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Effect of Boron on Nutritional Quality of Groundnut Grown in Coastal Sandy Soils

K. M. Haneena[1*], P. Venkata Subbaiah[2], Ch. Sujani Rao[3] and K. Srinivasulu[4]

[1]Department of Soil Science and Agricultural Chemistry, Agricultural College, Bapatla, Andhra Pradesh, India.
[2]Saline Water Scheme, Agricultural College Farm, Bapatla, India.
[3]Department of Environmental Science and Technology, APGC, Lam, Guntur, India.
[4]Department of Agronomy, Agricultural College, Bapatla, India.

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

Aim: To study the effect of boron on quality parameters and micronutrient uptake of groundnut in coastal sandy soils.
Study Design: The experiment laid out in randomized block design with three replications.
Place of Study: At College Farm, Agricultural College, Bapatla, Guntur.
Methodology: After the preliminary layout, the TAG-24 variety of groundnut was used as a test crop, with a spacing of 30 cm x 10 cm in the experimental site. Plant samples were collected at 45, 90 DAS, and harvest. Plant samples were shade dried and kept in hot air oven at 75°C until a constant weight was obtained. Samples were powdered and then analysed for micronutrients using standard chemical procedures.
Results: Protein content, boron content and uptake of micronutrients viz., iron, zinc, manganese, copper and boron were significantly improved with the application of boron in groundnut. Oil content and oil yield were not significantly influenced by the application of boron. The highest value of all these parameters were recorded in T_4 (RDF + soil application of Borax @ 12.5 kg/ha).
Conclusion: Application of boron along with RDF improved the nutritional quality of groundnut in coastal sandy soils.

Keywords: Groundnut; boron; micronutrient uptake.

**Corresponding author: E-mail: haneenakm201541434@gmail.com;*

1. INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important leguminous oilseed crop grown in tropics and subtropics. It is used as oil seed as well as food crop. It is known as "king of oilseeds" owing to its high oil content. It contains about 50 % oil, 25-30 % protein, 20 % carbohydrate and 5 % fiber and ash which make a substantial contribution to human. Peanuts contain 13 different vitamins including A, B, C and E groups, 26 essential minerals like iron, potassium, calcium, phosphorus, zinc and boron. The high-energy value protein content and minerals make groundnut a rich source of nutrition at a comparatively low price. It is estimated that as much as 30% of the population from many countries in the world are suffering from malnutrition [1].Groundnut, which is a rich source of protein and essential amino acids, can help in preventing malnutrition [2].

Groundnut is mainly grown for its seed but all parts of the plant are utilized. The groundnut haulm (vines with leaves) is one of the most important peanut by-products used to supply feed to cattle. Groundnut haulms are more palatable and rich in protein compared to stovers of cereals which have low nitrogen, high fibre content, and poor digestibility and therefore have low nutritive value and are used as supplementary feed [3].

Boron is an important micronutrient required for normal plant growth and obtaining high quality crop yields [4]. Boron is neither constituent of any enzyme nor does it directly affect any enzyme activity, but it has an important role in- sugar transport, cell wall synthesis, lignification of cell wall structure, membrane integrity, carbohydrate metabolism, RNA metabolism, IAA and phenol metabolisms [5].Boron plays an important role in nodule formation of legumes. Boron helps in better establishment of roots, thus absorption and metabolic process of different nutrients. Boron improves protein and oil content of crops.

Spectacular responses of cereals, pulses, oil seeds and cash crops to B application have largely observed on B deficient soils. Increase in nutrient contents and uptake due to B application in almost all crops have been reported by several workers. Increase in protein content with the application has been reported by Mahendran et al*.* [6] in groundnut and Sarker et al*.* [7] in soybean. Higher micronutrient uptakes with application of boron was reported by Aboyeji et al*.* [8] in groundnut, Hossain et al. [9] in mustard and Niaz et al. [10] in wheat. In view of this, the present investigation was undertaken to determine the effect of boron on quality parameters and micronutrient uptake of groundnut in coastal sandy soils.

