

Effect of pH of Supporting Electrolyte on Boron Adsorption by Some Soils of Punjab

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Adsorption is one of the most important processes affecting the availability of boron in soils. Boron adsorption on soil constituents is dependent on solution pH. Therefore, the effect of pH on boron adsorption by 12 soils from well defined soil series of Punjab was studied at varying pH of supporting electrolyte solutions of NaCl and CaCl₂. The adsorption of boron increased with increase in pH up to 8 or 9 and thereafter the adsorption decreased with increase in pH in most of the soils. However, in some of the soils, there was an increase in boron adsorption with increase in pH over the entire range of pH (5-11) in the presence of CaCl₂ only.

Key words: Supporting electrolyte, boron, adsorption, soils, Punjab

INTRODUCTION

Boron is one of the essential micronutrients required for the normal growth of plants. The concentration range between plant deficiency and toxicity is narrow¹. The narrowness of the range between deficient and toxic concentrations of boron for plant growth emphasises the importance of understanding the boron adsorption by soils. Adsorption reactions of boron generally control the available boron for plant uptake². pH is one of the most important factors affecting boron uptake by plants. The effect of pH on boron adsorption by clays has been intensively studied³⁻⁵ but the information regarding the boron adsorption on soil samples as a function of pH is scanty. Boron adsorption behaviour as a function of pH for two amorphous soils from Mexico⁶ and four soils from Israel⁷ was found to be similar to that for oxide and clay minerals, exhibiting an adsorption maximum near pH 9. Hence an attempt has been made to investigate the role of the pH variable in boron adsorption on 12 soil series of Punjab.

EXPERIMENTAL

Twelve surface soil samples (0-15 cm) from benchmark soils of Punjab representing Fatehpur (S₁), Gurdaspur (S₂), Kanjli (S₃), Ladhawal (S₄), Naura (S₅), Sadhu (S₆) (semiarid region), Jassipauwali (S₇), Bhangar (S₈), Kaoni (S₉),

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Doda (S₁₀) (arid region), Chamror (S₁₁) and Dhar (S₁₂) (subhumid region) soil series were used in the present investigation. The soil samples after drying in air were crushed and passed through 2 mm sieve. The samples were stored in sealed containers. Their site of collection, physical and chemical characteristics along with their classification are presented in Table-1.

TABLE-1
CLASSIFICATION AND PHYSICAL AND CHEMICAL CHARACTERISTICS
OF SOIL SAMPLES

Soil	Classification	(%)				pH*	EC dS m ⁻¹	(%)		CEC (cmol kg ⁻¹)
		Sand	Silt	Clay	Tex- ture			CaCO ₃	OC	
Fatehpur (S ₁)	Typic Ustipsamment	92.4	4.1	3.5	ls	7.70	0.14	Nil	0.12	2.80
Gurdaspur (S ₂)	Typic Haplustalfs	56.2	27.2	16.6	1	7.50	0.32	Nil	0.40	10.32
Kanjli (S ₃)	Typic Ustochrept	22.4	59.3	18.3	sl	8.40	0.20	0.5	0.35	7.91
Ladhowal (S ₄)	Aquic Ustifluent	38.7	47.7	13.6	1	8.50	0.30	0.9	0.25	6.40
Naura (S ₅)	Typic Haplustalfs	23.0	58.7	18.3	sl	8.16	0.35	11.5	0.40	10.52
Sadhu (S ₆)	Typic Ustochrept	5.4	34.9	59.7	sc	8.00	0.27	0.77	0.30	30.40
Jassipauwali (S ₇)	Typic Torripsamment	88.2	7.6	4.2	sl	8.60	0.29	2.8	0.10	2.80
Bhanger (S ₈)	Natraquic Ustochrept	79.6	10.4	10.0	sl	9.29	0.56	4.1	0.24	5.53
Kaoni (S ₉)	Natric Ustochrept	83.6	2.4	14.0	sl	9.00	0.35	1.9	0.41	8.10
Doda (S ₁₀)	Typic Ustochrept	74.7	13.8	11.5	sl	8.40	0.48	6.5	0.33	7.50
Chamror (S ₁₁)	Typic Dystochrept	42.0	43.4	14.6	1	7.13	0.37	Nil	0.92	8.30
Dhar (S ₁₂)	Typic Eutrochrept	46.8	42.0	11.2	1	7.40	0.29	0.5	0.60	7.60

*1 : 2 soil : water suspension.

