Title
Boron fertilization is a must to enhance peanut production in India

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Introduction

Peanut (*Arachis hypogaea* L.) is an important legume used as oilseed as well as a food crop in India and grown in most of the states on all soil types, under tropical to subtropical climates. Average productivity in India is very low as compared to USA and China mainly due to mineral deficiencies and unreliable weather conditions. Boron (B) and calcium (Ca) deficiencies are the important factors responsible for low yield in the recent cultivars with large seeds (Singh et al., 2004; 2007). In B-deficient acid soils (below 0.4 ppm available B), low pod filling, shriveled seeds and hollow darkening or off-colour in the center of the seed are commonly observed symptoms of B deficiency causing 10-50 % yield losses (Cox and Reid, 1964; Singh et al., 2004; 2007). Application of 0.5-1.0 kg ha^{-1} B to the soil normally alleviated the disorder, but there is no recommendation of any agriculture grade B fertilizer in India and farmers depend upon Borax and boric acid, two laboratory grade chemicals not easily available.

To increase the production, it is essential to grow the recently released large seeded peanut, using latest fertilizer recommendations. Since there are low-cost B products available in the international market and being tested in other crops, it becomes essential to test these new B fertilizers and find out their suitability for soil, seed and foliar application and recommend the most economic and effective sources and methods for peanut. Thus field experiments were conducted at various locations in sandy to clayey soils to find out effectiveness and feasibility of commercial grade B sources i.e. Agricol, Chemiebor, Solubor, Borosol and Borax for peanut.

Material and Methods

Field experiments were conducted during wet season at Junagadh, Raichur, Vriddhachalam, Mainpuri, Durgapura and Kolasib, the six locations situated throughout India and representing acid, neutral and alkaline soils. The soils of the experimental sites were a sandy loam acidic (pH 4.8) at Kolasib, a red laterite sandy soil (pH 6.5) at Vriddhachalam, a sandy loam (pH 6.5- 7.5) at Raichur, Mainpuri and Durgapura and clayey calcareous soil (pH 7.5) at Junagadh with medium fertility and 0.20 - 0.45 mg kg^{-1} hot water-soluble B. The experiments were laid out in a randomized block design (RBD) with three replications using high yielding large seeded peanut cultivars. There were 10 treatments at all the locations, but 13 treatments at Junagadh for testing of various B sources and their modes of application (Table 1 and 2).

The field was prepared by ploughing and levelling, divided into small plots of 25 m^2 (5m x 5m) by raising bunds and N, P, K, and S at 40, 50, 50 and 30 kg ha^{-1}, respectively, and gypsum at 1000 kg ha^{-1} were applied uniformly in all treatments. The soil applications of 2 kg ha^{-1} of different boron sources were made along with NPK fertilizer. For seed treatment, the B fertilizers at 1 kg B ha^{-1} were mixed with seeds forming a coating around the seed and sown in the field immediately. Different B sources were foliar applied as 0.1% aqueous solution, at 1 kg B ha^{-1}, in three applications at 30, 50 and 70 days after emergence (DAE). The seeds of peanut were sown at 45 x 10 cm spacing in the furrows and covered with soil after treatments. 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 percentage and 100 seeds weight were recorded.

Results and Discussion

The field experiments on various B sources at different locations revealed that application of B influenced flowering, yield and yield attributes at all the locations (Table 2, 3 and 4). All boron sources increased the pod yield of peanut significantly.

Table 1. Influence of various sources of boron on yield and yield components of GG 20 peanut at Junagadh

Treatments	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Shelling (%)	100 seed wt (g)
T_1-Control	580	2989	69	35
T_2-Borax (Soil)	802	3662	69	36
T_3-Boric acid (Soil)	676	3438	70	38
T_4-Agricol® (Soil)	793	3199	71	35
T_5- Agricol® (Seed)	148	1704	69	36
T_6-Chemiebor (Foliar)	938	4270	69	37
T_7-Solubor (Soil)	988	3678	69	38
T_8-Solubor (Foliar)	916	4023	70	37
T_9-Borosol (Soil)	693	3504	68	36
T_{10}-Borosol (Foliar)	743	4166	69	37
T_{11}-SSP – A (Soil)	740	3752	69	37
T_{12}-SSP – B (Soil)	743	4051	68	35
T_{13}-Super-Colemanite (S)	703	4001	68	34
CD at 5 %	104	520	NS	NS

At Junagadh application of boron increased pod and haulm yields (Table 1). Soil application of the same amounts of B as Borax, Agricol, Solubor, boronated SSP-A and SSP-B were at par. However, as foliar application the response of Chemiebor and Solubor was outstanding. Seed dressing of Agricol was highly detrimental to peanut as it decreased germination. The highest pod yield was obtained with soil application of Solubor and foliar sprays of Chemiebor. Various B sources also increased haulm yield significantly. Foliar sprays of Solubor, Borosol and Chemiebor were at par and all produced more than 4000 kg ha^{-1} haulm yield with the highest yield obtained by Chemiebor as against 2989 kg ha^{-1} in control.

At Durgapura, the highest pod yield (2877 kg ha^{-1}) was obtained with foliar application of 0.1 % aqueous solution of solubor followed by foliar spray of borosol and soil application of Borax. The performance of boric acid, Agricol and Chemiebor were at par (Table 2).

