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INFLUENCE OF ZINC AND IRON ON GROWTH AND YIELD OF PEARL MILLET HYBRID VARIETIES IN SEMI-ARID REGION OF RAJASTHAN INDIA

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ABSTRACT

The aim of this study was to identify optimal combination of hybrid varieties with soil and foliar application of zinc and iron that could enhance growth while maximizing grain, stover and biological yield of pearl millet. A two-year (2023–24) field experiment was conducted at Instructional Farm, SKNCOA, SKNAU, Jobner, Rajasthan, India in a split plot design, in which Factor A consisting of two hybrid varieties and Factor B in which four levels of soil application of zinc and iron in main plot. On the other hand, sub plot consists of four levels of foliar application of zinc sulphate and iron sulphate at 30 and 45 DAS. Increased plant height and dry matter accumulation promoted superior crop growth resulting in a significantly greater yield. Among both hybrid varieties, hybrid RHB-223 found better in terms of growth and yield of pearl millet. Basal application of 5.0 kg Zn ha⁻¹ + 5.0 kg Fe ha⁻¹ resulted in significantly higher dry matter and plant height led to maximum grain and stover yield which was 27.32 and 17.67% higher over control during both years of the study. Further, the foliar application of 0.5% ZnSO₄ + 0.5% FeSO₄ recorded the highest grain and stover yield of 26.58 and 20.02 % over control, respectively.

Key words: Pearl millet, Zinc, Fe, Semi-arid zone, and Yield

Introduction

Pearl millet, scientifically known as *Pennisetum glaucum* and commonly referred to as bajra, stands out as a resilient warm-season cereal crop. Its adaptability to various agro-climatic conditions, particularly dry and semi-arid environments, makes it a crucial staple crop in West Africa, India, and Pakistan. Notably, pearl millet exhibits the highest drought tolerance among warm-season cereals, which makes it a highly reliable and resilient crop for cultivation under water-limited and drought-prone conditions (Krishnan and Meera, 2018). 91% of the arable land in Rajasthan is cultivated for pearl millet, as it is the most resistant millet to abiotic and biotic stresses and can also withstand more climatic changes as compared to other millets. Rajasthan shares an area of 4.38 million

hectares occupies the first position in both area and production of pearl millet in India contributing major share to the national output and accounting for nearly 45–50 per cent of the total production of the crop in the country (Anonymous, 2024).

The major reason for dominance of pearl millet in Rajasthan is the ability of pearl millet to withstand most of the abiotic stresses. Because Bajra is a resilient crop that can tolerate these challenging circumstances, it is a good fit for cultivation in the area. It is a great option for places with little irrigation capacity because of its amazing capacity to endure in low-water situations (Ram and Meena, 2014). However, productivity in arid Rajasthan is still lower than the national average because of environmental constraints, which explains the need for

region-specific biofortified cultivars. Among micronutrients, it is loaded with an abundance of Fe and Zn content (Satyavathi *et al.*, 2021). Hence, Pearl millet is a highly nutritious cereal whereas bioavailability is low, because of the presence of certain anti-nutritional factors like phytic acid, polyphenols etc. Polyphenols content was found to range from 4.91 to 7.65 g kg⁻¹, whereas, phytic acid content ranged from 3.54 to 8.25 g kg⁻¹ (Satyavathi *et al.*, 2017) and low in glycemic index (55) because of the presence of slowly digestible starch and resistant starch, lysine, tryptophan, threonine and the sulfur-containing amino acids are also in low amount. Various approaches such as biofortification, nutrient supplementation, fortification and diet diversification have been implemented in order to overcome micronutrient malnutrition (White and Broadley, 2009).

Depletion of soil fertility and their imbalances is a severe global threat leaving large yield gaps between current farmers and achievable ones. The focused research emphasis on increasing crop production in these thirsty and hungry soils includes high yielding varieties with intensive fertilizer use (Lakshmi *et al.*, 2022). Insufficient micronutrient availability in soils paves the way for low quality and quantity of crops, contributing to malnutrition in the human population (Kumssa *et al.*, 2015). Biofortification also results in better crop productivity and nutritional quality, thus diminishing the micronutrient malnutrition in consumers (Dhaliwal *et al.*, 2009). Agronomic biofortification refers to the use of mineral fertilizers to improve concentration of nutrients in edible crops and also positively affects the crop yield (Dhaliwal *et al.*, 2019).