Solutions of boron having concentration 16 $\mu\text{g mL}^{-1}$ and 32 $\mu\text{g mL}^{-1}$ were prepared by dissolving H_3BO_3 in 0.01 M NaCl and 0.01 M $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ solutions. The pH of electrolyte solution was varied from 5.0 to 11.0 using acetic acid and sodium hydroxide. 1 g of each of the soil samples was equilibrated with 10 mL of the respective boron solution in polyethylene bottles. A preliminary experiment was performed and it was seen that equilibrium was achieved within 48 h. So sealed polyethylene bottles were incubated at 25°C for 48 h with frequent shaking. The suspensions were centrifuged and the supernatant solution was filtered off. The volume of the extract was made to 25 mL. The amount of boron in the extract was determined spectrophotometrically at a wavelength of 420 nm using azomethine-H method⁸.

RESULTS AND DISCUSSION

Boron adsorption as a function of solution pH in the presence of 0.01 M NaCl and 0.01 M $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ background electrolytes has been represented in Figs. 1–6. A perusal of the data indicates that when NaCl was used as supporting

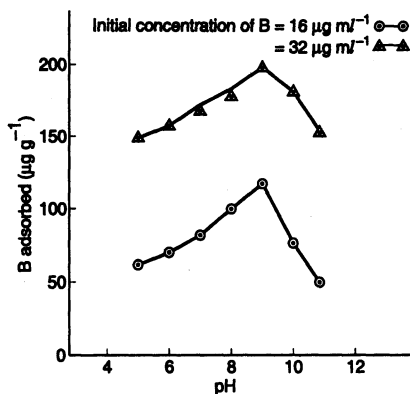


Fig. 1. Effect of pH of supporting electrolyte (0.01 M NaCl) solution on boron adsorption by Kanjli (S₃) soil at 25°C

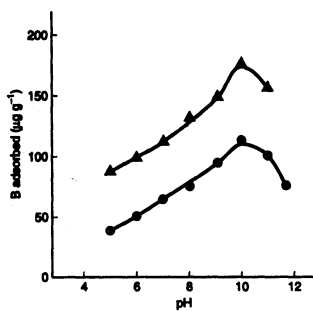


Fig. 2. Effect of pH of supporting electrolyte (0.01 M NaCl) solution on boron adsorption by Doda (S₁₀) soil at 25°C

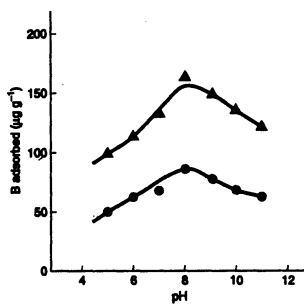


Fig. 3. Effect of pH of supporting electrolyte (0.01 M NaCl) solution on boron adsorption by Chamror (S₁₁) soil at 25°C

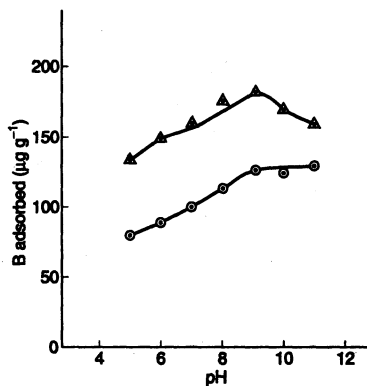


Fig. 4. Effect of pH of supporting electrolyte (0.01 M CaCl₂·2H₂O) solution on boron adsorption by Naura (S₅) soil at 25°C

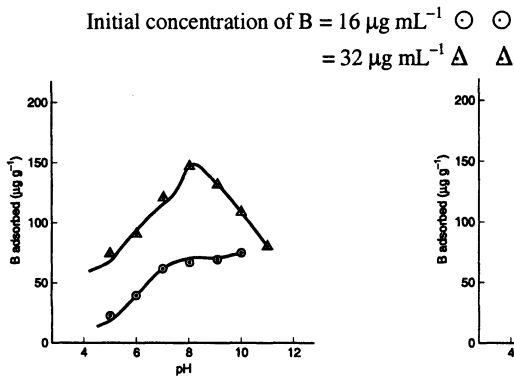


Fig. 5. Effect of pH of supporting electrolyte (0.01 M $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$) solution on boron adsorption by Kaoni (S_9) soil at 25°C

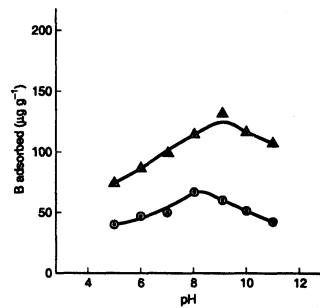


Fig. 6. Effect of pH of supporting electrolyte (0.01 M $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$) solution on boron adsorption by Chamror (S_{11}) soil at 25°C

electrolyte the adsorption first increased with increase in pH until a peak of adsorption was reached. The increase in boron adsorption is attributed to the ionization of boric acid. Above this peak, boron adsorption decreased as pH increased. The boron adsorption peak occurred near pH 8 or 9 in most of the soils. Similar results were obtained by Goldberg and Glaubig⁹ while studying boron adsorption as a function of solution pH on 15 soil samples from California.

