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Influence of Organics, Boron and Silicon Nutrition on the Growth, Yield and Nutrient Uptake by Groundnut in Coastal Saline Soil

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The most common cause of coastal salt-affected soils is boron deficiency. In certain places, there are also deficiencies in zinc, iron, manganese, and copper. In numerous enzymatic processes related to groundnut growth, production, and quality, boron is crucial. It is now known that the main cause of the low groundnut production in coastal locations is a nutritional shortage. A helpful or quasi-element that can reduce salinity stress, improve boron availability, and increase the amount of available beneficial cations is silicon. Therefore, it becomes essential to include silicon as a beneficial nutrient and boron as a micronutrient in the fertilization program in order to increase groundnut output in salinized conditions. Further, the poor nutrient retention and leaching of applied

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nutrients necessitates the application of increased rate of nutrients and bulky organic manures. The field experiment was carried out in a farmer's field during December - March, 2022 at Singarakuppam coastal village, near Chidambaram in Cuddalore district of Tamil Nadu. The experimental soil was sandy in texture and taxonomically classified as Typic Ustipsamments with pH – 8.25, EC– 4.11 dSm-1 and represented low status of organic carbon (2.36 g kg-1). Regarding available nutrient status, it was low in alkaline KMnO4-N (139.91 kg ha-1), low in Olsen-P (9.48 kg ha-1) and medium in NH4OAc-K (165.67 kg ha-1).The available B and Si content were 0.24 and 32.46 mg kg-1, respectively. The results of the study clearly indicated that the treatment (T12), which received combined application of borohumate at 1.5 kg B ha-1 + diatomaceous earth at 60 kg Si ha-1 through soil application along with foliar application of borohumate at 0.5% + silixol plus at 1.0% twice at pre - flowering stage (PFS) and at flowering stage (FS) + recommended dose of NPK and composted coirpith (CCP)at 12.5 t ha-1 recorded the highest growth, yield, quality and nutrient uptake by groundnut.

Keywords: Boron; silicon; groundnut; composted coirpith; coastal saline soil.

1. INTRODUCTION

"Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crops of the world. Groundnut contains an average 40 per cent of oil and 25.3 per cent of protein and is a rich source of calcium, iron and vitamin B complex like thiamine, riboflavin, niacin and vitamin A. It is used not only as a major cooking medium for various food items but also for manufacture of soaps, cosmetics, shaving creams and lubricants. At worldwide groundnut is grown over 100 countries in 26.4 million hectares with a total production of 37.1 million tonnes and an average productivity of 1.4 tonnes ha^{-1}" [1]. "Developing countries constitute 97% of the global area and 94% of the global production of this crop. The production of groundnut is concentrated in Asia and Africa with 56 and 40% of the global area and 68 and 25% of the global production respectively" [2].

The beneficial effect of boron was boosted by combined addition of boron with humate. Humic acid is an organic product that enhances the plant growth, improves the nutritional status of soil and plant system and provides growth regulatory substance, which is necessary for crop growth. Humic acid helps in protein and nucleic acid synthesis. Polyphenol released by the humic acid catalyze plant respiration and root growth. High CEC of humic acid prevents leaching of nutrients. The metal complexing nature (Chelating) of humic acid easily binds with other nutrients. In borohumate boron element attached with humic acid by covalent bond and released the nutrient in slow process and when the plant requires. By this way combination of humic acid and boron in the form of borohumate enhance the plant growth with adequate supplementation of boron with plant growth regulatory substance [3,4].

"Silicon (Si) is classified as a beneficial element. This element limits the effects of abiotic and biotic stresses in plants. In recent years, more research has been performed with regards to soil and foliar nutrition using silicon fertilizers, which brings unequivocal production benefits, and at the same time, it is much cheaper and more convenient to use than soil fertilization especially in coastal salt affected soils". [5] "As a result, it improves the profitability of many agriculture and horticulture crops. The positive effect of silicon observed, in the studies, results in many cases in which the susceptibility of plants to drought stress is reduced. Silicon has also a beneficial effect on limiting the adverse effects of other abiotic stresses; caused by salinity, heavy metals, high and low temperature, water flooding, etc". [6].

