir gently and allow to stay at room temperature in dark, blue color develops. Make the volume up to 5 ml with double distilled water
- Record the absorbance at 500 nm wavelength
- A blank is run, in which 0.2 ml of distilled water is added, instead of enzyme extract

Starch content of the grains was determined by following anthrone method and expressed in mg per gram of seeds by taking 0.5 g of sample was homogenized with 20 ml of 80 per cent hot ethanol and centrifuged at 10000 rpm for 10 minutes. The supernatant was discarded and the residue was retained. The residue was washed 2 to 3 times with 80 per cent ethanol and finally dried over a hot water bath. To the residue, 5 ml of water and 6.5 ml of 52 per cent perchloric acid was added and extracted at 0ºC for 20 minutes. It was then centrifuged and the supernatant was preserved. Extraction and centrifugation was repeated for 2 to 3 times and supernatant was collected. The final volume was made up to 100 ml with distilled water.

RESULT AND DISCUSSION

The pooled data analysis showed that with seed treatment by $ZnSO_4$ @ 0.5 % + $FeSO_4$ @ 0.5 % and foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded significantly higher total dry matter (32.7, 165.3 and 200.1 g plant^{-1} plant^{-1} at 30, 60 DAS and at harvest, respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded (31.6, 168.5 and 195.7 g plant^{-1} at 30, 60 DAS and at harvest, respectively) as compared with rest of the treatments. However, the control treatment recorded significantly lower total dry matter (19.8, 111.0 and 131.8 g plant^{-1}, at 30, 60 DAS and at harvest, respectively).

LA: The pooled data analysis showed that with seed treatment by $ZnSO_4$ @ 0.5 % + $FeSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded significantly higher leaf area duration (56.6 and 99.7 days at 30-60 DAS and at harvest, respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % $_+$ foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded (56.6 and 99.7 days at 30- 60 DAS and at harvest, respectively) as compared to control (36.6 and 63.2 days at 30-60 DAS and at harvest, respectively).

The pooled data analysis showed that with seed treatment by $ZnSO_4$ @ 0.5 % + $FeSO_4$ @ 0.5 % and foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded higher specific leaf weight (4.73 and 1.30 mg cm^{-2} at 30-60 DAS and at harvest, respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded (3.04 and 0.69 mg cm^{-2} at 30- 60 DAS and at harvest, respectively) as compared to control (3.04 and 0.69 mg cm^{-2} at 30- 60 DAS and at harvest, respectively).

The pooled data analysis showed that with seed treatment by $ZnSO_4$ @ 0.5 % + $FeSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded higher specific leaf area (27.7, 155.2 and 169.0 cm^{-2} g^{-1} at 30, 60 DAS and at harvest respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % $_+$ foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded (26.6, 149.9 and 154.2 cm^{-2} g^{-1} at 30, 60 DAS and at harvest, respectively) compared with all other treatments. However, the control treatment recorded lower specific leaf area (21.2, 135.1 and 141.0 cm^{-2} g^{-1} at 30, 60 DAS and at harvest, respectively).

The pooled data analysis showed that with seed treatment by $ZnSO_4$ @ 0.5 % + $FeSO_4$ @ 0.5 % and foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded crop growth rate (24.5 and 7.40 g m^{-2} day^{-1} at 30-60 DAS and at 60 DAS- harvest, respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % $_+$ foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded (23.7 and 6.70 g m^{-2} day^{-1} at 30-60 DAS and at 60 DAS-harvest, respectively). However, the control treatment recorded lower crop growth rate (16.8 and 3.84 g m^{-2} day^{-1} at 30-60 DAS and at 60 DAS- harvest, respectively).

