Chapter 2

A survey of boron mobility in tropical species: a field study

2.1 Introduction

Boron (B) is unique amongst the essential elements in that its mobility (Chapter 1) varies among species (Brown and Shelp, 1997). In most plant species, B mobility is insignificant. Evidence for this type of behavior is widespread, for example in young squash (Hu and Brown, 1994) and tomato (Oertli, 1993). However, observations of phloem mobility of B have been made in a number of plants, including apple, pear, plum, cherry (Hanson, 1991; Brown and Hu, 1996), olive (Delgado *et al.*, 1994), celery and peach (Hu *et al.*, 1997).

These all studies examined B retranslocation in temperate plants and data for tropical species are limited. Accordingly, this study investigated possible B mobility in tropical species especially woody species growing in Thailand, by examining the nutrient concentration gradients between young and old leaves of plants growing in the field. The assumption is that the B concentration will increase with leaf age in those species in which B is immobile, while such concentration gradient will not exist in those species in which B is phloem mobile.

2.2 Materials and methods

Plant materials

2.2.1 Boron mobility in mangosteen

This study is aimed to examine B mobility in mangosteen (*Garcinia mangostana* L., Family Clusiaceae) by comparing trends in B concentration in leaves of different age with potassium (K: phloem mobile) and calcium (Ca: phloem immobile). Leaf samples in this study were brought from a farmer's orchard in Chantaburi province (eastern Thailand), part of a research project of Assoc. Prof. Dr. Sumitra Poovarodom, King Mongkut's Institute of Technology Ladkrabung. Leaves from 15 trees (16-18 years old) were collected as follows (Fig. 2.1): the second leaf pair was taken from the shoot apex of each branch [4 branches on each side of the tree (north, south, west and east)], at two positions in the canopy - top (3-4 m from ground) and bottom (1-2 m from ground) at approximately monthly intervals from January 2001 to May 2001 (3 to 7 months old). Leaf samples from 4 sides were pooled for nutrient analysis of each canopy position.

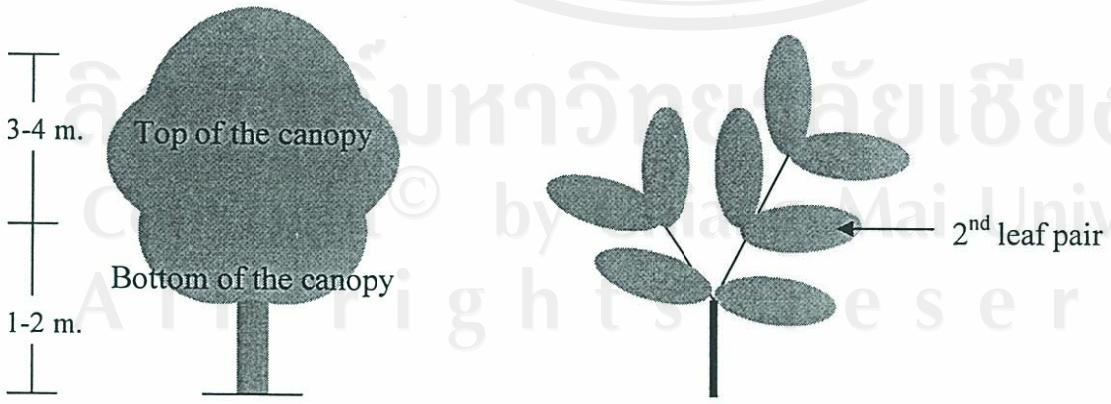


Figure 2.1 Position of mangosteen leaf sample collection.

2.2.2 Boron mobility in durian

Durian (cv. Mon thong) seedlings [*Durio zibethinus* L., Family Malvaceae (Bombacaceae)] were grown in the field in low B soil (0.10-0.15 mg B kg^{-1} soil hot water soluble extract) for 2 years. Treatments were arranged in Randomized Complete Block Design (RCB) with 10 replicate plants. Ten plants were treated with B at 18.75 kg borax (sodium tetraborate, 11.3% B) ha^{-1} (B+). The borax was dissolved in 1 L of distilled water and applied directly to the soil in a circle of 20 cm radius from the trunk. For the control treatment (B0), 1 L of filtered water was applied to each of another 10 trees. Leaves 1-4 from the base of branches (Figure 2.2) were harvested individually before B application (H1) and 1 month after B application (H2). Leaves from 4 braches of each tree (replicate) were pooled to one sample for nutrient analysis.

