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EFFECT OF ZINC FERTILISATION ON GROWTH AND YIELD OF FINGER MILLET (*ELEUSINE CORACANA* L. GAERTN.)

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Abstract: A two-year study at the S.G. College of Agriculture & Research Station, Jagdalpur showed that an increase in grain yields. Deep placement and broadcasting of Zn both the drilling and broadcasting of Zn application were equally effective in increasing grain and zinc uptake of finger millet. Zn concentration in finger millet grains was increased due to Zn fertilization; average increase being about 9.76% over control. In stem, the highest Zn concentration was noticed as deep placement at sowing by drill @ 8 kg Zn ha^{-1} as $ZnSO_4$ (6.39 and 6.09 mg per 100g in 2012-2013, respectively) followed by 2, 4 and 6 kg Zn ha^{-1} which was at par with 8 kg Zn ha^{-1} in both years. However, leaf lamina and leaf sheath greater in Zn concentration was noticed with foliar spray at 25 DAS as applied 2, 4, 6 and 8 kg ha^{-1} and at par with each others in 2012 and 2013. The highest concentration of Zn was found under application of 8 kg Zn ha^{-1} as foliar application at 25 DAS in both years of experimentation.

Keywords: Zn-fertilization, Zn fertilizing finger millet seeds, Deep placement of Zn and Zn nutrition.

Introduction

Zinc (Zn) deficiency in humans has received considerable interest in the recent past and as much as one-third of the world's population may be at risk from inadequate Zn intake [3]. Black et al. [4] reported that more than 450,000 children under the age of 5 years died during 2008 due to diarrhea caused by Zn deficiency. Zn deficiency leads to diarrhea and pneumonia in children [6]. It also leads to dwarfism in children [5] enrichment of cereal grains, which are the staple food in developing countries, has therefore received considerable attention during recent years. There are three major ways of biofortification of cereal grains. These include food supplements [1, 23], genetic biofortification and agronomic manipulation through micronutrient fertilizers [26]. A number of global projects on genetic biofortification of food crops are underway [9, 22]. Despite the enormous research activities, so far, only two biofortified crop cultivars have been successfully developed. Vitamin A-rich orange-fleshed sweet potato has already been introduced and is being produced in South Africa [14]. Similarly Beta carotene rich golden rice has been allowed to be cultivated in the Philippines [10]. No Zn-rich cultivar has been released in any food crop so far Agronomic manipulation

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(Ferti-fortification) is a quicker and faster approach to increase Zn concentration in finger millet. Available reports show that Zn fertilization increased Zn concentration in rice grain from 35 to 141 % in rice [12, 27, 33], from 24 to 48 % in wheat [26, 34] and 72 % in maize [12]. Finger millet is emerging as an important dietary cereal, due to its high nutrient content, which imparts it human health benefits in terms of benefiting nutrient for blood glucose levels [2, 15]. Finger millet requires considerable amount of zinc as well as calcium for its growth and grain development. Deficiency of secondary and micronutrients lead to reduction in number of effective tillers and improper grain filling (25). Finger millet is being increasingly incorporated in breakfast cereals, beverages and infant foods as oat [7], which makes it an important crop that deserves attention for fortification of its grains with Zn. Therefore, the present study was undertaken to study the effect of methods and time of application of Zn on the grain yield and Zn concentration in finger millet [24].

Materials and Methods

Experimental Site, Soil and Weather Parameters

Field experiments were conducted during *kharif* season (June to October) of 2012 and 2013 at the research cum instructional farm of S.G. College of Agriculture & Research Station; Jagdalpur situated at 543 m at msl coordinating $18^{0}05'$N latitude and $81^{0}57'$ E longitude. The mean annual rainfall of Jagdalpur is 1404 mm and more than 80 % of it is generally occurred during July–September. The experimental site used for this experiment was under small millet during previous cropping season (*kharif*). Before the start of the experiment in the season, the soil samples were taken and as regards the initial fertility status of experimental field, it had 155 kg ha^{-1} alkaline permanganate oxidizable N [31], 22.0 kg ha^{-1} 0.5 M $NaHCO_3$ extractable P [19], 240 kg ha^{-1} 1 N ammonium acetate exchangeable K [11] and 0.41 % organic carbon as determined by the procedure described by Walkley and Black [32]. The pH of soil was 6.9 (1:2.5 soil and water ratio) and DTPA-extractable Zn [13] in soil was 0.64 mg kg^{-1} of soil, and the response to Zn was expected. The weather parameters during the growing period of the finger millet crops in 2012 and 2013 are given in Fig. 1a, b, however, there was no relationship of weather parameters with Zn fortification during 2 years of study.

