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RESEARCH ARTICLE

Agronomic biofortification of zinc in baby corn: A strategy for higher yields and better nutrition

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Abstract

Maize requires high nutrients and sensitive to zinc deficiency, which causes a disorder called "White bud" and is considered an indicator plant for zinc deficiency. Zinc deficiency is the most widespread among micronutrients and about 50 % of soils in our country are deficient it, leading yield losses in major food crops and contributing to zinc deficiency in our diet. Considering the above facts a field experiment was laid out in Randomized block design with three replications on a clay soil at the Agricultural College Farm, Bapatla. The treatments consists of soil, foliar or a combination of $ZnSO_4$ applications at 15 & 30 DAS against control. The results revealed that the highest values for baby corn yield, green and dry fodder yield, per day productivity at 20, 40 DAS and at harvest, physical ear attributes such as ear length, girth, ear weight with and without husk, ear density and chemical quality parameters including crude protein, sugar, ash and zinc content in plant and ear were recorded with combination of soil application of zinc sulphate at 25 kg ha^{-1} and foliar spray @ 0.2 % at 15 DAS and 30 DAS *i.e.* T_{12} followed by T_{11}, T_{10} and T_9 treatments and the lowest values for crude fibre and husk percentage were also registered under the same treatment conditions.

Keywords: baby corn; growth; yield; zinc

Introduction

Baby corn (also known as mini corn, young corn or candle corn) is the ear of maize (*Zea mays* L.) plant harvested young, when the silks have either just emerged or not emerged and no fertilization has taken place. It is one of the most well-known dual-purpose crop grown round the year in India (1). Baby corn is becoming well liked in foreign and domestic markets and has enormous processing and export potential. Baby corn is popular due to its sweet flavour and crisp nature and making it a valuable ingredient in many fancy dishes today. Recently it was becoming popular as vegetable, pakora, salad, chutney, pasta, soup, cutlets, chat, dry vegetable, masala, kofta curry, Manchurian, chilly, raita, candy, pickle, jam, murabba, laddu, burfi, halwa, kheer and other palatable dishes in different Chinese hotels and restaurants. One hundred grams of baby corn contain 89.1 % moisture, 0.2 g fat, 1.9 g protein, 0.06 g ash, 8.2 mg carbohydrate, 86 mg phosphorus, 28 mg calcium and 11 mg ascorbic acid (2). An interesting recent development is of growing maize for vegetable purpose (3).

Currently, Thailand and China are recognized as the leading producers of baby corn globally, Thailand, has established itself as the world's top exporter, accounting for approximately 80 % of global exports. However, specific nationwide data on the total area under baby corn cultivation, its production volume and productivity metrics are not comprehensively documented, as baby corn is often categorized under the broader maize statistics.

Due to its short duration, high yielding capability, wider adaptability and fast-growing habit, baby corn get a prominent place in most of the intensive cropping systems and make it a potential alternative for diversification and value addition (4). Maize is a high nutrient requirement crop and sensitive to zinc deficiency in soil that leads to a disorder called "White bud" (5) and is considered an indicator plant for zinc deficiency. Among the various micronutrients zinc deficiency appears to be the most widespread due to intensive agricultural practices, usage of high purity NPK fertilizers and no or limited application of zinc by farmers. About 50 % of soils in our country are deficient in zinc causing yield losses in major food crops (6). Low zinc content in ear and straw of baby corn result in poor zinc nutrition of human beings and animals, which has received considerable attention. It not only reduces crop production but also cause zinc deficiency in our diet (7).

Zinc plays an important role in various physiological and enzymatic activities in the plant system. It performs many stimulating functions in the plant besides transformation of carbohydrates, protein and chlorophyll synthesis (8). Zinc nutrition serves to increase the density of zinc and protein in seeds, pneumatic organs and the overall quality of seed production and its vital role for more than 300 enzymes in human body, it activates growth and cell division (9). Diminished rate of net photosynthesis due to decrease of carbonic anhydrase enzyme are in conditions where there is a lack of zinc and it also impairs the biochemical capacity of the plant to fix CO_2 (9). Biofortification strategies include the development of crop genotypes that acquire more zinc from the soil and applied Zn-fertilizers. Agronomic biofortification can be achieved by increasing soil zinc Phyto availability or by applying zinc fertilizers. Root Zn concentrations up to 600-5000 mg kg^{-1} dry matter and leaf Zn concentrations up to 110-700 mg kg^{-1} dry matter, can be achieved without loss of yield when Zn-fertilizers are applied to the soil. Generally, zinc content in the corn plant (shoot) is about 19.9 mg kg^{-1} dry matter and this content was increased upto 35.6 mg kg^{-1} by the addition of $ZnSO^4$ @ 50-60 $kgha^{-1}$ (10).