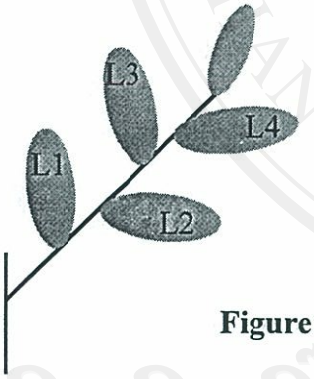


Figure 2.2 Position of durian leaf sample collection.

2.2.3 Survey of tropical woody and fruit species for B retranslocation

This study explored the foliar B levels in 17 species of tropical woody and fruit species (Table 2.1), growing in the fields of the Chiang Mai Valley in low B soil (0.10-0.15 mg kg^{-1} hot water soluble extract). The leaves of seven replicate trees were collected from the position of the youngest fully expanded leaf (YFEL), the middle leaf age (ML) and the oldest leaf (OL) of lateral branches. Leaf samples were

taken from branches on four sides in the middle of the canopy of the tree and were combined to make one sample for each leaf position.

Plant analysis

Leaf samples were oven-dried at 80 °C for 48 hours, ground to pass a 1 mm mesh and ashed-dry at 500 °C for 8 hours. The B concentration was analyzed by the azomethine-H method (Lohse, 1982) and the K and Ca were determined by atomic absorption spectrophotometry.

Statistical analysis

Data of nutrient concentration in leaves were analysed by analysis of variance (ANOVA) with Completely Randomized Design (CRD) for 2.2.1 and 2.2.3 and with Randomized Complete Block Design (RCB) for 2.2.2. The concentration means of different leaf positions were compared by least significant difference (LSD) at $P<0.05$.

Table 2.1 Tropical species sampled for foliar boron.

Family	Common name	Scientific name	Date of collection	Season
Anacardiaceae	Cashew	*Anacardium occidentale* L.	June 2002	Wet
Anacardiaceae	Mango	*Mangifera indica* L.	Dec. 2002	Dry
Annonaceae	Custard apple	*Annona squamosa* L.	June 2002	Wet
Caricaceae	Papaya	*Carica papaya* L.	Nov. 2002	Dry
Euphorbiaceae	Cassava	*Manihot esculenta* Crantz.	June 2002	Wet
Leguminosae	Indian walnut	*Samanea samen* (Jacq.) Marrill.	June 2002	Wet
Leguminosae	Cork wood tree	*Sesbania grandiflora* (L.) Pers.	June 2003	Wet
Leguminosae	Tamarind	*Tamarindus indica* L.	June 2002	Wet
Moraceae	Jackfruit	*Artocarpus heterophyllus* Lamk.	June 2002	Wet
Myrtaceae	Guava	*Psidium guajava* L.	June 2002	Wet
Oxalidaceae	Star fruit	*Averrhoa carambola* L.	June 2003	Wet
Passifloraceae	Passion fruit	*Passiflora edulis* Sims.	Nov.–Dec. 2002	Dry
Rubiaceae	Coffee	*Coffea arabica* L.	Dec. 2002	Dry
Rutaceae	Lime	*Citrus aurantifolia* Swingle.	Nov. 2002	Dry
Sapindaceae	Longan	*Euphoria longana* Lam.	June 2003	Wet
Sapindaceae	Lychee	*Lychi chinensis* Sonn.	June 2003	Wet
Verbenaceae	Teak	*Tectona grandis* L.	June 2002	Wet

