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Effect of Foliar Nutrition on Zinc and Iron Content of Hybrid Pearl Millet

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Abstract

A field experiment was conducted at MJRP College of Agriculture and Research Jaipur during kharif season 2023 on loamy sand soil, which consisted ten treatments of foliar nutrition (T_1: control, T_2: RDF, T3: RDF + water spray, T_4: RDF + urea 2% spray at FI, T_5: RDF+ DAP 2% spray at (Flower initiation) FI, T_6: RDF + MOP 2% spray at FI, T_7: 19:19:19 (NPK) 2% spray at FI, T_8: RDF + B chelate 0.5% spray at FI, T_9: RDF + Zn chelate 0.5% spray at FI, T_{10}: RDF + Fe chelate 0.5% spray at FI and were tested in randomized block design with three replications. Results indicated that zinc, content in grain and stover was significantly increased due to application of T_9 (RDF + Zn chelate 0.5% spray at FI), iron content in grain and stover was maximum in T_{10} (RDF + Fe chelate 0.5% spray at FI).

***Key words*: *Pennisetum glaucum*, Flower initiation, Foliar nutrition, Zinc, Iron**

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is one of the most significant staple food crops, particularly for the poor and smallholder farmers across the arid and semi-arid regions of Asia and Africa. Due to its ability to thrive under harsh agro-climatic conditions, it plays a critical role in ensuring food and nutritional security in resource-constrained areas. Among all the millet varieties, pearl millet stands out as the principal food grain and an important fodder crop, offering dual benefits to farming communities [1]. It is widely cultivated for both human consumption and livestock feed, especially in regions with limited rainfall and degraded soils where other cereals struggle to survive. India is the largest producer of pearl millet, contributing nearly 50% of the world's total millet output, highlighting its central role in global millet production and its importance in the Indian agricultural economy [2]. It is the most drought tolerant cereal grown in arid and semi-arid regions of the world and can be grown in areas where rainfall is less sufficient (200 to 600 mm year) for the cultivation of maize and sorghum. It is the fifth most important cereal crop in the world after rice, wheat, maize, and sorghum. The nutrient of pearl millet grain is very well comparable with other cereals and millets. Nutritional value of pearl millet is better than wheat, rice, maize and sorghum. It is good source of energy, carbohydrate 67%, fat (5%), ash, dietary fibre (11.49 g/100 g), protein (11.6%), antioxidant such as coumaric acids with better digestibility. Pearl millet has higher contents of nutrients such as iron, zinc, calcium, magnesium, copper, manganese, phosphorus, folic acid and riboflavin. Cultivation of pearl millet is mainly confined to semi-arid and arid region of India. In India, pearl millet occupies an area of 7.4 million ha with an average production of 9.13 million tonnes and productivity of 1237 kg/ha [3]. Pearl millet is generally grown in light or shallow depth of soil which has less moisture condition hence fertilizer application through soil is not much effective as compare with foliar application or spraying. Foliar spraying of nutrient gives better growth and yield. Pearl Millet absorb nutrient through cuticle, which has fast result. The trends in area, production and productivity of pearl millet suggest that area has increased marginally 2 percent during last two years and productivity has gone up by 19 per cent [4]. Normally pearl millet is grown under rainfed conditions and can fit into any of the cropping systems due to its shorter duration. Because of its high nutritive value, its demand has been increased in the recent years. Hybrid varieties of pearl millet have been developed to improve yield and nutritional quality. However, micronutrient deficiencies especially zinc (Zn) and iron (Fe) remain a major concern, particularly in regions where diets rely heavily on cereals for nutrition. Foliar nutrition, which involves spraying nutrient solutions directly on plant leaves, has emerged as an effective strategy to enhance the micronutrient content of crops without altering soil properties significantly.

Iron is an essential micro nutrient for all living organisms and it plays critical role in metabolic processes such as DNA (deoxyribonucleic acid) synthesis, respiration photosynthesis. In plants, iron is involved in the synthesis of chlorophyll and it is essential for the maintenance of chloroplast structure and function. Zinc is one of the eight essential micronutrients. It is needed by plants in smaller amounts, but yet crucial to plant development. In plant, Zinc is a key constituent of many enzymes and proteins. It plays an important role in a wide range of processes, such as growth hormone production and internode elongation. In India, Zn is one of the multi-nutrient deficiencies causing poor crop yields. Indian soils are deficient in zinc which causes disturbance in photosynthesis and nitrogen metabolism of plants. Iron is an important constituent of cytochromes, ferredoxin, catalase, peroxidase, ferrochrome and also for

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chlorophyll synthesis in plants. Foliar supplementation of zinc and iron had improved the grain quality, yield and higher economic production [5].