Materials and Methods

Experimental site

The field experiment, investigating various planting materials and integrated nutrient management strategies, was conducted during two consecutive seasons of *Kharif*, 2023 & 2024 at the Instructional Farm, SKNCOA, SKNAU, Jobner, Rajasthan, India. The experimental site had sandy loam soil texture at 0–15 cm depth. The experiment was replicated three times under a split plot design with 32 treatment combinations during the both years of study, viz. 2023 and 2024. The experiment consists of two hybrid varieties and four levels of soil application of zinc and iron in main plot. On the other hand, sub plot consists of four levels of foliar application of zinc sulphate and iron sulphate at 30 DAS and 45 DAS. The zinc and iron were applied as zinc sulphate (ZnSO₄.7H₂O) and ferrous sulphate (FeSO₄.7H₂O)

containing 21% Zn and 19.6% Fe, respectively. The dose of zinc and iron sulfate is 25 kg ha⁻¹ as per the all treatments wherever applicable.

Crop cultivation details

The field was prepared with help of ploughing thoroughly with tractor drawn lough disk followed by cross harrowing and planking. The area of each plot was 14.4 m² (4.0 m length × 3.6 m width). The seed rate used was 4 kg ha⁻¹ and planted at a distance of (45 cm × 10 cm). A basal dose of 1/3rd N and the full dose of phosphorus, zinc and iron sulfate were applied as per the treatments accordingly. Top dressing of the remaining 2/3rd N was done at 25 days after sowing.

Dry matter accumulation

Dry matter accumulation was recorded at 30 days after sowing (DAS), 60 DAS, and at harvest. Plants were randomly uprooted from three spots in the outer rows of each plot. After removing the root portion, the samples were air-dried for several days, followed by oven-drying at 70°C until constant weight was achieved. The dry weight was then recorded and expressed as average dry matter per plant (g plant⁻¹).

Plant height

Five plants selected randomly from each plot were tagged, the height of these five plants were measured at 30, 60 DAS and at harvest from the base of the plant to top of the plant by meter scale and expressed as average height in centimeter.

Grain yield

The grain yield of each net plot was recorded in kg plot⁻¹ after cleaning the threshed produce and was converted to kg ha⁻¹.

Stover yield

Stover yield was calculated by subtracting the grain yield from biological yield of each net plot and then expressed as kg ha⁻¹.

Biological yield

The weight of the thoroughly sun-dried harvested produce of each plot was recorded separately before threshing as biological yield and then converted into kg ha⁻¹.

Harvest index

Harvest index was computed by using the formula outlined below:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

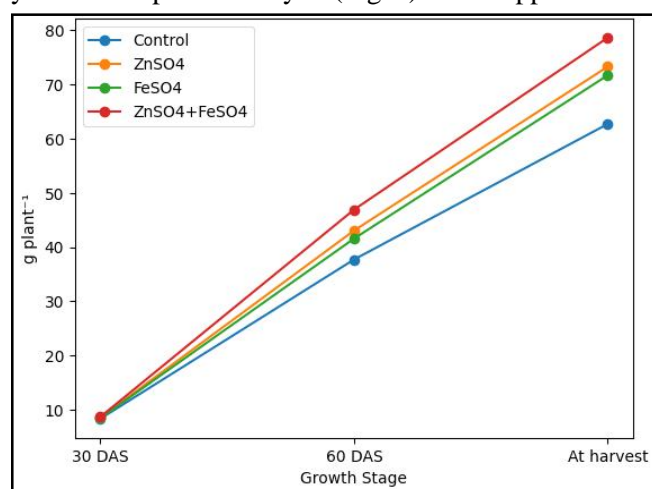
Table 1: Effect of agronomic biofortification of pearl millet hybrid varieties with zinc and iron on plant height (cm) at different growth stages of pearl millet.

