Relationship and distribution of various forms of Boron with different physico chemical properties of soil in major districts of Kashmir

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ABSTRACT

This study investigated the distribution of soil boron and its relationship with some soil properties in the soil collected from different districts of Kashmir valley. Bulk soil samples were air dried and grinded so as to pass through 2mm sieve. The prepared soil samples were analyzed for pH, electrical conductance and organic carbon, as per the standard methods. Co-relation coefficients among soil properties and various forms of boron were worked out statistically. A significant co-relation was found among available boron content and E.C., pH and organic carbon. On the basis of the physico chemical parameters, the suitability of soil of the above locations was adjudged.

Key Words: Available Boron, Physico Chemical Parameters, Sampling, Soil, Total Boron.

1 INTRODUCTION

Boron is an essential micronutrient element required for the normal growth of plants. Boron deficiency is most likely in coarse textured soils in humid regions. Temporary boron deficiency can be triggered by liming of acid soils because of increased B adsorption at higher soil pH [1]. Plants vary in their boron requirement, but the range between deficient and toxic soil solution concentrations of boron is smaller than for any other nutrient element. Both deficient and toxic levels of boron in the soil solution can occur during a single growing season [1]. In arid and semi-arid areas, boron toxicity results from high levels of boron in soils and from additions of boron via the irrigation water. In saline soils, lack of drainage leads to excessive concentrations of boron in the soil solution. Land application of coal ash residues is often limited by their high boron content [2]. Reclamation of high boron soils requires about three times as much water as reclamation of saline soils [3].

Compared with other nutrient elements, the chemistry of boron in soils is very simple. Boron does not undergo oxidation-reduction reactions or volatilization reactions in soils. Boric acid is a very weak, mono basic acid that acts as a Lewis acid by accepting a hydroxyl ion to form the borate anion. Boron containing minerals are either very insoluble (tourmaline) or very soluble (hydrated boron minerals) and generally do not control the solubility of boron in soil solution [4]. The boron concentration in the soil solution is generally controlled by boron adsorption reactions; as is the amount of water soluble boron available for plant uptake. Plants respond only to the
boron activity in soil solution; boron adsorbed by the soil surfaces is not perceived as toxic by plants [5&6]. Factors affecting boron availability and extent of boron adsorption in soils are solution pH, soil texture, soil moisture, and temperature.

II EXPERIMENTAL SECTION

Study Area The study was conducted in ten districts of the Kashmir state. Bulk soil samples were collected from the areas under study. All the soil samples taken were geo-referenced with the available GPS equipment. Soils Anantnag (S3), Shalimar (S6), Bandipora (S7) and Sagipora soils (S9) are from low altitude zone, Khag (S2), Kulgam (S4) and Tral (S5) are from the mid altitude zone and Tangmarg (S1), Kangan (S8) and Shopian (S10) represent the High altitude zone of Kashmir.

Soil Sampling Bulk soil samples from the various districts of the Kashmir were collected for the purpose of the study. All the samples were air dried in the laboratory at room temperature. After drying the soil samples, they were ground in pastel mortar and passed through 2mm sieves. The sieved samples were preserved for the analytical work in polypropylene jars.

All the soil samples collected for this purpose of study were analyzed for various physico chemical properties, which are described as under:-

Soil pH It is the most important chemical property of soil as a medium of plant growth. pH can be described as the effective concentration of hydrogen ions which indicates all sources such as those arising by dissociation of soluble acids and those dissociated from soil particles. Soil pH was taken in soil water suspension. For this purpose 1:2.5, soil: water suspension was prepared. Soil samples were taken in a beaker and added with the required amount of water and then agitated on a mechanical shaker for 15 minutes. The pH of the soil suspension was measured on pH meter using glass electrode.

Electrical Conductance Electrical conductivity was measured for various soil samples in 1:2.5, soil water suspension. The conductivity was recorded in mili mhos per centimeter at room temperature with the help of Soluble bridge conductivity meter at 25°C [7].

Organic Carbon Organic carbon is the chief element of soil organic matter that is readily measured quantitatively. Organic carbon was determined by Walkley and Black’s rapid titration method [8]. 1.0 gram soil was digested with a mixture of Potassium dichromate (10 ml) and concentrated sulphuric acid (20 ml). The excess of Potassium dichromate not reduced by the organic matter of the soil was determined by titration using standard ferrous ammonium sulphate solution in the presence of ortho-phosphoric acid using diphenylamine as an indicator.

Water soluble boron Water soluble boron (WS-B) was extracted by shaking 20 g of soil with 20 ml of deionized water in a 75 ml polyethylene centrifuge tube for two hours [9]. The contents were centrifuged and the supernatant was preserved in refrigerator for boron estimation.

