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Effect of Organic Matter on Boron Adsorption by Some Soils of Punjab

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Boron, one of the essential micronutrient elements, has a marked effect on plants, from the standpoint of both plant nutrition and toxicity. Organic matter is one of the main sources of boron in soils. Therefore, the present investigation was undertaken to study the effect of organic matter on boron adsorption by twelve soils of Punjab. Results revealed that there was a decrease in the adsorption of boron with the removal of organic matter content in majority of the soils except in some soils of semi-arid and arid regions. In most of these soils there was a negligible change in adsorption with the removal of organic matter.

Key Words: Organic matter, Boron, Adsorption, Soils, Punjab.

INTRODUCTION

Organic matter is an active portion of soil. Organic soil constituents have been considered by many workers to play a major role in the retention of essential elements in soils. Although most of the cultivated soils contain 1–5% organic matter, this small amount can significantly modify the soil's chemical properties.[1]

Organic matter is one of the main sources of boron in acid soils, as relatively little boron adsorption on the mineral fraction occurs at low pH levels[2]. Berger and Pratt[3] observed that a large part of total boron in soils is associated with the organic matter in tightly bound compounds. Parks and White[4] showed that there is considerable affinity between humic substances and boron, but boron release from an organic matter substrate was hysteretic[5]. A positive correlation between organic matter and hot water soluble boron content in soils was found[6]. Since solubility in hot water is considered as an availability index, this result supports the hypothesis that organic matter is the main reserve of boron easily available to plants. Although the influence of organic constituents on boron adsorption has been investigated by many researchers, however, its effect is still not clearly understood. Hence, an attempt was made to evaluate the influence of organic matter on boron adsorption by soils.

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EXPERIMENTAL

Surface soil samples (0–15 cm), differing in their physical and chemical properties, were collected from twelve well defined soil series of Punjab, namely, Fatehpur (S_1), Gurdaspur (S_2), Kanjli (S_3), Ladhowal (S_4), Naura (S_5), Sadhu (S_6) (semi-arid region); Jassipauwali (S_7), Bhanger (S_8), Kaon i(S_9), Doda (S_{10}) (arid regicn); Chamror (S_{11}) and Dhar (S_{12}) (subhumid region). Their site of collection, physical and chemical characteristics along with their classification are given in Table-1. For the adsorption studies in the absence of organic matter, the dried soil was first treated with H_2O_2 (10%) and boiled on water bath for removal of organic matter. The process of addition of H_2O_2 and boiling on water bath was continued till the effervescence ceased. At the end of oxidation the suspension was boiled till soil : H_2O became about 1 : 1 to ensure complete removal of H_2O_2. The suspensions were then filtered and the samples were air-dried. A preliminary experiment was performed and it was seen that equilibrium was attained within 48 h. The adsorption of boron was studied by equilibrating 1 g of both treated and non-treated soil samples with 10 mL of solution containing graded levels of boron ranging from 0 to 50 $\mu g\ mL^{-1}$ in the form of H_3BO_3. The solutions were incubated for 48 h at 25°C with frequent shaking and then centrifuged. Supernatant solutions were decanted, filtered and boron in the extract was determined spectrophotometrically using azomethine-H method[7].

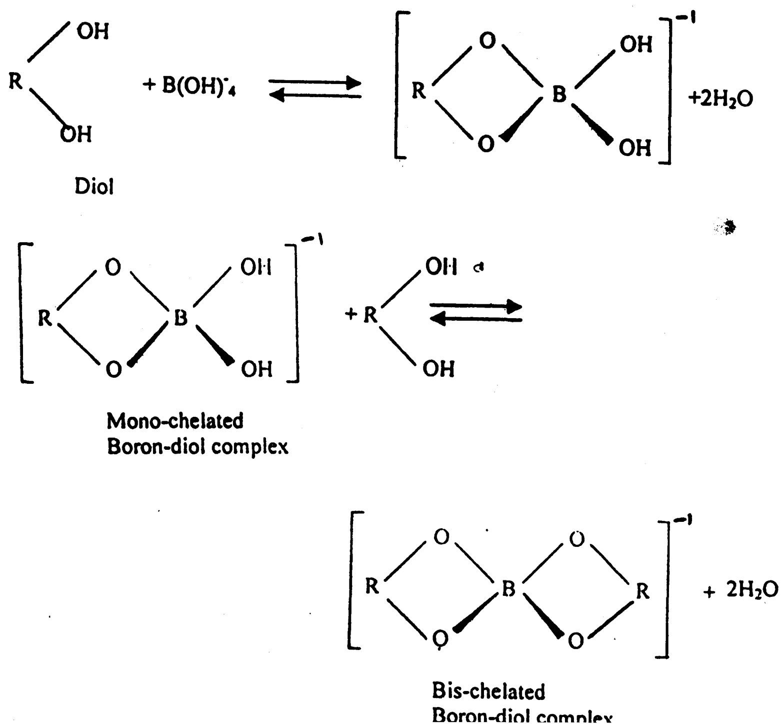
TABLE-1
CLASSIFICATION AND PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOIL SAMPLES

