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Effect of foliar application of zinc and iron on nutrient content and their uptake by transplanted rice crop (*Oryza sativa* L.)

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Abstract
To study the effect of zinc and iron application on nutrient content and their uptake by transplanted rice crop, a field experiment was carried out during the *kharif* of 2023 at the Research Farm, School of Agriculture, Abhilashi University, Chail Chowk, Mandi (H.P). The experiment was performed in randomized block design with eight treatments and replicated thrice. The different treatment combination were T_1= Control (Spray of water), T_2= 100% RDF, T_3= 100% RDF + Spray of 0.5% $ZnSO_4$, T_4= 100% RDF + Spray of 0.3% $FeSO_4$, T_5= 100% RDF + Spray of 1% $ZnSO_4$, T_6= 100% RDF + Spray of 0.5% $FeSO_4$, T_7= 100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$ and T_8= 100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$.

The study of data revealed that the application of treatment T_8 recorded significantly highest nitrogen, phosphorus and potassium content in grains and straw and uptake of these nutrients by grains and straw and total uptake by transplanted rice crop, which was statistically at par with treatment T_7 and T_5. Treatment T_8 also recorded the highest content of zinc and iron which was statistically on par with treatment T_5 and T_7 for zinc and T_6 and T_7 for iron content. Treatment T_8 also recorded the uptake of zinc and iron which was at par with treatment T_7 and T_5 for zinc and T_7 and T_6 for iron uptake. However, the minimum content of nitrogen, phosphorus, potassium, zinc and iron were observed under treatment T_1 during the field experiment.

Keywords: Rice, zinc, iron, nutrient content and uptake

Introduction

Rice is the staple cereal component that sustains two-thirds of the world's population. Rice is the primary source of foods for humans because of its abundance, nutritional richness and sovereignty (Burlando and Cornara., 2014) [8]. A small portion of rice grains are utilized as ingredients in the manufacturing of foods and non-foods, whereas the majority is eroded as cooked rice. Being a significant source of carbohydrates, it makes up a large portion of the world's calorie intake and offers vital nutrients such as dietary fiber, vitamins and minerals (Juliano., 2010) [20]. Over 2 billion people in Asia alone derive 80% of their energy needs from rice, which contains 80% carbohydrates, 7-8% protein, 3% fat and 3% fiber (Chaudhari *et al.*, 2018) [12]. Rice, with its nutritional and economic importance, has cultural and religious significance in various parts of the world. The total world production of rice during 2023-24 is 515.53 million metric tons with an area of 165.98 million hectares and an average productivity of 4.64 metric tons ha^{-1} (Anonymous, 2024) [5].

Zinc is one of the micro nutrients essential for plants, animals and human beings. Zinc plays multiple roles in basic bio-chemical processes such as enzyme catalysis or activation, protein synthesis, carbohydrate and auxin metabolism, chlorophyll production, pollen formation, cytochrome and nucleotide synthesis, maintenance of membrane integrity and energy dissipation (Alloway, 2009) [4]. Zinc is an important nutrient for the healthy growth and development of plants. Zinc deficiency is common in high pH soils. The widespread deficiency of nitrogen and phosphorus is followed by Zn deficiency. Grain yield may be enhanced by application of zinc in soil; however concentration of zinc can be improved by foliar Spray of Zn fertilizer. Based on various studies, soil and foliar application of zinc enhance the yield of crops. Hence, Zn deficiency is considered one of the most important nutritional stresses limiting irrigated rice production in Asia at present

(Quijano-Guerta *et al*. 2002) [27]. The decrease in grain Zn also reduces its bioavailability in humans and may contribute to Zn deficiency in susceptible human populations (Cakmak *et al*. 2008) [10]. Zinc deficiency in rice has been widely reported in many rice-growing regions of the world. Zn deficiency in crop plant results not only in yield reduction but also Zn malnutrition in humans, i.e. diarrhea in infants, dwarfism in adolescents, where a high proportion of rice is consumed as a staple food (Chasapis *et al*., 2012) [11].

Iron (Fe) is also an essential micronutrient which plays a significant role in various physiological and biological pathways in plants. It serves as a component of many vital enzymes and it is thus required for wide range of biological functions. Under aerobic condition, deficiency of iron is more pronounced due to oxidation of available ferrous form to unavailable ferric form in soil (Joshi *et al*., 2013) [19].

Foliar application of fertilizers is a common agricultural practice used to deliver the nutrients to the crop plants which facilitate the growth and yield. Foliar feeding with nutrients can improve the potential yield and physiological and morphological traits of crops such as rice. Shaygany *et al*. (2012) [30] used foliar application of nutrients during different growth stages of rice plants and reported significant increases in the number of panicles per square meter, 1000-grain weight, biological yield, and grain yield in 2 years field experiments. The best results were found when foliar application of nutrients was conducted during different stages of transplanting, tillering, and panicle formation. Similarly, Sedghi and Sharif (2012) [29] demonstrated that supplemental foliar feeding significantly increased the grain yield of hybrid rice. In addition, Radhika *et al*. (2013) [28] used foliar application of nutrients in rice and reported that application of 1% foliar treatment three times a day for 15 days after transplanting resulted in increased tillering and panicle initiation, and higher numbers of tillers, panicles, reproductive tillers, and more grains per panicle.

There are several potential approaches to increase the concentration of Fe and Zn in staple foods which includes food nutrient fortification and supplementation programes (Michaelsen and Friis, 1998; Hurrell, 2002; Davidsson, 2003) [25, 16, 13] although fortification or supplementation in rice has proven to be effective for certain nutrients (Poletti *et al*., 2004) [26].

