Water Soluble B Concentration as Affected by Different Chemical Amendments and Its Impact on B Content of Paddy and Barley Plants in Salt Affected Soils

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In India about 7 million hectares of land have been affected by salinity or alkalinity or both (ABROL and BHUMBLA [1]). Conditions which are considered to be favourable for the formation of such soils are also conducive to accumulation of soluble boron in soils. Consequently saline alkali soils are relatively richer in soluble boron as compared to normal soils (MAIR [7]). The importance of water soluble boron in salt affected soils lies in its marked toxicity to plants, even when present in relatively small amounts. USDA Salinity Laboratory staff [11] considered that boron concentration in saturation extract below 0.7 ppm is safe for sensitive crops, while 0.7 to 1.5 ppm is marginal and more than 1.5 ppm is unsafe. SINGH and SINGH [10] reported that saline soils of Uttar Pradesh contained 0.82 to 10.05 ppm boron as compared to 0.10 to 1.55 ppm in the normal soil. DEO and RUHL [3] mentioned that salinity associated with higher level of boron had more depressive and harmful effect on yield than salinity alone. DHANKER and DAHIYA [4] observed that yield and dry matter of ber *(Zizyphus rotundifolia)* decreased with increasing level of boron and salinity. In view of these facts it appears imperative to suggest that in order to grow successful crops on a salt affected soil, it is necessary that along with other improvements, its boron concentration be lowered to safe limits. This can be accomplished either by leaching or by reducing the solubility of boron.

A number of inorganic and organic amendments have been in use for ameliorating salt affected soils. Among inorganic amendments, gypsum, sulphuric acid, ferrous sulphate, aluminium sulphate are known to improve saline alkali condition. Recently iron pyrite, which contains varying amounts of sulphur and is available in abundance as natural deposits in India, has been in use as an amendment to improve sodic soils with considerable success. However, comprehensive information with regard to the effect of these chemical amendments on the solubility of boron in salt affected soils is lacking. Since boron is one of the essential micronutrients found abundantly in salt affected soils, therefore systematic studies were conducted to find out the effect of different chemical amendments on the solubility of boron in salt affected soils and its consequential impact on the boron content of paddy and barley plants.

Materials and methods

Pot culture study was undertaken to study the effect of chemical amendments on the solubility of B and its consequent impact on the B content of paddy and barley plants in saline alkali soil condition. The soil under experiment was collected from Azad Krishi Prakshetram Dalipnagar, Kanpur which lies in the typical saline alkali belt of the Gangetic alluvium of Uttar Pradesh. The soil of the farm is saline alkali in nature and has developed due to imperfect drainage resulting from the evenness of topography of the area.

A composite sample of surface soil (0—15 cm) was procured and analysed for various physico-chemical properties (Table 1.). The soil was highly sodic

Table 1

Physico-chemical properties of the soil

Soil property (Depth: 0—15 cm)		Soil property (Depth: 0—15 cm)	
pH	10.12	Mechanical composition, %	
EC, mmhos/cm	10.50	Sand	46.40
$CaCO_3$, %	2.80	Silt	31.60
Gypsum requirement, t/ha	26.50	Clay	22.00
E. S. P.	69.40		
Exchangeable sodium, me/100 g	8.60	Texture	Loam
Cation exchange capacity, me/100 g	12.50		

in nature having initial pH 10.2, EC 10.5 mmhos/cm and exchangeable sodium percentage 69.4. As many as seven chemical amendments viz. calcium chloride, magnesium chloride, ferrous sulphate, aluminium sulphate, sulphuric acid, iron pyrite, calcium sulphate were mixed with the soil separately at the rate of 20, 40 and 60 per cent of total gypsum requirement. Polythene lined pots were filled with treated soil. Treatments were replicated three times. The dose of gypsum was calculated by the standard SCHOONOVER's method on the basis of 15 cm soil depth which was estimated to be 26.5 tons/ha. Paddy (IR-8) was sown in treated pots. Required doses of N : P : K fertilizers were applied. Paddy seedlings were allowed to grow up to sixty days only. Meanwhile soil samples and plant samples were collected at the interval of 30 and 60 days and were analysed for boron by using HATCHER and WILCOX [6] technique. Similar procedure was adopted in the case of barley crop in a parallel experiment.