2.3 Results

2.3.1 Boron mobility in mangosteen

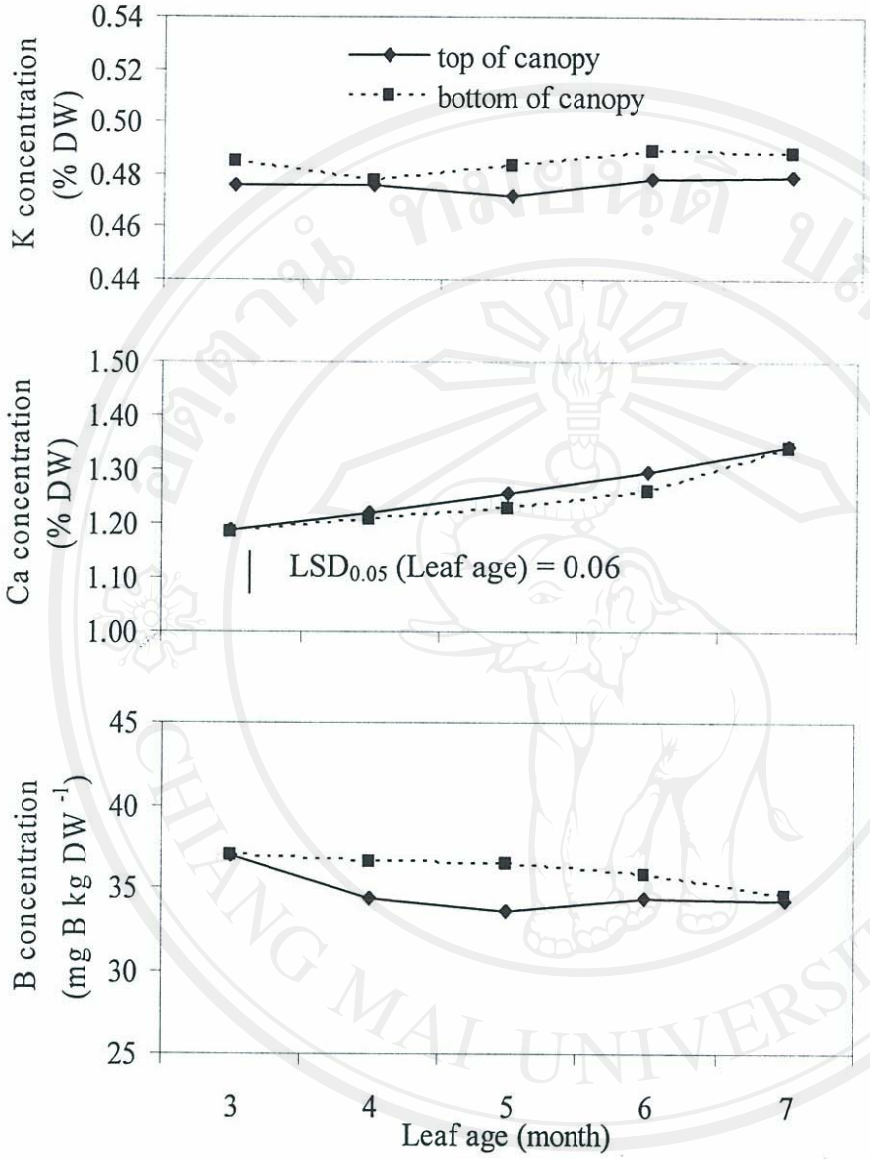
Trends in concentration of B, Ca and K in mangosteen leaves in both canopy positions are shown in Figure 2.3. Unlike Ca where there was a significant increase in concentration with leaf age, B and K concentrations in leaves of different ages were not significantly different. The B concentration at 3 months was 37 mg kg DW^{-1} in both positions of the canopy. When leaf age increased to 7 months, the B concentration in leaves from the top and the bottom of the canopy was 34.2 and 34.5 mg kg DW^{-1}, respectively. Potassium concentrations were in the range of 0.47 – 0.49 % DW. For Ca, concentrations increased from 0.19 % DW at 3 months to 1.34 % DW at 7 months in both canopy positions.

2.3.2 Boron mobility in durian

Boron treatment did not affect K or Ca concentrations in durian leaves at harvest 2 (Figure 2.4). The K concentration did not differ with leaf position but it decreased with leaf age. For Ca, the concentration increased with both leaf position and harvest. The B concentration in B0 trees remained constant over time in all leaf positions. In contrast, the B concentration increased significantly after B was applied (B+). However, there was no difference between leaf positions.

