# Chapter 4

# Boron mobility in peanut (Arachis hypogaea L.)

#### 4.1 Introduction

Peanut (*Arachis hypogaea* L.) is a crop that is most sensitive to B deficiency and most responsive to B application (Shorrocks, 1997). Boron deficiency in peanut is widespread in Thailand (Rerkasem, 1988; Bell *et al.*, 1990). Symptoms of B deficiency commonly occur in organs with limited to no transpiration, such as hollow heart in the buried seed of peanut (Bell *et al.*, 1990) and male sterility in developing ears that are enclosed in the leaf sheath of wheat and barley (Nachiangmai et al, 2004; Wongmo *et al.*, 2004; Rerkasem and Jamjod, 2001). The location of these defects is typical of phloem immobility (Marschner, 1995). However, it has been suggested that B could be transported via the phloem into fruits of peanut developing in a B-free medium (Campbell *et al.*, 1975) but this is controversial. Previously (Chapter 3), it was suggested that B may be partly phloem mobile in peanut based on B content data in the new growth of plants transferred from B-adequate (supplied by nutrient solution with 10  $\mu$ M B) to B-deficient (supplied by nutrient solution without B) media. However, more detailed investigation on B distribution and redistribution is required to substantiate this hypothesis.

Therefore, this study aimed to determine if B is retranslocated from the old leaves of peanut under conditions of low external B supply and the effects of any B

mobility on vegetative growth and reproductive development. Three experiments were undertaken. The first examined B distribution and redistribution in peanut by withdrawing B supply. The second was a tracer experiment to confirm B remobilization. The third looked at variation of B mobility between two peanut cultivars.

#### 4.2 Materials and methods

#### 4.2.1 Experiment 1: Boron distribution and redistribution in peanut

This study was conducted to determine if B is retranslocated from the old leaves of peanut under B deficiency and B withdrawal. The experiment was set up as a split plot in randomized complete block design (RCB). The main plot consisted of 4 B treatments, including 10 µM B throughout experiment, 0 µM B throughout experiment, B withdrawal at flowering and B withdrawal at pod set. The sub plot was 4 harvests, including at flowering (R<sub>1</sub>: 25 days after germination), pod set (R<sub>3</sub>: 58 days after germination), grain filling (R<sub>5</sub>-R<sub>6</sub>: 75 days after germination) and grain maturity (R<sub>8</sub>: 103 days after germination).

Peanut (*Arachis hypogaea* L. cv. Tainan 9) was germinated in sand culture to which a commercial rhizobium inoculum had been applied. Nutrient solution (modified from Broughton and Dilworth (1971) as described in chapter 3) with boron 10 μM B (BA: adequate) or without boron (BD: deficient) was applied to each pot after germination. Boron was withdrawn from nutrient solution at the flowering stage (<sub>F</sub>) and pod set (<sub>P</sub>). The treatments for this experiment were the following: BA/BD<sub>F</sub>, BA/BD<sub>P</sub>, BA/BA and BD/BD. Plants were harvested at flowering (H1), pod set (H2), grain filling (H3) and grain maturity (H4). The number of nodes and flowers were

counted in harvest 1. The number of pegs, pods and seed (normal/hollow heart) were quantified in harvest 2, 3 and 4. The B concentration was analysed separately in each plant part by using the azomethine-H method (Loshe, 1982), including leaflets, petioles and stem, flowers, pegs, pods, lateral branches and roots.

# 4.2.2 Experiment 2: Confirming B remobilization using tracer B (10B)

This experiment consisted of two sub experiments, one with <sup>10</sup>B-foliar applied and one with <sup>10</sup>B applied to the roots.

