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Growth, Yield and Uptake of Nutrients by Finger Millet (*Eluesine coracana* L.) in an Alfisol of Central Dry Zone of Karnataka as Influenced by the Application of Zinc and Boron

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Abstract

Field experiments were conducted to study the effect of zinc and boron application on growth, yield and nutrient uptake by finger millet on farmer's field, Gutthikatte, Hosadurga taluk, Chitradurga district for two years during *Kharif* 2015-16 and 2016-17. Among the treatments, application of RDF + FYM with $ZnSO_4$ @ 15 kg / ha and Borax @ 12.5 kg / ha recorded significantly higher plant height (113.81 cm), no. of tillers / hill (5.94), number of ear heads / hill (5.19), ear head length (8.27 cm), 1000 grain wt (3.44 g), grain yield (50.47 q / ha) and straw yield (62.79 q / ha) compared to absolute control. Significantly higher uptake of N (76.47 and 51.18 kg / ha), P (16.4 and 13.50 kg / ha) and K (25.00 and 74.41 kg / ha) in grain and straw were recorded in the treatment combination of RDF + FYM with $ZnSO_4$ @ 15 kg / ha and Borax @12.5 kg / ha.

Keywords : Finger millet, alfisol, uptake, zinc, boron

Finger millet (*Eleusine coracana* L.) enjoys considerable importance as a staple food crop in India, Africa and in some parts of Asia. It is estimated that finger millet is grown annually over an area of 4.50 million hectares with a total production of about 5.00 million tonnes of grains in the world. In India, it is grown on an area of 1.38 million hectares with a production of 2.04 million tonnes of grains and average productivity of 14.77 q ha^{-1} (Anon., 2015). Its cultivation is confined largely to Southern India covering 70 per cent area in Karnataka, Tamil Nadu, Andhra Pradesh and Maharashtra. It is grown predominantly in red soils of dry farming areas. Finger millet has realized its importance for adaptive versatility, easy cultivation and yield stability under poor management, long storability and nutritional qualities.

However, to meet the requirement of this food grain for the population of next decade, the current production has to be increased by nearly 50 per cent. This increase has to come from increased productivity. The higher yield in future would have to be harvested from the vertical rather than horizontal expansion of net cropped area. Soil fertility is the primary limiting factor which influences the production under intensive cultivation. Introduction of exhaustive high yielding varieties and hybrids in many crops, increased the use of high analysis chemical fertilizers devoid of micronutrients and inadequate application of organic manures due to scarcity, has resulted in wide spread of micronutrient deficiencies and nutrient imbalance which adversely affected yield of many crops. Therefore, it is essential to supply macro and micro nutrients in a balanced ratio in required quantity for obtaining higher crop yield.

Zinc and boron micronutrients are deficient in soils of many parts of Karnataka. In view of these facts the present investigation was undertaken with an objective to study the "effect of zinc and boron application on growth, yield and uptake of nutrients by finger millet in Central Dry Zone of Karnataka".

Material and Methods

Field experiments were conducted at Farmer's field, Gutthikatte, Hosadurga taluk, Chitradurga district for two years during *Kharif* 2015-16 & 2016-17. The experiments were laid out in randomized complete block design with fifteen treatments and replicated thrice. The initial physico-chemical properties of soil were estimated by using appropriate methods presented in Table I. The treatments comprise of T_1:Absolute control, T_2: RDF (only NPK), T_3:RDF + FYM, T_4: Only FYM, T_5: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1},

TABLE I

Initial physico - chemical properties of soil in the study area

Soil properties	Value
Particle size analysis	
a. Sand (%)	65.25
b. Silt (%)	14.20
c. Clay (%)	19.74
Texture	Sandy clay loam
pH (1:2.5)	7.23
Electrical conductivity (dS m^{-1})	0.29
Organic carbon (%)	0.53
Available nitrogen (kg ha^{-1})	298.6
Available phosphorus (kg ha^{-1})	23.22
Available potassium (kg ha^{-1})	152.2
Exchangeable calcium(c mol (P^+) kg^{-1})	4.14
Exchangeable magnesium(c mol (P^+) kg^{-1})	1.68
Available sulphur (mg kg^{-1})	8.15
DTPA-iron (mg kg^{-1})	2.76
DTPA- manganese (mg kg^{-1})	2.58
DTPA- copper (mg kg^{-1})	0.89
DTPA- zinc (mg kg^{-1})	0.48
Hot water soluble B (mg kg^{-1})	0.36

