Geospatial distribution of boron in major banana growing soils of Theni district, Tamil Nadu

S Suganya, PP Mahendran, P Saravana Pandian, P Kannan, G Balasubramaninan and R Babu

Abstract
The present study was undertaken to assess the status of hot water soluble boron (HWS-B) in the major banana growing blocks of Theni district, Tamil Nadu. A total of 720 geo referenced surface (0-15 cm) and subsurface soil samples (15-30 cm) were collected from four blocks viz., Cinnamani, Cumbum, Uthamapalayam and Periyakulam and analyzed for basic soil properties and hot water soluble boron. Simple correlation was worked out to ascertain the degree of relationship between soil properties and HWS-B content of soils of study area. HWS-B in the entire banana growing soils ranged from 0.11 to 3.56 mg kg⁻¹, 0.03 to 2.28 mg kg⁻¹ in surface and subsurface soil samples respectively. The results revealed that 38.61 per cent of the soils were deficient in available B while 35.83 and 25.55 per cent soils were medium and high in available B in surface soil samples. In subsurface samples 42.50 per cent of the soils were deficient in B while 30.55 and 24.16 per cent soils were medium and high in available B. As per the nutrient index study, the soils of study area recorded marginal to high fertility rating for available B and the mean nutrient index value (NIV) ranged from 1.81 to 1.91 and 1.72 to 1.88 in surface and subsurface samples respectively. Among the soil properties, EC, SOC, clay, silt and CEC had a positive influence on the availability of B whereas, total sand, pH, CaCO₃, Fe₂O₃, Al₂O₃ and SiO₂ contents had negative impact on available boron. The step-wise multiple regression equation indicated that 46.20 per cent variation in available B was observed due to pH, EC, SOC, CEC, Fe₂O₃, Al₂O₃ and silt content in surface soil samples whereas in subsurface soil samples pH, EC, SOC, Al₂O₃ total sand and clay accounted 53.90 per cent variation in available B.

Keywords: HWS-B, pH, CaCO₃, correlation and multiple regression

Introduction
Banana is the most important fruit crop in India, amongst fruit crops, banana occupies prime place of importance, next to mango in India. Being a cash crop of high value, it is a good source of income for growers, and its taste and high nutritional value keep it in high demand by consumers, throughout the year. Banana called as the “fruit of the wise men” is an important fruit crop cultivated widely and consumed by the majority of the population in India as well as in Tamil Nadu. Tamil Nadu is the largest producer of banana in India. In Tamil Nadu, Theni District holds first position in area under cultivation of banana followed by Coimbatore, Erode and Tuticorin districts. (Saravanapandeeswari and Vanitha, 2018) [20]. Micronutrients play a vital role in crop growth, crop productivity, soil fertility and human nutrition. Among the micronutrients, B plays an important role in the crop growth by increasing growth and pollen viability of the crop (Das, 2014) [4]. Further, B is involved in sugar transport, cell wall synthesis, lignification’s and IAA synthesis, phenol metabolism and stomata regulation. At the same time, it is involved in photosynthetic activity and enzyme activity, which ultimately affect pollen formation and fertilization. The total B content in Indian soils ranged from 20 to 200 mg kg⁻¹ (Mengel and Kirkby, 1987) [12] and the available B content varied from 0.08 to 2.6 mg kg⁻¹ (Singh, 2001) [17]. In Tamil Nadu, soils were recorded more than 21 per cent of B deficiency (Goswami, 2016) [7]. Their deficiencies result in reduction in weight and size of the bunch and improper filling of the individual fruit units. Boron deficiency symptoms include leaf curling and deformation, presence of white stripes perpendicular to the veins on the underside of the lamina. Hence, among the micronutrients, boron deserves special attention especially in banana. Therefore, this research examined the distribution and primary factors influencing B deficiency in the banana growing soils of Theni district.
Material and Methods

Study Area

The study was undertaken in banana growing soils of Theni district of Tamil Nadu. It is essentially an inland district lying at the foot of Western Ghats, it geographically lies between 9°30' and 10°12' north latitude and 77°10' and 77°42' east longitude. It is bounded by Dindigul at in the north, Madurai district in the east, Virudhunagar at in the south and Kerala state in the west. The district has 5 taluks and 8 blocks with a total geographical area of 2889.23 km. The climate of this region is semi-arid with an annual rainfall is 760.8 mm, mostly received from North East monsoon. The mean maximum, minimum and average air temperatures are 33.34, 23.55, 28.45°C respectively. The soils of Theni district comprise of red, black and alluviu soil groups with rice, pulses, banana and other vegetables and millets as major crops.

