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Effect of iron and zinc fortification on chemical properties of soil and nutrient content and uptake by summer pearl millet (*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz)

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Abstract

An experiment was conducted at the Instructional Farm, Department of Agronomy, College of Agriculture, JAU, Junagadh during summer season of 2019 on medium black calcareous soil. The experiment containing 9 treatment combinations was arranged in factorial randomized block design with 3 replications. The results revealed that N content and uptake by grain and stover of pearl millet was significantly higher under FeSO_4 @ 1.0% at 25 & 50 DAS and ZnSO_4 @ 0.5% at 25 & 50 DAS. Zinc concentration in pearl millet increased with zinc application, but decreased with increasing foliar spray of iron. While iron concentration in pearl millet increased with iron application, but decreased with increasing foliar spray of zinc. Available zinc in soil after harvest was significantly higher under ZnSO_4 @ 0.5% at 25 & 50 DAS. Whereas, Available iron in soil after harvest was significantly higher under FeSO_4 @ 1.0% at 25 & 50 DAS. Available N, P_2O_5 and K₂O in soil after harvest were not affected by foliar spray of zinc and iron.

Keywords: FeSO_4 , iron, pearl millet, ZnSO_4 and zinc

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz] is the most widely grown type of millet. It has been grown in Africa and South Asia since prehistoric times. In Asia, important pearl millet growing countries are India, China, Nigeria, Pakistan, Sudan, Egypt, Arabia and Russia. Pearl millet belongs to Gramineae family. It is one of the most important food grain cereal crop of India and ranks fourth in area after rice, wheat and sorghum. It is one of the major cereal crop grown in the arid and semi-arid regions of the world. India is the largest single producer of the crop, both in terms of area 6.93 million hectares and production 8.61 million tonnes and productivity of 1243 kg/ha (Directorate of Millets Development, 2020) [5] during summer season. Major pearl millet growing states in India are Rajasthan (52.34%), Maharashtra (14.6%) and Gujarat (9.9%). Banaskatha, Junagadh, Jamnagar, Rajkot, Mehsana, Kheda, Amerali and Kutch are the major pearl millet growing districts of Gujarat. The area under summer pearl millet was 2.26 lakh hectares with an annual production of 6.17 lakh tonnes and productivity of 2721 kg/ha in Gujarat state during 2019-2020 (Anon., 2020) [3]. Zinc plays significant role in various enzymatic and physiological activities of plant. Zinc is an essential micro nutrient required for growth and development of the higher plants (Kochian, 1993 & Marschner, 1995) [8, 11] and is involved in membrane integrity, enzyme activation and gene expression (Kim *et al.*, 2002) [7]. Iron plays a role in the formation of plant chlorophyll. Iron-containing plant haemoglobins are another promising target for altering Fe content in plant-based foods. Plant haemoglobin is similar to the human haemoglobin, with Fe binding capacity and is most commonly found in nodulating legumes (nitrogen fixing plants) (Kundu *et al.*, 2003) [9]. Bio fortification is the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding or modern biotechnology. Bio fortification differs from conventional fortification in that bio fortification aims to increase nutrient levels in crops during plant growth rather than through manual means during processing of the crops.

Agronomic approaches such as application of Zn and Fe-containing fertilizers appear to be rapid and simple solution to address the Zn and Fe deficiency in crop and human health. Agronomic fortification with foliar application of micronutrients particularly zinc and iron not only increase the yield but also nutrient quality of pearl millet for obtaining good economic return and also nutritional security. So, enrichment of pearl millet with zinc and iron fortification is one of the option to improve the quality.

Materials and Methods

A field research was carried out at the Instructional farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh during the summer season of the year 2019 with test crop pearl millet (Var. GHB-732). The experiment was conducted with three foliar spray of FeSO_4 viz., F₁: Control (No spray), F₂: FeSO_4 @ 1.0% at 25 DAS, F₃: FeSO_4 @ 1.0% at 25 & 50 DAS and three foliar spray of ZnSO_4 viz., Z₁: Control (No spray), Z₂: ZnSO_4 @ 0.5% at 25 DAS, Z₃: ZnSO_4 @ 0.5% at 25 & 50 DAS in factorial randomized design replicated three time. The soil was clayey in texture and slightly alkaline in reaction with pH 7.9 and EC 0.33 dS/m. The soil of the experimental site was medium in available nitrogen (277 kg/ha), available phosphorus (27.02 kg/ha), available potassium (279.55 kg/ha), medium in available zinc (0.65 ppm) and medium in available iron (5.53 ppm).

