Journal of Experimental Agriculture International

Volume 46, Issue 7, Page 973-982, 2024; Article no.JEAI.119224
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Impact of Foliar Fortification of Zinc and Iron on Nutrient Content and their Uptake by Maize Crop

Vishal [a++], Jay Nath Patel [a#*] and Mohd Shah Alam [a#]

[a] Department of Agronomy, School of Agriculture, Abhilashi University, Chail Chowk, Mandi, Himachal Pradesh, 175028, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jeai/2024/v46i72652

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/119224

Original Research Article

Received: 28/04/2024
Accepted: 02/07/2024
Published: 06/07/2024

ABSTRACT

Aim: To study the effect of zinc and iron foliar fortification on nutrient content and their uptake by maize crop.
Study Design: Randomized block design.
Place and Duration of Study: One year field study at Research Farm, School of Agriculture, Abhilashi University, Chail Chowk, Mandi (H.P).
Methodology: The experiment was conducted with three replications and eight treatments.
Results: Spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 recorded significantly highest content of the nitrogen, phosphorus and potassium in grains and stover of maize along with their maximum uptake by grains, stover and total uptake by maize crop, which was at par with spray of $ZnSO_4$ @ 1

[++] *M.Sc. Research Scholar;*
[#] *Assistant Professor;*
**Corresponding author: E-mail: pateljaynduat333@gmail.com;*

Cite as: *Vishal, Jay Nath Patel, and Mohd Shah Alam. 2024. "Impact of Foliar Fortification of Zinc and Iron on Nutrient Content and Their Uptake by Maize Crop". Journal of Experimental Agriculture International 46 (7):973-82. https://doi.org/10.9734/jeai/2024/v46i72652.*

% + spray of $FeSO_4$ @ 0.1. Significantly highest zinc content in grains and stover was noted in spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 and it was statistically at par with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.1, however, the content of iron in grains and stover was found highest in spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 and it was on par with spray of $ZnSO_4$ @ 0.5 % + spray of $FeSO_4$ @ 0.3 %. The uptake of zinc and iron by grains, stover and total uptake by maize crop was significantly maximum under spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 %. Whereas, the content of all these nutrients in grains and stover and their uptake by grains, stover and total uptake by maize crop were found minimum under control (Spray of water) during the experiment.

Conclusion: This study showed that the foliar application of zinc and iron significantly increases the content of nutrients and their uptake by maize crop.

Keywords: Maize; zinc; iron; foliar application; nutrient content and uptake.

1. INTRODUCTION

Maize is one of the most important cereal crops occupying third position in the world after wheat and rice. It is the most versatile crop and is grown in more than 166 countries across the globe, including tropical, subtropical and temperate regions. In world, maize crop occupies an area of 202.92 million hectares with production of 1227.86 million metric tons with a mean productivity 6.05 metric tons ha^{-1} in the year of 2023-24 and China was the world leader in maize production, producing 288.84 million metric tons, followed by European Union, Africa, Ukraine, Russia and India [1]. In India, maize crop occupies an area 10.40 million hectare with production of 35.50 million metric tons with an average yield of 3.41 metric tons ha^{-1} [2]. Exploitative agriculture involving modern production technology with the introduction of high yielding sweet corn, coupled with use of high analysis fertilizers lead to deficiency of micronutrients, particularly zinc (Zn) and iron (Fe). In future, it may emerge as an alarming situation in the intensively cultivated areas.

The process of adding vitamins or minerals to the crops in order to improve their overall nutrient content is called as fortification. It has two types, genetic biofortification and agronomic fortification. Enhancing a particular nutrient by addition of fertilizer to soil or to foliage in appropriate form, time and growth stages of the crop is known as agronomic fortification which is a simple and rapid solution to the problem.

About half of the world's population suffers from micronutrient malnutrition, including iron, zinc and iodine which are mainly associated with low dietary intake of micronutrients in diets with less diversity of food. Recent reports indicate that nearly 5,00,000 children under 5 years of age die annually because of Zn and Fe deficiencies. Iron and zinc are essential minerals for humans. Deficiencies in both contribute to severe cases of malnutrition. Zinc and iron are very important essential micronutrients for the growth and development of the plants and these micronutrients are also important for the human beings and can be available for the humans by plants. The maize crop is an important cereal grain crop which can provide the zinc and iron to the humans as well as to the animal.

Among the micronutrients, zinc deficiency is most common in the world [3]. Worldwide incidence of zinc deficiency in soils is becoming more important due to its impact on human health [4]. Zinc deficiency in Indian soils is expected to increase from 42 per cent in 1970 to 63 per cent in 2025 due to continuous depletion of soil fertility. Zinc plays an important role in chlorophyll formation, carbohydrate metabolism and protein synthesis. Proper method of nutrient application can be another approach for better uptake and utilization of Zn. Among the different methods; the foliar spray of micronutrients is efficient for enhancement of crop productivity [5].