Experimental Design and Treatments

The experiment was laid out in a randomized block design with three replications. The treatments were 13 combinations of two rates (2, 4, 6 and 8 kg Zn ha^{-1}), and 3 methods of Zn application and a control (no Zn). Zn was applied as broadcasting, deep placement at 5 cm below the seed (with seed cum fertilizer drill) at sowing and spraying on standing finger millet at 25 DAS and 12 kg ha^{-1} was used for sowing 1 ha of land. Commercial grade $ZnSO_4$ contained 20% Zn and thus 10, 20, 30 and 40 kg ha^{-1} was required to supply 2, 4, 6 and 8 kg Zn ha^{-1}, respectively. All plots received 40 kg P ha^{-1} as single superphosphate and 20 kg K ha^{-1} as muriate of potash, which was broadcasted before final ploughing. Nitrogen @ 60 kg ha^{-1} as urea was applied in all plots in two equal applications; half at the time of sowing and the remaining half at 25 DAS on field capacity condition.

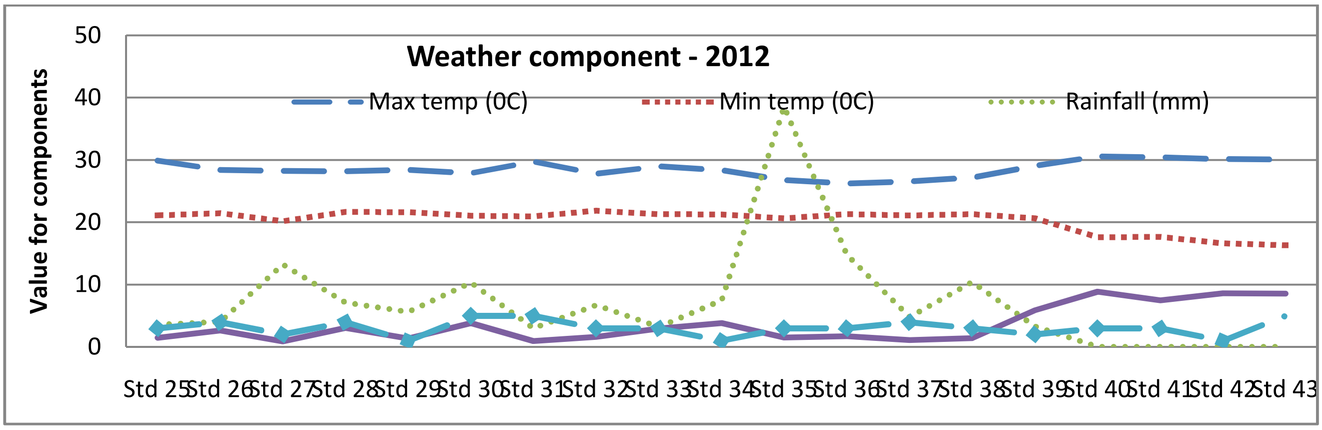

Fig 1a. Weather parameters prevailing during 2012

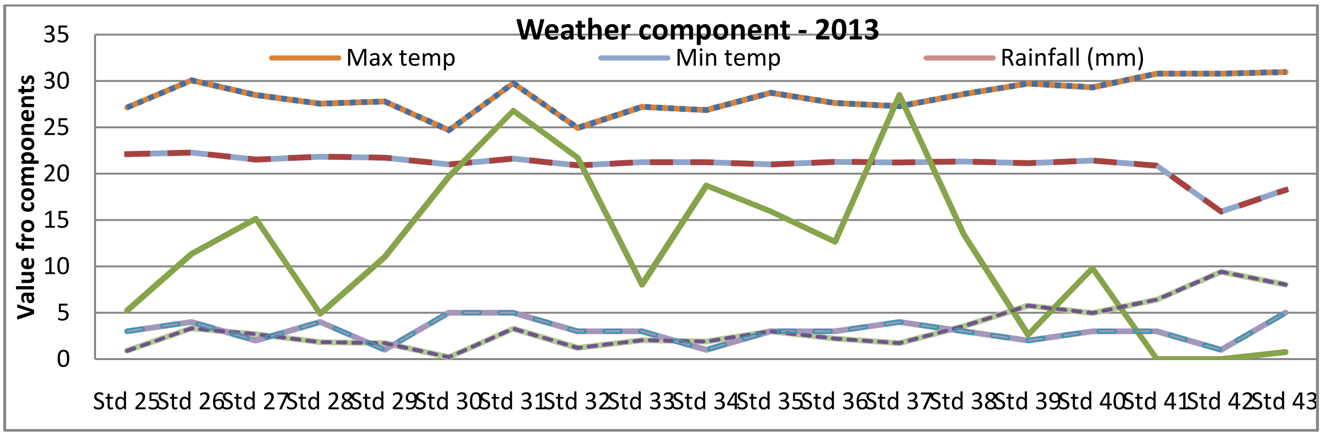

Fig 1b. Weather parameters prevailing during 2013

Sowing and Raising of Crop

Sowing of the finger millet variety 'GPU 28' was done with a seed drill adjusted for an inter-row spacing of 30 cm in the second fortnight of June (26 & 28th) during both the years. The plot size was 5x5 m seeded with rate of 12 kg ha^{-1}. The crop was harvested in the third week of October (18 & 20th) during both the years of experimentation. Seeds at the time of maturity the net plots (leaving two border rows on each side and 0.5 m area from each side of the length were separated) were harvested and sun-dried for 3 days in the field. The weight of the harvested plants after sun drying and before threshing was recorded. After threshing, cleaning and drying the grain yield was recorded for each plot and adjusted at 14% moisture. Zinc uptake was obtained by deducting the grain weight from the total weight (biological yield). The grain yields were expressed in g m^{-2}. Sampling of Grains for Zn Analysis 100 g grain samples were collected from the harvest of each plot and dried in hot air oven at 60 ± 2 _C for 6 hr. The oven dried samples were ground in a Wiley Mill and sieved to pass through a 40-mesh sieve. A 0.5 g grain sample was digested in a 3:10 mixture of perchloric and nitric acid and Zn concentration in the digest was determined on an atomic absorption spectrophotometer (Perkin Elmer; Model-A Analyst 100) [18][20].

