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EFFECT OF APPLIED CALCIUM-BORON RATIO ON THE ACCUMULATION OF NUTRIENT-ELEMENTS BY RADISH (*Raphanus sativus L.*)

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ABSTRACT

The present study was based on the hypothesis whether applied Ca/B ratio has an association with other plant nutrients. A green house study was carried out in sandy heath land soil, growing radish *(cv. French breakfast)* as a test crop. The experiment was laid out in a randomized complete block design and replicated three times. Different Ca/B ratios were applied 2000:1, 1000:1, 500:1, 250:1, 125:1 and 25:1, 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. Significant treatment effects were observed in the growth response of radish and maximum dry matter yield of tops and roots were recorded at Ca/B ratio of 1035:1 in soil solution or applied 500:1. Results further revealed that B deficiency and toxicity symptoms were clearly apparent on plant leaves when the radish plants received higher and lower Ca/B ratios, respectively. However, no visible symptoms of other nutrients were found on plants during growth. The concentrations of P, K, Ca, Mg, Na, Mn and B in plants were significantly affected, while the total uptake of all nutrients were significantly changed due to Ca/B ratios in soil, in terms of applied or in soil solution, and showed close similarity to growth response. Correlation between Ca/B ratios and the concentrations of P, Ca, Mg, Na, Cu, Fe, Mo and B attained statistical significance, while in case of total uptake only N, P and Na showed significance**,** suggesting Ca/B ratios have some association with the other plant nutrients. It appears from the present study that no single or narrow range of Ca/B ratios in soil, whether applied or in soil solution is best for the concentration and total uptake of plant nutrients studied. However, considering the test soil from sandy heath land and the radish crop it seems that the best Ca/B ratios for the concentration and total uptake of nutrients ranged from 1000:1 to 500:1, corresponding to soil solution ratios ranged from 4369:1 to 1035:1. However, the role of Ca/B ratio on the behavior of plant nutrients is still not well defined, and further experimentations are desirable in this field.

Keywords: nutrients, concentration, uptake, Ca/B ratio, relationship, radish, crop.

INTRODUCTION

It is well understood that an extreme low or high Ca/B ratio significantly changes the growth response of crops. Perhaps due to the interaction of these two elements, or/and the apparent reduction in crops yield might be due to enhanced or reduced accumulation of other nutrient-elements. Because maximum growth of a crop occurs when all the essential-elements are present in an optimum concentration and a proper balance is maintained between them. Appearance of deficiency/toxicity symptoms of a particular nutrient does not always mean that it is present in very low/high concentrations, but indicates that the element may be low or high in relation to one or more of the other elements. Such a case might occurs with Ca/B ratio in soil-plant system. Because the relationship of Ca/B ratio with other plant nutrients is still lacking in the literature. However, a great deal of attention has been given to studying the effect of Ca/B ratio in relation to growth and production of various crops, but information on the resulting concentration and uptake of other plant nutrients is limited and not well known. Although some investigators observed this relationship with K and Na (Beauchamp and Hussain, 1974) in rutabaga and again with K (Kumar *et al.*, 1981) in rice, but not for other essential elements in crop like radish. It was therefore decided, to investigate the effect of Ca/B ratio on the concentration and uptake of other plant nutrients in greater detail, to test the general question as to whether the applied Ca/B ratio has an association with the plant content of Ca and B, if so, it is likely there must be some association with other plant nutrients as well. Keeping in view, these points the present experiment was proceeded with the main objective, to determine the relationship between applied Ca/B ratio with the concentration and total uptake of other plant nutrients.

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, and was laid out in randomized complete block design with six Ca/B ratios and three replications. 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 30cm of 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°C and the minimum 18°C. The relative humidity was approximately 65%, and the lighting period was distributed in 16hrs day and night.

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Description of the soil used

The soil used in the present experiment is known to be a boron deficient soil, collected from the Bracknell area near Reading. The soil is from sandy heath land, and is an unfertilized acid soil. A bulk sample of the top soil (0-20cm) was collected from different points at random in the area, after clearing the surface litter, and made a composite sample. The composite soil sample was air dried, ground, passed through a 2mm sieve and characterized for various physico-chemical properties by routine standard procedures

Pot, seed pre-germination and planting

Each pot received 1kg 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 deionized water and dried in oven at 40°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 more 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.