Soil	Classification	Sand (%)	Silt (%)	Clay (%)	Texture	pH*	EC dS m^{-1}	$CaCO_3$ (%)	OC (%)	CEC cmol kg^{-1}
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	l	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	0.50	0.35	7.91
Ladhowal(S_4)	Aquic Ustifluvent	38.7	47.7	13.6	l	8.50	0.30	0.90	0.25	6.40
Naura(S_5)	Typic Haplustalfs	23.0	58.7	18.3	sl	8.16	0.35	11.50	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)	Ustic 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	l	7.13	0.37	Nil	0.92	8.30
Dhar(S_{12})	Typic Eutrochrept	46.8	42.0	11.2	l	7.40	0.29	0.5	0.60	7.60

*1 : 2 soil : water suspension.

RESULTS AND DISCUSSION

The amount of boron adsorbed increases with increase in concentration of boron in equilibrium solution, in all the twelve treated and untreated soil samples. The adsorption isotherms are of L-shape. On comparing the boron adsorption behaviour of treated with the respective untreated soil sample, it has been observed that the trend in boron adsorption was different in various treated soils. A decrease in the boron adsorbing capacity was observed in Fatehpur (S_1), Gurdaspur (S_2), Ladhowal (S_4), Naura (S_5), Jassipauwali (S_7) and Kaoni (S_9) soils in comparison to untreated soils (*cf.* Fig. 1). In the publications pertaining to boron adsorption on soils from other laboratories, adsorbed boron has been found to be significantly positively correlated with carbon content for 23 soils from Japan[8] and for 10 soils from New Mexico[9]. Parks and White[4] were first to observe that soil humus exhibits a chemical affinity for boron and it seems to play an important role in retention of boron by soils. The sorption of boron species by soil organic matter is probably by ligand exchange mechanism on dihydroxy or hydroxy carboxy functional groups as proposed for sugars such as manitol or for tartaric acid[10]. Boron-diol complexes have been postulated to form with the breakdown products of soil organic matter.[4] Huettl[11] postulated α-hydroxy carboxylic acid groups as also being important in boron sorption on organic matter. The formation of monochelated and bischelated boron-diol complexes from reaction of borate with the polyhydroxy compounds ethylene glycol, propane-1,2-diol, propane-1,3-diol and glycerol has been certified with NMR spectroscopy.[12] The formation reactions of these mono-chelated and bis-chelated boron-diol complexes has been depicted as[13]



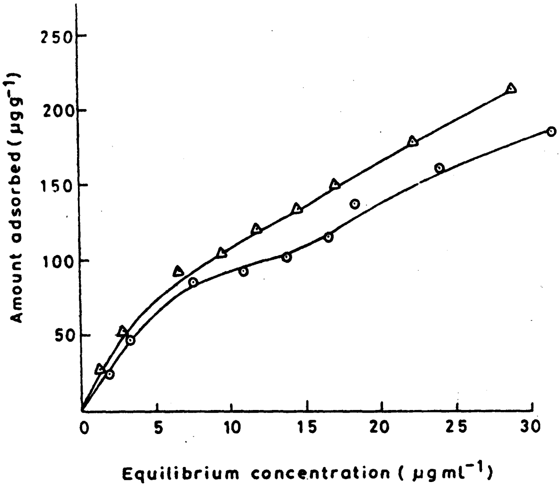


Fig. 1. Adsorption isotherms for boron adsorption on Fatehpur (S_1) soil, untreated (Δ——Δ) and treated (⊙——⊙) for the removal of organic matter at 25°C

Out of the twelve treated samples there was negligible change in the adsorption capacity of Kanjli (S_3), Sadhu (S_6) and Doda (S_{10}) soils (Fig. 2) after the removal of organic matter. Mezuman and Keren[14] studied the effect of organic matter on boron adsorption by a soil containing 1.2% organic matter and found it to be negligible. However, there was an increase in boron adsorption in Bhanger (S_8) soil with the removal of organic matter (Fig. 3). Increase in adsorption can be ascribed to the activation of adsorption sites, *i.e.*, Fe and Al hydroxides previously coated by the organic matter which become available for boron adsorption.[15] In Chamror (S_{11}) and Dhar (S_{12}) soils, there is a decrease in boron adsorption at

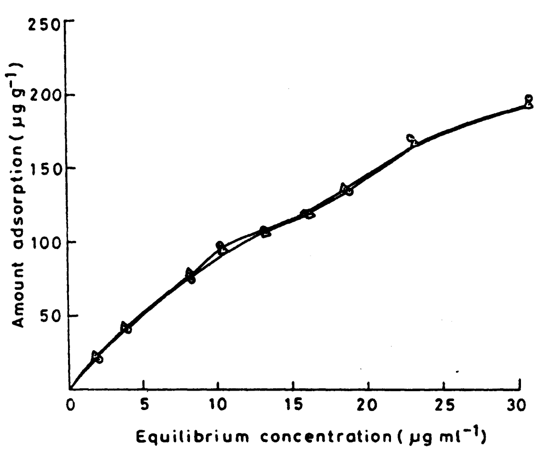


Fig. 2. Adsorption isotherms for boron adsorption on Doda (S_{10}) soil, untreated (Δ——Δ) and treated (⊙——⊙) for the removal of organic matter at 25°C

