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Effect of Various Sources of Zinc and Iron on Dry Matter Yield, Nutrient Content and Nutrient Uptake of Finger Millet (*Eleusine coracana* l.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author AK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KS and KBR managed the analyses of the study. Author SHKS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Kharif* 2018 at College Farm, College of Agriculture, PJTSAU to evaluate the effect of various sources of zinc and iron on dry matter yield, nutrient content and nutrient uptake of finger millet. This experiment was conducted with randomized block design with 14 treatments and replicated thrice.The results revealed that application of different Zinc and iron sources at different rates significantly influenced the dry matter yield, nutrient content and nutrient uptake of finger millet. The highest dry matter production was reported with T_{10} - application of RDF (60:40:30 kg N,P_2O_5 and K_2O kg ha^{-1})+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS at all the stages followed by T_{14}- (RDF+ foliar application of Fe-humate @ 0.25% twice at 30 and 60 DAS). Nutrient content decreased and Nutrient uptake (Nitrogen, phosphorous, potassium, iron and zinc) by the crop steadily increased with advancement in age of the crop upto

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harvest. The treatment receiving (T_{10}) RDF+ foliar spray of FeSO4 @ 0.5% twice at 30 and 60 DAS recorded the highest nutrient content and (N, P, K & Fe) uptake by crop at 30DAS, 60 DAS and at harvest followed by (T_{14}) RDF+ foliar application of Fe-humate @ 0.25% twice at 30 and 60 DAS. While, the Zinc content and uptake by crop at 30 DAS, 60 DAS and at harvest was highest with the treatment receiving (T_8) -RDF + Zn-Humate foliar spray @ 0.25% twice at 30 and 60 days after sowing and was followed by treatment T_7-RDF + Zn-Humate soil application @ 42 Kg ha^{-1}.

Keywords: Finger millet; dry matter yield; nutrient content; nutrient uptake.

1. INTRODUCTION

Next to sorghum and pearl millet, finger millet or ragi is the third most important millet crop of India, The total area under finger millet in India is 11.38 $ha^{-1}$with production of 18.22 tonnes and productivity of 16.01 kg ha^{-1} [1]. Among different states of India, Karnataka ranked first both in area and production while Tamil Nadu recorded the highest productivity followed by Karnataka during 2016-17 [2]. In Telangana total area under ragi is 1000 ha^{-1} with production of 1000 tonnes and productivity of 1000 kg ha^{-1} [1]. Ragi is commonly known as "Nutritious millet" as the grain is nutritionally superior to many cereals (rice, corn and sorghum) providing proteins, minerals, iron, calcium and vitamins in abundance. Especially for people doing hard work, when consumed as food, it provides a sustaining diet. Straw makes valuable fodder for both draught and milch animals. Finger millet is considered as wholesome food for diabetic patients. Grain is malted and flour of the malted grain is used as cakes or porridge and a nourishing food for infants and invalids [3]. Deficiency of zinc is now recognized as one of the most widespread mineral deficiencies in global human nutrition. It is needed for the structural and functional integrity of about 2800 proteins, also for protein biosynthesis and is a key defence factor in detoxification of highly toxic oxygen free radicals [4]. Cakmak [5] concluded that foliar or combined foliar and soil application of zinc fertilizer under field conditions is highly effective and very practical way to maximize uptake and accumulation of zinc in whole wheat grain. Iron deficiency is more severe in calcareous soils with low Fe availability due to high soil pH. Cropping systems of 200 to 300% intensity deplete the soil iron due to higher crop production [6]. Thus, Fe deficiency is aggravated further as farmers do not apply it externally and its mining occurs. Keeping this in view the present research was conducted to know effect of various sources of Zinc and Iron on Dry matter yield, nutrient content and nutrient uptake of finger millet. Rao et al. [7] reported increases in yield and grain protein content in finger millet due to N fertilizer application rates of up to 40 kg N ha^{-1} in Andhra Pradesh, India. The authors claimed that the economic optimum rate of N fertilizer for finger millet was 43.5 kg ha^{-1} under rainfed conditions. These results suggest that application of the correct dose of N fertilizer is important in order to maximize the profits of poor finger millet farmers. Tenywa et al. [8] found that application of P fertilizer (20–40 kg P_2O_5 ha^{-1}) increased the growth and yield of finger millet compared to the no fertilizer control under row planting conditions. However, Hedge and Gowda (1986) reported a reduction in finger millet grain yields from 16.3 to 14.7 kg per kg P_2O_5 when the P application rate was increased from 30 to 60 kg ha^{-1} P_2O_5. Based on a 25 year long term experiment conducted under rainfed conditions on alfisols in Bangalore (Southern India), it was observed that application of N:P_2O_5:K_2O at 50:50:25 kg ha^{-1} increased finger millet yield and soil fertility status compared to non-fertilized plants.