Iron (Fe) is an important nutrient for humans and plants. It is a very important mineral for humans that is essential for the production of hemoglobin, a protein in red blood cells that carries oxygen throughout the body. Iron is also involved in respiration, energy metabolism, collagen synthesis and immune function. Iron deficiency can cause anemia, which is a condition where the blood has low levels of hemoglobin and oxygen, resulting in fatigue, weakness and poor performance. Iron (Fe) is also important for plants. Iron deficiencies hindered plant growth and production [6]. Soil Fe deficiency is a global problem that not only affects crop yield reduction, but also food quality [6], [7]. Iron fertilizers were widely used to increase yield and concentration of iron in fruits as well as crop quality. They could be applied in different ways, such as foliar application, soil application (sprayed on the soil surface or applied into the soil) and seed coating method. Foliar application was considered the most effective method for increasing both grain yield and grain micronutrient content [8]. It is a simple and direct application on the leaves [9]. Iron is essential element for not only the human beings, but also for animals and plants [10], plays a significant role in different biochemical reaction such as electron transport, DNA and RNA synthesis, and acts as a catalyst in enzymatic processes [11]. It also aids in synthesis and maintenance of chlorophyll and it is constituent of nitogenase. Zn and Fe when applied to fodder maize will boost the fodder yield [12].

Iron is one of the micronutrients for normal plant growth. Although Fe is the fourth most abundant element in the earth's crust, it is the third-most limiting nutrient for plant growth [13]. Fe is involved in many important compounds and physiological processes in plants. It is required for the activity of ALA synthase, which catalyzes the first identified step of the tetrapyrrole biosynthetic pathway leading to chlorophyll formation and therefore, it is indirectly responsible for much of the green color of growing plants. Iron plays an important role in electron transfer in photosynthesis, respiration, nitrogen fixation as well as in DNA synthesis. Khurana et al [14] observed a spectacular response of maize to zinc and iron application. Balanced and optimum use of fertilizers plays a vital role in increasing the yield of cereals [15]. Supplementation of micronutrients through foliar results in better nutrient balance in plants [16]. Foliar nutrition increases the utilization of plant nutrients. The nutrients absorbed by the leaves stimulate the metabolic processes in the plant, positively influencing the nutrient uptake via the roots. Among the different agronomic manipulations to increase the yield, the application of micronutrients plays an important role. Further, the micronutrients can be supplied efficiently through foliar application.

2. MATERIALS AND METHODS

2.1 Experimental Site and Edaphic Conditions

The experiment was carried out at the Research Farm of School of Agriculture, Abhilashi University, Chail Chowk, Mandi (H.P.) during the *Kharif season* of 2023. The experimental farm is situated at 30º 32' N latitude and 74º 53' E longitude, with an elevation of 1391 m above mean sea level. The soil of the experimental field was moderately acidic in reaction, medium in organic carbon, low in available nitrogen (226.59 kg ha^{-1}), medium in available phosphorus (16.77 kg ha^{-1}), and high in available potassium (295.81 kg ha^{-1}). The pH of experimental soil was moderately acidic in reaction (5.8) with in electrical conductivity of 0.006 dS m^{-1}, high in organic carbon (0.78%), deficient in zinc (0.80 mg kg^{-1}) and sufficient in iron (41.39 mg kg^{-1}).

2.2 Details of Experiment and Methodology of Nutrient Determination

A field experiment was laid out in a randomized block design with eight treatments and replicated thrice. The treatments comprised of T_1= Control (Spray of water), T_2= Spray of $ZnSO_4$ @ 0.5 %, T_3= Spray of $ZnSO_4$ @ 1 %, T_4= Spray of $FeSO_4$ @ 0.1 %, T_5= Spray of $FeSO_4$ @ 0.3 %, T_6= Spray of $ZnSO_4$ @ 0.5 % + Spray of $FeSO_4$ @ 0.3 %, T_7= Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %, T_8= Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %. Maize crop was fertilized with recommended doses of N, P, K (120:60:40) and treatment wise doses of zinc and iron were applied through Urea, DAP, MOP, Zinc sulphate and Ferrous sulphate, respectively. Maize cultivar 'Hybrid corn-9220' was shown at spacing of 20 × 60 cm. For analysis of the content of nutrients in grains and stover of maize crop, the plant samples were collected from each treatment after harvest of the crop and they were cleaned and shade dried. Later, the shade dried samples were oven dried at 60 ± 2º C for 24-48 hours till their weight were constant and the samples then finely powdered using a mixer grinder. The finely grind plant samples were used for the analysis of N, P, K, Zn and Fe content in maize crop. The estimation of the nitrogen content in the plant samples was done by the modified Kjeldahl's digestion and distillation method as described by Jackson [17]. The phosphorus content in the plant was determined by the venadomolybdate phosphoric yellow color method and the phosphorus content in the plant samples was estimated using a spectrophotometer as described by Jackson [17]. Potassium content in plant samples of maize was determined by using a flame photometer [17]. The zinc and iron content in plant samples was determined by di acid method with estimation by AAS [18]. The N, P, K (kg ha^{-1}), Zinc and Iron (mg ha^{-1}) uptake by grains and stover of maize in each treatment was calculated by multiplying the N,P,K content in (%) and Zinc and iron content (mg kg^{-1}) with yields of grain and stover (q ha^{-1}). The total uptake of different nutrients was calculated after sum of their uptake by grains and stover of maize crop.

