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Effect of Different Levels of Borax and Gypsum on Soil Chemical Properties and Yield of Finger Millet (*Eleusine corocana* L) in Southern Dry Zone of Karnataka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out in Kharif 2016 on B-deficient sandy loam soil at College of Agriculture, VC Farm, Mandya to study the effect of graded levels borax (5, 10, 15 and 20 kg ha1) and gypsum (100 and 200 kg $ha^{-1)}$ on yield and soil chemical properties of irrigated finger millet (*Eleusine corocana* L.) in Southern Dry Zone of Karnataka. A significantly higher grain yield of 45.95 q ha^{-1} (17.56% higher than the control) and a B:C ratio of 3.06 were also recorded at T_{12} compared with RDF + FYM (T_1). Due to application of borax and gypsum, the pH, EC, and organic carbon content in soil during flowering stage and at crop harvest were non-significant. However, at the flowering and harvest of the crop, the T_4 treatment had the lowest pH (7.49 and 7.43, respectively), whereas the T_{12} (flowering stage) and T_{10} (after harvest) treatments had the highest pH (7.65 and 7.67, respectively). Higher soil NPK values were detected in all treatments at

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flowering stage compared to after the crop was harvested. Application of borax 10kg ha^{-1} + 100 kg gypsum ha^{-1} along with RDF and FYM had a significantly higher exchangeable calcium content after harvest (6.77 cmol kg^{-1}) than T_1 (5.23 cmol kg^{-1}). Sulphur content in soil at flowering stage and after harvest of crop was found to be significant among the treatments due to application of different levels of gypsum. High levels of borax applied treatments, i. e. T_5 (T_1+20 kg borax ha^{-1}) and T_{15} (T_5 + 200 kg gypsum ha^{-1}) recorded significantly higher content of B at flowering stage (4.18 and 4.09 mg kg^{-1}, respectively) and at harvest of crop (3.88 and 3.68 mg kg^{-1}, respectively) when compared to T_1 (1.32 and 1.16 mg kg^{-1}, respectively). Therefore finger millet absorption of boron may be reduced by using borax with a greater dosage of gypsum (200 kg ha^{-1}). As a result, optimising the Ca/B ratio in the soil and plant is critical for increasing irrigated finger millet yields.

Keywords: Boron; calcium; soil properties; finger millet; gypsum.

1. INTRODUCTION

Out of the total minor millets produced, finger millet (*Eleusine coracana* L. Gaertn) accounts for about 85% of production in India [1] and it has the pride of place in having highest productivity among small millets. In India, finger millet is cultivated mainly in the states of Karnataka, Tamil Nadu, Andhra Pradesh, Orissa, Jharkhand, Uttaranchal, Maharashtra, and Gujarat occupying an area of 1.27 million hectares with a production of 2.61 million tonnes and average productivity of 1489 kg ha^{-1} [2]. Karnataka is accounts for 60.8 percent of the state's land area and two-thirds of its production (68.4%) [3]. Furthermore, finger millet is an excellent diet for diabetic individuals because of more calcium (0.38%), protein (6-8%t), fibre (18 percent), phenolic compounds (0.3-3%), and sulfur-containing amino acids.

Calcium is a key cation found in the cellwall of middle lamella, where it plays a role in protein synthesis and cell division. Finger millet is a high-calcium crop (450 mg/100 g). It also promotes rapid plant development while maintaining the structural integrity of stems. Plant-based calcium such as that found in traditional staple grains is important for diets in many countries. It is noteworthy that finger millet has been shown to be consistently high in calcium regardless of the variety (364 ± 58 mg/100 g) and is balanced with other minerals such as zinc and magnesium.

Boron increases cell division, cell elongation, cell wall strength, flowering, pollination, seed set, and sugar translocation in crop plants, as well as their development and nutrition. The propensity of boron to form complexes with chemicals with cis-diol structures is the most important role of boron in plant growth and development. It has been observed that the boron requirement for reproductive growth is substantially higher than that for vegetative growth in most plant species [4].

Although calcium and boron both play an important role in enhancing cereals yields, combined effect of boron and gypsum, influence boron availability and use by plants [5]. The few available studies show that finger millet provides high calcium bioavailability, and contributes to higher calcium retention due to its calcium content compared to other staples which can exert beneficial effects especially for children, the elderly, and women. Increased calcium supply has been linked to an increased boron deficient symptom in plants. Similarly, calcium translocation to the shoot and fruit was affected by boron deprivation. It denotes the need for a balanced supply of calcium and boron for proper plants growth and development. According to recent research, there is an antagonistic link between B and Ca. There is need to supply Ca and B in optimum quantity for normal growth and development of plants.

Most farmers are growing finger millet by applying less amount of NPK with or without the addition of secondary and micro nutrients, but research studies show finger millet also responds well to Ca, S, and micronutrients like B, Zn, and Fe. Secondary nutrients like calcium and sulphur in the form of gypsum and micronutrient boron in the form of borax have been recommended by the Karnataka state department of agriculture under the Bhoochetana scheme along with N, P and K fertilizers. In view of above facts, the experiments were undertaken to know the calcium and boron nutrition on grain yield of finger millet and their interaction in soil with entitle as "Effect of Different Levels of Borax and Gypsum on Soil Chemical Properties and Yield of Finger Millet (*Eleusine Corocana* L) in Southern Dry Zone of Karnataka".

2. MATERIALS AND METHODS

2.1 The Experimental Site and Soil

The field experiment was conducted in the College of Agriculture, V. C. Farm, Mandya, Karnataka, during the Kharif–2016 season, located in Karnataka's Southern Dry Zone (Zone No.6). It is situated at an altitude of 695 metres above mean sea level, between 120 32' N latitude and 760 53' E longitude. Table 1 shows the climatic conditions that prevailed during the crop growth period. Appendix 1 contains a calendar of operations for the finger millet growth season.