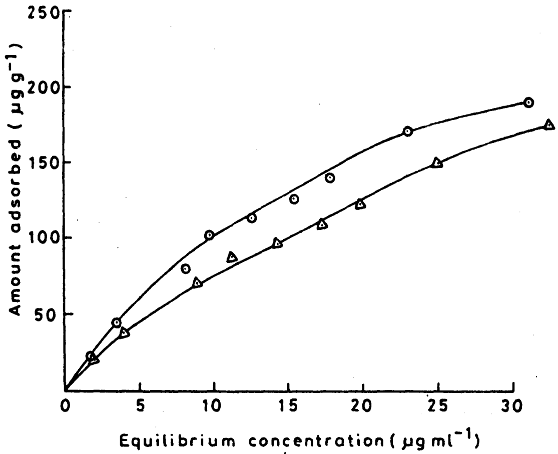


Fig. 3. Adsorption isotherms for boron adsorption on Bhanger (S_8) soil, untreated (Δ——Δ) and treated (⊙——⊙) for the removal of organic matter at 25°C

lower concentrations, but in the higher concentration range there is a little change in boron adsorption with removal of organic matter (Fig. 4).

The perusal of the data reveals that the role of organic matter present in soil on boron adsorption varies from soil to soil. It is difficult to assign a specific mechanism for the interaction of boron with soil organic matter.

Evaluation of the partial molar free energy clange ($\Delta\overline{G}$)

The partial molar free energy change ($\Delta\overline{G}$) as a result of adsorption can be used as a measure of the extent or driving force of the adsorption reaction. Greater

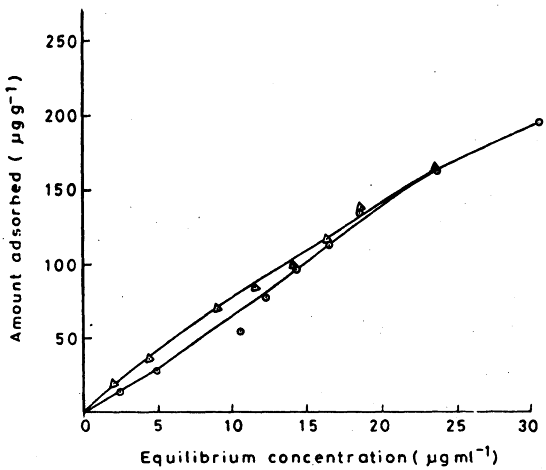


Fig. 4. Adsorption isotherms for boron adsorption on Chamror (S_{11}) soil, untreated (Δ——Δ) and treated (⊙——⊙) for the removal of organic matter at 25°C

magnitude of $\Delta\bar{G}$ value indicates the greater extent to which adsorption reaction takes place. The change in partial molar free energy ($\Delta\bar{G}$) of a system has been evaluated using the following thermodynamic relationship:

$$\Delta\bar{G} = -RT \ln C_0/C$$

where R is the molar gas constant, T is the absolute temperature, C is the equilibrium concentration and C_0 is the initial concentration of boron. The calculated average values of partial molar free energy change ($\Delta\bar{G}$) for boron adsorption on untreated and treated soil samples have been recorded in Table-2. The comparison of the $\Delta\bar{G}$ values between untreated and treated soils reveals that the average values of $\Delta\bar{G}$ decrease in S_1, S_2, S_4, S_5 S_7, S_9, S_{11}, and S_{12} while it increases in S_8 and remains almost same in S_3, S_6 and S_{10} soils after the removal of organic matter. This trend in the $\Delta\bar{G}$ values agrees with the boron adsorption behaviour of the soil samples after the removal of organic matter.

TABLE-2
AVERAGE $\Delta\bar{G}$ (PARTIAL MOLAR FREE ENERGY CHANGE) VALUES FOR BORON ADSORPTION ON SOILS AT 25°C

Soil	$\Delta\bar{G}$ (J mole^{-1})	
	Untreated samples	Treated samples
S_1	1930	1598
S_2	2296	1836
S_3	2186	2181
S_4	2078	1549
S_5	2582	1850
S_6	2816	2826
S_7	2045	1482
S_8	1353	1631
S_9	1601	1203
S_{10}	1544	1515
S_{11}	1372	1074
S_{12}	1205	913

It can be concluded that organic matter present in the soil has a characteristic influence on the behaviour of boron in the soil. More work is required to understand the role of organic matter in influencing boron adsorption by soils.

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