Ca/B ratio and basal nutrients application

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 procedures for preparing the ratios were as follows:
Soil contains a" mg Ca kg^{-1} and b" mg B kg^{-1}. We take 1kg 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. The other essential nutrient-elements being supplied in constant amounts according to the following rates:
N 24 mg kg^{-1} , P 40 mg kg^{-1}, K 110 mg kg^{-1}, Mg 60 mg kg^{-1}, Zn 1.20 mg kg^{-1}, Cu 0.56 mg kg^{-1}, Fe 0.20 mg kg^{-1}, Mn 2.40 mg kg^{-1}, Mo 0.08 mg kg^{-1}. For all applied nutrients laboratory grade reagents were used.

Harvest and measurements

The radish plants were harvested at marketable maturity. The plants were washed thoroughly with deionized water, then placed on tissue paper to remove excess water. The both tops and roots were oven dried at 80°C for 48 hrs and the dry matter yield was recorded for the determination of nutrients uptake.

Soil analysis

At harvest fresh soil from each treatment pot was collected and the soil solution from saturated soil was extracted using centrifugal drainage a method as suggested by Kinniburgh and Miles (1983), and subjected to elemental analysis for Ca and B by ICP-OES.

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 P, K, Ca, Mg, Na, Zn, Cu, Fe, Mn, Mo and B for their elemental content followed by ICP-OES (Mozafar, 1989). Elemental standard solutions were prepared of 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. Total-N was determined by C/N analyzer the method as described by Watkins and Barraclough (1996).

Statistical analysis

Statistical analysis of all the data collected during investigations were performed 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 mineral nitrogen, available phosphorus, potassium, molybdenum and hot water soluble-boron (Table-1).

Table-1. 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
NO_3 –N*	mg kg^{-1}	0.13
NH_4 –N*	"	0.40
P*	"	3.36
K*	"	25.0
Ca*	"	125
Mg*	"	7.60
Na*	"	10.0
Zn*	µg g^{-1}	4.20
Cu*	"	1.54

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Fe*	"	5.13
Mn*	"	5.00
Mo*	"	0.03
B*	"	0.44

* Available nutrients.

Dry matter yield

Dry weight of tops and roots were recorded separately, when fresh plant biomass were oven dried until a constant weight was established. Figure-1 show an 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 indicate 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 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). 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).

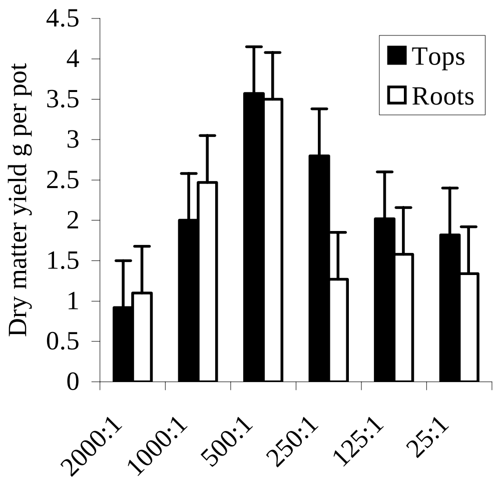

Figure-1. Effect of applied Ca/B ratios on the yield of radish plants.

Nutrients concentration and uptake

Nitrogen

Results showed no considerable changes were occurred in the concentration of N of plant tops and roots (Table-2), which resulted in a low correlation with regard to varying Ca/B ratios in soil (Table-3). On the other hand, a significantly negative correlation existed in the case of N uptake by tops (Tables 4 and 5), suggesting close similarity to growth response, but in the case of roots the data shows a poor relationship between the Ca/B ratios in soil and N uptake by roots. These inconsistent results suggests that the plants absorbed the N from the soil in a similar way as it is present in soil but on reaching to leaves the trend presumably changed due to increased or decreased carbohydrate production or of increased respiration (Wallace and Bear, 1949). Moreover, results show a small depression in the N concentration in both tops and roots of plant at 500:1 Ca/B ratio which may be due to dilution effect, because this ratio produced maximum yield. Results indicate that applied Ca/B ratio has no marked effect on the behavior of N in plants under the conditions of the experiment.

