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EFFECT OF APPLIED CALCIUM-BORON RATIO ON THE AVAILABILITY OF EACH TO RADISH (*Raphanus sativus* L.)

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ABSTRACT

The present study was based on the hypothesis whether Ca/B ratio is significant in soil solution terms or in applied terms. A green house study was carried out in sandy heath land soil, growing radish *(cv. French breakfast)* as a test crop during 1997 at the University of Reading, England. The experiment was laid out in a randomized complete block design and replicated three times. Varying Ca/B ratios i.e. 2000:1, 1000:1, 500:1, 250:1, 125:1 and 25:1 were applied, corresponding to soil solution ratios 7959:1, 4369:1, 1035:1, 851:1, 486:1 and 45:1 along with a basal dose of all essential nutrients. Results revealed that significant treatment effects were observed in the growth response of radish plants and maximum fresh and dry matter yields were recorded at Ca/B ratio of 1035:1 in soil solution or applied 500:1, corresponding to Ca/B ratio in tops and roots were found to be 187 and 41, respectively. The concentration of Ca decreased and B increased significantly with decreasing the Ca/B ratio in the soil. While, the total uptake of Ca and B showed similar response to radish yield as affected by varying Ca/B ratio either in soil solution or applied. Direct correlations were found between the Ca/B ratio in the soil solution or applied with the Ca/B ratio in radish plants, suggested that both Ca/B ratios are significant from the soil fertility and plant nutrition point of view. Soil pH significantly increased as the Ca/B ratio in soil solution or applied decreases.

INTRODUCTION

It is well documented that B has a close relationship with Ca both in plant and soil. It appears that Ca increases the B requirement of plants due to similarity in function (Valmis and Ulrich, 1971; Golakiya and Patel, 1988) and in soil reduces its availability perhaps due to the formation of a calcium metaborate complex (Sillanpaa, 1972). Some times this mutuality is indicated by the Ca/B ratio of plants. The concept of a certain Ca/B ratio used for the status of B nutrition in plants, resulted in many publications by a number of investigators (Gupta and Cutcliffe, 1972; Manchanda and Yadav, 1978; Lal *et al.*, 1979 and Golakiya and Patel, 1988). The investigators showed that crops grow normally if a certain balance exists both in the intake and tissue concentration of Ca and B. However, the results regarding Ca-B relationships appear to be conflicting, because some researchers grown plants in culture solution (Brennan and Shive, 1948; McIlrath and Debruyn, 1956) and others grown plants in soils (Manchanda and Yadav, 1978; Golakiya and Patel, 1988) using traditional extractrants for the determination of available Ca and B in soil, however, hardly few studies were carried out on the extraction of soil solution. Because, soil solution is the source of nutrients for plants and most soil chemical reactions involve this phase. An understanding of nutrient concentration in soil solution is therefore essential, because it influences the processes of nutrient supply to the plant. Soil solution chemistry may therefore, provide a valid measure of the nutrient status of a soil (Campbell *et al*., 1989). Therefore, the main aim of the present investigation was to study the effect of Ca/B ratio on the availability of each in soil solution and their uptake by plants. Secondly, to see whether the concentration of these two elements in soil solution run parallel with plant uptake, or if any adsorption, precipitation and exchange reactions of ions did occur during plant growth. Keeping in view these points an experiment was proceeded to test the general hypothesis as to whether the Ca/B ratio is significant in soil solution terms or in applied terms, using radish as a test crop.

MATERIALS AND METHODS

Experimental conditions and layout

The experiment was carried out in 1997 at the Department of Soil Science, University of Reading, England under green house conditions in randomized complete block design with six Ca/B ratios and replicated three times. Each treatment was represented by a plastic pot in which four healthy plants of equal size were planted. Each block was situated within a distance of 30 cm from each other. The position of each pot was randomly changed once a week, to minimize spatial variation in the green house during the experimental period. The maximum temperature was 22 ^{0}C and the minimum 18 ^{0}C. The relative humidity was approximately 65%, and the lighting period was distributed in 16 hrs day and night.