3. RESULTS

3.1 Nitrogen Content (%) and Uptake (kg ha^{-1})

The data regarding nitrogen content and uptake by maize crop data has been presented in Table 1. and illustrated in Fig. 1. The study of the data showed that the nitrogen content and nitrogen uptake among the different treatments were affected significantly by foliar application of zinc and iron.

Significantly highest nitrogen content in grains (1.36), stover (0.60) of maize crop and nitrogen uptake by grains (74.41), stover (42.96) as well as total uptake (117.37) by maize crop was found with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 %, which was statistically at par with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.1 %. Whereas, significantly lowest nitrogen content in grains (1.07), stover (0.34) of maize and nitrogen uptake by grains (32.93), stover (14.60) and total uptake (47.53) by maize crop was recorded with control (Spray of water) during field experiment.

3.2 Phosphorus Content (%) and Uptake (kg ha^{-1})

The data regarding phosphorus content and uptake by maize crop data has been presented in Table 2. and illustrated in Fig. 2. The study of

Table 1. Effect of zinc and iron fortification on nitrogen content (%) and their uptake (kg ha^{-1}) by maize crop

S.N.	Treatments	Nitrogen Content (%)		Nitrogen Uptake (kg ha^{-1})		
		Grains	Stover	Grains	Stover	Total
T_1	Control (Spray of water)	1.07	0.34	32.93	14.60	47.53
T_2	Spray of $ZnSO_4$ @ 0.5 %	1.20	0.46	54.62	25.09	79.71
T_3	Spray of $ZnSO_4$ @ 1 %	1.24	0.48	57.15	27.79	84.94
T_4	Spray of $FeSO_4$ @ 0.1 %	1.12	0.38	46.82	19.37	66.19
T_5	Spray of $FeSO_4$ @ 0.3 %	1.17	0.41	49.88	21.92	71.80
T_6	Spray of $ZnSO_4$ @ 0.5 % + Spray of $FeSO_4$ @ 0.3 %	1.25	0.54	63.14	34.74	97.88
T_7	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %	1.34	0.58	71.40	39.72	111.12
T_8	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %	1.36	0.60	74.41	42.96	117.37
	SEm(±)	**0.03**	**0.01**	**1.87**	**1.09**	**3.07**
	CD (5%)	**0.10**	**0.04**	**5.75**	**3.34**	**9.40**

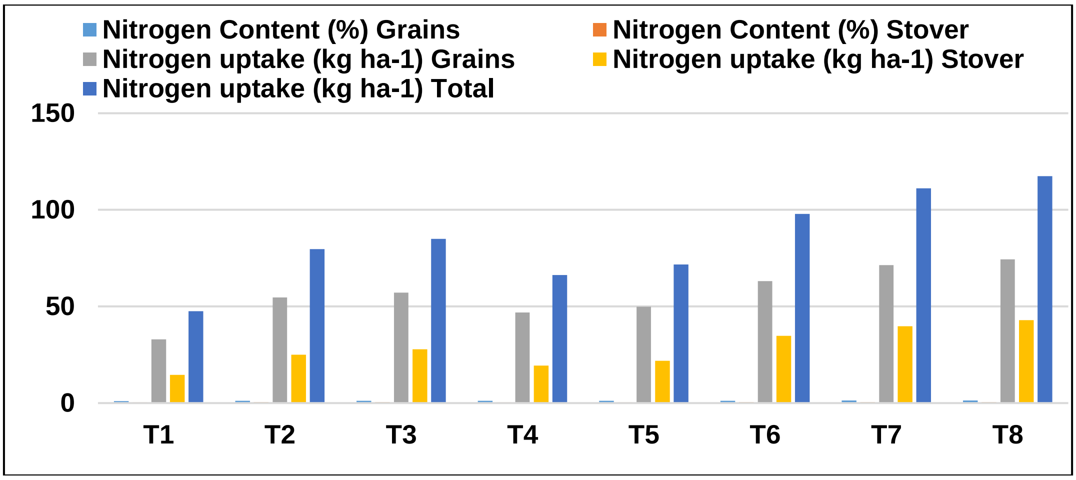

Fig. 1. Effect of zinc and iron fortification on nitrogen content (%) and their uptake (kg ha^{-1}) by maize crop

the data showed that the phosphorus content among the different treatments were affected significantly by foliar application of zinc and iron.