Soil Analysis

A total of 720 geo-referenced surface (0-15 cm) and subsurface soil samples (15-30 cm) covering all banana growing blocks (Cinnamanur, Cumbum, Uthamapalayam and Periyakulam) were collected during 2017 using Garmin GPS instrument (Table 1). The soil samples were air dried, gently powered with wooden mallet and sieved through 2 mm plastic sieve. The processed soil samples were analyzed for pH, EC (Jackson, 1973) [9], texture (Piper, 1966) [14], Organic carbon (Walkley and Black method, 1934) [22], CaCO3 (Piper method, 1966) [14], Iron and aluminium (Volumetric method), Sesquioxides (Gavimetric method) by Piper (1966) [14] and CEC (Jackson, 1973) [9].

Extraction of hot water soluble boron

Hot water soluble boron (HWSB) of soils was estimated by using Azomethine-H through spectrophotometer at 420 nm. Based on the analytical results, these soils were categorized into below critical level (< 0.46 mg g-1), sufficient (0.46 – 1.00 mg g-1) and above critical level (>1.0 mg g-1) outlined by Berger and Truong (1940) [1].

Statistical and Spatial Analysis

The Pearson correlation coefficients were estimated for all possible paired combinations of the response variables to generate a correlation coefficient matrix. These statistical parameters were calculated with SPSS 16.0® software (SPSS Inc., Chicago, Ill., USA). The multiple regression equations were arrived at as per the method described by Fisher (1936) [5]. In this research, the base map wrested study area, the GPS points and values (chemically analysis results) are coupled together. The study area boundary was digitized using ArcGIS-10 environment and polygonized. The geo coordinates of sampling sites was fed into the Arc GIS environment and finally transformed in to thematic map by spatial interpolation technique of kriging.

Results and Discussion

Particle size distribution

The soils of banana growing blocks of Theni district were light to medium in texture at surface and in subsurface the soils were medium to heavy in texture. Sand was the dominant fraction of mechanical composition and most of the soils under study were sandy clay loam in texture. The results on textural classes revealed that 63.05 per cent surface soil samples in the study area were sandy clay loam, 21.38 per cent clay loam, 11.66 per cent sandy loam and 3.88 per cent loamy sand in texture. Similarly, 70.00 per cent of sub surface soils had sandy clay loam, 11.11 per cent clay loam, 11.94 per cent sandy loam, 2.77 per cent loamy sand and 4.16 per cent clay in texture.

Soil reaction

The pH of investigated surface soils ranged from 5.82 to 8.90 with a mean of 7.54. Whereas in subsurface it varied from 6.15 to 8.92 with a mean of 7.74. In general, subsurface soil pH was recorded to be high as compared to that of surface soil. The observations on pH of surface soils indicated that 7.77 per cent samples were slightly acidic (6.0 – 6.5), 35.00 per cent neutral (6.6 – 7.3), 51.11 per cent mildly alkaline to alkaline (7.4 – 8.4) and 6.11 per cent strongly alkaline (8.5 – 9.0).

The variation in pH from acidic to alkaline range may be attributed to the variation in the parent materials and different compounds and ions present in the soil. Besides, variation in management practices may also contributed to slight extent in accordance with the variation in pH. Similar results were reported by Sharma et al. (2008) [18]. The mild to strongly alkalinity could be due to accumulation of exchangeable sodium and calcium carbonate. The results confirm the findings of Singh et al. (2014) [19].

Salt Concentration

The electrical conductivity of soil gives an indication about salt concentration. Soils having EC less than 0.80 dS m-1 are rated as non-saline (Bali et al., 2010) [2]. The EC of majority of the soils was normal. The modest EC values of the soil samples could be ascribed to leaching of salts to lower horizon as frequent copious irrigations are very common in banana cultivation. Salt concentration observed in the study area gives an idea that by and large salinity is not a problem in banana growing tracts of Theni district.

Soil organic carbon

Organic carbon (OC) content ranged from 0.30 to 5.6 g kg-1 with an average value of 3.07 g kg-1 in surface soils and 0.22 to 5.51 g kg-1 with an average value of 2.83 g kg-1 in subsurface soils. As per the ratings as suggested by Muhr et al. (1965), 93 and 97 per cent of soils are in low (0.50%), 7 and 3 percent in medium (0.50 – 0.75%) and none of the soil samples were found in high (<0.75%) in organic carbon content in surface and subsurface soils, respectively.