Moreover, the right method of zinc application can be another approach for better uptake and utilization of Zn. Among various methods, the foliar spray is an efficient way for betterment of crop productivity due to its easiness and simple in improving plant nutritional quality. Soil applied Zn is crucial in improving the grain yield while Zn concentration in grain improves via foliar spray (11). Considering the above facts, the present investigation was planned and executed.

Materials and Methods

Location and climatic condition

A field experiment was conducted at the Agricultural College Farm, Bapatla during kharif, 2018-19. During the crop period, a total rainfall of 301.9 mm was received in 18 rainy days. The weekly mean maximum temperature in between 37.60 C to 34.80 C with an average of 34.00 C and the weekly mean minimum temperature ranged from 24.80 C to 26.80 C with an average of 25.20 C. The average relative humidity was 84.0 % at 8:30 a.m. and 56.5 % at 5:30 p.m.

Experimental soil

The soil was slightly alkaline with organic carbon (0.49 %) and had nitrogen (164 kg ha^{-1}), phosphorus (26 kg ha^{-1}) and potassium (315 kg ha^{-1}).

Organic carbon (%) =Walkley and Black, wet digestion method (12)

Available N (kg ha^{-1}) = Alkaline permanganate method (13)

Available P_2O_5 (kg ha^{-1}) = Olsen's extractant method (14)

Available K_2O (kg ha^{-1}) = Neutral normal ammonium acetate method (15)

Available Zn (mg kg^{-1}) = AAS (16).

Experiment details

The experiment was laid out in a Randomized block design (17) thrice and the treatment details were T1: Control (no zinc), T2: Foliar spray of ZnSO4 @ 0.2 % at 15 DAS, T3: Foliar spray of ZnSO4 @ 0.2 % at 30 DAS, T4: Foliar spray of ZnSO4 @ 0.2 % at 15 DAS and at 30 DAS, T5: Soil application ZnSO4 @ 12.5 Kg ha-1, T6: T5+ foliar spray of ZnSO4 @ 0.2 % at 15 DAS, T7: T5+foliar spray of ZnSO4 @ 0.2 % at 30 DAS, T8: T5+foliar spray of ZnSO4 @ 0.2 % at 15 DAS and 30 DAS, T9: Soil application of ZnSO4 @ 25 kg ha-1, T10: T9+ foliar spray of ZnSO4 @ 0.2 % at 15 DAS, T11: T9+foliar spray of ZnSO4 @ 0.2 % at 30 DAS and T12: T9+foliar spray of ZnSO4 @ 0.2% at 15 DAS and 30 DAS.

Cultivar details

The Baby corn variety (G-5414) was used for this trail.

Cultivation details

Gap filling was done at 7 DAS Zinc in the form of ZnSO4 for both soil and foliar application. Recommended fertilizer dose 120:60:40 kg NPK ha^{-1} was applied uniformly in all treatments through Urea, SSP and Muriate of potash, respectively.

Post-harvest observations

Ear weight (g ear^{-1}), Size of ear (cm), Baby corn yield (kg ha^{-1}), Green and dry fodder yield at harvest (t ha^{-1}),

Chemical analysis

The following methods are used to assess the various parameters

Crude protein (18)

Crude fibre (19)

Sugar content (20)

Ash content (21)

Zinc content (16)

Results and Discussion

Effect on baby corn yield (kg ha^{-1})

The highest corn yield (10000 kg ha^{-1}) was registered T_{12} and it was on a par with T_{11} (9633 kg ha^{-1}), T_{10} (9453 kg ha^{-1}) and T_9 (9013 kg ha^{-1}). However, T_{12} treatment was significantly superior over T_8, T_7, T_6, T_5, T_4, T_3, T_2 and T_1. Significantly the lowest corn yield of (6892 kg ha^{-1}) was recorded by the control treatment which was comparable with T_2 and T_3 treatments (Table 1).

The improvement in yield due to application of zinc might be due to its favourable effect in increasing crop growth and better utilization and partitioning of food material which ultimately reflected in baby corn yield. Increased yield at higher levels of $ZnSO_4$ applied to soil along with foliar sprays made zinc more available and absorbed. The synergistic effect of zinc along with other essential plant nutrients resulted in balanced nutrient uptake and higher yield attributes might have contributed for higher yields in these treatments (22-25).

Green and dry fodder yield (t ha^{-1})

Among the treatments tested, the combined application of zinc sulphate through soil (25 kg ha^{-1}) and foliar sprays (0.2 %) at 15 & 30 DAS *i.e.* (T_{12}) has recorded the highest green & dry fodder yield (24.5 & 5.0 t ha^{-1}) followed by T_{11} (23.7 & 4.7 t ha^{-1}), T_{10} (23.2 & 4.6 t ha^{-1}) and T_9 (22.0 & 4.4 t ha^{-1}). Significantly the lowest yield (18.6 & 3.7 t ha^{-1}) was observed in control (Table 1). At all the levels of zinc soil application *i.e.* 0, 12.5 and 25 kg $ZnSO_4$ ha^{-1}, single spray of 0.2% $ZnSO_4$ either at 15 or 30 DAS and two sprays of 0.2% $ZnSO_4$ both at 15 and 30 DAS were statistically comparable.

