

Boron deficiency and its nutrition of groundnut in India

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Introduction

The groundnut (*Arachis hypogaea* L.) is an important food legume and oilseeds crop of India grown in about 8 m ha land, the largest area in the world, but stand second in production due to its low productivity. Presently, the average productivity of groundnut, in India, is around 1300 kg ha⁻¹ which is very low as compared to USA and China mainly because, the crop is mostly grown as rain fed in dry lands, under low fertility and low input management, often subject to the vagaries of the weather conditions. However, in recent years, combination of improved genotypes and nutrient management practices has increased the productivity.

Presently, Gujarat, Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu states contribute about 90 % of the groundnut production in India, of these Gujarat, Tamil Nadu and Maharashtra are the major areas producing export quality groundnut. However due to deficiencies of boron (B) and calcium (Ca), there is poor seed filling and hence low quality produce is obtained from these areas (Singh et al, 2004). Thus looking to the export market, which requires high quality and well-filled seed, it is essential that these aspects be looked carefully. After much work Ca fertilizer is recommended, but there are only few reports on B nutrition of groundnut in India. Soil parent material and texture are considered to be major soil factors associated with the occurrence of B deficiency that can readily be prevented and corrected by soil and foliar applications (Shorrocks, 1997). Thus the study on B nutrition of groundnut was initiated at this research center about a decade ago and some of the findings are summarized here.

Materials and Methods

Field, pot and micro-plot experiments were conducted at the National Research Centre for Groundnut, Junagadh, India in a medium black, calcareous (19 - 21 % CaCO₃), clayey (35% sand and 44% clay) soil containing 7.6 - 7.8 pH, 0.71- 0.81 % organic carbon, 660 - 710 mg kg⁻¹ total N, 6.0-6.2 mg kg⁻¹ available P, 10 - 11 mg kg⁻¹ heat soluble S, 3.02, 4.9, 0.61 and 0.60 mg kg⁻¹ DTPA

extractable Fe, Mn, Zn, and Cu, respectively and 0.20 - 0.36 mg kg⁻¹ hot water soluble B.

The crop was grown under recommended package of practices and proper care was taken to protect it from weeds, insects, pests and diseases during the entire cropping season. The crop was harvested at maturity, dried in sun for a week and pod and haulm yields, shelling percent, percentage sound mature seeds and 100-seed mass recorded. The B in plant samples were analyzed colorimetrically using curcumine. All these data were analyzed statistically. The experiment-wise details of the methodologies are given below.

Pot experiments: *Diagnosis of B deficiency symptoms and Requirement*

Soil and sand culture pot experiments were conducted under various levels of B to find out the deficiency symptoms and role of B in the nutrition of groundnut. Fifteen kg of soil or sand, as per the experimental requirement, was filled in a number of pots of 25 cm diameter with a bottom hole plugged with glass wool. The groundnut genotypes were sown at a rate of four seeds per pot in 4 replicates.

A series of sand culture pot experiment were conducted under various deficiency and toxicity levels of B, during 1993-1995, to find out the correct levels of B for best growth and yield of groundnut and to diagnose the B deficiency symptoms under low B conditions. The rate of photosynthesis, growth and pod yield recorded.

In sand culture experiments Steinberg's nutrient solutions, was used. For different doses of B, the minus solution containing all nutrients except B was taken as base solution and as per the treatments, the required quantity of B from the stock solutions (Boric acid) was added. The pots were initially irrigated with one liter of complete solution in each pot on the day it was sown (DAE). After 7 DAE (days after emergence) the pots were flushed with water and the treatment of different doses of macronutrient was started by providing 250 ml of nutrients solution pot⁻¹ day⁻¹ from 7-30 DAE, and 500 ml pot⁻¹ day⁻¹ there after. The nutrient solution was stopped 5 days before harvest. The pots were flushed with water at weekly interval. After maturity, the plants from each pot were harvested, dried and observations on the plant height and pod numbers and yield recorded. The oven dried plant and seed samples were ground to a fine powder and analyzed for B.

