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Research Article

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Direct and Residual Effect of Zinc and Boron on Yield and Yield Attributes of Finger Millet – Groundnut Cropping System

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ABSTRACT

Field experiments were conducted in the farmers' field at Gutthikatte village, Hosadurga taluk, Chitradurga district of Karnataka during 2015-16 and 2016-17 to study the direct and residual effect of zinc and boron on yield and yield attributes of finger millet – groundnut cropping system in zinc and boron deficient soil. The finger millet was the test crop to study the direct effect and groundnut crop was raised to study the residual effect. The experiments were laid out in Randomized Complete Block Design with fifteen treatments and replicated thrice. The pooled analysis revealed that significantly higher yield and yield attributes of finger millet and succeeding groundnut crops were recorded with the application of NPK (100:50:50 kg ha^{-1}) + FYM (10 t ha^{-1}) + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} and residual effect of NPK + FYM + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} compare to other treatments.

Key words: *Yield, NPK, Residual effect, Cropping System, Zinc.*

INTRODUCTION

Cropping systems comprising cereals and legumes are the ultimate solution to overcome the drawbacks of mono-cropping system for enhanced food production of our country. Continuous cropping with single crop results in rapid decline in soil fertility and thus requires a serious attention for efficient fertilizer use. Therefore, fertilizer recommendations should be framed for a whole cropping system instead of a single crop because fertilizer recommendations for a single crop often results in high and uneconomical use of fertilizer and do not consider the fertilizer needs of a crop which will vary with the characteristics of the preceding crop in the system due to residual effect of fertilizers to succeeding crop. Moreover recovery of the fertilizer micronutrients by the crop plants even under the best management practices seldom exceeds 10 per cent[15].

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Finger millet (*Eleusine coracana* (L.) Gaertn.) is a major food crop of the semi-arid tropics of Asia and Africa. In India, it is grown on an area of 1.19 m ha with a production of 1.98 m t with an average productivity of 1661 kg ha^{-1}. The major finger millet growing states are Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Jharkhand, Maharashtra and Uttaranchal. Karnataka is the largest producer of finger millet grown on an area of 1.05 m ha with a production of 1.57 m t and the average productivity is 1889 kg ha^{-1}. Finger millet is the main dietary component in Southern Karnataka particularly in districts of Bangalore rural, Tumkur, Mysore, Hassan, Mandya and Chitradurga. Further, finger millet is also an ideal food for patients suffering from diabetes.

Groundnut (*Arachis hypogaea* L.) is a major edible oil seed and a food crop of the world. It is popularly called as poor man's almond and considered as king of oilseeds. Groundnut occupies an area of 24.7 m ha with a production of 33 m t in the world. In India groundnut occupies an area of 7.40 m ha with a production of 4.59 m t and productivity of 1764 kg ha^{-1}. Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra are the major groundnut growing states which account for 70 per cent of the groundnut area and 75 per cent of production. Karnataka ranks fifth in the country with a production of 0.50 m t from an area of 0.65 m ha with productivity of 844 kg ha^{-1}. Even though it is an energy rich crop, the cultivation of groundnut mainly confined to marginal and less fertile soils in India with inadequate nutrition. Groundnut is a potential oilseed crop of semi-arid region which is generally grown after finger millet in many of the southern districts of Karnataka. It can be successfully raised on residual fertility where the previous finger millet crop received adequate nutrition including deficient micronutrients.

Increased cropping intensity along with cultivation of modern crop varieties having high yield potential has resulted in deterioration of soil fertility with an emergence of micronutrient deficiency in Bangladesh. Among the micronutrients, zinc and boron deficiencies have widely been reported[7]. Nevertheless, micronutrients have great roles in the fertilizer programme to achieve higher and sustainable crop yields. Micronutrients are also important for seed formation and seed quality. Boron deficiency may induce grain sterility in crops. Usually dicots have higher boron requirement than monocots.