Phosphorus

Results show that with decreasing the Ca/B ratios in soil the concentration of P in both tops and roots significantly increases and resulted in a negative and significant correlation (Table 2 and 3). These results are in line with the previous work of John *et al.* (1977), Bartlett and Picarelli (1973) and Singh and Singh (1983). Results also revealed that the concentration of P in both pant parts became almost equal when the plants were growing in the higher Ca/B ratios such as 2000:1 and 1000:1, corresponding to soil solution ratios of 7959:1 and 4369:1, indicating that higher ratios did not change the distribution of P between the tops and roots of radish plants. Furthermore, the P concentration found in plants seems to be below the level of 0.3% required for the optimal growth of various crops (Marschner, 1993). Similarly, P uptake by plants showed significantly negative correlation with varying Ca/B ratios in soil (Tables 4 and 5). It is also evident from the results that an almost similar pattern was found in the uptake of P and B by plants, suggesting plants absorbed both elements in the same manner. This may be due to the positive interaction of B and P with in plant or in soil. Several hypothesis have been reported whether the synergism of B-P is direct or indirect (Patel and Mehta, 1966) or this synergism may be due to the functional relationships between these nutrients in plants (Kabata-Pendias and Pendias, 1984) or due to chemical reactions in soil (Bartlett and Picarelli, 1973). However, the present results are in line with the work of latter authors, who reported that B and P have similar reactions with OH^- groups thus the uptake of these elements by plants is likely to follow similar pattern.

Potassium

The data show an irregular trend for the concentration and uptake of K in plants, with regard to applied Ca/B ratios in soil (Tables 2 and 4), which resulted low correlation in both cases (Tables 3 and 5). It is interesting to note that the concentration and uptake of K followed a similar pattern to growth response, indicating

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both K and dry matter yield being affected by varying Ca/B ratios in a similar way. The increasing trend of K in plants with decreasing the Ca/B ratios in soil might be due to the indirect effect of B through Ca (Kumar *et al.*, 1981). Because it is known that the uptake of K depends on the Ca concentration in soil. This could also be observed in the present study. Because results indicate that the behavior of K in plants was mainly due to ion exchange processes in soil, Ca displaces the K.

Calcium

As expected the reverse trend occur in the case of Ca (Figure-2). Results show 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 or in soil solution (Table-3). 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. 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 (Figure-3), but non significant and negative correlations were existed for both tops and roots either applied or in soil solution ratios (Table-5). 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.

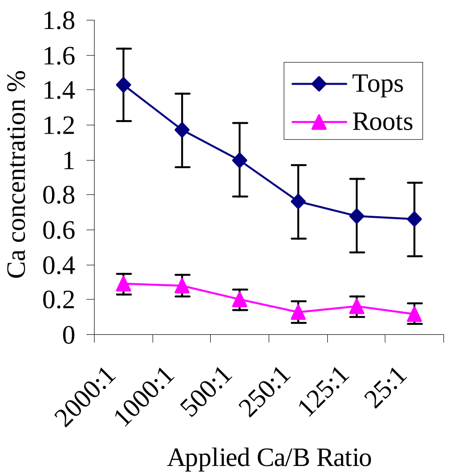

Figure-2. Effect of applied Ca/B ratios on the concentration of Ca in plants.

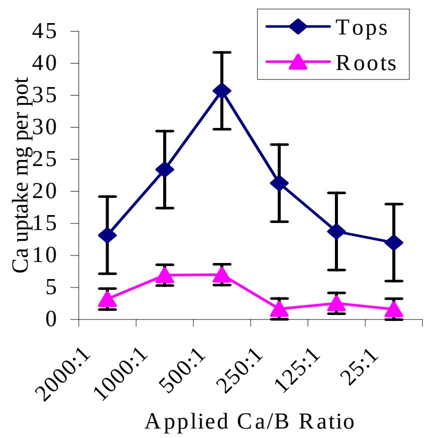

Figure-3. Effect of applied Ca/B ratios on the total uptake of Ca by plants.

Magnesium

Results show a similar pattern for the concentration and uptake of Mg by plants as found for K (Tables 2 and 4). The data show that as the Ca/B ratios in soil decreases the concentration and uptake of Mg in plant tops increases up to 500:1 corresponding to soil solution ratio of 1035:1 and on wards decreases which resulted significantly negative correlation to one another (Tables 3 and 5). A similar response to Mg was also reported by Oyewole and Aduayi (1992). While, in the case of roots both variables showed low correlation. Results also showed that the concentration of Mg found in the tops and roots at a highest Ca/B ratio below the critical level of 0.1% (Scott and Robson, 1990). This indicates that the highest Ca/B ratio in soil reduced the Mg in plants below the deficiency level.