# 4.2.2.1 Experiment 2.1: $^{10}B$ – foliar application

Four peanut (*Arachis hypogaea* L. cv. Tainan 9) seeds were grown in baked clay pots with directly added rhizobium. They were thinned to 2 plants after 7 days. Nutrient solution (modified from Broughton and Dilworth (1971) as described in chapter 3) with 10 μM boron (BA: B-adequate) or without boron (BD: B-deficient) was applied to each pot after germination until the stage of V<sub>6</sub> (the 6<sup>th</sup> trifoliate leaf is fully expanded). The application of <sup>10</sup>B was treated by immersing leaf 1 – leaf 4 (from the base) for 20 seconds in 20 mM boric acid containing 95% enriched <sup>10</sup>B (National Institute of Standards and Technology, Department of Commerce, USA) (Figure 4.1). The treatments were as follows: BA + F <sup>10</sup>B, BD + NF <sup>10</sup>B, BA + F <sup>10</sup>B, BD + NF <sup>10</sup>B. Plants were harvested before <sup>10</sup>B application, 1 day after <sup>10</sup>B application and at V<sub>10</sub> (the 10<sup>th</sup> trifoliate leaf is fully expanded: flowering: 13 days after <sup>10</sup>B treatment). Harvested plants were removed roots and separated into main stems and lateral branches. The main stems were partitioned into the following parts: leaflets + petioles of leaf 1 – leaf 4 [L1–L4 (LL+pt)], stem below leaf 1 - leaf 4 [L1–L4 (LL+pt)]

L4 (st)], leaflets + petioles of leaf 5 - leaf 7 [L5-L7 (LL+pt)], and stem below leaf 5 - leaf 7 [L5-L7 (st)]. Additionally, there were leaflets + petioles of leaf 8 - leaf 11 [L8-L11 (LL+pt)], stem below leaf 8 - leaf 11 [L8-L11 (st)] and flowers for harvest 3.

a)

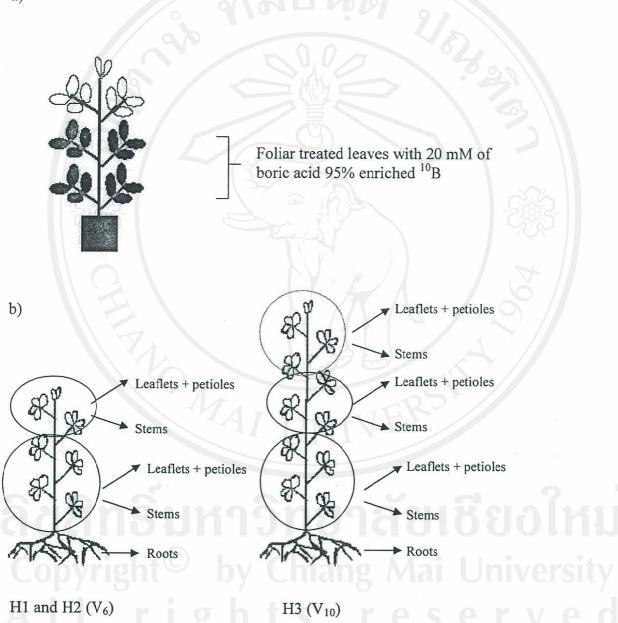


Figure 4.1 Diagram of peanut plants.