The low organic carbon content in these soils could be due to high rate of organic matter decomposition under hyper thermic temperature regime which leads to extremely high oxidizing conditions. Further, large scale monoculture of banana and wide spread crop residue burning might be the major reason for low OC content in the soils of study area. Besides this, coarse textured soils are generally low in organic carbon. Similar results were observed by Singh et al. (2014) [19].

Calcium Carbonate

There was a wide variation in CaCO3 in soils of the study area. It varied from 0.34 to 6.38 per cent with an average value of 2.23 per cent in surface soils. Whereas, in subsurface soil samples the values ranged from 0.41 to 7.60 per cent with an average value of 2.95 per cent.

As per the rating limit proposed by FAO (1973), about 83 per cent of the samples were non calcareous (CaCO3 content <5%) and 17 and 27 per cent samples were found in calcareous (CaCO3 content >5%) in surface and subsurface
soils, respectively. The accumulation of CaCO$_3$ in soils might be due to the climatic condition. In arid and semi-arid regions, rainfall is less as compared to annual evapotranspiration; hence, less water is available for the leaching of insoluble carbonates and bicarbonates of calcium. This may have facilitated the accumulation of CaCO$_3$ in these soils (Dhir et al., 1979 and Qadir et al., 1996) [3-15].

**Cation Exchange Capacity**

CEC governs the overall nutrient supplying capacity of the soil and in surface soils it varied from a maximum value of 24.65 to a minimum of 6.21 cmol(p) kg$^{-1}$ with an average value of 15.70 cmol(p) kg$^{-1}$. Similarly CEC of subsurface soils ranged from maximum value of 25.82 to a minimum of 6.88 cmol(p) kg$^{-1}$ with an average value of 16.27 cmol(p) kg$^{-1}$. About 70 per cent of soil samples of the study area have CEC >15 cmol(p) kg$^{-1}$. Soils with textural classes of loamy sand, sandy loam, sandy clay loam, clay loam and clay had CEC in the range of 6.21 to 11.07, 6.74 to 11.55, 10.52 to 19.99, 14.19 to 24.90 and 21.00 to 25.82 cmol(p) kg$^{-1}$ respectively.

**Available boron (B)**

Available B content was higher in surface soils than those in the subsurface soils wherein B varied from 0.21 to 3.50, 0.19 to 3.50, 0.26 to 2.35 and 0.11 to 2.20 mg kg$^{-1}$ with corresponding mean values of 0.88, 0.86, 0.81 and 0.78 mg kg$^{-1}$ in Cinnamanur, Cumbum, Uthamapalayam and Periyakulam blocks respectively. Similarly, the B content in subsurface soils of Cinnamanur, Cumbum, Uthamapalayam and Periyakulam blocks ranged from 0.03 to 7.30, 0.11 to 2.28, 0.09 to 2.18, and 0.03 to 2.06 mg kg$^{-1}$ with the corresponding mean values were 0.64, 0.62, 0.71 and 0.70 mg kg$^{-1}$ respectively (Table 2).

The data indicated that 37, 42.66, 41.17 and 35 per cent of surface soils of Cinnamanur, Cumbum, Uthamapalayam and Periyakulam blocks were deficient in available B following critical limit of <0.46 mg kg$^{-1}$ for hot water soluble boron (Berger and Trough, 1940) [1]. Similarly, the per cent deficiency in subsurface soils of Cinnamanur, Cumbum, Uthamapalayam and Periyakulam were 43, 48, 42.35 and 38 respectively.

The deficiency of boron in soils might be due to the continuous mining without external sources of boron fertilization, reduced application of organic manure and high free calcium carbonate content in the soil. The increase in calcium carbonate content of the soils obviously would result in the formation of calcium octaborates, whose solubility is very less (Ksp = 0.000012 @ 25 to 35 °C), that might be the reason for the lower availability of B in soils. On the other hand, the lower availability of B could be due to the adsorption of boron on clay minerals and fixation via ligand exchange (Keren et al., 1994) [10]. Followed by it, the various reasons such as texture, nature of clay minerals, liming, organic matter content, interrelationship with other elements, and environmental conditions like moderate to heavy rainfall, dry weather and high light intensity play a vital role in altering the B availability in soils (Moraghan and Mascagni, 1991) [13]. In common, soils derived from igneous rocks, and those in tropical and temperate regions of the world, have much lower B concentrations than soils derived from sedimentary rocks (Ho, 2000).

**Nutrient index**

Considering the concept of soil nutrient index the soils of studied area was found from marginal to high for available B and the mean NIV ranged from 1.81 to 1.91 and 1.72 to 1.88 in surface and subsurface samples respectively. There was no very low and low B fertility rating in the banana growing blocks of Theni district.