Soils of the farm belong taxonomically to *Typic Rhodustalfs.* A composite soil sample was drawn from the experimental site by collecting samples from 0-15 cm depth before initiation of experiment. The soil was air-dried, powdered and passed through 2 mm sieve and was analyzed for chemical properties. The results of initial soil analysis are furnished in Table 2.

2.2 Treatment

With fifteen treatments, the experiment was set up in RCBD (p=0.05) and replicated three times with a net plot size of 3.8 m × 2.1 m. The experiment used the KMR 301 variety, with prescribed nitrogen, phosphorus, and potassium dosages of 100: 50: 50 kg, N: P_2O_5: K_2O kg ha^{-1} in the form of urea, single super phosphate (SSP), and muriate of potash, respectively, and FYM at 10 t ha^{-1} applied to all plots. Before transplanting the seedlings, borax ($Na_2B_4O_7$.10H2O containing 11 percent B) and gypsum ($CaSO_4$. $2H_2O$ containing 29 per cent Ca and 24 per cent S, as a source of calcium and sulphur) were mixed with the soil at the appropriate dosage according to treatment.

The treatment details are as follows:

T_1= RDF+FYM, $T_2 = T_1$ + 5 kg ha^{-1} borax, $T_3 = T_1$ + 10 kg ha^{-1} borax, $T_4 = T_1$ + 15 kg ha^{-1} borax, $T_5 = T_1$ + 20 kg ha^{-1} borax, $T_6 = T_1$ + 100 kg ha^{-1} gypsum, $T_7 = T_1$ + 200 kg ha^{-1} gypsum, $T_8 = T_2$ +100 kg ha^{-1} gypsum, $T_9 = T_2$ + 200 kg ha^{-1} gypsum, $T_{10} = T_3$ + 100 kg ha^{-1} gypsum, $T_{11}= T_3$ + 200 kg ha^{-1} gypsum, $T_{12} = T_4$ +100 kg ha^{-1} gypsum, $T_{13} = T_4$ +200 kg ha^{-1} gypsum, $T_{14}= T_5$ + 100 kg ha^{-1} gypsum, $T_{15}= T_5$ + 200 kg ha^{-1} gypsum

2.3 Chemical Analysis of Soil and Plant Samples

Soil samples (0-15 cm) collected from each plot after layout of experiment, at flowering stage and after the harvest of crop. The samples will be processed and used for analysis. Soil texture was analysed using International pippet method (Piper, 1966). Soil pH was measured in 1:2.5 soil: water suspension, using pH meter [6]. The clear supernatant solution of the soil - water suspension was taken out and electrical conductivity was measured by using conductivity bridge [6] and expressed as dS m^{-1}. Soil organic carbon was estimated by Walkley and Black wet oxidation method as described by Jackson [6] and expressed as g kg^{-1}. Soil available nitrogen was determined by alkaline permanganate method as described by Subbaiah and Asija (1956) and expressed as kg ha^{-1}. The available phosphorus in the soil was extracted with Olsen's reagent. The extracted phosphorus was then estimated by chlorostannous reduced molybdophosphoric blue colour method. The intensity of blue colour was read in spectrophotometer at 660 nm [6]. Available potassium was extracted from the soil with neutral normal ammonium acetate solution and potassium present in the extractant was estimated using flame photometer as described by Jackson [6]. Exchangeable calcium and magnesium was estimated from neutral normal ammonium acetate extract of the soil by titration with standard versenate solution using murexide and EBT indicators respectively for calcium and calcium plus magnesium. The difference between the value of calcium plus magnesium and calcium gives the amount of exchangeable magnesium [6]. The values are expressed in cmol. kg^{-1} soil. Soil was extracted using 0.15 per cent calcium chloride solution, and the sulphur content was determined by Turbidometry by precipitating sulphur as barium sulphate and turbidity measured at 420 nm using spectrophotometer [7]. The values are expressed in mg kg^{-1}. Hot water soluble boron in the soil sample was determined by Azomethine-H method (Berger and Truog, 1939) using spectrophotometer. The values are expressed in mg kg^{-1}.

2.4 Statistical Analysis

The results from the experiment at various phases of growth were statistically analysed, as reported by Gomez & Gomez [8]. P = 0.05 was chosen as the criterion of significance in the F and t tests. When the F test was determined to be significant, critical difference (CD) values were generated for the P = 0.05.

3. RESULTS AND DISCUSSION

The soil texture at the test site was sandy loam, and the soil reaction was neutral (pH, 7.44). The organic carbon content was low (3.9 g kg^{-1}) and the electrical conductivity was normal (0.13 dSm^{-1}) (Table 1). The soil has a low available N content (175.6 kg ha-1) and a medium available K2O concentration (231.16 and 25.25 kg ha-1, respectively). The amount of available B and S content was low (0.28 and 8.5 mg kg^{-1} respectively).

3.1 Climatic Condition

The crop received more than normal rainfall during the month of August, whereas in the month of September and October there was nearly 85 mm deficit rainfall. Maximum relative humidity of 92.3 was recorded in the month of August and the minimum relative humidity of 54.7 was also recorded in the month of September during crop growth. Maximum mean daily sun shine hours were recorded in the month of October and minimum in September. The crop growth suffered at tillering stage due to lower mean sun shine hours recorded during the month of September (2.5 hours) (Fig. 1).