Soil culture pot experiments were conducted at various doses of B to find out the deficiency and toxicity levels of B for growing groundnut in calcareous soil.

Field experiments

The field was prepared by ploughing and labeling and 10 cm deep furrows were opened at 30 cm spacing. The field was then divided into small plots of 25 m² (5 m x 5 m) by raising bunds. A basal dose of 20 kg N⁻¹ and 22.5 kg P ha⁻¹ as diammonium phosphate and 40 kg K ha⁻¹ as muriate of potash were

mixed in the soil before sowing. The groundnut was sown at 30 cm x 10 cm spacing in the furrows and covered with soil.

Micro-plot experiment

Experiments were conducted, in polythene-lined micro-plots in field and supplied with various doses of B, to find out the sufficiency and deficiency levels in both plant and soils. The soil and plant samples from the experiments were analyzed and based on the soil analysis, the critical sufficiency level of B in soil was fixed.

Assessment of yield losses due to B deficiency

Field experiments were conducted during three (wet 1993, dry 1994 and dry 1995) seasons in a randomized block design with three treatments as detailed in Table 1 and six replications. Groundnut genotype FeESG 10-1 was grown and observations on yield and related attributes recorded.

Effectiveness of soil and seed dressing of Boron

A field experiment was conducted during two wet seasons in a factorial randomized block design with two modes of application through seed and in furrows as the main plots and the B fertilizers in the sub-plots with three replications.

The boron containing salts at 5 kg ha⁻¹ (which contained 1 kg B ha⁻¹) were applied through seed and directly in soil using furrows (Table 2). To apply through seed, these salts were mixed with the water soaked seed and shaken so as to make a uniform coating of these salts around the seed and then sown in the furrows. In the other method the nutrient salts were applied in the furrows. The groundnut genotype, FeESG 10-1 was grown and effect of B application on seed and seedlings and percent germination were recorded in the field. The crop was harvested at maturity, and observations on yield and related attributes recorded.

Comparison of soil, foliar and drip application

Field experiments were conducted, using groundnut variety GG 2, during Rabi-summer 1995 (February to May) and Rabi 1995-96 (Mid October to February) seasons in a randomized-block design with five treatments as in table 5 and three replications. For the first time flood irrigation was given to all plots to maintain adequate soil moisture for uniform germination and from the second irrigation onward, as per treatment, the drip or flood irrigation was given. The seed germinated within a week. The B (1 kg ha⁻¹ B as boric acid) was applied through soil application (in furrows), through foliar sprays (foliar application of 0.2% aqueous solution) and through drip irrigation (Feeding 0.5% aqueous solution through ventury) thrice at 30, 50 and 70 DAS (Days after sowing).

The chlorophyll content of leaves was measured at 40 DAE (Days after emergence). Five plants from each plot were uprooted randomly both at 60 DAE

and at maturity, washed, separated into leaves, stems and nodules, weighed after drying in an oven at 60°C for about a week, and subjected to dry wt. measurement.

Nutrition of bold seed groundnut

Field experiments were conducted during rabi-summer 1995 (February to May) and rabi 1995-96 (Mid Oct.-Feb.) seasons in a factorial randomized-block design with two groundnut genotypes (TKG 19A, a large seeded and FeESG 10 as an ordinary groundnut) in main plot and eight treatments, as in table 7, as sub plots with three replications. The treatments 100 kg ha⁻¹ Ca as gypsum, 100 kg ha⁻¹ K as muriate of potash and 2 kg ha⁻¹ B as borax were applied in soil 50% as basal and 50 % 50 days after emergence (DAE).

Results and discussion

Deficiency and toxicity symptoms and requirement

From the sand and soil culture pot experiments at various levels of B, the deficiency and toxicity levels of B and their symptoms in groundnut were identified and the requirement of B was worked out.