**Boron and its relationship with soil characteristics**

The data on simple correlation studies between available B and soil properties are presented in (Table 3 and 4). The available B was significantly and positively correlated with EC, silt, clay, organic carbon and CEC while it was negative with pH, CaCO$_3$ and total sand in both surface and subsurface soil samples. Thus, a soil having greater surface is expected to retain greater amount of this ion and vice versa. Increase in finer fraction of the soil leads to increase in the surface area for ion exchange and hence can contribute to greater amount of available B. In addition to clay minerals, organic and inorganic soil colloids also provide the exchange sites that retain more B than coarse textured soils. Hence B is less liable to leaching from the fine textured soils. Similar results were also reported by Ray and Banik (2016) [16].

The results on correlation studies further revealed that the available B decreased significantly with increasing pH and CaCO$_3$ contents. At higher pH, CaCO$_3$ levels, B may be converted into sparingly soluble Ca – borate or borosilicate and hence the availability of B would be reduced. The negative relationship between B and CaCO$_3$ in soils was observed by Yadav and Meena (2009) [23]. The iron and aluminium oxides (sesquioxides) adsorbs large amount of B on its surface than various chemical reactions (Tisdale et al., 1985) [21].

The multiple regression coefficients and step-down regression analysis were carried out to study the effect of soil properties on predictability of HWS-B. The dependence of HWS-B on the soil properties is shown in the following equation:

**Step-down multiple regression for surface soil samples**

$$Y_1 = 0.274-0.235x_1+0.299x_2+0.012x_3+0.092x_4+0.025x_5+0.040x_6 -0.057x_7 +0.015x_8 +0.030x_9+0.008x_{10}$$

$$Y_2 = 0.126-0.210x_1+0.295x_2+0.090x_3+0.024x_4+0.040x_5 -0.057x_6 +0.015x_7 +0.030x_8 +0.009x_{10}$$

$$Y_3 = 0.879-0.218x_1+0.290x_2+0.092x_3+0.026x_4 +0.040x_5 -0.058x_6 +0.008x_7 +0.023x_8$$

$$Y_4 = 1.504-0.203x_1+0.289x_2+0.094x_3+0.016x_4 +0.042x_5 -0.060x_6 +0.015x_9$$

**Step-down Multiple regression for subsurface soil samples**

$$Y_1 = 2.188-0.114x_1+0.248x_2-0.018x_3+0.088x_4+0.009x_5+0.019x_6 -0.054x_7 +0.011x_8 +0.005x_9-0.012x_{10}$$

$$Y_2 = 2.649-0.115x_1+0.245x_2-0.018x_3+0.088x_4+0.009x_5+0.019x_6 -0.054x_7 +0.016x_8 -0.016x_{10}$$

$$Y_3 = 2.649-0.115x_1+0.245x_2-0.018x_3+0.088x_4+0.009x_5+0.019x_6 -0.054x_7 +0.016x_8 -0.016x_{10}$$

$$Y_4 = 2.649-0.115x_1+0.245x_2-0.018x_3+0.088x_4+0.009x_5+0.019x_6 -0.054x_7 +0.016x_8 -0.016x_{10}$$

$$Y_5 = 3.157-0.156x_1+0.252x_2+0.088x_4-0.039x_5-0.019x_6+0.015x_{10}$$
Where X1-pH, X2-EC, X3-CaCO3, X4-SOC, X5-CEC, X6-Fe2O3, X7-Al2O3, X8-Sand, X9-Silt, X10-Clay

The multiple regression study indicated that the available B showed significant negative regression coefficients with pH, CaCO3, sand, Fe2O3, Al2O3 and positive correlation with SOC, silt, clay, EC, CEC in surface and subsurface samples. The step-wise multiple regression equation indicated that 46.20 per cent variation in available B was observed due to pH, EC, SOC, CEC, Fe2O3, Al2O3 and silt content in surface soil samples whereas in subsurface soil samples pH, EC, SOC, Al2O3 total sand and clay accounted for 53.90 per cent variation in available B.

Conclusion

The present investigation revealed that the banana growing soils of study area were nearly acidic to strongly alkaline in reaction. In general, higher accumulation of CaCO3 in heavy textured soils induced alkalinity problem in soils. The available B in the banana growing soils of the study area ranged from 0.11 to 3.56 mg kg⁻¹, 0.03 to 2.28 mg kg⁻¹ in surface and subsurface soil samples respectively. In the present study, it was further observed that 40.55 per cent of the soils were deficient in B while 33.19 and 24.86 per cent areas were medium and high in HWS-B respectively. Geospatial distribution of boron in the soils of study area will be highly useful for guiding the banana growing farmers to decide the optimum amount of boron to be applied for getting higher yield and economic returns. Further, the findings of the present investigation underlines the importance of complete soil testing for micronutrients along with macronutrients which will pave the way for adoption of site specific micronutrient management for banana.