Only four plant nutrients *viz.* N, P, K and S are commonly used by the farmers in Bangladesh. The importance of the use of micronutrients is mostly ignored although they could be chief limiting factor for crop production. However, micronutrient application needs a careful control. It is essential, but the amount of requirement is much less compared to macronutrient. Every crop application of micronutrient fertilizer may not be needed since its residual effect might be sufficient for achieving sustainable yield over a cropping pattern. There is a report that elevated concentration of boron would have toxic effect on crops[13]. Toxicity may arise in plants due to continuous application of micronutrients. Keeping the above points in view, the experiments were undertaken with an objective to study the direct and residual effects of Zn and B on yield and yield attributes of finger millet and groundnut crops.

MATERIAL AND METHODS

The field experiments were conducted under irrigated condition in the farmer's field at Gutthikatte village, Hosadurga taluk, Chitradurga district during *kharif* and summer seasons of 2015-16 to 2016-17. Prior to laying out of the experiment, composite soil samples were drawn from a depth of 0-15 cm and analysed for physical and chemical parameters. The initial physico-chemical properties of soil were estimated by using appropriate methods given in Table 1. The experiments were laid out in randomized complete block design with fifteen treatments and replicated thrice. The two experiments were conducted during *kharif* 2015 and 2016 with finger millet (GPU-28) main crop and the residual effect of the said treatments were studied during summer seasons of 2016 and 2017 with Groundnut (ICGV-91114) as succeeding crop.

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}, 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^{-1}) and FYM (10 t ha^{-1}) were applied finger millet main crop as per the UAS, package.

Table 1: Initial physico-chemical properties of soil in the study area

Sl. No.	Particulars	Value obtained
I	**Physical properties of soil**	
1	**Mechanical properties of soil (% oven dry basis)**	
	Sand (%)	51.42
	Silt (%)	21.51
	Clay (%)	27.07
	Textural class	Sandy clay loam
2	Maximum water holding capacity (%)	43.52
3	Bulk density (Mg m^{-3})	1.44
II	**Chemical properties of soil**	
1	pH (1:2.5)	7.23
2	Electrical conductivity (d Sm^{-1})	0.45
3	Organic carbon (%)	0.53
4	Cation exchange capacity [c mol (p^+) kg^{-1}]	11.32
5	Available N (kg ha^{-1})	288.6
6	Available P_2O_5 (kg ha^{-1})	23.22
7	Available K_2O (kg ha^{-1})	152.2
8	Exch.Ca [c mol (p^+) kg^{-1}]	4.14
9	Exch. Mg [c mol (p^+) kg^{-1}]	1.68
10	Available S (mg kg^{-1})	8.15
11	DTPA Fe (mg kg^{-1})	2.76
12	DTPA Mn (mg kg^{-1})	2.58
13	DTPA Zn (mg kg^{-1})	0.48
14	DTPA Cu (mg kg^{-1})	0.89
15	Hot water soluble B (mg kg^{-1})	0.36

Groundnut cultivated as a succeeding crop. Need based plant production and protection measures were taken up and the crops were grown to maturity and harvested. The yield and yield parameters were recorded during harvest stage of finger millet and groundnut crops.

RESULTS AND DISCUSSION

The yield and yield attributes of crops differed significantly during first (2015-16) and second (2016-17) year of experiments and the pattern of response to zinc and boron application was similar in both the years. Therefore, only pooled data of the two years are used to highlight the results and discussed in this chapter.

Yield attributes of finger millet

The data pertaining to number of ear heads $hill^{-1}$, ear head length (cm) and 1000 grain weight (g) as influenced by levels of zinc and boron are presented in Table 2.

Application of RDF + FYM + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (T_{13}) recorded significantly highest number of ear heads (5.14) followed by T_{15} (5.02) and T_{14} (4.94) as compared to absolute control (T_1:2.18). Ear head length was significantly longest (8.17 cm) with application of RDF + FYM + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} as compared to absolute control (5.95 cm) and was on par with T_{12} (7.92 cm), T_{14} (7.97 cm) and T_{15} (8.02 cm). Application of RDF + FYM + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (T_{13}) recorded significantly highest 1000 grain weight (3.39 g) and was on par with T_6(3.23 g), T_{11}(3.28 g), T_{12}(3.30 g), T_{14}(3.32 g) and T_{15}(3.35 g). Lowest test weight (2.24 g) was recorded in T_1 (Absolute control).