Significantly highest phosphorus content in grains (0.38), stover (0.157) and phosphorus uptake in grains (20.79), stover (11.24) as well as total uptake (32.03) by maize crop was found with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 %, which was statistically at par with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.1 %, Whereas, significantly lowest phosphorus content in grains (0.16), stover (0.123) and phosphorus uptake by grains (4.92), stover (5.28) and total uptake (10.20) by maize crop was recorded with control (Spray of water) during field experiment.

3.3 Potassium Content (%) and Uptake (kg ha^{-1})

The data regarding potassium content and uptake by maize crop data has been presented in Table 3. and illustrated in Fig. 3. The study of the data showed that the potassium content among the different treatments were affected significantly by foliar application of zinc and iron.

Table 2. Effect of zinc and iron fortification on phosphorus content (%) and their uptake (kg ha^{-1}) by maize crop

S.N.	Treatments	Phosphorus Content (%)		Phosphorus uptake (kg ha^{-1})		
		Grains	Stover	Grains	Stover	Total
T_1	Control (Spray of water)	0.16	0.123	4.92	5.28	10.20
T_2	Spray of $ZnSO_4$ @ 0.5 %	0.26	0.138	11.84	7.53	19.37
T_3	Spray of $ZnSO_4$ @ 1 %	0.28	0.142	12.91	8.20	21.11
T_4	Spray of $FeSO_4$ @ 0.1 %	0.20	0.126	8.36	6.42	14.78
T_5	Spray of $FeSO_4$ @ 0.3 %	0.23	0.135	9.80	7.22	17.02
T_6	Spray of $ZnSO_4$ @ 0.5 % + Spray of $FeSO_4$ @ 0.3 %	0.32	0.146	16.16	9.42	25.58
T_7	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %	0.37	0.151	19.71	10.32	30.03
T_8	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %	0.38	0.157	20.79	11.24	32.03
	SEm(±)	**0.009**	**0.04**	**0.42**	**0.24**	**0.72**
	CD (5%)	**0.02**	**0.01**	**1.28**	**0.74**	**2.21**

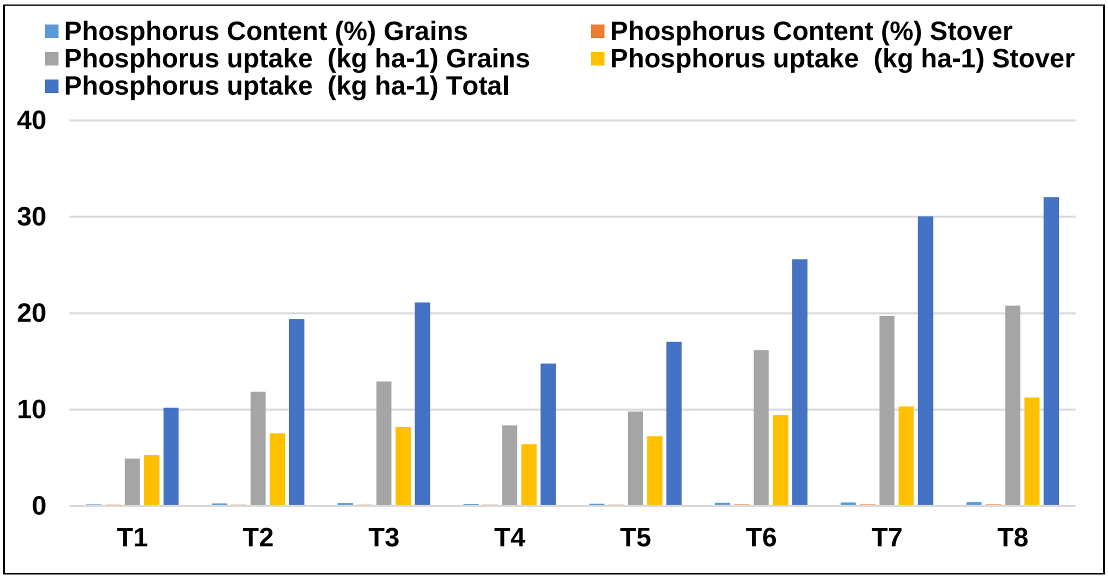

Fig. 2. Effect of zinc and iron fortification on phosphorus content (%) and their uptake by maize crop

Significantly highest potassium content in grains (0.52), stover (1.29) of maize crop and potassium uptake in grains (28.45), stover (92.60) as well as total uptake (121.05) by maize crop was found with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 %, which was statistically at par with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.1 %, whereas significantly lowest Potassium content in grains (0.22), stover (1.05) and potassium uptake by grains (6.77), stover (45.08) and total uptake (51.85) by maize crop was recorded with control (Spray of water) during field experiment.

3.4 Zinc Content (mg kg^{-1}) and Uptake (mg ha^{-1})

The data regarding zinc content and uptake by maize crop data has been presented in Table 4. and illustrated in Fig. 4. The study of the data showed that the zinc content among the different treatments were affected significantly by foliar application of zinc and iron.

