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Physiological biofortification of iron and zinc on growth, yield and biochemical parameters 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 , chlorophyll content in leaves, Starch content (seeds),TSS, dehydrogenase activity (OD value) and α-Amylase (mm) enzymatic activity.*
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 [5]. The U.S. was the highest sweet corn producer by mass produced, 4.09 million metric tons, and by area harvested, 243,790 ha [5]. 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.

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 [13].

The sweet corn is highly important crop for industrial point of view. Industrial use of corn includes production of soaps, paints, beverages, sweeteners. Canned products like whole kernels and cream styles. Frozen products like cobetts, whole cobs and whole kernels. The sweet corn industry is expanding in India because of increasing domestic consumption, export development and import replacement. It is an attractive crop for producers to grow because the plant grows quickly and is considered a valuable rotational crop and farming operation can be mechanized. Most sweet corn is grown for the processing sector ending up on the super market.

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 [9]. 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 [15].

Plenty of research has been done in maize crop but sweet corn has received very less concern especially in India. Because of less popularity of crop or crop based products and also sweet corn has very less base studies to appoint new research strategies. But now days its popularity gets accelerating because it is becoming industrially as well as economically important crop. So our concern doing this research is to assess the best ideotype with morpho-physiological characters with respect to yield and yield related parameters.

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.

Dehydrogenase enzyme activity (OD value)

Reagents: Sodium acetate buffer (0.1 M: pH 4.7)

Solution A: 0.2 M solution of acetic acid 11.55 ml of acetic acid was dissolved in 1000 ml distilled water

Solution B: 0.2 M solution of sodium acetate (16.4 g of sodium acetate was dissolved in 1000 ml distilled water). Final volume was made up to 100 ml with 25.5 ml solution A and 24.5 ml of solution B was mixed just before use.

Representative seeds (25) from each treatment were taken and preconditioned by soaking in water overnight at room temperature. Seeds were taken at random and the embryos were excised. The embryos were steeped in 0.25 per cent solution of 2, 3, 5-triphenyl tetrazolium chloride solution and kept in dark for two hours at 40o C for staining. The stained seeds were thoroughly washed with water and then soaked in 10 ml of 2 methoxy ethanol (methyl cellosolve) and kept overnight for extracting the red color formation. The intensity of red color was measured using ELICO UV-VIS spectrophotometer (model SC-159) using blue filter (470 nm) and methyl cellosolve as the blank. The OD value obtained was reported as dehydrogenase activity [7].

α - amylase activity (mm)

One gram of seed sample was taken in a beaker, to which 5-10 volume of ice cold 10 mM calcium chloride solution was added by grinding with mortar and pestle and kept for 3 hours at room temperature. Then the sample mixture was centrifuged at 54000 g at $4^{o}C$ for 20 minutes and supernatant was collected, which was used as enzymes source.

Reagents

Sodium acetate buffer (0.1 M: pH 4.7)

Solution A: 0.2 M solution of acetic acid 9 11.55 ml of acetic acid was dissolved in 1000 ml distilled water

Solution B: 0.2 M solution of sodium acetate (16.4 g of sodium acetate was dissolved in 1000 ml distilled water). Final volume was made up to 100 ml with 25.5 ml solution A and 24.5 ml of solution B was mixed just before use.

The α-amylase activity was analyzed as per the method suggested by Simpson and Naylor [14]). Two gram of agar spreads and one gram of potato starch was mixed together in water to form paste and the volume was made up to 100 ml with distilled water. The homogenous solution of agar-starch mixture after boiling was poured into sterilized petri-dishes and allowed to settle in the form of gel after cooling. The pre-soaked (for 8 hour) and half cut seeds (with their half endosperm and embryo portion intact) were placed in the petri-dishes in such a way that the endospermic part remained in contact with agar-starch gel. The petri-dishes were closed and kept in dark at 30 o C. After 48 hour, the petri-dishes were uniformly smeared with potassium iodide solution (0.44 g of iodine crystal + 20.008 g potassium iodide in 500 ml distilled water) and excess solution was drained off after few minutes. The diameter of halo (clear) zone formed around the seed was measured in mm and reported as α – amylase activity.

RESULT AND DISCUSSION

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 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 % 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) Table .3 and Fig.3

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). Table 1 and Fig 1.

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 TSS concentration (24.9, 13.0 and 24.9 brix 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 (23.3, 11.9 and 23.3 brix from 0, 5 and 10 DAH, respectively. However, control treatment recorded lower TSS content (15.3, 8.87 and 15.brix from 0, 5 and 10 DAH, respectively) Table 2 and Fig 3.