Description of the soil used

The soil used was boron deficient, collected from the Bracknell area near Reading. The soil was from sandy heath land, and is an unfertilized acid soil. A bulk sample of the top soil (0-20) was collected from different points at random in the area, after clearing the surface litters, and made a composite sample. The composite soil sample was air dried, ground, passed

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through a 2 mm sieve and characterized for various physico-chemical properties by routine standard procedures

Pot, seed pre-germination and planting

Each pot received 1 kg of air dry soil and four equal size plants. Before use the pots and saucers were thoroughly washed in 3% hydrochloric acid and then with deionised water and dried in oven at 40 ^{0}C. A glass wool filter paper was placed at the bottom of each pot to cover holes for preventing loss of soil, and the pot placed on a plastic saucer. Equally sized of radish seeds (*cv. French breakfast*) were selected, and pre-germinated in acid washed sand for five days. Then the uniform seedlings were transplanted to the pots. It was kept around at 20% by weight moisture content with deionized water by successive weighing, throughout the growth period. The plant water consumption was recorded. As the plants were growing an extra amount of water equivalent to the plant fresh weight applied at every weighing, and also one pot without plants was included to measure the water losses by evapotranspiration.

Application of Ca/B ratios

The soil was prepared by adding solutions of $CaCl_2.2H_2O$ and H_3BO_3 in different proportions, to bring the original soil to desired Ca/B ratios. The ratios of total Ca to B in each treatment were as follows:- 2000:1, 1000:1, 500:1, 250:1, 125:1 and 25:1 corresponding to the soil solution ratios 7959:1, 4369:1, 1035:1, 853:1, 486:1 and 45:1, respectively. The detail procedure for preparing the ratios were as follows:- Soil contains a" mg Ca kg^{-1} and b" mg B kg^{-1}. We take 1 kg soil for each pot, this contains ac" mg Ca and bc" mg B. For example, to obtain the 1000:1 Ca/B ratio we need to add: d" mL of $CaCl_2.2H_2O$ containing e" mg Ca L^{-1}. Total f" mg Ca (a-d), and g" mL of H_3BO_3 containing h" mg B L^{-1}: Total j" mg B (b-g). Then ac+f/bc+j = 1000/1.

Harvest and measurements

The radish plants were harvested at marketable maturity. The plants were washed thoroughly with deionised water, then placed on tissue paper to remove excess water. The fresh matter yield for tops and roots were measured. Then both tops and roots were oven dried at 80 ^{0}C for 48 hours and had their dry matter yield recorded.

Soil analysis

At harvest fresh soil from each treatment pot was collected and the soil solution from saturated soil was extracted using centrifugal drainage as suggested by Kinniburgh and Miles (1983), and subjected to elemental analysis for Ca and B by ICP-OES. At harvest sub-samples from each treatment pot was taken for the determination of soil pH (1:2 soil: water suspension), to see any pH changes occurred due to varying Ca/B additions.

Plant analysis

The dry plant materials were ground using Tema mill which was cleaned thoroughly with a brush and acetone for each treatment, then extracted by dry ashing technique and analyzed for Ca and B for their elemental content followed by ICP-OES (Mozafar, 1989). Elemental standard solutions were prepared for low, moderate and high concentrations in the same matrix as the samples to calibrate the ICP-OES before introducing the samples, and the results printed on Dec-writer II input/output terminal.

Statistical analysis

Statistical analysis of all the data collected during investigations were analyzed by MSTAT-C computer package, using ANOVA technique and the means were compared by the LSD-test of significance (Steel and Torrie, 1980). In addition, correlation coefficients (r) were determined between the variables of the experiment.

RESULTS AND DISCUSSION

Results showed that the experimental soil was loamy sand in nature, acidic in reaction, having adequate organic matter, and deficient in hot water soluble-boron (Table I).

