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Boron in Soil and Water Samples in some Tea Garden Belt of Golaghat district, Assam

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ABSTRACT

Boron is none uniformly distributed, ubiquitous essential micronutrient element for plant as well as human beings. Extensive use of agrochemicals in soil as well as various natural processes increases the boron concentration in soil and water. Significant risks for human and plant health may results from exposure to non toxic boron contaminants from drinking water, so is important to monitor it. A study has carried out to investigate the level of boron in 15 underground drinking water samples in addition to other physico-parameters (pH, Electrical Conductance, Ca, Mg, Na, K, NO_3^- and HCO_3^-) from three tea garden belt areas of Golaghat district of Assam, India. Fifteen surface soil samples also analysed for pH, EC, BD, WHC and porosity. The study reveals that five water samples have boron concentration slight higher than the WHO limit. The study further reveals that 10 surface soil samples have boron below detection limit. It may be due to higher leaching of boron during monsoon rains from surface soils beyond the root zone. The presence of boron in drinking water sources in this area is of anthropogenic origin. Thus, there is possibility of severe pollution problem with boron in near future.

Key words: Anthropogenic origin, boron, drinking water, essential micronutrient, surface soil.

INTRODUCTION

Boron is none uniformly distributed, ubiquitous essential micronutrient element for plant growth as well as human beings and needed in small amount, representing only 0.001% in the Earth crust. It does not appear on the earth in elemental form but is found in combined state as borax, boric acid, tourmaline, colemanite, kernite, ulexite and borates [1], [2], [3], [4]. In aqueous solution at pH < 7, it occurs mainly as un-dissociated boric acid (H_3BO_3) but at higher pH boric acid accepts hydroxyl ions from water thus forming a tetrahedral borate anion [5].

$B(OH)_3 + 2H_2O \leftrightarrow B(OH)_4^- + H_3O^+$. In acidic soil conditions also boron is more water soluble and there is possibility of leaching below the root zones of plants by rainfall or irrigations.

Parr and Loughman, (1983) reported that boron has active role in various metabolisms in plants such as: sugar transport, cell wall synthesis, lignification, cell wall structure, carbohydrate metabolism, RNA metabolism, respiration, indole acetic acid (IAA) metabolism and phenol metabolism [6]. Studies also reported that boron is essential to human body for numerous processes, including effective lipid and mineral metabolism, proper immune system and brain function [7]. Boron helps in the metabolism or utilization of Ca, Cu, Mg, glucose, triglycerides and estrogen in our life processes [8].

Boron deficiency is much more common in crops that are grown in soil that have higher amount of free carbonates, low organic matter, and high pH [9]. Common symptom that appears in plants due to boron deficiency are abnormal growing of parts, thicker and wrinkle leaves, brittle stem, spiral or twisted leaves for grasses, abnormal leaf tips for broad leaf plants etc. Symptoms of B deficiency on rice crop are white necrotic streaks on youngest leaf, which later on form a large white irregular patch. Deformed and reduced flowering, improper pollination as well as thickened, curled, wilted and chlorotic new growth are a common symptom of boron deficiency. It has been well reported that symptoms of boron deficiency are associated with high soil pH values (alkaline conditions). Under alkaline soil conditions boron solubility decreases, result in less plant uptake and increased potential for boron deficiencies. Complex borosilicate (tourmaline, colemanite, kernite) and boric acid are the main boron containing mineral found in most soils. Boric acid is mobile and is and easily lost by leaching whereas releases of boron from borosilicate minerals are quite slow. Boron deficient symptoms are common in Assam because as the seasonal crop plants are removed from the field, hardly any crop residue gets recycled back to the soil resulting in decreasing boron content; abundant soil moisture in torrential monsoon rains during May-August causes B leaching, beyond the root zone [10]. And subsequent to green revolution, crop yields and crop intensification have risen and, hence, increased amounts of B are being removed from soils, year after year. Moreover many newly introduced crop varieties are more susceptible to boron deficiency than landraces [11]. Hence, soil conditions and agronomic practices are conducive to the incidence of B deficiency in plants.
Boron toxicity in soil is mainly due to anthropogenic and excessive use of agrochemicals [12]. Boric acid and borates are used in glass manufacture, soaps and detergents, flame retardants, and neutron absorbers for nuclear installations can cause boron toxicity in environment. Boric acid, borates and perborates can introduced to environment as these have been used in mild antiseptics, cosmetics, pharmaceuticals [13]. Borates have various agricultural uses as fertilizer, insecticide and herbicide because they are not carcinogenic to mammalian and lack of insect resistance compared with organic insecticides [14], [15]. Boron occurs as borosilicate in igneous, metamorphic, sedimentary rocks which are resistant to weathering and not readily available to plants. But weathering in the pedosphere, which includes reactions of acid-bases, oxidation-reduction and dissolution- precipitation, converted the immobile boron to mobile form resulting boron toxicity in soil and water [12]. Excessive boron can cause off color and stunting of plant growth. As boron concentrations in plant tissue increase to toxic levels, older foliage may exhibit leaf edge burning or necrosis. Some plants will also develop black spots on older foliage.