Materials and Methods

The experiment was carried out at the Research Farm of School of Agriculture, Abhilashi University, Chail Chowk, Mandi (H.P.) during the *Kharif* of 2023. The experimental farm is situated at 30^0 32' N latitude and 74^0 53' E longitudes, with an elevation of 1391 m above mean sea level. The pH of the experimental soil was slightly acidic in reaction (5.15) with an electrical conductivity of 0.022 dS m^{-1}, medium in organic carbon (0.62%), low in available nitrogen (230.81 kg ha^{-1}), medium in available phosphorus (23.35 kg ha^{-1}), potassium (267.40 kg ha^{-1}), low in available zinc (0.40 mg kg^{-1}) and low in available iron (36.82 mg kg^{-1}). The spacing for the tested variety hybrid paddy super-120 was 20 × 10 cm, row to row and plant to plant. The experiment was laid out in a randomized block design (RBD) with eight treatments and three replications. The treatments, *viz*., T_1= Absolute control (Spray of water), T_2= 100% RDF, T_3= 100% RDF + Spray of 0.5% $ZnSO_4$, T_4= 100% RDF + Spray of 0.3% $FeSO_4$, T_5= 100% RDF + Spray of 1% $ZnSO_4$, T_6= 100% RDF + Spray of 0.5% $FeSO_4$, T_7= 100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$ and T_8= 100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$. Nutrients were applied as per treatments and recommended doses of N, P, K, Zn and Fe were applied through Urea, DAP, and MOP, Zinc Sulphate and Ferrous Sulphate. Plant samples were collected from each treatment after harvest and they were cleaned and shade-dried. Later, the shade-dried samples were oven-dried at 60 ± 5 °C for 24 to 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 and their uptake by transplanted rice crop. The estimation of nitrogen content in the plant sample was done by the modified Kjeldahl 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 sample was estimated using a spectrophotometer as described by (Jackson, 1973) [17]. Potassium content in plants was estimated by using a flame photometer (Jackson, 1973) [17] . Zinc and Iron content in samples of rice was determined by the di acid method with estimation by the AAS (Lindsay and Norvell, 1978) [23]. The N, P, K, Zn and Fe (kg ha^{-1}) uptake by grains and straw of transplanted rice in each treatment was calculated by multiplying the N, P, K, Zn and Fe content (%) with yields of grains and straw (q ha^{-1}). The total uptake of different nutrients was calculated after summing their uptake by grain and straw of transplanted rice crop. The collected data were analyzed statistically following the one factor analysis of variance (ANOVA) technique and the mean differences were adjusted with operational statistics (OPSTAT) software.

Results and Discussion

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

The nitrogen content in grains and straw and their uptake by grains and straw as well as total uptake by transplanted rice crop is presented in Table- 1 and depicted in Fig.-1. The study of data showed the content of nitrogen in grains and straw with their uptake by grains, straw and total uptake by transplanted rice crop were affected significantly by the foliar application of zinc and iron during the study.

The application of treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$) recorded significantly highest nitrogen content in grains and straw of transplanted rice crop and it was statistically at par with treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$) and T_5= (100% RDF + Spray of 1% $ZnSO_4$). While, lowest nitrogen content in grains and straw of rice crop was recorded under treatment T_1 (Absolute control) during the experiment.

The maximum nitrogen uptake by grains and straw as well as their total uptake was noted under treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$) which was statistically at par with treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$) and T_5= (100% RDF + Spray of 1% $ZnSO_4$). However, the minimum nitrogen uptake by grains, straw and total uptake by rice crop were recorded with treatment T_1= Control (Spray of water).

The higher nitrogen content in grain could be due to zinc application since zinc is essential for synthesis of DNA and RNA and for the production of carbohydrate, lipids and proteins. Further the results clearly indicated that nitrogen content at different stages and at harvest both by straw and grain were increased with the application of zinc and iron along with RDF. The increase in nitrogen content was also observed by Keram *et al*., 2012 [21] due to Zn and Fe application. At harvest the nitrogen content in grain was higher as compared to that of straw. Application of various inorganic and iron fertilizers remains ineffective for increasing grain iron concentration. However, improving nitrogen nutritional status of plants promoted accumulation of Fe and Zn in grain. It appears that nitrogen nutritional status of plants plays a critical role in biofertification of cereal grains with Zn and Fe and also reported that soil application of Zn is less effective in increasing grain Zn, while foliar application of Zn resulted in remarkable increase in grain Zn concentration of rice (Cakmak *et al*., 2010) [9]. The combined soil or foliar application of zinc and iron increased higher nitrogen uptake at all stages of crop growth. The higher nutrient uptake may be attributed to enhanced nutrient availability with the external application of micronutrients. Due to the steady and continuous availability of nitrogen in the rhizosphere coupled with enhanced dry matter production resulted in higher uptake of nitrogen. These results were in conformity with those of Majumdar *et al*. (2007) [24] and Aruna (2009) [7].

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

The phosphorus content and their uptake by grains and straw of transplanted rice is presented in Table- 2 and depicted in Fig.-2. The application of various treatments was substantially varied the phosphorus content, uptake by grains and straw as well as their total uptake of rice crop.

The highest phosphorus content in grains and straw was observed under treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$ which was statistically on par with treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$) and T_5= (100% RDF + Spray of 1% $ZnSO_4$). Whereas, treatment T_1= Control (Spray of water) was observed the lowest phosphorus content in grains and straw of transplanted rice crop.

Treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$) recorded the highest uptake by grains and straw and their total uptake of P which was comparable to treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$) and T_5= (100% RDF + Spray of 1% $ZnSO_4$). However, the lowest P uptake by grains and straw as well as their total uptake was recorded under treatment T_1= Control (Spray of water).

Zinc might enhance the efficacy of phosphorus-absorbing mechanisms and encourages root growth, which in turn helps in uptake of phosphorus by transplanted rice crop. By stimulating enzymes essential for phosphorus absorption and metabolism and enhancing root development, iron might help rice crop to use phosphorus more efficiently. These properties might facilitate their uptake by plant at the micro-scale, improving uptake of phosphorus in transplanted rice crop. Some similar results were also found by Sultana *et al*. (2015) [31]. However, the zinc and iron fertilization did not affect the P content significantly in grain and straw of rice plant. The P content decreased from tillering to panicle initiation. It might be due to the dilution effect of nutrient. Similar findings were reported by Ghoneim *et al*. (2016) [15]. The higher P uptake might be due to the solubilization of native phosphorus by the inorganic acids under reduced conditions in addition to applied fertilizers which ultimately resulted in better root growth and increased physiological activity of roots to absorb more phosphorus. (Sumagala, 2003; Elayaraja and Singaravel, 2012) [32, 14].

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

Data concerning the potassium content, their uptake by grains and straw and their total uptake of the transplanted rice crop are described in Table- 3 and illustrated in Fig.-3 and the significant variation were noticed in the potassium content, uptake and their total uptake.

Among the various treatment applications the treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$) was noted the maximum potassium content in grains and straw of rice crop which was significantly at par with treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$) and T_5= (100% RDF + Spray of 1% $ZnSO_4$). However, the minimum values of potassium content in grains and straw was noted under treatment T_1= Control (Spray of water).

The uptake by grains and straw as well as total uptake of k was found to higher under treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$), which was statistically at par with treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$) and T_5= (100% RDF + Spray of 1% $ZnSO_4$). However, the minimum K uptake by grain and straw and their total uptake by rice crop was found in treatment T_1= Control (Spray of water).

Zinc promotes root growth and might enhance potassium uptake efficiency in rice crop by improving nutrient transport mechanisms. Iron might aid in potassium absorption by stimulating root development and activating enzymes crucial for nutrient assimilation. Together, zinc and iron optimize potassium uptake in transplanted rice crop. Zinc and iron might facilitate potassium uptake in rice by improving root surface area and enhancing nutrient absorption efficiency. The micronutrient properties enhance the effectiveness of nutrient uptake mechanisms, leading to increased potassium assimilation and utilization by rice crops, ultimately promoting overall uptake of potassium in transplanted rice crop. These results were in close agreement with the findings of (Sultana *et al*., 2015) [31]. Many iron dependent enzymes are involved in carbohydrate metabolism in general and leaves in particular, impartment of potassium in stomataregulation, phloem assimilation from the source into the sink, maintained water balance in the soil-plant-atmosphere continuum. Iron sufficiency is also associated with the marked increase in potassium efflux from roots, shoots into growth medium. Iron also facilitates the movement of K in guard cells of stomata (Ali *et al*., 2011) [3]. The combined soil or foliar application of zinc and iron fertilization increased higher potassium uptake at all stages of crop growth. The massive increase in potassium uptake due to the interaction of K and Zn by the improvement of enzymatic activity and metabolic processes of plant, which might have ultimately facilitated the removal of potassium and consequently the yield. These results were in accordance with those of Khan *et al*. (2003) [22].

Zn content (mg kg^{-1}) and Zn uptake (g ha^{-1})

The Zn content and their uptake by grains and straws and their total uptake of transplanted rice crop are presented in Table- 4 and displayed in Fig. - 4. The application of zinc and iron significantly varied the zinc content, uptake and their total uptake by rice crop.

The integration of treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$) was significantly recorded the highest zinc content in grains and straw of transplanted rice crop and it was statistically at par with treatment T_5= (100% RDF + Spray of 1% $ZnSO_4$) and treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$). The lowest zinc content in grains and straw was recorded under treatment T_1= Control (Spray of water).

The highest zinc uptake by grains and straw as well as total uptake of transplanted rice crop was found under treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$) and it was statistically at par with treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$) and T_5= (100% RDF + Spray of 1% $ZnSO_4$). The lowest uptake of zinc by grains and straw as well as total uptake noted in treatment T_1= Control (Spray of water).

Application of Zn and Fe might enhance root development and enzyme activity, facilitating zinc absorption by transplanted rice crop. Better zinc and iron transporters, more efficient control of the transport systems and improved absorption and storage can all lead to increased zinc uptake capacity. Similarly, the foliar application of zinc with its reduced particle size, might efficiently promote zinc uptake by plant roots, collectively contributing to increased zinc absorption in the transplanted rice crop. Fertilizers might enhance zinc uptake in plants by improving the efficiency of nutrient delivery and absorption mechanisms. The properties of these fertilizers, such as increased surface area and reactivity, facilitate better interaction with plant roots. Additionally, formulations can protect Zn from soil interactions that may reduce its availability, ensuring a higher uptake by transplanted rice crop. The results are in submission with (Apoorva *et al.*, 2017) [6]. The results indicated that combined application of zinc and iron fertilization enhanced zinc concentration at all stages of crop growth which was significantly superior to control. Higher level of zinc through soil application significantly increased zinc content in straw and grain at harvest. The soil application of zinc sulphate significantly increased the zinc uptake by plants. The superiority of T_8 and T_5 treatments might be due to combined application of zinc and iron nutrients as basal and foliar applications along with RDF through which nutrients are available throughout the crop growth period at required quantities and enhanced the zinc uptake. These results are in accordance with Jadhav *et al.* (2014) [18] and Ghoneim (2016) [15].