The improvement in yield attributes is the manifestation of better growth, higher photosynthetic activity and transport of photosynthates from source to sink. The improvement in growth as a result of improved physiological processes in plant might be due to enhanced supply of nutrients by application of FYM along with chemical fertilizers. Besides, the application of FYM might have improved soil physical, chemical and biological properties which together might have favoured the nutrient transformation processes in soil thus contributing to increased availability of nutrients. The higher values of yield parameters might be due to increased transportation of photosynthates from source to sink due to zinc and boron application as reported by Jena *et al.*[10] and Mohamed *et al.*[14]. The supremacy of yield parameters due to combined application of N, P and K along with Zn and B might be due to increased plant vigour, improved photosynthesis and better translocation of photosynthates from source to sink[20].

Grain and straw yield (q ha^{-1}) of finger millet

The data pertaining to grain and straw yield (q ha^{-1}) as influenced by zinc and boron application are presented in Table 10 and Figure 4. Significantly highest grain yield was observed in T_{13} treatment which received RDF + FYM + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (43.67 q ha^{-1}) which was on par with T_{15} (42.42 q ha^{-1}) closely followed by T_{14} (41.78 q ha^{-1}) treatments, respectively. The lowest grain yield of 17.96 q ha^{-1}was recorded in absolute control treatment as compared to other treatments.

Similarly, significantly highest straw yield was recorded in T_{13} treatment which received RDF + FYM+ $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (58.88 q ha^{-1}) which was on par with T_{15} (RDF +FYM+ $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1}), T_{14} (RDF +FYM+ $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 10 kg ha^{-1}) and T_{12} (RDF +FYM+ $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 10 kg ha^{-1}) treatments, respectively (57.45, 57.13 and 56.41 q ha^{-1}). The lower straw yield of 27.23 q ha^{-1} was recorded in T_1 (Absolute control) treatment as compared to other treatments. Economic yield is expressed as a function of factors that contribute to yield, which are known as yield attributes. Increase in yield might be attributed to improvement in yield components, due to better partitioning of carbohydrates from leaf to reproductive parts resulting in increased yield[3].

Table 2: Effect of graded levels of zinc and boron on yield parameters of finger millet in finger millet – groundnut cropping system

Treatments	No. of ear heads hill^{-1}			Ear head length (cm)			1000 grain weight (g)		
	2015-16	2016-17	Pooled mean	2015-16	2016-17	Pooled mean	2015-16	2016-17	Pooled mean
T_1: Absolute control	2.23	2.12	2.18	6.06	5.83	5.95	2.32	2.15	2.24
T_2: RDF (only NPK)	3.30	3.48	3.39	6.40	6.78	6.59	2.85	3.16	3.01
T_3: RDF + FYM	3.63	3.82	3.73	6.58	6.96	6.77	2.90	3.23	3.07
T_4: Only FYM	2.70	2.91	2.81	6.19	6.51	6.35	2.56	2.85	2.71
T_5: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}	4.06	4.28	4.17	6.96	7.38	7.17	3.00	3.29	3.15
T_6: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}	4.58	4.76	4.67	7.22	7.59	7.41	3.13	3.33	3.23
T_7: T_3+ $ZnSO_4$ @ 20 kg ha^{-1}	4.41	4.62	4.52	7.10	7.45	7.28	3.10	3.31	3.21
T_8: T_3+ Borax @ 10 kg ha^{-1}	3.85	3.96	3.91	6.70	7.09	6.90	2.96	3.26	3.11
T_9: T_3+ Borax @ 12.5 kg ha^{-1}	3.86	4.09	3.98	6.83	7.22	7.03	2.99	3.28	3.14
T_{10}: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	4.65	4.86	4.76	7.42	7.82	7.62	3.05	3.36	3.21
T_{11}: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}	4.73	4.92	4.83	7.58	7.96	7.77	3.18	3.38	3.28
T_{12}: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	4.77	4.98	4.88	7.79	8.05	7.92	3.20	3.40	3.30
T_{13}: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}	5.04	5.23	5.14	7.98	8.36	8.17	3.29	3.48	3.39
T_{14}: T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	4.83	5.04	4.94	7.78	8.16	7.97	3.21	3.43	3.32
T_{15} T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}	4.92	5.11	5.02	7.94	8.22	8.08	3.25	3.45	3.35
S.Em±	**0.07**	**0.08**	**0.08**	**0.13**	**0.13**	**0.13**	**0.06**	**0.06**	**0.06**
CD @5%	**0.22**	**0.23**	**0.22**	**0.38**	**0.39**	**0.39**	**0.16**	**0.17**	**0.17**