The pooled data analysis showed that with seed treatment by $ZnSO_4$ @ 0.5 % & $FeSO_4$ @ 0.5 % and foliar spray of $ZnSO_4$ @ 1.0 % & $FeSO_4$ @1.0 % recorded significantly higher relative growth rate (24.5 and 4.71 mg^{-1} g^{-1} day^{-1} at 30-60 DAS and at harvest respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded (23.5 and 4.65 mg^{-1} g^{-1} day^{-1} at 30-60 DAS and at 60 DAS-harvest, respectively) compared with all other treatments. However, the control treatment recorded significantly lower relative growth rate (21.0 and 4.01 mg^{-1} g^{-1} day^{-1} at 30-60 DAS and at 60 DAS- harvest, respectively).

The pooled data analysis showed that with seed treatment by $ZnSO_4$ @ 0.5 % & $FeSO_4$ @ 0.5 % and foliar spray of $ZnSO_4$ @ 1.0 % & $FeSO_4$ @1.0 % recorded significantly higher absolute growth rate (4.73 and 1.20 g plant day^{-1} at 30-60 DAS and at harvest, respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded (4.27 and 1.21 g plant day^{-1} at 30-60 DAS and at harvest, respectively) compared with all other treatments. However, the control treatment recorded significantly absolute growth rate (3.04 and 0.69 g plant day^{-1} at 30-60 DAS and at harvest, respectively).

Results noticed that with seed treatment by $ZnSO_4$ @ 0.5 % + $FeSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded significantly higher fresh cob yield (174.6, 184.0 and 179.3 q ha^{-1} during the year 2017, 2018 and pooled analysis data, respectively). There was 16.29 per cent yield increase over control followed by (13.54 per cent) compared with all other treatments. Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded fresh cob yield (168.2, 179.0 and 173.6 q ha^{-1} during both the year 2017, 2018 and pooled analysis data, respectively) as compared with all other treatments. However, the control treatment recorded significantly lower fresh cob yield (146.1, 154.0 and 150.1 q ha^{-1} was recorded during the year 2017, 2018 and pooled analysis data, respectively).

The pooled data of 2017 and 2018 indicated that seed treatment with $ZnSO_4$ @ 0.5 percent + $FeSO_4$ @ 0.5 per cent+ foliar application of $ZnSO_4$ @ 1.0 percent and $FeSO_4$ @ 1.0 percent recorded significantly higher starch concentration (297.6, 375.6 and 515.8 mg g^{-1} fresh weight from 0, 5 and 10 DAH, respectively) in grain and which was onpar with seed treatment with $ZnSO_4$ @ 0.5 per cent + foliar application of $ZnSO_4$ @ 1.0 per cent + foliar application of $FeSO_4$ @ 1.0 per cent (296.2, 372.3 and 501.9 mg g^{-1} fresh weight from 0, 5 and 10 DAH, respectively. However, control treatment recorded lower starch content (160.3, 228.3 and 512.1 mg g^{-1} fresh weight from 0, 5 and 10 DAH, respectively)

The pooled data of 2017 and 2018 indicated that seed treatment with $ZnSO_4$ @ 0.5 percent + $FeSO_4$ @ 0.5 per cent+ foliar application of $ZnSO_4$ @1.0 percent and $FeSO_4$ @ 1.0 percent from the 0, 5 and 10 DAH has recorded (12.9, 9.96 and 2.64 mg g^{-1} fresh weight at 0, 5 and 10 DAH, respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 per cent + foliar application of $ZnSO_4$ @ 0.5 per cent + foliar application of $FeSO_4$ @ 1.0 per cent recorded (12.8, 6.54 and 2.33 mg g^{-1} fresh weight from 0, 5 and 10 DAH, respectively). However, minimum protein content was recorded (8.87, 4.88 and 2.83 mg g^{-1} fresh weight from 0, 5 and 10 DAH respectively) in control treatment (no seed treatment and foliar application with $ZnSO_4$ and $FeSO_4$).

Results noticed that with seed treatment by $ZnSO_4$ @ 0.5 % + $FeSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded shelling per centage (72.7, 78.9 and 75.8 g during the year 2017, 2018 and pooled analysis data respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded shelling per centage (65.9, 65.6 and 65.7 During 2017,, 2018 and pooled analysis data, respectively) compared with all other treatments. However, the control treatment recorded lesser shelling per centage (59.8, 59.7 and 59.7 during the year 2017, 2018 and pooled analysis data, respectively).