Jakhar [6] conducted a pot experiment on fenugreek in green house and reported that increasing levels of zinc (0, 10 and 20 mg / kg) significantly increased the plant height, number of pods per plant, number of seeds per pod, test weight, seed and straw yield of fenugreek. Ravi *et al*. [7] found that combined foliar application of iron 0.5% + zinc 0.5% at 30 and 60 DAS in safflower recorded significantly higher growth parameters like plant height, number of leaves, primary and secondary branches/ plant and dry matter accumulation as compared to control. Choudhary *et al*. [8] reported that foliar application of zinc sulphate @ 0.5% at star bud stage + borax spray @ 0.20% at ray floret initiation stage in sunflower recorded significantly higher filled seeds/head (594.56), lower % chaffiness (6.33) and seed yield (53.80 g/plant) as compared to other treatments. Sammauria and Yadav [9] reported that application of 5.0 kg Zn/ha as basal dose significantly increased number of pods per plant, seed, straw and biological yield, whereas, branches per plant increased up to the level of Zn @ 7.5 kg /ha and seeds per pod and test weight only up to 2.5 kg Zn/ha level. Guru Prasad *et al*. [10] revealed that 0.5% foliar spray of iron sulphate at 30 and 45 DAS and application of 25 kg iron sulphate at sowing registered significantly higher Fe and Zn uptake in groundnut crop. Bhadauria *et al*. [11] also reported that soil application of zinc @ 10 kg/ha recorded significantly higher iron, manganese, copper and zinc uptake as compared to control in oilseed crops. In light of the above findings, it is evident that the foliar application of micronutrients like zinc and iron holds significant potential to enhance the growth, yield, and nutritional quality of various crops, including pearl millet. Given the inherent nutrient deficiencies in Indian soils and the low efficiency of soil-applied fertilizers under arid and semi-arid conditions, foliar nutrition emerges as a more effective and targeted approach. Therefore, assessing the impact of foliar application of iron and zinc on pearl millet is crucial for optimizing nutrient management strategies, improving crop productivity, and addressing micronutrient malnutrition through bio-fortified grains.

MATERIALS AND METHODS

This experiment was conducted at Agronomy Farm, MJRP College of Agriculture and Research Jaipur (Rajasthan) on field kharif, 2023. The climate of this region is a typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 43°C, while in winters, it may fall as low as-1.0 °C. The crop was irrigated from storage tank of the college which receives water from tala mode village.

The treatments were randomly allotted to different plots, using random number table of Fisher and Yates [12]. Varietal characteristics Hybrid 'RHB-173' was released from Agricultural Research Station, Durgapura (Jaipur). It is a medium maturity (78-80 days) hybrid and attains a height of about 190- 210 cm with 2-3 tillers. It has medium thick and long cylindrical head. This hybrid is medium in flowering (50 days). It has long ear heads (26-32 cm) with grain weight of 35 g/ear. The average yield of variety is 25- 30 q/ha under normal sowing and moderate level of management.

In treatment RDF through fertilizer, half dose of nitrogen and full dose of phosphatic fertilizers was drilled as per plan through urea and DAP at the time of sowing and remaining half dose of N was applied as top dressing in split by urea. The recommended dose of fertilizer is 60:40:0. The foliar spray was done at flowering initiation as per treatments. Seeds of the hybrid bajra variety, RHB-173 were sown on 13th July, 2023 an optimum plant population is essential for crop production which may be achieved by using proper seed rate. Healthy and good quality certified seeds were used and sown by 'Kera' method using a seed rate of 4 kg/ha.