T_6: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}, T_7: T_3+ $ZnSO_4$ @ 20 kg ha^{-1}, T_8: T_3+ Borax @ 10 kg ha^{-1}, T_9: T_3+ Borax @ 12.5 kg ha^{-1}, T_{10}: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 10 kg ha^{-1}, T_{11}: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}, T_{12}: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 10 kg ha^{-1}, T_{13}: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}, T_{14}: T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 10 kg ha^{-1} and T_{15}: T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}. The recommended NPK fertilizers (100:50:50 kg/ha) and FYM (10 t/ha) were applied as per the UAS, package. A net plot size of 3 m x 3 m was maintained for finger millet. About 20-25 days old seedlings were transplanted by maintaining the spacing of 30 x 10 cm.

Observations were recorded on growth parameters like plant height, number of tillers/hill and yield attributes like number of ear heads per hill, ear head length, 1000 grain weight, grain and straw yield of crops at harvest in each plot every year. Similarly, plant samples were collected from each plot at harvest and analysed for uptake of nitrogen, phosphorus and potassium (kg/ha) every year.

The difference in the effects of fertilizer treatments on finger millet yield was tested in each year and also when pooled over years based on the standard analysis of variance (ANOVA). The treatments were compared and superior treatments were identified based on least significant difference (LSD) criteria at $P<0.05$ level of probability.

RESULTS AND DISCUSSION

The crop growth, yield and uptake parameters were slightly differed from first experiment to second experiment. The crop growth, yield and uptake parameters were pooled and pooled mean of two years are presented in this paper.

Growth parameters : The plant height and number of tillers per hill at harvest stage of crop growth was significantly influenced by zinc and boron application and are presented in Fig. 1.

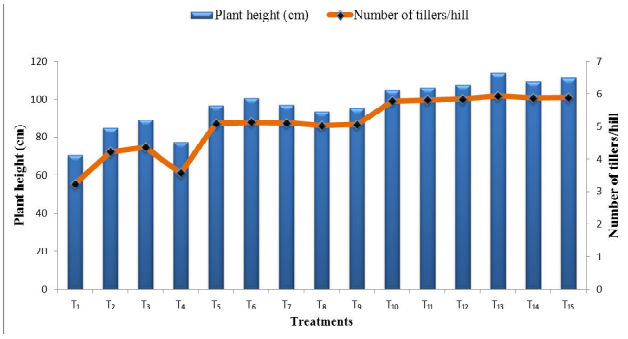

Fig. 1: Growth parameters of finger millet at harvest as influenced by application of zinc sulphate and borax

Significantly higher plant height was (113.8 cm) recorded with the application of $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (T_{13}) at harvest as compared to other treatments. However, it was found on par (112.35 cm) with application of $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (T_{15}) at harvest. The improvement in plant height due to micronutrients application may be attributed to proper nourishment

and optimum crop growth. Addition of FYM might have influenced in the release of micronutrients favourably for the crop growth. Increased activity of meristamatic cells and cell elongation with application of micronutrients along with recommended dose of major nutrients favours effect on metabolic process. Jakhar *et al.* (2006) also observed higher plant height with Zn application.

Application of $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (T_{13}) recorded significantly higher number of tillers per hill (5.94 tillers) as compared to absolute control. However, it was found on par with application of $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (T_{15}) at harvest (5.89 tillers per hill at harvest). The increased number of tillers due to application of these micronutrients may be related to their physiological role in plants. The results very clearly indicated the importance of application of both the nutrients in increasing the number of tillers per hill and also the need for application of boron at an early stage of the crop to increase the tillers numbers. These results were in accordance with that of Muhammad *et al.* (2012).