The B deficiency caused retarded growth in groundnut plant particularly of the apical portion, death of the stem apex, and regeneration from the lateral bud, malformation of the leaf vein, chlorosis, necrosis of basal margins in emerging leaves are commonly observed. Boron deficiency also causes thickened and stiff growing bud at terminal end, young leaves turn pale green starting at basal end, leaves deformed, twisted, and brittle, shortened internodes and bushy or rosette appearance of the plant (Singh *et. al.* 2004). However, these visual symptoms on leaves were not observed in field grown groundnut crop, even on B deficient soils. But, as B deficiency symptoms invariably occur in the young tissues and apical meristems, shortened growth and bushy appearance was common. The B deficiency was similar to that of Ca, except that in B the necrotic areas are localized near leaf margins but in Ca they are distributed over the entire surface. Roots become blackened and growth of root nodules is suppressed. Goldberg and Forster (1991) reported that B can be adsorbed by Calcium carbonate and a positive correlation was found between amount of adsorbed B and Calcium carbonate.

The deficiency of B causes low pod filling and hollow darkening or off-colour area develop in the center of the seed known as 'hollow heart' of groundnut reducing the quality of seed. Many a times there were shriveled seeds due to B deficiency. In groundnut, boron facilitates translocation of sugar and fat synthesis and is important for RNA synthesis, cell division, differentiation, and maturation and pollen germination. It is transported primarily in xylem, but is relatively immobile in phloem and hence commonly occur in neutral to alkaline and weathered light texture soils where groundnut is mainly grown in India. The most common B deficiency symptom is hollow-heart of kernel in which the inner faces of the cotyledons are depressed and discolored reducing the quality of seed (Cox

and Reid, 1964). Groundnut kernels containing 6.7-17.3 mg B kg⁻¹ showed the incidence of hollow-heart. Deficiency of B is more commonly observed in groundnut grown in coarse textured and hilly soils of India particularly in Tamil Nadu, northern Bihar and part of Assam, West Bengal, northern Orissa, north east India, Karnataka and Gujarat (Singh and Basu, 2005). Though the clear-cut symptoms of B deficiency are observed in Tamil Nadu, Karnataka, Bihar and a few pockets of Gujarat, the response of B is reported from most of the groundnut growing areas in India causing considerable yield losses.

Results of the soil culture pot and field experiments in polythene-lined microplots at various B doses clearly demonstrated the sufficiency and deficiency levels of B in both plant and soils. The soil and plant samples when analyzed the sufficiency level of B (hot water soluble B) in soil was found to be 0.35-0.5 ppm. The B deficiency occurred when the B of the soil was less than 0.2 ppm, however, depending upon the soil and groundnut genotypes, the critical limits of B may vary from 0.2-0.4 ppm (Singh, 1994). There is a strong correlations between B and organic carbon contents of soils and the risk of B deficiency increases when organic matter declines as it has the ability to complex large amount of B (Yermiyaho *et al.* 1988). Boron is an important both at deficient as well as toxic level in soil. It is required in very small quantity and application of 5-10 kg ha⁻¹ B showed toxicity symptoms in leaves. The concentration above 5 ppm of B in soil was toxic to the groundnut plant (Singh, 1994).

In polythene-lined micro-plot, in the field, a good correlation between the amount of B applied, soil B and pod yield was obtained, however, the B requirement of groundnut varied with cultivars. On an average, the healthy plant showed 40 ppm B, however, the sufficiency level of B in the leaf during flowering and fruiting (40-70 DAE) was 25-60 ppm. The critical level of B was observed to be 20 ppm, but the clearcut deficiency symptoms was observed only when the leaf B concentration fell below 15 ppm. However, Hill and Morrill (1974) reported 26 ppm of B at 30-60 DAP, and Gopal (1968) found 20 ppm as the critical level in leaves. The groundnut kernels containing less than 17 ppm B showed the incidence of hollow-heart.