Fe content (mg kg^{-1}) and Fe uptake (g ha^{-1})

The Fe content and their uptake by grains and straws and total uptake of transplanted rice crop are given in Table- 5 and depicted in Fig. - 5. The Fe content, uptake and their total uptake of the transplanted rice crop was affected significantly by the different treatments used in the study.

The integration of treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$) was significantly recorded the highest iron content in grains and straw of transplanted rice crop and it was statistically at par with treatment T_6= (100% RDF + Spray of 0.5% $FeSO_4$) and treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$). The lowest iron content in grains and straw was recorded under treatment T_1= Control (Spray of water).

However, the maximum iron uptake by grains and straw as well as total uptake of transplanted rice crop was found under treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$) and it was statistically at par with treatment T_7= (100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$) and T_6= (100% RDF + Spray of 0.5% $FeSO_4$). The minimum uptake by grains and straw as well as total uptake of iron was recorded in treatment T_1= Control (Spray of water).

The superiority of T_8 and T_7 treatments might be due to combined application of zinc and iron nutrients as foliar applications along with RDF through which required nutrients were available to the crop throughout growth period at required quantities and so enhanced the iron uptake. These findings are in agreement with the results of Application of higher level of iron significantly increased iron uptake by both straw and grain. These results are in agreement with Gohil *et al.* (2017) [34].

Table 1: Effect of foliar application of zinc and iron on nitrogen content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

S. N.	Treatment	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Control (Spray of water)	1.21	0.37	25.97	14.49	40.45
T_2	100% RDF	1.25	0.40	50.15	18.50	68.65
T_3	100% RDF + Spray of 0.5% $ZnSO_4$	1.31	0.44	61.43	23.35	84.78
T_4	100% RDF + Spray of 0.3% $FeSO_4$	1.28	0.42	53.43	20.24	73.68
T_5	100% RDF + Spray of 1% $ZnSO_4$	1.33	0.46	65.67	25.42	91.09
T_6	100% RDF + Spray of 0.5% $FeSO_4$	1.30	0.43	57.72	22.06	79.77
T_7	100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$	1.40	0.49	71.25	28.10	99.35
T_8	100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$	1.44	0.49	75.79	28.61	104.39
	SEm±	0.04	0.01	3.63	1.61	4.80
	CD(P=0.05)	0.12	0.04	11.12	4.92	14.70

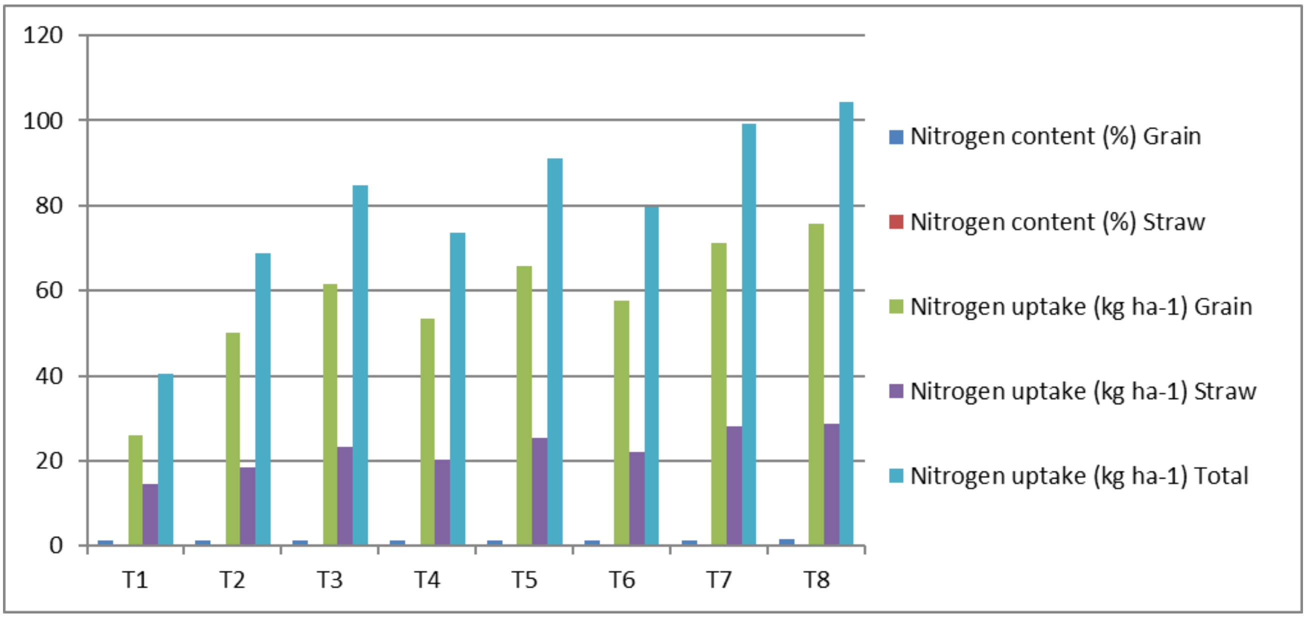

Fig 1: Effect of foliar application of zinc and iron on nitrogen content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