Statistical Analysis

All the data obtained were statistically analyzed using the F-test [8] and least significance difference (LSD) values at P = 0.05 were calculated.

Results

Grain yield and Zinc uptake of Finger millet

In both the years of study grain yield of finger millet were significantly increased due to Zn fertilization (Tables 1). When deep placement by drill of 8 kg Zn ha^{-1} as $ZnSO_4$ produced significantly more grain yield than 2 & 4 kg Zn ha^{-1}, But it produced significantly more grain yield than no Zn (control). Deep placement of 4, 6 & 8 kg Zn ha^{-1} as $ZnSO_4$ produced significantly more grain yield than its broadcast application. In both the years of studies, finger millet with $ZnSO_4$ @ 8 kg Zn ha^{-1} produced the highest grain yield regardless method of application. Deep placement and broadcasting of Zn both the methods of Zn application were equally effective in increasing grain and zinc uptake of finger millet irrespective of the method of application. Zn concentration in finger millet grains was 2.92 mg $100g^{-1}$ in control plots and increased 1.99 mg $100g^{-1}$ due to Zn fertilization; average increase being about 9.76% over control (Table 2). When broadcast at sowing, a significant increase in Zn concentration (29–29.5 % over control) in finger millet grains was recorded. But it was more pronounced in deep placement with increasing quantum of Zn which was equally effective in mining Zn in grains in both years. As increased in quantity of Zn increased uptake in grain, earhead and root simultaneously, it was significantly varied when application methods were adopted for placing that is why it observed that the deep placement with seed cum fertilizer drill uptake was remarkable higher than other method and they were on par with each others. The lowest was recorded with each 8 treatment as control by any methods.