The Harvesting was done manually with the help of sickle on 4-10-2023 when the crop attained physiological maturity. The produce of each net plot was tied into bundles, dully labeled and allowed to sun drying for 3-4 day in respective plots. The weight of bundles was recorded from each plot by using balance. Then the bundle to each plot was transported to threshing yard and then store house. Threshing of the bundles of each plot was done separately by beating with wooden sticks, then seeds/grains were cleaned by using hand fan (Supa) manually. The weight of clean seeds obtained from each net plot was recorded. The straw yield was obtained by subtraction of grain yield from total biological yield (grain + straw) and converted into qh/ha.

Zn, and Fe content (ppm) in both grain and stover was estimated by Atomic Absorption Spectrophotometer [13].

Statistical analysis

The observations recorded for growth, yield and quality characters were subjected to statistical analysis in accordance with the 'Analysis of variance' technique as suggested by Fisher [14] for randomized block design. Appropriate standard error for each of the factor was worked out. Significance of differences among treatment effects was tested by 'F' test. Critical difference (CD) was worked out wherever the difference was found significant at 5 or 1 per cent level of significance. To elucidate the nature and the magnitude of effects, treatment summary tables along with SEm± and CD were prepared and given in the text of chapter "Experimental Results" and their analyses of variance in the appendices at the end.

RESULTS AND DISCUSSION

Zinc concentration in grain and stover

It is evident from data (Table 1) that application of foliar nutrition significantly increased the zinc content in grain and stover of hybrid pearl millet wherein application of T_9 (RDF + Zn chelate 0.5% spray) recorded the maximum zinc content of 36.68 ppm in grain and 27.49 ppm in stover and registered an increase of 23.79, 8.066, 10.12 and 3.44 percent in grain and 27.03, 11.96, 8.50 and 7.34 per cent in stover of hybrid pearl millet over control, 19:19:1 (NPK) 2% spray at FI, RDF +water and RDF, respectively. However, it remained at par with T_6 (36.63 and 25.98 ppm) (MOP 2% spray at FI), T_4 (36.33 and 25.73 ppm) (RDF + urea 2% spray at FI), T_{10} (35.03 and 25.78 ppm) (RDF + Fe chelate 0.5% spray at FI) and T_8 (33.28 and 24.73 ppm) (RDF + B chelate 0.5% spray at FI) with respect to Zn content of hybrid pearl millet.

Zinc uptake

A perusal of data (Table 1) reveals that foliar application of different nutrition significantly increased the zinc uptake by grain and stover of hybrid pearl millet. Application of T_6 (86.13 and 162.23 g/ha) (RDF + MoP 2% spray at flower initiation), T_4 (80.87 and 158.73 g/ha) (RDF + urea 2% spray at flower initiation), T_5 (79.58 and 158.31 g/ha) (RDF + DAP 2% spray at flower initiation), T_9 (77.90 and 152.58 g/ha) (RDF + Zn 0.5% spray at flower initiation), T_{10} (75.03 and 146.08 g/ha) (RDF + Fe 0.5% spray at flower initiation) and T_8 (70.23 and 140.92 g/ha) (RDF + B 0.5% spray at flower initiation) being at par with each other gave significantly higher zinc uptake indicating an increase of 82.55, 71.40, 68.67, 65.11, 59.02 and 48.22 percent by grain and 86.06, 82.05, 81.56, 74.99, 67.54 and 61.62 per cent by stover, respectively over control.

Table 1 Effect of foliar nutrition on Zn content in grain and stover and its uptake by pearl millet

Treatments	Zn content (ppm)		Zn uptake (g/ha)	
	Grain	Stover	Grain	Stover
T_1: Control	29.63	21.64	47.18	87.19
T_2: Recommend dose of fertilizers (RDF)	30.65	23.23	67.38	122.68
T_3: RDF + Water spray at flower initiation (FI)	32.63	23.48	68.03	131.92
T_4: RDF + Urea 2% spray at FI	36.33	25.73	80.87	158.73
T_5: RDF + DAP 2% spray at FI	33.64	25.07	79.58	158.31
T_6: RDF + MOP 2% spray at FI	36.63	25.98	86.13	162.23
T_7: 19:19:19 (NPK) 2% spray at FI	32.03	24.23	59.68	122.15
T_8: RDF + B chelate 0.5% spray at FI	33.28	24.73	70.23	140.92
T_9: RDF + Zn chelate 0.5% spray at FI	36.68	27.49	77.90	152.58
T_{10}: RDF + Fe chelate 0.5% spray at FI	35.03	25.78	75.03	146.08
SE m±	0.44	0.39	0.94	2.12
CD (p=0.05)	1.31	1.15	2.80	6.30