Table 3: Effect of graded levels of zinc and boron on grain and straw yield of finger millet in finger millet – groundnut cropping system

Treatments	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})		
	2015-16	2016-17	Pooled mean	2015-16	2016-17	Pooled mean
T_1: Absolute control	18.38	17.53	17.96	28.05	26.41	27.23
T_2: RDF (only NPK)	29.69	31.84	30.77	44.13	47.92	46.03
T_3: RDF + FYM	32.36	33.51	32.94	46.10	49.08	47.59
T_4: Only FYM	22.78	24.03	23.41	37.23	40.19	38.71
T_5: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}	35.41	36.76	36.09	49.76	52.78	51.27
T_6: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}	37.03	38.78	37.91	50.86	54.63	52.75
T_7: T_3+ $ZnSO_4$ @ 20 kg ha^{-1}	35.46	37.81	36.64	50.64	53.96	52.30
T_8: T_3+ Borax @ 10 kg ha^{-1}	32.50	34.59	33.55	47.69	50.57	49.13
T_9: T_3+ Borax @ 12.5 kg ha^{-1}	34.23	36.38	35.31	49.17	51.82	50.50
T_{10}: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	37.51	39.46	38.49	51.99	55.73	53.86
T_{11}: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}	39.50	40.35	39.93	53.22	57.04	55.13
T_{12}: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	40.27	41.82	41.05	54.53	58.28	56.41
T_{13}: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}	43.05	44.28	43.67	56.91	60.84	58.88
T_{14}: T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	41.20	42.35	41.78	55.35	58.91	57.13
T_{15} T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}	41.88	42.96	42.42	55.77	59.13	57.45
S.Em±	**0.62**	**0.65**	**0.64**	**0.88**	**0.94**	**0.91**
CD @5%	**1.82**	**1.89**	**1.86**	**2.58**	**2.74**	**2.66**

The main yield attributes in finger millet are number of tillers $hill^{-1}$, number of earheads $hill^{-1}$, earhead length, and 1000-grain weight. This might be attributed to supply of balanced proportion of nutrients to finger millet. The per cent increase in grain and straw yields due to application of (RDF + FYM+ $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1}) T_{13} treatment over T_2 (Only RDF) and T_3 (RDF + FYM) was 41.92, 32.58 and 27.91, 23.72%, respectively.

Thus, application of zinc and boron in a soil deficient in zinc and boron improved overall growth and development of plants and ultimately the grain and straw yields. These findings are also supported by Shrivastava *et al.*[23], Sammauria[22], Singh *et al.*[25], Tripathi *et al.*[26] and Jat *et al.*[9] in different crops. In this experiment, the crop yield increased to a much greater extent due to the combined use of Zn and B than their individual application. These results are in accordance with those of Muhammad *et al*.[16] and Quddus *et al.*[19].

The increase in yield due to zinc application might be attributed to its role in various enzymatic reactions and its role as a catalyst in various growth processes and hormone production and protein synthesis. It might also be ascribed to its improvement in metallo enzymes system regulatory function and growth promoting auxines production[1,8,20] reported that straw yield was significantly higher due to soil application of $ZnSO_4$ and was attributed to higher growth attributes and more numbers of tillers. The higher yield obtained in hybrid rice due to the combined effect of NPK with zinc sulphate and gypsum was attributed to enhanced vegetative growth and yield attributing parameters of hybrid rice as a result of increase in the activity of meristematic cells and cell elongation. Baktear Hossain *et al*.[4] also reported similar improvement in growth and yield of rice crop with the application of NPK and Zn.

Yield attributes of groundnut

The data on the residual effects of graded levels of zinc and boron on yield and yield attributes of groundnut *viz.*, number of pods $plant^{-1}$, 100 kernel weight (g), pod yield (q ha^{-1}), haulm yield (q ha^{-1}) and shelling percentage are presented in Tables 4 and 5.