In aerial parts of finger millet, Zn concentration is significantly differed by application of zinc fertilizers. The lowest concentration of Zn in stem, leaf lamina and sheath was under control treatment in both the years. In stem, the highest Zn concentration was noticed as deep placement at sowing by drill @ 6 kg Zn ha^{-1} as $ZnSO_4$ (6.39 and 6.09 mg per 100g in 2012-2013, respectively) followed by 2,4 and 6 kg Zn ha^{-1} which were at par with 8 kg Zn ha^{-1}, similar trend was observed in both year. However, leaf lamina and leaf sheath greater in Zn concentration was noticed with foliar spray at 25 DAS as applied 2, 4, 6 and 8 kg ha^{-1}, these all treatments were at par with each others in 2012 and 2013. The highest concentration of Zn was found under application of 8 kg Zn ha^{-1} as foliar application at 25 DAS in both years of experimentation.

Table 1: Effect of rate and method of Zn application on grain yield of finger millet

Treatment	**Grain yield (g m^{-2})**	
	2012	**2013**
Control (no Zn)	195	194
2 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	241	240
2 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	212	211
2 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	221	218
4 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	270	262
4 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	237	236
4 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	248	239
6 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	302	301
6 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	266	258
6 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	277	280
8 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	339	338
8 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	298	295
8 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	310	309
SEM± 0.05	**22.92**	**25.87**
LSD (P = 0.05)	**69.21**	**77.62**

Table 2: Effect of rate, source and method of Zn application on zinc uptake of finger millet in grain (mg ha^{-1})

Treatment	Zinc uptake(mg/100 g)					
	Grain		Ear head		Root	
	2012	2013	2012	2013	2012	2013
Control (no Zn)	2.92	3.05	4.09	4.21	2.21	2.38
2 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	**3.40**	**3.38**	**5.01**	**5.16**	7.89	8.48
2 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	3.01	3.15	4.32	4.45	**3.56**	**3.83**
2 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	2.30	2.45	2.78	2.92	2.50	2.68
4 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	**3.84**	**4.01**	**5.66**	**5.83**	**4.02**	**4.32**
4 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	3.40	3.39	4.88	5.03	8.92	9.58
4 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	3.73	3.30	3.40	3.56	2.82	3.03
6 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	**4.34**	**4.54**	**6.40**	**6.59**	**8.07**	**8.83**
6 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	2.84	3.26	5.52	5.68	4.55	4.89
6 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	4.21	3.40	4.10	4.29	3.19	3.43
8 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	**4.91**	**3.13**	**7.23**	**7.45**	**11.38**	**12.24**
8 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	3.34	4.56	6.23	6.42	5.14	5.52
8 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	3.76	3.38	4.90	4.10	3.60	3.87
SEM± 0.05	**0.35**	**0.37**	**0.52**	**0.54**	**0.82**	**0.88**
LSD (P = 0.05)	**1.09**	**1.14**	**1.59**	**1.65**	**2.51**	**2.68**

Table 3: Effect of rate, source and method of Zn application on Zn concentration in finger millet grains