Results noticed that with seed treatment by $ZnSO_4$ @ 0.5 % & $FeSO_4$ @ 0.5 % and foliar spray of $ZnSO_4$ @ 1.0 % & $FeSO_4$ @1.0 % recorded significantly higher (16.0, 16.1 and 16.0 number of rows per cob during the year 2017, 2018 and pooled analysis data, respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded (15.2, 15.3 and 15.2 number of rows per cob during both the year 2017, 2018 and pooled analysis data, respectively) compared with all other treatments. However, the control treatment recorded significantly lesser number of rows per cob (11.9, 12.0 and 11.9 during the year 2017, 2018 and pooled analysis data, respectively).

Results noticed that with seed treatment by $ZnSO_4$ @ 0.5 % & $FeSO_4$ @ 0.5 % and foliar spray of $ZnSO_4$ @ 1.0 % & $FeSO_4$ @1.0 % recorded significantly higher (35.2, 35.9 and 35.6 number of seeds per row during the year 2017, 2018 and pooled analysis data respectively). Which was onpar with seed treatment with $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % recorded (30.6, 33.3 and 31.9 seeds per row during both the year 2017, 2018 and pooled analysis data, respectively). However, the control treatment recorded significantly lesser number of seeds per row (28.1, 28.6 and 28.4 during the year 2017, 2018 and pooled analysis data, respectively).

Similar results were reported by reported (4) among the seed treatment and foliar application of micronutrients $ZnSO_4$ and $FeSO_4$ 1.0 per cent was recorded high fresh cob (313.7q ha^{-1}) and fodder yield (616.6 q ha^{-1}) respectively. Higher yield it might be due to foliar spray of micronutrients (zinc and iron) are essential for several enzymes that regulates the metabolic activities in plants. They involve in auxin production, transformation of carbohydrates and regulation of sugars in plants. Especially zinc and iron involved in synthesis of growth promoting hormones and reproductive process of many plants which are vital role for grain formation. Interaction effect of enriched $ZnSO_4$ and $FeSO_4$ @ 20 and 40 DAS was recorded higher yield in sweet corn

Micro management at the critical stage is an important factor which largely decides the yield of the crop produced. The economic yield is the manifestation of various biological events involving morphological, growth, biochemical and physiological changes which take place during development in accordance with the supply of light, water, temperature and micro nutrients [1]. The grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The production and translocation of synthesized photosynthates depend upon mineral nutrition supplied either through soil or foliar application and plant growth and development during early stages of crop growth. Foliar nutrition increases the utilization of plant nutrients more efficiently.

Number of kernel rows per cob and number of kernel per row are the major yield attributing parameters of sweet corn. The foliar application of different nutrients improved the number of kernel rows per cob and number of kernels per row compared to the control where only recommended dose of fertilizer was applied. Among the different treatments, seed treatment and foliar spray of $ZnSO_4$ and $FeSO_4$ at different growth stages (pre flowering and post flowering) showed the better performance. This might be due to the fact that number of rows per cob and number of kernels per row are predetermined factor at early vegetative stage between 30-60 DAS. The foliar nutrition at these critical stages helped in the increased nutrient supply for cob development. This present work is in line with Tahir *et al.* [9] and Manasa and Devaranavadagi [5] .

Fresh cob yield ha^{-1} is an ultimate end product of many yield-contributing components, physiological and morphological processes taking place in plants during growth and development. Fresh cob yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as the extent of translocation into sink (grains) and also on plant growth and development during early stages of crop growth. This may be attributed to fulfillment of the demand of the crop by higher assimilation and translocation of photosynthates from source (leaves) to sink (grains) through supply of required micro nutrients by foliar spray.