3.2 Effect of Application of Graded Levels of Borax and Gypsum on Grain and Straw Yield in Irrigated Finger Millet

Application of 15 kg borax ha^{-1} + 100 kg gypsum ha^{-1}+ RDF + FYM recorded significantly higher grain and straw yield (45.95 q ha^{-1}, 65.42q ha^{-1} respectively) followed by T_4 (44.58 q ha^{-1} , 64.85 q ha^{-1} respectively) when compared to T_1 (37.88 q ha^{-1} , 53.45 q ha^{-1} respectively with RDF + FYM only (Table 2). However, treatments like T_3 (T_1+5 kg borax ha-1), T_{13} (T_4 + 200 kg gypsum ha^{-1}) and T_{10} (T_3+100 kg gypsum ha^{-1}) recorded on par yield. The other treatments recorded statistically non significant when compared to T_1. Significant increase in grain yield in T_{12} was due to more number of tillers per hill, ear heads per square meter and number of fingers per ear head. Finger millet has considerable capacity to produce more number of tillers per hill under optimum borax and gypsum fertilization specially in low B soils. Grain yield increase may be due to the reason that the application of boron which has enhanced pollen tube germination and grain setting. Boron requirement in the anthers for successful fertilization was met by application of boron at booting stage and the grain yield was higher than control [9]. Similar results were obtained by Mishra et al. [10] and Ramachandrappa et al. [11]. Chitralekha et al. [12] also have observed that when both calcium and boron were applied, calcium did not bring about desired changes but application of boron to the deficient soil resulted in good response.

The grain and straw yield were significantly reduced in T_5 treatment which received 20 kg borax ha^{-1} along with recommended NPK and FYM which might be attributed to the negative effect of excess B application on plant growth. [13,14] have reported that excess B resulted in reduced vigour, stunted plant growth, delayed development, decreased number, size and weight of fruits and discoloration of leaves. The present study treatments T_{14} and T_{15} which received 20 kg borax ha^{-1} along with 100 kg gypsum ha^{-1} and 200 kg gypsum ha^{-1} respectively, decrease in yield due to boron toxicity is less when compared to application of 20 kg borax ha^{-1} alone because plants can tolerate higher amount of boron without any toxic effect if they have adequate supply of calcium [12].

3.3 Effect of Application of Borax and Gypsum on Electro-chemical Properties and Available Nutrient Status of Soil at Flowering Stage and at Harvest of the Crop

3.3.1 Electro-chemical properties of soil

The data presented in Table 3 reveals that there was no significant effect of different treatments on soil pH, electrical conductivity and organic carbon content at flowering stage and at harvest of the crop. Soil pH, electrical conductivity and organic carbon content did not differ significantly due to treatments effect. However, the lowest pH was noticed in T_4 treatment at flowering stage and harvest of the crop (7.49 and 7.43, respectively) and higher was recorded in T_{12} (flowering stage) and T_{10} (after harvest) treatment which recorded 7.65 and 7.67, respectively. While the lowest EC value of 0.09 d Sm^{-1} was recorded in T_{10} T_3 and T_{15} in flowering stage and higher was recorded in T_9 (0.14 dsm^{-1}), at harvest of and higher in T_6 and T_{10} (0.14 d sm^{-1}). With regard to organic carbon content, the highest values were noticed at flowering stage and at harvest of crop in T_{13} and T_4, respectively (4.0 and 4.5 g kg^{-1}, respectively) and minimum (3.3 g kg^{-1}) value was noticed in T_4 and T_{15} treatments, respectively at both the crop stages. The pH and EC at flowering stage slightly increased from initial EC in gypsum treated plots, because of application of higher dose gypsum. Electrical conductivity has a negative relationship with water soluble boron content in soil [15]. Organic carbon did not change significantly among treatments at flowering stage and after harvest of crop. These results are in line with Arya et al. [16]. Major nutrients data presented in Table 4 reveals that the effect of different treatments on nitrogen, phosphorous and potassium content at flowering and post harvest soil did not differ significantly due to treatments effect. Available N content at flowering stage and post harvest soil was found to be non significant. Numerically higher values recorded in T_5 (T_1+ 20 kg borax ha^{-1}) and T_9 (T_2 + 200 kg gypsum ha^{-1}) treatments which recorded 225.79 and 200.70 kg ha^{-1}, respectively in flowering and after harvest of crop. However, lowest nitrogen noticed in treatments T_8 and T_1 (179.80 and 171.43 kg ha^{-1}, respectively).

The available phosphorous in soil at flowering and after harvest did not differ significantly among the treatments. However, numerically higher phosphorous in T_8 at flowering stage (57.00 kg ha^{-1}) and T_6 (45.65 kg ha^{-1}) after harvest of crop was recorded in treatments which received T_5 + 100 kg gypsum ha^{-1} and T_1+ 100 kg gypsum ha^{-1}, respectively. The lower phosphorous content of 38.00 and 31.39 kg ha^{-1} was observed in T_{11} (T_3 + 200 kg gypsum ha^{-1}) and T_2 (T_1 + 5 kg borax ha-1) treatments in flowering stage an after harvest of the crop and rest of the treatments values are intermediate. The available potassium in soil at flowering and after harvest did not differ significantly among the treatments. However, numerically higher potassium of 333.23 and 294.59 kg ha^{-1} was The lower potassium content of 291.68 and 235.79 kg ha^{1} were observed in T_8 (T_2 + 100 kg gypsum ha^{-1}) and T_{12} (T_4 + 100 kg gypsum ha^{-1}) treatments, respectively and rest of the treatments are intermediate. Available N, P_2O_5 and K_2O were not influenced significantly at flowering stage and at harvest of finger millet by graded levels of borax and gypsum application. Higher NPK values in all treatments observed at flowering stage compared to after harvest of crop. The minor differences in the values could be attributed to the differences in the crop uptake of different nutrients due to different treatments which could again be related to yield levels. These results are in accordance with Tariq and Mott [17]. recorded in treatment T_6 (T_1+100 kg gypsum ha^{-1}) at both the growth stages, respectively.

