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Effect of Boron Application On Growth, Yield Parameters, Nutrient Uptake, Quality and Economics of Groundnut (*Arachis hypogaea L.*); A Review

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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

Groundnut is an important crop cultivated all over world owing to its versatile nature of adaptation to different agro-climatic and soil conditions. In India groundnut gains momentum as an edible oil and India next to food grain. Nutritionally groundnut contains 50 % oil, 25-30 % protein, 20% carbohydrate and 5%fiber. The productivity is lower due to different factors among which nutrient management especially boron that plays pivot role in governing the growth, yield and quality of groundnut. Boron plays various role in the physiological processes of plants, such as cell elongation, cell maturation, meristematic tissue development and protein synthesis, cellular membrane function, reproductive structures and anti- oxidative defence system. It induces flowering, fertilization, hormonal metabolism and translocation of sugars from source to sink. Extensive investigations of research on boron levels were critically reviewed. Application of boron at 10-15 kg ha^{-1} of soil application and foliar application of 0.5 percent at critical stage was found to increase the growth and yield attributes, yield, quality as well as higher benefit cost ratio sustaining the livelihood of groundnut growers.

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1. INTRODUCTION

India is one of the largest oilseeds producers in the world and occupies an important position in the Indian Agricultural Economy. Oilseed crops is the second largest agricultural production in India next to food grain. Groundnut is called as the "King of oilseeds", it is stands as the most important oilseed crop of the world it contains 50 % oil, 25-30 % protein, 20% carbohydrate and 5%fiber [1]. In the global scenario, India occupies first position in the area (7.5 m ha) but ranks second in production (6 m t yr^{-1}) [2]. In India, the groundnut production is concentrated mainly in Tamil Nadu, Karnataka, Andhra Pradesh and Gujarat [3]. In Tamil Nadu, groundnut was raised under an area of 0.36 m ha with a production of 0.91 m t yr^{-1} during the year 2014. In order to meet the edible oil need of our ever increasing population, the groundnut production in India should be increased from 29.75 m t to 55 m t by 2020 A.D. This shows that, there is an urgent need to step up oil seed production on sustainable basis. The optimization of mineral nutrition is the key to optimize the groundnut production. The nutritional disorder causes yield reduction of groundnut from 30 to 70 per cent so it is high time to look into the nutrition aspects of groundnut for achieving higher yield. Among all the essential nutrients, boron influences the growth of groundnut through arresting the flower drop and also involves in the synthesis of carbohydrate and fats. Adequate boron application will enhance the groundnut growth, yield and quality.

Boron plays various role in the physiological processes of plants, such as cell elongation, cell maturation, meristematic tissue development and protein synthesis, cellular membrane function, reproductive structures and anti-oxidative defense system. It induces flowering, fertilization, hormonal metabolism and translocation of sugars from source to sink, thus contributes to an increase in seed yield [4-5]. Besides the importance, B is the second largest deficient nutrient in India which results in the significant crop losses both in yield and quality of field crops [6]. In groundnut the B deficiency results in poor pollen viability, reduced peg formation, low pod filling, shrived seeds and hallow heart symptoms are commonly observed causing yield loss in 20-40 percent [7-8]. Hence the application of boron is must to prevent the disorder and to enhance the growth and yield of groundnut.