Table 1. Influence of seed treatment and foliar spray of iron and zinc on cob length, cob girth and cob weight of sweet corn

Treatments	Cob length (cm)			Cob girth (cm)			Cob weight (g)			Fresh cob yield (q ha^{-1})		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1	19.4	19.9	19.6	12.7	13.2	12.9	310.9	317.8	314.4	150.6	158.7	154.6
T_2	18.2	18.7	18.4	12.1	13.0	12.5	309.2	316.5	312.8	150.3	158.4	154.3
T_3	20.6	21.2	20.9	12.8	13.3	12.7	311.1	317.9	314.5	154.8	170.6	164.5
T_4	18.6	19.1	18.9	12.5	12.6	12.4	308.1	315.2	311.7	150.1	158.2	154.1
T_5	19.8	20.4	20.1	13.3	13.6	13.4	308.3	316.1	312.2	158.2	163.1	159.0
T_6-	18.1	18.6	18.3	14.7	13.3	13.1	311.4	319.0	315.2	160.2	168.7	164.5
T_7	21.6	22.2	21.9	14.8	13.7	13.6	305.4	312.8	255.8	157.7	166.4	162.1
T_8	18.8	19.4	19.1	13.9	13.0	12.8	311.4	318.6	315.0	160.0	169.0	164.5
T_9	19.8	20.4	20.1	14.5	13.6	13.4	308.6	315.6	312.1	157.5	165.7	161.6
T_{10}	24.2	22.5	23.7	14.8	13.7	13.6	312.8	320.6	316.7	168.2	179.0	173.6
T_{11}	20.2	20.8	20.5	12.2	13.7	13.5	306.8	314.3	310.6	157.6	169.7	163.9
T_{12}	24.4	25.1	24.8	15.7	15.5	15.3	316.4	323.1	319.8	174.6	184.0	179.3
T_{13}	17.9	18.5	18.2	11.8	12.4	12.1	241.5	246.7	244.1	146.1	154.0	150.1
S. Em (±)	**1.15**	**1.13**	**1.20**	**0.31**	**0.41**	**0.58**	**1.21**	**0.89**	**1.06**	**5.16**	**5.03**	**4.08**
C.D. @ 5%	**3.42**	**3.34**	**3.60**	**0.95**	**1.20**	**1.75**	**3.65**	**2.68**	**3.20**	**15.1**	**14.7**	**11.9**

In the present investigation, it is clear that foliar application of micronutrients increased the grain yield compared to control where only recommended dose of fertilizers was applied. Among the different treatments, seed treatment and foliar spray of $ZnSO_4$ and $FeSO_4$ @ 0.5 and 1.0 per cent at different growth stages (pre and post flowering) increased grain yield by 16.29 % (T_{12}) followed by 13.54% (T_{10}) per cent respectively as compared to control T_{13} (no seed treatment and foliar application with $ZnSO_4$ and $FeSO_4$).

Seed treatment and foliar nutrition with iron and zinc at the early vegetative stage improved the cob development and grain yield pertaining to the significant variation in early silking, increased chlorophyll contents, photosynthesis rate which in turn increased the sugar contents and dry matter production. In addition, the foliar nutrients improved translocation and assimilation of nutrients by sweet corn plants leading to significant increase in grain yield. Similar results were obtained(2), who reported that foliar application of $ZnSO_4$ at 30-60 DAS leaf stage significantly increased the grain yield of corn hybrid. These results are also in consonance with a study which exhibited that foliar application of $ZnSO_4$ is better to increase the grain yield of maize hybrids (9).

Table 2. Influence of seed treatment and foliar spray of iron and zinc on number of seeds row^{-1}, number of seed rows cob^{-1} and shelling per centage and test weight