"Boron (B) and silicon (Si) elements are similar in many chemical characteristics. Both are taken up by plant roots in the form of weak, undissociated acids. Boron concentration in plant tissues increased with increasing boron concentration in the nutrient solution, which leads to toxicity but was reduced by additional Si supply. Both silicon and boron applications correct to some extent the negative effects of salinity either on growth, yield and nutrients uptake by groundnut" [7,8].

"Further, there is a strong consensus among scientists that incorporation of organics along with NPK is essential to sustain soil health and crop production. Utilization of organic manures in coastal sandy loam/sandy soils has multidimensional effect in improving all the soil related constraints. Organic matter helps in increasing adsorptive power of soil for cations and anions particularly phosphate, nitrates and micronutrients” [9]. “These adsorbed ions are released slowly for the benefit of crop during entire growth period. The decomposition of organic matter releases many nutrients, such as N, P, K and S as well as many secondary and micronutrients. Organic manures improve the organic carbon status, available primary and secondary nutrients and also supply sufficient number of micronutrients in available forms. Several earlier works have emphasized the need for application of organic manures for increasing the growth, yield and quality of groundnut” [10]. Considering the inherent poor soil fertility, poor yield and economic condition of the coastal farmers, it is an imperative need to recycle the locally available organic wastes to achieve sustainable yield at minimum cost. Coastal areas of Tamil Nadu are endowed with a variety of organic wastes, which contain plant nutrients and several growth principles and enzymes, which can sustain soil health and crop production.

2. MATERIALS AND METHODS

The field experiment was carried out in a farmer’s field during December - March, 2022 at Singarakuppam coastal village, near Chidambaram in Cuddalore district of Tamil Nadu. The experimental soil was sandy in texture and taxonomically classified as *Typic Ustipsamments* with pH – 8.25, EC– 4.11 dSm^{-1} and represented low status of organic carbon (2.36 g kg^{-1}). Regarding available nutrient status, it was low in alkaline $KMnO_4$-N (139.91 kg ha^{-1}), low in Olsen-P (9.48 kg ha^{-1}) and medium in NH_4OAc-K (165.67 kg ha^{-1}). The available B and Si content were 0.24 and 32.46 mg kg^{-1}, respectively. The various treatments included were, T_1- Control (RDF alone), T_2-RDF + composted coirpith (CCP) at 12.5 t ha^{-1}, T_3-RDF + borohumate (BH) at 1.5 kg B ha^{-1} + diatomaceous earth (DE) at 60 kg Si ha^{-1} as soil application (SA), T_4-RDF + BH (SA) + Silixolplus (SP) as foliar application (FA) at 1.0% twice, T_5-RDF + DE (SA) + BH as foliar application (FA) at 0.5% twice, T_6-RDF + (BH + SP) FA, T_7-RDF + (BH + DE) SA + (BH + SP) FA, T_8-RDF + CCP + (BH + DE) SA, T_9-RDF + CCP + BH (SA) + SP (FA), T_{10}-RDF + CCP + DE (SA) + BH (FA), T_{11}-RDF + CCP + (BH + SP) FA, T_{12}-RDF + CCP + soil application of borohumate at 1.5 kg B ha^{-1} with diatomaceous earth at 60 kg Si ha^{-1} + foliar spray of borohumate and silixol plus at 0.5% twice at flowering and pre flowering stages. The experiment was carried out in a Randomized Block Design (RBD) with three replications, using groundnut variety VRI 2 as test crop. Fertilizer application was followed by the recommended dose of 17:34:54 kg of N: P_2O_5: K_2O per hectare was applied to all experimental plots uniformly. Half of the N and entire P_2O_5 and K_2O were applied as basal and the remaining half dose of N was applied in two splits at flowering and peg formation stage. Composted coirpith (CCP) at 12.5 t ha^{-1} were applied basally and well incorporated into the soil as per the treatment schedule. Required quantities of boron humate (BH), diatomaceous earth (DE) and silixolplus were applied either through soil or foliar spray and or both as per the treatment schedule. The pod and haulm yield from each plot were recorded at 14 per cent moisture content and expressed in kg ha^{-1}. Periodic soil samples were collected at critical stages of groundnut *viz.*, flowering, peg formation and at harvest stages were taken and dried in shade, powdered, sieved and analysed for various parameters like, physico-chemical properties, available nutrients and biological properties. The plant samples were then shade dried and kept in oven for 72 h at 65°C. After taking weight, the plant samples were powdered in the Willey mill and analysed for major nutrients and micronutrients (B and Si) contents. The total uptake of individual nutrients was computed by multiplying the respective nutrient content with DMP. At the harvest stage, the pod and haulm samples were separately analysed for the above nutrients and uptake were calculated. The data obtained from the field experiments were statistically analysed as suggested by Gomez and Gomez [11].