2. MATERIALS AND METHODS

The experiment was carried out at the Agricultural College Farm, Bapatla situated in Krishna Zone of Andhra Pradesh, India (150 55' N latitude and 800 30' E longitude) during *rabi* season with Randomised Block Design with nine treatments replicated thrice. TAG-24 variety of groundnut was used as a test crop, with a spacing of 30 cm x 10 cm. The treatments comprised of T_1 - RDF (35:40:50 N-P_2O_5-K_2O kg/ha through Urea, SSP and MOP along with 500 kg gypsum), T_2 - RDF + soil application of Borax @ 7.5 kg/ha, T_3 - RDF + soil application of Borax @ 10 kg/ha, T_4 - RDF + soil application of Borax @ 12.5 kg/ha, T_5 - RDF + foliar spray of Borax @ 0.1% at 45 DAS, T_6 - RDF + foliar spray of Borax @ 0.1% at 65 DAS, T_7 - RDF + foliar spray of Borax @ 0.1% @ 45 & 65 DAS, T_8 - T_2 + foliar spray of Borax @ 0.1% at 65 DAS and T_9 - T_3 + foliar spray of Borax @ 0.1% at 65 DAS. During experimentation the study area experienced average maximum and minimum temperatures of 26.2°C and 17.9°C, respectively with a total rainfall of 421 mm over 19 rainy days.

The initial composite sample collected from experimental field and analyzed for physical, physico-chemical properties and nutrient status. The results of the analyses indicated that the soil was sandy in texture with neutral reaction (pH 6.77), non-saline (EC 0.28 dS/m) and low in organic matter (1.3 g/kg). The bulk density was 1.69 Mg/m^3.The soil was low in nitrogen (113 kg/ha), phosphorus (21.79 kg P_2O_5 /ha) and potassium (112 kg K_2O /ha), sufficient in sulphur (20 ppm), iron (6.01 mg/kg), manganese (4.63 mg/kg) and copper (1.85 mg/kg) and deficient in boron (0.30 mg/kg) and zinc (0.48 mg/kg). A common dose of 35 kg nitrogen ha^{-1} was applied as urea, in two equal splits as half at basal and half at 30 DAS by taking the plot size into consideration. A common dose of phosphorus @ 40 kg/ha in the form of single super phosphate and potassium @ 50 kg/ha in the form of muriate of potash was applied as basal just before sowing. Boron is applied as soil application of borax @ 7.5 kg/ha, 10 kg/ha and 12.5 kg/ha as basal just before sowing and foliar application of borax @ 0.1 % at 45 DAS and 65 DAS as per the treatments.

The groundnut variety TAG-24 was planted in the third week of October. The crop was raised with all the standard package of practices and protection measures also timely carried out as they required.

Oil content was measured by using grain analyzer in which 100 grams of kernels were kept inside the NMR instrument and it displayed the results in percentage which was a non destructive method. The protein per cent in the seeds was calculated by multiplying the nitrogen content by a factor of 6.25. Five representative plants were collected, sun-dried and then oven dried at 70^{0}C temperature for 24 to 48 hours till the constant weight and then weighed and averaged to get data in g/plant, then calculated on hectare basis. Fe, Zn, Mn, Cu and B contents in plants were analyzed using standard procedures in the laboratory. Plant uptakes were worked out by using nutrient content and drymatter accumulation. The data were analyzed statistically following the analysis of variance (ANOVA) technique as suggested by Panse and Sukhathme [11] for Randomized block design.

Micronutrient Uptake (g/ha) = (Nutrient concentration (mg/kg) $\times$ Dry matter yield (kg/ha)/ 1000)

3. RESULTS AND DISCUSSION

3.1 Quality Parameters

3.1.1 Protein content

Protein content was significantly increased by the application of boron (Table 1). The maximum protein content (29.38%) was recorded in the treatment T_4 (RDF + soil application of Borax @ 12.5 kg/ha) and it was or par with the treatments T_9 followed by T_3, T_8, T_7, T_2, T_6 and T_5. The minimum protein content (24.06%) was recorded in treatment T_1 (RDF).

Boron has significant influence in the protein and nucleic acid metabolism, maintaining the structural integrity of the plant and protects plasma membrane from external damage. Boron improves root growth and nodulation in leguminous plants, thus stimulates nitrogen content and that might increase protein synthesis and subsequent storage of protein. Poonguzhali et al*.* [12] supported the significant increase in protein content with application of boron in groundnut.

3.1.2 Oil content and oil yield

There was non-significant influence on oil content and oil yield of groundnut the boron treatments imposed. However there was a slight increase in the boron applied treatments. Highest oil content (49.92 %) and oil yield (910.04 kg/ha) and was observed in T_4 which received RDF + soil application of Borax @ 12.5 kg/ha and the lowest oil content (47.50 %) and oil yield (647.72 kg/ha) was observed in T_1 (RDF).