The toxicity of B caused stunted growth and interveinal chlorosis leading to iron deficiency. Excess of B accumulation caused imbalance of other nutrient, the leaflets tips become yellow, interveinal chlorosis followed by necrosis. The B toxic leaves showed curling with scorch sign, the chlorotic areas were golden yellow at margin. Leaves assumed a scorch appearance and fall off. The rate of photosynthesis, growth and pod yield of were maximum at 0.5 ppm of B in nutrient solution, indicating that this is the optimum concentration of B. The respiration rate in groundnut roots was more at the toxic levels (5 ppm) of B.

Assessment of yield losses due to B deficiency

In groundnut, severe mineral deficiencies are commonly observed in most part of the country, however the visual symptoms of B are rarely observed in spite of its good response. Thus, presuming that the B deficiency is hidden in groundnut, though many a time express in kernel, an experiment was conducted

to assess the loss of yield due to B deficiency where encouraging results were obtained (Table 1).

The perusal of data show that application of macro- plus micro-nutrients produced 39.7-94.4 % more pod yield than the untreated control and withholding of B caused considerable decrease in pod yield. Depending upon the year the yield-losses due to B deficiency were 14.5-26 %. Being a legume crop groundnut requires B for partitioning, and hence shortage of this element showed yield reduction.

Table 1. Yield losses due to B deficiency in groundnut in calcareous soils

Details of the Treatments	Pod yield (kg ha ⁻¹)			Yield losses over T2, a full package of macro-and micro-nutrients (%)		
	1993	1994	1995	1993	1994	1995
T1-Control	979	1292	2005	-	-	-
T2-All macro- and micro-nutrients	1903	2131	2795	-	-	-
T3- T2 minus B	1626	1576	2328	14.5	26.0	16.7

The macronutrients N, P, K, Ca, S and Mg at 40, 40, 60, 100, 30 and 10 kg ha⁻¹, respectively were applied 50% as basal in the furrows and 50 % at 30 DAE in all the treatments except control. The micronutrients Fe, Mn, Zn, Cu, B and Mo at 10, 10, 5, 2, 2 and 1 kg ha⁻¹, respectively were used 50 % as basal in the furrows along with macronutrients and 50 % applied at 30 DAS.

Boron (B) is a constituent of cell membrane and essential for cell division, nitrogen metabolism and protein formation and acts as a regulator of K/Ca ratio in the plant. It helps in nitrogen absorption and translocation of sugars and carbohydrates in the plants. It is important in pollination and seed production. As boron is highly essential to complete the plant life cycle, the deficiency of boron caused yield reduction in groundnut. Total soil B content ranged from 0.01 to 10 ppm. However, only a small fraction of this amount is available to the crop. Much of the total soil B is present as a component of tourmaline a highly insoluble mineral.

In Tamil Nadu, based on random soil sample analysis, the B deficiency accounts for 21% and depending upon the soils conditions, B application at 5-25 kg ha⁻¹ increased yield of groundnut, however under irrigated conditions 15 kg ha⁻¹ borax with NPK as basal is used (Muthusamy and Sundararajan, 1973). In field trials borax at 1.25 kg B ha⁻¹ increased 25 to 30% yield of groundnut at Pollachi in Coimbatore district and 15-30% in South Arcot district (Chitdeswari and Poongothai, 2003). However, application of 2.5 kg ha⁻¹ B at Tindivanam increased 57% yield of groundnut hybrid over control.

Effectiveness of Soil and seed dressing of Boron fertilizers

The borax and boric acid are the two commonly used boron fertilizers in India and their effectiveness and methods of application, as seed dressing and in the furrows in the soil, at 1 kg B ha⁻¹ were judged in groundnut crop. In general, these salts showed their positive response to groundnut grown in calcareous soil and increased the number of pods, pod yield, shelling per cent, oil content and

seed size of groundnut over control (Table 2 and 3). However, there was interaction among the methods of applications on the yields and other parameters. When borax and boric acids were applied as soil, in the furrows, showed positive response with good germination and increased the pod yield, pod number and oil content. But, as seed dressing these was detrimental to groundnut seedling. Boric acid was comparatively more detrimental than borax. In a study on the effects of nutrient salts on the germination reveals that, in general, the groundnut seed took 6 days for their germination, but seed coating with borax and boric acid delayed field emergence for 3 and 4 days respectively and reduced germination (Table 4).