Treatments	Number of seeds row^{-1}		No. of seed rows cob^{-1}			Shelling per centage			Test weight (g)			
	2017	2018	2017	2018	Pooled	Pooled	2017	2018	Pooled	2017	2018	Pooled
T_1	29.4	29.9	62.8	62.7	62.8	29.6	12.5	12.6	12.5	25.7	25.5	25.6
T_2	28.2	28.7	62.6	62.4	62.5	28.4	12.7	12.9	12.8	25.9	25.7	25.8
T_3	28.9	29.5	634.	63.2	63.3	29.2	13.1	13.2	13.1	26.9	25.6	26.2
T_4	28.6	29.2	62.3	62.1	62.2	28.9	11.5	11.7	11.6	24.7	24.5	24.6
T_5	30.2	30.8	65.0	64.7	64.8	30.5	14.0	14.1	13.5	26.9	25.9	26.2
T_6	30.2	30.8	64.6	64.3	64.5	30.5	14.1	14.8	14.7	26.3	26.1	26.2
T_7	30.0	30.6	64.0	63.7	63.9	30.3	13.5	13.6	13.5	25.7	26.5	26.1
T_8	29.8	30.4	64.9	64.8	64.8	30.1	13.2	13.3	13.3	25.4	24.2	24.8
T_9	28.8	29.4	64.9	64.7	64.8	29.1	13.5	13.6	12.1	25.9	25.7	25.8
T_{10}	30.6	33.3	65.9	65.6	65.7	31.9	15.2	15.3	15.2	27.0	27.4	27.2
T_{11}	29.8	30.4	64.8	64.5	64.7	30.1	12.9	13.0	12.9	24.3	24.1	24.2
T_{12}	35.2	35.9	72.7	78.9	75.8	35.6	16.0	16.1	16.0	29.2	28.0	28.6
T_{13}	28.1	28.6	59.8	59.7	59.7	28.4	11.9	12.0	11.9	23.1	24.9	24.0
S. Em (±)	**1.14**	**1.25**	**2.30**	**3.50**	**3.40**	**1.18**	**1.23**	**1.12**	**1.33**	**1.73**	**1.89**	**1.91**
C.D. @ 5%	**3.32**	**3.64**	**6.90**	**10.5**	**10.2**	**3.45**	**3.6**	**3.3**	**4.10**	**4.47**	**4.51**	**4.57**

Table 3. Influence of seed treatment and foliar spray of iron and zinc on protein, total sugars and starch composition of sweet corn seeds

Treatments	Protein content (mg g^{-1})			Total soluble sugar (TSS) (^{0}Brix)			Starch content (mg g^{-1})		
	Days after harvest			Days after harvest			Days after harvest		
	0	0	5	0	5	0	213.2	306.9	526.3
T_1	9.90	20.0	10.4	20.0	10.4	20.0	201.3	323.8	498.1
T_2	12.3	19.6	7.82	19.6	7.82	19.6	204.3	280.2	479.5
T_3	12.0	20.6	10.6	20.6	10.6	20.6	182.3	276.4	405.3
T_4	10.1	19.6	8.12	19.6	8.12	19.6	227.1	383.9	479.8
T_5	12.2	20.9	8.23	20.9	8.23	20.9	244.2	367.4	447.6
T_6	12.6	21.4	9.90	21.4	9.90	21.4	202.0	337.2	405.3
T_7	11.9	19.5	8.95	19.5	8.95	19.5	238.5	297.3	380.5
T_8	11.6	18.8	8.11	18.8	8.11	18.8	209.1	312.1	500.7
T_9	12.1	20.5	8.99	20.5	8.99	20.5	296.2	372.3	501.9
T_{10}	12.8	23.3	11.9	23.3	11.9	23.3	241.5	282.1	533.4
T_{11}	12.1	19.7	9.62	19.7	9.62	19.7	297.6	375.6	515.8
T_{12}	12.9	24.9	13.0	24.9	13.0	24.9	160.3	228.3	512.1
T_{13}	8.87	15.3	8.87	15.3	8.87	15.3	213.2	306.9	526.3
S. Em (±)	**0.30**	**2.27**	**1.51**	**2.27**	**1.51**	**2.27**	**8.78**	**7.18**	**10.72**
C.D. @ 5%	**0.89**	**6.82**	**4.52**	**6.82**	**4.52**	**6.82**	**25.62**	**21.62**	**31.26**

Table 4: Influence of seed treatment and foliar spray of iron and zinc on various growth indices on growth and development of sweet corn