The increase in oil content may be because of role of boron in the synthesis of essential amino acids, protein and lipids that acts as an electron carrier in the photosynthetic process required for production of oil. Boron also has a positive role on the enhancement of oil content perhaps due to the indirect effect on the synthesis of fat.Sarker et al*.* [7] and Cerak et al*.* [5] also reported similar results in soybean.

3.2 Micronutrient Uptake

3.2.1 Iron

There was no significant difference in iron content of groundnut plants at different stages of crop growth. However, an increase in iron content in treatments that received boron was noticed.

Iron uptake by groundnut at different growth stages was significantly influenced by the application of boron (Table 2). The Highest iron uptake at peg penetration stage (280.81 g/ha) was recorded in the treatment T_4 and it was on par with T_9, T_3, T_2 and T_8. At pod development stage, the highest iron uptake (481.36 g/ha) was recorded in the treatment T_4 and it was on par with T_9 and T_3. At harvest stage, the highest iron uptake in haulm (290.38 g/ha) was recorded in the treatment T_4 and it was on par with all the other boron applied treatments. In groundnut pods, T_4 recorded the highest iron uptake (189.77 g/ha) and it was on a par with all the other boron treatments except T_6. The lowest iron uptake (219.04, 326.06, 214.82 and 143.34 g/ha in peg penetration stage, pod development stage, harvest stages (haulm and pod) respectively) was recorded in T_1 (RDF).
Alveraz-Tinaut [13] found a positive relation between boron and iron. Also, the increase in the

uptake of iron by boron fertilization could be attributed to better growth of crop resulting in greater absorption of nutrients from soil leading to its higher iron content and uptake. The results were in conformity with the findings of Aboyeji et al. [8] and Hirapara et al. [14] in groundnut.

3.2.2 Zinc

Application of boron had no significant influence on zinc content at any stage of the crop growth. However, an increase in zinc content was observed in treatments that received boron compared to treatments T_1 (RDF).

Application of boron positively influenced uptake of zinc at different growth stages of groundnut (Table 3). At peg penetration stage, the highest zinc uptake (80.68 g/ha) was recorded in the treatment T_4 and it was on par with the treatments T_3, T_9, T_8 and T_2. The highest zinc uptake (134.99 g/ha) at pod development stage was recorded in the treatment T_4 and it was on par with the treatments T_9, T_3, T_8, T_7, T_5 and T_2. At harvest stage, the highest zinc content in haulm (93.27 g/ha) was recorded in the treatment T_4 and it was on par with the treatments T_9, T_8, T_3. And in groundnut pods, the treatment T_4 recorded the highest zinc uptake (58.44 g/ha) and it was on a par with all the other boron treatments. The lowest zinc uptake 63.13, 99.33, 63.97 and 42.63 g/ha in peg penetration stage, pod development stage, harvest stages (haulm and pod) respectively) was recorded in T_1 (RDF).

The increase in zinc uptake with boron application might be due to the synergistic interaction between boron and zinc. Application of boron also resulted in higher drymatter accumulation as well as zinc content which ultimately resulted in higher zinc uptake. Shaaban et al. [15] and Aboyeji et al. [8] also recorded similar results.

Table 1. Effect of boron on protein content of groundnut

Treatment	Protein content (%)
T_1: RDF	24.06
T_2: RDF + soil application of Borax @ 7.5 kg ha^{-1}	27.19
T_3: RDF + soil application of Borax @ 10 kg ha^{-1}	27.56
T_4: RDF + soil application of Borax @ 12.5 kg ha^{-1}	29.38
T_5: RDF + foliar spray of Borax @ 0.1% at 45 DAS	27.13
T_6: RDF + foliar spray of Borax @ 0.1% at 65DAS	27.19
T_7: RDF + foliar spray of Borax @ 0.1% at 45 & 65 DAS	27.38
T_8: T_2+ foliar spray of Borax @ 0.1% at 65DAS	27.50
T_9: T_3+ foliar spray of Borax @ 0.1% at 65DAS	29.13
SEm (±)	0.94
CD@0.05	2.81
CV (%)	5.92

Table 2. Effect of boron on iron uptake (g/ha) of groundnut

Treatments	Iron uptake (g/ha)			
	Peg penetration stage	Pod development stage	Harvest stage	
			Haulm	Pod
T_1	219.04	326.06	214.82	143.34
T_2	260.26	414.76	269.43	172.87
T_3	263.36	433.94	277.93	176.97
T_4	280.81	481.36	290.38	189.77
T_5	219.90	412.62	258.50	166.18
T_6	222.54	349.19	258.98	164.71
T_7	222.16	414.08	260.47	166.40
T_8	259.67	415.91	278.95	180.55
T_9	264.82	434.45	287.89	188.29
SEm (±)	14.61	20.62	12.94	8.05
CD@0.05	43.79	61.83	38.79	24.14
CV (%)	10.29	8.73	8.41	8.10