Secondary nutrients and boron The data on exchangeable calcium, magnesium, sulphur and boron as influenced by application of graded levels of borax and gypsum at flowering and after harvest of crop presented in Table 5 and 6. Exchangeable Ca content at flowering stage was found to be non significant among treatments (Table 5). Numerically higher values recorded in T_7 (T_1+ 200 kg gypsum ha^{-1}) and T_9 (T_2 + 200 kg gypsum ha^{-1}) which recorded 4.92 and 4.81 cmol kg^{1} followed by T_6 (4.61 cmol kg^{-1}). However, lowest calcium noticed in T_1 (RDF + FYM) with 4.08 cmol kg^{-1}. Significantly higher exchangeable calcium content after harvest was observed in T_{10} (T_3 + 100 kg gypsum ha^{-1}) with 6.77 cmol kg^{-1} compared to T_1 (5.23 cmol kg^{-1}). All other treatments were on par with T_{10} except T_2 (T_1+ 5 kg borax ha^{-1}), T_3 (T_1+ 10 kg borax ha^{-1}), T_4 (T_1+ 15 kg borax ha^{-1}), T_5 (T_1+ 20 kg borax ha^{-1}) and T_8 (T_2 + 100 kg gypsum ha^{-1}) treatments which recorded 5.63, 5.53, 5.57, 5.13 and 5.53 cmol kg^{-1}, respectively. Exchangeable Mg content in flowering stage was found to be non significant among treatments (Table 5). Higher values are obtained in T_2 (T_1+ 5 kg borax ha^{-1}) lowest magnesium noticed in T_{12} (2.17 cmol kg^{-1}) which received only 15 kg borax ha^{-1}+ 100 kg gypsum ha^{-1}+ RDF + FYM. The magnesium content at post harvest soil did not differ significantly among the treatments. However, the numerically higher Mg content 1.73 cmol kg^{-1} was found in treatment T_7 which received 200 kg ha^{-1}+ RDF + FYM. However, the lower Mg content was observed in treatment T_4 (1.07 cmol kg^{-1}) which received 15 kg borax ha^{1}+ RDF + FYM. The calcium content in soil at flowering stage showed non significant difference due to treatments effect and after harvest of crop it showed significantly higher values in T_{10} (6.77 cmol kg^{-1}) which received 10 kg borax ha^{-1} + 100 kg gypsum ha^{-1} + RDF + FYM when compared to gypsum untreated plots (Table. 5). Higher values of Ca are obtained in higher dose gypsum treated plots compared to untreated due to frequent release of Ca from gypsum. The results are in line with Tariq and Mott [17]. Cox and Reid [18] reported that there was no interaction between the effect of calcium and boron application on uptake of the nutrient into the plants. Available magnesium content in soil was not influenced significantly at flowering stage and at harvest of finger millet by graded levels of borax and gypsum application. Lowest Mg content in soil after harvest of crop observed in T_4 (1.07 cmol kg^{-1}) which received only borax along with RDF.

Sulphur content in soil at flowering stage and after harvest of crop was found to be significant among the treatments due to application of different levels of borax and gypsum Table 6. At flowering stage, significantly higher sulphur content of 16.71 mg kg^{-1} was recorded in T_{15} (T_5 + 200 kg gypsum ha^{-1}) followed by T_{13} (T_4 + 200 kg gypsum ha^{-1}) (16.46 mg kg^{-1}) as compared to control (10.03 mg kg^{-1}). T_{15} was on par with all other treatments except T_2 (T_1+5 kg borax ha^{-1}), T_3 (T_1+10 kg borax ha^{-1}) and T_4 (T_1+15 kg borax ha^{-1}) (11.27, 11.52 and 10.99 mg kg^{-1}, respectively). Significantly higher sulphur content of 34.15 mg kg^{-1} was recorded in T_{14} (T_5 + 100 kg gypsum ha^{-1}) followed by T_{15} (T_5 + 200 kg gypsum ha^{-1}) (33.65 mg kg^{-1}) as compared to T_1 (25.34 mg kg^{-1}) at harvest. T_{14} was on par with all other treatments except T_2 (T_1+5 kg borax ha^{-}), T_3 (T_1+10 kg borax ha^{-1}), T_4 (T_1+15 kg borax ha^{-1}), T_5 (T_1+20 kg borax ha^{-1}) and T_9 treatments with 25.13, 24.97, 26.22, 27.22 and 30.70 mg kg^{-1}, respectively.

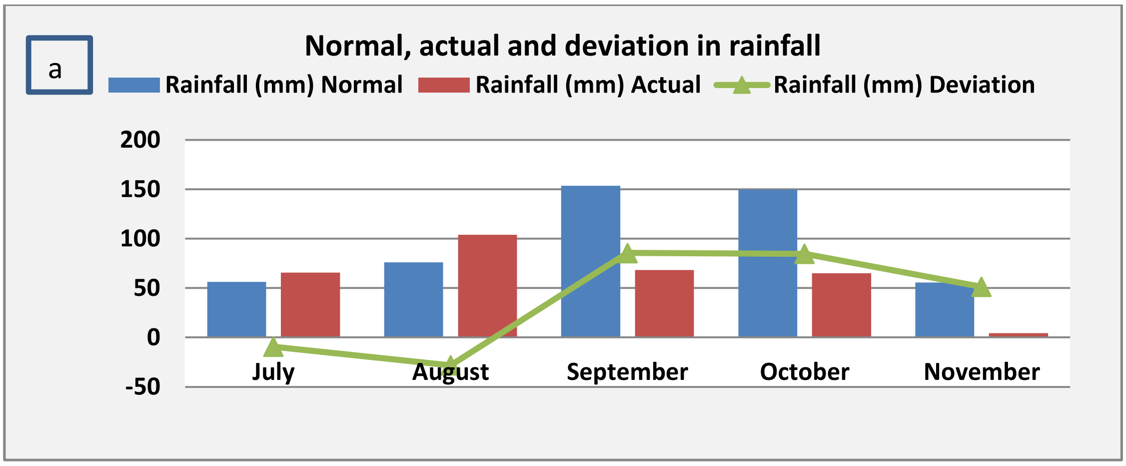
The data presented in Table 6 reveals that the effect of different treatments on boron content at flowering stage and post harvest soil differed significantly due to treatments effect. Significantly higher boron content at flowering stage was observed in T_5 (T_1+20 kg borax ha^{-1}) (4.18 mg kg^{-1}) followed by T_{15} (T_5 + 200 kg gypsum ha^{-1}) (4.09 mg kg^{-1}) compared to T_1 (0.21 mg kg^{-1}) which received RDF + FYM only. All other treatments were on par with T_5 except T_2 (T_1+5 kg borax ha^{-1}), T_6 (T_1+ 100 kg gypsum ha^{-1}) and T_7 (T_1+200 kg gypsum ha^{-1}) treatments which recorded 1.88, 1.30 and 1.58 mg kg^{-1}. The plots that received gypsum and borax had significantly higher content of available S and B respectively, than those which were not applied gypsum and borax. Application of 20 kg borax ha^{-1} + 200 kg gypsum ha^{-1} treated plots T_{15} (16.71 and 33.65 mg kg^{-1}) showed high S content in soil at flowering and at harvest. The reason for this could be attributed to the release of S from $CaSO_4$ to the soil. After utilization of part of the released S from $CaSO_4$, the left over amount might have contributed to the soil available pools of sulphur.