Results and discussion

Observations regarding changes in the soils' soluble B concentration as influenced by different chemical amendments after a period of 30 and 60 days have been recorded in Table 2. Data of the Table clearly indicate that application of amendments resulted in a decrease of water soluble boron concentration. However, maximum reduction to the extent of about 80 per cent was evidenced by the application of magnesium chloride when applied at the rate of 60 per

Table 2

Water soluble boron (ppm) in salt affected soils 30 and 60 days after treatment

Treatments	30 days 20 per cent of GR	30 days 40 per cent of GR	30 days 60 per cent of GR	30 days Mean	60 days 20 per cent of GR	60 days 40 per cent of GR	60 days 60 per cent of GR	60 days Mean
Control	—	—	—	3.50	—	—	—	3.50
Calcium chloride	3.0	1.4	1.3	1.90	2.9	1.3	1.1	1.77
Magnesium chloride	2.8	1.0	0.7	1.50	2.7	0.9	0.7	1.43
Ferrous sulphate	3.3	1.8	1.5	2.20	3.2	1.7	1.4	2.10
Aluminium sulphate	3.4	2.2	1.9	2.50	3.3	2.1	1.8	2.40
Sulphuric acid	3.2	1.6	1.4	2.07	3.1	1.5	1.3	1.97
Iron pyrite (22% S)	3.5	2.6	2.3	2.80	3.4	2.5	2.2	2.70
Calcium sulphate	3.0	1.4	1.2	1.87	2.9	1.3	1.1	1.77
Mean	3.17	1.71	1.47		3.07	1.61	1.37	
C. D. at 5%: Amendments		0.18				0.07		
Doses		0.12				0.05		
Amendments × doses		0.32				0.13		

cent of gypsum requirement. While application of other amendments like calcium chloride, ferrous sulphate, aluminium sulphate, sulphuric acid, iron pyrite, calcium sulphate, resulted in the decrease of soluble boron concentration to the order of 68, 60, 48, 62, 37 and 68 per cent, respectively. Observations recorded in aforesaid Table would further reveal that concentration of soluble boron in the soil progressively decreased with increase in the doses of amendments. Although reduction in boron concentration could be noticed even at the level of 20 per cent application but radical decline was effected through the application of amendments at the rate of 40 and 60 per cent of gypsum requirement. While comparing the reduction of soluble boron concentration with time space it could be seen that drop in soluble boron concentration was maximum 30 days after amendment application, although extending the period from 30 to 60 days resulted in insignificant decline in soluble boron level. This indicates that reduction of water soluble boron by application of amendments was completed within 30 days of their application.

Effect of amendment on the boron content of paddy and barley plants

Data regarding the effect of different amendments on the B content of different parts of paddy and barley plants are presented in Table 3. and 4. Results appended in these Tables clearly reflect the corresponding changes brought about by amendments in soil. Boron content of the plant including leaves, stems progressively decreased with increase in the doses of chemical amendments. Making closer scrutiny of data regarding impact of levels on boron content of paddy and barley plants, it is revealed that boron content of the plants significantly decreased with increase in the doses from 20 to 40 per cent but increase in the doses beyond 40 per cent did not significantly reduce the boron concentration. The decrease in boron concentration in plant body can be explained on account of the fact that soluble boron concentration was reduced in the soil by the application of amendments. As regards efficiency

Table 3

Average boron content (ppm) in 30 and 60 days old paddy plants as influenced by chemical amendments