3. RESULTS AND DISCUSSION

3.1 Growth Characters (Table 1)

The results obtained in present investigation confirmed the usefulness of the treatment, application of 100 per cent recommended dose of NPK + borohumate (BH) at 1.5 kg B ha^{-1} + diatomaceous earth (DE) at 60 kg Si ha^{-1} through soil application + foliar spray of borohumate at 0.5% + silixol plus (SP) at 1.0 per cent along with CCP at 12.5 t ha^{-1} (T_{12}), recorded a highest growth characters of plant height (59.98 cm), No. of branches $plant^{-1}$ (12.76) and DMP (5615 kg ha^{-1}) at the harvest stage of groundnut. This was followed by the treatments, the treatment supplied with RDF + CCP + borohumate at 1.5 kg B ha^{-1} + diatomaceous earth at 60 kg Si ha^{-1} (SA) as soil application (T_8) and RDF + CCP + borohumate at 1.5 kg B ha^{-1} through soil along with foliar spray of silixol plus at 1.0% (T_9). This was followed by the application of recommended dose of NPK fertilizer (RDF) + CCP + diatomaceous earth at 60 kg Si ha^{-1} (SA) through soil + borohumate at 0.5% (FA) through foliar application (T_{10}). However, it was found to be comparable with treatment T_{11} (application of RDF + CCP + borohumate at 0.5 per cent + Silixol plus at 1.0 percent as foliar spray alone) which recorded the highest growth parameters of plant height (54.83 cm), No. of branches plant^{-1} (11.40) and DMP (5092 kg ha^{-1}) at harvest stage of groundnut.

This was followed by the treatments, supplied with RDF along with boron and silicon fertilization (without organics) such as RDF + borohumate + diatomaceous earth (BH+DE) through soil application along with borohumate at 0.5% + silxol plus at 1.0% through foliar spray (T_7), RDF + borohumate + diatomaceous earth (BH+DE) through soil application alone (T_3), RDF + borohumate (SA) + silixol plus (FA) at 1.0 per cent through foliar application (T_4), RDF + diatomaceous earth (SA) + borohumate at 0.5 percent through foliar application (T_5) and RDF + borohumate at 0.5% + silixol plus + at 1.0 per cent (BH+SP) through foliar application alone (T_6) these treatments which recorded a lowest growth parameters of groundnu as compared to above said organic applied treatments (RDF + B + Si and organics).

"In coastal saline soil, groundnut responded well to the application of silicon and boron nutrition. Among the various treatments, the treatment T_{12} recorded the highest plant height, number of branches plant^{-1} and dry matter production. This might be due to the increased nutrient supply with the addition of fertilizer and organics. Further, micronutrients might have direct effect of plant growth like auxin activity contributing to increase in plant height, number of branches and DMP" [12,13].

3.2 Yield and Yield Characters of Groundnut (Table 2)

3.2.1 Yield characters

Among the various treatments, combined application of 100 per cent recommended dose of NPK + composted coirpith (CCP) at 12.5 t ha^{-1} + borohumate (BH) at 1.5 kg B ha^{-1} + diatomaceous earth (DE) at 60 kg Si ha^{-1} through soil application (BH+DE) along with foliar spray of borohumate at 0.5% and silixol plus (SP) at 1.0 per cent (BH + SP) twice at pre flowering stage and at flowering stage (T_{12}) recorded the highest number of pods plant^{-1} (34.76), 100 pod weight (96.51 g) and shelling percentage (74.99%) of groundnut, respectively. This was followed by the treatments which received RDF + CCP + BH at 1.5 kg B ha^{-1} + DE at 60 kg Si ha^{-1} through soil application (T_8), RDF + CCP + BH at 1.5 kg B ha^{-1} + SP at 1.0 per cent through foliar application (T_9) and RDF + CCP + soil application of DE at 60 kg Si ha^{-1} + foliar application of BH at 0.5% (T_{10}). However, the treatment T_{10} was closely on par with the treatment T_{11}.

