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Effect of boron management on yield of rape *(Brassica campestris)* and its mobility in soil and plant*

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With the introduction of high-yielding crop varieties coupled with modern agro-techniques, most nutrients especially boron are becoming deficient due to continuous mining of nutrients from soils. It is evident that oilseeds, particularly rape is highly responsive to the application of boron (Chakraborty and Das 2000 and Mandal *et. al*. 2009). The role of soil organic matter on B soil solution concentration and its uptake by plants is not fully understood rather contradictory. However, the combined application of organic manures as well rotten farmyard manure (FYM) and B at 0.5 mg/kg to the soil significantly affect the B concentration in plants by increasing the availability of native as well as applied B (Sharma *et.al*. 1999) and organic matter in general increased the recovery of added boron from soils in all the extractable forms of B (Sharma *et.al*. 2000). Keeping these in view, the present field experiments were undertaken to study the effect of boron management on the yield and quality of rape (*Brassica campestris* L.) and its mobility in soil and plant.

Field experiments were conducted during the winter seasons of 2006–07 and 2007–08 with rape (cv. B 9) in an Aeric Endoaquept (*p*H 6.8, organic carbon 0.52%, CEC 12.50 c mol (p+)/kg and hot calcium chloride extractable boron 0.23 mg/kg) at the Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya (22.93°N latitude and 88.53°E longitude, average altitude of 9.75 m above mean sea level), West Bengal. The treatments were used as control, only recommended dose of fertilizers (80:40:40) (T_1), N, P_2O_5 and K_2O as recommended + organic manure @5 tonnes/ha (T_2), N, P_2O_5 and K_2O as recommended + B as calbor (1 kg B/ha) (T_3), N, P_2O_5 and K_2O as recommended + B as calbor (0.5 kg B/ha) + organic manure @5 tonnes/ha (T_4), N, P_2O_5 and K_2O as recommended + B as borax (1 kg B/ha) (T_5), N, P_2O_5 and K_2O as recommended + B as borax (0.5 kg B/ha) + organic manure @5 tonnes/ha (T_6). Experiments were laid out in a randomized block design (RBD), and the respective treatments were applied to each plot. Each treatment was replicated thrice. A basal dose of each P_2O_5 and K_2O was applied at 40 kg/ha and N was applied at 80 kg/ha in two splits, ie 40 kg N/ha as basal , 40 kg N/ha at 21 days after sowing. Nitrogen , P_2O_5 and K_2O were applied in the form of urea , single super phosphate and muriate of potash respectively. Calbor (4.5 % B, 1.7 % K as K_2O, 11% Ca as CaO, 12 % S , 1% Mg) and borax (10.5 % B) were used as a source of B. Farmyard manure (FYM) at 5 tonnes/ha (0.28 mg/kg B) was incorporated to the soil at the time of final land preparation . The size of each plot was 5m × 2 m. Seeds were sown at a spacing of 20 cm × 15 cm. Irrigation channels measuring 0.5 m wide were placed between the replications to ensure easy and uninterrupted flow of irrigation water.

Soil samples were collected periodically at an interval of 30 days from five to six randomly selected locations of each plot up to 90 days of sowing. Boron was determined with the help of spectrophotometer by Azomethine – H method (Wolf 1971) after extracting the soil with hot $CaCl_2$ solution (Parker and Gardner 1981).The plant samples were collected periodically at regular intervals and analyzed for total B content by Azomethine –H method (Wolf 1971) after digesting the samples with triacid mixture (HNO_3 :$HClO_4$:H_2SO_4 ::10:4:1; Jackson 1973). Yields were recorded after harvest of the crop. The percentage of oil content in rapeseed was determined by adopting Soxhlet's Ether Extraction method (AOAC 1984). The crude protein of rape seed was determined by microk-jeldhal digestion method (Jackson 1973). The amount of protein content was obtained by multiplying the nitrogen content with a constant factor of 6.25. All the replicated data of two years were pooled statistically. Univariate ANOVA technique for RCBD followed by Duncan's test at 5 % level of significance was used for comparing day-wise mean boron concentration.