2. MATERIALS AND METHODS

An experiment was carried out during *Kharif,* 2018 at College Farm, College of Agriculture, PJTSAU. The experimental site is geographically located at 17°19' N latitude and 78°23' E longitude at an altitude of 542.6 m above mean sea level on Hyderabad-Bangalore National highway. The soil of the experimental site was sandy loam soil which is low in organic carbon(0.42%), available nitrogen(132 kg ha^{-1}), P_2O_5(18.13 kg ha^{-1})and high in K_2O(464.8 kg ha^{-1}).The DTPA extractable zinc(0.3mg kg^{-1}) and iron(3.8 mg kg^{-1}) was lower than the critical limit. The soil was slightly non-saline in nature. The experiment was laid out in Randomized block design with 14 treatments (as detailed in Table 1.) and replicated thrice. The gross plot size was 4.5 m × 4.5 m (20.25 m^2). Crop was sown by line sowing (variety GPU-28) adopting a spacing of 30 cm × 15 cm. As the seed was fine it was mixed with sand to ensure optimum population. The recommended dose of fertilizer was 60:40:30 kg N, P_2O_5 and K_2O ha^{-1}. Entire recommended dose of phosphorous and potassium were applied as basal dose in the form of DAP and MOP. A uniform dose of nitrogen was applied through urea in 3 equal splits (1/3rd as basal and 1/3rd at vegetative phase and remaining 1/3rd) at panicle initiation stage to all the plots. Nitrogen content in plant samples was estimated by modified Microkjeldahl method (Piper, 1966) after digesting the organic matter by H_2SO_4 and H_2O_2 and expressed in per cent. In the digested extract, phosphorus content was determined by Vanado–molybdo phosphoric yellow color method as described by Piper [9] using Spectrophotometer (Elico SL – 177) at 420 nm and P content was expressed as per cent. Potassium content in the triacid digest was determined using flame photometer Elico CL 361[9] and expressed as per cent. The zinc and iron content in the triacid digest was estimated using Atomic absorption spectrophotometer. FS 420 model of Varian make [10].

$$\text{N, P and K (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x Dry matter (kg ha}^{-1}\text{)}}{100}$$

$$\text{Zinc uptake (g ha}^{-1}\text{)} = \frac{\text{Zinc content (mg kg}^{-1}\text{) x Dry matter (kg ha}^{-1}\text{)}}{1000}$$

$$\text{Iron uptake (g ha}^{-1}\text{)} = \frac{\text{Iron content (mg kg}^{-1}\text{) x Dry matter (kg ha}^{-1}\text{)}}{1000}$$

3. RESULTS AND DISCUSSIONS

3.1 Dry Matter Yield

The data reported for dry matter production as influenced by various sources of zinc and iron recorded at 30 DAS, 60 DAS and at harvest is presented in Table 1.

At 30 DAS, highest dry matter yield (2402 kg ha^{-1}) was reported in T_{10}- treatment (RDF + foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS) which was on par with T_{14} and T_8 treatments. Similar to 30 DAS, at 60 DAS also T_{10} treatment (RDF + foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS) recorded highest dry matter production of 5278 kg ha^{-1} which was on par with T_4,T_6,T_7,T_8,T_9,T_{12},T_{13} and T_{14} treatments.

Likewise at harvest, the T_{10} treatment (RDF + foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS) maintained its superiority and recorded highest dry matter production (9614 kg ha^{-1}) and was on par with T_6, T_8 and T_{14} treatments (Table 1).