In order to the application of RDF along with boron and silicon treatments *viz.,* T_7 (RDF + borohumate at 1.5 kg B ha^{-1} + diatomaceous earth at 60 kg Si ha^{-1} through soil along with foliar application of borohumate at 0.5% + silixol plus at 1.0%), T_3 (RDF + borohumate at 1.5 kg B ha^{-1} + diatomaceous earth at 60 kg Si ha^{-1} through SA), T_4 (RDF + borohumate at 1.5 kg B ha^{-1} SA) + silixol plus at 1.0% FA), T_5 (RDF + diatomaceous earth at 60 kg Si ha^{-1} SA + borohumate at 0.5% FA) and T_6 (RDF + borohumate at 0.5% + silixol plus at 1.0% through foliar alone) recorded the lowest yield characters as compared to combined application of boron and silicon in both mode of application (soil and foliar spray) along with the organics applied treatments.

This was followed by the application of recommended dose of NPK fertilizer along with composted coirpith at 12.5 t ha^{-1} (T_2) which recorded a low yield characters *viz.,* number of pods plant^{-1} (24.39), 100 pod weight (80.34 g) and shelling percentage (72.92%) of groundnut, respectively. When compare to the above said treatments the minimum yield parameters such as number of pods plant^{-1} (23.28), 100 pod weight (78.51 g) and shelling percentage (72.73%) of groundnut was recorded in the control treatment T_1, (without B, Si nutrition and organics).

"High yield characters of groundnut might be attributed to increased dry matter accumulation in the reproductive parts and formation of higher sink capacity with the addition of organics. An adequate supply of plant nutrients enhanced the metabolic activity. Not only amount of nutrients present in soil but also their availability in meeting out needs of crop at critical growth stages resulted in increased plant growth and yield characters". Kamalakannan [14]; Elayaraja and Jawahar [8]; Kumar et al, [15].

Table 1. Effect of composted coirpith boron and silicon fertilization on the growth characters of groundnut

Treatments	Plant height (cm)	Number of branches plant^{-1}	Dry matter production (kg ha^{-1})
T_1 – Control (RDF alone)	39.62	7.49	3715
T_2 – RDF + CCP at 12.5 t ha^{-1}	42.96	8.85	3854
T_3 – RDF + BH at 1.5 kg B ha^{-1} + DE at 60 kg Si ha^{-1} (SA)	51.43	10.57	4760
T_4 – RDF + BH + SP (FA) at 1.0% at twice	49.64	10.16	4488
T_5 – RDF + DE (SA) + BH (FA)	47.51	9.85	4131
T_6 – RDF + (BH + SP) FA	45.07	9.41	3997
T_7 – RDF + (BH + DE) SA + (BH + SP) FA	53.08	11.02	4928
T_8 – RDF + CCP + (BH + DE) SA	58.35	12.38	5443
T_9 – RDF + CCP + BH (SA) + SP (FA)	56.70	11.96	5287
T_{10} – RDF + CCP + DE (SA) + BH (FA)	55.04	11.51	5144
T_{11} – RDF + CCP + (BH + SP) FA	54.83	11.40	5092
T_{12} – RDF + CCP + (BH + DE) SA +(BH + SP) FA	59.98	12.76	5615
SE_D	**0.90**	**0.16**	**63.12**
CD (p=0.05)	**1.89**	**0.33**	**132.56**

Table 2. Effect of composted coirpith boron and silicon fertilization on the yield characters and yield of groundnut