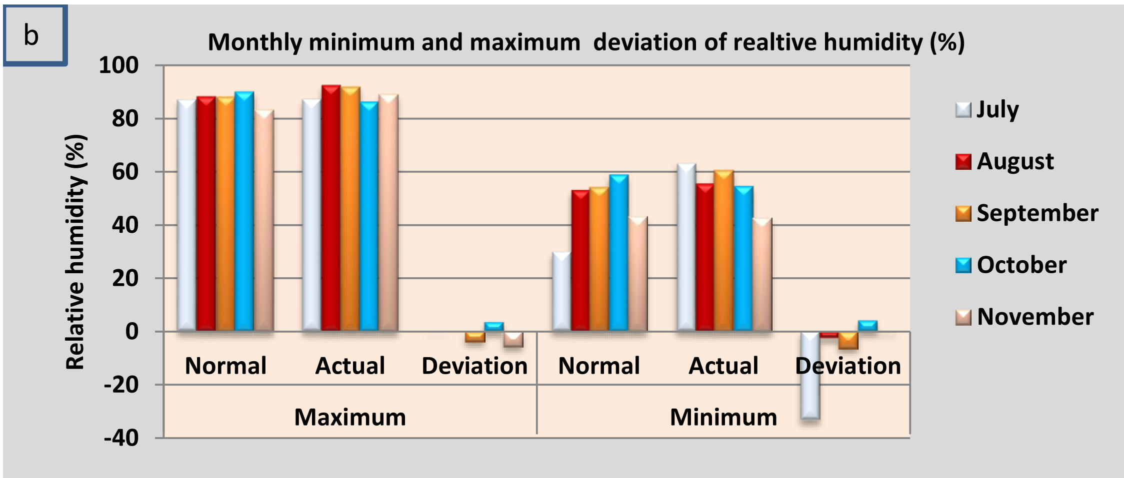
Table 1. Physico - chemical properties of soil at the experimental site

Sl.No	Soil property	Value	Method
1.	Particle size analysis		International pipette method
	a. Sand (%)	84.03	-
	b. Silt (%)	2.00	-
	c. Clay (%)	13.55	-
	Texture	Sandy loam	-
2.	pH (1:2.5 soil : water suspension)	7.44	Jackson, [6]
3.	Electrical conductivity(dSm^{-1})	0.13	Jackson, [6]
4.	Organic carbon (g kg^{-1})	3.90	Walkley and Black wet oxidation method [6]
5.	Available nitrogen (kg ha^{-1})	175.6	Alkaline permanganate method by Subbaiah and Asija (1956)
6.	Available phosphorus (kg ha^{-1})	25.25	Jackson, [6]
7.	Available potassium (kg ha^{-1})	231.16	Jackson, [6]
8.	Exchangeable calcium (cmol kg^{-1})	5.70	Jackson, [6]
9.	Exchangeable magnesium (cmol kg^{-1})	2.40	Jackson, [6]
10.	Available sulphur (mg kg^{-1})	8.50	Turbidometry [7].
11.	Available boron (mg kg^{-1})	0.28	Azomethine-H method [21]

Table 2. Influence of graded levels of borax and gypsum on grain and straw yield of finger millet

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1 : RDF+FYM	37.88	53.45
T_2 : T_1 + 5 kg ha^{-1} borax	39.41	56.27
T_3 : T_1 + 10 kg ha^{-1} borax	43.24	62.68
T_4 : T_1 + 15 kg ha^{-1} borax	44.58	64.85
T_5 : T_1 + 20 kg ha^{-1} borax	38.81	56.09
T_6 : T_1 + 100 kg ha^{-1} gypsum	40.24	56.34
T_7 : T_1 + 200 kg ha^{-1} gypsum	40.62	56.46
T_8 : T_2 +100 kg ha^{-1} gypsum	40.67	56.43
T_9 : T_2 + 200 kg ha^{-1} gypsum	38.93	56.40
T_{10}: T_3 + 100 kg ha^{-1} gypsum	42.45	62.16
T_{11}: T_3 + 200 kg ha^{-1} gypsum	40.33	58.88
T_{12}: T_4 +100 kg ha^{-1} gypsum	45.95	65.42
T_{13}: T_4 +200 kg ha^{-1} gypsum	42.90	62.56
T_{14}: T_5 + 100 kg ha^{-1} gypsum	41.36	57.19
T_{15}: T_5 + 200 kg ha^{-1} gypsum	39.97	55.32
S.Em±	**1.55**	**2.64**
CD (p=0.05)	**4.50**	**7.64**