- a) foliar treated position
- b) sampling positions

### 4.2.2.2 Experiment 2.2: <sup>10</sup>B applied to the roots

This experiment was conducted in solution culture with the basal nutrients as in Experiment 2.1. Stock solution of each element were prepared with B-free water (Triple Deionized Water). The B-free water was also used for the preparation of Peanut seeds (cv. TAG 24\*) were germinated in paper towels solution culture. moistened with B-free water. The 1- week old seedlings were transplanted to basal solution culture without B for 2 weeks. The seedlings were then transferred to basal solution culture containing <sup>10</sup>B (prepared from boric acid 99.52 At% enriched <sup>10</sup>B, Eagle Ep Picher, Boron Department) at either 10 μM (<sup>10</sup>BA: <sup>10</sup>B-adequate) or 0.1 μM (10BD: 10B-deficient) until V<sub>5</sub> (the 5<sup>th</sup> trifoliate leaf is fully expanded; harvest 1; 10 days after starting the treatment). After harvest 1, the remaining plants were transferred into solution culture with <sup>11</sup>B (prepared by boric acid 99.27 At% enriched <sup>11</sup>B, Eagle Ep Picher, Boron Department). Half of the plants in the <sup>10</sup>BA treatment were transferred to 0.1  $\mu M$   $^{11}B$  ( $^{10}BA \rightarrow ^{11}BD$ ). The remainder of the  $^{10}BA$  and all the  $^{10}BD1$  plants were supplied with the same B concentration ( $^{10}BA \rightarrow {}^{11}BA$  and  $^{10}\mathrm{BD} \to ^{11}\mathrm{BD}$ ) as prior to transfer. Plants were harvested at 10 days after treatment (H1; V<sub>5</sub>), 20 days after treatment [H2; flowering (R<sub>1</sub>)] and 51 days after treatment [H3; pod filling ( $R_5$ )]. Plant parts were subdivided into leaflets of leaf 1 – leaf 6 [ $L_1$ -L<sub>6</sub> (LL)], petioles and stem below leaf 1 – leaf 6 [L<sub>1</sub>-L<sub>6</sub> (pt + st)], lateral branches and roots. Other parts harvested were leaflets of leaf 7 - leaf 11 [L<sub>7</sub>-L<sub>11</sub> (LL)], petioles and stem below leaf 7 - leaf 11 [ $L_7$ - $L_{11}$  (pt + st)] and flowers for harvest 2; and

This experiment was conducted in Australia; the cultivar used in the earlier experiments could not be used. A comparison of the 2 cultivars is given in Experiment 3 of this Chapter.

leaflets of leaf 12 –leaf 18 [ $L_{12}$  –  $L_{18}$  (LL)], petioles and stem below leaf 12 – leaf 18 [ $L_{12}$  –  $L_{18}$  (pt + st)], pegs, pods and seeds for harvest 3.

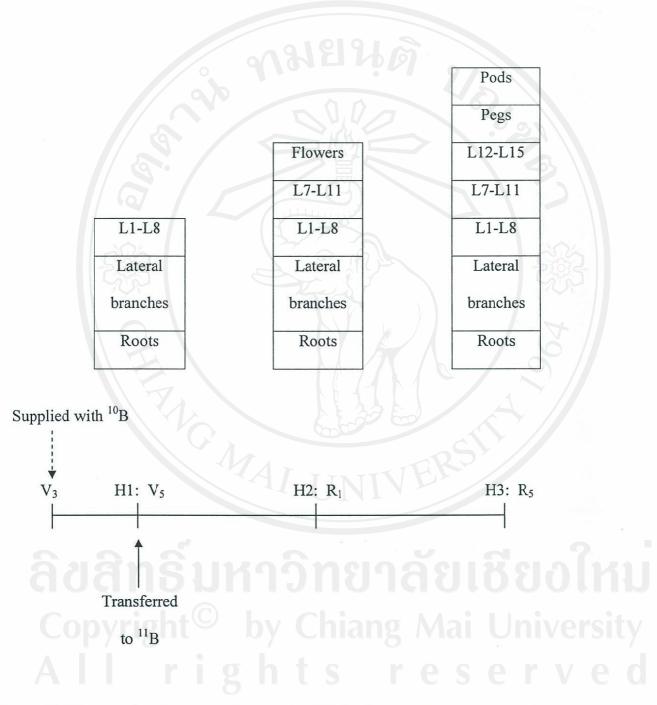


Figure 4.2 Diagram showing parts of peanut (cv. TAG 24) sampled at three harvests.

#### **B-isotope** analysis

Samples were digested by rapid nitric acid digestion (Huang *et al.*, 2004) in a microwave oven (CEM Mars5, CEM Corp., USA) after being oven-dried at 70 °C for 48 hours and ground to pass a 1-mm mesh. All digested samples were spiked with 1000 ppb Beryllium (Be) as the internal standard and the <sup>10</sup>B: <sup>11</sup>B isotope ratio was determined with an inductively coupled plasma-mass spectrometer (ICP-MS, Elan 6000, Perkin-Elmer Sciex).