At all the crop growth stages, treatment T_1 receiving only recommended dose of fertilizers recorded the lowest dry matter production. The above results indicated that the dry matter production of finger millet increased with the application of $FeSO_4$ than that of Fe-complexes. This could be attributed to the increased solubility of Fe from $FeSO_4$ than from Fe-complexes and made it available to crop plants at a faster rate. Similar results were earlier reported by Srilatha [11] in rice. Sandhya Rani et al. [12] reported higher grain and straw yield (7810 kg ha^{-1} and 3370 kg ha^{-1} respectively) of finger millet with application of 150% RDF+$ZnSO_4$ @ 0.5% Foliar spray + $FeSO_4$ @ 0.2%.

3.2 Nutrient Content (N, P and K)

Nitrogen content in the crop steadily decreased with advancement in age of the crop upto harvest. At 30 DAS, the maximum nitrogen content (2.21%) was noticed in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with treatment T_6,T_8,T_{12} and T_{14} treatments. At 60 DAS, the maximum nitrogen content (1.44 %) was noticed in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_4,T_6,T_8,T_9,T_{12} and T_{14} treatments. At harvest, the maximum nitrogen content (1.15%) was noticed in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_8 and T_{14} treatments (Table 2). The beneficial role of micronutrient in increasing the cation exchange capacity of root helped in the increased absorption of nutrients from the soil. Further, the beneficial role of micronutrient in chlorophyll formation, regulating the auxin concentration and its stimulatory effect on most of physiological and metabolic processes of the plant might have helped the plants in absorption of greater amount of nutrients from soil. Our results are in concurrence with the findings of Mohammad et al. [13] in wheat and Singh and Kumar [14] in wheat.

Table 1. Effect of Zinc and iron nutrition on dry matter yield (kg ha^{-1}) at different stages of finger millet

Treatments	Dry matter production		
	30 Das	60 Das	Harvest (Grain+Straw)
T_1- RDF (60-40-30 kg N-P_2O_5-K_2O ha^{-1})	1941	4067	6105
T_2 - Vermicompost@ 5.0 t ha^{-1}+ RDF	1951	4138	6603
T_3-RDF+$ZnSO_4$@50 $kgha^{-1}$soil application.(Basal)	1960	4380	7430
T_4 - RDF + $ZnSO_4$ @ 0.2% foliar spray twice at 30 and 60 DAS	2077	4993	8671
T_5 - RDF + Zn-EDTA soil application @ 10 $kgha^{-1}$.	1982	4792	7576
T_6 - RDF + Zn-EDTA foliar spray @ 0.1% twice at 30 and 60 DAS.	2150	5081	9082
T_7 - RDF + Zn Humate soil application @ 42 $kgha^{-1}$.	1987	4884	7749
T_8 - RDF + Zn Humate foliar spray @ 0.25% twice at 30 and 60 DAS.	2250	5130	9237
T_9 - RDF + $FeSO_4$ @ 50 kg ha^{-1} soil application.	2020	4969	8358
T_{10} - RDF + $FeSO_4$ @ 0.5% foliar spray twice at 30 and 60 DAS.	2402	5278	9614
T_{11} - RDF + Fe-EDTA soil application @ 10 $kgha^{-1}$.	1975	4641	7469
T_{12} - RDF + Fe-EDTA foliar spray @ 0.% twice at 30 and 60 DAS	2106	5020	8829
T_{13} - RDF + Fe Humate soil application @ 42 $kgha^{-1}$.	2001	4887	7915
T_{14}-RDF + Fe Humate foliar spray @ 0.25% twice at 30 and 60 DAS	2279	5268	9506
S. E m. ±	60.3	199.16	186.72
C.D. (0.05)	176.2	582.15	545.80

Table 2. Effect of Zinc and Iron nutrition on nitrogen, phosphorus and potassium content at different stages of finger millet (%)