Treatments	Number of pods plant^{-1}	100 pod weight (g)	Shelling (%)	Yield (kg ha^{-1})	
				Pod	Haulm
T_1 – Control (RDF alone)	23.28	78.51	72.73	1728	2736
T_2 – RDF + CCP at 12.5 t ha^{-1}	24.39	80.34	72.92	1763	2804
T_3 – RDF + BH at 1.5 kg B ha^{-1} + DE at 60 kg Si ha^{-1} (SA)	28.96	87.56	73.82	1943	3075
T_4 – RDF + BH + SP (FA) at 1.0% at twice	27.83	85.75	73.55	1907	3010
T_5 – RDF + DE (SA) + BH (FA)	26.67	83.77	73.36	1860	2938
T_6 – RDF + (BH + SP) FA	25.58	82.08	73.13	1812	2863
T_7 – RDF + (BH + DE) SA + (BH + SP) FA	30.14	89.31	74.06	1985	3141
T_8 – RDF + CCP + (BH + DE) SA	33.75	94.79	74.73	2119	3367
T_9 – RDF + CCP + BH (SA) + SP (FA)	32.64	93.02	74.48	2082	3292
T_{10} – RDF + CCP + DE (SA) + BH (FA)	31.45	91.34	74.27	2032	3213
T_{11} – RDF + CCP + (BH + SP) FA	31.23	91.05	74.24	2020	3204
T_{12} – RDF + CCP + (BH + DE) SA +(BH + SP) FA	34.76	96.51	74.99	2159	3434
SE_D	**0.47**	**0.77**	**0.08**	**15.29**	**24.81**
CD (p=0.05)	**0.98**	**1.62**	**0.16**	**32.11**	**52.11**

Table 3. Effect of composted coirpith boron and silicon fertilization on the quality parameters of groundnut

Treatments	Protein yield (kg ha^{-1})	Oil yield (kg ha^{-1})
T_1 – Control (RDF alone)	223.63	486.42
T_2 – RDF + CCP at 12.5 t ha^{-1}	240.55	522.37
T_3 – RDF + BH at 1.5 kg B ha^{-1} + DE at 60 kg Si ha^{-1} (SA)	285.17	617.61
T_4 – RDF + BH + SP (FA) at 1.0% at twice	273.59	593.14
T_5 – RDF + DE (SA) + BH (FA)	262.60	569.90
T_6 – RDF + (BH + SP) FA	251.55	545.88
T_7 – RDF + (BH + DE) SA + (BH + SP) FA	297.46	645.11
T_8 – RDF + CCP + (BH + DE) SA	338.38	732.78
T_9 – RDF + CCP + BH (SA) + SP (FA)	324.17	702.55
T_{10} – RDF + CCP + DE (SA) + BH (FA)	313.60	678.88
T_{11} – RDF + CCP + (BH + SP) FA	311.29	673.75
T_{12} – RDF + CCP + (BH + DE) SA +(BH + SP) FA	346.76	750.61
SE_D	**3.34**	**7.25**
CD (p=0.05)	**7.02**	**15.22**

Table 4. Effect of composted coirpith boron and silicon fertilization on the boron and silicon uptake (g ha^{-1}) by groundnut

Treatments	B uptake		Si uptake	
	Pod	Haulm	Pod	Haulm
T_1 – Control (RDF alone)	15.46	11.42	9.70	12.36
T_2 – RDF + CCP at 12.5 t ha^{-1}	19.83	14.64	20.92	24.65
T_3 – RDF + BH at 1.5 kg B ha^{-1} + DE at 60 kg Si ha^{-1} (SA)	32.37	19.52	33.80	51.41
T_4 – RDF + BH + SP (FA) at 1.0% at twice	27.38	18.40	31.86	48.47
T_5 – RDF + DE (SA) + BH (FA)	24.79	16.94	29.33	44.61
T_6 – RDF + (BH + SP) FA	22.44	15.83	28.22	42.78
T_7 – RDF + (BH + DE) SA + (BH + SP) FA	36.47	21.19	34.99	53.22
T_8 – RDF + CCP + (BH + DE) SA	49.53	33.20	38.65	58.78
T_9 – RDF + CCP + BH (SA) + SP (FA)	45.47	24.85	37.54	57.10
T_{10} – RDF + CCP + DE (SA) + BH (FA)	40.64	23.15	36.52	55.56
T_{11} – RDF + CCP + (BH + SP) FA	40.23	22.91	36.15	54.99
T_{12} – RDF + CCP + (BH + DE) SA +(BH + SP) FA	55.03	42.67	39.87	60.64
SE_D	**1.08**	**0.51**	**0.45**	**0.77**
CD (p=0.05)	**2.26**	**1.07**	**0.94**	**1.62**

3.2.2 Yield of groundnut

The groundnut responded well for the boron and silicon nutrition fertilizers application. The significant influence of B and Si fertilization (boron + silicon) along with recommended dose of NPK and composted coirpith in increasing the pod and haulm yield of groundnut was well evidenced in the present investigation.