Soil application of higher $ZnSO_4$ level along with foliar application of zinc might be due to its critical role in crop growth, involving in photosynthesis processes, respiration and other biochemical and physiological activities and thus improvement in growth parameters *viz.*, taller plants with more dry matter yield and yield components (26). Higher biological yield due to zinc fertilization was also attributed to the enhanced synthesis of carbohydrates and their transport to the site of production (6, 27, 28).

Table 1. Corn yield (kg ha^{-1}), green and dry fodder yield (t ha^{-1}) and per day productivity (g m^{-2} day^{-1}) of baby corn as influenced by zinc nutrition

Treatments	Baby corn yield (kg ha^{-1})	Green fodder (t ha^{-1})	Dry fodder (t ha^{-1})	Per day productivity (g m^{-2} day^{-1})		
				0-20 DAS	20-40 DAS	40 DAS to harvest
T_1: Control (no zinc)	6892	18.6	3.7	0.5	8.7	6.1
T_2: Foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS	7415	19.0	3.8	0.5	10.4	6.9
T_3: Foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS	7669	19.3	3.9	0.6	11.3	6.9
T_4: Foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and at 30 DAS	8185	20.5	4.1	0.6	12.1	7.4
T_5: Soil application of $ZnSO_4$ @ 12.5 Kg ha^{-1}	8324	21.1	4.2	0.6	12.1	7.6
T_6: T_5+ foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS	8597	21.3	4.3	0.6	12.5	8.9
T_7: T_5+foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS	8729	21.5	4.3	0.6	13.3	8.2
T_8: T_5+foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and 30 DAS	8879	21.7	4.3	0.7	13.4	8.6
T_9: Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	9013	22.0	4.4	0.7	15.0	9.2
T_{10}:T_9+ foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS	9453	23.2	4.6	0.7	16.0	9.3
T_{11}:T_9+foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS	9633	23.7	4.7	0.7	16.6	9.4
T_{12}:T_9+foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and 30 DAS	10000	24.5	5.0	0.8	17.6	10.5
S.Em±	381.9	0.9	0.2	0.04	0.9	0.5
CD (P = 0.05)	1120.0	2.7	0.6	0.1	2.7	1.4
CV (%)	7.7	7.4	8.3	11.9	11.8	9.7

Per day productivity (g m^{-2} day^{-1})

At all the growth stages, (Table 1) the highest per day productivity (g m^{-2} day^{-1}) was recorded with T_{12} treatment (0.8, 17.6 and 10.5 g m^{-2} day^{-1}) at 20, 40 DAS and at harvest, respectively which was comparable with T_{11} (0.7, 16.6 and 9.4 g m^{-2} day^{-1}), T_{10} (0.7, 16.6 and 9.4 g m^{-2} day^{-1}) and T_9 (0.7, 15.0 and 9.2 g m^{-2} day^{-1}) and the lowest was observed in control.

There was a gradual increase in per day productivity up to 40 DAS and after wards there was decline. In C_4 plant like corn, carbonic anhydrase activity is 1 % in bundle sheath chloroplasts and 20-60 in plasma membrane. Hence, zinc deficiency in plants have a direct influence on photosynthesis. It is also clear from the findings of earlier scientists that zinc plays a vital role in protein synthesis and zinc is the structural component of ribosomes and in zinc deficiency the ribosomes disintegrate. Hence, the per day productivity in zinc sufficiency was higher due to the favourable enzyme activity and vice versa. More taller plants with higher dry matter accumulation could also might have helped in higher per day productivity (29).

Effect on physical quality parameters

Size of ear (cm)

Length: The data (Table 2 & Fig. 1) recorded on length of ear, revealed the application of ZnSO4 @ 25 kg ha^{-1} as basal soil application along with two foliar sprays at 15 & 30 DAS (T_{12}) has registered longer ears (8.0 cm) and was on a par with T_{11}, T_{10} and T_9 treatments but T_{12} alone was significantly superior over rest of the treatments. The shortest ears (6.5 cm) were registered in control treatment.

Girth: Among different zinc fertilization treatments imposed on crop, the highest ear girth (4.1 cm) was recorded in treatment fertilized with soil application of zinc sulphate @ 25 kg ha^{-1} as basal + foliar spray of zinc sulphate @ 0.2 % at 15 & 30 DAS i.e., T_{12} followed by T_{11}, T_{10} and T_9. The lowest cob girth (3.1 cm) was noticed in T_1 treatment and was on a par with T_2 and T_3 treatments (Table 2 & Fig. 1). Involvement of zinc in various enzymatic processes which helps in catalysing reaction for growth finally leading to development of superior yield attributing characters (30-32).