Table I ***Physico-chemical properties of experimental soil***

Properties	Units	Values
Clay	%	4.20
Silt	%	11.4
Sand	%	84.4
Texture	-	Loamy sand
pH $(1:2)_s$	-	4.93
CEC	cmolc kg^{-1}	4.94
Base saturation	%	45.1
Organic matter	%	4.14
Available Ca	mg kg^{-1}	125
HWS-B	µg g^{-1}	0.44

Fresh matter yield

The fresh weight of tops and roots of radish plants were recorded separately at harvest. It is evident from the results that both tops and roots showed similar responses to varying Ca/B ratios in soil (Table II). A maximum fresh matter yield was obtained when the plants received a ratio 500:1 (applied) or 1035:1 (soil solution), beyond this ratio the yield was gradually decreases as the ratio increased. Results also showed significant differences in yields with regard to various ratios, but the yield of the highest and lowest ratios were found statistically at par. This suggests that the decline in yield of radish can occurred in both deficient and toxic B conditions. On the basis of statistical significance with regard to the effects of Ca/B ratios in soil, it can be said that the applied ratios from 250:1 to 500:1 corresponding to soil solution ratios 853:1 to 1035:1 would be desirable for obtaining good yield of radish from the present tested soil. The ratios lower or higher than this range would likely to reduce the fresh matter yield. These results are in agreement with those of Lal *et al*. (1979) who reported that the average Ca/B ratios in soil from 600 to 1000 for *Bajra* crop.

Dry matter yield

The dry weight of tops and roots were recorded separately, when fresh plant biomass were oven dried until a constant weight was established. Results of dry matter yield showed a similar pattern to varying Ca/B ratios in soil as in the case of fresh matter yield (Table II). The optimum Ca/B ratio for both tops and roots of radish plants appears to be 500:1 (applied) or 1035:1 (soil solution). Further results showed that no significant difference was found in the dry matter of tops and roots as the plants received 250:1, 125:1 and 25:1 ratios in soil corresponding to soil solution ratio of 853:1, 486:1 and 45:1 indicating that both plant parts were equally developed on such ratios of Ca/B. It is evident from the results that an almost similar yield responses were obtained for both fresh and dry matter yields of radish, suggesting that fresh matter yield can be used as an approximate guide for the expected dry matter yield of radish plants. It was also evident that the lowest yield was found in the treatment receiving a highest Ca/B ratio in soil, indicating the dry matter yield considerably reduced either due to Ca excess or B deficiency in soil. This point complicates the present situation. However, it is more likely that the lower yields may be due to deficiency of B, because it is well known that cruciferous or root crops have high B demands (Sillanpaa, 1972; Murphy and Walsh, 1972; Katyal and Randhawa, 1983 and Shorrocks, 1984). Secondly, perhaps in the B deficient condition the resulting concentration of other nutrient-elements may have changed their status in plants and resulted lower yields. These results are in line with the previous work of Valmis and Ulrich (1971) and Carpena-Artes and Carpena-Ruiz (1987).

Table II ***Effect of different Ca/B ratios on the yield of radish***

Ca/B Ratio		Fresh matter yield g pot^{-1}		Dry matter yield g pot^{-1}	
Applied	Soil solution	Tops	Roots	Tops	Roots
2000:1	7959:1	11.88	20.50	0.92	1.10
1000:1	4369:1	28.90	35.13	2.00	2.47
500:1	1035:1	32.74	41.35	3.57	3.50
250:1	853:1	21.19	39.33	2.80	1.27
125:1	486:1	20.59	29.02	2.02	1.58
25:1	45:1	10.77	26.00	1.82	1.34
LSD(P<0.01)**		6.60	11.41	0.41	1.12
LSD(P<0.05)*		4.64	8.02	0.58	0.88

*, ** = indicate significance at P <0.05 and 0.01 levels, respectively

Ca concentration and uptake

As expected the reverse trend occur in the case of Ca (Table III). Results showed that with decreasing the Ca/B ratios in soil the concentration of Ca both in tops and roots decreased, and resulted in a significantly positive correlations either applied (r = +0.97, 0.90), or in soil solution (r = +0.95, 0.90), respectively. However, large differences were found in the distribution of Ca between tops and roots of plant, indicated as the availability of Ca in soil solution increases the concentration in both tops and roots also increased which resulted significantly positive correlations to one another (r = +0.92 and +0.87). Similar results were reported by Oyewole and Audayi, (1992). The positive relationship between Ca in plants and Ca/B ratios in soil suggests that the Ca absorption and utilization by radish is dependent to the levels of B in soil. Results regarding the total uptake of Ca showed similar trend as found for dry matter yield (Table III), but non significant and negative correlations were existed for both tops (r = -0.07, -0.29) and roots (r = -0.17, -0.24) either applied or in soil solution ratios, respectively. Results further indicate that both dry matter yield and Ca uptake were affected approximately by the same way due to varying Ca/B ratios in soil. However, a maximum Ca uptake was obtained from the treatment receiving 500:1 ratio in soil corresponding to soil solution ratio of 1035:1. These results are in line with previous study of Woodbridge *et al.* (1974).