2. IMPORTANCE OF BORON FOR PLANTS

Boron is one of the essential micronutrients for the plant growth. It helps in pollen and ovary formation and seed development. It plays an important role in cell division as it is the necessary component of cell wall. Therefore under deficiency symptoms the plants results in dwarfing, rolling of leaves, cracking of leaves, death of growing point and poor seed set [9]. Abdul *et al.,* [10] found that boron is concerned with sugar translocation from complex compounds of carbohydrates which are translocated. Ahmad *et al.,* [11] observed that B inhibits the conversion of sugars to starch by complexing at the active site of starch phosphorylase which inhibits the action of phosphorglucomutase so that glucose-6-phosphate, fructose-6-phosphate and fructose would be reduced and thus sucrose synthesis would be restricted, thereby affect sugar translocation [12] Alloway [13] mentioned that boron is present in relatively high concentration in chloroplasts. During boron deficiency, chloroplasts degenerate and cell wall undergo profound structural changes before any visual deficiency symptoms are apparent. Ashour and Reda [14] reported that boron enhances carbohydrate metabolism and stimulates other physiological processes of the plants. Thereby resulting in an increased area, high dry matter and soluble carbohydrate accumulation. Gupta [15] found that boron is continuously required for growth of most of the plants otherwise, plants grow in low boron media exhibit boron deficiency symptoms of various forms, boron deficiency symptom can be observed in vegetative and reproductive parts such as growth inhibition of roots and shoot tips, inhibition of flower development, reduced setting and malformation of fruit and seeds, male sterility and seed abortions. Kumar *et al.* [16] have studied the response of groundnut to boron application in acid sedimentary soil. Their studies have shown response to boron and enhancement in yield of groundnut by application in deficient soils. Analysis of the structure of the BRG-II complex reveals that the complex is composed of boric acid and two chains of monomeric RG-II. boric acid crosslink's two chains of pectic polysaccharides at the RG-II region through borate diester bonding, thus forming a network of pectic polysaccharides in cell walls, it is clear that boric acid links some cell wall components [17].

3. EFFECT OF BORON APPLICATION ON GROUNDNUT GROWTH ATTRIBUTES

In general, B is taken up by the plant roots as $H_2BO_3^-$, when B is supplied in $H_2BO_3^-$ as borax it would have increased the availability of $H_2BO_3^-$to crops as both the soils were deficient in B status, as the B availability increases it would have regulated the growth as it plays a vital role in cell wall structure formation, stabilizing the membrane molecules and regulating the expression of genes involved in membrane function. Susan poonguzhali and Saravanapandian [18] conducted a field experiment in Madurai district with different levels of boron application in soil and foliar along with RDF and results are reported that the application of 15 kg ha^{-1} of B as soil application plus 0.5% foliar application of B at critical stages recorded the maxmimum plant height (61.7 cm), number of branches plant^{-1} (14.5), number of nodules plant^{-1} (107.6). The soil and foliar application of B improved the growth accompanied by increased B concentration in plant parts. The improvement in plant height might be due to the enhancement in photosynthetic and other metabolic activities, which lead to an increase in plant metabolism resulting in the increased plant growth parameters reported by Revathi *et al*. [19]. Nandi *et al.,* [20] conducted a experiment in West Bengal in three levels of boron application viz., (0, 0.3 and 0.45% B foliar application) and results are reported that the plant height of ground was 35.6 cm at flowering and 41.5 cm at harvest stage. Quamruzzaman *et al.,* [21] initiated the field experiment of three levels of boron application like 0-kgBha^{-1}, 1-kg B ha^{-1}, and 2-kg B ha^{-1} and the results are reported that the 2 kg boron application treatment recorded the maximum plant height of 43.78 cm at 60 DAS and 103.49 cm at harvest stage, number of branches 8.61 at 60 DAS and 10.39 at harvest stage. The increasing trend of number of branches plant^{-1} is due to the fact that B helped in side branching and it also promoted the vegetative growth of peanut [22]. The similar result was reported that number of branches plant^{-1} increased with application of boron in peanut [23]. Hirpara *et al.,* [24] conducted a research trail in Gujarat comprising of five levels of boron viz., 0, 2, 4, 8 and 10 kg B ha^{-1} in soil application of black calcareous soil and results are reported that maximum plant height (23.30 cm) was obtained with boron application of 8 kg ha^{-1}, which was statistically at onpar with application of 4 and 10 kg B ha^{-1}. Maximum number of primary branches (3.89) per plant was recorded in 10 kg boron per hectare which was statistically at par with application of 4 and 8 kg B ha^{-1}. Kaisher *et al*. [25] reported that the application of boron increase in plant height of groundnut crop might be due to soil and foliar applied B, which could be attributed to metabolic regulation and enzymatic process including photosynthesis, respiration and symbiotic N-fixation.