Ear weight with husk and without husk (g ear^{-1}): Among the evaluated treatments, soil application of zinc sulphate @ 25 kg ha^{-1} combined with foliar sprays of zinc sulphate (0.2 %) at 15 & 30 DAS (T_{12}) recorded the highest ear weight with and without husk (91.5 & 60.8 g ear^{-1}) but was comparable to T_{11}, T_{10}, T_9, T_8 and T_7 treatments. While the lowest ear weight with and without husk (67.5 & 34.4 g ear^{-1}) was noticed in control, which was statistically comparable with T_2 and T_3 treatments (Table 2).

Husk percentage: The highest husk percentage (49.0 %) was registered by the treatment T_1 *i.e.* control which was on par with T_2 and T_3 and were significantly superior over rest of the treatments. Similarly, the lowest husk percentage (33.4 %) was noticed in the

Table 2. Size of ear (cm), fresh ear weight with and without husk (g ear^{-1}), husk percentage and density of ear (w/v) of baby corn as influenced by zinc nutrition

Treatments	Length	Girth	With husk	Without husk	Husk percentage	Density of ear
T_1: Control (no zinc)	6.5	3.1	67.5	34.4	49.0	1.7
T_2: Foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS.	7.0	3.3	71.9	39.1	45.5	1.7
T_3: Foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS.	7.0	3.4	73.9	41.4	43.9	1.7
T_4: Foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and at 30 DAS.	7.1	3.5	75.9	43.2	43.1	1.8
T_5: Soil application of $ZnSO_4$ @ 12.5 Kgha^{-1}	7.2	3.5	78.3	44.9	42.6	1.8
T_6: T_5+ foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS.	7.2	3.7	81.2	47.4	41.5	1.8
T_7: T_5+foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS.	7.3	3.7	83.8	50.2	40.1	1.9
T_8: T_5+foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and 30 DAS	7.3	3.6	85.8	52.8	38.4	1.9
T_9: Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	7.6	3.8	87.3	55.5	36.4	1.9
T_{10}:T_9+ foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS.	7.7	3.9	88.3	56.4	36.1	1.9
T_{11}:T_9+foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS.	7.8	4.0	89.6	58.7	34.4	2.0
T_{12}:T_9+foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and 30 DAS.	8.0	4.1	91.5	60.8	33.4	2.0
S.Em±	0.2	0.1	2.7	2.6	1.8	0.1
CD (P = 0.05)	0.5	0.3	7.9	7.7	5.3	0.1
CV (%)	4.0	4.9	7.0	9.4	7.7	6.8

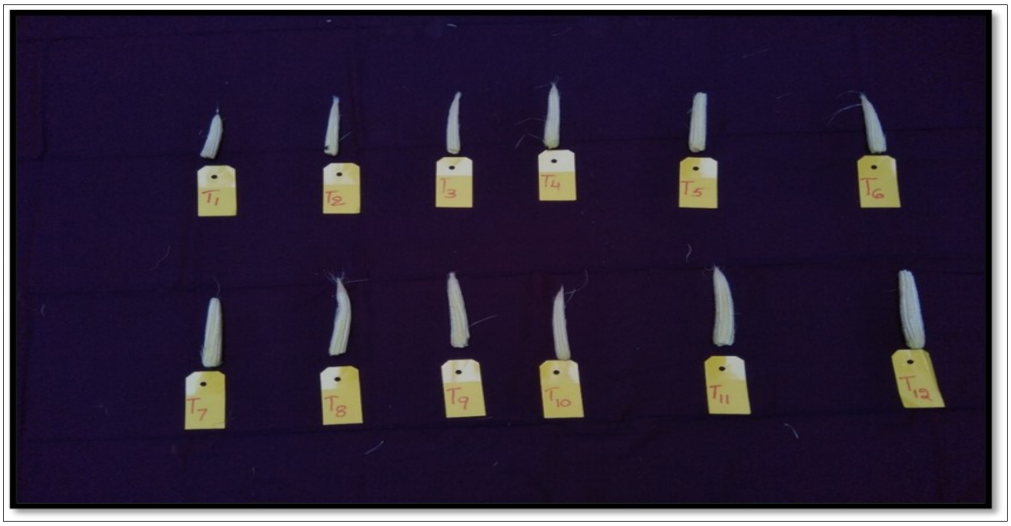

Fig. 1. Treatment wise length of baby corn.

treatment T_{12} and was statistically on par with the treatments T_{11}, T_{10}, T_9 and T_8. Taller plants with high dry matter accumulation and better transportation of photosynthates to sink *i.e.* ear could be the possible reason for low husk percentage (33) (Table 2).

Density of ear: Data revealed that zinc sulphate usage by soil (25 kg ha^{-1}) as basal and by foliar spray (0.2 %) at 15 & 30 DAS registered the highest density of ear (2.0) which was statistically comparable with T_{11}, T_{10}, T_9, T_8 and T_7 treatments. Control treatment recorded the lowest density of ear (1.7) and it may be due to high growth, higher translocation of photosynthate to sink *i.e.* ear due to favourable hormonal and enzymatic reactions at higher zinc availability (25) (Table 2).