Significantly highest Zinc content in grains (58.97) and stover (62.64) of maize crop was found with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 %, which was statistically at par with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.1 %, Whereas, significantly lowest zinc content in grains (37.78), stover (40.87) was recorded with control (Spray of water).

The highest zinc uptake in grains (3226.25), stover (4485.02) as well as total uptake by maize crop (7711.27)

Table 3. Effect of zinc and iron fortification on potassium content (%) and their uptake (kg ha^{-1}) by maize crop

S.N.	Treatments	Potassium Content (%)		Potassium Uptake (kg ha^{-1})		
		Grains	Stover	Grains	Stover	Total
T_1	Control (Spray of water)	0.22	1.05	6.77	45.08	51.85
T_2	Spray of $ZnSO_4$ @ 0.5 %	0.41	1.16	18.66	63.28	81.94
T_3	Spray of $ZnSO_4$ @ 1 %	0.46	1.18	21.20	68.31	89.51
T_4	Spray of $FeSO_4$ @ 0.1 %	0.3	1.11	12.54	56.59	69.13
T_5	Spray of $FeSO_4$ @ 0.3 %	0.37	1.15	15.77	61.48	77.25
T_6	Spray of $ZnSO_4$ @ 0.5 % + Spray of $FeSO_4$ @ 0.3 %	0.48	1.19	24.24	76.24	100.48
T_7	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %	0.51	1.26	27.17	86.28	113.45
T_8	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %	0.52	1.29	28.45	92.60	121.05
	SEm(±)	**0.01**	**0.03**	**0.59**	**2.07**	**2.59**
	CD (5%)	**0.03**	**0.10**	**1.82**	**6.36**	**7.94**

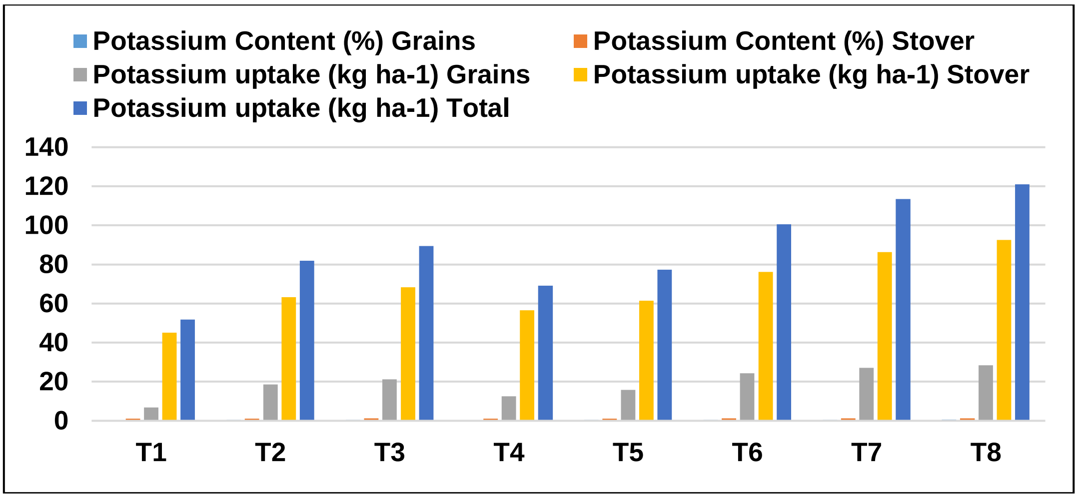

Fig. 3. Effect of zinc and iron fortification on potassium content (%) and their uptake (kg ha^{-1}) by maize crop

was found under spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 %, whereas the lowest zinc uptake in grains (1162.87), stover (1754.55) and total zinc uptake (2917.42) by maize crop was recorded with control (Spray of water).

3.5 Iron Content (mg kg^{-1}) and Uptake (mg ha^{-1})

The data regarding iron content and uptake by maize crop data has been presented in Table 5. and illustrated in Fig. 5. The study of the data showed that the iron content among the different treatments were affected significantly by foliar application of zinc and iron.

Significantly highest Iron content in grains (69.52) and stover (74.63) of maize crop was found spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 %, after harvesting of crop, which was statistically at par with spray of $ZnSO_4$ @ 0.5 % + spray of $FeSO_4$ @ 0.3 %. Whereas, significantly lowest iron content in grains (35.38), stover (38.57) of maize was recorded under control (Spray of water).