Sodium

Sodium also followed the trends of K and Mg in plants (Tables 2 and 4). Results show as the Ca/B ratios in soil decreases the concentration and uptake of Na in plants generally increases and resulted in a significantly negative correlations (Tables 3 and 5). These results are in line with the previous work of Singh and Singh (1983) and Singh and Singh (1984). These authors reported that the increased absorption of Na and decreased Ca by plants at higher B levels may be due to the formation of sodium borate in soil. The present results suggest that the increased absorption of Na seems to be the direct effect of Ca through increase B in both soil and plant. Because it is known that exchange reactions occur in soil in the availability of cations such as K^+, Ca^{++} Mg^{++} and Na^+, which affect the elemental content of plants. Results further show that as in the cases of P and Mg the concentrations of Na found in the plants were lower than the normal limit of 0.1% required for various crop plants

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(Marschner, 1993), indicating imbalance Ca/B ratio may reduced the Na content in plant below the deficiency level.

Zinc

Results show that the concentration of Zn in plants increase up to 1000:1 corresponding to soil solution ratio of 4369:1 then onward regularly decreases with decreasing the Ca/B ratios in soil (Tables 2 and 3). This suggests that the changes occurred in the concentration of Zn, perhaps due to the physiological disturbance with in plants such as P/Zn ratio, as the results of both P and Zn sowed increasing and decreasing trends, respectively in their contents of plants. The evidence also suggests that the opposite trends found in their uptake may be due to the increase P/Zn ratio in plants through decreasing Ca/B ratios in soil. Further, low Zn concentration was recorded at highest Ca/B ratio in soil, indicating that low B reduced the Zn absorption by plants through increase P/Zn ratio in plants. Similar observations were made by Leece (1976 and 1978). He suggested that low B levels in soil prevent the full utilization of Zn and caused imbalance of P/Zn ratio in plants. Regarding uptake of Zn, a maximum Zn uptake by tops and roots were found at a Ca/B ratio 500:1 in soil corresponding to soil solution ratio of 1035:1 (Tables 4 and 5), beyond this range Zn uptake was considerably reduced, and showed similarity to growth response, again the r-values did not attain statistical significance. Chandel *et al.* (1985) and El-Gharably and Bussler (1985) also reported that both plant growth and Zn uptake were decreased at highest B supply.

Copper

Results showed that on decreasing the Ca/B ratios in soil the concentration of Cu in both tops and roots decreases and resulted in a positive relationship (Tables 2 and 3), but the differences found in the various treatments were statistically non significant. These results suggests that the decreasing trends of Cu in plants perhaps mainly due to the increasing concentration of B in soil. These results are in line with the work of Singh *et al.* (1990) and Alvarez-Tinaut. (1990). Results also showed that the concentration of Cu in roots is significantly higher than tops, indicating either that Cu may be retranslocated from tops to roots or that some Cu did not reach to the leaves during plant growth. The work of Alvarez-Tinaut *et al.* (1979) indicated that the Cu translocation was also affected by B and perhaps such a situation also occurred in the present study. A contrasting results were found in the case of uptake as compared to concentration of Cu in plants, suggesting negative relationship (Tables 4 and 5) between the uptake by tops and various Ca/B ratios in soil, but in the case of roots no relationship was found. The present results also showed close similarity to dry matter yield, suggested Cu was properly utilized by plants.

Iron

The concentration and uptake of Fe show an increasing trend with decreasing Ca/B ratios in soil (Tables 2 and 4), which resulted in a significant negative correlation in the case of tops, but in roots non significant relationship existed (Tables 3 and 5). Further LSD-test show non significant for tops and significant difference for roots among the various treatments of Fe in plants. Results also show that the concentration of Fe in tops and roots become almost equal at Ca/B ratios of 1000:1 and 500:1, corresponding to soil solution ratio 4369:1 and 1035:1, respectively, suggesting these ratios affected the translocation of Fe from roots to tops within plant. Moreover, a maximum uptake of Fe for both tops and roots was obtained when the plants receiving a Ca/B ratio of 500:1 in soil corresponding to soil solution ratio of 1035:1, which also produced a maximum dry matter yields, suggesting close similarity to growth response. Results further showed as the availability of Fe in soil increases simultaneously the concentration of Fe in plants tended to increase which resulted positive correlation to one another (Warnock, 1970). The increasing trend of Fe in plants with regard to decreasing Ca/B ratios in soil, suggests that the Fe availability may reduced due to higher Ca/B ratios or (lower B). Similar observations were also made by McIlrath *et al.* (1960).