Hot Water soluble Boron Hot Water soluble Boron (HWS-B) was extracted by the method described by Wear (1965). 20 gm of soil was taken in a 250 ml (B-free) Erlenmeyer flask, 40 ml of deionized water and 0.4 gm of activated charcoal were added and reflux condenser (water cooled) was attached to the flask. The flask was heated.
on the hot plate to first sign of boiling, followed by refluxing of the contents exactly for 5 minutes. The contents were allowed to cool and then filtered using Whatman No. 42 (B-free) filter paper.

**CaCl₂ soluble Boron** CaCl₂ soluble Boron was extracted by adding 20 ml of 0.01 M CaCl₂ and 0.4 g of activated charcoal to 10 gm of soil in a 250 ml (B-free) Erlenmeyer flask [10]. Reflux condenser was attached to the flask. The mixture was heated on a hot plate for 5 minutes and refluxed thereafter for 5 minutes. When still warm, contents of the flask were filtered through Whatman No. 42 filter paper to get clear extract.

**Acid soluble Boron** Acid soluble Boron was determined by extracting 10 gm of soil with 20 ml of 0.05 N HCl in 50 ml polyethylene centrifuge tube. The contents were shaken on a horizontal shaker for five minutes followed by centrifuging and supernatant solution was preserved for boron estimation [11].

**Leachable Boron** Leachable Boron (adsorbed plus soluble B) was extracted by the method of [12]. Five grams of soil was taken in 50 ml polyethylene centrifuge tube and shaken for 16 hours with 25 ml each of 0.01 M Manitol- 0.01 CaCl₂ solution. After centrifuging, the clear supernatant solution was kept in refrigerator for B determination.

**AB-DTPA-Boron** AB-DTPA Boron was extracted by adding 20 ml each of 1.0 M NH₄ HCO₃ and 0.005 M DTPA adjusted to pH 7.6 to 10 ml of soil. [13]

**Total Boron** For extraction of total boron, one gm of soil was fused with 6 gm of Na₂CO₃ at 1000°C in a platinum crucible of 30 ml capacity. The residue was dissolved in 50 ml of 6N HCl according to the modified procedure developed by Gupta [14]. The final volume was made up to 100 ml and subsequently used for analysis of total boron by Azomethane-H method.

### III RESULTS AND DISCUSSION

Physico chemical properties of the soil under study and distribution of various forms of Boron are given in Table: 1. The data indicates that pH value ranged from 5.6 to 7.8. The soils are slightly to moderately alkaline in nature. The soil conductivity varies from 0.11 to 0.36 dS m⁻¹. The organic carbon content varied from 0.98 to 3.93 per cent. Calcium carbonate varied from 0.01 to 1.28 per cent and cation exchange capacity from 10.48 to 18.17 cmol c⁻¹ kg⁻¹.

The concentration of water soluble boron was found to be considerably higher in the soil of Sagipora, and lowest in soils of Bandipora. Clay and silt contents were positively and significantly correlated with water soluble boron content with coefficient values of r = 0.524** and 0.338**, respectively, whereas relationship of water soluble boron with sand content was negatively significant (r=−0.760**) (Table 3).

Water soluble boron content was also found to be significantly related with pH (r=0.872**) and EC (r=0.727**). There was a negatively significant correlation between water soluble content and organic carbon content (r=−0.451*). Calcium carbonate content was negatively and non-significantly related to water soluble boron content (r=−0.335). The cation exchange capacity showed positive and significant correlation to water soluble boron (r=0.588**).
Results on hot water soluble boron in different soils (Table 2) showed that it varied from 0.10 to 1.27 mg kg\(^{-1}\) soil, with a mean value of 0.46 mg kg\(^{-1}\) soil. Higher content of hot water soluble of 1.27 mg kg\(^{-1}\) soil was found in Sagipora soil and lowest in Bandipora soil. The clay content was positively and significantly correlated (r=0.575*) with hot water soluble boron content of soil. The relationship between organic carbon and hot water soluble boron was negatively and significantly correlated with each other (r=-0.443*) (Table 3). Calcium carbonate content of soil showed non-significant negative correlation (r=-0.117) with hot water soluble boron. The silt content showed positive and significant correlation with hot water soluble boron (r=0.182*) whereas relationship with sand content was negatively significant (r=-0.637**).