4. EFFECT OF BORON APPLICATION ON GROUNDNUT YIELD AND YIELD ATTRIBUTES

As the soil was deficient in B initially, due to the continuous groundnut cropping the soils must be in higher need of B, hence timely application of B both as soil and foliar application obviously would increase the yield attributes perhaps through the process of tissue differentiation from somatic to reproductive, meristematic activity. Added to it the development of floral primordial might have increased the number of flowers which helps in the setting of pod thereby increasing the number of pods per plant. These results were in accordance with the results of other workers Nadaf and Chidanandappa [26] and Khanna and Gupta [27].

Mahale *et al.* [28] conducted a field experiment to study the effects of boron and drum rolling on the yield of groundnut. The experimental result showed that foliar application of 0.1 ppm. B at 35 and 55 days after sowing significantly increased the pods yield (1.5 t ha^{-1}) compared to the treatment which was not applied with the foliar spray of B (1.3 t ha^{-1}). Sahu *et al.* [29] observed that application of B at graded levels (0, 1.5, 2.0 and 2.5 kg B ha^{-1}) in the form of borax to lateritic soils the application of 1.5 kg B ha^{-1} increased the pod yield upto 32.1 per cent and shelling percentage of groundnut over control. Kumar *et al*. [16] conducted a field experiment in B deficient acid sedentary soils of Ranchi and they found that the groundnut responded significantly to boron application @ 3 kg ha^{-1} and pod yield increased remarkably from 1140 kg ha^{-1} in control to 1530 kg ha^{-1}. However, further increase in B application up to 4.5 kg ha^{-1} reduced pod yield. Subrahmaniyan *et al.* [30] reported that combined application of $ZnSO_4$ @

5 kg ha^{-1} + borax @ 5 kg ha^{-1}+ $FeSO_4$ @ 10 kg ha^{-1} recorded the maximum yield attributes *viz*., number of matured pods $plant^{-1}$ (14.6), 100 kernel weight (47.61 g) and shelling percentage (70.60 %) compared to other treatments under red sandy loam soil with low fertility status. Chitdeshwari and Poongothai [31] had reported that the soil application of Zn 5 kg ha^{-1} + B 1.0 kg ha^{-1} + S 40 kg ha^{-1} significantly increased the groundnut pod yield to the tune of 24.2 per cent for TMV 7 and 14.8 per cent for JL 24 over control.

Murthy [32] reported that the increase in seed yield due to B application was 90,150,210,320 and 370 kg ha^{-1} in sesame, linseed, mustard, sunflower and groundnut respectively. Singh *et al*. [6] reported that application of B has pronounced influence on flowering and yield attributes such as shelling percentage and 100 seed weight in groundnut. Soil application of 1.0 kg B ha^{-1} as agricol, solubor and borosol increased pod yield by 8-23, 6-18, 12-18 per cent, respectively compared to 9-28 per cent by borax and 5-24 per cent by boric acid. Foliar application (0.1 % aqueous solution) of borosol, chemiebor and solubor showed similar response in increasing the pod yield by 7-39, 6-32, and 6-35 per cent, respectively. Sonawane *et al*. [33] found that the application of micronutrients resulted in increase in dry matter and pod yield of groundnut. They concluded that combined application of 20 kg Zn + 5 kg borax + RDF had registered an increase in pod yield of 49.94 per cent as compared to RDF alone. Susan poonguzhali and Saravanapandian [18] trailed a field experiment in boron deficient soils of Madurai district with different levels of boron along with RDF and results are reported that the maximum pod yield of 2013 kg/ha and the haulm yield of3017 kg/ha was recorded in RDF + 15 kg B as soil application along with 0.5 per cent foliar application of B at critical stages of crop growth. Boron are also involved in carbohydrate metabolism which increases the uptake of nutrients that ultimately results in increasing the yield. The results are in conformity with those of Tiwari *et al.* [34]. The carbohydrate metabolism may be an additional reason through the increased transformation of photosynthesis towards yield. Hirpara *et al.,* [24] conducted a research trail in Gujarat comprising of five levels of boron viz., 0, 2, 4, 8 and 10 kg B ha^{-1} in soil application of black calcareous soil and results are reported that the maximum numbers of pods per plant (10.556) and maximum number of mature pods per plant (7.572), which was remain statistically at par with 10 kg B. Application of 8 kg B ha^{-1} recorded significantly the higher shelling percentages (67.15%) and 100-seed weight (43.40 g), which was remain statistically at par with 4 and 10 kg B ha^{-1}. Similar findings were recorded by Nandini *et al.* [35] and Crak *et al.* [36].

