Original Research Article

Impact of foliar fortification of zinc and iron on nutrient content and their uptake by maize crop

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 field experiment was laid out in randomized block design with three replications and eight treatments *viz*.- 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 %.

Results: Treatment T_8 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 treatment T_7. Significantly highest zinc content in grains and stover was noted in T_8 and it was statistically at par with treatment T_7, however, the content of iron in grains and stover was found highest in treatment T_8 and it was on par with treatment T_6. The uptake of zinc and iron by grains, stover and total uptake by maize crop was significantly maximum under treatment T_8. 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 treatment T_1 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.*

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1. INTRODUCTION

Maize is one of the most important cereals 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 region. 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 **(Anonymous, 2024a) [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} **(Anonymous, 2024b) [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.

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The process of adding vitamins or minerals to the crops in order to improve their overall nutrient content is called as fortification. It is two types, genetic biofortification and agronomic fortification. Enhancing of 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 **(Alloway 2004) [3].** Worldwide incidence of zinc deficiency in soils is becoming more important due to its impact on human health **(Singh et al. 2005) [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 **(Savithri et al. 1999) [5].**

Iron (Fe) is an important nutrient for humans and plants. It is very important mineral for human 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 **(Kanai et al. 2009) [6].** Soil Fe deficiency is a global problem that not only affects crop yield reduction, but also food quality **(Kanai et al. 2009 [6], Manzeke et al. 2014) [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 **(George and Schmitt. 2002) [8].** It is a simple and direct application on the leaves **(Hosseini et al. 2007) [9].** Iron is essential element for not only the human beings, but also for animals and plants **(Kobayashi and Nishizawa 2015) [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 **(Aguado-Santacruz et al. 2012) [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 **(Singh et al. 2019) [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 **(Zuo and Zhang 2011) [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 tetrapyr role 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. (2002) [14]** observed 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 **(Asghar et al. 2010) [15].** Supplementation of micronutrients through foliar results in better nutrient balance in plants **(Patra et al. 1995) [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 manipulation to increase the yield, the application of micronutrients plays an important role. Further, the micronutrients can be supplied efficiently through foliar application.

2. MATERIAL 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

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2.2 Details of experiment and methodology of nutrient determination

The experiment was laid out in a randomized block design (RBD) with eight treatments and three replications. The treatments used in field experiment were 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 %. Recommended doses of N, P, K and treatment wise dose of zinc and iron were applied through Urea, DAP, MOP, Zinc sulphate and Ferrous sulphate, respectively. The spacing for the tested variety hybrid corn-9220 was 20 × 60 cm for row to row and plant to plant. For analysation of content of nutrients in grains and stover of maize crop, the plant samples were collected from the 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 than 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, 1973) [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, 1973) [17].** Potassium content in plant sample of maize was determined by using flame photometer **(Jackson, 1973) [17].** The zinc and iron content in plant samples was determine by di acid method with estimation by AAS **(Lindsay and Norvell, 1978) [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.

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3. RESULTS

3.1 Nitrogen content (%) and uptake (kg ha^{-1})

The data regarding to 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 under the treatment T_8= (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %), which was statistically at par with the treatment T_7= (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %. Whereas, the 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 under treatment T_1= Control (Spray of water) during field experiment.

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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 (P= .05)	***0.10***	***0.04***	**5.75**	**3.34**	**9.40**

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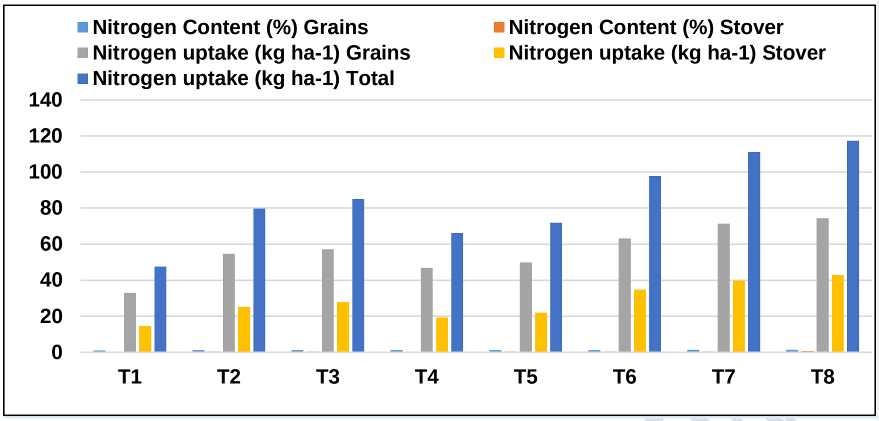