*Short notes

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The results (Table 1) show that the HCC extractable B (non-specifically adsorbed B, NSA-B) was recorded a significant increase in all the treatments over control. However, such magnitude has been found to be decreased with the progress of crop growth, irrespective of treatments. The mean percent increase of HCC extractable B (NSA-B) was recorded as 19.31 in the treatment receiving recommended NPK and organic manure at 5 tonnes/ha was applied while such per cent increase was further enhanced (118.69) in the treatment T_4 where recommended NPK (80:40:40) , B at 0.5 kg/ha as calbor sources and organic manures were applied togetherly. This might be explained partly by the use of organic manure and also partly by the calcium content in the calbor exhibiting a positive role in releasing B in the soil solution (Bose *et al.*2002). As regards to sources of B, it was found that the amount of HCC extractable B did not vary significantly between calbor and borax applied as their equivalent levels of B along with NPK fertilizers., but differed significantly when these two sources of B (calbor and borax) were applied at 0.5 kg/ha B along with organic manure at 5 tonnes/ha NPK as recommended. The applied organic manure may help towards minimising loss of B from the soil and at the same time maintaining B in a reasonably extractable form. Milijkovic *et al*. (1966) obtained a correlation coefficient (r = 0.80 **) between water soluble B and organic matter x *p*H , indicating that increases in water soluble B associated with *p*H are greater in soils with higher organic matter contents.

The results (Table 1) reveal that the B content in the plant biomass gradually decreased with the progress of crop growth up to 90 days irrespective of treatments which might be due to the dilution effect resulting from the increased biomass. However, the magnitude of B content varied with the treatments. Comparing the results of different treatment, it was found that the amount of B content has been recorded a significant increase with the application of B as its different sources as well as organic manure along with recommended doses of NPK fertilizers, being a greater magnitude with B application at 1 kg/ha as calbor compared to equivalent level of B as borax. Such increase in the former case might be due to the presence of Ca which showed a positive interaction effect between B and Ca for the enhanced content of B in the plant. Bose *et al.*(2002) also confirmed the results of present study in which the B content on rape was increased due to combined application of B and lime in soils. The results also indicated that such mean increased in

Table 1 Effect of organic manure and boron application on the changes in hot $CaCl_2$ (HCC) extractable B (mg/kg) content in soil and in rape (*Brassica campestris* L.) during 2006–07 and 2007–08(pooled data of two years)

Treatment	Boron content in soil					Boron content in soil				
	Days after sowing					Days after sowing				
	30	50	70	90	Mean	30	50	70	90	Mean
T_1 control (only NPK recommended	0.351^{f}	0.329^{f}	0.308^{f}	0.297^{e}	0.321^{M}	8.03^{f}	7.63^{f}	6.65^{f}	6.15^{f}	7.12^{F}
T_2 NPK as recommended + organic manure @5 tonnes/ha	0.423^{e}	0.395^{e}	0.367^{e}	0.348^{d}	0.383^{L} (19.31)	9.07^{e}	8.57^{e}	7.74^{e}	7.03^{e}	8.08^{E}
T_3 NPK as recommended + B as calbor (1 kg B/ha)	0.688^{b}	0.543^{c}	0.607^{b}	0.506^{c}	0.586^{J} (82.55)	15.77^{b}	12.89^{b}	11.37^{b}	10.41^{b}	12.61^{B}
T_4 NPK as recommended + B as calbor (0.5 kg B/ha)+ organic manure @5 tonnes/ha	0.741^{a}	0.708^{a}	0.683^{a}	0677^{a}	0.702^{I} (118.69)	17.17^{a}	15.32^{a}	13.14^{a}	11.56^{a}	14.30^{A}
T_5 NPK as recommended + B as borax (1 kg B/ha)	0.636^{c}	0.592^{b}	0.573^{c}	0.566^{b}	0.592^{J} (84.42)	12.36^{d}	10.16^{d}	9.27^{c}	8.46^{d}	10.06^{D}
T_6 NPK as recommended + B as borax (0.5 kg B/ha)+ organic manure @5 tonnes/ha	0.542^{d}	0.494^{d}	0.524^{d}	0.485^{c}	0.511^{K} (59.19)	13.12^{c}	11.05^{c}	10.33^{c}	9.12^{c}	10.91^{C}
Mean	0.564^{W}	0.510^{X}	0.510^{Y}	0.480^{Z}		012.59^{P}	10.94^{Q}	9.73^{R}	8.79^{S}	

Within a column**:** means followed by the same letter are not significantly different at the 0.05 level of probability by Duncan's Multiple Range Test (DMRT), Parentheses indicate mean per cent increase over control

Table 2 Effect of organic manure and boron application on the changes in B content , uptake, yield , oil and protein content in rape (*Brassica campestris* L.) during 2006–07 and 2007–08 (pooled data of two years)