Treatment	30 DAS			60 DAS			At harvest		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Varieties									
RHB-223	35.31	41.20	38.26	136.34	157.59	146.96	179.38	184.18	181.78
MPMH-17	33.99	39.70	36.85	127.43	146.63	137.03	162.20	172.45	167.32
SEm \pm	0.51	0.50	0.36	1.83	1.96	1.34	2.36	2.44	1.70
CD (P=0.05)	NS	NS	NS	5.56	5.94	4.13	7.15	7.40	5.23
Basal application of Zn and Fe									
Control	31.14	38.38	34.76	126.16	145.80	135.98	159.93	167.21	163.57
5.0 kg Zn ha ⁻¹	35.41	40.59	38.00	132.70	152.74	142.72	171.28	179.17	175.22
5.0 kg Fe ha ⁻¹	34.42	39.88	37.15	130.36	150.96	140.66	169.74	178.03	173.88
5.0 kg Zn ha ⁻¹ + 5.0 kg Fe ha ⁻¹	37.62	42.97	40.29	138.32	158.93	148.63	182.20	188.86	185.53
SEm \pm	0.71	0.71	0.50	2.59	2.77	1.90	3.33	3.45	2.40
CD (P=0.05)	2.17	2.16	1.56	7.86	8.40	5.84	10.11	10.47	7.39
CV (%)	10.11	8.63		9.62	8.92		9.56	9.48	
Foliar application of Zn and Fe									
Control	33.85	39.45	36.65	126.14	144.26	135.20	160.12	169.16	164.64
0.5% ZnSO ₄	34.82	40.89	37.86	133.64	153.29	143.47	172.45	178.69	175.57
0.5% FeSO ₄	34.12	40.12	37.12	130.14	151.23	140.69	170.12	177.15	173.64
0.5% ZnSO ₄ + 0.5% FeSO ₄	35.81	41.35	38.58	137.62	159.66	148.64	180.46	188.26	184.36
SEm \pm	0.69	0.69	0.49	2.04	2.24	1.51	2.63	2.75	1.90
CD (P=0.05)	NS	NS	NS	5.80	6.36	4.24	7.48	7.83	5.34
CV (%)	9.73	8.33		7.57	7.20		7.55	7.57	

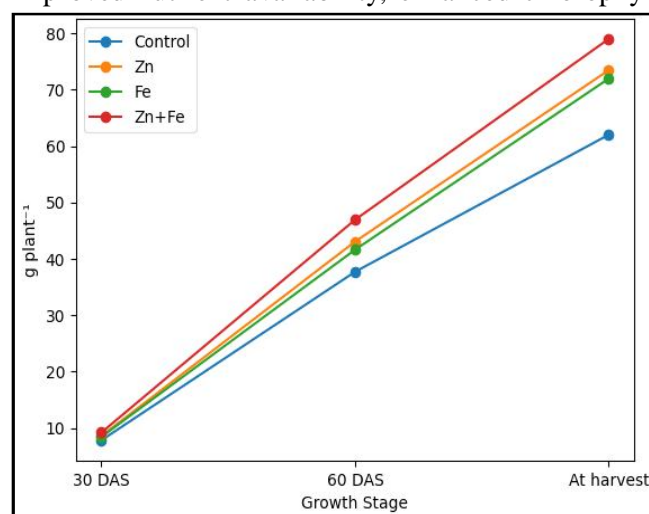
Results and Discussion

Dry Matter Accumulation

The hybrid varieties and soil and foliar application of zinc and iron influenced the dry matter accumulation at 30, 60 DAS and at harvest during the both years of experiment. Hybrid varieties did not influence dry matter accumulation at 30 DAS, however, at 60 DAS and at harvest significantly higher dry matter accumulation was recorded with RHB-223 over MPMH-17 during both years and in pooled analysis (Fig. 1). Basal application of

**Fig. 1:** Effect of pearl millet varieties on dry matter accumulation at different growth stages.

5.0 kg Zn ha⁻¹ + 5.0 kg Fe ha⁻¹ resulted in significantly higher dry matter accumulation as compared to individual application of 5.0 kg Zn ha⁻¹, 5.0 kg Fe ha⁻¹ and control at all growth stages during both the years and on pooled basis (Fig. 2). The individual application of 5.0 kg Zn ha⁻¹ and 5.0 kg Fe ha⁻¹ remained statistically at par with each other at all growth stages (Fig. 3). The significantly higher dry matter accumulation was recorded with combined soil application of zinc and iron may be attributed to improved nutrient availability, enhanced chlorophyll

**Fig. 2:** Effect of basal application of zinc and iron on dry matter accumulation.

synthesis and enzyme activation. Similar findings were reported by Kumar and Bohra (2014) and Meena *et al.*, (2020) in pearl millet, who observed increased biomass and growth with Zn and Fe fertilization.