Treatment	Nitrogen content (%)			Phosphorus content (%)			Potassium uptake (%)		
	30 das	60 das	Harvest	30 das	60 das	harvest	30 das	60 das	Harvest
T_1	1.80	1.15	0.86	0.19	0.16	0.10	2.30	1.5	1.30
T_2	1.82	1.18	0.88	0.22	0.18	0.12	2.35	1.52	1.35
T_3	1.88	1.19	0.89	0.25	0.19	0.13	2.40	1.68	1.43
T_4	2.01	1.33	1.02	0.27	0.20	0.15	2.58	1.78	1.69
T_5	2.04	1.25	0.93	0.26	0.19	0.14	2.46	1.6	1.58
T_6	2.15	1.38	1.06	0.28	0.21	0.16	2.64	1.8	1.72
T_7	2.10	1.26	0.96	0.26	0.19	0.15	2.50	1.72	1.60
T_8	2.18	1.40	1.08	0.28	0.21	0.16	2.68	1.84	1.73
T_9	2.18	1.32	1.01	0.27	0.20	0.15	2.57	1.76	1.67
T_{10}	2.21	1.44	1.15	0.28	0.22	0.18	2.72	1.88	1.78
T_{11}	2.00	1.21	0.9	0.26	0.19	0.14	2.42	1.71	1.56
T_{12}	2.10	1.35	1.05	0.28	0.20	0.15	2.60	1.79	1.70
T_{13}	2.00	1.29	0.99	0.27	0.20	0.15	2.52	1.74	1.64
T_{14}	2.20	1.43	1.12	0.29	0.21	0.17	2.70	1.86	1.75
S. E m. ±	0.09	0.04	0.03	0.02	0.03	0.01	0.09	0.062	0.13
C.D. (0.05)	0.28	0.12	0.09	NS	NS	0.01	0.26	0.181	NS

There is no significant difference between the treatments at 30 and 60 DAS. The maximum phosphorus content (0.29%) was noticed in the crop with treatment receiving RDF+ Fe-humate foliar application twice at 30 and 60 DAS and lowest was recorded with application of RDF alone (0.19%). At 60 DAS, the maximum phosphorus content (0.22%) was noticed in the crop with treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS and lowest was recorded with application of RDF alone (0.16%). At harvest, the maximum phosphorus content (0.18%) was noticed in the crop with treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with treatment receiving

RDF+ foliar application of Fe-humate (0.17%) twice at 30 and 60 DAS and lowest was recorded with application of RDF alone (0.10%). The increased P content in different wheat parts with HA application may be due to the fact that HA increases P availability and uptake by decreasing calcium phosphate (Ca-P) precipitation rates [15], competing for adsorption sites [16] and decreasing the number of adsorption sites by promoting dissolution of metal solid phases by chelation Guppy et al. [17] (Table 2).

At 30 DAS, the maximum potassium content (2.72%) was noticed in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_4,T_5,T_6,T_7,T_8,T_9,T_{12},T_{13} and T_{14} treatments. At 60 DAS, the maximum potassium content (1.88%) was noticed in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_4,T_6,T_7,T_8,T_9,T_{12},T_{13} and T_{14} treatments. At harvest, the maximum potassium content (1.78%) was noticed in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_4,T_6,T_8,T_9,T_{12}, and T_{14} treatments. Similarly, increase in wheat K content and K-uptake recorded may be due to the reduced K fixation with the addition of HA. Delfine et al. [18] in durum wheat. The increase in growth characteristics of wheat in response to HA may be due the presence of growth promoting substances like indole acetic acid (IAA), gibberellins and auxin in its structure that are directly involved in cell respiration, photosynthesis, oxidative phosphorylation, protein synthesis, and various enzymatic reactions [19] in wheat. This increase may also be owing to the effect of HA on root development. Stimulation of root hairs and enhancement of root initiation by HA may increase nutrients uptake that eventually affected the growth characteristics of plant as reported earlier [20] in gerbera (Shahrayri et al. 2011), [21] in wheat [22] in common vetch (*Vicia sativa* L.) (Table. 2)

3.3 Nutrient Content (Fe and Zn)

Maximum content of iron (693 ppm) at 30 DAS was recorded in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_{14}, T_8, T_6 and T_{12} treatments. Maximum content of iron (603 ppm) at 60 DAS was recorded in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_{14} and T_8 treatments. Maximum content of iron (470 ppm) at harvest was recorded in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with treatment receiving RDF+ foliar application of Fe-humate (450 ppm) twice at 30 and 60 DAS and lowest was recorded with application of RDF alone (205 ppm). Many researchers reported that soil or foliar application of HA significantly increased the macro (N, P, K, Ca, Mg) and micro nutrient (Fe, Cu, Zn Mn) contents of different crops *i.e.*, in gerbera [20] (Haghighi et al. 2014); in maize (Celik et al. 2011); in wheat [23]; in cucumber (El-nemer et al. 2012) (Table 3).