Table 3. Effect of boron on zinc uptake (g/ha) of groundnut

Treatments	Zinc uptake (g/ha) Peg penetration stage	Pod development stage	Harvest stage	
			Haulm	Pod
T_1	63.13	99.33	63.97	42.63
T_2	75.55	117.90	82.93	51.08
T_3	76.94	122.55	88.37	55.18
T_4	80.68	134.99	93.27	58.44
T_5	63.24	118.12	80.11	50.58
T_6	63.90	93.43	80.73	51.52
T_7	63.60	118.29	81.54	52.76
T_8	75.68	119.62	89.69	55.90
T_9	76.84	123.58	92.31	58.03
SEm (±)	3.85	6.29	3.94	2.78
CD@0.05	11.55	18.85	11.16	8.34
CV (%)	9.39	9.35	8.16	9.11

3.2.3 Manganese

Manganese content in groundnut plants at different stages was not significantly influenced by the application of boron. However, an increase in manganese content in treatments that received boron compared to treatments T_1 (RDF) was noticed.

Application of boron positively influenced manganese uptake at all the growth stages of groundnut (Table 4). At peg penetration stage, the highest manganese uptake (89.96 g/ha) was recorded in the treatment T_4 and it was on par with the treatments T_9, T_3, T_8 and T_2. The highest manganese uptake at pod development stage (157.44 g/ha) was recorded in the treatment T_4 and it was on par with the treatments T_9 and T_3. At harvest stage, the highest manganese uptake in haulm (108.98 g/ha) was recorded in the treatment T_4 and it was on par with all the other boron treatments except T_5. In groundnut pods, the highest manganese uptake (63.19 g/ha) was recorded in the treatment T4 was on a par with all the other boron treatments. The lowest manganese uptake (69.11, 103.47, 73.77 and 45.44 g/ha in peg penetration stage, pod development stage, harvest stages (haulm and pod) respectively) was recorded in the treatment T_1 (RDF).

The increase in the uptake of manganese by boron fertilization could be attributed to better growth of crop resulting in greater absorption of nutrients from soil leading to its higher content. The findings were in consonance with the results reported by Aboyeji et al. [8] and Hirapara et al. [14] in groundnut.

3.2.4 Copper

Application of boron had no significant influence on copper content at any stage of the crop growth. However, an increase in copper content in the treatments that received boron compared to treatments T_1 (RDF) was noticed.

Application of boron positively influenced the copper uptake of groundnut at all the stages of crop growth (Table 5). The highest copper uptake at peg penetration stage (22.27 g/ha) was recorded in the treatment T_4 was on par with the treatments T_9, T_3 and T_8. At pod development stage, the highest copper uptake (46.78 g/ha) was recorded in the treatment T_4 and it was superior over all the other boron treatments. At harvest stage, the highest copper uptake in haulm (36.90 g/ha) was recorded in the treatment T_4 and it was on par with all the other boron treatments except T_5 and T_6. In groundnut pods, the treatment T_4 recorded the highest copper uptake (24.86 g/ha) and it was on a par with the treatments T_9, T_3, T_8 and T_7. The lowest copper uptake (16.41, 28.97, 24.45 and 15.11 g/ha in peg penetration stage, pod development stage, harvest stages (haulm and pod) respectively) was recorded in the treatment T_1 (RDF).

Alveraz- Tinaut [13] and Niaz et al. [10] reported synergistic relationship between boron and copper, which might result in increased higher copper content and uptake in boron fertilized plants. These results were coincided with the findings of Shaaban et al. [15] in wheat and Aboyeji et al. [8] in groundnut.

3.2.5 Boron

The results of the investigation showed that application of boron significantly influenced boron content of groundnut plants at different growth stages (Table 6). At peg penetration and pod development stage, the highest boron content (26.34 and 48.38 mg/kg respectively) was recorded in the treatment T_4 (RDF + soil application of Borax @ 12.5 kg/ha) and it was on par with all the other boron treatments. The lowest boron content (15.05 and 29.01 mg/kg) was recorded in the treatment T_1 (RDF). At harvest stage, the highest boron content in haulm (43.27 mg/kg) was obtained by T_4 (RDF + soil application of Borax @ 12.5 kg/ha) and it was or par with the treatments T_9, T_3, T_8, T_7 and T_2. The lowest boron content (22.01 mg/kg) was obtained by T_1 (RDF). In groundnut pods, the highest boron content (25.35 mg/kg) was recorded in the treatment in T_4 (RDF + soil application of Borax @ 12.5 kg/ha) and it was on par with all the other boron treatments. The lowest boron content (14.35 mg/kg) is recorded in the treatment T_1 (RDF).