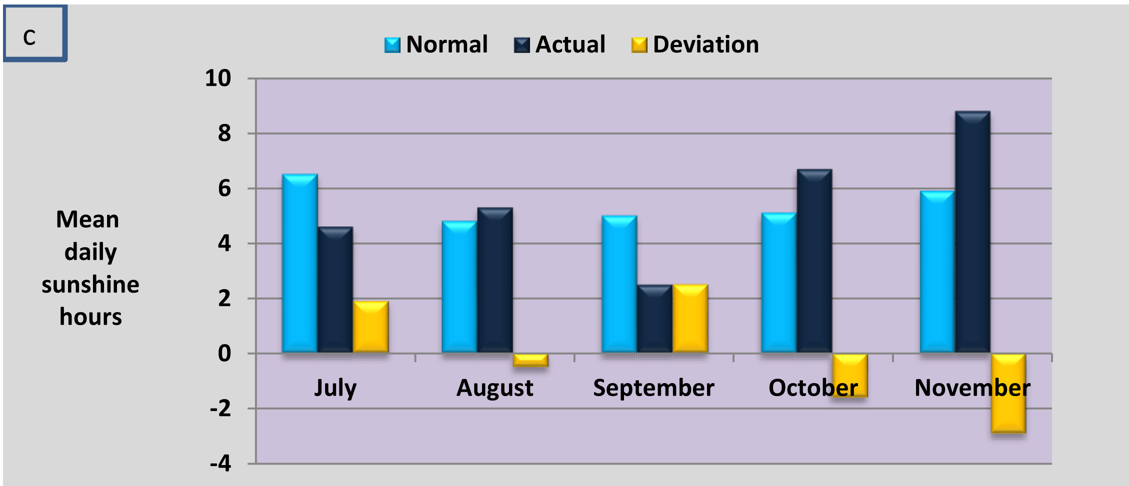


Fig. 1. Mean monthly normal, actual and deviation of (a) rainfall (mm) (b) Relative humidity (%) (c) Mean daily sunshine hours for the experimental period (2016) at College of Agriculture, V. C. Farm, Mandya

Table 3. Soil pH, EC and OC content of soil as influenced by application of graded levels of borax and gypsum at flowering and at harvest of crop

Treatment	pH		EC ($dS\ m^{-1}$)		OC ($g\ kg^{-1}$)	
	At flowering	At harvest	At flowering	At harvest	At flowering	At harvest
T_1 : RDF+FYM	7.56	7.52	0.11	0.12	3.5	3.8
T_2 : T_1 + 5 kg ha^{-1} borax	7.50	7.44	0.10	0.10	3.9	4.3
T_3 : T_1 + 10 kg ha^{-1} borax	7.51	7.57	0.09	0.11	3.5	3.9
T_4 : T_1 + 15 kg ha^{-1} borax	7.49	7.43	0.12	0.12	3.3	4.5
T_5 : T_1 + 20 kg ha^{-1} borax	7.51	7.58	0.10	0.13	3.8	4.0
T_6 : T_1 + 100 kg ha^{-1} gypsum	7.63	7.46	0.11	0.14	3.5	3.9
T_7 : T_1 + 200 kg ha^{-1} gypsum	7.50	7.52	0.12	0.11	3.6	4.1
T_8 : T_2 +100 kg ha^{-1} gypsum	7.58	7.53	0.11	0.13	3.7	3.9
T_9 : T_2 + 200 kg ha^{-1} gypsum	7.51	7.62	0.14	0.13	3.7	4.1
T_{10}: T_3 + 100 kg ha^{-1} gypsum	7.59	7.67	0.09	0.14	3.5	3.8
T_{11}: T_3 + 200 kg ha^{-1} gypsum	7.56	7.63	0.10	0.09	3.8	3.9
T_{12}: T_4 +100 kg ha^{-1} gypsum	7.65	7.61	0.10	0.11	3.8	4.1
T_{13}: T_4 +200 kg ha^{-1} gypsum	7.62	7.61	0.12	0.13	4.0	3.8
T_{14}: T_5 + 100 kg ha^{-1} gypsum	7.56	7.56	0.10	0.11	3.5	3.7
T_{15}: T_5 + 200 kg ha^{-1} gypsum	7.61	7.64	0.09	0.11	3.7	3.3
S.Em±	**0.04**	**0.06**	**0.01**	**0.02**	**0.01**	**0.03**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4. Available NPK content of soil at flowering and harvest as influenced by graded levels of borax and gypsum application

Treatments	Nitrogen ($kg\ ha^{-1}$)		Phosphorous ($kg\ ha^{-1}$)		Potassium ($kg\ ha^{-1}$)	
	At flowering	At harvest	At flowering	At harvest	At flowering	At Harvest
T_1 : RDF+FYM	196.52	171.43	48.22	38.98	294.49	253.46
T_2 : T_1 + 5 kg ha^{-1} borax	204.89	175.62	41.16	31.39	297.17	243.44
T_3 : T_1 + 10 kg ha^{-1} borax	199.72	181.56	45.73	40.77	300.30	241.68
T_4 : T_1 + 15 kg ha^{-1} borax	192.34	179.80	40.36	40.81	326.96	288.72
T_5 : T_1 + 20 kg ha^{-1} borax	225.79	188.16	50.93	45.58	324.61	255.79
T_6 : T_1 + 100 kg ha^{-1} gypsum	208.18	193.23	46.83	45.65	333.23	294.59
T_7 : T_1 + 200 kg ha^{-1} gypsum	188.56	185.08	49.20	44.64	317.55	265.20