Treatments	30 days old				60 days old			
	20	40	60	Mean	20	40	60	Mean
	per cent of GR				per cent of GR			
Paddy leaf								
Control	—	—	—	34.40	—	—	—	34.30
Calcium chloride	29.4	25.3	24.4	26.37	29.2	25.1	24.0	26.10
Magnesium chloride	26.4	22.2	21.3	23.30	26.2	22.0	21.0	23.07
Ferrous sulphate	31.3	27.5	26.4	28.40	31.1	27.3	26.1	28.17
Aluminium sulphate	32.2	28.1	27.0	29.10	32.0	28.0	26.7	28.90
Sulphuric acid	30.4	26.4	25.3	27.37	30.2	26.2	25.0	27.13
Iron pyrite (22% S)	32.9	28.7	27.6	29.71	32.6	28.4	27.4	29.47
Calcium sulphate	29.5	25.4	24.3	26.40	29.3	25.2	24.0	26.17
Mean	30.30	26.23	25.19		30.09	26.03	24.89	
C. D. at 5%: Amendments		0.85				0.96		
Doses		0.55				0.61		
Amendments × doses		N. S.				N. S.		
Paddy stem								
Control	—	—	—	28.50	—	—	—	28.30
Calcium chloride	24.3	20.2	19.1	21.20	14.0	20.1	19.0	21.03
Magnesium chloride	21.4	17.2	16.1	18.23	21.0	17.0	16.0	18.03
Ferrous sulphate	26.4	22.2	21.1	23.23	26.0	22.0	21.0	23.00
Aluminium sulphate	27.4	23.4	22.3	24.37	27.2	23.1	22.0	24.10
Sulphuric acid	25.5	21.2	20.1	22.27	25.2	21.0	20.0	22.07
Iron pyrite (22% S)	28.0	24.1	23.2	25.10	27.8	23.6	23.0	24.80
Calcium sulphate	24.4	20.2	19.2	21.27	24.0	20.0	19.1	21.03
Mean	25.34	21.21	20.16		25.04	20.97	20.01	
C. D. at 5%: Amendments		0.87				0.61		
Doses		0.60				0.41		
Amendments × doses		N. S.				N. S.		
Whole paddy plant								
Control	—	—	—	32.40	—	—	—	32.30
Calcium chloride	28.3	24.2	23.1	25.20	28.0	24.0	23.0	25.00
Magnesium sulphate	25.3	21.2	20.2	22.23	25.1	21.0	20.1	22.07
Ferrous sulphate	30.2	26.1	25.0	27.10	30.0	26.0	24.9	26.97
Aluminium sulphate	31.3	27.2	26.1	28.20	31.2	27.0	26.0	28.07
Sulphuric acid	29.5	25.3	24.2	26.33	29.3	25.0	24.0	26.10
Iron pyrite (22% S)	31.9	27.7	26.6	28.40	31.6	27.4	26.4	28.47
Calcium sulphate	28.4	24.5	23.4	25.43	28.1	24.2	23.7	25.33
Mean	29.27	25.17	24.09		29.04	24.96	24.01	
C. D. at 5%: Amendments		0.86				0.68		
Doses		0.55				0.45		
Amendments × doses		N. S.				N. S.		

of different amendments, it would be evident from the data appended in Tables 3. and 4. that magnesium chloride proved most effective in reducing the boron content of barley and paddy plants followed by calcium chloride, calcium sulphate, sulphuric acid, iron sulphate, aluminium sulphate and iron pyrite. Close scrutiny of data would further reveal that two amendments i. e. calcium chloride and calcium sulphate, had more or less similar impact in bringing down the boron concentration. Plant samples collected at the interval of 30 and 60 days

Table 4

Average boron content (ppm) in 30 and 60 days old barley plants as influenced by chemical amendments