B concentration and uptake

Again as expected with decreasing the Ca/B ratios in soil, the concentration of B both in tops and roots of plants increased considerably (Table III) and showed a negative but non significant correlation for both tops and roots either applied (r = -0.54, -0.80) or in soil solution (r = -0.55, -0.76), respectively. This explained the chemical and physiological relationships between Ca-B in soil and in plants. Similar results were also observed by various workers for example, Chouhan and Powar (1978), Blamey and Chapman (1979 b), Golakiya and Patel (1988) and Su *et al.* (1994). Furthermore, it is evident from the results that the concentrations of B found in soil and plant tops and roots run parallel to each other, which resulted a close positive relationships (r = +0.99 and +0.86), respectively. This again suggests that the B availability in soil and uptake by plants is dependent to the Ca/B ratios in the soil. Similar relationships between the plant and soil solution B were also reported by Prasad and Byrne (1975), John *et al*. (1977), Su *et al*. (1994) and Rashid *et al*. (1994). Results also revealed that the concentrations of B found in plant tops are considerably higher than that of roots except the treatments receiving the Ca/B ratios of 2000:1 and 1000:1 (applied) or 7959:1 and 4369:1 (soil solution), respectively. This suggests higher Ca levels in soil affected the translocation of B from roots to tops of radish plant. Results regarding the total uptake of B also showed significantly negative correlation for tops (r = -0.70, -0.69), while in the roots poor correlation existed (r = -0.27, -0.34) with both applied or in soil solution Ca/B ratios. Results indicate that a maximum uptake for both plant parts were obtained when the plants receiving a 500:1 Ca/B ratio corresponding to soil solution ratio of 1035:1 (Table III) and beyond this ratio considerably decreased, perhaps due to lower dry matter yield. Dwivedi (1992) also reported that the reduced uptake of B by pea and corn was due to the reduced dry matter yield at highest rate of B fertilization.

Table III ***Effect of different Ca/B ratios on the concentration and total uptake of Ca and B by radish***

Ca/B Ratio		Concentration		Total uptake	
Applied	Soil solution	Ca %	B µg g^{-1}	Ca mg pot^{-1}	B µg pot^{-1}
		Tops			
2000:1	7959:1	1.43	35.67	13.16	32.82
1000:1	4369:1	1.17	47.67	23.40	95.34
500:1	1035:1	1.00	53.33	35.70	190.4
250:1	853:1	0.76	63.67	21.28	178.3
125:1	486:1	0.68	73.67	13.74	148.8
25:1	45:1	0.66	258.3	12.01	470.2
LSD(P<0.01)**		0.30	26.34	8.55	121.3
LSD(P<0.05)*		0.21	18.52	6.01	85.29
		Roots			
2000:1	7959:1	0.29	38.67	3.19	42.54
1000:1	4369:1	0.28	48.33	6.92	119.4
500:1	1035:1	0.20	48.33	7.00	169.2
250:1	853:1	0.13	48.33	1.65	61.38
125:1	486:1	0.16	50.56	2.53	79.88
25:1	45:1	0.12	63.33	1.61	84.86
LSD(P<0.01)**		0.08	14.59	2.23	64.13
LSD(P<0.05)*		0.06	10.26	1.63	45.09

*, ** = indicate significance at P <0.05 and 0.01 levels, respectively

Ca/B Ratio

Ca-B ratio in both tops and roots of radish plants were plotted against the Ca/B ratio in soil to see the relationship between soil-plant ratio (Fig. 1). In general, results show that as the Ca/B ratio in soil decreases the ratio in plants decreases and resulted in a positive and significant correlation for both tops (r = + 0.96) and roots (r = + 0.94), respectively. Similar relationships existed for both tops (r = + 0.98) and roots (r = + 0.94) when the plant's ratio plotted against the total Ca/B ratio in soil. These results suggests that the plant's ratio is dependent on the soil ratio (applied or/and soil solution), and can be used as an indication of the status of these two present in soils (Singh and Sinha, 1976; Golakiya and Patel, 1988). Moreover, results showed that a maximum yield of radish is associated with 187 and 41 in tops and roots, respectively corresponding to the soil solution ratio 1035:1 and applied ratio of 500:1. The radish (leaves) ratio is close to previous studies of Singh and Gangwar (1974) on sugar beet (220), and Chouhan and Powar (1978) on peas (213). In general, the evidence suggests that the Ca/B ratio is significant in terms of both physiological as well as from the soil point of view.