### 4.2.3 Experiment 3: Boron mobility in two cultivars of peanut

The two peanut cultivars (*Arachis hypogaea* L. cv. Tainan 9 and TAG 24) were grown in sand culture with directly added rhizobium (4 seeds per pot and thinned to 2 plants after 7 days). All pots were supplied with nutrient solution (modified from Broughton and Dilworth, 1971) without boron (BD, deficient) after germination until R<sub>3</sub> (peg setting) when half the plants were given foliar B (F). The foliar B was applied by painting 20 mM B as boric acid (H<sub>3</sub>BO<sub>3</sub>) solution onto mature leaves everyday for 7 days. So, the treatments were as follows: BD + F and BD + NF. Plants were harvested at the end of foliar B application and at grain maturity (R<sub>7-8</sub>). The plants were separated into the main stem, lateral branches, reproductive parts and roots for determination of B contents as described in Experiment 1 (this Chapter).

Table 4.1 Summary of experiments for detailed study for B mobility in peanut.

Peanut	Medium	Treatment	Harvest
cultivar			
Experiment	1: Boron distribution	on and redistribution in	peanut
Tainan 9	Sand culture	1. BA/BA	1. Flowering
		2. BA/BD <sub>P</sub>	2. Pod set
		3. BA/BD <sub>F</sub>	3. Grain filling
		4. BD/BD	4. Grain maturity
Experiment	2: Confirm B remol	oilization using tracer E	B (10B)
Experiment .	2.1: <sup>10</sup> B – foliar applic	cation	
Tainan 9	Sand culture	1. BA + F <sup>10</sup> B	1. Before <sup>10</sup> B application
		2. BA + NF <sup>10</sup> B	2. 1 day after <sup>16</sup> B application
		3. BD + F <sup>10</sup> B	3. V <sub>10</sub> (13 days after <sup>10</sup> B application)
		4. BD + NF <sup>10</sup> B	
Experiment .	2.2 : <sup>10</sup> B applied to the	roots	
TAG 24	Solution culture	$1.^{10}BA \rightarrow {}^{11}BA$	1. V <sub>5</sub> (35 days after germination)
		$2. {}^{10}\mathrm{BA} \rightarrow {}^{11}\mathrm{BD}$	2. R <sub>1</sub> (45 days after germination)
		$3. ^{10}BD \rightarrow ^{11}BD$	3. R <sub>5</sub> (77 days after germination)
Experiment	3: Boron mobility in	n two cultivars of peanu	tela aeli Rela l
Tainan 9	Sand culture	1. BD + F	1. Before foliar B application
TAG 24		2. BD + NF	(R <sub>3</sub> : Peg setting)
			2. End of foliar B application

#### 4.3. Results

#### 4.3.1 Experiment 1: Boron distribution and redistribution in peanut

The effect of withdrawing B on dry weight of peanut is shown in Figure 4.3. Plant top dry weight was not affected by the withdrawal of B at harvest 1 (flowering: 25 days after germination), harvest 2 (pod set stage: 58 days after germination) and harvest 3 (grain filling: 75 days after germination). However, at harvest 4 (grain maturity: 103 days after germination), total top dry weight of BA/BA and BA/BD<sub>P</sub> plants were significantly higher than BA/BD<sub>F</sub> and BD/BD plants. Boron deficiency (BD/BD) increased root dry weight from harvest 2. Withdrawal of B at flowering (BA/BD<sub>F</sub>) also increased root dry weight at harvest 3 and harvest 4 while BA/BD<sub>P</sub> did not influence root dry weight. Boron deficient plants (BD/BD) produced more lateral branches in both BA/BA and BA/BD plants late in the experimental period (Table 4.2). Examination of the dry weights of parts of the stem (Figure 4.4) revealed that a long period of adequate B supply reduced the dry weights of relative to plants with more deficient B supply (BA/BA < BA/BD<sub>P</sub> < BA/BD<sub>F</sub> < BD/BD) at all harvests, except leaflets of L9-L16 at harvest 4 which were not significant different between B treatments. Dry weights of most organs either increased with age or did not change. By contrast, the dry weight of leaflets and petioles (L1-L8 and L9-L16) declined at