Table 2: Influence of various Boron fertilizers and their modes of application on the pod and haulm yields, number of pods, oil content, percent shelling and 100-seed weight of FeESG 10 groundnut during Wet 1995.

Treatment	Pod yield (kg ha ⁻¹)			Haulm Yield (kg ha ⁻¹)			Pods plant ⁻¹		
	Seed	Soil	Mean	Seed	Soil	Mean	Seed	Soil	Mean
Control	950	950	950	3167	3167	3167	6.3	6.3	6.3
Borax	1211 (27.5)	1399 (47.3)	1305 (37.4)	3000	3433	3217	7.7	8.0	7.9
Boric acid	862 (-9.2)	1460 (53.7)	1161 (22.2)	3522	3356	3434	7.0	8.6	7.8
Mean	1008	1270	1139	3230	3319	3273	7.0	7.6	7.3
LSD (0.05)									
Application mode		64			82			0.3	
Treatments		183			234			0.9	
Interaction		259			332			1.2	
	Oil %			Shelling %			100-seed wt.		
Control	48.5	48.5	48.5	61.0	61.0	61.0	24.4	24.4	24.4
Borax	50.6 (4.3)	49.5 (2.0)	50.1	66.2	62.8	64.5	26.5	29.1	27.8
Boric acid	49.7 (2.3)	49.9 (2.8)	49.8	63.7	62.5	63.1	24.7	25.9	25.3
Mean	49.6	49.3		63.6	62.1		25.2	26.4	
LSD (0.05)									
Application mode		0.46			NS			NS	
Treatments		1.31			2.8			2.0	
Interaction		1.86			3.9			2.8	

Figures in parenthesis are the percent changes over control

Seed dressing with boric acid caused damage to seed initially, as a result reduction in field germination was observed and hence these could not cope up with growth and field cover to produce significant increase in yield and other parameters. Thus, these should not be used as seed dressing. However, as soil

application, both boric acid, and borax were excellent and hence these should be used.

The increase in oil content, shelling percent and 100-seed weight of groundnut was observed due to application of borax either through seed or in soil indicating that B has played an important role in increasing these parameters and hence its application is essential in calcareous soil. Though role of micronutrients in increasing the yields and yield attributes, in calcareous soil, is well known (Singh, 1999; Singh et al 1990; Singh and Chaudhari, 1997), the present study has clearly demonstrated the effectiveness of these B fertilizers and its essentiality for groundnut in getting good quality produce.

Table 3. Influence of Boron fertilizers and their mode of application on the pod and haulm yields, oil content, percent shelling, sound mature kernels (SMK), and 100-seed weight of groundnut genotypes FeESG-10 during Wet, 1996.

Treatment	Pod yield (kg ha ⁻¹)			Haulm yield (kg ha ⁻¹)		
	Seed	Soil	Mean	Seed	Soil	Mean
Control	985	1042	1013	1333	1600	1467
Borax	918 (-6.8)	1293 (24.1)	1106	1233	1800	1516
Boric acid	697 (-29.2)	1300 (24.8)	998	1300	1833	1567
Mean	867	1212		1289	1744	
LSD (0.05)						
Application mode		58			97	
Treatments		137			227	
Interaction		194			321	
	Shelling %			100 kernel wt (g)		
Control	64.9	65.1	65.0	28.1	28.0	28.0
Borax	66.5	68.1	67.3	25.8	27.1	26.5
Boric acid	65.9	67.6	66.7	25.6	27.8	26.7
Mean	65.8	67.0		26.5	27.6	
LSD (0.05)						
Application mode		0.87			0.71	
Treatments		2.03			1.65	
Interaction		2.88			2.35	
	SMK %			Oil %		
Control	79.0	78.7	78.9	49.0	49.2	49.1
Borax	82.5	84.7	83.6	50.3	52.5	51.4
Boric acid	83.3	84.0	83.7	52.8	53.4	53.1
Mean	81.6	82.5		50.7	52.4	
LSD (0.05)						
Application mode		NS			0.64	
Treatments		3.1			1.52	
Interaction		4.7			2.15	

