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Boron Status of Paddy Soils in the States of Kedah and Kelantan, Malaysia

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ABSTRACT

Management of micronutrient B in soil is difficult because of its high mobility. Soil sampling and analysis is the first important step in managing the nutrients required by plants. This study was conducted to evaluate the B status in soils of rice growing areas in Kedah and Kelantan which are the main rice growing states of the country. Soil samples were collected from 15 soil series namely Kranji, Sedeka, Guar, Kundur, Tualang, Teluk Chengai, Kuala Kedah, Rotan, Sedu, Kangkong, Batu Hitam, Lubok Itek, Tepus, Telemong and Chempaka to determine B status and other physico-chemical properties. The soils of paddy growing areas investigated were very low in available B status. All the fifteen soil series had B below 0.5 mg kg^{-1}, irrespective of depth and locations. Kundur and Chempaka Series soils had the highest B content (0.46 mg kg^{-1}) among all the series while the Tualang Series soil had the lowest B (0.22 mg kg^{-1}). Boron status in soils differed significantly with depth; the upper layers had higher B concentrations compared to lower depths because of high organic carbon content. Boron showed a positive correlation with organic carbon content but a negative correlation with soil pH.

Keywords: Correlation study, hot water extractable B, paddy soils

INTRODUCTION

Boron is an essential micronutrient element required for the normal growth of plants. The range between B deficiency and toxicity symptoms in plants is typically narrow, in the range of 0.028 to 0.093 mmol L^{-1} for sensitive crops and 0.37 to 1.39 mmol L^{-1} for tolerant crops (Goldberg 1997). Boron deficiency is the most widespread of all the micronutrients deficiencies in many crop regions, from tropical to temperate zones. Chronic and marginal B deficiency has been reported in many crop species across large areas of field production (Shorrocks 1997). Availability of B to plants is affected by a variety of soil factors including soil solution pH, soil texture, soil moisture, temperature, oxide content, carbonate content, organic matter content and clay mineralogy. Liming of acid soils also induces B deficiency (Goldberg *et al.* 2000).

Boron deficiency is of great concern in areas receiving heavy rainfall because of leaching losses. Compared with other micronutrients, the chemistry of B in soils is very simple. The pH is one of the most important factors affecting the

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availability of B in soil. Boron becomes less available to plants with increasing pH (Gupta 1993). Boron adsorption on soil constituents is very dependent on solution pH. Available B in the soil decreases with increasing pH because of more fixation to the soil sites at high pH values. Maximum B fixation occurs at pH 6 to 9 (Goldberg 1997).

Boron-containing minerals are either insoluble (tourmaline) or very soluble (hydrated B minerals) and generally do not control the solubility of B in soil solution (Goldberg 1997). Boron is critical for the process of cell differenciation at all growing tips of the plant (meristems) where cell division is active (Liu 2000) and when it is low, crops experience yield reductions.

The main paddy growing areas of Malaysia are the states of Kedah and Kelantan. It is forecasted that a 50 to 60% increase in rice production will be required to meet the demands of the population by 2025 (IRRI Notes 2008). A rice yield increase is likely to occur through fine-tuning of crop management.

Boron deficiency in crops is widespread in a number of countries including Malaysia (FFTC, 1999). The FAO global study on micronutrients conducted by Sillanpaa (1982) reported that oil palm growing areas of Malaysia are deficient in B and other micronutrients. Gyul'akhmedov (1984) and Domingo (1983) also reported that Malaysian soils are deficient in micronutrients. B status and other physico-chemical properties of soils grown with paddy were determined in this study.

MATERIALS AND METHODS

Sample Collection and Analysis

Soil samples were collected from the main rice growing areas of Kedah and Kelantan. Ten soil series were identified. Those developed on marine alluvium parent materials from Kedah were the Kranji, Sedeka, Guar, Kundur, Tualang, Teluk Chengai, Kuala Kedah, Rotan, Sedu and Kangkong, whilst soil series developed on riverine alluvium parent materials from Kelantan were Batu Hitam, Lubok Itek, Tepus, Telemong and Chempaka. At the time of sampling, the crop had been recently harvested and the soil was drained and bare. Sampling was performed using an auger. Samples were taken from three different locations in the same field area of each soil series and at depths of 0 to 15, 15 to 30 and 30 to 45 cm. Three replications of each sample were maintained for chemical analysis. Soil and geographical maps of the area were used as guidelines with the location of the sampling site being recorded using GPS. Soil samples were air-dried, ground and sieved through a 2-mm sieve for laboratory analyses.