Number of pods plant^{-1}

Significantly higher number of pods plant^{-1} (Table) was observed in T_{15} treatment which received RDF + FYM + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (26.48pods plant^{-1}) which was significantly superior over all other treatments closely followed by T_{14} treatment which received RDF + FYM + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 10 kg ha^{-1} (23.79 pods plant^{-1}). The lowest number of pods plant^{-1} (10.77) were recorded in T_1 (absolute control) as compared to other treatments.

It is well known fact that, boron application influences pollination, seed setting, mobilization of sugars from source to sink, growth of pollen tube and fertilization. Further, thereis a beneficial effect of FYM applied in conjunction with boron in the present experiment. On a weight basis, organic matter retains more boron than mineral soil constituents[24]. In line with present study, the findings of Patnaik *et al*.[17], Aparna and Puttaiah[2] who were also of the same opinion. This might be due to continuous and balanced supply of major and micro nutrients due to the release of nutrients from organic and inorganic sources which resulted in better translocation of photosynthates. The results are in confirmation with the findings of Polara *et al.*[18] in groundnut.

100 kernel weight (g)

The 100 kernel weight was significantly influenced by residual effect of graded levels of zinc and boron on yield attributes of groundnut (Table 4). Highest 100 kernel weight was recorded in T_{15} treatment which received RDF + FYM + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (35.33g) and was on par with $T_{14,}$ $T_{13,}$ T_{12} and T_{11} treatments. Lowest 100 kernel weight was recorded in absolute controlT_1 (28.62 g). Yield contributing characters of groundnut were significantly influenced by the application of organics in combination with recommended fertilizers and micronutrients. The improvement in yield attributes leading to higher yield by zinc might be possible due to the enhanced synthesis of carbohydrates and proteins and their transport to the sink through effective physiological activities in plants, as evident from improved physiological parameters. The results corroborate the findings of Aparna and Puttaiah[2], Kulhare *et al.*[11] who observed improvement in yield parameters of soybean due to application of zinc sulphate over control.

Table.4 Residual effect of graded levels of zinc and boron on yield parameters of groundnut in finger millet – groundnut cropping system

Treatments	Number of pods plant^{-1}			100 kernel weight (g)			Shelling percentage		
	2015-16	2016-17	Pooled mean	2015-16	2016-17	Pooled mean	2015-16	2016-17	Pooled mean
T_1	11.31	10.23	10.77	29.07	28.16	28.62	63.35	63.04	63.20
T_2	14.46	16.83	15.65	30.11	30.32	30.22	65.31	66.04	65.68
T_3	15.92	18.12	17.02	30.93	30.98	30.96	65.81	66.32	66.07
T_4	12.56	13.93	13.25	29.23	30.05	29.64	64.74	65.84	65.29
T_5	17.48	20.18	18.83	31.85	32.53	32.19	66.45	67.5	66.98
T_6	17.91	20.94	19.43	32.21	33.02	32.62	66.91	67.75	67.33
T_7	18.13	21.48	19.81	32.46	33.13	32.80	67.15	68.35	67.75
T_8	16.98	19.06	18.02	31.09	32.04	31.57	65.87	66.55	66.21
T_9	17.13	19.15	18.14	31.46	32.34	31.90	66.03	66.91	66.47
T_{10}	20.03	21.83	20.93	33.17	33.85	33.51	68.31	69.28	68.80
T_{11}	20.51	22.14	21.33	33.52	34.03	33.78	68.53	69.55	69.04
T_{12}	20.89	22.78	21.84	33.92	34.16	34.04	68.85	69.81	69.33
T_{13}	21.06	23.9	22.48	34.08	34.44	34.26	69.15	70.05	69.60
T_{14}	22.18	25.39	23.79	34.56	35.08	34.82	69.53	70.75	70.14
T_{15}	24.32	28.63	26.48	34.89	35.76	35.33	69.9	71.32	70.61
S.Em±	**0.32**	**0.37**	**0.34**	**0.59**	**0.60**	**0.59**	**1.24**	**1.25**	**1.24**
CD @5%	**0.94**	**1.07**	**1.00**	**1.72**	**1.74**	**1.73**	**3.61**	**3.65**	**3.63**