Figures in parenthesis are percent changes over control

Comparison of boron application through soil, foliar and drip

The micronutrients due to its lesser quantity are generally applied on foliage in solution form, but due to dry weather the leaves do not effectively absorb it fully. Now-a-days, looking to the water economy in semi-arid and arid regions which are the main groundnut area of India, the drip system of irrigation is becoming popular. Therefore, a field experiment conducted to reveals that application of B through drip irrigation, increased the yield and yield parameters, fertilizer use efficiency and was superior over their soil and foliar application in increasing all these parameters (Table 5 and 6).

Table 4. Influence of various salts and their modes of application on field emergence of FeESG 10 groundnut genotypes.

Treatments	% Germination with various application modes		Time taken for 50% germination in seed treatment	
	Seed	Soil	Days for germination	Delay (days)
Control	90	90	6	
Borax	75	>80	9	3
Boric acid	45	>80	10	4
Iron sulphate	80	>80	8	2
Manganese sulphate	80	>80	8	2
Zinc sulphate	80	>80	8	2

Table 5. Boron and their methods of application on plant height, chlorophyll, pod weight, percent sound mature seeds (SMS) and oil in GG 2 groundnut.

Treatments	Plant height at harvest		Chlorophyll content (mg g ⁻¹ dry wt.) in leaves at 40 DAE			Pod wt. (g plant ⁻¹)		% SMS	% Oil	
	1995 RS	1995-96 R	Chl. a	Chl. b	Total Chl	1995 RS	1995-96 R	1995-96 R	1995 RS	1995-96 R
Control	27.6	22.9	4.94	1.61	6.55	4.5	4.1	70.0	49.9	49.0
B, soil	30.5	23.8	5.22	1.73	6.95	5.7	5.5	73.7	49.8	49.9
B, foliar	29.3	24.1	4.76	1.60	6.36	4.9	5.8	76.7	49.1	49.9
Drip	32.0	25.2	5.95	1.88	7.83	6.2	4.9	82.0	49.0	49.2
Water										
B, drip	32.6	25.3	5.47	1.65	7.12	6.9	6.0	84.7	49.5	49.7
LSD (0.05)	4.0	2.1	0.80	0.45	1.02	0.9	1.03	8.3	NS	NS

Where R is Rabi (Mid Oct.- Feb.) and RS is Rabi-summer (Feb.-May) crop.

Boron when applied in soil or as foliar spray, though could not influence much on pod and haulm yields and shelling percentage, it increased percent SMS and 100-seed weight during both the seasons. However drip application of B could increase all these parameters significantly.

Depending upon the season and year, soil, foliar and drip application of B increased pod yield by 5.6-7.7, 6.1- 6.4, and 14.8-20.8 % respectively over control. Drip application of B increased, 12-33% 100-seed mass, 7% shelling out-turn and 11% SMS over control which were also superior over their soil and foliar applications. In B deficient soils, application of 0.5-1.0 kg ha⁻¹ B as borax or boric acid recover the deficiency, but for better response the B should be applied prior to bloom stage. Foliar application of 0.05-0.1% aqueous solution of boric acid is effective in alleviating B deficiency of groundnut in the standing crop in the field (Singh et al., 1993). The response of boronated SSP in calcareous soil is also promising. Golakia and Patel (1986) the maximum yield of groundnut observed at 2 ppm of soil B and Ca:B ratio of 218-224.