Effect on chemical quality parameters

Crude protein content (%)

The data on crude protein content of plant and ear estimated at harvest was significantly affected by the treatments given and are presented in Table 3. The highest protein content in plant and ear (8.9 & 15.0 %) was recorded by the T_{12} treatment, which was on par with T_{11}, T_{10} and T_9treatments. Significantly the lowest protein in plant and ear (6.7 & 10.7 %) was found in control. The increase in protein content by zinc application might be due to its involvement in protein synthesis (zinc mottifis) of plants, as it is an important structural component of protein synthesis machinery and it is involved as zinc mottifis in protein synthesis of plant (34).

Crude fibre (%) in plant and ear

The data with respect to crude fibre (%) in plant and ear are presented in Table 3. The highest crude fibre (33.5 & 5.8 %) content in plant & ear was recorded with control (no zinc) however it was on par with (T_2). The lowest crude fibre content in plant as well as ear (24.0 and 3.6 %, respectively) was noticed in T_{12} treatment which was comparable with T_{11}, T_{10} and T_9 treatments.

Due to soar in protein synthesis and slump in the soluble carbohydrates could be responsible for lower content of crude fibre in plant and ear of baby corn. It is due to inverse relationship existing between protein and fibre content. These results could be attributed to the more protein synthesis at higher rates of zinc application thereby decreasing the fibre content of baby corn (35).

Ash content (%) in plant and ear

The highest ash content in plant (12.4 %) and ear (1.9 %) were obtained under treatment T_{12}. The treatments T_{12}, T_{11}, T_{10} and T_9 were on at par with each other recorded 55.0, 50.0, 48.7 and 43.7 % more ash content (%) of plant and 35.7, 35.7, 28.6 and 28.6 % in ear respectively, over the control. The lowest ash content in plant (8.0 %) and ear (1.4 %) was found with control treatment (Table 3).

Increase in ash contents due to increase in growth parameters and dry matter production because of synergistic

Table 3. Crude protein (%), crude fibre (%), Ash content (%), sugar content (%) in plant and ear of baby corn as influenced by zinc nutrition

Treatments	Crude protein (%)		Crude fibre (%)		Ash content (%)		Sugar content (%)	
	Plant	Ear	Plant	Ear	Plant	Ear	Plant	Ear
T_1: Control (no zinc)	6.7	10.7	33.5	5.8	8.0	1.4	3.6	8.3
T_2: Foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS	6.9	11.0	32.0	5.5	8.4	1.4	3.8	8.7
T_3: Foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS	7.0	11.4	30.3	5.2	8.6	1.5	3.9	9.0
T_4: Foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and at 30 DAS	7.2	11.7	29.0	5.0	9.0	1.5	4.3	9.8
T_5: Soil application of $ZnSO_4$ @ 12.5 kg ha^{-1}	7.7	12.2	28.7	4.9	10.0	1.7	4.8	10.4
T_6: T_5+ foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS	7.9	12.3	28.3	4.6	10.3	1.7	5.0	11.4
T_7: T_5+foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS	7.9	12.8	27.0	4.4	10.7	1.7	5.3	11.9
T_8: T_5+foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and 30 DAS	8.1	13.3	26.3	4.3	11.3	1.8	5.6	12.3
T_9: Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	8.4	13.9	25.0	3.9	11.5	1.8	6.0	12.8
T_{10}:T_9+ foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS	8.6	14.0	24.6	3.9	11.9	1.8	6.0	13.0
T_{11}:T_9+foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS	8.7	14.5	24.3	3.8	12.0	1.9	6.1	13.2
T_{12}:T_9+foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and 30 DAS	8.9	15.0	24.0	3.6	12.4	1.9	6.3	13.7
S.Em±	0.2	0.4	0.8	0.1	0.3	0.0	0.2	0.4
CD (P = 0.05)	0.6	1.2	2.3	0.4	1.0	0.1	0.5	1.0
CV (%)	4.5	5.7	4.8	5.3	5.6	3.5	5.3	5.5

effect among N and zinc which might have helped in higher uptake of nitrogen and manufacturing more leaf area resulting in more assimilates production (36-43).

Sugar Content (%) in plant and ear

The highest sugar content in plant (6.3 %) and ear (13.7 %) were registered in T_{12} treatment which was on a par with T_{11}, T_{10} and T_9 treatments. The lowest sugar content in plant (3.6 %) and ear (8.3 %) were observed with the control. T_1, T_2 and T_3 were uniform in their performance (Table 3).

Role of zinc is well known in hormone and enzyme formation that accelerates more photosynthesis, transportation to sink resulting in higher sugar content in plant and ear of baby corn (44).