The total B concentration in soils ranges from 20-200 mg kg^{-1} but most of it is unavailable to plants. The available (hot water soluble) fraction generally ranges from 0.4-5 mg kg^{-1} [16], [17]. Boron concentration range depends on soil textural properties and sensitivity varies from crop to crop. Traces of boron >0.5 ppm are injurious to citrus, nuts and deciduous fruits; cereals and cotton are moderately tolerant to boron; while alfalfa, beet, asparagus and dates are quite tolerant (1-2 ppm). According to BIS (105000) and WHO boron concentration in drinking water was considered to be 1-5 mg/L and 0.5 mg/L respectively. For irrigation water boron range is 0-2 mg/L. Toxicity guidelines and relative tolerance to boron for some common crops are listed in Table 1 and 2.

Table 1. Interpretation of Boron content in soil

Soil Texture	Very Low	Low	Optimum	High	Excessive
Sands, Loamy Sands	<0.2	0.3-0.4	0.5-1.0	1.1-2.5	>2.5
Sandy Loams, Loams, Silt Loams Silts, Clays	<0.3	0.4-0.8	0.9-1.5	1.6-3.0	>3.0

Source: *Kelling, K. A., Soil and Applied Boron (A2522), University of Wisconsin System Board of Reagents and University of Wisconsin Extension, Cooperative Extension, US Deptt. Agri.*

Table 2. Toxicity guidelines and tolerance limit to Boron [12]

Water Class	Boron (ppm)	Boron (ppm)	Boron (ppm)
Excellent	< 0.33	< 0.67	< 1.00
Good	0.33-0.67	0.67-1.33	1.00-2.00
Permissible	0.67-1.00	1.33-2.00	2.00-3.00
Doubtful	1.00-1.25	2.00-2.50	3.00-3.75
Unsuitable	1.25 +	2.50 +	3.75 +

The soil boron concentration range between plant deficiency and toxicity symptoms is very narrow but both deficiency and toxicity conditions can lead to marked yield reductions of crop plants and economic losses. Despite being categorized as less sensitive to boron deficiency and toxicity, a number of crops suffer nutritional disorder in Assam. Although B fertilization is a simple and cost-effective solution to the problem, practical constraints are prohibitive in its adoption by farmers cultivating low/ high B soils as well as in water. Monitoring of soil and water boron and B fertilization is in infancy in Assam. Therefore to reduce the crop yield losses when grown in low/ high B soils and significant risks for human health exposure to non pathogenic and non toxic boron contaminants from drinking water, a study has carried out in the tea garden belts of Golaghat district of Assam, India.

METHODOLOGY

Site Description

Golaghat district is cartographically confined with latitudes of $25^0 45^/$ N and $27^0 10^/$ N and Longitudes of $93^0 30^/$ E and $94^0 22^/$ E with a total geographical area of 3502 sq. km. It is bounded in the north by Sonitpur district on the east by Jorhat district on the south Karbi Anglong and Nagaon district and the west by Nagaland.

Water Sampling and Analysis

A total of 15 ground water samples were sampled during March to October, 2009 from three tea garden belt viz. Khomtai, Behora and Negheriting TE areas of Golaghat district of Assam, India for estimation of pH, EC, Ca, Mg, Na, K, NO_3^-, HCO_3^- and B. The pH of water samples was determined with a digital pH meter (Eutech, Model-356C, India). EC of water samples were measured using a digital conductivity meter (ATC, Model 975-C, India).

Soil Sampling and Analysis

Surface soil samples (0-15 cm) are randomly collected from the paddy fields from the tea garden belts with two replicate at each site. Sampling sites in the paddy fields are mainly contaminated by sewage irrigation generates from the tea gardens. Soil samples are air dried and any clods and crumbs are removed, crushed and homogenized to pass through a 2 mm mesh sieve and stored in plastic container until analysis. Soil pH has determined using a digital pH-meter (Eutech-356C, India) at a soil to deionized water ratio of 1:5 after reciprocal shaking for one hour [18]. Electrical Conductance (EC) also determined with the same suspension using a digital conductivity meter ATC-975-C, India. Soil organic matter content (OMC%) was measured by using Walkley-Black $K_2Cr_2O_7$ wet oxidation method [19]. Ca and Mg in water samples and exchangeable form in soil was estimated by EDTA titrimetric method and Na and K by flame photometer (Labtronics, LT- 34, India). The BD, WHC and porosity of soil samples were measured as described by Jackson in 1973 [20].