Manganese

Results regarding the Mn in plants are slightly different from the other cationic micronutrients. Results show negative correlation of Mn concentration in plants to decreasing Ca/B ratio in soil (Tables 2 and 3). However, a minimum and maximum absorption of Mn in both plant parts occurred when the plants receiving Ca/B ratios of 2000:1 and 1000:1, corresponding to soil solution ratios of 7959:1 and 4369:1, respectively. As the results indicate with decreasing Ca/B ratios in soil the concentration of Mn in plants tended to significantly increase, but its availability in soil significantly decreases which resulted in a negative correlation to plant Mn. These results suggests that more Mn was present in soil solution but plant roots were unable to absorb, perhaps due to low pH or high Al content in soil. Marschner (1988) reported that with soil acidification Mn concentration in soil solution increases much more than the corresponding Mn uptake and contents in the shoots, and this effect can mainly be attributed to the strong inhibitory effects of high H^+ concentrations on uptake of Mn^{++}. Results further showed that the plants absorbed more Mn at normal Ca/B ratios than higher or lower ratios, perhaps due to the increased root growth at normal ratios. On the other hand, the total uptake of Mn by tops and roots showed a similar trend as found in the case of concentration (Tables 4 and 5), but the correlation did not attain the statistical significance. Generally, the total uptake of Mn data run parallels to growth response, suggesting both were affected similarly to varying Ca/B ratios in soil.

Molybdenum

The concentration of Mo in plant tops decreases up to 250:1 corresponding to soil solution ratio 853:1 then on ward increases with decreasing the Ca/B ratios in soil, and resulted in a positive correlation, while in roots a

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fairly constant trend was found which resulted low but negative correlation to varying Ca/B ratios in soil (Tables 2 and 3). Furthermore, LSD-test showed that Ca/B ratio has no significant effect on the concentration of Mo in both parts of radish plants. The present evidence suggests that Mo absorption by tops was reduced at 250:1 corresponding to soil solution ratio of 853:1 due to the dilution effect because of increase dry matter yield. In contrast, the total uptake of Mo showed a negative correlation, but roots again shows no correlation to Ca/B ratios in soil (Tables 4 and 5). The uptake of Mo in both plant parts show close similarity to growth response, indicating both were affected in a similar manner to varying Ca/B ratios in soil. The overall results indicate that Ca/B ratios in soil have no direct influence on the accumulation of Mo in radish plants. These results are also in line with the previous findings of McIlrath *et al.* (1960) and Bonilla *et al.* (1980). Generally, these authors reported that the antagonism between B-Mo is indirect and based on the biochemical and physiological processes within plants rather than chemical interactions in soil. However, it can be concluded from the present results that higher B concentration may reduces the Mo absorption by plants, presumably due to the competition between borate and molybdate anions on root cells.

Boron

Again as expected with decreasing the Ca/B ratios in soil, the concentration of B both in tops and roots of plants increased considerably (Figure-4) and showed a negative but non significant correlation for both tops and roots either applied or in soil solution (Table-3). This explained the chemical and physiological relationships between Ca-B in soil and in plants. Similar results were also observed by 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 relationship. 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 John *et al.* (1977), Su *et al.* (1994). Results 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 show significantly negative correlation for tops, while in the roots poor correlation existed with both applied or in soil solution Ca/B ratios (Table-5). 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 (Figure-5) 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.

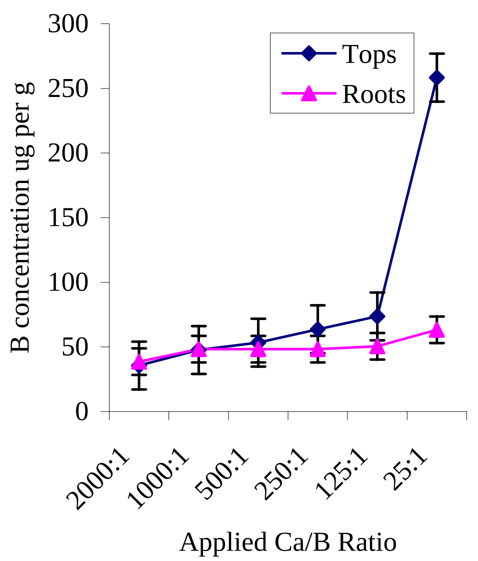

Figure-4. Effect of applied Ca/B ratios on the concentration of B in plants.

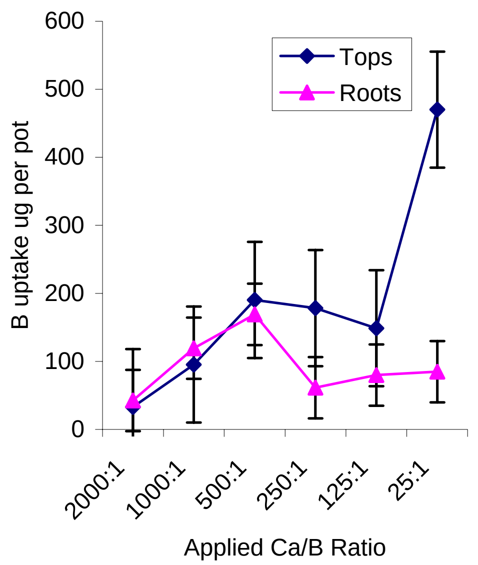

Figure-5. Effect of applied Ca/B ratios on the total uptake of B by plants.