Iron concentration in grain and stover

The data (Table 2) that application of foliar nutrient significantly increased the iron content in grain and stover of hybrid pearl millet. Application of T_{10} (51.63 and 107.63 ppm) (RDF + Fe chelate 0.5% spray at FI), T_4 (48.03 and 105.83 ppm) (RDF + urea 2% spray at FI), T_5 (48.33 and 106.23 ppm) (RDF + DAP 2% spray at FI), T_9 (49.33 and 106.33 ppm) (RDF+ Zn chelate 0.5% spray at FI), T_8 (46.33 and 104.03 ppm) (RDF+ B chelate 0.5% spray at FI) and T_6 (46.83 and 104.43 ppm) (RDF + MOP 2% spray at FI) being at par with each other gave significantly maximum iron content in both (grain and stover). The increase in iron content due to RDF + Fe chelate 0.5% spray at FI over control, RDF, 19:19:19 (NPK) 2% spray at FI and RDF + water spray were 28.65, 12.95, 10.46, 9.22 per cent in grain and 19.94, 12.59, 11.81, 9.47percent in stover of hybrid pearl millet, respectively.

Table 2 Effect of foliar nutrition on Fe content in grain and stover and its uptake of pearl millet

Treatments	Fe content (ppm)		Fe uptake (g/ha)	
	Grain	Stover	Grain	Stover
T_1: Control	40.13	89.73	62.43	372.53
T_2: Recommend dose of fertilizers (RDF)	45.33	101.03	87.33	558.03
T_3: RDF + Water spray at flower initiation (FI)	44.43	98.23	92.33	572.13
T_4: RDF + Urea 2% spray at FI	48.03	105.83	110.43	672.53
T_5: RDF + DAP 2% spray at FI	48.33	106.23	113.43	687.33
T_6: RDF + MOP 2% spray at FI	46.83	104.43	107.23	667.03
T_7: 19:19:19 (NPK) 2% spray at FI	43.83	100.33	86.03	522.03
T_8: RDF + B chelate 0.5% spray at FI	46.33	104.03	100.13	597.53
T_9: RDF + Zn chelate 0.5% spray at FI	49.33	106.33	104.73	604.23
T_{10}: RDF + Fe chelate 0.5% spray at FI	51.63	107.63	107.03	626.83
SE m±	0.54	1.55	1.61	11.25
CD (p=0.05)	1.60	4.60	4.79	33.43

Iron uptake

A perusal of data (Table 2) reveals that foliar application of different nutrition significantly increased the iron uptake by grain and stover of hybrid pearl millet. Application of T_5 (113.43 and 687.33 g/ha) (RDF+ DAP 2% spray at FI), T_4 (110.43 and 672.53 g/ha) (RDF+ urea 2% spray at FI), T_6 (107.23 and 667.03 g/ha) (RDF + MOP 2% spray at FI) and T_{10} (107.03 and 626.83 g/ha) (RDF+ Fe chelate 0.5% spray at FI) being at par with each other gave significantly higher iron uptake indicating an increase of 81.69, 76.88, 71.76 and 71.44 per cent by grain and 84.50, 80.53, 79.05 and 68.26 percent by stover, respectively, overcontrol.

Effect of foliar nutrition

Application of micronutrient (Fe, Zn) might have increased the availability and steady supply of micro nutrients for plant metabolism and photosynthetic activity resulting into optimum growth and development of the crop. In addition, zinc is important in the synthesis of tryptophan, a component of some proteins and a compound needed for production of growth hormones (auxins) like IAA. Such improvement under increased availability of zinc in rhizosphere might have resulted in greater uptake by the plant consequently leading to a favourable stimulatory effect on physiological and metabolic processes of pearl millet plant. These favourable influences of nutrients resulted into greater meristematic activities and apical growth, thereby improving plant height, tillers per meter row length and higher value of leaf area ultimately resulting in improved LAI, chlorophyll content. The results obtained in present investigation are in line with the findings of [15-16] reported that the foliar applied nutrients enhance the mobilization of photosynthates from source to sink and improved the sink accumulation capacity which resulted in increased grain weight.