Among foliar spray, the dry matter accumulation did not differ significantly at 30 DAS, whereas, significantly higher dry matter accumulation recorded at 60 DAS and at harvest with foliar spray of 0.5% ZnSO₄ + 0.5% FeSO₄ over 0.5% ZnSO₄, 0.5% FeSO₄ and control, although, individual spray of 0.5% ZnSO₄ and 0.5% FeSO₄ remained statistically at par with each other during both the years and on pooled basis. The higher dry matter accumulation with combined application of zinc and iron might be due to improved enzymatic activity and photosynthetic efficiency. The significant increase in dry matter accumulation and crop growth rate with foliar spray of ZnSO₄ + FeSO₄ may be attributed to rapid absorption and efficient utilization of nutrients during critical growth stages. Similar results were reported by Choudhary *et al.*, (2018) and Kumar *et al.*, (2021) in pearl millet.

Plant height

Data pertaining to effect of agronomic biofortification of pearl millet hybrid varieties with zinc and iron on plant height of pearl millet recorded at 30, 60 DAS and at harvest are given in Table 1.

Hybrid RHB-223 recorded significantly higher plant height at 60 DAS and at harvest over MPMH 17 except at 30 DAS during both years and on pooled basis. Basal application of zinc and iron significantly influenced the plant height at 30, 60 DAS and at harvest during both the years and on pooled basis. The significantly higher plant height was recorded with the application of 5.0 kg Zn ha⁻¹ + 5.0 kg Fe ha⁻¹ over individual application of 5.0 kg Zn ha⁻¹, 5.0 kg Fe ha⁻¹ and control, whereas, individual application of 5.0 kg Zn ha⁻¹ and 5.0 kg Fe ha⁻¹ remained statistically at par with each other during both the years and in pooled mean. The significantly higher plant height with combined soil application of zinc and iron might be due to improved cell elongation, auxin synthesis and enhanced metabolic activities, leading to better vegetative growth. These findings are in close conformity with the results of Kumar and Bohra (2014) and Meena *et al.*, (2018) in pearl millet, who reported significant increase in plant height with application of Zn and Fe.

Plant height was significantly influenced by foliar spray of zinc and iron at all the growth stages except at 30 DAS. However, at 60 DAS and at harvest combined spray of 0.5% ZnSO₄ + 0.5% FeSO₄ resulted in significantly higher plant height over individual application of 0.5% ZnSO₄, 0.5% FeSO₄ and control, however,

individual application of 0.5% ZnSO₄ and 0.5% FeSO₄ were statistically at par with each other during both the years and on pooled basis. The increased plant height with foliar spray of ZnSO₄ and FeSO₄ might be attributed to rapid absorption and translocation of micronutrients, resulting in enhanced photosynthesis and growth processes. Similar results were reported by Choudhary *et al.*, (2018) and Kumar *et al.*, (2020) in pearl millet.

Grain yield

A perusal of data presented in Table 2 revealed that grain yield of pearl millet differed significantly by hybrid varieties, basal and foliar application of zinc and iron during both years of experimentation and on pooled basis. Hybrid RHB-223 recorded significantly highest grain yield over MPMH-17. On pooled basis, hybrid RHB-223 recorded 13.15 per cent higher grain yield as compared to MPMH-17.

Combined application of 5.0 kg Zn ha⁻¹ + 5.0 kg Fe ha⁻¹ recorded significantly highest grain yield over individual application of 5.0 kg Zn ha⁻¹ and 5.0 kg Fe ha⁻¹ and control, while application of 5.0 kg Zn ha⁻¹ and 5.0 kg Fe ha⁻¹ were statistically at par with each other during both the years and in pooled analysis. On the basis of pooled analysis of data, the per cent increase in grain yield by soil application of 5.0 kg Zn ha⁻¹ + 5.0 kg Fe ha⁻¹ was 11.61, 12.75 and 27.32 per cent over 5.0 kg Zn ha⁻¹, 5.0 kg Fe ha⁻¹ and control, respectively. The higher grain yield under combined soil application of Zn and Fe could be due to improved photosynthetic efficiency, better nutrient uptake and enhanced translocation of assimilates. These results are in close conformity with the findings of Yadav *et al.*, (2020) and Choudhary *et al.*, (2019) in pearl millet.