Boron in the soil samples was extracted using hot water (Bingham 1982). Available B in the soil extracts was measured colorimetrically at 420 nm using the azomethine-H dye. Soil pH was determined by taking 10 g of soil and mixing with 25 ml of distilled water, shaken for 15 minutes and left to stand overnight, after which pH of the extract was read on PHM210 Standard pH meter. Electrical conductivity (EC) was determined by taking 10 g soil and mixing with 25 ml of distilled H_2O, then shaken for 15 minutes and left to stand overnight. Electrical conductivity was analyzed using the EC meter (Radiometer) at 24^0C. Phosphorus was extracted using Bray and Kurtz No. 2 extractants (Bray and Kurtz 1945). Organic carbon in the soils was determined by using non-dispersive, infrared, digital-controlled instrument CR-412 Carbon Analyser. Soil texture was determined using the pipette method (Gee and Bauder 1986). For statistical analysis, the SAS programme was used while the separation of means was tested using Tukey test at the probability level of 0.05.

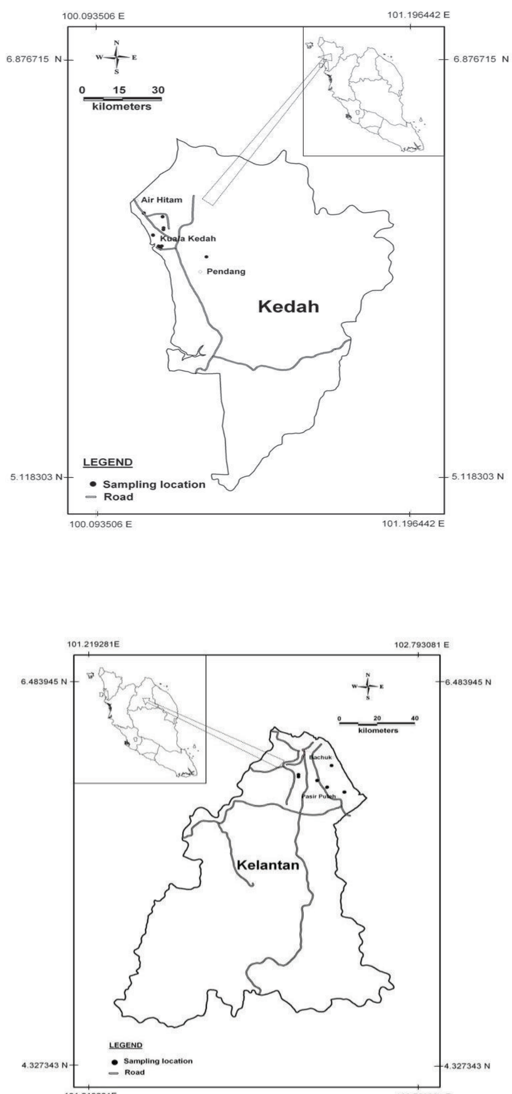

Fig. 1: Dots in the Kedah and Kelantan maps showing the soil sampling locations

RESULTS AND DISCUSSION

Boron Status of Rice Soils of Kedah and Kelantan States

The soils from Kedah were of marine alluvium parent material while the five soil series from Kelantan were derived from riverine alluvium (Table 1). All the fifteen soil series of Kranji, Sedeka, Guar, Kundur, Tualang , Teluk Chengai, Kuala Kedah, Rotan, Sedu, Kangkong, Batu Hitam, Lubok Itek, Tepus, Telemong and Chempaka had available B below 0.5 mg kg^{-1} at all three depths irrespective of location (Tables 2a-b). Kundur and Chempaka series soils had the highest B content (0.46 mg kg^{-1}) among all series while Tualang series soil had the lowest B (0.22 mg kg^{-1}) for two out of three locations. In all other soils, the available B was between 0.25 to 0.40 mg kg^{-1}. As no soil series had available B of more than 1 mg kg-1, all these soils may be considered as deficient in B status (Bingham 1982). Soil samples were taken from three locations of each soil series and no significant difference was observed in available B content among locations of the same soil series. There was significant difference in B status according to depth with available B being significantly higher in the upper layer (0 to 15 cm) as compared to the lower depths.