Yield and yield attributes : The yield attributes of finger millet as influenced by application of zinc and boron are presented in Table II. Application of $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM recorded significantly higher

TABLE II

Yield attributes of finger millet as influenced by application of zinc sulphate and borax

Treatment		No. of ear heads / hill	Ear head length (cm)	1000 grain weight (g)
T_1:	Absolute control	2.17	5.83	2.38
T_2:	RDF (only NPK)	3.29	6.33	2.54
T_3:	RDF + FYM	3.41	6.43	2.63
T_4:	Only FYM	2.76	6.08	2.48
T_5:	T_3 + $ZnSO_4$ @ 12.5 kg ha^{-1}	3.97	7.21	2.98
T_6:	T_3 + $ZnSO_4$ @ 15 kg ha^{-1}	4.03	7.30	3.02
T_7:	T_3 + $ZnSO_4$ @ 20 kg ha^{-1}	4.00	7.26	3.00
T_8:	T_3 + Borax @ 10 kg ha^{-1}	3.86	7.08	2.92
T_9:	T_3 + Borax @ 12.5 kg ha^{-1}	3.92	7.13	2.96
T_{10}:	T_3 + $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1}	4.76	7.97	3.32
T_{11}:	T_3 + $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @ 12.5 kg ha^{-1}	4.84	8.02	3.34
T_{12}:	T_3 + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 10 kg ha^{-1}	4.91	8.05	3.36
T_{13}:	T_3 + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1}	5.19	8.27	3.44
T_{14}:	T_3 + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 10 kg ha^{-1}	4.99	8.11	3.38
T_{15}	T_3 + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1}	5.07	8.16	3.40
	S.Em±	0.12	0.16	0.07
	C. D. at 5%	0.36	0.45	0.21

number of ear heads (5.19) per hill followed by $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (5.07) and $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 10 kg ha^{-1} along with RDF and FYM (4.99) as compare to absolute control. However, all these treatments were found to be on par with each other. Absolute control treatment recorded significantly lower number of ear heads per hill (2.17).

Significantly higher ear head length was registered with application of $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (8.27cm) followed by $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (8.16 cm). However, all these treatments were found to be on par with each other. Significantly shorter ear head length (5.83 cm) was recorded in absolute control.

Application of $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (3.44 g) recorded significantly higher 1000 grain weight compare to other treatments. However, it was found on par with application of $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (3.40g) and $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 10 kg ha^{-1} along with RDF and FYM (3.38g) as compare to absolute control. Higher production of photosynthates due to sufficient assimilation of nutrients to which in turn helps vigorous plant growth would have synthesized the carbohydrates and translocated to the reproductive parts and developing ears which resulted in better filling and more grain weight leading to increased yield components. (Chakraborty *et al.,* 2012).

The highest grain and straw yields (50.47 and 62.79 q/ha) and the lowest (25.13 and 36.72 q/ha) were recorded by T_{13} (T_3 + Zinc sulphate @15 and borax12.5 kg ha^{-1}) and T_1 (absolute control) respectively (Table. III). The favourable influence of applied Zn on yield may be due to its catalytic or

TABLE III

Grain and straw yield of finger millet as influenced by application of zinc sulphate and borax

Sl. No.	Treatment	Grain yield (q/ha)	Straw yield (q/ha)
T_1:	Absolute control	25.13	36.72
T_2:	RDF (only NPK)	34.18	45.78
T_3:	RDF + FYM	36.17	47.84
T_4:	Only FYM	28.18	38.99
T_5:	T_3 + $ZnSO_4$ @ 12.5 kg ha^{-1}	42.04	53.73
T_6:	T_3 + $ZnSO_4$ @ 15 kg ha^{-1}	43.70	55.73
T_7:	T_3 + $ZnSO_4$ @ 20 kg ha^{-1}	42.83	54.55
T_8:	T_3 + Borax @ 10 kg ha^{-1}	39.66	51.87
T_9:	T_3 + Borax @ 12.5 kg ha^{-1}	41.43	53.38
T_{10}:	T_3 + $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1}	47.09	59.75
T_{11}:	T_3 + $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @ 12.5 kg ha^{-1}	47.38	60.07
T_{12}:	T_3 + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 10 kg ha^{-1}	47.61	60.78
T_{13}:	T_3 + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1}	50.47	62.79
T_{14}:	T_3 + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 10 kg ha^{-1}	48.14	61.34
T_{15}	T_3 + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1}	48.74	61.75
	S.Em±	1.07	0.97
	C. D. at 5%	3.20	2.90