T_1 : Absolute control	T_6 : T_3+ $ZnSO_4$ @ 15 kg ha^{-1}	T_{11} : T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}
T_2 :RDF (only NPK)	T_7 : T_3+ $ZnSO_4$ @ 20 kg ha^{-1}	T_{12} : T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 10 kg ha^{-1}
T_3 :RDF + FYM	T_8 : T_3+ Borax @ 10 kg ha^{-1}	T_{13} : T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}
T_4 :Only FYM	T_9 : T_3+ Borax @ 12.5 kg ha^{-1}	T_{14} : T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 10 kg ha^{-1}
T_5 :T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}	T_{10} : T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	T_{15} : T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}

Table 5: Residual effect of graded levels of zinc and boron on pod and haulm yield (q ha^{-1}) of groundnut in finger millet – groundnut cropping system

Treatments	Pod yield (q ha^{-1})			Haulm yield (q ha^{-1})		
	2015-16	2016-17	Pooled mean	2015-16	2016-17	Pooled mean
T_1: Absolute control	5.85	5.48	5.67	11.42	10.69	11.06
T_2: RDF (only NPK)	7.53	8.55	8.04	14.08	15.23	14.66
T_3: RDF + FYM	8.85	9.81	9.33	14.72	16.41	15.57
T_4: Only FYM	6.65	7.45	7.05	12.19	13.60	12.90
T_5: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}	9.83	10.02	9.93	15.95	16.74	16.35
T_6: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}	10.06	10.59	10.33	16.14	17.18	16.66
T_7: T_3+ $ZnSO_4$ @ 20 kg ha^{-1}	10.82	10.92	10.87	16.36	17.53	16.95
T_8: T_3+ Borax @ 10 kg ha^{-1}	8.96	9.62	9.29	15.02	15.80	15.41
T_9: T_3+ Borax @ 12.5 kg ha^{-1}	9.50	9.90	9.70	15.76	16.23	16.00
T_{10}: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	12.30	13.02	12.66	18.65	19.78	19.22
T_{11}: T_3+ $ZnSO_4$ @ 12.5 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}	12.46	13.78	13.12	18.86	19.90	19.38
T_{12}: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	13.32	14.25	13.79	20.03	21.22	20.63
T_{13}: T_3+ $ZnSO_4$ @ 15 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}	13.98	14.60	14.29	21.51	22.50	22.01
T_{14}: T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 10 kg ha^{-1}	14.09	14.81	14.45	22.72	24.06	23.39
T_{15} T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}	14.72	15.49	15.11	23.42	24.65	24.04
S.Em±	**0.19**	**0.20**	**0.20**	**0.31**	**0.33**	**0.32**
CD @5%	**0.56**	**0.59**	**0.57**	**0.89**	**0.95**	**0.92**

The increasing trend in test weight due to increase in zinc doses during both the years of experiment might be due to the fact that, application of zinc led to increase in the availability of zinc to plants in the zinc deficient soil. Zinc is an important substrate involved in photo system-II of photosynthesis and plays vital role in energy metabolism process in plants. Thus, the increased availability and efficient absorption of zinc resulted in vibrant metabolism in plant which is an important reason for increase in test weight of the kernels. The results obtained are in agreement with the evidence presented earlier by Polara *et al.*[18] in groundnut.

Shelling percentage

A significant increase in shelling percentage (Table 4) of groundnut was noticed in T_{15} treatment which received RDF + FYM + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (70.61%),but was on par with T_{14}, T_{13}, T_{12} and T_{11} treatments which received combined application of NPK + FYM + $ZnSO_4$ + Borax followed by T_{10} treatment which received RDF + FYM + $ZnSO_4$ @ 12.5 kg ha^{-1} + Borax @ 10 kg ha^{-1} (68.80%).The lowest shelling percentage was recorded in absolute control treatment (63.20%).

The improvement in overall growth of plants was due to fertilizers and FYM application coupled with transport of photo synthates towards reproductive structures which might have increased the yield attributes. The higher values of yield attributes is the result of higher nutrient availability resulted in better growth and more translocation of photo synthates from source to sink[18]. Singh *et al.*[24] also revealed that, combined application of micronutrients along with RDF recorded significant increase in the shelling percentage. Organic and inorganic manures supply secondary and micronutrients also along with N, P and K which might be the reason to record higher test weight and shelling per cent. These results are in line with Polara *et al.*[18] in groundnut. The supremacy of yield parameters due to combined application of N and Zn might be due to increase in plant vigour, accumulation of photo synthates and better translocation from source to sink[18].