Table 2: Effect of foliar application of zinc and iron on phosphorus content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

S.N.	Treatment	Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Control (Spray of water)	0.18	0.101	3.85	3.95	7.81
T_2	100% RDF	0.19	0.106	7.62	4.86	12.49
T_3	100% RDF + Spray of 0.5% $ZnSO_4$	0.24	0.108	11.07	5.67	16.74
T_4	100% RDF + Spray of 0.3% $FeSO_4$	0.21	0.107	8.74	5.20	13.94
T_5	100% RDF + Spray of 1% $ZnSO_4$	0.27	0.110	13.13	6.05	19.19
T_6	100% RDF + Spray of 0.5% $FeSO_4$	0.22	0.107	9.94	5.46	15.41
T_7	100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$	0.27	0.116	13.74	6.65	20.39
T_8	100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$	0.28	0.119	14.47	6.93	21.67
	SEm±	0.01	0.00	0.57	0.34	1.06
	CD(P=0.05)	0.02	0.01	1.75	1.05	3.26

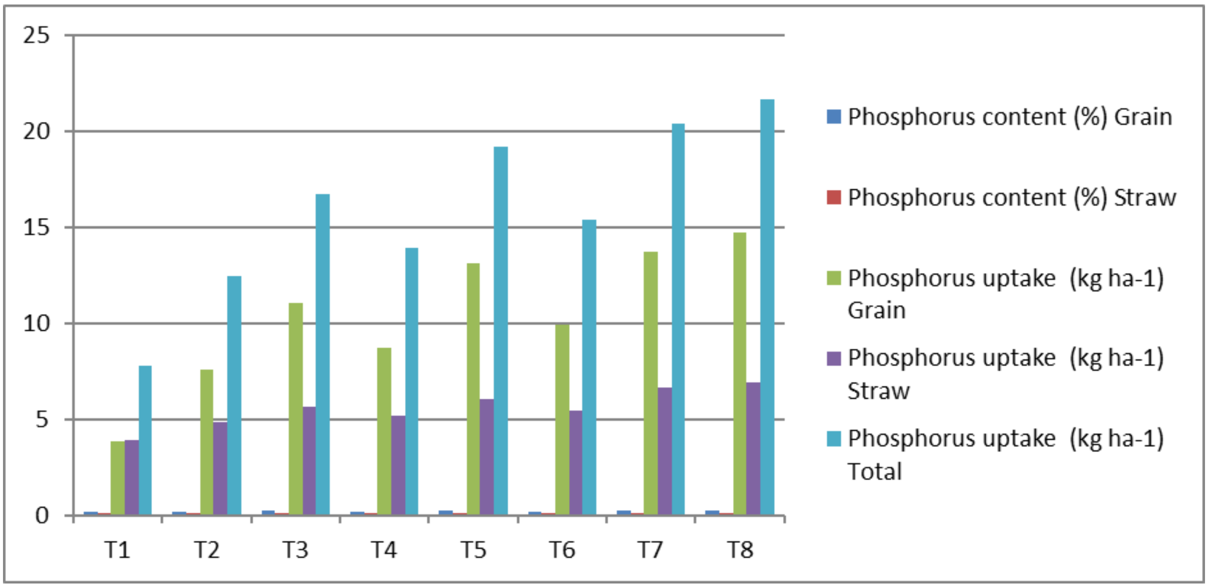

Fig 2: Effect of foliar application of zinc and iron on phosphorus content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

Table 3: Effect of foliar application of zinc and iron on potassium content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

S.N.	Treatment	Potassium content (%)		Potassium uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Control (Spray of water)	0.25	1.21	5.35	47.25	52.6
T_2	100% RDF	0.26	1.24	10.43	56.88	67.31
T_3	100% RDF + Spray of 0.5% $ZnSO_4$	0.31	1.26	14.50	67.24	81.74
T_4	100% RDF + Spray of 0.3% $FeSO_4$	0.28	1.25	11.52	60.73	72.24
T_5	100% RDF + Spray of 1% $ZnSO_4$	0.33	1.34	16.25	73.51	89.76
T_6	100% RDF + Spray of 0.5% $FeSO_4$	0.29	1.26	12.91	64.31	77.22
T_7	100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$	0.34	1.37	17.30	77.79	95.09
T_8	100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$	0.35	1.38	18.42	80.75	99.17
	SEm±	0.01	0.04	0.82	3.52	4.29
	CD(P=0.05)	0.03	0.11	2.51	10.77	13.15