Treatment	B Content in rape seed (mg/kg)	B Uptake by rape seed (mg/ kg)	Yield (tonnes/ ha)	Oil content (%)	Protein content (%)
T_1 control (only NPK recommended	9.90^{D}	58.27^{E}	0.559^{E}	36.58^{C}	20.29^{D}
T_2 NPK as recommended + organic manure @5 tonnes/ha	11.32^{C}	74.80^{D}	0.684^{D}	3836^{B}	21.01^{D}
T_3 NPK as recommended + B as calbor (1 kg B/ha)	12.18^{A}	88.94^{B}	0.812^{B}	41.16^{A}	25.05^{AB}
T_4 NPK as recommended + B as calbor (0.5 kg B/ ha)+ organic manure @5 tonnes ha	13.57^{A}	95.85^{A}	0.895^{A}	41.65^{A}	25.52^{A}
T_5 NPK as recommended + B as borax (1 kg B/ha)	11.65^{BC}	79.16^{C}	0.726^{C}	40.11^{A}	23.71^{C}
T_6 NPK as recommended + B as borax (0.5 kg B/ ha)+ organic manure 5 tonnes/ha	11.88^{B}	77.59^{CD}	0.782^{B}	40.89^{A}	24.23^{BC}

Within a column**:** means followed by the same letter are not significantly different at the 0.05 level of probability by Duncan's Multiple Range Test (DMRT)

B content has been further enhanced (14.30 mg/kg) with the application of organic manure at 5 tonnes/ha along with recommended NPK (80:40:40) and B as calbor at 0.5 kg/ha compared to equivalent level of B as borax source. Sharma *et al.* (1999) also reported similarly who showed that the combined application of boron and FYM significantly affect the B concentration in stalk as well as total B accumulation in sunflower. Pakrashi and Haldar (1992) and Sakal (2001) also reported that the application of organic matter to B-deficient soil increased the utilization and recovery of applied B by maintaining relatively higher proportion of B in the soils and the extent of increase was more with increasing levels of organic matter.

The results (Table 2) show that the amount of B content and uptake by rapeseed have increased significantly in all the treatments over the control. However, the magnitude of such increase in B content (12.18 mg/kg) and uptake (8.89 tonnes/ ha) was relatively higher in the treatment when recommended dose of NPK (80:40:40) and B at 1 kg/ha as calbor was applied compared to equivalent doses of B as borax. Such increased per cent uptake (23.53) of B by rape seed further enhanced in the treatment where FYM at 5 tonnes/ha along with B at 0.5 kg/ha as calbor and recommended levels of NPK were applied. This might be explained by the higher yield and biomass production resulting from the highest number of branches and siliqua. Mandal *et al*. (2009) reported that the B content in the plant was recorded highest when integrated application of 0.5 kg B/ha as calbor and organic manure , FYM at 5 tonnes/ha.

The results (Table 2) show that the yield of rapeseed showed a significant variation with different treatments. However, the yield of rape seed has been found to be increased with treatments, being highest (0.895 tonnes/ha in the treatment T_4 where NPK (80:40:40), B at 0.5 kg/ha as calbor and organic manure at 5 tonnes/ha was applied. Lu *et al.* (2000) and Salroo *et al.* (2002) also reported that integrated boron management practices increased the yield of brown sarson. The per cent increase of rape seed yield in the treatment T_4 over control was 60.10 followed by the treatment T_3 (43%). The yield of rape seed followed the order of $T_4 > T_3 > T_6 > T_5 > T_2 > T_1$. Zou *et al.* 2008 also reported similarly who showed that the application of boron increased the yield and yield components of rape. The oil and protein content have been found to be increased significantly with the application of different treatments (Table 2). The highest mean oil (41.65) and protein content (25.52) was recorded in the treatment T_4 receiving recommended level of NPK (80: 40 : 40), B at 0.5 kg/ha as calbor and organic manure at 5 tonnes/ ha. The oil and protein contents of rape and soybean have been found to be increased with different levels of boron fertilizers (Deosarkar *et al.* 2002 and Hu *et al.* 1994). The highest percent increase in oil (13.86) and protein content (25.77) over control was recorded in the treatment T_4.

SUMMARY

The results of two year's field experiment show that the amount of hot $CaCl_2$ – extractable (HCC) B in soil and total B content in plant dry matter was significantly highest in the treatment where recommended levels of N, P , K (80 :40:40) along with 0.5 kg/ha B as calbor and farmyard manure at 5 tonnes/ha were applied while that of B content in and uptake by seed was recorded highest in the treatment where recommended levels of N, P, K and B at 0.5 kg/ha as calbor was applied. The yield of rape seed has been found to be increased with different treatments, being highest (0.895 tonnes/ha) in the treatment T_4 where NPK (80:40:40), B at 0.5 kg/ ha as calbor and organic manure at 5 tonnes/ha was applied togetherly with the simultaneous highest mean increase in oil and protein content as 41.65 and 25.52% respectively.

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