Pod yield and Haulm yield (q ha^{-1})

Data on pod and haulm yields of groundnut differed significantly due to residual effect of graded levels of zinc and boron application (Table 5 and Figure 2).

Among the different treatments, application of RDF + FYM + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (T_{15}) recorded significantly higher pod yield (15.11 q ha^{-1}) as compared to all other treatments. However, lowest pod yield (5.67 q ha^{-1}) was recorded in absolute control (T_1) as compared to other treatments. Application of RDF + FYM + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (T_{15}) recorded significantly highest haulm yield (24.04 q ha^{-1}) and was on par with T_{14} which received RDF + FYM + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} (23.39 q ha^{-1}).

However, lowest haulm yield was recorded in absolute control (11.06 q ha^{-1}).

The higher yield in these treatments might be accounted for the balanced application of nutrients which were conducive to better growth, development and nutrient uptake. Indeed, the balanced fertilization seems to help in restoration of better nutritional environment, facilitating genetic expression of crop potential for its growth, yield components and ultimately the yield. Thus, the application of zinc and boron to a soil deficient in zinc and boron improved overall growth and development of plants and ultimately the pod and haulm yield increases. These findings are also supported by Yang *et al.*[27], Channabasavanna *et al.*[6], Singh *et al.*[24], Kulhare *et al.*[11] and Begum *et al.*[5] in different crops.

The increase in yield might be attributed basically to the fact that, zinc shows beneficial effects on chlorophyll synthesis and so it indirectly influences the photosynthesis and reproduction. The channelization of photosynthates during reproductive stage might have been influenced by zinc by the way of its involvement in electron transfer and activation of various enzymes which inturn can directly or indirectly affect the synthesis of carbohydrates and proteins. This might has contributed to the increase in the yield attributes. Favourable influence on the yield attributes due to zinc application contributed to significant increase in seed yield. Similar favourable effects of zinc were reported by Renukadevi *et al*.[21], Lokanath[12] and Polara *et al*.[18] in different legumes. In addition to zinc, application of boron also favoured better root growth and nitrogen assimilation with higher nodulation which in turn resulted in better growth and development of sink size (number of pods $plant^{-1}$, number of $seedsplant^{-1}$, pod length, pod yield and higher seed yield). Present results are in confirmation with those of Aparna and Puttaiah[2] and Patnaik *et al.*[17].