The soil samples were collected and analyzed for available N by alkaline potassium permanganate method (A.O.A.C., 1965) ^[1], P by colourimetrically (Olsen *et al.*, 1954) ^[12], K by flame photometer method (Jackson, 1974) ^[6] and Fe and Zn by Atomic Absorption Spectrophotometer method (Lindsay and Norvell, 1978) ^[10]. The nitrogen from plant samples were estimated separately by micro Kjeldahls method as described by Jackson (1974) ^[6]. Iron and zinc content from grain and stover were estimated with Atomic Absorption Spectrophotometer method (Lindsay and Norvell, 1978) ^[10].

Results and Discussion

Effect of iron on nutrients content and uptake

Foliar spray of FeSO_4 @ 1.0% at 25 & 50 DAS recorded maximum Fe content and uptake in grain and stover (Table 1 and 2). Increasing spray of iron was recorded higher value of Fe content and uptake in pearl millet. Increased of iron uptake might be due to significantly increased content in grain and stover. Similar results have been reported by Yadav *et al.* (2002) ^[15].

Significant decrease in zinc content with increasing foliar spray of iron was observed in pearl millet. Foliar spray of FeSO_4 @ 1.0% at 25 & 50 DAS recorded lowest value of Zn content in pearl millet (Table 1). While progressive increased in foliar spray of iron enhanced zinc uptake by grain and stover beyond which non-significant result was noted. This might be due to antagonistic effect of iron with zinc. Higher concentration of iron reduced the mobility of available zinc which resulted in lesser availability of zinc to plants. Fe behaved antagonistically with and decrease the concentration of Zn, this might be due to two reasons firstly, the competition for two ions for absorption secondly, the precipitation of Zn along with Fe (Singh and Yadav, 1980) ^[14].

A significant increase in nitrogen content and uptake by pearl millet was recorded with the successive application of FeSO_4 @ 1.0% at 25 & 50 DAS. This might be due to synergistic relationship existing between iron and nitrogen and better root and shoot growth. Similar result has been observed by Abbas *et al.*, 2012 ^[2] in wheat.

Effect of zinc on nutrients content and uptake

The foliar application of 0.5% ZnSO_4 (two spray) recorded significantly higher values of zinc and nitrogen content and uptake in grain and stover of pearl millet. Among the different treatments foliar spray of ZnSO_4 @ 0.5% at 25 & 50 DAS recorded maximum Zn and N content and uptake in grain and stover (Table 1&2). Increased in content and uptake of nitrogen and zinc in grain with the application of zinc sulphate might be due to the beneficial role of zinc in increasing the cation exchange capacity of roots, the beneficial role of zinc in chlorophyll formation, regulating the auxins concentration and its stimulatory effect on most of the physiological and metabolic processes of the plant, might have helped the plants in absorption of greater amount of nutrients from soil. The beneficial role of Zn in increasing CEC of roots helped in increasing absorption of nutrients from the soil. The favourable influence of zinc on photosynthesis and metabolic processes, production of photosynthates and their translocation to different plant parts including seed and ultimately increased the concentration of nutrients in seed may also be a reason of higher content and uptake of these nutrients. Similar results were also reported by Dadhich and Gupta (2003) ^[4].

Foliar spray of ZnSO_4 @ 0.5% at 25 & 50 DAS recorded the lowest value of Fe content in grain and stover (Table 1) of pearl millet. The increased concentration of zinc might have generated hindrance in absorption and translocation of iron from the roots to the above parts (Reddy and Yadav, 1994) ^[13]. So that, reduction in the content of iron in pearl millet owing to application of zinc is due to the antagonistic relationship of iron with zinc.

Effect of iron on soil available nutrients

Application of FeSO_4 @ 1.0% at 25 & 50 DAS was given maximum value of iron in soil after harvest of pearl millet. The increased in available status of Fe may be due to higher amount depletion of Fe resulted due to low nutrient use efficiency of the crop with applied micronutrient fertilizer. The available nitrogen, phosphorus and potassium (Table 3) in the soil after harvest of pearl millet were not influenced significantly by application of foliar spray of iron.

Effect of zinc on soil available nutrients

A linear increase in zinc content in soil was observed with increasing amount of zinc sulphate, after harvest of the crop. The experimental soil being medium in available zinc might have resulted increased available zinc with the increase in the application of zinc sulphate. The increase in available status of Zn may be due to higher amount in depletion of Zn resulted due to low nutrient use efficiency of the crop with applied micronutrient fertilizer. The available nitrogen, phosphorus and potassium (Table 3) in the soil after harvest of pearl millet were not influenced significantly by application of foliar spray of zinc.