5. EFFECT OF BORON APPLICATION ON GROUNDNUT QUALITY OF CROPS

Saraswathy *et al.* [37] observed that application of boron improved the fruit quality *viz.,* TSS, ascorbic acid, total sugar, reducing sugar, non-reducing sugar content, pulp : seed ratio over control. Thapa [38] studied the effect of sulphur and boron on yield and oil content of rapeseed and the results showed that application of boron alone @ 1 kg ha^{-1} produced the highest oil yield (288.5 kg ha^{-1}). Kushwaha *et al*. [39] found that increasing levels of boron application significantly improved the protein content. Nadaf *et al.* [40] studied the effect of zinc and boron on quality parameters and oil yield of groundnut. The results showed that protein content, oil content and oil yield of groundnut was significantly increased over the control due to application of boron @ 5 kg ha^{-1} and zinc sulphate at three level 5, 10 and 20 kg ha^{-1} either alone or in combination with borax. Soil application of B @ 2 kg ha^{-1} recorded the highest oil content of 36.6 per cent over control 32.2 per cent and the achene protein was enhanced upto 20.38 per cent over control (14.7 %) Mehmood *et al*. [41]. Poonguzhali *et al.,* [42] conducted a field experiment in vylogam soil series with different levels of boron application in soil and foliar along with RDF and results are reported that the application of 15 kg ha^{-1} of B as soil application plus 0.5% foliar application of B at critical stages recorded the highest oil and crude protein content in the soil series with the values of 50.6 per cent oil content 15.0 per cent of crude protein content in the soils of Vylogam soil series. The boron deficiency in plant causes internal tissue disintegration, causing abnormalities such as aborted pollen grains, distorted seed set, poor pod filling capacity, hallow heart symptoms in the pods and shriveled seeds, these are the major causes for the yield and quality reduction in the crops [43].

6. EFFECT OF BORON APPLICATION ON GROUNDNUT NUTRIENT UPTAKE

The deficiency of boron not only affects the relative values of individual elements, but also affects the balance among the other nutrients within the plants, hence the optimum application of boron to the crop plants brought up with a balanced nutrient ratio, which might be the cause behind the increased B content and uptake in the plants. Luo *et al.* [44] recorded that the application of B fertilizer promoted the uptake of N, P and Tripathy *et al.* [45] reported that application of zinc, boron and molybdenum significantly enhanced the uptake of nutrients namely zinc and boron and this were attributed to higher pod and haulm yield of groundnut. Hassanein *et al*. [46] reported that application of boron increased the contents of P, K, Ca, Fe, Mn, Zn and Cu in plants. Application of boron enhanced the N content in roots and shoots of pea plant under salinity conditions [47]. Shankhe *et al*. [48] studied the effect B application on groundnut and the results revealed that foliar application of boron + soil application of molybdenum along with recommended doses of fertilizers were found to be superior in increasing the yield and uptake of B by groundnut over recommended doses of fertilizer alone. Singh *et al*. [49] reported that application of boron 1kg ha^{-1} increased the B content, boron uptake in groundnuts and pigeon pea. Nasef *et al.* [50] reported that different level of B significantly increased the uptake of Fe, Mn, Zn and B by haulm and seed of peanut. The highest values of Fe and Mn uptake by haulm and seed of peanut plants were obtained by using 200 ppm of B, while the highest values of Zn and B uptake by haulm and were obtained by using 300 ppm of boron. Jena *et al*. [51] conducted a field experiment to evaluate the effect of boron and boron enriched organic manure on yield and quality of groundnut. They found that application of 1 kg ha^{-1} boron and B enriched cow dung significantly increased the pod yield of groundnut. Mohapatra and Dixit [52] investigated the effect of integrated use of FYM, recommended dose of fertilizer, Rhizobium, gypsum and boron on performance of groundnut and soil fertility. The results revealed that application of FYM+75 per cent RDF + *Rhizobium* + gypsum + boron recorded significantly higher uptake of N, P, K, and B.