2.3.3 Survey of tropical woody and fruit species for B retranslocation

Distribution of nutrients in each species are shown in Tables 2.2, 2.3 and 2.4. There were no significant differences in K concentrations of leaves at different positions of the cork wood tree, tamarind, coffee and lime. In the remaining species, concentration of K in the YFEL was the highest and decreased with leaf age (Table 2.2). By contrast, concentrations of Ca were lower in the younger leaves and higher in the older leaves (Table 2.3). The results for B concentration, when compared to K and Ca, could be arranged into 3 groups of species. In the first group, B concentration gradients were the same as Ca, including cashew, mango, custard apple, cassava, Indian walnut, cork wood tree, star fruit, lime, passion fruit and lychee. The second group comprised of species which showed B concentration gradients similar to K, including, tamarind, guava and teak. The third group had B concentration gradients that differed from both K and Ca, including, papaya, jackfruit, coffee and longan. Boron concentrations of papaya, coffee and longan were not significantly different with leaf age. Boron concentrations of jackfruit increased in middle-age leaves and decreased in old leaves relative to young leaves.



Analysis of variance	K	Ca	B
P (Age)	ns	< 0.01	ns
P (Position)	ns	ns	ns
P (Age X Position)	ns	ns	ns

Figure 2.3 Trends in nutrient concentration of mangosteen with leaf age at two positions in the canopy.

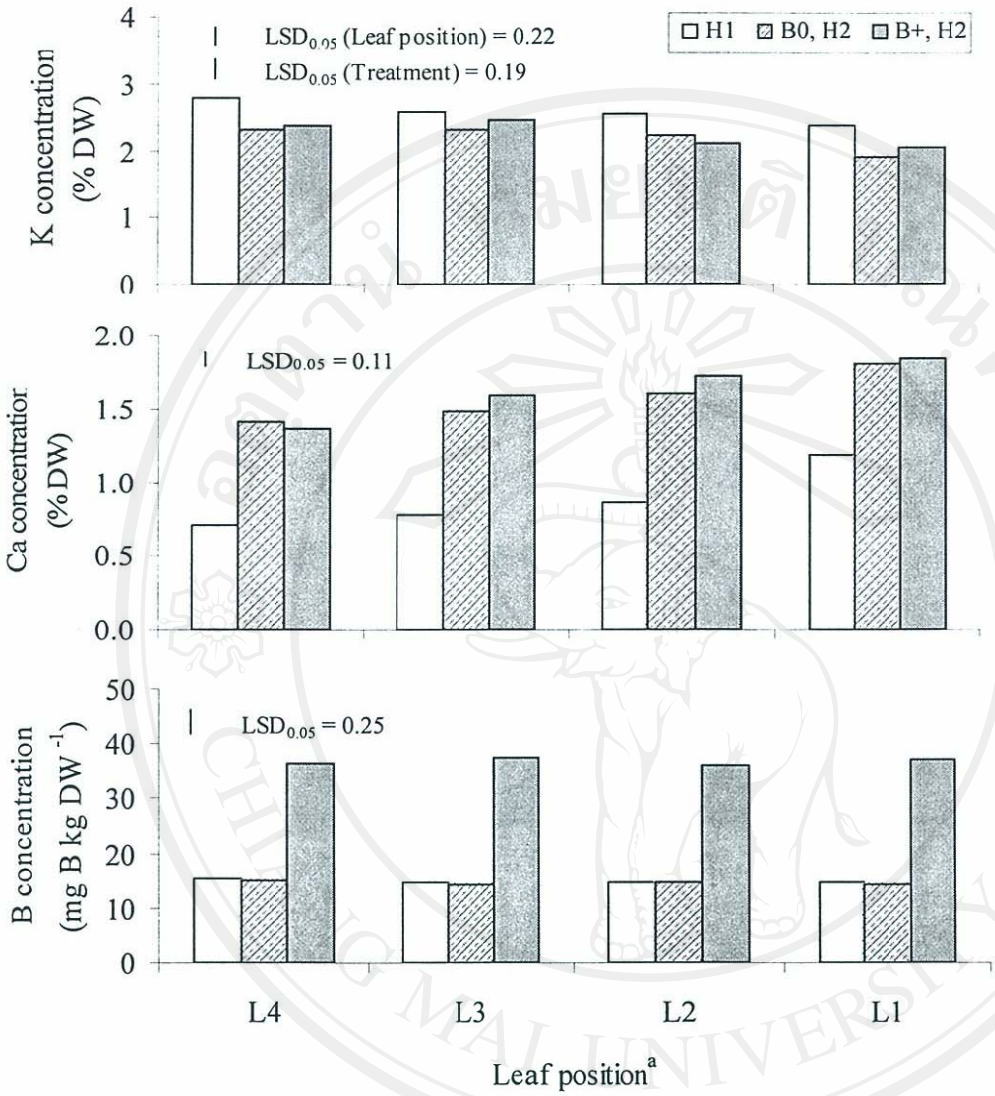


Figure 2.4 Concentration of K, Ca and B in durian leaves.