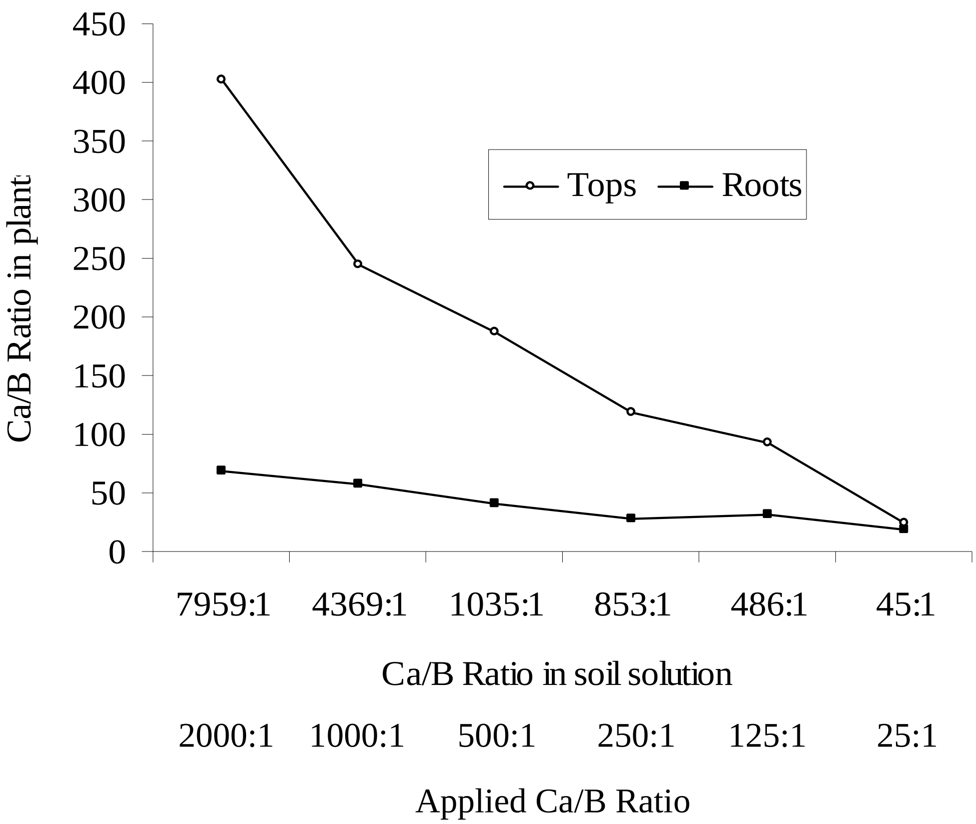

Fig. 1 Relationship between Ca/B ratio in soil and in radish plants

Soil pH

Soil pH was determined at harvest to see any change in soil reaction during plant growth. Results showed that as Ca/B ratio in soil decreases the pH of soil increases (Fig. 2). Although a small depression was found at Ca/B ratio of 125:1 in soil corresponding to soil solution ratio of 486:1, but LSD-test showed such a difference is non significant. Further results showed as the soil pH increases the acidity in soil solution significantly decreased, suggesting the lower pH at higher Ca/B ratios was due to the increase of total acidity in soil solution. The other possible explanation for the increase pH with decreasing Ca/B ratios seems to be the effect of $CaCl_2$ used as a source of Ca, because $CaCl_2$ has greater ability to reduce the pH due to the liberation of H^+ ions as a result of more acidity in soil solution.