Table 1: Physico-chemical characteristics of the different soils of Kashmir under investigation.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tangmarg (S1)</td>
</tr>
<tr>
<td>pH (1:2.5)</td>
<td>6.1</td>
</tr>
<tr>
<td>EC (dS m(^{-1}))</td>
<td>0.12</td>
</tr>
<tr>
<td>OC (%)</td>
<td>3.93</td>
</tr>
<tr>
<td>CaCO(_3) (%)</td>
<td>1.28</td>
</tr>
<tr>
<td>CEC [cmol kg(^{-1})]</td>
<td>15.32</td>
</tr>
<tr>
<td>Coarse sand (%)</td>
<td>1.12</td>
</tr>
<tr>
<td>Fine sand (%)</td>
<td>19.08</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>45.20</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>34.60</td>
</tr>
<tr>
<td>Textural class</td>
<td>Silty clay loam</td>
</tr>
</tbody>
</table>
Cation exchange capacity also showed positive and significant correlation \((r=0.537^*)\) with hot water soluble boron. Hot water soluble boron showed positive and highly significant correlation with pH and EC of the soil \((r=736^{**} \text{ and } 0.593^{**})\). Perusal of data presented in Table 2 showed that 0.01 M CaCl\(_2\) extractable boron in different soils range between 0.27 to 1.44 mg kg\(^{-1}\) with an average value of 0.63 mg kg\(^{-1}\) soil. The CaCl\(_2\) extractable boron content in the soils investigated was in the order of agipora> Anantnag> Shopian> Tral> Khag> Tangmarg> Kulgam> Shalimar> Kangar> Bandipora with the values of 1.44, 0.95, 0.69, 0.65, 0.64, 0.58, 0.46, 0.35, 0.30, and 0.27 mg kg\(^{-1}\) soil, respectively. Calcium chloride boron contributed 1.36 per cent to total boron content (Table 4).

Calcium chloride extractable boron was positively and significantly correlated with pH \((r=0.721^{**})\) and EC \((r=0.593^{**})\) of the soil. The clay content was positively and significantly correlated \((r=0.576^{**})\) with calcium chloride soluble boron while as silt content was positively and non-significantly correlated \((r=0.152)\) with calcium chloride soluble boron. Significant negative correlation \((r=-0.431^*)\) was observed between CaCl\(_2\)-soluble boron and organic carbon content of soils. Calcium Carbonate showed negative but non-significant relationship \((r=-0.098)\) with CaCl\(_2\) extractable boron. Positive and significant correlation \((r=510^*)\) between cation exchange capacity and CaCl\(_2\) extractable boron was observed (Table 4) while as significant and negative relationship was observed between CaCl\(_2\) extractable boron and sand content of soils \((r=-0.608^{**})\).
The content of boron extracted in 0.05 N HCl i.e. the acid soluble boron varied from 1.13 to 1.69 mg kg\(^{-1}\) soil with an average value of 1.40 mg kg\(^{-1}\) soil (Table 2). The acid soluble boron was higher than water soluble, hot water soluble and calcium chloride extractable boron. The data in table 2 showed that there was wide variation in acid soluble boron concentrations in different soils. Acid soluble boron was maximum in the soils of Sagipora (1.69 mg kg\(^{-1}\) soil) while minimum in Shalimar soil (1.13 mg kg\(^{-1}\)).

There was a significant positive curvilinear correlation between 0.05 N HCl extractable boron and clay (\(r=0.564^{**}\)), pH (\(r=0.637^{**}\)) and EC (\(r=0.520^{**}\)) of the soils (Table 3). The acid extractable boron was positively and significantly related with calcium carbonate content of the soils (\(r=0.460^{*}\)). Organic carbon content of the soils was negatively and non-significantly correlated (\(r=-0.148\)) with acid extractable boron. There was positive and non-significant correlation (\(r=0.359\)) between cation exchange capacity and acid soluble boron. A negative but significant correlation (\(r=-0.677^{**}\)) was observed between acid soluble boron and sand content of the soils under study. The results clearly revealed that available forms of boron (water soluble, hot water soluble, calcium chloride extractable and acid extractable) were mainly associated with clay fraction followed by pH and EC of the soils studied.

The leachable boron consists of “adsorbed plus soluble boron” [12]. It ranged from 0.99 to 1.48mg kg\(^{-1}\) soil with a mean value of 1.25 mg kg\(^{-1}\) soil (Table 4.2). The content of leachable boron was maximum in soils of Sagipora (1.48mg kg\(^{-1}\)), and minimum in Bandipora (0.99mg kg\(^{-1}\)). Per cent contribution of leachable boron fraction to the total boron fraction of soils was found to be 2.70 (Table 4).