Treatments	Nitrogen (kg ha^{-1})		Phosphorous (kg ha^{-1})		Potassium (kg ha^{-1})	
	At flowering	At harvest	At flowering	At harvest	At flowering	At Harvest
T_8 : T_2 +100 kg ha^{-1} gypsum	179.80	188.16	51.00	39.16	291.68	244.03
T_9 : T_2 + 200 kg ha^{-1} gypsum	183.98	200.70	45.53	37.99	328.53	284.60
T_{10}: T_3 + 100 kg ha^{-1} gypsum	200.70	175.62	40.89	35.18	324.61	269.90
T_{11}: T_3 + 200 kg ha^{-1} gypsum	209.07	179.80	38.00	37.24	299.41	253.44
T_{12}: T_4 +100 kg ha^{-1} gypsum	204.89	193.49	45.45	40.52	297.17	235.79
T_{13}: T_4 +200 kg ha^{-1} gypsum	204.89	173.86	45.46	43.22	305.01	258.32
T_{14}: T_5 + 100 kg ha^{-1} gypsum	188.16	179.71	48.92	38.20	315.98	267.55
T_{15}: T_5 + 200 kg ha^{-1} gypsum	204.89	183.98	38.64	40.72	308.14	254.39
S.Em±	**14.07**	**7.84**	**3.04**	**2.80**	**11.92**	**15.82**
CD (p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 5. Calcium and magnesium content of soil at flowering and harvest stage as influenced by graded levels of borax and gypsum application

Treatment details	Calcium (cmol kg^{-1})		Magnesium (cmol kg^{-1})	
	At flowering	At flowering	At flowering	At harvest
T_1 : RDF+FYM	4.08	2.27	2.27	25.34
T_2 : T_1 + 5 kg ha^{-1} borax	4.18	2.47	2.47	25.13
T_3 : T_1 + 10 kg ha^{-1} borax	4.16	2.40	2.40	24.97
T_4 : T_1 + 15 kg ha^{-1} borax	4.26	2.37	2.37	26.22
T_5 : T_1 + 20 kg ha^{-1} borax	4.20	2.40	2.40	27.22
T_6 : T_1 + 100 kg ha^{-1} gypsum	4.61	2.33	2.33	31.78
T_7 : T_1 + 200 kg ha^{-1} gypsum	4.92	2.30	2.30	32.20
T_8 : T_2 +100 kg ha^{-1} gypsum	4.44	2.47	2.47	31.01
T_9 : T_2 + 200 kg ha^{-1} gypsum	4.81	2.30	2.30	30.70
T_{10}: T_3 + 100 kg ha^{-1} gypsum	4.26	2.37	2.37	34.33
T_{11}: T_3 + 200 kg ha^{-1} gypsum	4.65	2.40	2.40	33.72
T_{12}: T_4 +100 kg ha^{-1} gypsum	4.57	2.17	2.17	33.59
T_{13}: T_4 +200 kg ha^{-1} gypsum	4.47	2.20	2.20	32.35
T_{14}: T_5 + 100 kg ha^{-1} gypsum	4.20	2.33	2.33	34.15
T_{15}: T_5 + 200 kg ha^{-1} gypsum	4.84	2.30	2.30	33.65
S.Em±	**0.29**	**0.13**	**0.13**	**1.96**
CD (p=0.05)	**NS**	**0.35**	**NS**	**5.67**

Table 6. Sulphur and boron content of soil at flowering and harvest stage as influenced by graded levels of borax and gypsum application

Treatment details	Sulphur (mg kg^{-1})		Boron (mg kg^{-1})	
	At flowering	At harvest	At flowering	At harvest
T_1 : RDF+FYM	10.03	25.34	0.82	0.76
T_2 : T_1 + 5 kg ha^{-1} borax	11.27	25.13	1.88	1.54
T_3 : T_1 + 10 kg ha^{-1} borax	11.52	24.97	2.64	2.35
T_4 : T_1 + 15 kg ha^{-1} borax	10.99	26.22	2.92	2.54
T_5 : T_1 + 20 kg ha^{-1} borax	12.83	27.22	4.18	3.88
T_6 : T_1 + 100 kg ha^{-1} gypsum	13.10	31.78	1.30	1.20
T_7 : T_1 + 200 kg ha^{-1} gypsum	15.75	32.20	1.58	1.30
T_8 : T_2 +100 kg ha^{-1} gypsum	13.61	31.01	2.02	1.52
T_9 : T_2 + 200 kg ha^{-1} gypsum	14.63	30.70	2.36	1.74
T_{10}: T_3 + 100 kg ha^{-1} gypsum	13.49	34.33	2.81	2.02
T_{11}: T_3 + 200 kg ha^{-1} gypsum	14.17	33.72	3.36	2.73
T_{12}: T_4 +100 kg ha^{-1} gypsum	13.27	33.59	3.58	2.56
T_{13}: T_4 +200 kg ha^{-1} gypsum	16.46	32.35	3.76	2.97
T_{14}: T_5 + 100 kg ha^{-1} gypsum	13.36	34.15	3.74	3.19
T_{15}: T_5 + 200 kg ha^{-1} gypsum	16.71	33.65	4.09	3.68
S.Em±	**0.90**	**1.96**	**0.20**	**0.19**
CD (p=0.05)	**2.60**	**5.67**	**0.59**	**0.55**

High levels of borax applied treatments, i. e. T_5 (T_1+20 kg borax ha^{-1}) and T_{15} (T_5 + 200 kg gypsum ha^{-1}) recorded significantly higher content of B at flowering stage (4.18 and 4.09 mg kg^{-1}, respectively) and at harvest of crop (3.88 and 3.68 mg kg^{-1}, respectively) when compared to T_1 (1.32 and 1.16 mg kg^{-1}, respectively). High boron content in soil was observed in borax alone treatment compared to borax and gypsum combination treatment. The reason for this could be attributed to less extractable boron in soil solution in gypsum treated plots due to high amount Ca in soil solution leads to conversion of soluble boron to less soluble calcium metaborate complex. These results are in accordance with Chitralekha et al*.* [12]. Tariq and Mott [17] reported that concentration of boron increases with decreasing the Ca/B ratio in soil solution. These same was reported with work of Golakiya and Patel [19]. The application of Ca could reduce the availability of B by localization of Ca in cell wall which leads to decrease in cell wall boron permeability Murat et al. [20].