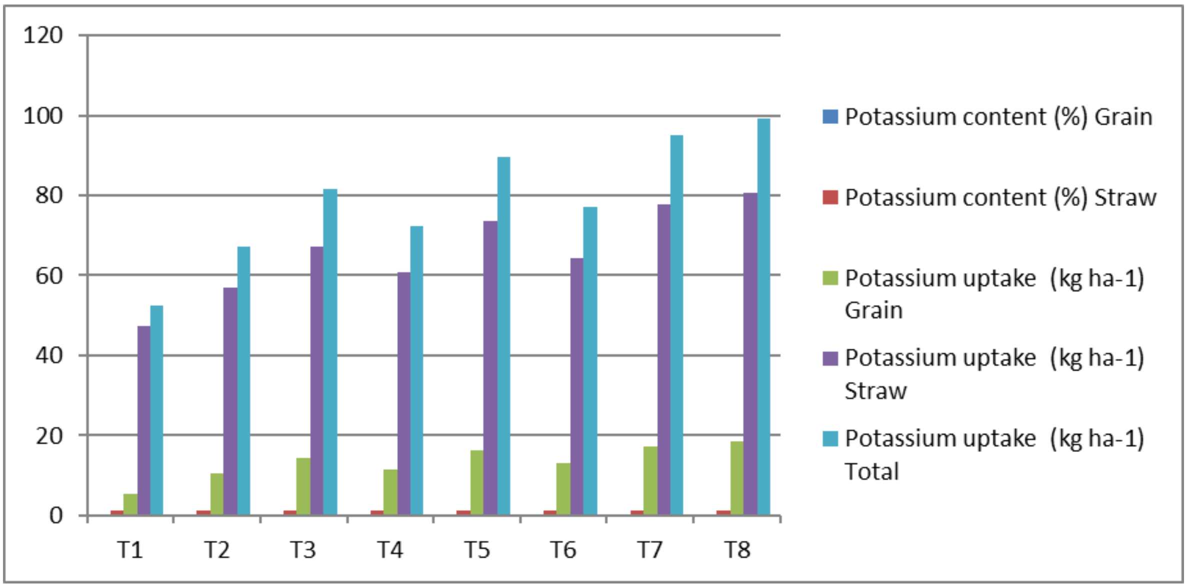

Fig 3: Effect of foliar application of zinc and iron on potassium content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

Table 4: Effect of foliar application of zinc and iron on zinc content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

S.N.	Treatment	Zinc content (%)		Zinc uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Control (Spray of water)	10.27	14.88	219.71	582.70	802.41
T_2	100% RDF	11.65	16.37	467.53	750.89	1218.42
T_3	100% RDF + Spray of 0.5% $ZnSO_4$	14.34	19.02	670.73	1001.78	1672.51
T_4	100% RDF + Spray of 0.3% $FeSO_4$	12.79	17.18	532.49	834.61	1367.09
T_5	100% RDF + Spray of 1% $ZnSO_4$	16.02	21.12	789.04	1158.64	1947.68
T_6	100% RDF + Spray of 0.5% $FeSO_4$	13.99	18.21	622.70	927.07	1549.77
T_7	100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$	15.67	20.64	797.45	1183.50	1980.94
T_8	100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$	16.83	21.74	885.76	1269.40	2155.16
	SEm±	0.50	0.70	39.60	64.48	106.89
	CD(P=0.05)	1.54	2.15	121.27	197.47	327.35

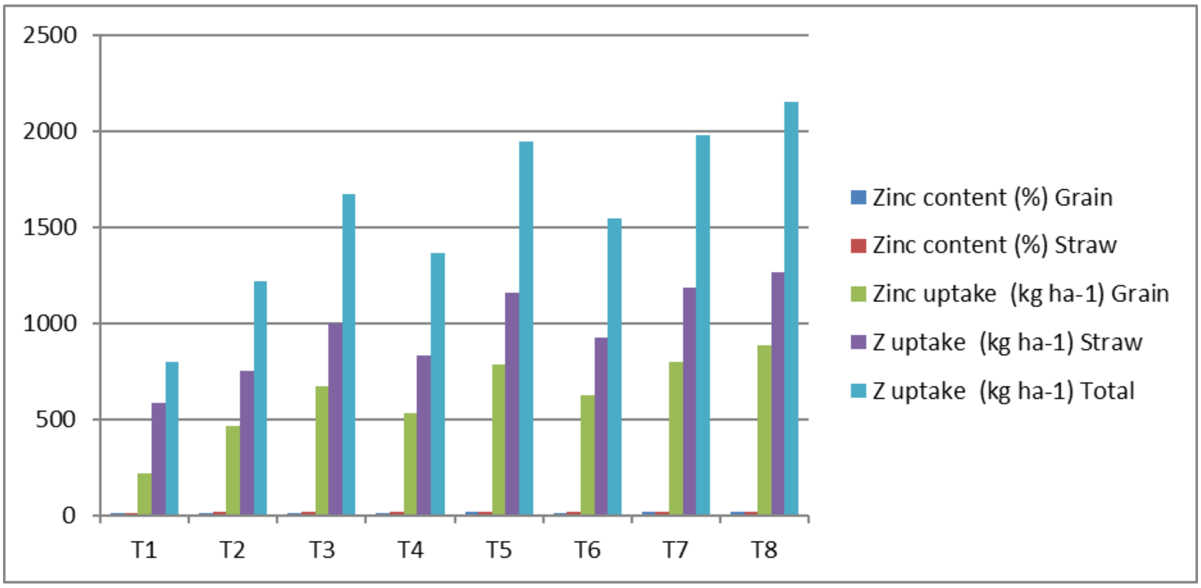

Fig 4: Effect of foliar application of zinc and iron on zinc content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

Table 5: Effect of foliar application of zinc and iron on iron content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

S.N.	Treatment	Iron content (%)		Iron uptake (kg ha^{-1})		
		Grain	Straw	Grain	Straw	Total
T_1	Control (Spray of water)	8.25	19.95	176.55	781.24	957.80
T_2	100% RDF	9.83	22.53	394.38	1033.45	1427.83
T_3	100% RDF + Spray of 0.5% $ZnSO_4$	10.91	23.66	510.14	1246.17	1756.31
T_4	100% RDF + Spray of 0.3% $FeSO_4$	12.34	25.98	513.76	1262.11	1775.87
T_5	100% RDF + Spray of 1% $ZnSO_4$	11.77	25.11	579.88	1377.54	1957.41
T_6	100% RDF + Spray of 0.5% $FeSO_4$	13.95	28.26	620.91	1438.72	2059.63
T_7	100% RDF + Spray of 0.5% $ZnSO_4$ + 0.3% $FeSO_4$	13.20	27.86	671.75	1597.49	2269.24
T_8	100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$	14.39	30.05	757.35	1754.62	2511.97
	SEm±	0.43	0.85	35.67	109.45	151.11
	CD(P=0.05)	1.31	2.61	109.23	335.20	462.77