Application of boron positively influenced uptake of boron at different growth stages of groundnut (Table 6). At peg penetration stage, the highest boron uptake (59.51 g/ha) was recorded in the treatment T_4 was on par with the treatments T_3, T_9, T_2 and T_8. The highest boron uptake (177.47 g/ha) at pod development stage was recorded in the treatment T_4 and it was on par with the treatments T_9 and T_3. At harvest stage, the highest boron uptake in haulm (127.90 g/ha) was recorded in the treatment T_4 and it was on par with all the other boron treatments except T_5 and T_6. In groundnut pods, the highest boron uptake (53.83 g/ha) was recorded in the treatment T4 was on a par with all other boron treatments. The lowest Boron uptake (29.68, 82.72, 52.90 and 26.00 g/ha in peg penetration stage, pod development stage, harvest stages (haulm and pod) respectively) was recorded in the treatment T_1 (RDF).

The experimental soil was low in available boron and this might be one of the reasons for higher response to varied boron levels. Increased boron content in plants might be due to better availability of boron in soil either through soil application or foliar application of boron as well as better plant growth leading to higher uptake of nutrients. Significantly higher boron uptake was also reported by Mahendran et al*.* [6] and Kamalakannan and Elayaraja [16].

Table 4. Effect of boron on manganese uptake (g/ha) of groundnut

Treatments	Manganese uptake (g/ha)			
	Peg penetration stage	Pod development stage	Harvest stage	
			Haulm	Pod
T_1	69.11	103.47	73.77	45.44
T_2	82.74	134.24	99.01	57.15
T_3	83.71	141.90	103.32	60.29
T_4	89.96	157.44	108.98	63.19
T_5	69.77	130.62	94.19	55.55
T_6	69.79	109.66	94.71	56.20
T_7	69.75	130.83	95.23	58.02
T_8	82.88	134.55	104.95	61.13
T_9	84.15	142.29	106.68	62.65
SEm (±)	3.86	6.77	4.93	2.62
CD@0.05	11.56	20.31	14.77	7.87
CV (%)	8.56	8.91	8.72	7.87

Table 5. Effect of boron on copper uptake (g/ha) of groundnut

Treatments	Copper uptake (g/ha)			
	Peg penetration stage	Pod development stage	Harvest stage	
			Haulm	Pod
T_1	16.41	28.97	24.45	15.11
T_2	19.28	38.22	32.53	21.31
T_3	20.51	40.89	34.86	23.69
T_4	22.27	46.78	36.90	24.86
T_5	16.50	38.22	31.07	20.87
T_6	16.66	31.19	31.22	21.26
T_7	16.70	38.23	31.81	21.98
T_8	19.43	38.75	34.91	23.64
T_9	20.58	40.95	36.60	24.69
SEm (±)	0.95	1.92	1.80	1.13
CD@0.05	2.85	5.76	5.39	3.39
CV (%)	8.80	8.76	9.53	8.94

Table 6. Effect of boron on boron content (mg/kg) and boron uptake (g/ha) of groundnut

Treatments	Boron content (mg/kg)				Boron uptake (g/ha)			
	Peg penetration stage	Pod development stage	Harvest stage		Peg penetration stage	Pod development stage	Harvest stage	
			Haulm	Pod			Haulm	Pod
T_1	15.05	29.01	22.01	14.35	29.68	82.72	52.90	26.00
T_2	24.68	45.17	39.15	23.24	54.16	149.61	111.81	47.58
T_3	25.37	46.48	41.61	24.01	56.07	158.10	120.63	49.97
T_4	26.34	48.38	43.27	25.35	59.51	177.47	127.90	53.83
T_5	15.39	43.61	36.82	23.39	30.16	143.49	99.64	46.73
T_6	15.33	30.37	37.92	23.41	30.25	86.64	102.94	46.95
T_7	15.67	43.58	39.97	23.57	30.86	143.20	108.84	47.63
T_8	24.69	45.28	40.14	23.67	53.88	149.63	117.60	49.18
T_9	25.27	46.28	42.82	24.58	55.36	158.40	125.93	52.04
SEm (±)	0.98	1.83	1.6	1.02	3.59	7.45	6.66	2.53
CD@0.05	2.93	5.47	4.80	3.06	10.76	22.34	19.97	7.59
CV (%)	8.10	7.53	7.26	7.75	13.99	9.30	10.72	9.40