The pooled data of both the years 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 higher (14.6, 14.9 and 14.8 % α-amylase concentration 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 fresh cob yield (13.8, 13.9 and 13.9 % during 2017, 2018 and pooled analysis data, respectively) as compared with all other treatments. However, the control treatment recorded lower α- amylase concentration (11.3, 11.5 and 11.4 % during the year 2017, 2018 and pooled analysis data, respectively).

Results of both the years and pooled data 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 higher dehydrogenase concentration (1.75, 1.70 and 1.72 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 (1.64, 1.66 and 1.68 during both the year 2017, 2018 and pooled analysis, respectively) compared with all other treatments. However, the control treatment recorded lower dehydrogenase concentration (1.25, 1.30 and 1.27 during the year 2017, 2018 and pooled analysis data, respectively) Table 2 and Fig 3.

Similar results were reported by reported by Fakeerappa *et al.* [6] 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 [4].

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 Manasa and Devaranavadagi [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 by El-Azab [4], 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 [12]. Similar findings were reported by Mohsin *et al.* [11], Manasa and Devaranavadagi [8].

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})**			**% yield increase over control**
	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	**2.91**
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	**2.72**
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	**8.53**
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	**2.60**
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	**5.60**
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	**8.75**
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	**7.40**
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	**8.75**
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	**7.12**
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	**13.54**
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	**8.42**
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	**16.29**
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**	-

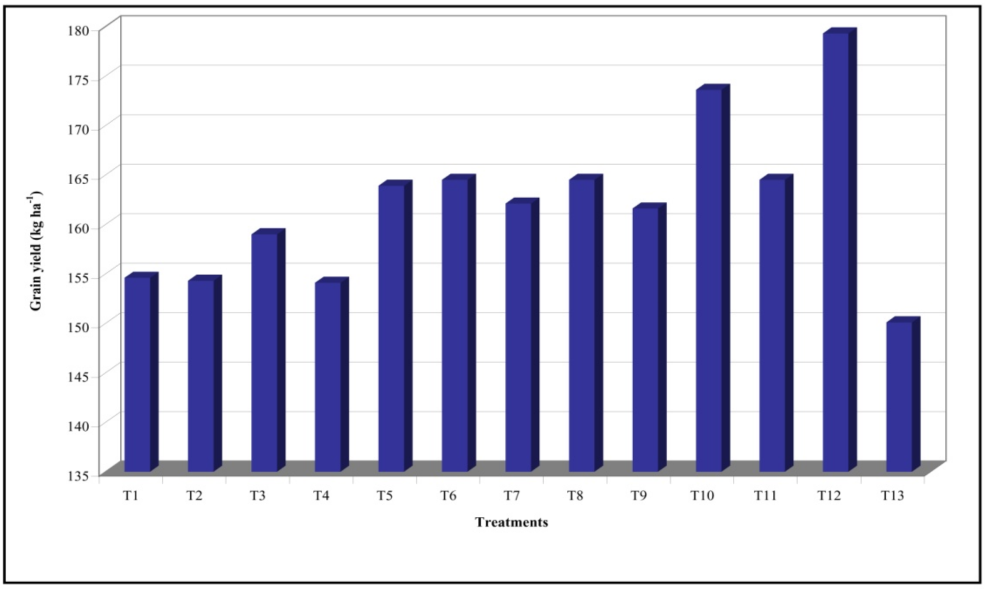

Fig. 1 Influence of seed treatment and foliar spray of iron and zinc on grain yield of sweet corn