Leachable boron was significantly and positively correlated with pH (\(r=0.576^{**}\)) and EC (\(r=0.610^{**}\)) following curvilinear relationships with these parameters (Table 3). Non-significant but negative correlation was found between organic carbon (\(r=-0.140\)) and leachable Boron. There was also a significant and negative correlation between sand (\(r=-0.486^{*}\)) and leachable boron. A positive but non-significant correlation was also observed between CEC (\(r=0.140\)), CaCO\(_3\) (\(r=0.327\)), silt (\(r=0.203\)) and clay (\(r=0.362\)) and leachable boron.

The recently developed AB-DTPA (Ammonium bicarbonate-diethylenetriaminepenta acetic acid) extractant has proven to be effective for boron on alkali soils (Gupta, 1993). The extractant consists of 1.0 M NH\(_4\)HCO\(_3\) and 0.005 M DTPA, maintaining the pH to 7.6 [15].

In the soil samples, the concentration of AB-DTPA extractable boron ranged from 0.60 to 1.30 mg kg\(^{-1}\) soil with a mean value of 0.83 mg kg\(^{-1}\) soil (Table 2). The concentration of AB-DTPA extractable boron in the soils was in the order of Sagipora> Anantnag> Tangmarg> Tral> Khag> Kulgam> Kangan> Shopian> Shalimar > Bandipora, where it was found as 1.30, 1.21, 0.89, 0.89, 0.74, 0.71, 0.69, 0.67, 0.64, and 0.60 mg kg\(^{-1}\) soil, respectively. AB-DTPA soluble boron fraction contributed 1.81 per cent to the total boron fraction of the soils (Table 4).

pH and EC were significantly and positively correlated with coefficient values of \(r=0.874^{**}\) and \(r=0.684^{**}\), respectively (Table 3). Positive and significant correlation was observed between silt (\(r=0.399^{**}\)) and AB-DTPA boron, while as clay content observed highly significant and positive correlation (\(r=0.580^{**}\)) with AB-DTPA boron. Organic carbon was significantly and negatively correlated (\(r=-0.436^{**}\)) with AB-DTPA boron. This form
was also positively and significantly correlated with cation exchange capacity \( r=0.663^{**} \) of the soils. The sand fraction was also significantly and negatively correlated with AB-DTPA boron\( r=-0.463^{**} \). Although total boron does not affect the plant growth and its concentration is low as compared to other forms of boron, but it helps in knowing its potential reserve in the soil. The data in Table 2 show that total boron content ranged from 40.72 to 50.55 mg kg\(^{-1}\) soil with an average value of 45.46 mg kg\(^{-1}\) soil (Table 2). The higher content of total boron \( (50.55 \text{ mg kg}\(^{-1}\)) \) was observed in Sagipora soil, followed by 49.36 mg kg\(^{-1}\) in Anantnag soil, 48.52 mg kg\(^{-1}\) in Tangmarg soil, 47.82 mg kg\(^{-1}\) in Tral soil, 45.64 mg kg\(^{-1}\) in Kulgam soil, 44.84 mg kg\(^{-1}\) in Khag soil, 43.78 mg kg\(^{-1}\) in Shalimar soil, 42.46 mg kg\(^{-1}\) in Bandipora soil, 41.86 mg kg\(^{-1}\) in Kangan soil and 40.72 mg kg\(^{-1}\) in Shopian soil.

Total boron content of soils depends upon the parent material [16]. Soils derived from sedimentary rocks contain higher content of boron. The perusal of Table 3 showed that total boron content significantly correlated with pH \( (r=0.686^{**}) \), EC \( (r=0.421^{*}) \), CEC \( (r=0.766^{**}) \), silt \( (r=0.498^{*}) \) and clay \( (r=0.563^{*}) \) of the soil. There is negative and significant correlation between total boron and sand \( (r=-0.928^{**}) \) and non-significant negative correlation with organic carbon \( (r=-0.219) \) and CaCO\(_3\) \( (r=-0.080) \).