Treatments	30 days old				60 days old			
	20	40	60	Mean	20	40	60	Mean
	per cent of GR				per cent of GR			
Barley leaf								
Control	—	—	—	41.10	—	—	—	41.30
Calcium chloride	36.6	31.4	30.8	32.93	36.3	31.0	30.4	32.57
Magnesium chloride	33.4	28.3	27.8	29.83	33.2	28.0	27.4	29.53
Ferrous sulphate	38.8	33.6	32.9	35.10	38.6	33.3	32.5	34.80
Aluminium sulphate	40.0	35.1	34.5	36.53	39.8	34.8	34.1	36.23
Sulphuric acid	37.5	32.4	31.8	33.90	37.3	-32.1	31.4	33.60
Iron pyrite (22% S)	40.9	35.6	34.9	37.13	40.6	35.3	34.5	36.80
Calcium sulphate	36.4	31.5	31.0	32.97	36.2	31.2	30.3	32.57
Mean	37.66	32.56	31.96		37.43	32.24	31.51	
C. D. at 5%: Amendments		0.69				0.44		
Doses		0.45				0.29		
Amendments × doses		N. S.				N. S.		
Barley stem								
Control	—	—	—	35.30	—	—	—	35.30
Calcium chloride	30.3	25.2	24.8	26.77	30.0	24.9	24.4	26.43
Magnesium chloride	27.3	22.2	21.9	23.80	27.0	21.8	21.4	23.40
Ferrous sulphate	33.2	28.1	27.7	29.67	33.0	27.7	27.2	29.30
Aluminium sulphate	34.3	29.2	28.8	30.77	34.1	28.9	28.3	30.43
Sulphuric acid	32.4	27.3	26.8	28.83	32.0	26.9	26.4	28.43
Iron pyrite (22% S)	34.9	29.8	29.3	31.33	34.8	29.4	28.9	31.03
Calcium sulphate	30.4	25.2	24.8	26.80	30.2	24.8	24.4	26.47
Mean	31.83	26.71	26.30		31.59	26.34	25.86	
C. D. at 5%: Amendments		0.58				0.44		
Doses		0.38				0.29		
Amendments × doses		N. S.				N. S.		
Whole barley plant								
Control	—	—	—	40.30	—	—	—	40.20
Calcium chloride	35.3	30.2	29.8	31.77	35.0	29.8	29.4	31.40
Magnesium chloride	32.1	27.0	26.5	28.33	31.8	26.7	26.0	28.17
Ferrous sulphate	38.2	33.2	32.7	34.70	38.0	32.8	32.2	34.33
Aluminium sulphate	39.1	34.2	33.8	35.70	39.0	33.8	33.3	35.37
Sulphuric acid	37.2	32.1	31.6	33.63	37.0	31.7	31.2	33.30
Iron pyrite (22% S)	39.8	34.6	34.0	36.13	39.6	34.3	33.6	35.83
Calcium sulphate	35.2	30.1	29.7	31.67	35.0	29.7	29.3	31.33
Mean	36.70	31.07	31.15		36.49	31.26	30.71	
C. D. at 5%: Amendments		0.54				0.71		
Doses		0.35				0.52		
Amendment × doses		0.93				N. S.		

did not show any marked decline in boron content of both paddy and barley plants which substantiate the previous conclusion that maximum reduction in soluble boron concentration in soil is completed within 30 days.

The leaves of both barley and paddy plants, in general, showed comparatively higher boron content than the stems did.

From the above observations it could be concluded that magnesium chloride was better than other amendments in reducing the solubility of B in soils which consequently affected the boron content of paddy and barley plants. RHOADES et al. [8] showed that magnesium hydroxide has an excellent property and possesses capability of removing boron from soluble phase. He demonstrated that boron is incorporated into the crystal lattice of magnesium hydroxide in the form of precipitate and thus forms a new compound. Of calcium chloride and another Ca salt, calcium sulphate, the application of the former one was a little more effective in reducing boron concentration. In salt affected soils having pH greater than 9.2 boron is present in toxic concentration in the form of sodium metaborates. Calcium salts applied in the soil as amendments react with sodium metaborate and form sodium sulphate and calcium metaborate. Since calcium metaborate is less soluble than sodium metaborate, calcium amendments render boron insoluble resulting in the decrease of boron content of soil and plant. COLEWELL and CUMMINGS [2] explained reduced boron adsorption in over-limed soil on account of the fact that calcium metaborates form an endless chain structure. Similarly GUPTA and CHANDRA [5] observed that reduction in boron concentration by application of gypsum was due to formation of calcium metaborates in highly sodic soil.