Table 1: Soil properties of banana growing soils of Theni district

<table>
<thead>
<tr>
<th>Block name</th>
<th>pH (1:2.5)</th>
<th>EC (dS m⁻¹)</th>
<th>CaCO3 (%)</th>
<th>SOC (g kg⁻¹)</th>
<th>CEC (cmol (p+) kg⁻¹)</th>
<th>Fe2O3 (%)</th>
<th>Al2O3 (%)</th>
<th>R2O5 (%)</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cinnamun</td>
<td>6.21-5.82</td>
<td>0.09-2.21</td>
<td>0.34-5.97</td>
<td>6.71-23.44</td>
<td>5.12-19.76</td>
<td>5.48-19.15</td>
<td>9.06-29.39</td>
<td>30.09-72.39</td>
<td>12.43-36.04</td>
<td>9.62</td>
<td>43.46-86.67</td>
<td>SCL,CL,SL,LS</td>
</tr>
<tr>
<td>Cumbum</td>
<td>6.21-5.82</td>
<td>0.09-2.21</td>
<td>0.34-5.97</td>
<td>6.71-23.44</td>
<td>5.12-19.76</td>
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<td>9.62</td>
<td>43.46-86.67</td>
<td>SCL,CL,SL,LS</td>
</tr>
<tr>
<td>Uthamapalayam</td>
<td>6.21-5.82</td>
<td>0.09-2.21</td>
<td>0.34-5.97</td>
<td>6.71-23.44</td>
<td>5.12-19.76</td>
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</tr>
<tr>
<td>Periyakulam</td>
<td>6.21-5.82</td>
<td>0.09-2.21</td>
<td>0.34-5.97</td>
<td>6.71-23.44</td>
<td>5.12-19.76</td>
<td>5.48-19.15</td>
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<td>30.09-72.39</td>
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<td>9.62</td>
<td>43.46-86.67</td>
<td>SCL,CL,SL,LS</td>
</tr>
</tbody>
</table>

Table 2: Hot water soluble boron status in banana growing soils of Theni district

<table>
<thead>
<tr>
<th>S. No</th>
<th>Block name</th>
<th>HWS-B (mg kg⁻¹)</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cinnamun</td>
<td>0.21</td>
<td>3.50</td>
<td>0.87</td>
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<tr>
<td>2</td>
<td>Cumbum</td>
<td>0.19</td>
<td>3.50</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Uthamapalayam</td>
<td>0.26</td>
<td>2.35</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Periyakulam</td>
<td>0.11</td>
<td>2.20</td>
<td>0.78</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Geospatial distribution of boron in the soils of study area

<table>
<thead>
<tr>
<th>Block name</th>
<th>pH (1:2.5)</th>
<th>EC (dS m⁻¹)</th>
<th>CaCO3 (%)</th>
<th>SOC (g kg⁻¹)</th>
<th>CEC (cmol (p+) kg⁻¹)</th>
<th>Fe2O3 (%)</th>
<th>Al2O3 (%)</th>
<th>R2O5 (%)</th>
<th>Sand (%)</th>
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<th>Clay (%)</th>
<th>Texture</th>
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</table>
Table 3: Simple correlation of boron with soil properties of surface soil samples

<table>
<thead>
<tr>
<th>pH</th>
<th>EC</th>
<th>B</th>
<th>CaCO₃</th>
<th>SOC</th>
<th>CEC</th>
<th>Fe₂O₃</th>
<th>Al₂O₃</th>
<th>R₂O₃</th>
<th>Sand</th>
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<td>1.00</td>
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<td></td>
<td>0.265</td>
<td>0.477</td>
<td>0.752</td>
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<td>0.104</td>
<td>0.092</td>
<td>-0.123</td>
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<tr>
<td>-0.336**</td>
<td>1.00</td>
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<td>0.970**</td>
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<td></td>
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<td></td>
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<tr>
<td>-0.479**</td>
<td>0.503**</td>
<td></td>
<td>1.00</td>
<td>0.103</td>
<td>0.045</td>
<td>0.064</td>
<td>0.105</td>
<td>0.073</td>
<td>0.083</td>
<td>-0.035</td>
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</tbody>
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Reference:


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