Among foliar spray, significantly highest grain yield was recorded with foliar spray of 0.5% ZnSO₄ + 0.5%

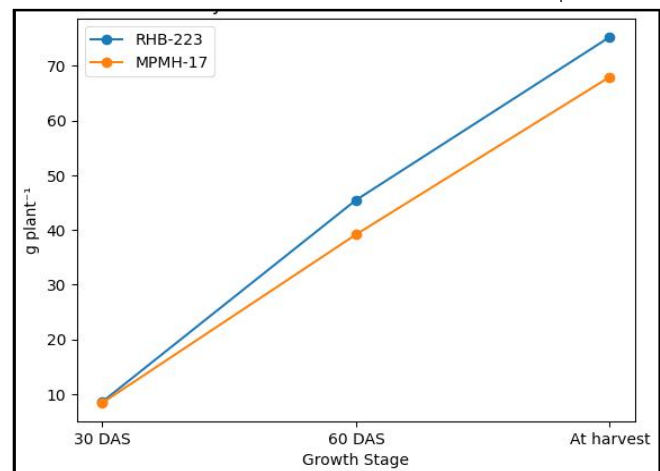


Fig. 3: Effect of foliar application of Zn and Fe on dry matter accumulation.

Table 2: Effect of agronomic biofortification of hybrid pearl millet varieties with zinc and iron on grain, stover and biological yield and harvest index of pearl millet.

Treatments	Yield (kg ha ⁻¹)									Harvest index (%)		
	Grain			Stover			Biological					
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Varieties												
RHB-223	2499	2526	2513	5276	5306	5291	7775	7832	7804	32.08	32.18	32.13
MPMH-17	2204	2239	2221	4662	4798	4730	6866	7037	6951	32.03	31.74	31.89
SEm _±	31	28	21	69	63	47	99	95	69	0.34	0.39	0.26
CD (P = 0.05)	94	86	65	210	192	145	299	289	211	NS	NS	NS
Basal application of Zn and Fe												
Control	2059	2109	2084	4530	4629	4580	6589	6738	6663	31.23	31.25	31.24
5.0 kg Zn ha ⁻¹	2361	2393	2377	5037	5113	5075	7398	7505	7452	31.89	31.83	31.86
5.0 kg Fe ha ⁻¹	2340	2367	2353	4967	5031	4999	7307	7398	7353	32.00	31.95	31.97
5.0 kg Zn ha ⁻¹ + 5.0 kg Fe ha ⁻¹	2646	2661	2653	5342	5435	5389	7989	8096	8042	33.10	32.82	32.96
SEm _±	44	40	30	98	90	66	139	135	97	0.48	0.56	0.37
CD (P = 0.05)	133	121	92	298	272	205	423	409	299	NS	NS	NS
CV (%)	9.16	8.23		9.68	8.70		9.33	8.89		7.29	8.51	
Foliar application of Zn and Fe												
Control	2088	2109	2099	4432	4621	4527	6520	6730	6625	31.98	31.29	31.63
0.5% ZnSO ₄	2342	2382	2362	5035	5115	5074	7377	7497	7437	31.70	31.73	31.71
0.5% FeSO ₄	2331	2364	2350	4981	5038	5009	7312	7405	7359	31.83	31.94	31.89
0.5% ZnSO ₄ + 0.5% FeSO ₄	2645	2669	2657	5429	5436	5433	8074	8105	8090	32.71	32.88	32.80
SEm _±	37	35	26	65	85	54	86	103	67	0.35	0.40	0.27
CD (P = 0.05)	106	101	72	186	241	150	245	294	189	NS	NS	NS
CV (%)	7.80	7.27		6.44	8.22		5.77	6.81		5.42	6.14	

FeSO₄ over 0.5% ZnSO₄, 0.5% FeSO₄ and control, although foliar application of 0.5% ZnSO₄ and 0.5% FeSO₄ were statistically at par with each other during both years and on pooled basis. Foliar spray of 0.5% ZnSO₄ + 0.5% FeSO₄ recorded an increase in grain yield by 12.49, 13.06 and 26.58 per cent over 0.5% ZnSO₄, 0.5% FeSO₄ and control, respectively during both the years and on pooled mean basis. The higher grain yield with foliar application of Zn and Fe could be due to quick correction of micronutrient deficiencies and improved metabolic activities during reproductive stages. These findings corroborate with Meena *et al.*, (2017) and Yadav *et al.*, (2019) in pearl millet.