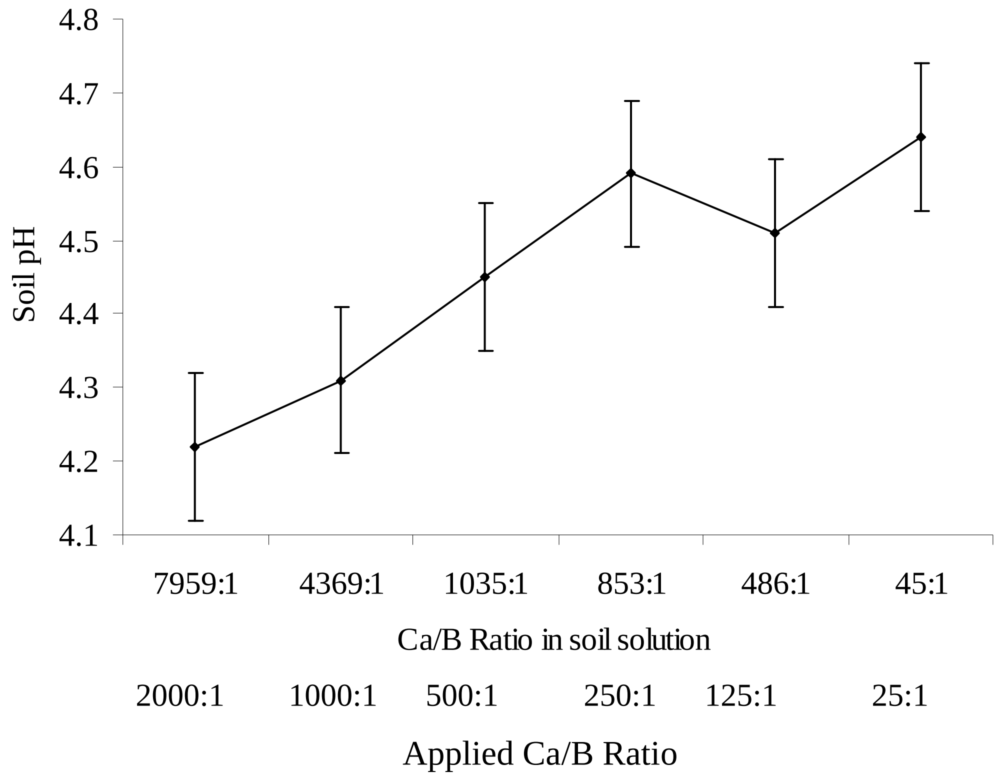

Fig. 2 Relationship between Ca/B ratio in soil and soil pH. Bar represents LSD-value of 0.21 at $P<0.05$

CONCLUSIONS

The following conclusions were drawn from the present study

I. Significant treatment effects were observed in the growth response of radish plants and maximum yields were recorded at Ca/B ratio of 1035:1 in soil solution or applied 500:1, corresponding to Ca/B ratio in tops and roots (D M) were found to be 187 and 41, respectively.

II. The concentration of Ca decreased and B increased significantly with decreasing the Ca/B ratio in the soil. While, the total uptake of Ca and B showed similar response to radish yield as affected by varying Ca/B ratio either in soil solution or applied.

III. Direct correlations were found between the Ca/B ratio in the soil solution or applied with the Ca/B ratio in radish plants, suggesting both Ca/B ratios are significant from the soil fertility and plant nutrition point of view.

IV. Soil pH significantly increased as the Ca/B ratio in soil solution or applied decreases.

REFERENCES

Blamey, F.P.C. and J. Chapman. 1979. Soil amelioration effects on boron uptake by sunflowers. Commun. Soil Sci. and Plant Anal. 10:1057-1066.

Brennan, E.G. and J.W. Shive. 1948. Effect of calcium and boron nutrition of the tomato on the relation between these elements in the tissues. Soil Sci. 66:65-75.

Campbell, D.J., D.G. Kinniburgh and P.H.T. Beckett. 1989. The soil solution chemistry of some Oxfordshire soils: temporal and spatial variability. J. Soil Sci. 40:321-339.

Carpena-Artes, O. and R.O. Carpena-Ruiz. 1987. Effects of boron in tomato plant. Leaf evaluations. Agrochimica. 31:391-400.

Chauhan, R.P.S. and S.L. Powar. 1978. Tolerance of wheat and pea to boron in irrigation water. Plant and Soil. 50: 145-149.