The presence of organic matter was found to be higher in the upper layer and its presence was found to have a significant positive correlation with available B (r = 0.54*, n=405) (Table 3). These results are in agreement with the findings of Shorrocks (1997) who reported that organic matter is the primary source of 'reserve' B. Available B had significant negative correlation (r = -0.24*, n=405) with soil pH. Chemical analysis of soil samples showed that in high pH soils, B content was comparatively low which indicates that increasing pH reduces available B content in soil. Keren and Bingham (1985) reported that B becomes less available with increasing solution pH due to increased B adsorption at higher soil pH levels. The decline in available B content is correlated with increasing rainfall and paddy growing areas of Kedah state having an annual rainfall of more than 2600 mm (MMD 2009). The high precipitation may be the major cause of prolonged B leaching from soils. It is observed that these rice growing areas have been under cultivation for a long period of time with continuous uptake of B by crops. However, B fertilizer is not applied to replenish the soils and nutrient mining is offered as one possible reason for B deficiency. All the soil series had a silty clay and clay loam texture. Stevens *et al*. (2005) stated that in fine textured soils, plant available B may be low because B is strongly held by clay surfaces. Soil critical limits of B are categorised as follows: <1 mg kg^{-1} - insufficient for plant growth; 1 to 2 mg kg^{-1} - sufficient for normal growth; 2.1 to 5.0 mg kg^{-1} – high; and >5 mg kg^{-1} -toxic to the plant (Bingham 1982).

TABLE 1
Taxonomic classifications of the soils collected from the rice growing areas of Kedah and Kelantan, Malaysia

Soil series	Great group	Parent material
Kranji	Sulfaquent	Marine, estuarine deposits
Sedaka	Paleudult	Marine, estuarine deposits
Gu ar	Hydraquent	Brackish water deposits
Kundur	Fluvaquent	Marine, estuarine deposits
Tualang	Fluvaquent	Riverine deposits
Teluk Chengai	Paleudult	Marine, estuarine deposits
Kuala Kedah	Fluvaquent	Marine, estuarine deposits
Rotan	Fluvaquent	Marine, estuarine deposits
Sedu	Sulfaquept	Marine, estuarine deposits
Kangkong	Hapludult	Marine, estuarine deposits
Batu Hitam	Endoaqualf	Recent alluvium
Lubok Itek	Fluvaquent	Recent alluvium
Tepus	Kandiaquult	Recent alluvium
Telemong	Udorthent	Recent alluvium
Chempaka	Paleudult	Recent alluvium

(Source: Paramananthan 1987; Paramananthan 2000)

TABLE 2a

Available B (mg kg^{-1}) status of the soil series of Kedah soils at different sites and depths

Soil series	GPS location	………….Depth (cm)…………..		
		0 - 15	15 - 30	30 - 45
Kranji		……………mg kg^{-1}	……………	
Site 1	N 06° 05.363′ E 100° 18.848′	0.50	0.30	0.22
Site 2	N 06° 05.086′ E100°19.087′	0.25	0.12	0.08
Site 3	N 06° 05.086′ E 100°19.309′	0.29	0.18	0.12
Mean		0.34 a	0.20 b	0.14 c
Sedaka				
Site 1	N 05° 53.310′ E 100° 26.364′	0.20	0.15	0.10
Site 2	N 05° 53.307′ E 100° 26.313′	0.32	0.24	0.20
Site 3	N 05° 53.307′ E 100° 26.292′	0.20	0.12	0.08
Mean		0.24 a	0.17 b	0.12 b
Guar				
Site 1	N 05° 52.098′ E 100° 27.578′	0.42	0.28	0.18
Site 2	N 05° 52.126′ E 100° 27.593′	0.11	0.09	0.04
Site 3	N 05° 52.194′ E 100° 27.583′	0.34	0.20	0.12
Mean		0.29 a	0.19 b	0.11 c
Tualang				
Site 1	N 06° 02.653′ E 100° 28.900′	0.36	0.22	0.18
Site 2	N 06° 02.625′ E 100° 28.900′	0.10	0.05	0.02
Site 3	N 06° 02.623′ E 100° 28.933′	0.20	0.12	0.06
Mean		0.22 a	0.13 b	0.08 b

Means with the same letter within the rows are not significantly different at p>0.05

Soil series	GPS location	………….Depth (cm)…………..		
		0 - 15	15 - 30	30 - 45
		……………mg kg^{-1}	…………….	
Kundur				
Site 1	N 05°58.800′ E 100°26.005′	0.46	0.32	0.20
Site 2	N 05°58.821′ E 100°25.948′	0.42	0.22	0.12
Site 3	N 05°58.816′ E 100°25.881′	0.40	0.22	0.15
Mean		0.42 a	0.25 b	0.15 c
Kangkong				
Site 1	N 06°13.643′ E 100°15.698′	0.28	0.21	0.14
Site 2	N 06°13.643′ E 100°15.719′	0.12	0.08	0.05
Site 3	N 06°13.709′ E 100°15.765′	0.40	0.28	0.20
Mean		0.26 a	0.19 b	0.15 b
Teluk Chengai				
Site 1	N 06°05.389′ E 100°19.504′	0.35	0.20	0.12
Site 2	N 06°05.369′ E 100°19.504′	0.28	0.21	0.15
Site 3	N 06°05.330′ E 100°19.476′	0.14	0.09	0.04
Mean		0.25 a	0.16 b	0.10 c
Kuala Kedah				
Site 1	N 06°08.078′ E 100°17.712′	0.43	0.32	0.20
Site 2	N 06°08.117′ E 100°17.692′	0.29	0.16	0.40
Site 3	N 06°08.147′ E 100°17.673′	0.42	0.30	0.20
Mean		0.38 a	0.26 b	0.26 c