4. CONCLUSION

Soil application of 15 kg borax ha-1 and 100 kg gypsum ha-1 along with RDF + FYM increased the finger millet yield by 17.56 per cent when compared to RDF practices in boron deficient soil. The plots that received gypsum and borax had significantly higher content of available Ca, S and B respectively at harvest stage, than those which did not receive gypsum and borax. Due to the frequent release of Ca from gypsum, greater Ca values are found in higher dosage gypsum treated plots compared to untreated plots. Development of a calcium-metaborate complex, high boron concentration in soil was found in the borax alone treatment at both growth stages compared to the borax and gypsum combination treatment. Finger millet absorption of boron may be reduced by using borax with a greater dosage of gypsum (200 kg ha^{-1}). As a result, optimising the Ca/B ratio in the soil and plant is critical for increasing irrigated finger millet yields.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sakamma S, Umesh KB, Girish MR, Ravi SC, Satishkumar M, Veerabhadrappa Bellundagi. Finger millet (*Eleusine coracana* L. Gaertn.) production system: Status, potential, constraints and implications for improving small farmer's welfare. Journal of Agricultural Science, 2018;10(1):162-17.
2. Agricultural Statistics as a Glance. Government of India, Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics and Statistics; 2017.
3. Anonymous. Micronutrient management for enhancing the productivity of finger millet-pulse-oil based productivity system for Alfisols of Karnataka. Annual report of micronutrient project 2006-07, All India Coordinated Research Project for Dry land Agriculture, University of Agricultural Sciences, Bangalore. 2007;39-52
4. Matoh T, Ishigaki KI, Mizutani M, Matsunaga W, Takabe K. Boron nutrition of cultured tobacco BY-2 cells: I. Requirement for and intracellular localization of boron and selection of cells that tolerate low levels of boron. Plant and cell physiology. 1992;33(8):1135-1141.
5. Kanwal S, Rahmatullah Aziz T, Maqsood MA, Abbas N. Critical ratio of calcium and boron in maize shoot for optimum growth. J. Pl. Nutri. 2008;31:1535-1542.
6. Jackson ML. Soil chemical analysis. Prentice Hall India Pvt. Ltd., New Delhi; 1973.
7. Black CA. Method of soil analysis part II agronomy monograph No, 9, American Society of Agronomy, Madison, Wisconsin. 1965;148.
8. Gomez KA, Gomez AA. Statistical procedures for Agric. Res. 2nd Ed. John Wiley & Sons, New York; 1984.
9. Tahir M, Tanveer A, Tajamal HS, Naeem F, Allah W. Yield response of wheat (*Triticum aestivum* L.) to boron application at different growth stages. Pakisthan J. life soc. Sci. 2009;7(1):39-42.
10. Mishra SS, Gulati JML, Nanda SS, Garnayk LM, Jana SN. Micronutrient studies in wheat. Orissa J. Agri. Res. 1989;22(2):94-96.

11. Ramachandrappa BK, Sathish A, Dhanapal GN, Srikanth Babu PN. Nutrient management strategies for enhancing productivity of dry land crops in Alfisols. Indian J. Dryl. Agric. Res & Dev. 2014;29(2):49-55.
12. Chitralekha C, Pratima S, Nirmala N, Shirish CA, Chandra PS. Metabolic changes associated with boron-calcium interaction in maize. Soil Sci. Pl. Nutr. 1987;33(4):607-617.
13. Lovatt CJ, Bates LM. Early effects of excess boron on photosynthesis and growth of Cucurbita pepo. J. Exp. Bot. 1984;35:297–305.
14. Nable RO, Ba˜Nuelos GS, Paull JG. Boron toxicity. Pl. Soil. 1997;193:181–198.
15. Bhumbla D, R, Chhabra R, Abrol I, L. Annual report, Central Soil Salinity Res. Ins., Karnal, India. 1980;20-25.
16. Arya VS, Balraj D, Balwan S, Anoop S. Effect of boron in irrigation of different EC and SAR levels on yield and its concentration in wheat grain and straw. Haryana J. Agron., 2009;25(1/2):39-42.
17. Tariq M, Mott CJB. Effect of boron on the behaviour of nutrients in soil-plant systems. Asian J. Pl. Sci. 2006;6:195-202.
18. Cox FR, Reid PH. Calcium-boron nutrition as related to concealed damage in peanuts 1. Agronomy Journal. 1964;56(2):173-176.
19. Golakiya VK, Patel MS. Effect of calcium carbonate and boron application on yield and nutrient uptake by groundnut. J. Indian Soc. Soil Sci. 1986;34(4):815-820.
20. Murat AT, Nilgun T, Süleyman T. Effect of calcium on the alleviation of boron toxicity and localization of boron and calcium in cell wall of wheat. Not. Bot. Hort. Agrobot. 2009;37(2):99-103.
21. Page AL, Miller RH, Kenay DR. Methods of soil analysis part-2 soil science of America. Inc. Pubis. Madison, Wisconsin, USA; 1982.

APPENDIX-I

Calendar of operations during growth period of finger millet

Sl. no.	Date	Particulars
1	12-07-2016	Sowing in nursery
2	17-07-2016	FYM application and land levelling
3	01-08-2016	Layout of the experiment
4	03-08-2016	Soil apllication of borax and gypsum along with full dose of P_2O_5, K_2O and half dose of N during transplanting of seedlings.
5	05-08-2016	pre emergence herbicide Londax power is applied at 4kg/ acre .
6	03-09-2016	Weeding and intercultivation along with application of remaining dose of N.
7	02-11-2016	Harvesting.

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