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Table-2. Effect of Ca/B ratios on the nutrients concentration of radish.

Ca/B Ratio Applied	Soil solution	N	P	K	Mg	Na	Zn	Cu	Fe	Mn	Mo
		-----------------%-------------------					-----------------μg g^{-1}------------------				
Tops											
2000:1	7959:1	4.61	0.03	1.89	0.04	0.01	75.67	29.67	69.67	53.67	3.50
1000:1	4369:1	3.96	0.09	4.24	0.21	0.04	97.67	29.67	78.33	114.3	3.50
500:1	1035:1	3.66	0.10	4.15	0.26	0.05	89.33	29.00	87.33	111.0	3.25
250:1	853:1	4.12	0.18	2.39	0.21	0.05	86.00	28.33	99.00	100.3	3.08
125:1	486:1	4.37	0.17	3.06	0.20	0.05	82.00	29.33	84.00	86.33	3.25
25:1	45:1	4.99	0.21	3.06	0.18	0.04	81.00	28.33	86.33	85.00	3.33
LSD (P<0.01)**		NS	0.03	2.07	0.30	0.08	NS	NS	NS	31.78	NS
LSD (P<0.05)*		NS	0.02	1.45	0.21	0.05	NS	NS	NS	22.34	NS
Roots											
2000:1	7959:1	3.15	0.01	0.22	0.01	0.003	37.22	50.00	54.44	47.78	0.95
1000:1	4369:1	2.79	0.08	1.99	0.08	0.03	92.85	51.67	77.78	65.56	1.03
500:1	1035:1	2.44	0.11	1.52	0.07	0.03	78.89	51.11	88.89	62.22	1.00
250:1	853:1	2.61	0.11	1.43	0.05	0.10	76.11	51.11	111.1	56.67	1.00
125:1	486:1	2.81	0.11	1.18	0.04	0.07	75.55	49.33	77.22	58.33	0.97
25:1	45:1	3.18	0.15	1.07	0.03	0.02	72.22	46.00	72.22	55.00	0.97
LSD (P<0.01)**		0.70	0.03	0.86	0.08	0.02	29.21	NS	29.22	7.74	NS
LSD (P<0.05)*		0.49	0.02	0.60	0.05	0.01	20.54	NS	20.54	5.54	NS

**, * = indicate significant at P< 0.01 and 0.05 levels, respectively.
NS = Non Significant

Table-3. Correlation coefficient (r) between plant nutrients concentration and Ca/B Ratio in terms of applied or/and soil solution.

Element	Applied Ca/B Ratio		Soil solution Ca/B Ratio	
	Tops	Roots	Tops	Roots
N	-0.00 NS	+0.33 NS	-0.06 NS	+0.39 NS
P	-0.93 **	-0.97 **	-0.89**	-0.96**
K	-0.30 NS	-0.49 NS	-0.32 NS	-0.47 NS
Ca	+0.97**	+0.90**	+0.95**	+0.90**
Mg	-0.76 **	-0.30 NS	-0.78*	-0.30 NS
Na	-0.88 **	-0.59 NS	-0.89**	-0.56 NS
Zn	-0.18 NS	-0.64 NS	-0.16 NS	-0.61 NS
Cu	+0.72*	+0.36 NS	+0.73*	+0.33NS
Fe	-0.80 *	-0.61 NS	-0.82 **	-0.63 NS
Mn	-0.51 NS	-0.41 NS	-0.52 NS	-0.41 NS
Mo	+0.73*	-0.21 NS	+0.76*	-0.19 NS
B	-0.54 NS	-0.80 *	-0.55 NS	-0.76*

**, * = indicate significant at P< 0.01 and 0.05 levels, respectively.
NS = Non Significant

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Table-4. Effect of Ca/B ratios on the total uptake of nutrients by radish.