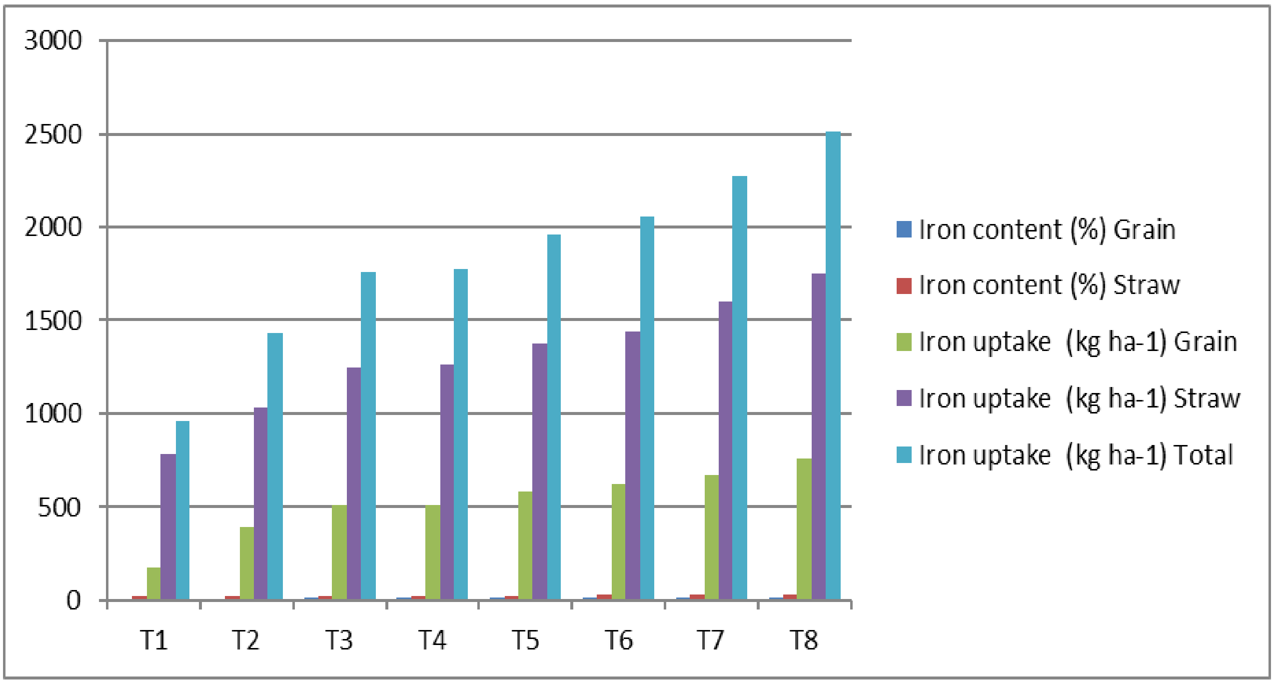

Fig 5: Effect of foliar application of zinc and iron on iron content (%) and their uptake (kg ha^{-1}) by transplanted rice crop

Conclusion

The content of nitrogen, phosphorus, potassium, zinc and iron in the grains and straw of the transplanted rice crop was varied significantly with the foliar application of zinc and iron at different concentrations during the field experiment. The maximum content of nitrogen, phosphorus, potassium, zinc and iron in the grains and straw along with their maximum uptake by grains, straw and total uptake by rice crop was found under treatment T_8= (100% RDF + Spray of 1% $ZnSO_4$ + 0.5% $FeSO_4$). The treatment T_8 was at par with treatment T_7 and T_5 for nitrogen, phosphorus and potassium content in grains and straw, while, for zinc content treatment T_8 was at par with treatment T_5 and T_7 and for iron content treatment T_8 was on par with treatment T_6 and T_7. Treatment T_8 was statistically at par with treatment T_7 and T_5 for nitrogen, phosphorus and potassium uptake by grains and straw, while, for zinc uptake treatment T_8 was at par with treatment T_7 and T_5 and for iron uptake, treatment T_8 was statistically on par with treatment T_7 and T_6. In conclusions, both foliar application of zinc and iron highlight its promising role in promoting enhanced nutrient utilization by the transplanted rice crop. These findings provide valuable insights for future research and agricultural strategies, emphasizing the importance of considering micronutrient interventions for nutrient content and their uptake by transplanted rice crop.