The highest iron uptake in grains (3803.46), stover (5343.51) as well as total uptake (9146.97)

Table 4. Effect of zinc and iron fortification on zinc content (mg kg^{-1}) and their uptake (mg ha^{-1}) by maize crop

S.N.	Treatments	Zinc Content (mg kg^{-1})		Zinc Uptake (mg ha^{-1})		
		Grains	Stover	Grains	Stover	Total
T_1	Control (Spray of water)	37.78	40.87	1162.87	1754.55	2917.42
T_2	Spray of $ZnSO_4$ @ 0.5 %	47.31	51.36	2153.55	2801.71	4955.26
T_3	Spray of $ZnSO_4$ @ 1 %	53.45	56.91	2463.51	3294.50	5758.01
T_4	Spray of $FeSO_4$ @ 0.1 %	44.49	46.73	1859.53	2382.31	4241.84
T_5	Spray of $FeSO_4$ @ 0.3 %	45.82	49.62	1953.29	2652.70	4605.99
T_6	Spray of $ZnSO_4$ @ 0.5 % + Spray of $FeSO_4$ @ 0.3%	49.73	54.48	2511.69	3505.24	6016.93
T_7	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %	56.63	60.59	3017.26	4149.23	7166.49
T_8	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %	58.97	62.64	3226.25	4485.02	7711.27
	SEm(±)	**1.56**	**1.66**	**66.24**	**93.42**	**160.88**
	CD (5%)	**4.77**	**5.08**	**202.86**	**286.13**	**492.11**

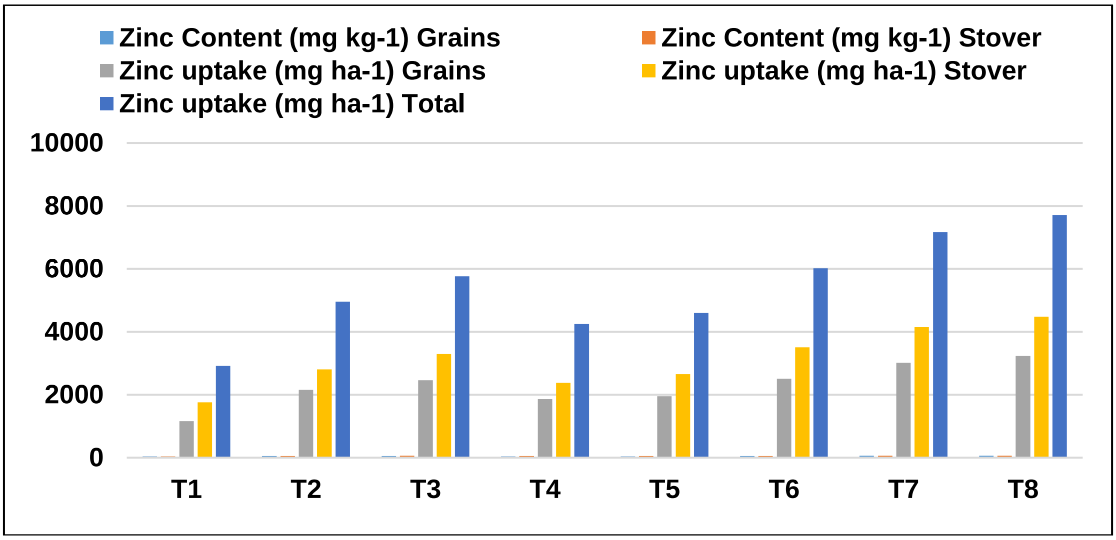

Fig. 4. Effect of zinc and iron fortification on zinc content (mg kg^{-1}) and their uptake (mg ha^{-1}) by maize crop

Table 5. Effect of zinc and iron fortification on iron content (mg kg^{-1}) and their uptake (mg ha^{-1}) by maize crop

S.N.	Treatments	Iron Content (mg kg^{-1})		Iron Uptake (mg ha^{-1})		
		Grains	Stover	Grains	Stover	Total
T_1	Control (Spray of water)	35.38	38.57	1089.00	1655.81	2744.81
T_2	Spray of $ZnSO_4$ @ 0.5 %	40.37	45.56	1837.63	2485.30	4322.93
T_3	Spray of $ZnSO_4$ @ 1 %	37.65	41.87	1735.29	2423.87	4159.16
T_4	Spray of $FeSO_4$ @ 0.1 %	45.74	49.05	1911.93	2500.57	4412.50
T_5	Spray of $FeSO_4$ @ 0.3 %	51.69	57.72	2203.54	3085.71	5289.26
T_6	Spray of $ZnSO_4$ @ 0.5 % + Spray of $FeSO_4$ @ 0.3 %	66.31	72.49	3349.33	4664.01	8013.34
T_7	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %	47.83	52.95	2548.38	3626.02	6174.40
T_8	Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %	69.52	74.63	3803.46	5343.51	9146.97
	SEm(±)	**1.89**	**1.67**	**70.29**	**105.45**	**186.55**
	CD (5%)	**5.80**	**5.12**	**215.26**	**322.95**	**571.35**