Table 6. Influence of boron and their methods of applications on the pod and haulm yields, shelling percent and 100-seed wt of groundnut variety GG 2.

Treatments	Pod yield (kg ha ⁻¹)		Haulm yield (kg ha ⁻¹)		Shelling (%)		100-seed wt (g)	
	1995 RS	1995- 96 R	1995 RS	1995- 96 R	1995 RS	1995- 96 R	1995 RS	1995 96 R
T1-Control	2158	2329	3360	2567	65.1	63.4	35.0	34.2
T4-B, soil	2278 (5.6)	2509 (7.7)	3778	2867	67.7	66.0	39.5	35.9
T7-B, foliar	2297 (6.4)	2470 (6.1)	3658	2606	69.5	64.6	43.1	37.6
T8-Drip Water	2523 (16.9)	2521 (8.3)	3925	2900	71.3	65.1	44.2	38.2
T1-B, drip	2607 (20.8)	2673 (14.8)	3904	3033	72.8	67.9	46.6	38.4
LSD (0.05)	475	283	529	286	3.45	2.8	5.1	1.8

Where R is Rabi and RS is Rabi-summer crop. Figures in parentheses indicate percent increase over control

The major advantages of B application through drip were precise application at appropriate times with desired concentration, uniform distribution, less damage to crop and soil and ultimately higher yield. The development of root system is more in a restricted volume of soil in drip irrigation and application of B through drip can efficiently place it in this zone of highest root concentrations resulting in increased nutrient use efficiency over soil and foliar applications. In Tamil Nadu B deficiency is more common and foliar application of 0.5 kg ha⁻¹ borax recorded higher plant height, dry matter, pod yield, shelling %, oil content in groundnut (Shanker *et. al.* 2004). Saxena and Mehrotra (1984) found that groundnut variety “Type 28” gave maximum increase in pod yield with application of 11.2 kg borax ha⁻¹. A net profit of Rs.4,328 ha⁻¹ was obtained with application of 2.5 kg ha⁻¹ borax in soil + 0.25 % foliar with a cost benefit ratio of 1.94 in Tamil Nadu (Sudharsan and Ramaswami,1993). Tripathy et al (1999) reported that borax 10 kg ha⁻¹ increased the groundnut pod yield significantly.

Nutrition of bold seeded groundnut

Being bigger in size and good looking, the large-seeded (bold) groundnuts and also the hand picked and selected (HPS) seeds from the ordinary genotypes attract export for table consumption and Saurashtra and Kutch, in India, is the main area for the production of such export groundnut. But the large seeded groundnuts having more than 65 g 100 seed-mass, under ordinary management condition show 5-10% lower shelling out-turn and 100 seed mass than its potential, indicating that these are not getting proper nutrition and need extra input of Ca, K and B for better seed filling. A field experiment on pod filling and yield of groundnut, in large-seeded (TKG, 19A) and an ordinary (FeESG 10-1) genotypes reveals that application of Ca (100 kg ha⁻¹) as gypsum, K (100 kg ha⁻¹) as muriate of potash, and B (2 kg ha⁻¹) as boric acid alone or in combinations improved the pod filling and pod and seed yields (Table 7). Application of Ca, K, and B increased 34.6, 23.4 and 15.8 % pod yield over control, respectively, however combined application of Ca+K+B increased 44.6% pod yield over control. Application of these nutrients improved kernel filling, as a result the shelling percent and 100 seed mass increased. In Thailand, application of 0.25-0.5 kg B ha⁻¹ increased the number and weight of pod and seed and proportion of large seed to small seed and decreased percentage of hollow-heart from 13-49% to less than 1% (Keerati-Kasikorn and Panya, 1988a).

Table 7. Effects of Ca, K and B on pod Yield, shelling (%) and seed-mass of groundnut genotypes.