Table 1: Effect of iron and zinc application on nutrient content in seed and stover of pearl millet

Treatment	Nutrient content in seed			Nutrient content in stover		
	N (%)	Fe (mg/kg)	Zn (mg/kg)	N (%)	Fe (mg/kg)	Zn (mg/kg)
Foliar spray of iron						
F ₁ : Control (No spray)	1.47	62.94	53.50	0.54	53.61	46.50
F ₂ : FeSO ₄ @ 1.0% at 25 DAS	1.64	68.15	50.92	0.62	58.15	43.47
F ₃ : FeSO ₄ @ 1.0% at 25 & 50 DAS	1.79	72.66	49.15	0.69	63.88	41.82
S.Em.±	0.03	0.75	0.67	0.01	0.78	0.68
C.D. at 5%	0.09	2.25	2.01	0.03	2.33	2.04
Foliar spray of zinc						
Z ₁ : Control (No spray)	1.54	70.15	46.60	0.57	61.04	39.82
Z ₂ : ZnSO ₄ @ 0.5% at 25 DAS	1.65	67.61	51.44	0.63	58.17	44.44
Z ₃ : ZnSO ₄ @ 0.5% at 25 & 50 DAS	1.71	65.99	55.53	0.66	56.44	47.53
S.Em.±	0.03	0.75	0.67	0.01	0.78	0.68
C.D. at 5%	0.09	2.25	2.01	0.03	2.33	2.04
C.V.%	5.49	3.32	3.96	5.33	3.99	4.69

Table 2: Effect of iron and zinc application on nutrients uptake by seed and stover of pearl millet

Treatment	Nutrient uptake by seed			Nutrient uptake by stover		
	N (kg/ha)	Fe (g/ha)	Zn (g/ha)	N (kg/ha)	Fe (g/ha)	Zn (g/ha)
Foliar spray of iron						
F ₁ : Control (No spray)	54.78	232.77	199.70	36.95	363.41	318.62
F ₂ : FeSO ₄ @ 1.0% at 25 DAS	68.48	272.09	205.09	46.62	436.94	328.68
F ₃ : FeSO ₄ @ 1.0% at 25 & 50 DAS	78.69	321.65	218.52	55.91	511.12	335.94
S.Em.±	2.58	10.76	7.57	1.79	16.80	12.88
C.D. at 5%	7.74	32.27	NS	5.37	50.37	NS
Foliar spray of zinc						
Z ₁ : Control (No spray)	58.59	257.35	169.69	38.78	414.21	268.19
Z ₂ : ZnSO ₄ @ 0.5% at 25 DAS	68.50	274.12	206.45	47.30	439.18	332.13
Z ₃ : ZnSO ₄ @ 0.5% at 25 & 50 DAS	74.85	295.04	247.17	53.40	458.08	382.92
S.Em.±	2.58	10.76	7.57	1.79	16.80	12.88
C.D. at 5%	7.74	NS	22.69	5.37	NS	38.61
C.V.%	11.51	11.72	10.93	11.55	11.53	11.79

Table 3: Effect of iron and zinc application on available nutrients in soil after harvest of crop

Treatment	N (kg/ha)	P ₂ O ₅ (kg/ha)	K ₂ O (kg/ha)	Fe (ppm)	Zn (ppm)
Foliar spray of iron					
F ₁ : Control (No spray)	251.68	25.83	271.12	5.09	0.62
F ₂ : FeSO ₄ @ 1.0% at 25 DAS	263.25	25.71	268.92	5.34	0.65
F ₃ : FeSO ₄ @ 1.0% at 25 & 50 DAS	267.02	24.77	275.90	5.56	0.66
S.Em.±	6.34	0.72	7.18	0.07	0.01
C.D. at 5%	NS	NS	NS	0.21	NS
Foliar spray of zinc					
Z ₁ : Control (No spray)	253.69	25.81	267.80	5.21	0.59
Z ₂ : ZnSO ₄ @ 0.5% at 25 DAS	262.42	25.30	268.64	5.35	0.64
Z ₃ : ZnSO ₄ @ 0.5% at 25 & 50 DAS	265.84	25.20	279.50	5.42	0.70
S.Em.±	6.34	0.72	7.18	0.07	0.01
C.D. at 5%	NS	NS	NS	NS	0.03
C.V.%	7.30	8.53	7.92	4.93	5.20

Conclusion

On the basis of the results obtained, it seems quite logical to conclude that higher Fe and Zn content and uptake by summer pearl millet (var. GHB-732) can be secured by foliar spray of FeSO₄ @ 1.0% at 25 & 50 DAS and ZnSO₄ @ 0.5% at 25 & 50 DAS, respectively. The antagonistic interaction of foliar applied Zn and Fe levels on their distribution in pearl millet was found due to hindrance in absorption and translocation from the roots to the above parts.

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