Fig.1 Effect of zinc and iron fortification on nitrogen content (%) and their uptake (kg ha^{-1}) by maize crop

3.2 Phosphorus content (%) and uptake (kg ha^{-1})

The data regarding to phosphorus content and uptake by maize crop data has been presented in Table 2. and illustrated in Fig. 2. The study of 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 under the treatment T_8= (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %), which was statistically at par with the treatment T_7= (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %), whereas, the 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 under treatment T_1= Control (Spray of water) during field experiment.

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 (P= .05)	***0.02***	***0.01***	**1.28**	**0.74**	**2.21**

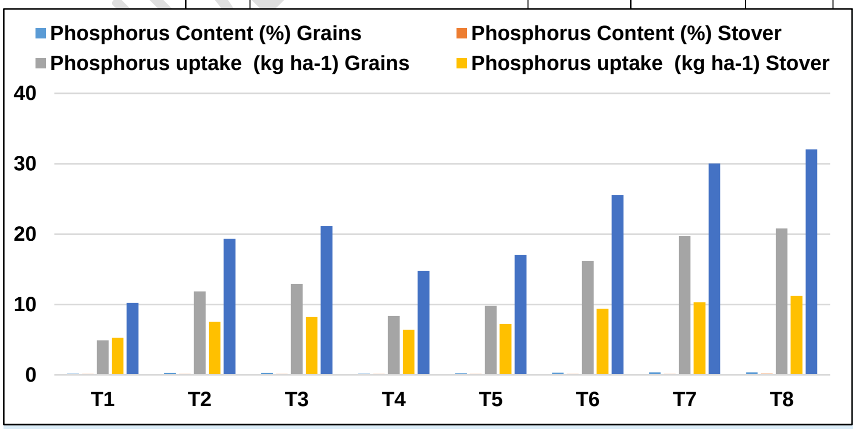

Fig.2 Effect of zinc and iron fortification on phosphorus content (%) and their uptake by maize crop

3.3 Potassium content (%) and uptake (kg ha^{-1})

The data regarding to 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.

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 under the treatment T_8= (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %), which was statistically at par with the treatment T_7= (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %), whereas the 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 under treatment T_1= Control (Spray of water) during field experiment.

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 (P= .05)	***0.03***	***0.10***	**1.82**	**6.36**	**7.94**

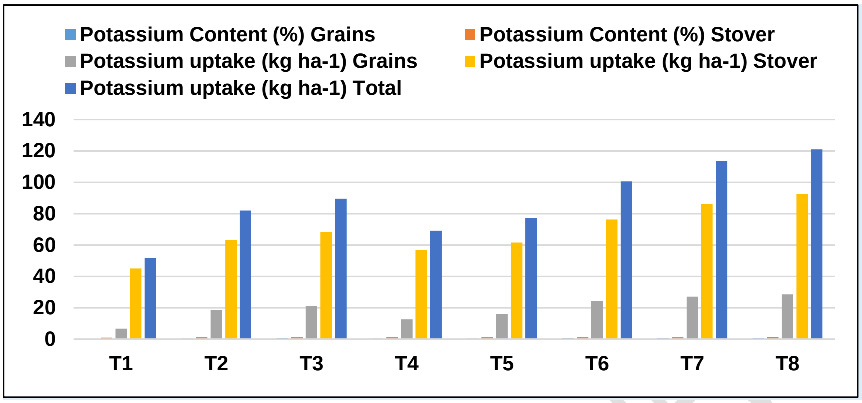

Fig.3 Effect of zinc and iron fortification on potassium content (%) and their uptake (kg ha^{-1}) by maize crop

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3.4 Zinc content (mg kg^{-1}) and uptake (mg ha^{-1})

The data regarding to 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 nutrient content in grains (58.97) and stover (62.64) of maize crop was found under the treatment T_8= (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %), which was statistically at par with the treatment T_7= (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %), whereas the lowest zinc content in grains (37.78), stover (40.87) was recorded under treatment T_1= 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) was found under the treatment T_8= (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 under the treatment T_1= Control (Spray of water).