Treatments Details	Pod yield (kg ha ⁻¹)		Shelling (%)		100 seed wt (g)	
	O	L	O	L	O	L
Control	1944	1064	60.9	63.2	27.2	55.9
B2	2172	1312	62.4	64.3	27.6	56.1
K100	2352	1360	63.5	67.2	31.2	59.3
K100+ B2	2434	1420	64.6	67.7	30.4	61.1
Ca100	2455	1594	64.8	67.1	29.9	59.8
Ca100+B2	2669	1397	65.7	66.6	29.2	59.9
Ca100+K100	2745	1555	65.3	67.4	30.7	60.8
Ca100+K100+B2	2814	1534	66.1	68.0	31.7	61.3
LSD (0.05)						
Treatments	256		1.95		2.45	
Genotypes	128		0.98		1.23	
Interactions	NS		NS		NS	

L and O are large-seeded (TKG 19A) and ordinary (FeESG 10-1) genotypes

Summary

Groundnut (*Arachis hypogaea* L.) is an important food legume crop of India occupying the largest area (8 m ha) in the world, however, its average productivity is very low (1300 kg ha⁻¹) as compared to USA and China. The deficiencies of boron (B) and calcium (Ca) are the important factors responsible for low yield and low pod filling in groundnut in India. The Ca fertilizer is widely used, but there is no recommendation for B. Therefore, pot and field studies were undertaken in the main groundnut growing areas of India, to find out the

diagnosis of symptoms, extent of yield losses and remedies of boron deficiency in groundnut.

In sand culture pot experiments, the B deficiency showed retarded growth of the apical portion, death of the stem apex, malformation of the leaf vein, chlorosis, necrosis of basal margins in emerging leaves. However, these symptoms were not observed in field grown groundnut crop, even on B deficient soils, where low pod filling, shriveled seeds and hollow darkening or off-colour in the center of the seed were commonly observed symptoms of B deficiency. Depending upon the severity of the malady, the B deficiency caused 15-26 % yield losses in calcareous soils with 0.2 - 0.36 ppm hot water soluble B of the main groundnut growing areas.

Borax and boric acid are the two commonly used boron fertilizers, in India, and their application at 0.5 -1.0 kg ha⁻¹ B either in soil as basal or prior to bloom stage (20-30 days after emergence), or foliar application of 0.05-0.1% aqueous solution of boric acid corrected B deficiency and increased pod filling, seed size, 100-seed weight, percent sound mature seeds and finally pod yield. In field experiments, though response of B was observed from 0.5 - 2 kg B ha⁻¹, 1.0 kg B ha⁻¹ was ideal for most of the groundnut cultivars. However, large seed size groundnut cultivars like TKG 19A require higher quantity of B than the normal seed-size groundnut as application of borax at 2 kg B ha⁻¹ increased 23.3% in pod yield over control in large seed size groundnut, as against 11.7 % increase in pod yield over control in normal seed-size groundnut genotypes. But, the higher doses of B, more than 5 kg B ha⁻¹, showed its toxicity in groundnut leaves, which reminds of its careful application.

The effectiveness of various methods of application of borax or boric acid, at 1 kg B ha⁻¹, were compared in field by applying these as seed dressing, in the soil, as foliar spray and also along with drip irrigation where the maximum response was observed when B was applied along with drip irrigation, followed by soil application. Boric acid caused scorching of leaves when applied on foliage, and as seed dressing it caused damage to seed reducing field germination. Hence, these practices should be avoided in groundnut.

Thus, soil application of 1.0 kg B ha⁻¹, either as basal or at 20-30 days after emergence, is recommended for production of well-filled and quality seeds of groundnut in India.

Conclusions

Thus, soil application of 1.0 kg B ha⁻¹, either as basal or at 20-30 days after emergence, is invariably recommended for production of well-filled and quality seeds of groundnut in India. As large-seeded groundnut requires more B for pod filling it must be applied. Further as the application of B through drip irrigation was more beneficial over their soil and foliar applications, this practice is recommended in the areas wherever drip irrigation facility exists in semi-arid and arid regions.

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