The yield realized under the present field experiment confirmed the beneficial effects of boron and silicon nutrition to groundnut with the results of previous field experiments. In the nutrient poverished coastal saline sandy soil, the highest pod yield (2159 kg ha^{-1}) and haulm yield (3434 kg ha^{-1}) of groundnut was recorded with the combined application of recommended dose of NPK fertilizer + borohumate (BH) at 1.5 kg B ha^{-1} + diatomaceous earth (DE) at 60 kg Si ha^{-1} along with CCP at 12.5 t ha^{-1} (SA) through soil as well as foliar spray of borohumate at 0.5% + silixol plus (SP) at 1.0 per cent twice at pre flowering and flowering stage (T_{12}). This was followed by the treatments T_8, (RDF + borohumate at 1.5 kg B ha^{-1} (SA) + diatomaceous earth at 60 kg Si ha^{-1} (SA) + CCP at 12.5 t ha^{-1}), T_9 (RDF + borohumate (SA) + Silixol plus at 1.0% (FA) + CCP at 12.5 t ha^{-1}) and T_{10} (RDF + diatomaceous earth (SA) + borohumate at 0.5% (FA) + CCP at 12.5 t ha^{-1}). However, the treatment T_{10} was on par with treatment T_{11} (RDF + borohumate at 0.5% (FA) + Silixol plus at 1.0% (FA) + CCP at 12.5 t ha^{-1}).

With regards to application of recommended dose of NPK along with boron and silicon nutrition on both soil and foliar alone without organics, the treatments which received RDF + BH at 1.5 kg B ha^{-1} + DE at 60 kg Si ha^{-1} through soil and foliar application of BH at 0.5% + SP at 1.0% (T_7) significantly increased the pod and haulm yield of 1985, 1470 and 3141 kg ha^{-1} of groundnut, respectively. This was followed by application of B and Si either through soil or foliar alone treatments *viz.,* T_3 (RDF + BH at 1.5 kg B ha^{-1} + DE at 60 kg Si ha^{-1} through soil alone), T_4 (RDF + BH at 1.5 kg B ha^{-1} through soil + SP at 1.0% through foliar), T_5 (RDF + DE at 60 kg Si ha^{-1} (SA) through soil + BH (FA) at 0.5%) and T_6 (RDF + BH at 0.5% + SP at 1.0%) these treatments which recorded the lowest pod yield (1943, 1907, 1860 and 1812 kg ha^{-1}) and haulm yield (3075, 3010, 2938 and 2863 kg ha^{-1}), respectively as compared to above said treatments. This was followed by the treatment T_2 (RDF + CCP at 12.5 t ha^{-1}).

Among the various treatments, the treatment (T_{12}), which received recommended dose of NPK + composted coirpith along with boron and silicon nutrients through both soil (BH at 1.5 kg B ha^{-1} + DE at 60 kg Si ha^{-1}) and foliar (BH at 0.5% + Silixol plus at 1.0%) application recorded a pod and haulm yield of 2159 and 3434 kg ha^{-1} which was 24.94 and 25.51 per cent increase over control or 100 per cent NPK alone (without B + Si nutrition and organics). The control treatment T_1, 100 per cent NPK alone recorded a lowest pod (1728 kg ha^{-1}) and haulm (2736 kg ha^{-1}) yield of groundnut as compare to all other treatments.

The favourable effect of B and Si reflected in pod and haulm yield was also might be attributed to their effect in maintaining soil available nutrients in balanced proportions for better growth of groundnut. The pronounced effect of boron and silicon foliar spray might have helped in enhancing the enzyme and photosynthetic activities, accumulation of photosynthates thereby higher yield. This corroborates the earlier report of Bahaa and Salim [16]; Kamalakannan [14]; Shwethakumari and Prakash [17] and Singh et al., [18].