Zinc content in plant (ppm) at 30, 40 and at harvest in plant and ear at harvest

The data pertaining to zinc content in plant at different growth stages as affected by different treatments are presented in the Table 4. Zinc is one of the most accumulated micronutrients in the above ground matter of maize followed by manganese, copper and boron (45). There was an increase in zinc content upto 40 DAS and afterward a gradual decrease was observed.

At 30 DAS zinc content in plant (31.4 ppm), the highest was found with T_{12} which was on a par with T_{11} (30.6 ppm) and T_{10} (29.7 ppm) and significant over rest of the treatments Significantly the lowest (18.0 ppm) was noticed in control.

At 40 DAS the highest zinc content (35.0 ppm) was obtained from the treatment T_{12} which remained on a par with treatments T_{11} (34.7 ppm), T_{10} (34.0 ppm) and T_9 (33.7 ppm). Significantly the lowest zinc content (17.3 ppm) was observed from control.

At harvest, similar trend that was observed at 30 DAS, got repeated. T_{12} treatment recorded significantly higher zinc concentration (28.0 ppm). Similarly, the lowest (13.0 ppm) occurred from control. With respect to zinc content in ear, same trend that was observed in case of zinc content of the plant was observed.

High concentration of zinc in early stages and declining after 40 DAS is a clear-cut sign of zinc remobilization from leaves. It is related to pollen production by tassels. The higher zinc content in T_{12}, T_{11} and T_{10} treatments might be due to the higher zinc supply and high zinc availability. These results are in line with the findings of (46). Stem is an important source of zinc for developing reproductive organs, which reached the maximum at tasselling. From this stage of plant growth up to harvest, the content of zinc in these organs were reduced by 50 %. It is the process of extended remobilization of nutrients from vegetative organs that occurred at the beginning of dough stage of kernel maturity (24).

Conclusion

Based on the above results and discussion, it can be concluded that more nourishment zinc, through root and foliar feeding promotes balanced absorption of all essential nutrients resulting in higher growth, yield attributes and yield. Role of zinc is well known in hormone and enzyme formation that accelerates more photosynthesis, transportation to sink resulting in superior quality parameters. The highest baby corn yield, (green and dry fodder yield, size of ear (length & girth), ear weight with husk, without husk, density, crude protein, ash & sugar content, zinc content in plant and ear and the lowest crude fibre & husk percentage were recorded with combination of $ZnSO_4$ (25 kg ha^{-1}) by soil and foliar spray (0.2 %) at 15 DAS and 30 DAS *i.e.* T_{12} followed by T_{11}, T_{10} and T_9 treatments.

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Authors' contributions

MSK carried out research trail, documentation and manuscript preparation, BV reviewed the research, MSR and PRKP provided the guidance and helped in process. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The Authors do not have any conflict of interest to declare.

Table 4. Zinc content in plant (ppm) at 30, 40 DAS and at harvest in plant and ear at harvest as influenced by zinc nutrition

Treatments	30 DAS	40 DAS	At harvest	
			Plant	Ear
T_1: Control (no zinc)	18.0	17.3	13.0	21.3
T_2: Foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS	21.7	25.7	19.7	25.3
T_3: Foliar spray of $ZnSO_4$ @ 0.2%at 30 DAS	23.7	26.0	20.3	26.0
T_4: Foliar spray of $ZnSO_4$ @ 0.2%at 15 DAS and at 30 DAS	23.3	26.3	21.7	27.2
T_5: Soil application $ZnSO_4$ @ 12.5 kg ha^{-1}	25.9	28.7	23.5	28.3
T_6: T_5+ foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS	26.0	31.0	24.7	31.2
T_7: T_5+foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS	26.7	32.0	24.8	32.4
T_8: T_5+foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and 30 DAS	27.4	32.3	25.3	33.8
T_9: Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	28.0	33.7	25.6	34.0
T_{10}:T_9+ foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS	29.7	34.0	26.0	35.7
T_{11}:T_9+foliar spray of $ZnSO_4$ @ 0.2% at 30 DAS	30.6	34.7	26.3	36.7
T_{12}:T_9+foliar spray of $ZnSO_4$ @ 0.2% at 15 DAS and 30 DAS	31.4	35.0	28.0	38.7
S.Em±	0.8	0.9	0.8	1.1
CD (P = 0.05)	2.3	2.5	2.2	3.3
CV (%)	5.3	5.0	5.7	6.3