Treatments	CGR	RGR	SLA	NAR	SLW	LA	LAD	AGR
T_1	4.83	4.30	146.4	52.8	0.91	3619	151.0	0.92
T_2	5.80	4.33	146.2	51.2	0.91	3485	146.5	0.91
T_3	4.81	4.46	147.6	55.9	1.00	4562	169.1	1.02
T_4	6.46	4.37	144.1	49.0	0.90	3426	141.8	0.91
T_5	6.71	4.35	149.9	58.6	1.20	4491	177.2	1.23
T_6	6.63	4.55	151.7	62.6	1.20	4969	185.8	1.04
T_7	6.35	4.10	149.5	57.1	1.22	4436	173.3	1.20
T_8	6.49	4.04	150.2	59.2	1.10	3951	177.4	1.12
T_9	6.73	4.20	148.0	57.0	1.16	4080	162.0	1.21
T_{10}	6.13	4.65	154.2	64.6	1.22	5420	195.7	1.21
T_{11}	7.51	4.51	149.0	63.0	1.10	5501	169.2	1.13
T_{12}	4.83	4.71	169.0	67.3	1.30	5555	200.1	1.22
T_{13}	3.88	4.01	141.0	45.5	0.69	3353	131.8	0.69
S. Em (±)	**1.11**	**0.23**	**4.51**	**1.86**	**0.20**	**176**	**2.54**	**0.20**
C.D. @ 5%	**3.23**	**0.69**	**13.1**	**5.60**	**0.58**	**528**	**6.62**	**0.58**

CONCLUSION

Based on the information generated from the present investigation, it was concluded that seed treatment $ZnSO_4$ @ 0.5 % + foliar spray of $ZnSO_4$ @ 1.0 % + $FeSO_4$ @1.0 % at pre and post flowering stages improved significantly the performance in morpho-physiological, biochemical changes and post harvest seed quality of sweet corn. Availability of nutrients to plants through foliar application at pre and post flowering stages improves cob development leading to better fresh cob yield, quality of seeds and fodder in sweet corn.

REFERENCES

1. Donald, C. M., (1962). Competition among crops and pasture plants. *Adv. in Agron.,* 15:1 – 14.
2. El-Azab, M. E., (2015). Increasing Zn ratio in a compound foliar NPK fertilizer in relation to growth, yield and quality of corn plant. *J. Innovations in Pharma. Bio. Sci.,* 2(4): 451-468.
3. FAOSTAT (Food and Agriculture Organization of the United Nations Statistics Division), 2017, *http://faostat.fao.org/default.aspx.*
4. Fakeerappa, A and Hulihalli U. K., (2018). Agronomic Fortification with Zinc and Iron to enhancing micronutrient concentration in sweet corn grain to ameliorate the deficiency symptoms in human beings, *Int. J. Current Micro. Applied Sci.,* (7) 2: 2319-7706.
5. Manasa, L. P. and Devaranavadagi, S. B., (2015). Effect of foliar application of micronutrients on growth, yield and nutrient uptake of maize. *Karnataka J. Agric. Sci*., 28 (4): 474-476
6. Meenakshi, J. V., Nancy, J., Johnson, Victor, M., Hugo, D. G., Joy, J., David, Y., Firdousi, N., James, G., Carolina, G. and Erika, M., (2014). How cost-effective is biofortification in combating micronutrient malnutrition? Anex-ante assessment. *Harvest Plus Working Paper 2.*pp. 2-27.
7. Poletti, S., Gruissem, W. and Sautter, C., (2004). The nutritional fortification of cereals. *Curr. Opin. Plant Biol.,* 15(2): 162–165.
8. Subhanullah, Khan, R. M. and Rahman, H. U., (2017). Influence of foliar urea on the phenology, growth and yiel. *Indian J. Agron*., 15: 269-275
9. Tahir, M., Ali, A., Khalid, F., Naeem, M., Fiaz, N. and Waseem, M., (2012). Effect of foliar applied boron applications on growth, yield and quality of maize (*Zea mays* L.). *Pakistan. J. Sci. Ind. Res.,* 55(3): 117 – 121.

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