3.3 Quality Parameters of Groundnut (Table 3)

Among the various organic combinations with boron and silicon treatments, the integrated application of recommended dose of fertilizer (RDF) + borohumate at 1.5 kg B ha^{-1} + diatomaceous earth at 60 kg Si ha^{-1} through soil as well as foliar sprays of borohumate at 0.5 percent and silixol plus at 1.0 percent twice at pre flowering and flowering stage along with CCP at 12.5 t ha^{-1} (T_{12}) registered a significantly higher protein (346.76 kg ha^{-1}) and oil yield (750.61 kg ha^{-1}) of groundnut seeds. This was followed by treatments T_8 (application of RDF + borohumate at 1.5 kg B ha^{-1} (SA) + diatomaceous earth at 60 kg Si ha^{-1} (SA) + CCP at 12.5 t ha^{-1}), T_9 (application of RDF + borohumate at 1.5 kg B ha^{-1} (SA) + Silixol plus at 1.0% (FA) + CCP at 12.5 t ha^{-1}) and T_{10} (application of RDF + DE (SA) + BH (FA) + CCP) which registered the groundnut protein yields of 338.38, 324.17 and 313.60 kg ha^{-1} and oil yields of 732.78, 702.55 and 678.88 kg ha^{-1}, respectively. However, the treatment T_{10} equally efficient with T_{11} which received RDF along with CCP at 12.5 t ha^{-1} through soil and foliar spray of BH at 0.5% + SP at 1.0% twice which recorded a comparable protein (311.29 kg ha^{1}) and oil yield (673.75 kg ha^{-1}) of groundnut, respectively.

The application of RDF along with boron and silicon nutrition without organics treatments like T_7, RDF + borohumate at 1.5 kg B ha^{-1} + diatomaceous earth at 60 kg Si ha^{-1} (SA) through soil and foliar application of borohumate at 0.5% + silixol plus at 1.0% (FA), treatment T_3, RDF + borohumate at 1.5 kg B ha^{-1} + Diatomaceous earth at 60 kg Si ha^{-1} (SA), treatment T_4, RDF + borohumate at 1.5 kg B ha^{-1} (SA) + silixol plus at 1.0% (FA), treatment T_5, RDF + diatomaceous earth at 60 kg Si ha^{-1} (SA) through soil + borohumate at 0.5% (FA) foliar spray and treatment T_6, RDF + borohumate at 0.5% + silixol plus at 1.0% (FA) through foliar spray which recorded the lowest protein yield of groundnut, respectively as compared to above said organic applied treatments (RDF + B +Si and organics).

Though the application of B and Si through soil application of borohumate and diatomaceous earth (T_3) or foliar spray of borohumate at 0.5% + silixol plus at 1.0% (T_6) recorded significantly higher quality parameters than control, they were inferior to the treatment which received boron and silicon nutrition (B and Si) both by soil and foliar application (T_{12}). The lowest quality parameter was recorded in the control or 100% NPK alone (without boron + silicon and organics) as compared to all other treatments.

Besides the addition of boron as borohumate promoted better quality through synthesis of oil, protein and amino acids through its effect on protein and lipid metabolism in plants. Similar results were earlier made by Ahmed et al. [19] and Naiknaware, [20]. The impact of NPK addition play a vital role in enhancing the glycoside content in seed, which upon hydrolysis and esterification's, resulted in higher oil yield in groundnut [21,22].