H1 - before B treatment, H2 - 1 month after B treatment

B0 - nil B treatment, B+ - 18.75 kg borax ha^{-1}

Leaf position[a]: L1, L2 L3 and L4 are the first, second, third and fourth leaves located from the base of branches (See Figure 2.2).

Table 2.2 Potassium (K) concentration (% DW) in young, mature and old leaves of 17 tropical plant species.

	Leaf position[a]			
Species	YFEL	ML	OL	$LSD_{0.05}$
Cashew	0.98 b	0.76 a	0.77 a	0.15
Mango	0.80 b	0.68 ab	0.56 a	0.13
Custard apple	1.42 c	1.16 b	0.90 a	0.22
Papaya	2.81 b	2.08 a	1.88 a	0.65
Cassava	2.10 b	1.29 a	1.33 a	0.13
Indian walnut	1.25 b	1.06 a	1.19 ab	0.18
Cork wood tree	2.77	2.33	2.16	ns
Tamarind	0.88	0.89	0.84	ns
Jackfruit	2.09 b	1.94 b	1.45 a	0.31
Guava	1.39 b	0.75 a	0.67 a	0.21
Star fruit	3.47 b	3.25 b	3.19 a	0.15
Passion fruit	3.89 b	3.77 ab	3.37 a	0.46
Coffee	1.23	1.13	1.19	ns
Lime	1.56	1.42	1.46	ns
Longan	1.46 b	1.29 a	1.32 a	0.13
Lychee	1.59 c	0.79 b	0.64 a	0.13
Teak	2.47 b	1.04 a	0.90 a	0.46

[a] Leaf position: YFEL - the youngest fully expanded leaf, ML - the middle age leaf of branch, OL - the oldest leaf

ns = not significant ($p < 0.05$)

Means within a row with the same letter do not differ significantly at $p<0.05$ with LSD.

Table 2.3 Calcium (Ca) concentration (% DW) in young, mature and old leaves of 17 tropical plant species.

Species	Leaf position[a]			
	YFEL	ML	OL	$LSD_{0.05}$
Cashew	0.16 a	0.37 b	0.44 c	0.03
Mango	1.77 a	2.05 b	2.56 c	0.22
Custard apple	1.24 a	1.73 b	2.39 c	0.21
Papaya	1.40 a	2.52 b	2.88 c	0.23
Cassava	0.53 a	0.99 b	1.81 c	0.11
Indian walnut	0.71 a	1.00 b	1.03 b	0.09
Cork wood tree	1.14 a	2.17 b	2.66 c	0.16
Tamarind	0.80 a	1.22 b	1.63 c	0.09
Jackfruit	1.03 a	1.47 b	2.00 c	0.21
Guava	0.82 a	1.31 b	1.77 c	0.19
Star fruit	0.65 a	1.16 b	1.10 b	0.15
Passion fruit	1.91 a	1.84 a	2.47 b	0.27
Coffee	1.55 a	2.23 b	2.38 b	0.19
Lime	2.20 a	2.25 a	2.83 b	0.21
Longan	0.34 a	0.65 b	0.71 c	0.05
Lychee	0.60 a	2.44 b	2.85 c	0.13
Teak	1.04 a	1.87 b	2.46 c	0.31

[a] Leaf position: YFEL - the youngest fully expanded leaf, ML - the middle age leaf of branch, OL - the oldest leaf

ns = not significant ($p < 0.05$)

Means within a row with the same letter do not differ significantly at $p<0.05$ with LSD.

Table 2.4 Boron (B) concentration (mg B kg DW^{-1}) in young, mature and old leaves of 17 tropical plant species.