The effect of pH variation of NaCl solution on boron adsorption in the case of soils of semiarid region (S_1 to S_6), all the six soils exhibited similar adsorption behaviour at two levels of boron ($16 \mu\text{g}$ and $32 \mu\text{g mL}^{-1}$). However, the pH at which the adsorption maximum occurred varied in different soils. The maximum adsorption was observed near pH 9 in S_3 , S_5 and S_6 soils. These results were found to be similar to those obtained for four soils from Israel⁷ exhibiting an adsorption maximum near pH 9. In the rest of the three soils, *i.e.*, S_1 , S_2 and S_4 , the adsorption maximum occurred near pH 8. In general the three soils of arid region (S_7 , S_8 and S_9) showed an increase in adsorption of boron with increase in pH upto 9 and thereafter showed a decrease in adsorption whereas soil S_{10} behaved a bit different. The adsorption maximum was observed near pH 10 in this soil. S_{11} and S_{12} soils of subhumid region exhibited similar adsorption behaviour as that of other soils but the maximum adsorption occurred near pH 8. The increase in boron adsorption with increase in pH can be explained as, below pH 7, $\text{B}(\text{OH})_3$ predominates but since the affinity of the sorbing surface for this species is relatively low, the amount of adsorption is small. Both $\text{B}(\text{OH})_4^-$ and OH^- concentrations are low at this pH; thus their contribution to the boron adsorption is small. As pH is increased to about 9, $\text{B}(\text{OH})_4^-$ concentration increases rapidly; the OH^- concentration is still low relative to boron concentration; the amount of adsorbed boron increases rapidly. Further increase in pH results in an enhanced OH^- concentration relative to $\text{B}(\text{OH})_4^-$ and boron adsorption decreases due to competition of OH^- for the adsorption sites¹⁰.

In semiarid soils the effect of pH variation at the two levels of boron addition (*i.e.*, 16 and $32 \mu\text{g mL}^{-1}$) of $0.01 \text{ M CaCl}_2 \cdot 2\text{H}_2\text{O}$ on boron adsorption indicates

that the adsorption of boron first increased with increase in pH upto pH 9 and further increase in pH caused a reduction in the boron adsorption at both the levels of boron addition (16 and $32 \mu\text{g mL}^{-1}$) in S_1 , S_2 and S_4 soils while the same trend was observed in S_3 soil at $16 \mu\text{g mL}^{-1}$ level of boron addition and in S_5 soil at $32 \mu\text{g mL}^{-1}$ of boron addition. In the rest of the soils, i.e., S_3 (at $32 \mu\text{g mL}^{-1}$ level), S_5 (at $16 \mu\text{g mL}^{-1}$ level) and S_6 (at both the levels), the amount of boron adsorbed increased with increase in pH and thereafter remained more or less constant at high pH levels. In the soils of arid region, i.e., S_7 and S_{10} (at both the boron addition levels), S_8 and S_9 (at $32 \mu\text{g mL}^{-1}$ level) the amount of boron adsorbed increased with increase in pH upto a particular pH level, attained a maximum value and thereafter decreased with increase in pH. However, S_8 and S_9 soils showed a constant increase in adsorption with increase in pH at lower boron concentration (at $16 \mu\text{g mL}^{-1}$ level). In S_{11} and S_{12} soils, the adsorption maximum was observed between pH 8 and 9.

When CaCl_2 was used as supporting electrolyte it was observed that there was continuous increase in boron adsorption in some of the soils with continuous increase in pH in the entire pH range used in the present investigation. It is assumed that in these soils increased concentration of OH^- ions at high pH is rendered unavailable due to the presence of Ca^{2+} ions for competing with $\text{B}(\text{OH})_4^-$ causing an increase in adsorption even at high pH. This difference in the behaviour of different soils in the presence of CaCl_2 may be attributed to the difference in the characteristics of soils.

It can be concluded that boron adsorption is also affected by the cationic species in the electrolyte. At a particular pH, its adsorption is greater in sodium chloride as compared to that of calcium chloride solution.

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