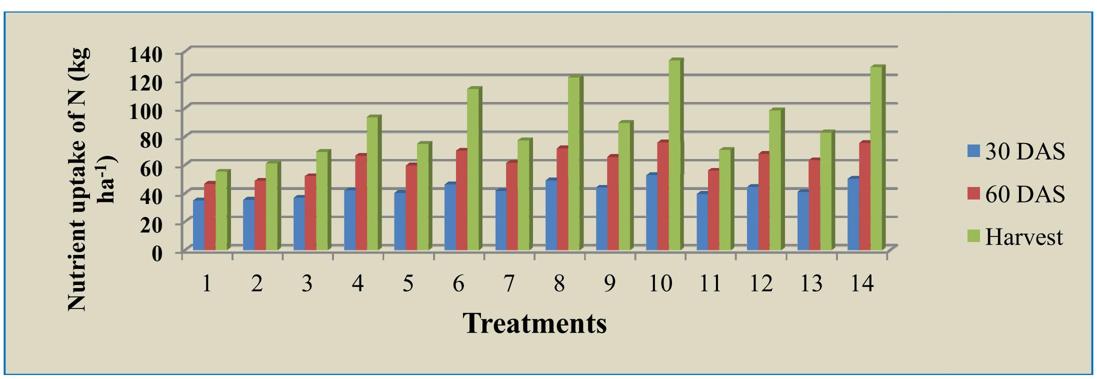

Fig. 1. Effect of various sources of zinc and iron on nitrogen uptake (kg ha^{-1}) at different growth stages of finger millet
Source (Kumar, E. Ajay, et al.,2020)

Table 3. Effect of Zinc and Iron nutrition on iron and zinc content at different stages of finger millet (ppm)

Treatments	Iron content (ppm)			Zinc content (ppm)		
	30 das	60 das	Harvest	30 das	60 das	Harvest
T_1	225	216	205	33	31	27
T_2	250	224	203	40	36	32
T_3	253	232	210	52	50	52
T_4	555	468	380	48	46	49
T_5	468	272	315	70	66	60
T_6	642	534	426	72	68	61
T_7	511	426	350	75	71	66
T_8	665	594	430	75	73	68
T_9	540	452	359	59	57	58
T_{10}	693	603	470	62	62	60
T_{11}	266	250	226	46	43	38
T_{12}	628	521	410	43	42	36
T_{13}	530	445	352	55	56	55
T_{14}	683	598	450	54	50	55
S. E m. ±	29.71	12.99	12.91	4.32	3.13	5.45
C.D. (0.05)	86.8	38.0	37.7	12.6	9.16	15.9

Maximum content of zinc (75 ppm) at 30 DAS and (73 ppm) at 60 DAS was recorded in the treatment receiving RDF + Zn Humate foliar spray @ 0.25% twice at 30 and 60 days after sowing which was on par with T_7,T_6 and T_5 treatments. At harvest, the maximum zinc content (68 ppm) was noticed in treatment receiving RDF + Zn Humate foliar spray @ 0.25% twice at 30 and 60 days after sowing which was on par with T_7,T_6 ,T_5, T_{10}, T_9, T_{13} and T_{14} treatments. The increase in nutrient concentration and uptake in response to HA in pearl millet might be due to the fact that humic substances may stimulate microbiological activity [24], and enhances nutrients uptake [25] in pearl millet (Table 3).

3.4 Nutrient Uptake (N, P and K)

Nitrogen uptake by the crop steadily increased with the advancement of ontogeny of the crop upto harvest witha consequent increase in dry matter production. At 30 DAS, highest nitrogen uptake (52.9 kg ha^{-1}) was reported in treatment T_{10}- receiving RDF + foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS and it was on par with T_{14},T_8,T_6,T_{12}. At 60 DAS (75.9 kg ha^{-1}) and at harvest (133.7 kg ha^{-1}) the N uptake was highest with RDF + foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_{14},T_8,T_6 treatments.

At all the crop growth stages, lowest nitrogen uptake was recorded with application of RDF alone. The relative effectiveness of iron sources in increasing nitrogen uptake from 30 DAS to harvest stage followed the order of $FeSO_4$> Fe-fulvate> Fe-humate> Fe-chelate.

With respect to zinc nutrition, zinc-chelates were more effective than zinc sulphates. The plant uptake in rice and utilisation of zinc from the applied sources, decreased in the following order: ZnDTPA> Zn-fulvate> Zn-EDTA > $ZnSO_4$ as reported by Chand et al. [26] in rice. (Table .4 and Fig.1).