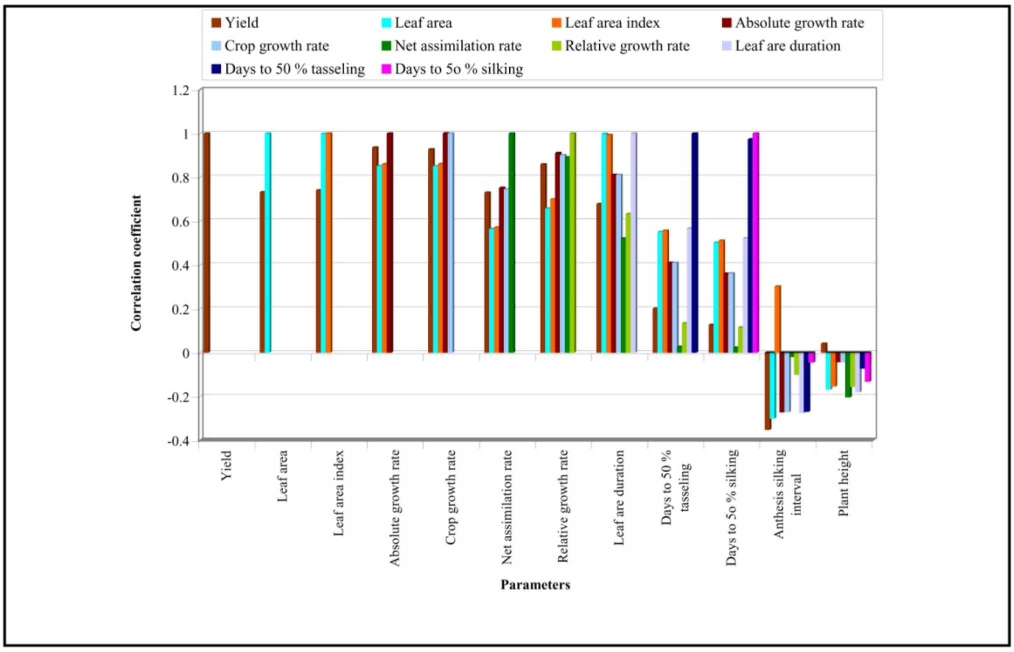

Fig. 2 Correlation between yield components and dry matter production in sweet corn

Table 2. Influence of seed treatment and foliar spray of iron and zinc on protein, total sugars and starch composition of sweet corn seeds

Treatments	α-Amylase (%)			Dehydrogenase (OD values)			Total soluble sugar (TSS) (⁰Brix) Days after harvest		
	2017	2018	Pooled	2017	2018	Pooled	0	5	0
T_1	12.5	12.4	12.5	1.48	1.50	1.49	20.0	10.4	20.0
T_2	12.1	12.0	12.1	1.40	1.46	1.43	19.6	7.82	19.6
T_3	12.6	12.7	12.7	1.35	1.4	1.39	20.6	10.6	20.6
T_4	11.5	11.8	11.7	1.43	1.44	1.43	19.6	8.12	19.6
T_5	12.6	12.8	12.7	1.66	1.55	1.60	20.9	8.23	20.9
T_6	13.2	12.9	13.1	1.62	1.58	1.60	21.4	9.90	21.4
T_7	12.1	12.5	12.3	1.45	1.62	1.53	19.5	8.95	19.5
T_8	12.9	13.5	13.2	1.55	1.58	1.56	18.8	8.11	18.8
T_9	12.5	12.6	12.6	1.63	1.59	1.61	20.5	8.99	20.5
T_{10}	13.8	13.9	13.9	1.64	1.66	1.68	23.3	11.9	23.3
T_{11}	12.9	13.1	13.0	1.69	1.68	1.63	19.7	9.62	19.7
T_{12}	14.6	14.9	14.8	1.75	1.70	1.72	24.9	13.0	24.9
T_{13}	11.3	11.5	11.4	1.25	1.30	1.27	15.3	8.87	15.3
S. Em (±)	**0.30**	**0.40**	**0.31**	**0.38**	**6.42**	**0.52**	**2.27**	**1.51**	**2.27**
C.D. @ 5%	**0.92**	**1.21**	**0.95**	**NS**	**NS**	**NS**	**6.82**	**4.52**	**6.82**

The pooled data of both the years 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 higher (14.6, 14.9 and 14.8 % α-amylase concentration 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 fresh cob yield (13.8, 13.9 and 13.9 % During 2017, 2018 and pooled analysis data, respectively) as compared with all other treatments. However, the control treatment recorded lower α- amylase concentration (11.3, 11.5 and 11.4 % during the year 2017, 2018 and pooled analysis data, respectively). Results of both the years and pooled data 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 higher dehydrogenase concentration (1.75, 1.70 and 1.72 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 (1.64, 1.66 and 1.68 during both the year 2017, 2018 and pooled analysis, respectively) compared with all other treatments. However, the control treatment recorded lower dehydrogenase concentration (1.25, 1.30 and 1.27 during the year 2017, 2018 and pooled analysis data, respectively) Table 2 and Fig 3.