7. EFFECT OF BORON APPLICATION ON THE AVAILABILITY OF NUTRIENTS

Sudarsan and Ramasamy [53] opined that boron application increased the availability of N in soils. Hassanein *et al*. [46] reported that application of boron increased the contents of P, K, Na, Ca, Fe, Mn, Zn, Cu and B in seeds. Seshadrireddy [54] in their study on effect of nutrients on nutrient status of groundnut they revealed that the availability K increased due to the application of boron compared to the other treatments. Murthy [32] suggested that the application of boron ranging from 15 to 25 kg ha^{-1} increased the available N, P and K in soils compared to treatments receiving less levels of B and no B applied plots. Chaudhury and Debnath [55] reported that the effect of boron application on the available B content in Entisol and Alfisol of West Bengal. The results showed that hot water soluble B in the soils generally increased with increasing rate of B application in both the soils. Elayaraja *et al*. [56] investigated the response of different levels of B and organics in groundnut and concluded that the highest amount of available soil nutrients such as N, P, K, Fe, Mn, Zn and Cu were observed in the treatment receiving 25 kg ha^{-1} Borax at three stages of crop growth such as flowering, peg formation and at harvest stage. Karthikeyan and Shukla [57] conducted a green-house experiment involving four levels of boron (0, 1, 2 and 3 mg kg^{-1}) in an acid Alfisols collected from Ranchi, Jharkhand with mustard and sunflower as test crops. It was found that different forms of B (Organically bound boron, specifically adsorbed and oxide bound) increased in soil solution with increasing levels of boron. Sathya *et al*. [58] studied the effect of various levels of boron application on availability of B and primary nutrients in soil. The results revealed that the soil application of borax @ 20 kg ha^{-1} recorded the highest level of available boron, nitrogen, and phosphorus and potassium status in post-harvest soil. Ganie *et al.* [59] studied the effect of various levels of boron on available nutrients. The post-harvest soil sample analysis showed that the treatment receiving1.5 kg B ha^{-1}increased the available soil nutrients *viz.* nitrogen, phosphorus, potassium, sulphur and boron.

8. EFFECT OF BORON APPLICATION ON ECONOMICS OF GROUNDNUT

Chiteswari and Poongothai [31] conducted an experiment on groundnut with different levels of zinc, boron and sulphur application and the results revealed that the application of Znic sulphate 5 kg ha^{-1} + solubar 1.0 kg ha^{-1} and sulphur 40 kg ha^{-1} through soil application increased mean groundnut productivity by 42 per cent over no application of boron. The net return and B:C (2.34) was higher in the plots receiving B as solubar by soil application. Ansari *et al*. [60]

proposed that on applying different forms of B fertilizer to groundnut crop, application of solubar stands to give the economic return compared to other B fertilizers. Solubar as soil application on an average fetched Rs. 23.61 × 10^3 ha^{-1} (42%) more net returns and thus had 1.42 (35%) more B:C than control. Verma *et al*. [61] conducted a field experiment to study the influence of boron on yield and economics of mustard and the results showed that the maximum net return of Rs. 22899 ha^{-1} and benefit cost ratio of 1.82 was obtained in the treatment receiving 2 kg ha^{-1} of B through soil application. Susan poonguzhali and Saravanapandian [18] conducted an field experiment to study the different levels of boron application in two different soil series and reported that the B application @ 15 kg/ha as soil application and 0.5 per cent foliar application along with RDF on an average fetched Rs 71939 of net return and thus had higher B-C ratio (3.1) over no boron application. The higher groundnut productivity coupled with the corresponding haulm yield and with increase in cost of cultivation resulted in higher net return and B-C ratio in B as soil and foliar application treatment. B application increased mean groundnut productivity over no application of boron.

9. CONCLUSION

A groundnut is a short duration crop, the crop source and sink develops together so top dressing and soil application plays a vital role in improving the crop productivity. Foliar spray of B seems to represent an easily applicable strategy to enhance the groundnut growth and productivity by enhancing soil and foliar B along with certain nutrients. The present study indicated that application of boron at 10-15 kg ha^{-1} of soil application and foliar application of 0.5 percent at critical stage was found to increase the growth and yield attributes, yield, quality as well as higher benefit cost ratio sustaining the livelihood of groundnut growers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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