Ca/B Ratio Applied	-Soil solution	N	P	K	Mg	Na	Zn	Cu	Fe	Mn	Mo
		---mg pot^{-1}---					---µg pot^{-1}---				
Tops											
2000:1	7959:1	42.41	0.28	17.39	0.37	0.09	69.62	27.30	64.10	49.38	3.22
1000:1	4369:1	79.20	1.80	84.80	4.20	0.80	195.3	59.34	156.7	228.7	7.00
500:1	1035:1	130.7	3.57	148.2	9.28	1.79	318.9	103.5	311.8	396.3	11.6
250:1	853:1	115.4	5.04	66.92	5.88	1.40	240.8	79.32	277.2	280.9	8.62
125:1	486:1	88.27	3.43	61.81	4.04	1.01	165.6	59.25	169.7	174.4	6.57
25:1	45:1	90.82	3.82	55.69	3.28	0.73	147.4	51.56	157.1	154.7	6.06
LSD(P<0.01)**		21.86	1.64	52.65	2.43	0.38	75.54	15.92	102.1	107.7	2.63
LSD (P<0.05)*		15.37	1.15	37.02	1.71	0.27	53.11	11.19	71.81	75.75	1.85
Roots											
2000:1	7959:1	34.65	0.11	2.42	0.11	0.03	40.94	55.00	59.88	52.76	1.05
1000:1	4369:1	68.91	1.98	49.15	1.98	0.74	229.3	127.6	192.1	161.9	2.54
500:1	1035:1	85.40	3.85	53.20	2.45	1.05	276.1	178.9	311.1	217.8	3.50
250:1	853:1	33.15	1.40	18.16	0.64	1.27	96.66	64.91	141.1	71.97	1.27
125:1	486:1	44.40	1.74	18.64	0.63	1.11	119.4	77.94	122.0	92.97	1.53
25:1	45:1	42.61	2.01	14.34	0.40	0.27	96.77	61.64	96.77	73.70	1.30
LSD (P<0.01)**		26.78	2.12	24.93	1.05	NS	88.48	83.06	146.4	62.61	1.12
LSD (P<0.05)*		18.83	1.49	17.53	0.74	NS	62.21	58.39	102.9	44.02	0.78

**, * = indicate significant at P< 0.01 and 0.05 levels, respectively.
NS = Non Significant

Table-5. Correlation coefficient (r) between plant nutrients uptake by radish and Ca/B Ratio in terms of applied or/and soil solution.

Element	Applied Ca/B Ratio		Soil solution Ca/B Ratio	
	Tops	Roots	Tops	Roots
N	-0.73*	-0.06 NS	-0.80*	-0.13 NS
P	-0.91**	-0.56 NS	-0.92**	-0.62 NS
K	-0.39 NS	-0.18 NS	-0.47 NS	-0.22 NS
Ca	-0.07 NS	-0.17 NS	-0.29 NS	-0.24 NS
Mg	-0.54 NS	-0.10 NS	-0.62 NS	-0.16 NS
Na	-0.64 NS	-0.60 NS	-0.72*	-0.62 NS
Zn	-0.51 NS	-0.20 NS	-0.58 NS	-0.25 NS
Cu	-0.55 NS	-0.07 NS	-0.63 NS	-0.15 NS
Fe	-0.60 NS	-0.24 NS	-0.68 NS	-0.32 NS
Mn	-0.48 NS	-0.12 NS	-0.56 NS	-0.19 NS
Mo	-0.54 NS	-0.10 NS	-0.62 NS	-0.17 NS
B	-0.70 *	-0.27 NS	-0.69 NS	-0.34 NS

**, * = indicate significant at P< 0.01 and 0.05 levels, respectively.
NS = Non Significant

CONCLUSIONS

The following conclusions were drawn from the present study:

- Significant treatment effects were observed in the growth response of radish and maximum dry matter yield of tops and roots were recorded at Ca/B ratio of 1035:1 in soil solution or applied 500:1. Boron deficiency and toxicity symptoms were clearly apparent on plant leaves when the radish plants received higher and lower Ca/B ratios, respectively. No visible symptoms of other nutrients were found on plants during growth.
- The concentrations of P, K, Ca, Mg, Na, Mn and B in plants were significantly affected, while the total uptake of all nutrients were significantly changed due to Ca/B ratios in soil, in terms of applied or in soil solution, and showed close similarity to growth response.
- Correlation between Ca/B ratios and the concentrations of P, Ca, Mg, Na, Cu, Fe, Mo and B

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attained statistical significance, while in case of total uptake only N, P and Na showed significance relationships to Ca/B ratios in soil.