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 (P= .05)	***4.77***	***5.08***	**202.86**	**286.13**	**492.11**

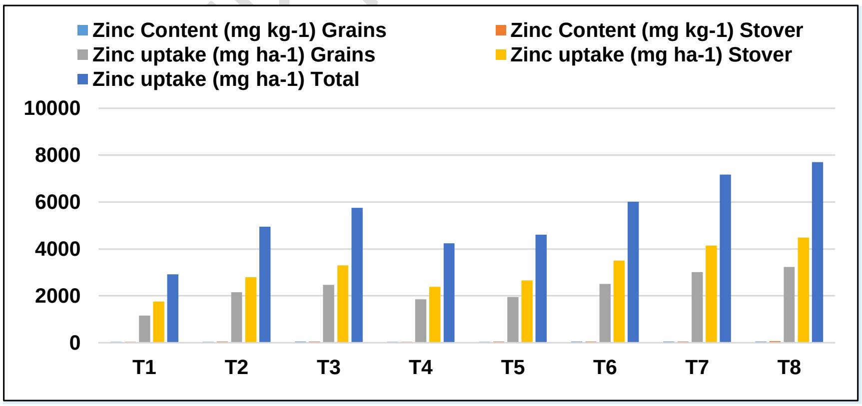

Fig.4 Effect of zinc and iron fortification on zinc content (mg kg^{-1}) and their uptake (mg ha^{-1}) by maize crop

3.5 Iron content (mg kg^{-1}) and uptake (mg ha^{-1})

The data regarding to 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 under the treatment T_8= (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %), after harvesting of crop, which was statistically at par with the treatment T_6= (Spray of $ZnSO_4$ @ 0.5 % + Spray of $FeSO_4$ @ 0.3 %). Whereas the lowest iron content in grains (35.38), stover (38.57) of maize was recorded under treatment T_1= Control (Spray of water).

The highest iron uptake in grains (3803.46), stover (5343.51) as well as total uptake (9146.97) by maize crop was observed in treatment T_8= (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 the treatment T_1 Control (Spray of water).

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 (P= .05)	***5.80***	***5.12***	**215.26**	**322.95**	**571.35**

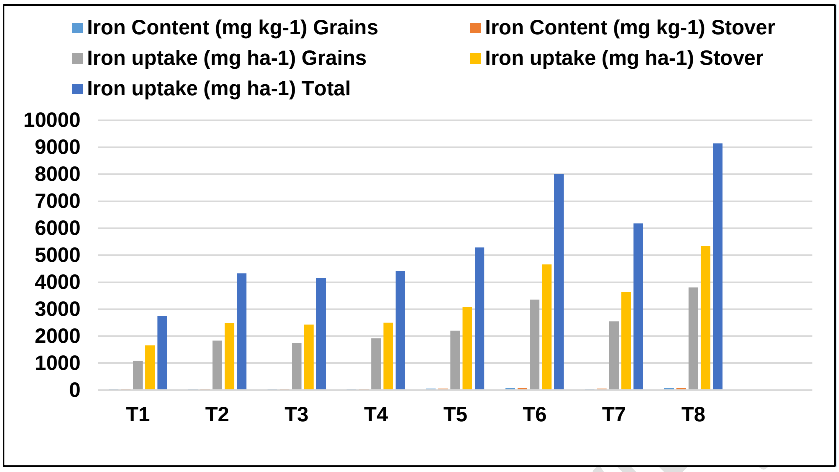

Fig.5 Effect of zinc and iron fortification on iron content (mg kg^{-1}) and their uptake (mg ha^{-1}) by maize crop

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Data of yield attributes , grain and stover yield should also be incorporated

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. (2011) [19], Parasuraman (2008) [20],** and **Somasundaram et al. (2007) [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 (2011) [22]** and **Aref (2012) [23]** also found the similar results when he applied the zinc, which is comparable to the results of this study.

5. CONCLUSION

This study shows that the treatment T_8 (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 statistically at par with the application of treatment T_7 (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %). The zinc content in grains and stover was significantly maximum under the treatment T_8 (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %) and it was statistically at par with the treatment T_7 (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.1 %), however, the content of iron in grains and stover was found highest under the treatment T_8 (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %) and it was statistically on par with the treatment T_6 (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 recorded significantly maximum under the treatment T_8 (Spray of $ZnSO_4$ @ 1 % + Spray of $FeSO_4$ @ 0.3 %) 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 the control treatment (T_1= 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.

Commented [x35]: Foliar spray of 1% $ZnSO_4$ + 0.3% $FeSO_4$

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