Stover and Biological yield

Data presented in Table 2 showed that stover and biological yield of pearl millet was significantly affected by hybrid varieties during both the years and on pooled basis. Stover and biological yield was significantly higher in hybrid RHB-223 than MPMH-17. Furthermore, significantly highest stover and biological yield was recorded with 5.0 kg Zn ha⁻¹ + 5.0 kg Fe ha⁻¹ over 5.0 kg Zn ha⁻¹, 5.0 kg Fe ha⁻¹ and control, whereas, individual application of 5.0 kg Zn ha⁻¹ and 5.0 kg Fe ha⁻¹ remained

statistically at par with each other. The increase in stover and biological yield with soil application of Zn and Fe might be due to enhanced vegetative growth and overall biomass production. Similar results were also reported by Meena *et al.*, (2019) and Kumar *et al.*, (2018) in pearl millet.

Moreover, the foliar spray of 0.5% ZnSO₄ + 0.5% FeSO₄ recorded significantly highest stover and biological yield than individual spray of 0.5% ZnSO₄, 0.5% FeSO₄ and control, however, foliar application of 0.5% ZnSO₄ and 0.5% FeSO₄ alone were statistically at par with each other during both the year of experimentation and in pooled analysis. The improvement in stover and biological yield under foliar spray might be due to enhanced photosynthetic activity and better assimilate partitioning. Similar findings were reported by Choudhary *et al.*, (2020) in pearl millet.

Harvest index

The harvest index of pearl millet did not differ significantly by hybrid varieties, basal and foliar application of zinc and iron during both the years and on pooled mean basis (Table 2), which is in agreement with the findings of Yadav *et al.*, (2017) and Kumar *et al.*, (2019) in pearl millet.

Conclusion

The findings of the present study highlight the pivotal role of zinc and iron in enhancing the growth performance and yield potential of pearl millet. Among the tested hybrids, RHB-223 exhibited superior performance, particularly at advanced growth stages, indicating its better genetic potential and adaptability. The combined soil application of 5.0 kg Zn ha⁻¹ and 5.0 kg Fe ha⁻¹ emerged as the most effective treatment, significantly improving dry matter accumulation, plant height, and yield attributes over individual applications and control. This synergistic effect can be linked to improved nutrient uptake, enhanced photosynthetic activity, and better metabolic efficiency. In addition, foliar supplementation with 0.5% ZnSO₄ + 0.5% FeSO₄ further boosted crop performance, especially during critical growth phases, by ensuring rapid nutrient absorption and utilization. The integrated use of soil and foliar application not only maximized grain, stover, and biological yields but also ensured balanced crop growth without significantly altering the harvest index. Overall, the study underscores that strategic agronomic biofortification using zinc and iron, coupled with the selection of a high-performing hybrid like RHB-223, can serve as a sustainable and effective approach to enhance productivity and nutritional security in pearl millet cultivation under semi-arid conditions.