Experimental results have further indicated that sulphuric acid proved useful in reducing the boron concentration next to calcium amendments. Efficiency of sulphuric acid may be due to reaction of acid with calcium carbonate and thus producing calcium sulphate in situ. As regards comparative efficiency of ferrous sulphate and aluminium sulphate, former proved better in reducing the boron concentration. The salts of ferrous sulphate and aluminium sulphate in highly sodic soil produce a number of hydroxy iron and aluminium compounds providing sites for boron adsorption. SIMS and BINGHAM [9] have reported that after aging for more than 14 days, at pH 10, the capacity of hydroxy aluminimum precipitate for boron adsorption was less than that of hydroxy iron precipitate. This explains why aluminium sulphate was less efficient than iron sulphate in decreasing the concentration of boron. Least efficiency of iron pyrite may be due to the reason that it might have passed through unfavourable condition of sulphur oxidation under sodic condition which resulted in few effective sites for boron adsorption.

Summary

A pot experiment was conducted to study the effect of seven chemical amendments viz. calcium chloride, magnesium chloride, ferrous sulphate, aluminium sulphate, sulphuric acid, iron pyrite, calcium sulphate, applied at the rate of 20, 40 and 60 per cent of gypsum requirement, on water soluble boron concentration in saline-alkali soils. Paddy *(IR-8)* and barley *(Ambar)* were grown on treated soil. Influence of amendments on water soluble boron concentration in soil at the time interval of 30 and 60 days was recorded and to ascertain its further impact on boron content of paddy and barley plants, 30 and 60 days old plant samples were collected and analysed for boron content. The studied soil was highly sodic in nature having initial pH 10.12, EC 10.5 mmhos/cm, and exchangeable sodium percentage 69.4. Experimental results revealed that all seven chemical amendments had positive effect in reducing soluble B concentration in soil and consequently reduced B concentration in paddy and barley plants. Regarding their effectiveness in reducing B solubility, the sequence of the studied amendments was magnesium chloride, calcium chloride, calcium sulphate, sulphuric acid, ferrous sulphate, aluminium sulphate, iron pyrite. As regards comparative efficiency of doses, it was observed that application of amendments in the soil at rate of 60% of G. R. proved better than the smaller doses in reducing B solubility, but further observations with regard to its subsequent impact on boron content of paddy and barley plants revealed that invariably amendments applied

at the rate of 40 and 60 per cent of gypsum requirement proved more effective, followed with 20% G. R. However, the response of 60% G. R. over 40% narrowed down considerably as compared to that of 40% over 20%.

It is further observed that reduction of water soluble boron by chemical amendments was completed within 30 days of incubation. Concentration of water soluble boron in soil and boron content in paddy and barley plants were not observed to decrease much with increase in incubation period from 30 days to 60 days. The boron content of the whole paddy and barley plants including leaves and stems progressively decreased with increase in doses of chemical amendments. It was further observed that leaves of paddy and barley showed more boron content than the stems.

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Discussion

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In the previous sessions the papers were devoted primarily to the basic aspects of genesis, characterization and nutrient relations etc. of the salt affected soils. The present session in a very logical sequence has dealt with the efforts made in developing the technology for utilization of these problem soils. Very valuable papers related to the technology for reclamation and utilization of salt affected soils for crop production have been presented in this session. The results presented by the various authors clearly indicate that several amendments are available for use in the reclamation programme and the choice can be made according to its easy availability in adequate quantity at a reasonable cost in a particular region. With the continuous increasing trend in the cost of the inputs it is very essential to find out appropriate methods for increasing the efficiency of the amendment, so that the desired results can be achieved with the use of minimum quantity of the amendment. I am very happy to note that some of the papers presented in this session reveal that there is ample scope for enhancing the efficiency of the amendment by increasing its solubility etc. In the context of the present rapid growth in population and a consequent greater demand for food production, it becomes imperative to utilize the salt affected soils for crop production which are occupying a vast expanse in many countries of the world and are lying practically barren. The agricultural scientists have the responsibility of working out suitable methods and practices for economic utilization of these land resources. I am sure that concerted efforts will continue to be made to develop economically viable and practically feasible technologies suited to the different local conditions.