At 30 DAS highest phosphorus uptake (6.81 kg ha^{-1}) was recorded with the treatment receiving (T_{10}) RDF + foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS, which was on par with T_{14},T_8,T_6,T_{12},T_4,T_9 treatments. At 60 DAS, there were no significant differences between treatments. At harvest (T_{10}) RDF + foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS obtained highest uptake which was on par with T_{14},T_8,T_6 treatments and the lowest P uptake was recorded with the RDF alone at all the crop stages. (Table 4 and Fig. 2).

Similar results of increased nutrient uptake in rice with humic acid were earlier reported by Sathiyabama [27] in rice and the improved nutrient uptake was attributed to the positive influence of these substances on protein and nucleic acid synthesis [28].

At 30 DAS, the highest potassium uptake (65.3 kg ha^{-1}) was reported with the treatment receiving RDF + foliar application of $FeSO_4$ @

0.5% twice at 30 and 60 DAS and it was on par with T_{14}, T_8, treatments (Table 2).

At 60 DAS(99.1 kg ha^{-1}) and at harvest (131.2 kg ha^{-1}) K uptake was highest with RDF + foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS and it was on par with T_{14}, T_8, T_6, T_{12}, T_4, T_9, treatments. Similar results of improved dry matter production and nutrient uptake in rice with foliar application of $FeSO_4$ @ 0.25% were earlier reported by Eshwar et al. [29] in rice.(Table 4. and Fig. 3).

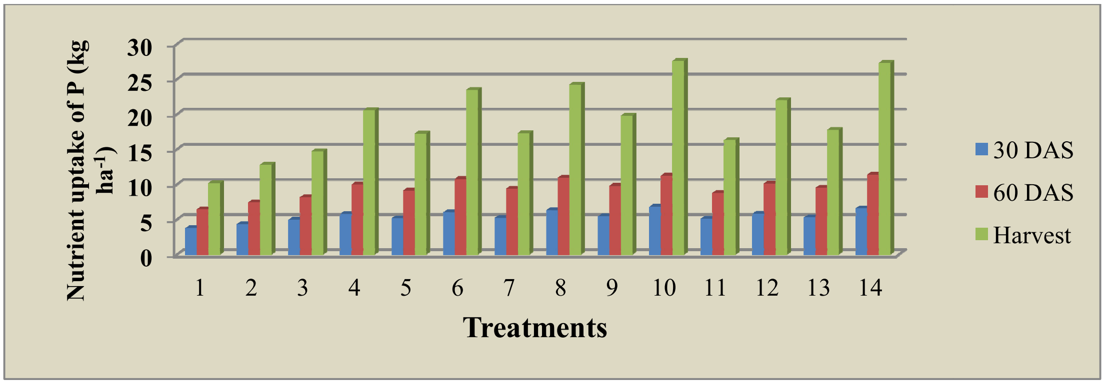

Fig. 2. Effect of various sources of Zinc and Iron on phosphorus uptake (kg ha^{-1}) at different growth stages of finger millet
Source (Kumar, E. Ajay, et al.,2020)

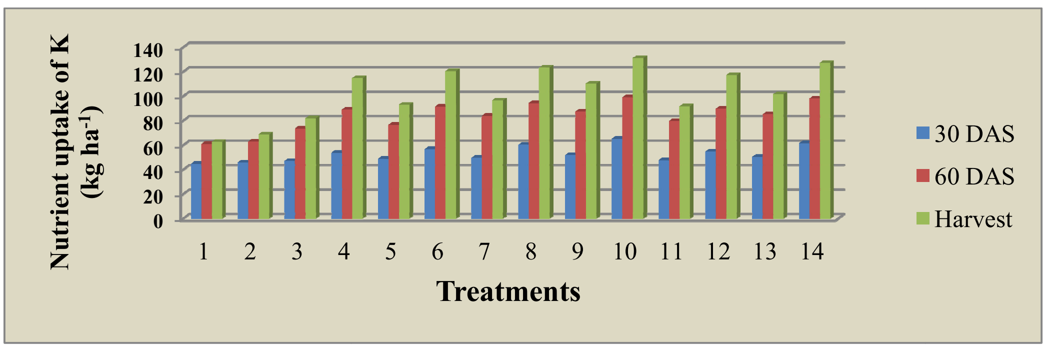

Fig. 3. Effect of various sources of Zinc and Iron on potassium uptake (kg ha^{-1}) at different growth stages of finger millet
Source (Kumar, E. Ajay, et al.,2020)