Treatment	Zn concentration in aerial parts (mg/100g)					
	Stem		Leaf lamina		Leaf sheath	
	2012	2013	2012	2013	2012	2013
Control (no Zn)	2.32	2.21	10.40	9.98	7.78	7.61
2 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	**4.43**	**4.22**	11.40	10.94	13.3	13.01
2 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	3.21	3.06	11.45	10.99	11.7	11.44
2 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	2.53	2.41	**22.40**	**21.50**	**13.08**	**12.79**
4 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	**5.01**	**4.77**	11.74	11.27	12.05	11.79
4 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	3.63	3.46	11.79	11.32	13.47	13.18
4 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	2.86	2.72	**23.07**	**22.15**	**13.70**	**13.40**
6 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	**5.66**	**5.39**	12.09	11.61	12.41	12.14
6 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	4.10	3.90	12.15	11.66	13.88	13.57
6 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	3.23	3.08	**23.76**	**22.81**	**14.11**	**13.25**
8 kg Zn ha^{-1} as ZnSO4, deep placed at sowing by drill	**6.39**	**6.09**	12.46	11.96	12.78	12.50
8 kg Zn ha^{-1} as ZnSO4, broadcast at final ploughing	4.63	4.41	12.51	12.01	14.29	13.98
8 kg Zn ha^{-1} as ZnSO4 Foliar spray at 25 DAS	3.65	3.48	**24.48**	**23.50**	**14.53**	**14.21**
SEM± 0.05	**0.47**	**0.44**	**0.70**	**0.67**	**0.28**	**0.28**
LSD (P = 0.05)	**1.43**	**1.35**	**2.11**	**2.02**	**0.85**	**0.86**

Discussion

As regards rate of Zn application, when applied 8 kg Zn ha^{-1} as deep placement at sowing produced significantly more grain than that of no Zn (control). A significant increase in grain yield of rice, wheat, maize and sorghum up to 5 kg Zn ha^{-1} has been reported in India [21], but no reports are available on finger millet. In the present study, a significant increase in Zn concentration in finger millet was recorded only when 2 kg Zn ha^{-1} was applied over control. A number of researchers have reported an increase in Zn concentration of other cereals [12, 27, 33 and 34]. As regards method of Zn application, $ZnSO_4$ @ 8 kg Zn ha^{-1} placed deep at sowing recorded the highest grain yield, Zn concentration in finger millet aerial and subaerial, significantly higher than even a broadcast application of Zn. Spraying of Zn onto foliage permits better absorption of Zn by plants and therefore gave better results. Seed treatment of rice with Zn was found to be quite effective in AR, USA [30]. Martens *et al.* [17] reported that band application of Zn fertilizers in contact with maize seeds at rates ranging from 0.34 to 1.34 kg Zn ha^{-1} produced grain yields equal to those achieved when 26.9 kg Zn ha^{-1} as $ZnSO_4$ was broadcast on soil surface and incorporated. Patel [21] also observed that seed may be a better option for supplying Zn to maize and wheat. Deep placement of $ZnSO_4$ also gave higher grain yield of finger millet than their broadcast application and foliar, but was not as good as rice and wheat Zn through deep placement. But it was obviously higher at higher (8 kg Zn ha^{-1}) quantity as compared to lower quantities. Significantly higher Zn concentration was recorded with 8 kg Zn ha^{-1} with deep placement at sowing by drill followed by 6 kg Zn ha^{-1}, 4 kg Zn ha^{-1} and 2 kg Zn ha^{-1} with the same method of Zn application which were at par with each others. However, all the treatment combinations were higher than control which was lowest in concentration. On other hands, leaf lamina and leaf sheath responded differently with method of application, foliar application of Zn was found significantly higher regardless to quantity [28]. The higher amount of concentration was recorded at 8 kg Zn/ha through foliar application which was statistically superior over rest of treatments except 2, 4 and 8 kg Zn ha^{-1} as foliar application and lowest was in control during both the years of experimentation, whereas in root Zn concentration is higher under higher quantity 8 kg Zn ha^{-1} with drill in row *i.e.* absorption was more due to direct contact of root interaction [35]. Nayyar *et al.* [18] reported that rice yield was reduced from 4.3 to 4.0 q ha^{-1}, when Zn application was delayed by 15 days after transplanting. As regards the timing, placing at sowing gave distinct effect in concentration of Zn into grain and stem, vice-versa aerial parts like leaf lamina and leaf sheath responded more with foliar application because of direct contact of nutrient absorption and retained [16]. Slaton et al. [29] have reported that for rice Zn fertilizers containing more water soluble Zn performed better.

Conclusion

The present study brings out that for higher yield of finger millet fertilization by drill at sowing should be a better option for zinc fortification.

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