Species	Leaf position[a]			
	YFEL	ML	OL	$LSD_{0.05}$
Cashew	7.45 a	8.53 b	9.75 c	0.82
Mango	20.83 a	22.00 ab	23.19 b	1.33
Custard apple	23.47 a	34.61 b	53.17 c	2.31
Papaya	35.42	33.76	34.68	ns
Cassava	20.10 a	24.96 b	32.51 c	0.65
Indian walnut	8.14 a	8.06 a	9.50 b	0.47
Cork wood tree	36.17 a	52.41 b	74.95 c	6.10
Tamarind	22.89 b	22.10 ab	19.96 a	2.57
Jackfruit	20.99 ab	22.38 b	20.00 a	1.47
Guava	21.88 b	21.70 b	17.91 a	1.80
Star fruit	49.52 a	67.49 b	73.16 c	5.49
Passion fruit	24.76 a	25.23 a	29.19 b	1.21
Coffee	34.50	38.79	40.47	ns
Lime	35.83 a	42.68 b	61.00 c	1.42
Longan	16.03	17.12	15.53	ns
Lychee	22.00 a	28.52 b	24.47 b	3.81
Teak	29.00 c	26.36 b	20.84 a	1.78

[a] Leaf position: YFEL - the youngest fully expanded leaf, ML - the middle age leaf of branch, OL - the oldest leaf

ns = not significant ($p < 0.05$)

Means within a row with the same letter do not differ significantly at $p<0.05$ with LSD.

2.4 Discussion

For elements that have high phloem mobility, such as K, their content in the oldest leaves declines as they are remobilized into new growth. Hence, the content of these elements are either higher in younger parts or there may be little change in concentration between older and younger parts (Greenway, 1965 cited by Marschner, 1995; Smith and Loneragan, 1997). On the other hand, increasing concentration with leaf age is in accordance with immobility in the phloem, such as the case of Ca (Kirkby, 1979 cited by Marschner, 1995) found in litchi (Menzel *et al.*, 1987), coconut (Broschat, 1997) and olive (Fernández-Escobar *et al.*, 1999). The behaviors of K and Ca found in this study are in agreement with these earlier reports. The K concentration did not vary with leaf age in mangosteen, cork wood tree, tamarind, coffee and lime while it decreased in older leaves in durian, cashew, mango, custard apple, papaya, cassava, Indian walnut, jackfruit, guava, star fruit, passion fruit, longan, lychee and teak. As expected, the Ca concentration of all species was increased with leaf age.

The B concentration gradient between leaves of different ages in mangosteen contrasted with K and Ca, indicating a possibility that B may be retranslocated in this plant. Comparison of B concentration gradients along the branches of durian of both B treatments also indicated the possibility of some phloem mobility in durian. If B was only transported in the transpiration stream of the xylem, it should accumulate to a higher concentration in older tissues where leaves maintain their transpiration as they age (Oertli, 1994). In the survey of tropical woody and fruit species, the concentration gradients of B in cashew, mango, custard apple, cassava, Indian walnut, cork wood tree, star fruit, lime, passion fruit and lychee were similar to those of Ca

whereas in tamarind, guava and teak B concentration gradients were more closely resemble those of K. The evidence for B mobility in papaya, jackfruit, coffee and longan was inconclusive in this study. Boron concentrations of papaya, coffee and longan were not significaly different with leaf age, while B concentrations of jackfruit increased in the middle leaf age and then decreased in the old leaf. The exact age of each leaf position of samples collected for this study could not be determined. The B concentration gradients observed in these species may probably be caused by seasonal effects (Fernández-Escobar *et al.*, 1999), especially due to the change of photoperiod and temperature (Mozafar *et al.*, 1993).

In conclusion, the foliar nutrient gradients in 3 field survey studies suggested that B is phloem immobile in cashew, mango, custard apple, cassava, Indian walnut, cork wood tree, star fruit, passion fruit, lime and lychee whereas it may be phloem mobile in mangosteen, durian, tamarind, guava and teak. The data are inconclusive for papaya, jackfruit, coffee and longan.

The information on foliar nutrient concentration gradients between old and young leaves obtained in this study provides only a rough indication of species with potential for B retranslocation. This is because the external B supply may have changed across seasons as leaves were produced. More definitive work needs to be undertaken to confirm phloem mobility and elucidate what is occurring in the inconclusive group (Chapter 3).