References

- Anonymous (2024). *Agricultural statistics on pearl millet production in Rajasthan and India (Govt Rep., 1–10)*.
- Choudhary, R.S., Yadav O.P., Meena R.K. and Kumar S. (2018). Effect of zinc and iron application on growth and yield of pearl millet. *Inter. J. of Chemical Studies*, **6**, 1200–1204.
- Choudhary, R.S., Yadav O.P., Meena R.K. and Kumar S. (2019). Influence of zinc and iron on productivity of pearl millet. *J. of Pharmacognosy and Phytochemistry*, **8**, 2100–2104.
- Choudhary, R.S., Yadav O.P., Meena R.K. and Kumar S. (2020). Effect of foliar application of micronutrients on yield of pearl millet. *Inter. J. of Chemical Studies*, **8**, 250–254.
- Dhaliwal, S.S., Naresh R.K., Mandal A. and Singh R. (2009). Agronomic biofortification of cereals to alleviate micronutrient malnutrition. *Journal of Plant Nutrition*, **32**, 181–197.
- Dhaliwal, S.S., Sharma V., Shukla A.K. and Singh J. (2019). Agronomic approaches for improving micronutrient concentration in crops. *Agronomy Journal*, **111**, 1–12.
- Krishnan, P. and Meera M.S. (2018). Pearl millet: A climate-resilient nutri-cereal for food and nutritional security. *Journal of Crop Science*, **58**, 123–130.
- Kumar, R. and Bohra J.S. (2014). Effect of zinc and iron fertilization on growth and yield of pearl millet. *Annals of Agricultural Research*, **35**, 45–50.
- Kumar, S., Meena R.K., Yadav O.P. and Choudhary R.S. (2018). Influence of nutrient management on pearl millet productivity. *Inter. J. of Chemical Studies*, **6**, 1800–1804.
- Kumar, S., Meena R.K., Yadav O.P. and Choudhary R.S. (2019). Effect of micronutrients on yield attributes of pearl millet. *J. of Pharmacognosy and Phytochemistry*, **8**, 1000–1004.
- Kumar, S., Meena R.K., Yadav O.P. and Choudhary R.S. (2020). Role of micronutrients in enhancing growth of pearl millet. *International Journal of Current Microbiology and Applied Sciences*, **9**, 2500–2505.
- Kumar, S., Meena R.K., Yadav O.P. and Choudhary R.S. (2021). Response of pearl millet to micronutrient fertilization under semi-arid conditions. *Journal of Pharmacognosy and Phytochemistry*, **10**, 150–155.
- Kumssa, D.B., Joy E.J.M., Ander E.L., Watts M.J., Young S.D., Walker S. and Broadley M.R. (2015). Cereal grain mineral micronutrient and soil chemistry interactions. *Science of the Total Environment*, **506–507**, 213–222.
- Lakshmi, S., Singh B., Kumar A. and Sharma R. (2022). Soil fertility depletion and strategies for sustainable crop production. *J. of Soil Sci. and Plant Nutrition*, **22**, 1100–1110.
- Meena, R.K., Yadav O.P., Kumar S. and Choudhary R.S. (2017). Foliar application of micronutrients in pearl millet. *International Journal of Chemical Studies*, **5**, 900–904.
- Meena, R.K., Yadav O.P., Kumar S. and Choudhary R.S. (2018). Effect of zinc and iron on plant height and growth parameters of pearl millet. *Annals of Agricultural Research*, **39**, 200–205.
- Meena, R.K., Yadav O.P., Kumar S. and Choudhary R.S. (2019). Effect of micronutrients on biomass and yield of pearl millet. *Annals of Agricultural Research*, **40**, 120–125.
- Meena, R.K., Yadav O.P., Kumar S. and Choudhary R.S. (2020). Influence of micronutrients on biomass production in pearl millet. *Indian Journal of Agronomy*, **65**, 78–83.
- Ram, K. and Meena R.P. (2014). Adaptability and resilience of pearl millet under arid conditions. *Indian Journal of Agronomy*, **59**, 45–50.
- Satyavathi, C.T., Govindaraj M., Rai K.N. and Nepolean T. (2017). Variability in polyphenol and phytic acid content in pearl millet grains. *Journal of Food Science and Technology*, **54**, 100–107.
- Satyavathi, C.T., Govindaraj M., Rai K.N. and Nepolean T. (2021). Nutritional quality and micronutrient richness in pearl millet (*Pennisetum glaucum* L.). *Indian Journal of Genetics*, **81**, 45–52.
- White, P.J. and Broadley M.R. (2009). Biofortification of crops with essential mineral elements. *Trends in Plant Science*, **14**, 586–593.
- Yadav, O.P., Rai K.N., Rajpurohit B.S. and Hash C.T. (2017). Harvest index response of pearl millet to nutrient management. *Indian Journal of Agronomy*, **62**, 300–305.
- Yadav, O.P., Rai K.N., Rajpurohit B.S. and Hash C.T. (2019). Effect of foliar nutrition on yield and quality of pearl millet. *Journal of Plant Nutrition*, **42**, 150–156.
- Yadav, O.P., Rai K.N., Rajpurohit B.S. and Hash C.T. (2020). Effect of micronutrient fertilization on yield of pearl millet. *Indian Journal of Agronomy*, **65**, 90–95.