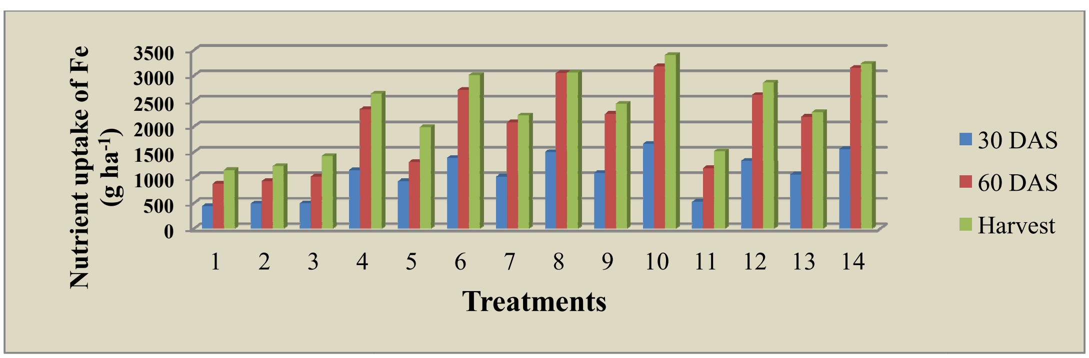

Fig. 4. Effect of various sources of zinc and iron on Iron uptake (g ha^{-1}) at different growth stages of finger millet
Source (Kumar, E. Ajay, et al.,2020)

Table 4. Effect of Zinc and Iron nutrition on Nitrogen, Phosphorus and Potassium uptake at different stages of finger millet (kg ha^{-1})

Treatment	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	30 Das	60 Das	Harvest (Grain+Straw)	30 Das	60 Das	Harvest (Grain+Straw)	30 Das	60 DAS	Harvest (Grain+Straw)
T_1	34.9	46.7	55.2	3.75	6.45	10.1	44.6	61.0	62.6
T_2	35.5	48.8	61.1	4.33	7.44	12.7	45.8	62.9	68.8
T_3	36.9	52.1	69.2	4.94	8.15	14.7	47.0	73.5	82.0
T_4	42.0	66.4	93.6	5.77	9.97	20.5	53.6	88.9	114.7
T_5	40.4	59.6	74.9	5.15	9.11	17.2	48.7	76.6	92.9
T_6	46.4	70.1	113.5	6.00	10.75	23.4	56.7	91.4	120.5
T_7	41.7	61.5	77.3	5.21	9.38	17.2	49.6	83.9	96.5
T_8	49.1	71.8	121.6	6.30	10.94	24.2	60.3	94.4	123.4
T_9	44.0	65.6	89.7	5.45	9.79	19.7	51.8	87.4	110.2
T_{10}	52.9	75.9	133.7	6.81	11.26	27.5	65.2	99.1	131.2
T_{11}	39.5	56.0	70.6	5.10	8.77	16.2	47.8	79.6	91.6
T_{12}	44.5	67.7	98.4	5.82	10.13	21.9	54.6	89.8	117.1
T_{13}	41.0	63.3	82.8	5.30	9.51	17.7	50.4	85.1	101.6
T_{14}	50.3	75.5	128.9	6.57	11.06	27.2	61.6	98.0	127.1
S. E m. ±	2.13	2.97	6.57	0.48	1.50	1.89	2.02	4.42	7.19
C.D. (0.05)	6.23	8.70	19.21	1.420	N S	5.53	5.90	12.92	21.02

Table 5. Effect of Zinc and Iron nutrition on iron and zinc uptake at different stages of finger millet (g ha^{-1})