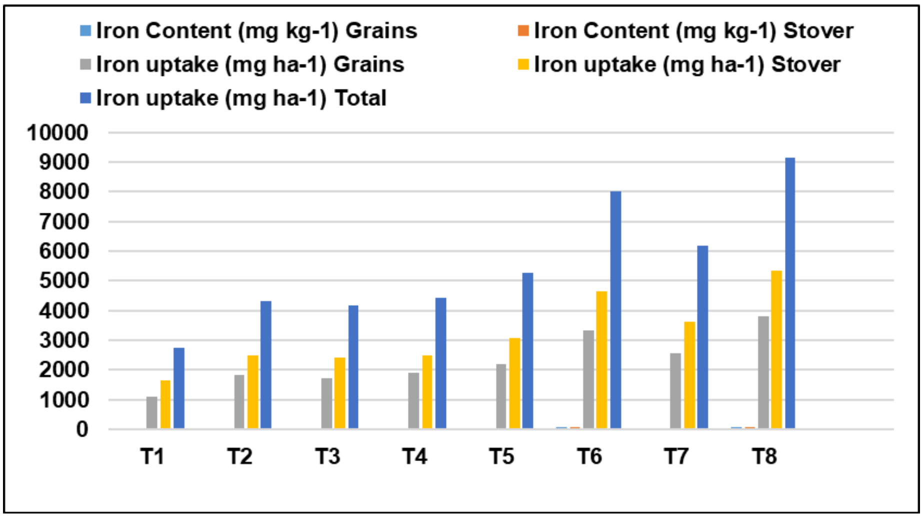

Fig. 5. Effect of zinc and iron fortification on iron content (mg kg^{-1}) and their uptake (mg ha^{-1}) by maize crop

by maize crop was observed with spray of $ZnSO_4$ @ 1 % + spray of $FeSO_4$ @ 0.3 %, Whereas the lowest iron uptake in grains (1089), stover (1655.81) and total iron uptake (2744.81) by maize crop was recorded under control (Spray of water).

4. DISCUSSION

Foliar application of zinc and iron at different concentration, significantly enhances the content and uptake of nitrogen, phosphorus, potassium, zinc and iron in grains and stover of the maize crop during the field experiment, which might be due to that zinc enhances enzymatic activities of plants because it is the constituents of many enzymes, which are responsible for better nutrients uptake in maize crop. The increase in content and nitrogen uptake by maize crop might be due to beneficial effect of foliar application of zinc and iron in maize crop, which promotes the protein synthesis, increased beneficial hormonal activities, photosynthetic activity, metabolic processes and many more functions which are driven by such nutrients, which raises the production of dry matter of the crop which resulted into higher uptake of the different nutrients by maize crop. The content and uptake of phosphorus might be increased due to foliar application of zinc and iron, which enhances the various enzymatic activity and nitrogen in crop plants which might improve the efficacy of phosphorus absorbing mechanism and encourage the direct and surface absorption, which helps in the phosphorus uptake by maize crop. Foliar application of zinc and iron increased the potassium content and uptake by maize crop was which might be due to the zinc and iron stimulates the activity of various enzymatic activity and many physiological and biochemical processes, such as photosynthesis and respiration and zinc and iron also improved the growth and development of crops which might be enhance the potassium content and uptake by maize crop. Afifi et al [19,20], and Somasundaram et al [21] also noted similar results. The reason for the increased content and uptake of zinc and iron by maize crop might be that when these nutrients were dissolved in water and sprayed on leaves, they are easily absorbed by the leaves and go to other plant parts and translocated within the plant system, leading to the synergistic action between zinc and iron and enhances the more zinc and iron content in maize plants and produced the higher dry matter of plants which further resulted in higher uptake of these nutrients by maize crop. Aref [22] and Aref [23] also found similar results when he applied the zinc, which is comparable to the results of this study.

5. CONCLUSION

Foliar spray of 1% $ZnSO_4$ + 0.3% $FeSO_4$ recorded significantly highest content of the nitrogen, phosphorus and potassium in grains and stover of maize along with their maximum uptake by grains, stover and total uptake by maize crop, which was statistically at par with foliar spray of 1% $ZnSO_4$ + 0.1% $FeSO_4$. The zinc content in grains and stover was significantly maximum under foliar spray of 1% $ZnSO_4$ + 0.3% $FeSO_4$ and it was statistically at par with foliar spray of 1% $ZnSO_4$ + 0.1% $FeSO_4$, however, the content of iron in grains and stover was found highest under foliar spray of 1% $ZnSO_4$ + 0.3% $FeSO_4$ and it was statistically on par with foliar spray of 0.5% $ZnSO_4$ + 0.3 % $FeSO_4$. The uptake of zinc and iron by grains, stover and total uptake by maize crop was recorded significantly maximum under foliar spray of 1% $ZnSO_4$ + 0.3% $FeSO_4$ over all other treatments. Whereas, the content of all these nutrients in grains and stover along with their uptake by grains, stover and total uptake by maize crop were found minimum under control (spray of water), during the experiment. In conclusion, this field experiment shows the remarkable increase in the content of the nitrogen, phosphorus, potassium, zinc and iron in grains and stover of maize crop along with their uptake by the grains, stover as well as their total uptake by maize crop.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENT

I am deeply thankful to my major advisor (Dr. Jay Nath Patel) for their valuable guidance, support and encouragement throughout the entire duration of this study. Their expertise and constructive instructions have been instrumental in shaping and direction of this research by their insightful suggestions and comments which have significantly enriched the quality of this research work. I am also indebted to the member of my research committee (Dr. Mohd Shah Alam) for their valuable comments. The authors are thankful to Department of Agronomy, School of Agriculture, Abhilashi University for providing necessary field and laboratory facilities. I would like to express my deepest thanks and appreciation who have provided their valuable suggestions to improve the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Anonymous. (USDA) World agricultural production. Foreign Agricultural Service Circular series WAP; 2024a.
2. Anonymous. (USDA) World agricultural production. Foreign Agricultural Service Circular series WAP; 2024b.
3. Alloway BJ. Zinc in soils and crop nutrition. International Zinc Association, Brussels, Belgium. 2004; 2: 101-107.
4. Singh B, Natesan SKA, Singh BK, Usha K. Improving zinc efficiency of cereals under zinc deficiency. Current Science. 2005;88 (1-10):36 – 44.
5. Savithri PR, Perumal, Nagarajan R. Soil and crop management technologies for enhancing rice production under micronutrient constraints. Nutrient

Cycling in Agroecosystems. 1999;53: 83-92.

6. Kanai M, Hirai M, Yoshiba M, Tadano T & Higuchi K. Iron deficiency causes zinc excess in *Zea mays*. Soil science and plant nutrition. 2009;55(2):271-276.
7. Manzeke GM, Mtambanengwe F, Nezomba H, Mapfumo P. Zinc fertilization influence on maize productivity and grain nutritional quality under integrated soil fertility management in Zimbabwe. Field Crops Research. 2014;166:128-136.
8. George R & Schmitt M. Zinc for crop production. Regents of the University of Minnesota; 2002.
9. Hosseini S, Maftoun M, Karimian N, Ronaghi A, Emam Y. Effect of zinc× boron interaction on plant growth and tissue nutrient concentration of corn. Journal of Plant Nutrition.2007;30(5): 773-781.
10. Kobayashi T, Nishizawa NK. Intracellular iron sensing by the direct binding of iron to regulators. Front Plant Science. 2015;6: 155.
11. Aguado-Santacruz GA, Moreno-Gomez B, Jimenez-Francisco B, Garcia-Moya E and Preciado-Ortiz RE. Impact of the microbial siderophores and phytosiderophores on the iron assimilation by plants: a synthesis. *Revista fitotecnia* Mexicana. 2012;35(1):9-21.
12. Singh C, Singh B, Satpal, Kumar P, Ankush, Gora MK, Kumar A. Micronutrient management for enhancing production of major fodder crops: A review. Forage Research. 2019;45(2):95-102.
13. Zuo Y, Zhang F. Soil and crop management strategies to prevent iron deficiency in crops. Plant Soil. 2011;339(1-2):83-95.
14. Khurana MPS, Bansal RL, Bhatti DS. Managing zinc and iron in kharif crops. Intensive Agriculture. 2002;23 - 25.
15. Asghar A, Ali A, Syed WH, Asif M, Khaliq T, Abid AA. Growth and yield of maize (*Zea mays* L.) cultivars affected by NPK application in different proportion. Pakistan Journal of Sciences. 2010; 62:41–44.
16. Patra AK, Tripathy SK, Samui RC. Effect of post flowering foliar application of nutrients on growth, yield and economics of rainfed groundnut (*Arachis hypogea* L.). Indian Journal of Plant Physiology. 1995;38(3): 203-206.
17. Jackson ML. Soil chemical analysis, Prentice hall of India, Pvt. Ltd., New Delhi. 1973.
18. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of America Journal*.* 1978;42(3):421-428.
19. Afifi MHM, Khalifa RKM, Camilia Y. Urea foliar application as a partial substitution of soil-applied nitrogen fertilization for some maize cultivars grown in newly cultivated soil. Australian Journal of Basic Applied Science. 2011;5(7):826-832.
20. Parasuraman P. Studies on integrated nutrient requirement of hybrid maize (*Zea mays* L.) under irrigated conditions. Madras Agricultural Journal. 2008;92(1): 89-94.
21. Somasundaram E, Mohmed MA, Thirukkmaran K, Chandrashekaran R,Vaijyapuri K. Biochemical changes, nitrogen flux and yield of crops due to organic sources of nutrients under maize based cropping system. Journal of Applied Science and Research. 2007;3(12):1724-1729.
22. Aref F. Zinc and boron content by maize leaves from soil and foliar application of zinc sulphate and boric acid in zinc and boron deficient soils. Middle-East Journal of Applied Sciences. 2011; 7(4):610-61.
23. Aref F. Manganese, iron and copper contents in leaves of maize plants (*Zea mays* L.) grown with different boron and zinc micronutrients. African Journal of Biotechnology. 2012;11(4):896-903.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/119224