4. CONCLUSION

From the analysis of the experimental data it could be concluded that the application of boron along with recommended dose of fertilizers improved the nutritional quality of groundnut crop in coastal sandy soils.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. The spectrum of Malnutrition; 2000.
   Accessed 19 August 2021.
   Available:http://www.fao.org/worldfoodsummit/english/fsheets/malnutrition.
2. Pelto GH,Armar-Klemesu M. Balancing Nurturance, Cost and Time: Complementary Feeding in Accra, Ghana. Maternal & Child Nutrition.2011;7(3):66-81.
3. Singh BB, Musa A, Ajeigbe HA, Tarawali SA. Effect of feeding crop residues of different cereals and legumes on weight gain of Yankassa rams. International Journal of Livestock Production. 2012; 2:17–23.
4. Murmu S,Saha S, Saha B, HazraGC. Influence of Zn and B on the Yield and Nutrition of Two Widely Grown Potato Cultivars (*Solanum tuberosum* L.). Annals of Biology. 2014;30(1):37-41
5. Cerak C, Odabas MS, Kevseroglu K, Karaca E, Gulumser A. Response of soybean (*Glycinemax*) to soil and foliar applied boron at different rates. Indian Journal of Agricultural Sciences. 2006;76(10):603–6.
6. Mahendran PP, Velmurugan R, Balasubramaniam P. Identifying critical limit in soil and plant for determining response of groundnut (*Arachis hypogea*) to boron application in madurai soils of Tamil Nadu, india. Journal of Plant Nutrition. 2015;39(2):190-4167.
7. Sarker SK, Chowdhury MAH, Zakir HM. Sulphur and boron fertilization on yield quality and nutrient uptake by Bangladesh soybean-4. Journal of Biological Sciences. 2002;2:729-733.
8. Aboyeji C, Dunsin O, Adekiya AO, Chinedum C, Suleiman KO, Okunlola FO, Aremu CO, Owolabi IO, Olofintoye TAJ. Zinc sulphate and boron-based foliar fertilizer effect on growth, yield, minerals, and heavy metal composition of groundnut (*Arachis hypogaea* L.) grown on an alfisol. International Journal of Agronomy. 2019;1-7.
9. Hossain MA, Jahiruddin, Khatun F. Effect of boron on yield and mineral nutrition of mustard (*Brassica napus*). Bangladesh Journal of Agricultural Research. 2011:36(1):63-73.
10. Niaz A, Muhammad A, Fiaz A, Muhammad AU, Qaisar J, Muhammad AA. Impact of boron fertilization on dry matter production and mineral constitution of irrigated cotton. Pakistan Journalof Botany. 2011;43(6):2903-2910.
11. Panse, V.G. and Sukhatme, P.V. 1978. Statistical methods for agricultural workers. ICAR, New Delhi. 199-211.
12. Poonguzhali RS, Pandian PS, Silviya RA. Effect of soil and foliar applied boron on soil available boron, yield and quality of groundnut in Alfisols of Madurai District, Tamil Nadu. Bulletin ofEnvironment, Pharmacology and Life Sciences. 2019;8(10):76-80.
13. Alvarez-Tinaut MC. Correlations between boron and other micronutrients. In: Behavior, Function and Significance of Boron in Agriculture. Report on an International Workshop at St. John's College, Oxford, England. Published by Borax Consolidated Limited, London; 1990.
14. Hirpara DV, Sakarvadia HL, Jadeja AS, Vekaria LC,Ponkia HP. Response of boron and molybdenum on groundnut (*Arachis hypogaea* L.) under medium black calcareous soil. Journal of Pharmacognosy and Phytochemistry. 2019;8(5):671-677.
15. Shaaban MM, El-Fouly MM,Abdel-Maguid AWA. Zinc-boron relationship in wheat plants grown under low or high levels of calcium carbonate in the soil. Pakistan Journal of Biological Science. 2004;7:633-639.

16. Kamalakannan P, Elayaraja D. Effect of organic and inorganic sources of nutrients in micronutrients uptake and availability on groundnut in sandy clay loam soil. Plant Archives. 2020;20(1):3721-3726.

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