Boron content in water samples

Boron in water and samples were estimated by spectrophotometrically using Azomethine-H method. Absorbance was recorded at 420nm in the UV Spectrophotometer (Hitachi-3210). A linear calibration was observed, followed by the calculation of the slope factor. Regression equation: y = 325153X + 2836.5; R^2 = 0.9998 (Fig. 1). Boron concentration was read directly from the standard curve.

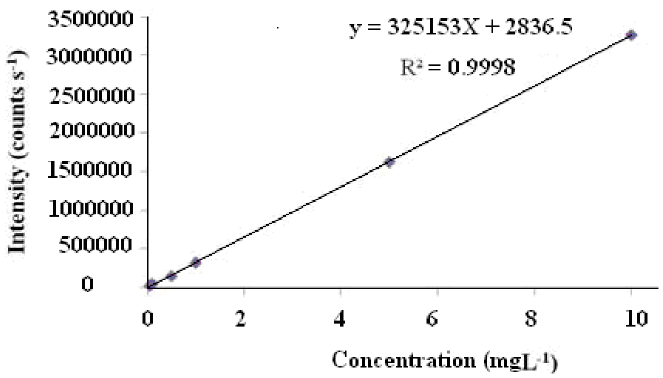

Fig.1. Calibration graph of Boron

Boron content in soil samples

It is difficult to predict the B concentration of the soil solution within the root zone before a complete equilibrium is attained due to the complex B adsorption/desorption and precipitation/ dissolution reactions in soil [21]. Equilibrium is especially important in potentially B toxic soils that have been created by the use of high B water for irrigation. Hot Water Extraction and $CaCl_2$ extraction methods are widely used methods for assessing B in soil [22].

Extraction of Boron from Soil

0.50 g of soil samples were weighed into 50 mL polyethylene centrifuge tubes to which 10 mL of 0.01 M $CaCl_2$ was added and the tubes were shaken at 25°C for 16 h. After centrifuging at 15 000 rpm for 30 min, the suspension was filtered through 0.22-µm Millipore filters [22]. And the filtrate was used for B determination by spectrophotometrically using Azomethine-H method. Each sample was run in triplicate and the mean of two successive results at the relative standard deviation not exceeding 5% were accepted as an estimation value. Statistical analysis was performed using SPSS- 13.0 version.

RESULTS AND CONCLUSION

Soil and water physico-chemical properties determined in the present study are presented in Table 3 - 7. Boron content found maximum (1.46 ppm) in Negheriting TE belt and minimum (0.025 ppm) was recorded in Khomtai TE belt. Out of the 15 water samples 9 samples recorded higher than the prescribed WHO limit (0.5 ppm) and all samples falls with in the BIS (105000) limit. Higher amount of Boron in ground water samples may be due to leaching of soil boron as maximum amount of mobile boron is present in the acidic soil in the study area. Moreover use of boron compounds as fertilizer, insecticide and herbicides at regular intervals and paddy fields around the tea gardens are subjected to wastewater irrigation disposal hence possibility of boron leaching in under ground water.

Table 3. Descriptive statistical analysis of Boron in three Tea Estates

Sampling spots	Min	Max	Mean	SD	Skewness	Kurtosis
Negheriting(N=5)	0.056	1.46	0.7444	0.639991	-0.30589	-2.7279
Khomtai (N=5)	0.025	1.34	0.6022	0.559159	0.145297	-1.6170
Behora (N=5)	0.067	1.39	0.8314	0.555936	-0.62513	-1.6342

Table 4. Descriptive statistical analysis of pH, EC, Ca, Mg, Na, K (N= 15)

Statistics	Min	Max	Mean	SD	Skewness	Kurtosis
pH	6.23	8.02	7.008667	0.340939	0.350505	2.458674
EC	89.92	412.39	154.3273	81.21457	1.996273	3.630062
Ca	13.56	156.83	64.399	40.72177	0.511251	-0.50978
Mg	2.19	49.83	19.101	13.66997	0.647758	-0.41396
Na	6.88	67.59	32.443	17.22439	0.24507	-0.91433
K	1.89	18.57	7.495333	4.734635	0.591311	-0.55622
NO_3^-N	0.19	5.03	1.798667	1.477782	0.736504	-0.85853
HCO_3^-	78.98	156.78	106.731	16.58738	1.195802	1.760286

Table 5. Descriptive statistical analysis of pH, EC, OM, BD and WHC of soil (N= 15)