- It appears that no single or narrow range of Ca/B ratios in soil, whether applied or in soil solution is best for the concentration and total uptake of plant nutrients studied. However, considering the test soil from sandy heath land and the radish crop it seems that the best Ca/B ratios for the concentration and total uptake of nutrients ranged from 1000:1 to 500:1, corresponding to soil solution ratios ranged from 4369:1 to 1035:1.
- However, the role of Ca/B ratio on the behavior of plant nutrients is still not well defined, and further experimentations are desirable in this field.

REFERENCES

Alvarez-Tinaut, M.C. 1990. Correlations between boron and other micronutrients. In: Behavior, Function and Significance of Boron in Agriculture. Report on an International Workshop at St. John's College, Oxford, England. 23-25 July. Published by Borax Consolidated Limited, London.

Alvarez-Tinaut, M.C., A. Leal, I. Agui and L. Recalde-Martinez. 1979. Physiological effects of B-Mn interaction in tomato plants. III. The uptake and translocation of microelements. Analse de Edafologia y Agrobiologia. 38 (5/6): 1013-1029.

Bartlett, R. J. and C.J. Picarelli. 1973. Availability of boron and phosphorus as affected by liming an acid potato soil. Soil Sci. 116: 77-83.

Beauchamp, E.G. and I. Hussain. 1974. Brown heart in rutabagas grown on southern Ontario soils. Can. J. Soil Sci. 54: 171-178.

Bonilla, I., O. Cadhia, O. Carpena and V. Hernando. 1980. Effects of boron on the nitrogen metabolism and sugar levels of sugar beet. Plant and Soil. 57:3-9.

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

Chandel, A.S., D. Sharma and V.S. Rathore. 1985. Radioactive studies on zinc and boron interaction in green gram and maize. J. Agric. Sci. 55:371-374.

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.

El-Gharably and W. Bussler. 1985. Critical levels of boron in cotton plants. Z. Pflanzenernaehr. Bodenk. 148: 681-688.

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.

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.

Kabata-Pendias, A. and Hyrenk-Pendias. 1984. Trace elements in soils and plants. CRC Press, Inc. Boca Raton, Florida.

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.

Kumar, S., B.R. Arora and H.S. Hundal. 1981. Potassium-boron synergism in the nutrition of rice (*Oryza sativa sativum L.*). J. Indian Soc. Soil Sci. 29: 563-564.

Leece, D.R. 1976. Occurrence of physiologically inactive zinc in maize on a black earth soil. Plant and Soil. 44: 481-486.

Leece, D.R. 1978 Effects of boron on the physiological activity of zinc in maize. Aust. J. Agric. Res. 29: 739-749.

Marschner, H. 1988. Mechanism of manganese acquisition by roots from soils. In: Manganese in soils and plants. (eds) Graham *et al.* (1988) pp. 191-204. Kluwar Academic Dordrecht, The Netherlands.

Marschner, H. 1993. Mineral Nutrition of Higher Plants. (2nd Ed.) Academic Press, London.

McIlrath, W.J., J.A. Debruyn and J. Skok. 1960. Influence of boron supply on the micronutrients content of setaria shoots. Soil Sci. 89: 117-121.

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 *et al.* (1972). Soil Sci. Soc. Am. Inc. Madison, Wisconsin, USA.

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

Patel, N.K. and B.V. Mehta. 1966. Effects of various calcium-boron and potassium-boron ratios on the growth and chemical composition of aromatic strain of bidi tobacco. J. Indian Soc. Soil Sci. 34: 815-820.

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Scott, B.J. and A.D. Robson. 1990. Distribution of magnesium in subterranean clover (*Trifolium subterranaeum L.*) in relation to supply. Aust. J. Agric. Res. 41: 499-510.

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

Singh, J.P., D.J. Dahiya and R.P. Narwal. 1990. Boron uptake and toxicity in wheat in relation to zinc supply. Fert. Res. 24: 105-110.

Singh, V. and S.P. Singh. 1983. Effect of applied boron on the chemical composition of lentil plants. J. Indian Soc.Soil Sci. 31: 169-170.

Singh, V. and S.P. Singh. 1984. Effect of applied boron on nutrients and uptake by barley crop. Curr. Agric. 8: 86-90.

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.

Wallace, A. and F.E. Bear. 1949. Influence of potassium and boron on nutrient element balance and growth of ranger alfalfa. Plant Physiol. 26: 664-680.

Warnock, R.E. 1970. Micronutrient uptake and mobility within corn plants (*Zea mays L.*) in relation to phosphorus induced zinc deficiency. Soil Sci. Soc. Am. Pro.34: 765-767.

Watkins, N. and D. Barraclough. 1996. Gross rates of N mineralization associated with the composition of plant residue. Soil Bio. and Biochem. 28: 169-175.