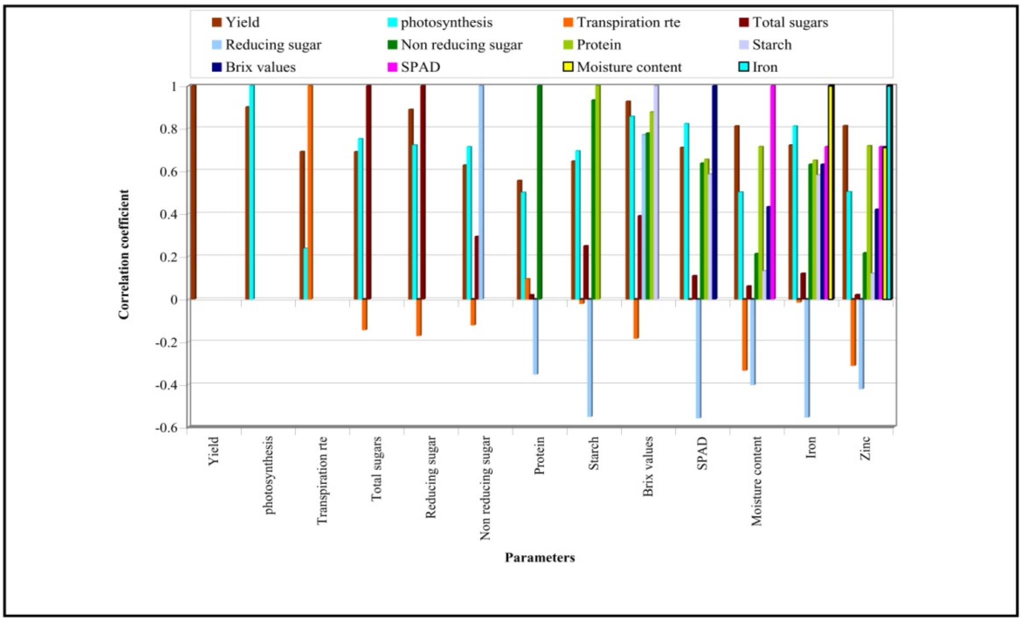

Fig. 3. Correlation between yield components and dry matter production in sweet corn

Table 3. Effect of iron and zinc biofortiofication on growth indices 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**

The plant performance is attributed to the genetic factors which are controlled by the differences in the biochemical parameters. It is well known that thousands of biochemical reactions are undergoing in plants simultaneously which ultimately decide the plant growth and development and the final yield. All the nutrients when given through foliar spray have been shown to influence these parameters in one way or the other.

Arune *et al*. [1] revealed that the protein content in maize could be improved with foliar spray of 0.5 % of $ZnSO_4$ at 50 % silking stage as compared to soil application of 50 kg $ZnSO_4$ ha^{-1}. The influence of foliar application of shale water (SW), with or without the micronutrients *viz*., zinc (Zn), manganese (Mn), copper (Cu), boron (B) and molybdenum (Mo) was evaluated regarding yield and quality of maize grains. The yield, the total antioxidant activity, content of starch, phenolic compounds and carotenoids were improved in maize grains following the application of three doses of 7 L ha^{-1} of SW, which indicates that SW may influence the primary and secondary metabolisms. The application of SW with micronutrients resulted in the increase of grain yield; however, did not result in the improvement of grain quality [10]. Arkadiusz and Katarzyna [2] showed that combined application of nitrogen with micronutrients such as Mn, Zn and Cu (RDN with 0.5% $MnSO_4$, 1% $ZnSO_4$ and $CuSO_4$ each) significantly increased the protein (3.8%) and gluten (4.4%) content, Zeleny sedimentation index (12.4%) and grain hardness (18.5%) in winter wheat compared to rest of the treatments.

Yakup [15] determined the effect of solution-I (Auxin and 8% soluble Zn) and Solution-II (10% soluble B) which were supplied through foliar application @ 0.15% on protein and fatty yield of corn. He reported that foliar application of solution-I lead to increased GDD, protein yield and fatty yield compared to foliar spray of solution-II. Significantly highest seed protein content (21.9%) of wheat was noticed with combined foliar application of $ZnSO_4$ (100 g ha^{-1}) + $FeSO_4$ (40 g ha^{-1}) + $MnSO_4$ (40 g ha^{-1}) and foliar Zn fertilization was an effective approach to promote grain Zn concentration and Zn bioavailability, especially in case of Zn-AA and $ZnSO_4$. On average, Zn-AA and $ZnSO_4$ increased Zn concentration in polished rice up to 24.04 per cent and 22.47 per cent, respectively and $ZnSO_4$ increased Zn bioavailability in polished rice up to 68.37 per cent and 64.43 per cent, respectively.

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.

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