Parameters	Min	Max	Mean	SD	Skewness	Kurtosis
pH	4.43	5.91	5.1	0.514948	0.277272	-1.52252
EC	0.06	14	1.055333	3.581438	3.871477	14.99167
OM	1.06	4.51	2.458	0.981756	0.358212	-0.46351
BD	0.83	2.02	1.365333	0.385521	0.193554	-1.13622
WHC	24.35	36.45	31.44067	2.780703	-0.65216	2.549517

Table 6. Estimated values of soil quality parameters

Tea Estates	pH	EC (μmhocm^{-1})	OM (%)	BD (gm cm^{-3})	WHC (%)	B (mg/Kg)
Negheriting	4.51	0.12	4.51	1.37	34.5	1.25
	5.03	0.13	3.09	1.38	31.4	1.02
	5.45	0.09	1.67	1.29	35.03	0.067
	5.71	0.17	1.98	0.98	29.88	BDL
	4.89	0.11	1.69	0.88	32.01	BDL
Behora	4.43	0.08	2.79	1.23	32.4	0.78
	4.55	0.21	2.63	1.78	31.6	0.89
	4.87	014	3.05	1.57	29.67	1.20
	5.91	0.27	3.05	1.09	24.35	1.05
	5.67	0.10	1.49	0.83	36.45	BDL
Khomtai	4.56	0.11	3.31	0.91	31.29	0.095
	5.78	0.14	1.19	1.78	31.04	0.098
	4.88	0.09	3.48	1.89	30.76	1.45
	4.79	0.06	1.88	2.02	31.56	0.56
	5.47	0.15	1.06	1.48	29.67	0.039

Table 7. Correlation analysis between soil quality parameters

Parameters	pH	EC	OM	BD	WHC	B
pH	1					
EC	0.677202	1				
OM	-0.57543	0.549541	1			
BD	0.421134	0.606222	0.882325	1		
WHC	0.316724	0.505712	0.715627	0.693563	1	
B	-0.348147	0.342641	0.004307	0.549879	0.562028	1

The calculated kurtosis values for Ca, Mg, Na, K, B, NO_3-N and HCO_3^- are less than 3 (β_2<3) showed a low peak relatively small number of scores fall in the center of the distribution Therefore the shape of the curve was platykurtic for all the above parameters**.** For EC it was Mesokurtic Curve (β_2 >3) because a moderate peak representing a normal number of scores in the middle of the distribution (Fig. 2).

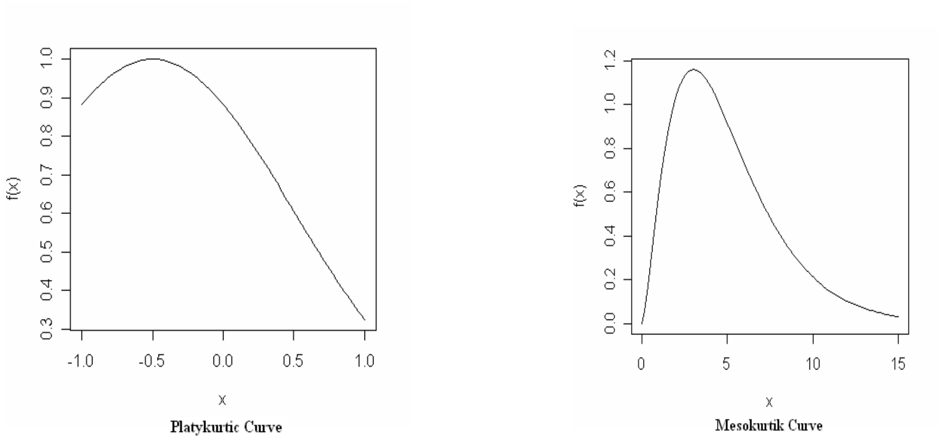

Fig. 2. Graphical representation of kurtosis of water samples tested

Soil properties viz., pH, texture, lime, moisture, temperature, organic matter and clay mineralogy have the largest effects on plant available B in the soil [21]. Studies reported that is one of the most important factors affecting the adsorption of boron indicated that in soils with high pH, lime and clay content, plant available boron was reduced by the formation of $B(OH)_4^-$ and adsorption of anions. This study also shows a negative relationship between available boron for plant uptake and pH and EC of soil samples. Negligible use of B in soil may create the incidence of B deficiency in soil and plants. Furthermore, the range between toxic and deficient B levels for crop growth is quite narrow; therefore, indiscriminate use of this essential micronutrient must be avoided. B fertilization methods and rates should be carefully defined because of the small amounts needed for correction of deficiency while avoiding over-application and possible toxicity.

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