Ethical issues: None

References

1. Singh AK, Kumar R, Bohra JS, Kumawat N. Fodder yield, nutrient uptake and quality of baby corn (*Zea mays* L.) as influenced by NPKS and Zn fertilization. Res Crop. 2015;16(2):243–9. https://doi.org/10.5958/2348-7542.2015.00036.4
2. Thavaprakaash N, Velayudham K, Muthukumar VB. Effect of crop geometry, intercropping system and integrated nutrient management practices on productivity of baby corn (*Zea mays* L.) based intercropping systems. Res J Agric Biol Sci. 2005;1(4):295–302. http://www.aensiweb.net/AENSIWEB/rjabs/rjabs/295-302.pdf
3. Dass S, Yadav VK, Kwatra A, Jat ML, Rakshit S, Kaul J, et al. Baby corn in India. Technical Bulletin. New Delhi: Directorate of Maize Research, Pusa Campus; 2008. 6(1):1–45.
4. Mahapatra A, Mishra GC, Barik AK. Integrated nutrient management in baby corn and its residual effect on green gram under rainfed ecosystem of Odisha. Int J Agric Environ Biotechnol. 2018;11(3):433–8. https://doi.org/10.30954/0974-1712.06.2018.3
5. El-Azab ME. Increasing Zn ratio in a compound foliar NPK fertilizer in relation to growth, yield and quality of corn plant. J Innov Pharm Biol Sci. 2015;2(4):451–68. https://jipbs.com/index.php/journal/issue/view/8
6. Cakmak I. Enrichment of fertilizers with zinc: an excellent investment for humanity and crop production in India. J Trace Elem Med Biol. 2009;23:281–9. https://doi.org/10.1016/j.jtemb.2009.05.002
7. Amanullah, Saleem A, Iqbal A. Foliar phosphorus and zinc application improve growth and productivity of maize (*Zea mays* L.) under moisture stress conditions in semi-arid climates. J Microbiol Biochem Technol. 2016;8(5):433–9. https://doi.org/10.4172/1948-5948.1000321
8. Chand SW, Susheela R, Sreelatha D. Quality studies and yield as influenced by zinc fertilization in baby corn (*Zea mays* L.). Int J Curr Microbiol Appl Sci. 2016;6(10):2454–60.
9. Sharma R, Choudhary R, Bhanwarlal J. Effect of nitrogen and zinc fertilization on growth and productivity of maize. Int J Agric Sci. 2017;13(2):161–76. https://www.cabidigitallibrary.org/doi/pdf/10.5555/20173278359
10. Zhang YQ. Zinc fertilizer placement affects zinc content in maize plant. Plant Soil. 2013;372:81–92. https://doi.org/10.1007/s11104-013-1904-9
11. Azeem T, Anjum SA, Randhawa MA, Ullah E, Naeem M, Qamar R, et al. Influence of zinc nutrition on growth and yield behaviour of maize (*Zea mays* L.) hybrids. Am J Plant Sci. 2014;5(18):2646. https://doi.org/10.4236/ajps.2014.518279
12. Walkley AJ, Black CA. Estimation of soil organic carbon by chromic acid titration method. Soil Sci. 1934;37:29–38. https://doi.org/10.1097/00010694-193401000-00003
13. Subbiah BV, Asija GL. A rapid procedure for estimation of available nitrogen in soils. Curr Sci. 1956;25:259–60.
14. Olsen SR, Cole CL, Watanabe PS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Washington (DC): United States Department of Agriculture; 1954. Circular No.: 939.
15. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt. Ltd.; 1973.
16. Lindsay WL, Norvell WA. Development of DTPA soil test for zinc, iron, manganese and copper. Soil Sci Soc Am J. 1978;42:421–8. https://doi.org/10.2136/sssaj1978.03615995004200030009x
17. Gomez KA, Gomez AA. Statistical procedures in agricultural research. 2nd ed. New York: Wiley; 1984:680.
18. Doubetz O, Wells D. Relation of barley varieties to nitrogen fertilizers. Indian J Agric Sci. 1968;70(3):253–6.
19. Madhadevan SA. Laboratory manual for nutrition research. 1965:56-8.
20. Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F. Sugar estimation by phenol-sulphuric acid method. Anal Chem. 1956;26:350.
21. Piper CS. Soil and plant analysis: a laboratory manual of methods for the examination of soils and the determination of the inorganic constituents of plants. Bombay: Hans Publications; 1966.
22. Lauer J. What happens within the corn plant when drought occurs? Wisconsin Crop Manag. 2006;10:225–8.
23. Peddababu P, Shanthi M, Prasad BR, Minhas PS. Effect of zinc in rice-blackgram cropping system in saline soils. Andhra Agric J. 2007;54(1-2):47–50.
24. Grzebisz W, Wronska M, Diatta JB, Dullin P. Effect of zinc foliar application at early stages of maize growth on patterns of nutrients and dry matter accumulation by the canopy. Part I. Zinc uptake patterns and its redistribution among maize organs. J Elementol. 2008;13(1):17–28.
25. Potarzycki J, Grzebisz W. Effect of zinc foliar application on grain yield of maize and its yielding components. Plant Soil Environ. 2009;55(12):519–27. https://pse.agriculturejournals.cz/#copy_link
26. Thalooth M, Tawfik M, Mohamed MH. A comparative study on the effect of foliar application of zinc, potassium and magnesium on growth, yield and some chemical constituents of mung bean plants under water stress conditions. World J Agric. 2006;2(1):37–46. https://idosi.org/wjas/wjas2(1)/7.pdf
27. Kaya C, Higgs DEB. Response of tomato (*Lycopersicon esculentum* L.) cultivars to foliar application of zinc when grown in sand culture at low zinc. Sci Hortic. 2002;93(1):53–64. https://doi.org/10.1016/S0304-4238(01)00310-7
28. Zeidan MS, Mohamed MF, Hamouda HA. Effect of foliar fertilization of Fe, Mn and Zn on wheat yield and quality in low sandy soils fertility. World J Agric Sci. 2010;6(6):696–9. https://www.idosi.org/wjas/wjas6(6)/11.pdf
29. Utsunomiya E, Muto S. Carbonic anhydrase in the plasma membranes from leaves of C3 and C4 plants. Physiol Plant. 1993;88(3):413–9.
30. Kenbaev B, Sade B. Response of field-grown barley cultivars grown on zinc-deficient soil to zinc application. Commun Soil Sci Plant Anal. 2002;33(3–4):533–44. https://doi.org/10.1081/CSS-120002762
31. Hussain F, Yasin M. Soil fertility monitoring and management in rice-wheat system. Annu Rep. 2004:1–33.
32. Jakhar SR, Singh M, Balap CM. Effect of farmyard manure, phosphorus and zinc levels on growth, yield, quality and economics of pearl millet (*Pennisetum glaucum*). Indian J Agric Sci. 2006;76(1):58–61.
33. Paramesh V, Dhar S, Vyas AK, Dass A. Studies on impact of phosphorus enriched compost, chemical fertilizer and method of zinc application on yield, uptake and quality of maize (*Zea mays*). Indian J Agron. 2014;59(4):613–8. https://doi.org/10.59797/ija.v59i4.4578
34. Jhaw GC. Effect of different fertilizer strategies on yield of winter wheat. Beijing Agric Sci. 1991;9(1):24–9.
35. Almodares CA, Jafarinia M, Hadi MR. Effects of nitrogen fertilizer on chemical compositions in corn and sweet sorghum. Am Eurasian J Agric Environ Sci. 2009;6(4):441–6. https://www.idosi.org/aejaes/jaes6(4)/11.pdf
36. Cheema HNA. Yield and quality response of maize (*Zea mays* L.) fodder grown on different nitrogen, phosphorus and seedling densities [MSc thesis]. Faisalabad (Pakistan): University of Agriculture; 2000.
37. Husnain MA. Effects of nitrogen application on fodder yield and quality of sorghum harvested at different times [MSc thesis]. Faisalabad (Pakistan): University of Agriculture; 2001.