In the earlier stages of growth before flowering, peanut plants grew normally in all treatments. The symptoms of B deficiency did not appear until plants were in the reproductive stage. Boron deficiency symptoms were found in BD/BD plants at day 42 (peg setting). The youngest mature leaves of these plants (YFEL and YFEL+1) showed water-soaked symptoms where the B concentration was lower than

9 mg B kg  $DW^{-1}$ . The  $BA/BD_F$  peanut also showed this B deficiency symptom after withdrawal of B for 26 days but the symptom occurred only in the YFEL (Figure 4.6).

At pod set (H2), the peanut plants grown with nil B in the nutrient solution produced fewer pegs and did not have extended peg. The number of pegs in BA/BD<sub>F</sub> (B withheld at flowering) plants was not different from BA/BA plants. Although BA/BD<sub>F</sub> plants developed fewer immature pods than B-adequate plants (BA/BA), it had more of them than in BD/BD plants. At harvest 3 (grain filling: 58 days after germination), BA/BDP and BA/BA plants had fewer expanded pegs than BA/BDF and BD/BD plants, both of which developed more immature pods (Tables 4.3, 4.5). Table 4.4 shows the number of pods, seeds and %hollow heart seed at harvest 4 (grain maturity; 103 days after germination). The highest number of mature pods was obtained in BA/BD<sub>P</sub> plants, and there were 30% fewer mature pods in BA/BA plants. Withdrawal of B at flowering depressed the number of mature pods by 55%. The number of mature pods in BD/BD was about one fifth of that in BA/BA plants. The number of seed was not affected by withdrawal of B at pod set (BA/BD<sub>P</sub>); while it was reduced by 37.5% in BA/BDF plants; and the lowest number of seed was found in BD/BD plants which were not supplied with B throughout experiment. The BA/BA plants produced seed that was almost normal. Withdrawal of B at pod set caused the symptom of internal cavity typical of B deficiency known as hollow heart (Harris and Brolman, 1966) in 10% of the seed, while earlier B withdrawal at flowering caused 53% hollow heart. Plants kept B deficient throughout the experiment (BD/BD) produced seed that showed 85% hollow heart symptom in their seed (Figure 4.7).

The B supply affected the B concentration in plant parts. At H1, B concentrations in various parts of BD plants were similar; in BA plants the B

concentration in petioles and stem were only slightly higher than those in BD plants, while those in the leaflets were more than twice as high. In all treatments, B concentration in each plant part declined over time. The decline was most pronounced in the leaflets, especially after B withdrawal. Moreover, B was found in new parts of plants that had developed since B was withdrawn. By H4, the B concentrations were generally much higher in BA/BD<sub>P</sub> than in BD/BD plants, including in the non-transpiring pods and seed. In only a few organs, leaflets and petioles of leaves 1-9 and the stem sections corresponding to leaves 22-26, did the concentrations in BA/BD<sub>F</sub> plants exceeded those in BD/BD plants. Boron concentrations of BA/BA plants at harvest 3 were the same as at harvest 2. However, the B concentration in the new parts (L17-L21) of BA/BD<sub>P</sub> plants decreased by about half from harvest 2 to 3. Notably, the B concentration in L7-L21 of BA/BD<sub>F</sub> and upper L9 of BD/BD was less than 10 mg kg DW<sup>-1</sup> (Table 4.6). When plants grew until grain maturity (H4), the B concentration in seed of BD/BD and BA/BDF plants which had high incidence of hollow heart was 3.8 and 4.6 mg kg DW<sup>-1</sup>, respectively. Though seed of BA/BD<sub>P</sub> plants had a lower B concentration than in BA/BA plants, they were three times higher than in BA/BD<sub>F</sub> plants (Table 4.6).