**Table 3.** Coefficient of Correlation between different forms of Boron and physico-chemical characteristics of soils

<table>
<thead>
<tr>
<th>Forms of Boron</th>
<th>pH (1:2.5)</th>
<th>EC (dSm(^{-1}))</th>
<th>CEC [cmol(_c) kg(^{-1})]</th>
<th>Organic carbon (%)</th>
<th>CaCO(_3) (%)</th>
<th>sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water soluble</td>
<td>0.872^{**}</td>
<td>0.727^{**}</td>
<td>0.588^{*}</td>
<td>-0.451^{*}</td>
<td>-0.335</td>
<td>-0.760^{**}</td>
<td>0.338^{*}</td>
<td>0.524^{**}</td>
</tr>
<tr>
<td>Hot water soluble</td>
<td>0.736^{**}</td>
<td>0.593^{**}</td>
<td>0.537^{*}</td>
<td>-0.443^{*}</td>
<td>-0.117</td>
<td>-0.637^{**}</td>
<td>0.182^{*}</td>
<td>0.575^{*}</td>
</tr>
<tr>
<td>CaCl(_2) soluble</td>
<td>0.721^{**}</td>
<td>0.593^{**}</td>
<td>0.510^{*}</td>
<td>-0.431^{*}</td>
<td>-0.098</td>
<td>-0.608^{**}</td>
<td>0.152</td>
<td>0.576^{**}</td>
</tr>
<tr>
<td>Acid soluble</td>
<td>0.619^{**}</td>
<td>0.520^{**}</td>
<td>0.359</td>
<td>-0.141</td>
<td>0.141^{*}</td>
<td>-0.677^{**}</td>
<td>0.231</td>
<td>0.564^{**}</td>
</tr>
<tr>
<td>Leachable-B</td>
<td>0.557^{**}</td>
<td>0.610^{**}</td>
<td>0.140</td>
<td>-0.141</td>
<td>-0.015</td>
<td>-0.686^{*}</td>
<td>0.197</td>
<td>0.362</td>
</tr>
<tr>
<td>AB-DTPA</td>
<td>0.867^{**}</td>
<td>0.684^{**}</td>
<td>0.663^{**}</td>
<td>-0.435^{*}</td>
<td>-0.265</td>
<td>-0.843^{**}</td>
<td>0.381^{*}</td>
<td>0.580^{**}</td>
</tr>
<tr>
<td>Total</td>
<td>0.686^{**}</td>
<td>0.421^{*}</td>
<td>0.766^{**}</td>
<td>-0.222</td>
<td>-0.30</td>
<td>-0.928^{**}</td>
<td>0.486^{*}</td>
<td>0.563^{*}</td>
</tr>
</tbody>
</table>
Table 4. Per cent contribution of different forms of Boron to Total Boron

<table>
<thead>
<tr>
<th>Soils</th>
<th>Water soluble</th>
<th>Hot water soluble</th>
<th>CaCl₂Soluble</th>
<th>Acid Soluble</th>
<th>Leachable</th>
<th>AB-DTPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁</td>
<td>1.50</td>
<td>2.89</td>
<td>2.23</td>
<td>3.28</td>
<td>2.70</td>
<td>1.83</td>
</tr>
<tr>
<td>S₂</td>
<td>1.14</td>
<td>2.59</td>
<td>2.54</td>
<td>2.85</td>
<td>2.72</td>
<td>1.65</td>
</tr>
<tr>
<td>S₃</td>
<td>2.33</td>
<td>3.24</td>
<td>2.94</td>
<td>3.20</td>
<td>2.84</td>
<td>2.45</td>
</tr>
<tr>
<td>S₄</td>
<td>1.18</td>
<td>2.61</td>
<td>2.10</td>
<td>2.67</td>
<td>2.72</td>
<td>1.56</td>
</tr>
<tr>
<td>S₅</td>
<td>1.53</td>
<td>2.86</td>
<td>2.40</td>
<td>3.16</td>
<td>2.66</td>
<td>1.86</td>
</tr>
<tr>
<td>S₆</td>
<td>0.89</td>
<td>2.51</td>
<td>1.94</td>
<td>2.58</td>
<td>2.38</td>
<td>1.46</td>
</tr>
<tr>
<td>S₇</td>
<td>0.85</td>
<td>2.43</td>
<td>1.81</td>
<td>2.71</td>
<td>2.33</td>
<td>1.41</td>
</tr>
<tr>
<td>S₈</td>
<td>1.05</td>
<td>3.13</td>
<td>1.91</td>
<td>3.20</td>
<td>2.84</td>
<td>1.65</td>
</tr>
<tr>
<td>S₉</td>
<td>1.05</td>
<td>3.13</td>
<td>1.91</td>
<td>3.20</td>
<td>2.84</td>
<td>1.65</td>
</tr>
<tr>
<td>S₁₀</td>
<td>2.45</td>
<td>3.72</td>
<td>3.84</td>
<td>3.34</td>
<td>2.93</td>
<td>2.57</td>
</tr>
</tbody>
</table>

IV CONCLUSION

It was concluded from the above study that different forms of boron showed positive and significant correlation with different physico-chemical properties of soils i.e. pH, EC, CEC and clay content. Sagipora and Bandipora soil showed the highest and lowest percentage of boron content (all the different forms), respectively, which could be attributed to their variability regarding their physico-chemical properties.

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