38. Ayub M, Nadeem MA, Ahmad R, Javaid F. Response of maize fodder to different nitrogen levels and harvesting times. J Life Sociol Sci. 2013;1(1):45–7. https://www.pjlss.edu.pk/pdf_files/2003_1/45-47.pdf

39. Ayub M, Nadeem MA, Tanveer A, Tahir M, Khan RMA. Interactive effect of different nitrogen levels and seed rates on fodder yield and quality of pearl millet. J Agric Sci. 2007;44:592–6.

40. Gandahi AW, Wagan MR, Rajper I, Sial NB. Response of maize fodder to soil and foliar applied zinc. In: Proceedings of the International Symposium and Workshop on Tropical Peatland, Sarawak, Malaysia. 2008:155–60. https://www.researchgate.net/publication/282685394

41. Iqbal MF, Sufyan MA, Aziz MM, Zahid Q, Ghani IA, Aslam S. Efficacy of nitrogen on green fodder yield and quality of oat (*Avena sativa* L.). J Anim Plant Sci. 2009;19(2):82–4.

42. Nadeem MA, Iqbal M, Ayub K, Mubeen, Ibrahim M. Effect of nitrogen application on forage yield and quality of maize sown alone and in mixture with legumes. Pak J Life Soc Sci. 2009;7(2):161–7. https://pjlss.edu.pk/pdf_files/2009_2/13.pdf

43. Iqbal J, Khan R, Wahid A, Sardar K, Khan N, Ali M, et al. Effect of nitrogen and zinc on maize (*Zea mays* L.) yield components and plant concentration. Adv Environ Biol. 2016;10(10):203–9. https://www.aensiweb.net/AENSIWEB/aeb/aeb/2016/October/203-208.pdf

44. Ramesh P, Panwar NR, Singh AB, Ramana S. Effect of organic manures on productivity, nutrient uptake and soil fertility of maize (*Zea mays* L.), linseed (*Linum usitatissimum*) cropping system. Indian J Agric Sci. 2008;78:351–4.

45. Borges ID, Von Pinho RG, Pereira JLDAR. Micronutrients accumulation at different maize development stages. Cienc Agrotec. 2009;33(4):1018–25. https://doi.org/10.1590/S1413-70542009000400011

46. Westgate ME, Lizaso J, Batchelor W. Quantitative relationships between pollen shed density and grain yield in maize. Crop Sci. 2003;43(3):934–42. https://doi.org/10.2135/cropsci2003.0934

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