At H1 the largest proportion of plant B content occurred in the leaflets of plants in all B treatments (Table 4.7). The amount of B in leaflets, stem and flowers of B-deficient plants was about half of that in B-adequate plants, while they were similar in the other parts. The B content in all parts of B-adequate plants (BA/BA) remained high during the experimental period compared with the other treatments. Although the B content declined over time in plants where B was withdrawn

(BA/BD<sub>F</sub> and BA/BD<sub>P</sub>), some parts of these plants had significant higher B than in B-deficient plants (BD/BD).

The B content in new organs (leaves 9-16 and their petioles and associated stems) in BA/BD<sub>F</sub> plants at harvest 2 was about half of BA/BA plants while it was higher than in BD/BD plants. Withdrawing B at pod set (BA/BD<sub>P</sub>) affected the B content in leaflets, petioles and stems of L17-L21 at harvest 3 and L22-L26 at harvest 4, and this was similar to BA/BD<sub>F</sub> and BD/BD plants. By harvest 4, the B content in L22-L26 leaflets of  $BA/BD_F$  and  $BA/BD_P$  plants was similar to BD/BD plants but it was half of BA/BA plants. The B content in older leaflets of withdrawal plants had B almost half of before B withdrawn, e.g. leaves 1-8 at harvest 2 and leaves 9-16 at harvest 3 while it was not changed in BA/BA plants. In the oldest leaflets and petioles (L1-L8), the B content in BA/BD<sub>F</sub> plants was reduced by harvest 2 to harvest 4 and in the same organs in BA/BDP plants it was reduced by harvest 3 to harvest 4. There was no change in the B content in L1-L8 leaflets of BA/BA and BD/BD plants from harvest 1 to harvest 2 or from harvest 2 to harvest 3. By contrast, the B content of the petioles and stems of these plants declined over time. Lateral branch was the greatest B accumulation among plant parts of all treatments at harvest 2 and later. The B content of lateral branches increased steadily with plant age but the BA/BA plants had higher B contents than in the other treatments at all harvests. The lowest B content was in branches of BD/BD plants followed by BA/BD<sub>P</sub> and BA/BD<sub>F</sub> plants. The B content in roots increased with plant age and did not differ between treatments for the first 3 harvest. However, by harvest 4, the BA/BA plants had about 1.5 times more B in the roots than in other treatments. The B content in the extended peg of BD/BD plants at harvest 3 was the lowest of all treatments. Pegs of BA/BA plants

had nearly twice the B of pegs in BA/BD<sub>F</sub> and BA/BD<sub>P</sub> plants. The immature pods of BA/BD<sub>P</sub> plants had about 5 times more B than in BA/BD<sub>F</sub> plants but only half of BA/BA plants. By harvest 4, the immature pods of BA/BD<sub>P</sub> plants had lower B contents than in BA/BD<sub>F</sub> about 1.8 times while had more B about 3 times in the shell and hypanthium, but this was about 1.3 times less than in BA/BA plants. Less B was transported into the seed of BA/BD<sub>P</sub> plants than in BA/BA plants. Relative to the B accumulated by seed of BA/BA plants, that in the seed of the other treatment were BA/BD<sub>P</sub> (65%), BA/BD<sub>F</sub> (4%) and BD/BD (0.7%).