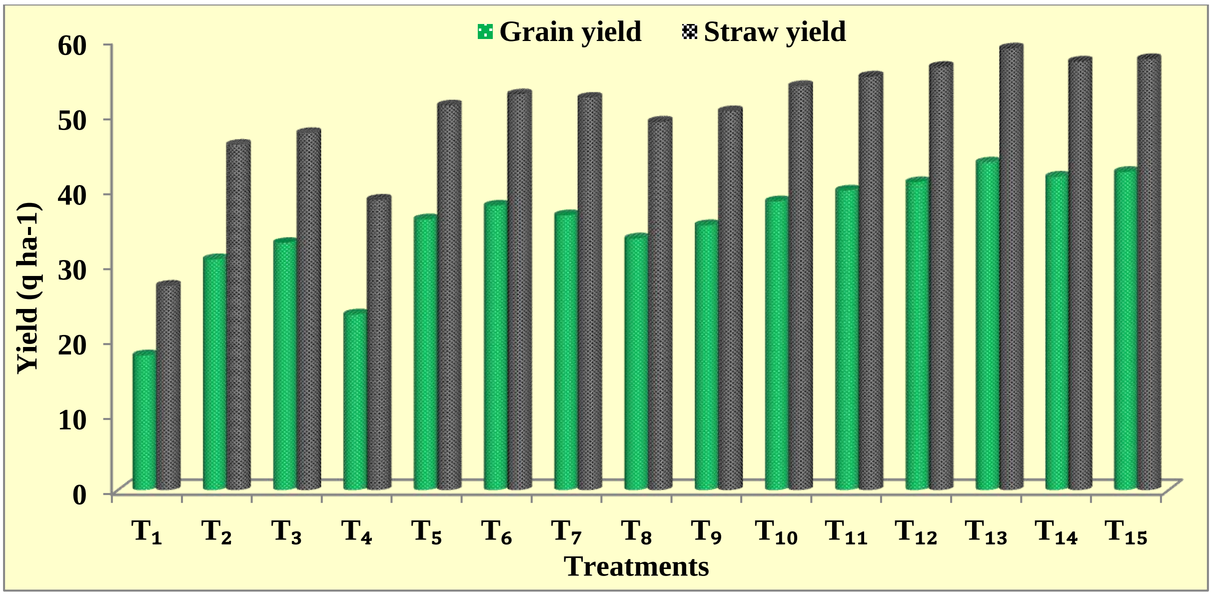

Fig. 1: Effect of graded levels of zinc and boron on grain and straw yield (q ha^{-1}) of finger millet in finger millet – groundnut cropping system

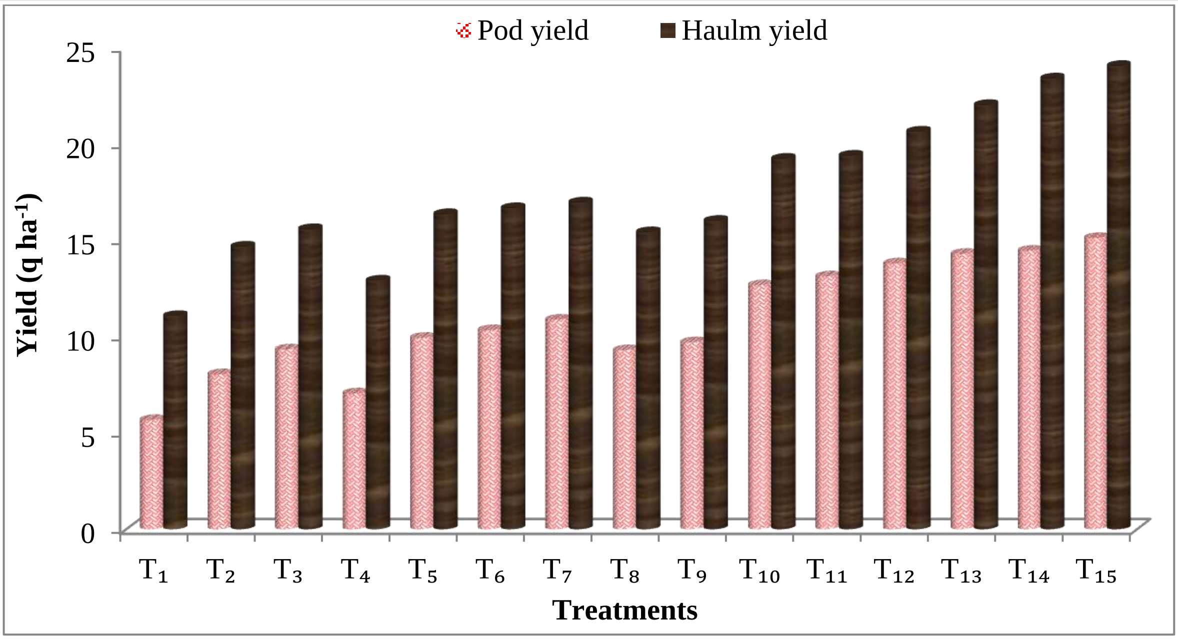

Fig. 2: Residual effect of graded levels of zinc and boron on yield (q ha^{-1}) of groundnut in finger millet – groundnut cropping system

Legend:

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}
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}
T_{15} : T_3+ $ZnSO_4$ @ 20 kg ha^{-1}+ Borax @ 12.5 kg ha^{-1}

CONCLUSION

It can be concluded that significantly higher yield and yield attributes of finger millet and succeeding groundnut crops were recorded with the application of NPK (100:50:50 kg ha^{-1}) + FYM (10 t ha^{-1}) + $ZnSO_4$ @ 15 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} and residual effect of NPK + FYM + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 12.5 kg ha^{-1} compare to other treatments.

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