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Reference

1. Agricultural statistics at a glance. Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India, New Delhi. 2018.
2. Ali EA. Effect of iron nutrient care sprayed on foliage at different physiological growth stages on yield and quality of some durum wheat varieties in sandy soil. Asian Journal of Crop Science. 2012;4:139-149.
3. Ali M, Ladha JK, Rickman J, Lales JS. Nitrogen dynamics in lowland rice as affected by crop establishment and nitrogen management. Journal of Crop Improvement. 2011;20(1-2):89-105.
4. Alloway BJ. Soil factors associated with zinc deficiency in crops and humans. Environmental Geochemistry and Health. 2009;31(5):537-545.
5. Anonymous. (USDA) World agricultural production. Foreign Agricultural Service Circular Series WAP. 2024;1-20.
6. Apoorva MR, Chandrasekhar PR, Padmaja G. Effect of zinc with special references to nano zinc carrier on yield, nutrient content and uptake by rice (*Oryza sativa* L.). International Journal of Current Microbiology and Applied Sciences. 2017;6(8):1057-1063.
7. Aruna P. Integrated nitrogen management in aerobic rice. M.Sc. (Ag.) Thesis. Acharya N.G. Ranga Agricultural University, Hyderabad, India. 2009.
8. Burlando B, Cornara L. Therapeutic properties of rice constituents and derivatives (*Oryza sativa* L.). Trends in Food Science and Technology. 2014;40(1):82-98.
9. Cakmak I, Pfeiffer WH, McClafferty B. Biofortification of durum rice with zinc and iron. Cereal Chemistry. 2010;87(1):10-20.
10. Cakmak I. Enrichment of cereal grains with zinc: agronomic or genetic biofortification. Plant and Soil. 2008;302:1-17.
11. Chasapis CT, Loutsidou AC, Spiliopoulou CA. Zinc and human health: an update. Archives of Toxicology. 2012;86(4):521-534.
12. Chaudhari PR, Tamrakar N, Singh L, Tandon A, Sharma D. Rice nutritional and medicinal properties: a review article. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):150-156.
13. Davidsson L. Approaches to improve iron bioavailability from complementary foods. Journal of Nutrition. 2003;133(3):1560-1562.
14. Elayaraja D, Singaravel R. Zinc and boron application on groundnut yield and nutrient uptake in coastal sandy soils. Asian Journal of Soil Science. 2012;7(1):50-53.
15. Ghoneim AM. Effect of different methods of Zn application on rice growth, yield and nutrients dynamics in plant and soil. Journal of Agriculture and Ecology Research. 2016;6(2):1-9.
16. Hurrell RF. Fortification: overcoming technical and practical barriers. Journal of Nutrition. 2002;133(2):806-812.
17. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt. Ltd.; 1973.
18. Jadhav KT, Lokhande DC, Asewar BV. Effect of ferrous sulphate and zinc sulphate management practices on rice under aerobic condition. Advanced Research Journal of Crop Improvement. 2014;5(2):131-135.
19. Joshi E, Kumar D, Lal B, Nepalia V, Gautam P, Vyas AK. Management of direct seeded rice for enhanced resource use efficiency. Plant Knowledge Journal. 2013;2(3):119-134.
20. Juliano B. Rice in human nutrition. International Rice Research Institute and Food and Agriculture Organization; 2010.
21. Keram KS, Sharma BL, Sawarkar SD. Impact of Zn application on yield, quality, nutrients uptake and soil fertility in a medium deep black soil (Vertisol). International Journal of Science, Environment and Technology. 2012;1(5):563-571.
22. Khan MU, Qasim M, Subhan M, Ahmad R, Ali L. Effect of zinc application by different methods on the chemical composition and grain quality of rice. Pakistan Journal of Applied Sciences. 2003;3(7):530-536.
23. 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.
24. Majumdar B, Venkatesh MS, Saha R. Effect of nitrogen, farmyard manure and non-symbiotic nitrogen-fixing bacteria on yield uptake and soil fertility in upland rice. Indian Journal of Agricultural Sciences. 2007;77(6):335-339.
25. Michaelsen KF, Friis H. Complementary feeding: a global perspective. Journal of Nutrition. 1998;128(4):763-766.

26. Poletti S, Gruissem W, Sautter C. The nutritional fortification of cereals. Current Opinion in Biotechnology. 2004;15:162-165.
27. Quijano-Guerta C, Kirk GJD, Portugal AM, Bartolome VI, McLaren GC. Tolerance of rice germplasm to zinc deficiency. Field Crops Research. 2002;76:123-130.
28. Radhika K, Hemalatha S, Maragatham S, Praveena S. Effect of foliar application of micronutrients on the yield components of rice and soil available micronutrients status. Asian Journal of Soil Science. 2013;8(2):419-421.
29. Sedghi M, Sharif RS. Effects of foliar supplements of nitrogen, phosphorus and potassium on grain yield and macro element transport and adsorption efficiency of hybrid rice (*Oryza sativa* L.). Research in Field Crops. 2012;1:64-75.
30. Shaygany J, Peivandy N, Ghasemi S. Increased yield of direct seeded rice (*Oryza sativa* L.) by foliar fertilization through multi-component fertilizers. Archives of Agronomy and Soil Science. 2012;58(10):1091-1098.
31. Sultana MS, Rahman MH, Rahman MS, Sultana S, Paul AK. Effect of integrated use of vermicompost, pressmud and urea on the nutrient content of grain and straw of rice (Hybrid Dhan Hira 2). International Journal of Scientific and Research Publications. 2015;5(11).
32. Sumangala BJ. Response of groundnut (*Arachis hypogaea* L.) to conjunctive and bio-inoculants at graded levels of fertilizers under dryland conditions. Ph.D. Thesis. University of Agricultural Sciences, Bengaluru, Karnataka (India); 2003.
33. Von Grebmer K, Fritschel H, Nestorova B, Olofinbiyi T, Pandya-Lorch R, Yohannes Y. Global Hunger Index. The Challenge of Hunger 2008. Bonn, Washington DC, Dublin; c2008.
34. Gohil R, Ballantyne DR. Modelling the vertical structure of nuclear starburst discs: a possible source of AGN obscuration at z∼ 1. Monthly Notices of the Royal Astronomical Society. 2017 Jul;468(4):4944-4955.