Means with the same letter within the rows are not significantly different at $p>0.05$

Soil series	GPS location	…………..Depth (cm)…………..		
		0 - 15	15 - 30	30 - 45
		……………mg kg^{-1} …………….		
Rotan				
Site 1	N 06°08.147′ E 100° 17.673′	0.22	0.12	0.09
Site 2	N 06°09.492′ E 100° 19.871′	0.40	0.32	0.25
Site 3	N 06°09.964′ E 100° 19.879′	0.34	0.20	0.16
Mean		0.32 a	0.21 b	0.16 b
Sedu				
Site 1	N 06°12.733′ E 100°19.693′	0.40	0.24	0.14
Site 2	N 06°12.766′ E 100°19.696′	0.32	0.24	0.12
Site 3	N 06°12.793′ E 100°19.691′	0.40	0.30	0.24
Mean		0.37 a	0.26 b	0.16 b

Means with the same letter within the rows are not significantly different at $p>0.05$

TABLE 2b

Available B (mg kg^{-1}) status of the soil series of Kelantan at different sites and depths

Soil Series	GPS location	………….. Depth (cm)……………		
		0 - 15	15 - 30	30 - 45
		… ………… mg kg^{-1} …………….		
Batu Hitam				
Site 1	N 05°55.539′ E 102°18.799′	0.45	0.22	0.28
Site 2	N 05°55.517′ E 102°18.788′	0.38	0.37	0.27
Site 3	N 05°55.500′ E 102°18.758′	0.21	0.19	0.14
Mean		0.34 a	0.26 b	0.23 b
Lubok Itek				
Site 1	N 05°53.274′ E 102°21.707′	0.25	0.19	0.15
Site 2	N 05°53.236′ E 102°21.661′	0.24	0.20	0.17
Site 3	N 05°53.185′ E 102°21.596′	0.40	0.35	0.30
Mean		0.29 a	0.24 b	0.20 b
Tepus				
Site 1	N 05°51.594′ E 102°26.697′	0.24	0.19	0.15
Site 2	N 05°51.584′ E 102°26.639′	0.21	0.11	0.19
Site 3	N 05°51.579′ E 102°26.600′	0.33	0.30	0.27
Mean		0.26 a	0.20 b	0.20 b
Telemong-Akob				
Site 1	N 06°00.584′ E 102°22.927′	0.39	0.31	0.25
Site 2	N 06°00.563′ E 102°22.936′	0.20	0.19	0.18
Site 3	N 06°00.560′ E 102°22.963′	0.41	0.31	0.31
Mean		0.33 a	0.27 b	0.24 c

Means with the same letter within the rows are not significantly different at $p>0.05$

Soil series	GPS location	………….Depth (cm)…………..		
		0 - 15	15 - 30	30 - 45
		……………mg kg^{-1} …………….		
Chempaka				
Site 1	N 05° 57.494′ E 102° 13.455′	0.40	0.30	0.22
Site 2	N 05° 57.483′ E 102° 13.453′	0.44	0.30	0.26
Site 3	N 05° 57.465′ E 102° 13.481′	0.46	0.42	0.40
Mean		0.43 a	0.34 b	0.35 c

Means with the same letter within the rows are not significantly different at $p>0.05$

TABLE 3

	Boron	pH	Organic carbon	P	EC
Boron		-0.239*	0.439*	0.120 ns	-0.001 ns
pH			-0.600*	0.047 ns	-0.269 ns
Organic carbon				0.121 ns	0.237*
P					0.087 ns

(Pearson Correlation Coefficients, n = 405)
Value presents R - value
ns - non-significant at 5% level
* - significant at 5% level

Correlation study on soil chemical properties of paddy soils

CONCLUSION

Soil sampling and laboratory analysis from different locations of 15 soil series of rice growing areas showed that all the soils are deficient in plant available B status as no soil series had B of more than 1 mg kg^{-1}. Boron fertilizers should be applied to these soils for higher crop yields.

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