stimulatory effect on most of the physiological and metabolic process of plants (Mandal *et al*., 2009) participation of zinc in biosynthesis of indole acetic acid (IAA) and its role in initiation of primordial reproductive parts and partitioning of photosynthates towards them are responsible for increasing yield. Application of B and Zn tried alone or in combination, resulted in significantly higher grain and straw yields than the absolute control. The beneficial effect of B on enhancement of crop yield has been reported by Raghuveer *et al*. (2013).

Uptake of nutrients is associated with the metabolic activities of plants and with the concentration and distribution of ions in the external medium (Fig. 2). Application of $ZnSO_4$ @ 15 kg ha^{-1} + Borax

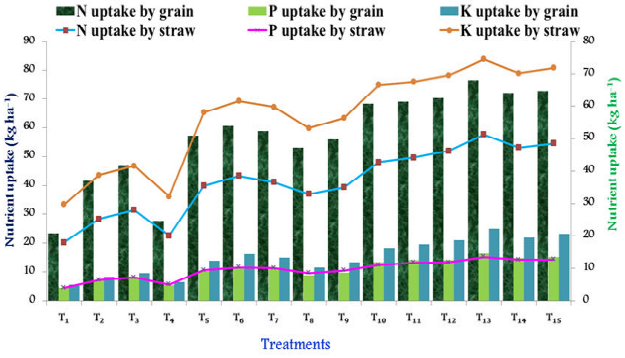

Fig. 2: Uptake of major nutrients by grain and straw of finger millet as influenced by application of zinc

@ 12.5 kg ha^{-1} along with RDF and FYM (T_{13}) recorded significantly higher uptake of nitrogen by finger millet in grain (76.47 kg/ha), straw (51.18 kg/ha) and was found on par with the application of $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM (72.63 and 47.85 kg/ha) in grain and straw. Synergistic effects among micronutrients (Zn and B), farm yard manure with nitrogen might have resulted in increased uptake of nitrogen. The increased uptake of nitrogen may be due to favourable effects of Zn on metabolic process of plant as an activator of several enzymes and intern may directly or indirectly affect the synthesis of carbohydrates and protein (Gulshan *et al.,* 2009).

The uptake of phosphorus differed significantly due to micronutrient application. Application of $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} along with RDF and FYM(T_{13}) recorded significantly higher phosphorus uptake by finger millet grain (16.41 kg/ha), straw (13.50 kg/ha) as compared to absolute control. Application of zinc along with (RDF) favoured the root growth with mobilization of plants nutrients at optimum level resulting in higher absorption of nutrients. The enhanced uptake of phosphorus by different crops with the application of borate has been documented by Wang *et al.* (2012). Further, application of FYM had increased the P uptake which might be ascribed to more availability of these nutrients from the added fertilizers and to the solubility action of organic acids produced during the degradation of organic materials thus resulting in more release of the native and applied phosphorus. Similar results were also reported by Gulshan *et al.* (2009).

The uptake of potassium by finger millet grain and straw differed significantly due to micronutrient application. Application of micronutrients (Zn and B) along with recommended dose of NPK and FYM (T_{13}) recorded significantly higher potassium uptake by grain (25.00 kg/ha), straw (74.41 kg/ha) as compared to absolute control. This could be due to the beneficial effect of combined application of micronutrients, FYM and inorganic fertilizers like NPK in increasing the absorption of potassium. The higher potassium uptake through addition of zinc was primarily due to its increased concentration coupled with higher grain and straw yield. A synergistic effect of B and Zn on K uptake has been reported by Lopez *et al.* (2008).

Based on the findings of the present study, it may be concluded that application of RDF + FYM with $ZnSO_4$ @ 15 kg/ha and Borax @ 12.5 kg/ha proved effective in enhancing growth, yield and nutrient uptake by finger millet. The beneficial effect of the two nutrients on crop yield was more pronounced when both of them were used together in comparison to their use in alone.

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