3.4 Boron and Silicon Uptake by Groundnut (Table 4)

3.4.1 Boron

Among the various treatments, the highest B uptake by pod (55.03 g ha^{-1}) and haulm (42.67 g ha^{-1}) was recorded with the application of recommended dose of NPK + CCP at 12.5 t ha^{-1} along with soil application of borohumate at 1.5 kg B ha^{-1} + diatomaceous earth at 60 kg Si ha^{-1} and foliar spray of borohumate at 0.5% + silixol plus at 1.0 per cent twice (T_{12}). This was followed by the treatments, which received both the nutrition (B and Si) with single mode of fertilization either soil or foliar applied treatments. The treatment T_8 - RDF + CCP + borohumate + diatomaceous earth (SA alone) and T_9 - RDF + CCP + borohumate (SA) + silixol plus (FA) recorded a lowest B uptake of groundnut as compared to above said treatment (boron + silicon nutrition both soil and foliar.) This was followed by application of RDF + CCP along with soil application of diatomaceous earth at 60 kg Si ha^{-1} + borohumate at 0.5 per cent foliar spray (T_{10}). However, this was found to be on par with treatment (T_{11}) which received RDF + CCP along with borohumate (BH) at 0.5% + Silixol plus (SP) at 1.0% through foliar and recorded a comparable B uptake of 40.64 and 40.23 g ha^{-1} by pod and 23.15 and 22.91 g ha^{-1} by haulm, respectively. This was followed by the treatments significantly arranged in the descending order as $T_7 > T_3 > T_4 > T_5 > T_6$ and T_2. These treatments were also statistically significant.

Application of 100 per cent NPK alone (T_1) recorded a comparatively lower B uptake of 15.46 g ha^{-1} by pod and 11.42 g ha^{-1} by haulm as compared to application of RDF along with CCP (T_2) which recorded a B uptake of 19.83 and 14.64 g ha^{-1} by pod and haulm, respectively.

In the present study addition of RDF + composted coir pith at 12.5 t ha^{-1} + borohumate at 1.5 kg B ha^{-1} + diatomaceous earth at 60 kg Si ha^{-1} through soil application along with foliar spray of borohumate at 0.5% and silixol plus at 1.0% significantly promoted the nutrition of B by groundnut. The increased B uptake might be due to direct addition of boron as impurities along with fertilizers. Further the application of organics might have increased the availability through enhanced mineralization and chelation action, which have increased the absorption and utilization of these nutrients. The earlier reports of Jawahar et al. [23]; Lavinsky et al. [24] and Aravinda Kumar et al. [25] support the present findings.

3.4.2 Silicon

As like boron uptake, the highest Si uptake by groundnut at all the critical stages was recorded with the application of recommended dose of NPK fertilizer + composted coir pith at 12.5 t ha^{-1} + borohumate at 1.5 kg B ha^{-1} (SA) + diatomaceous earth at 60 kg Si ha^{-1} (SA) through soil and foliar spray of borohumate at 0.5% + silixol plus at 1.0 per cent (T_{12}). It recorded a Si uptake of 39.87 and 60.64 g ha^{-1} by pod and haulm, respectively. This was followed by the treatments T_8 (RDF + CCP + borohumate + diatomaceous earth SA alone) and T_9 - RDF + CCP + borohumate (SA) + silixol plus (FA) recorded a lowest B uptake of groundnut as compared to above said treatment (boron + silicon nutrition both soil and foliar.) This was followed by application of RDF + CCP along with soil application of diatomaceous earth at 60 kg Si ha^{-1} + borohumate at 0.5 per cent foliar spray (T_{10}). However, this was closely on par with treatment T_{11} (RDF + CCP + borohumate at 0.5% + silixol plus at 1.0% FA). This was followed by the treatments arranged in the descending order like $T_7 > T_3 > T_4 > T_5 > T_6$ and T_2. These treatments were also statistically significant. The control (NPK alone) treatment recorded the lowest Si uptake at all the growth stages of groundnut (without B + Si nutrition and CCP).

The increase of nutrients in soil might be attributed to the improved availability of nutrients. Thus, silicon uptake by groundnut increased due to the higher availability of silicon in soil. Further a synergistic and positive effect of boron and silicon on the concentration of Si in soil was reported by earlier works Karthika [22]; Thangaraj [21] and Gokulapriya et al. [6,26].

4. CONCLUSION

The present investigation clearly concluded that the beneficial role of organic manures along with boron and silicon fertilization for increasing groundnut production in coastal saline soil. Application of recommended dose of NPK + composted coirpith at 12.5 t ha^{-1} with borohumate at 1.5 kg B ha^{-1} (15 kg ha^{-1} through borohumate) and diatomaceous earth at 60 kg Si ha^{-1} (66 kg ha^{-1} through diatomaceous earth) through soil application along with borohumate at 0.5% + silixol plus at 1.0% through foliar spray twice at critical stages like, pre - flowering and flowering stage was identified as best treatment combination to recommended for groundnut in coastal area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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