The effect of foliar spray of micro-nutrient (Fe, Zn) on grain yield can also be explained on the basis of relatively higher doses of micronutrient tended to produce more vegetative growth resulting from efficient utilization of nutrients, water, radiation and increased metabolic activities followed by increased translocation toward yield contributing characters, might have led to significant increase in grain yield. Further, the addition of the micronutrients also helps in better utilization of the major nutrients to produce higher yield of crops. Singh and Ram [17] have also reported similar increase in yield of wheat and rice due to Fe, Zn application under different agro-climatic conditions. Similarly, Patel and Singh [18] also found the beneficial effect of multi-micronutrients could be the balanced nutrition of the crops and thereby improved crop growth as well as yield. Increase in straw yield might be due to profuse tillering and improved vegetative growth by the application of fertilizer doses at early stages. Foliar nutrition spray of urea, iron and zinc increased the straw content by ensuring better nutrient availability [19-21].

The application of zinc in a soil improved overall growth and development of plants and ultimately the grain and stover yield. Increase in grain and stover yields due to zinc application may be attributed to the fact that the initial status of available Zn in the experimental soil was low [22-23].

As biological yield is a sum of grain and stover yields, the improvement in these parameters as discussed also enhanced the biological yield significantly due to these treatments. Foliar application of micronutrients is important when the roots could not be able to provide the necessary nutrients and hence the application on the foliage helped in the rapid absorption of the required nutrients by the crop for higher production. Recommended dose of fertilizer of plants appears to be synergistic with zinc, which may leads to increase in many physiological and molecular activities which in turn improve yield attributing characters [24-25].

Nutrient concentration, uptake and quality

The application of recommended dose of fertilizer with foliar spray significantly increased the concentration of major nutrients (nitrogen, phosphorus and potassium) and micronutrient (Fe, Zn) in grain and stover. It can mainly be associated with the better growth of the crop due to favorable nutritional environment mainly for supply of most of the macro and micronutrients in balanced and available form throughout the growing period of the crop and inadequate amounts. Application of Zn to deficient soil increased the availability of Zn in rhizosphere at a level below where the optimum requirement of crop is fulfilled. Further, the beneficial role of zinc in chlorophyll formation, regulating auxin concentration and its stimulatory effect on most of the physiological and metabolic processes of plant might have helped the plants to absorb higher amount of nutrients from the soil [26-28]. The increase in protein content of pearl millet due to application of zinc has also been reported by Dwivedi *et al.* [29], Shanmuga Sundaram and Savithri [30] in moth-bean.

CONCLUSION

The present study clearly demonstrates the positive impact of foliar nutrient application on zinc and iron concentration and uptake in grain and stover of hybrid pearl millet. Among the treatments, T_9 (RDF + Zn chelate 0.5% spray at FI) recorded the highest zinc concentration (36.68 ppm in grain and 27.49 ppm in stover), significantly surpassing the control and other treatments. It was closely followed by T_6, T_4, T_{10}, and T_8, indicating that various foliar-applied nutrients, especially when combined with RDF, effectively enhanced zinc accumulation. In terms of zinc uptake, T_6 (RDF + MOP 2% spray) emerged as the top performer, suggesting that potassium application also played a role in improving zinc utilization. Similar trends were observed in iron concentration and uptake, with T_{10} (RDF + Fe chelate 0.5% spray) showing the highest iron content, while T_5 (RDF + DAP 2% spray) led in iron uptake, reflecting the synergistic effects of combined nutrient application. These findings emphasize that foliar application of micronutrients such as Zn and Fe, in conjunction with recommended basal fertilization, improves nutrient availability, uptake efficiency, and ultimately the physiological performance of pearl millet. The increased concentrations and uptakes of Fe and Zn translated into better vegetative growth, yield components, and overall biological productivity. Such enhancements are especially valuable in micronutrient-deficient soils, where foliar feeding serves as a quick and effective strategy to meet crop nutritional demands. Therefore, integrating foliar nutrition, particularly Zn and Fe chelates, with conventional fertilization practices, represents a viable agronomic approach to boost nutrient content and yield in hybrid pearl millet under nutrient-limited conditions.

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