Treatments	Iron uptake (g ha^{-1})			Zinc uptake (g ha^{-1})		
	30 Das	60 DAS	Harvest (Grain+Straw)	30 Das	60 Das	Harvest (Grain+Straw)
T_1	436	879	1147	64	126	139
T_2	490	930	1222	78	149	170
T_3	495	1019	1422	103	244	312
T_4	1145	2339	2644	95	227	288
T_5	927	1305	1987	151	335	411
T_6	1382	2718	3009	161	350	418
T_7	1017	2083	2220	171	375	456
T_8	1498	3049	3058	180	384	479
T_9	1091	2250	2447	123	284	388
T_{10}	1660	3181	3401	131	313	396
T_{11}	525	1184	1514	91	202	229
T_{12}	1324	2618	2862	84	185	219
T_{13}	1061	2190	2282	111	282	355
T_{14}	1559	3149	3232	108	247	336
S. E m. ±	63.62	104.8	105.47	9.70	19.59	30.64
C.D. (0.05)	185.96	306.33	308.30	28.37	57.26	89.58

3.5 Iron and Zinc Uptake

Highest iron uptake was recorded in treatment receiving RDF+foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_{14}, T_8 treatments, At 30 (1660 g ha^{-1}) and 60 DAS (3181 g ha^{-1}). At harvest maximum uptake was observed in RDF+foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS which was on par with T_{14} treatment and lowest was obtained with RDF at all the crop stages. Significant improvement of Fe uptake (30.20, 16.11%) Zn (47.90, 18.32 %) and B (25.60, 19.75%) uptake were also obtained with soil + foliar and (Fe+ Zn+ B) application over control by Mathur et al . (2017) in sorghum.(Table 5 and Fig. 4).

At 30 DAS the highest Zinc uptake (180 g ha^{-1}) was noticed in treatment obtaining RDF + Zn Humate foliar application @ 0.25% twice at 30 and 60 DAS which was on par with T_7, T_6 treatments. At 60 DAS (384 g ha^{-1}) and at harvest (479 g ha^{-1}) maximum uptake was reported in treatment receiving RDF + Zn Humate foliar spray @ 0.25% twice at 30 and 60 DAS which was on par with T_7, T_6 T_5 treatments and the lowest was recorded with RDF alone at all the crop growth stages(Table 5 and Fig. 5). Eshwar et al. [29] in rice concluded that nutrient uptake, dry matter production significantly improved with foliar application of $FeSO_4$ @ 0.25% at vegetative and panicle initiation stage of rice over rest of the treatments.

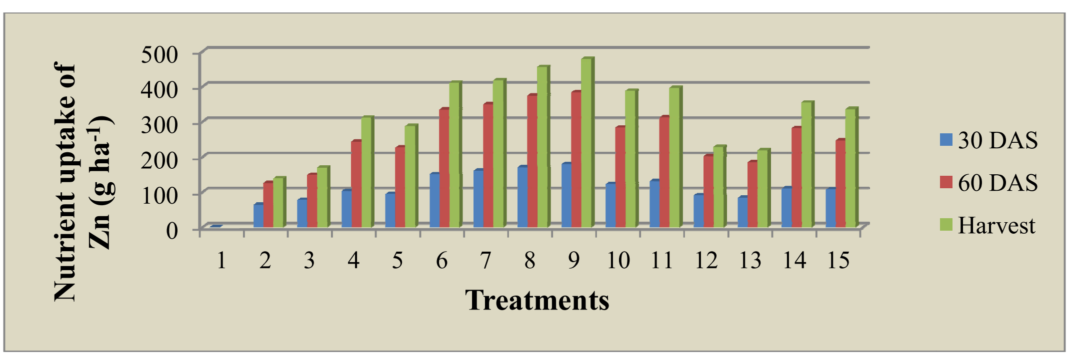

Fig. 5. Effect of various sources of zinc and iron on zinc uptake (g ha^{-1}) at different growth stages of finger millet
Source (Kumar, E. Ajay, et al.,2020)

4. CONCLUSION

The results have clearly brought out the fact that application of zinc and iron by foliar spray have resulted in higher nutrient content and uptake in crops. The highest dry matter production, nutrient content and uptake (N, P, K, Fe) was obtained in the treatment receiving RDF+ foliar application of $FeSO_4$ @ 0.5% twice at 30 and 60 DAS followed by RDF+ foliar application of Fe-humate twice at 30 and 60 DAS. The highest nutrient content and uptake of Zn in crop was obtained in treatment receiving RDF + Zn Humate foliar spray @ 0.25% twice at 30 and 60 days after sowing followed by RDF + Zn Humate soil application.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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