Dwivedi, B.S., R. Munna, B.P. Singh, M. Dos and R.N. Prasad. 1992. Effect of liming on boron nutrition of pea (*Pisum sativum L*.) and corn (*Zea mays* L.) grown in sequence in an acid Alfisol. Fert. Res. 31:257-262.

Golakiya, B.A. and M.S. Patel. 1988. Effect of Ca/B ratio on yield attributes and yield of ground nut. J. Indian Soc. Soil Sci. 36: 287-290.

Gupta, U.C. and J.A. Cutcliffe. 1972. Effects of lime and boron on brown-heart, leaf tissue, calcium/boron ratios, and boron concentration of rutabaga. Soil Sci. Soc. Am. Proc. 36:936-939.

John, M.K., H.H. Chuah and C.J. Van Laerhoven. 1977. Boron response and toxicity as affected by soil properties and rates of boron. Soil Sci. 124:34-39.

Katyal, J.C. and N.S. Randhawa.1983. Micronutrients. FAO, Fertilizer and Plant nutrition. Bulletin, No. 7. UN.

Kinniburgh, D.G. and D.L. Miles. 1983. Extraction and chemical analysis of interstitial water from soils and rocks. Environ. Sci. and Tech. 17:362-368.

Lal, F., P. Lal and M. Singh. 1979. Effect of Ca/B ratios in soil on the yield of *Bajra* grown on saline-sodic soils. J. Indian Soc. Soil Sci. 27:95-96.

Manchanda, H.R. and O.P. Yadav. 1978. Effect of boron application on barley in a sierozem sandy soil. Plant and Soil. 50:711-714.

McIlrath, W.J. and J.A. Debruyn. 1956. Calcium-boron relationships in Siberian millet. Soil Sci. 82: 329-336.

Mozafar, A. 1989. Boron effect on mineral nutrients of maize. Agron. J. 81:285-290.

Murphy, L.S. and L.M. Walsh. 1972. Correction of micronutrient deficiencies with fertilizers. pp: 347-381. In: Micronutrients in Agriculture (eds) Mortvedt, J.J., Giordano, P.M. and Linsay, W.L. (1972). Soil Sci. Soc. Am. Inc. Madison, Wisconsin, USA.

Oyewole, O.I. and E.A. Aduayi. 1992. Evalution of the growth and quality of "Ife plum' tomato as affected by B and Ca fertilization. J. Plant Nutr. 15:199-209.

Prasad, M. and E. Byrne. 1975. Boron source and lime effects on the yield of three crops grown in peat. Agron. J. 67:553-556.

Rashid, A., E. Rafique and N. Bughio. 1994. Diagnosing boron deficiency in rapeseed and mustard by plant analysis and soil testing. Commun. Soil Sci. and Plant Annal. 25:2883-2897.

Shorrocks, V.M. 1984. Boron deficiency its prevention and cure. Borax Holdings Limited, Borax House, Carlisle Place, London SW1P 1HT, England.

Sillanpaa, M. 1972. Trace elements in soils and agriculture. Food and Agric. Org. UN, Rome. Soils Bulletin No. 17.

Singh, K.P. and H. Sinha. 1976. Effect of boron application on K, Ca and Mg concentrations and their ratios with boron in plants. J. Instt. Chem. (India). 43:189-191.

Singh, R.R. and M.S. Gangwar. 1974. Critical boron concentration and calcium-boron balance as related to the boron need of sugar beet. Acta-Agronomica-Academiae-Scientiarum-Hungaricae. 23:108-113.

Steel, R.G.D and J.H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach. 2nd. Ed. McGraw Hill, New York, USA.

Su, C., L. J. Evans., T.E. Bates and G.A. Spires. 1994. Extractable soil boron and alfalfa uptake: Calcium carbonate effects on acid soil. Soil Sci. Soc. Am. J. 58:1445-1450.

Valmis, J. and A. Ulrich. 1971. Boron nutrition in the growth and sugar content of sugar beets. J. Am. Soc. Sugarbeet Tech. 16:428-439.

Woodbridge, C.G., J. Wieneke and F. Fur. 1974. The interaction between calcium and boron in apple seedlings. Zeitscrift fur pflanzenernahrung und Bodenkunde. 137:177-187.