At Kolasib, soil application of Borax, and Solubor and foliar application of Chemiebor and Borosol increased the peanut pod yield significantly over control, but seed dressing of Agricol and foliar application of solubor did not increase the yield(Table 2). Among the boron sources the highest pod yield (2546 kg ha^{-1}) was obtained by soil application of Borax, followed by foliar spray of Chemiebor (2454 kg ha^{-1}).

At Raichur statistically significant differences could not be observed due to in general low yields (Table 2). However, there was also a clear tendency that the boron sources increased the peanut pod yield varying from 3-38%. The foliar spray of Borosol showed maximum yield followed by Chemiebor and Solubor. Here also the seed dressing of Agricol was detrimental to peanut causing lesser germination and poor yield.

Table 2. Influence of various boron sources on pod yields (kg ha^{-1}) of peanut at various locations

Treatments	Durgapura	Kolasib	Raichur	Vriddhachalam	Mainpuri
T_1-Control	2119	2083	507	1431	1311
T_2-Borax (Soil)	2716	2546	606	1535	1427
T_3-Boric acid (Soil)	2632	1944	508	1564	1381
T_4-Agricol® (Soil)	2614	2083	523	1612	1413
T_5- Agricol® (Seed)	2186	1991	483	1550	1355
T_6-Chemiebor (Foliar)	2601	2454	671	1737	1397
T_7-Solubor (Soil)	2509	2222	584	1838	1387
T_8-Solubor (Foliar)	2877	1991	641	1500	1394
T_9-Borosol (Soil)	2496	1852	597	1601	1472
T_{10}-Borosol (Foliar)	2761	2199	707	1580	1400
LSD (0.05)	295	115	NS	90	71

At Mainpuri maximum pod yield was obtained with soil application of Borosol (1472 kg pod ha^{-1}) followed by Borax (1427 kg pod ha^{-1}) in peanut cultivar G-201 (Table 2). However, as foliar application the responses of Chemiebor, Borosol and Solubor were at par. The seed dressing of Agricol was not encouraging for peanut. Interestingly, B application caused 2-3 days early flowering (Table 3).

Table 3. Influence of boron sources on various yield parameters of G-201 (Kaushal) peanut at Mainpuri and VG 403 peanut at Vriddhachalam.

	Mainpuri				Vriddhachalam		
Treatment	Days to flowering	Haulm yield (kg ha^{-1})	Shelling (%)	100 seed wt (g)	Harvest index	Shelling (%)	100 seed wt (g)
T_1-Control	30	2265	66	37	41	61	53
T_2-Borax (S)	30	2767	70	41	47	73	57
T_3-Boric acid (S)	28	2733	67	39	31	74	54
T_4-Agricol® (S)	27	2797	69	41	42	71	61
T_5- Agricol® (Seed)	28	2846	68	38	41	73	63
T_6-Chemiebor (F)	27	2863	69	39	50	73	63
T_7-Solubor (S)	27	2704	70	39	53	64	64
T_8-Solubor (F)	28	2744	69	40	51	70	60
T_9-Borosol (S)	29	3119	71	41	51	73	63
T_{10}-Borosol (F)	29	2771	68	40	45	69	55
LSD (0.05)	2	337	2.5	2	2.7	2	3

Where S is soil and F is foliar applications

At Vriddhachalam, the highest pod yield was obtained by soil application of Solubor (1838 kg ha^{-1}) followed by foliar sprays of Chemiebor (1737 kg ha^{-1}). The harvest index, shelling percentage and 100 seed weight were also improved by B application. Various B sources increased pod yield by 5 to 27 %, shelling by 5-10 %, and 100-seed mass by 5-8 % (Table 3).

The results for various locations reveal that all sources of boron increased peanut pod yield, and soil application of the same amount of B as borax, Agricol, and Solubor were at par. The sufficiency level of hot water-soluble B in soil for peanut is 0.5 ppm, and depending on soil and genotype the critical limits of B vary from 0.2-0.4 ppm (Singh, 1994). As the soils of all experimental locations in this study had less than 0.5 ppm available B, the response was obvious. Soil application of 1.0 kg B ha^{-1} as Agricol, Solubor and Borosol increased pod yields to a similar degree as borax and boric acid. The foliar application of Borosol, Chemiebor and Solubor were similarly effective in increasing pod yields. However, foliar applications caused scorching of peanut leaves and seed dressing of Agricol damaged seeds and reduced field emergence during dry weather condition.

Soils at most of the locations in this study were B-deficient causing yield reductions in peanut, which were offset by external application of B fertilizers. The increase in shelling percent and 100-seed weight of peanut observed due to application of B indicate an important role in seed quality. Thus, B application was recommended in calcareous soil (Singh et al., 2007). Earlier, in field trials borax at 1.25 kg B ha^{-1} increased the yield of peanut by 25 to 30% at Pollachi and by 15-30% in South Arcot. Application of 2.5 kg ha^{-1} B increased the yield by 57 % at Tindivanam (Chitdeswari and Poongothai, 2003). The present study has clearly demonstrated the effectiveness of various B sources for enhancing the production and quality of peanut in various soils at reasonable cost.

Thus application of 1.0 kg B ha^{-1} to these B-deficient soils using any one of these B sources is recommended to enhance peanut productivity. However, Agricol is the cheapest source.

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