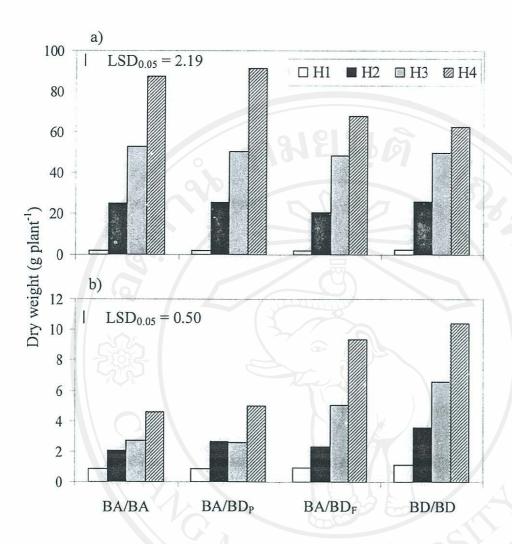
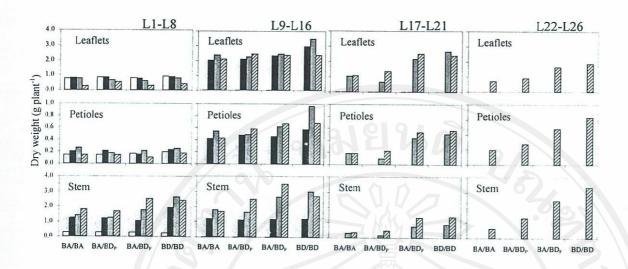
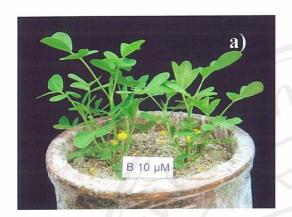


Figure 4.3 The effect of B withdrawal on dry weight (g plant<sup>-1</sup>) of peanut. a) total top dry weight (all parts above ground), and b) root dry weight. Bars are means of 4 replications.



Analysis of v	variance	Treatment	Harvest	TXH
L1-L8	Leaflets	< 0.05 (0.09)	< 0.01 (0.09)	ns
	Petioles	< 0.01 (0.02)	< 0.01 (0.03)	ns
	Stem	< 0.01	< 0.01	< 0.01 (0.33)
L9-L16	Leaflets	< 0.01	< 0.05	< 0.01 (0.44)
	Petioles	< 0.01 (0.10)	< 0.01 (0.10)	ns
	Stem	< 0.01	< 0.01	< 0.01 (0.44)
L17-L21	Leaflets	< 0.01	< 0.05	< 0.01 (0.34)
	Petioles	< 0.01 (0.05)	< 0.01 (0.03)	ns
	Stem	< 0.01	< 0.01	< 0.01 (0.10)
L22-L26	Leaflets	< 0.01 (0.19)	000	
	Petioles	< 0.01 (0.03)		
	Stem	< 0.01 (0.06)		

Figure 4.4 The effect of B withdrawal on dry weight (g plant<sup>-1</sup>) of various parts of peanut (cv. Tainan 9) main stem. Bars are means of 4 replications. ☐ H1 (flowering), ☐ H2 (pod set stage), ☐ H3 (grain filling), ☐ H4 (grain maturity). Probabilities from analysis of variance on dry weight of various parts of peanut cv. Tainan 9 are given below the figure. The values in parentheses are LSD at P < 0.05.



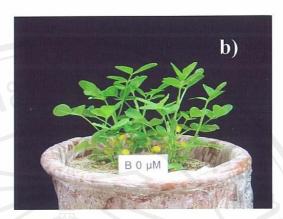


Figure 4.5 Normal peanut plants (cv. Tainan 9) at harvest 1 (day 25).

- a) BA (supplied with 10  $\mu M$  B, B-adequate)
- b) BD (supplied with 0 µM B, B-deficient)





Figure 4.6 Boron deficiency symptom (water soaked young leaves) in peanut cv.

#### Tainan 9.

- a) BD/BD (supplied with 0  $\mu M$  B throughout) at day 43
- b) BA/BD<sub>F</sub> (withdrawal B from nutrient solution at flowering) at day 52

Table 4.2 The effect of B withdrawal on the number of lateral branches of peanut.

Treatment		ŀ	Harvest		
	H1	H2	НЗ	H4	mean
BA/BA	3.8	4.3	4.3	4.5	4.2 a
BA/BD <sub>P</sub>	3.5	4.3	4.5	4.5	4.2 a
BA/BD <sub>F</sub>	4.0	4.3	4.5	4.5	4.3 a
BD/BD	4.8	5.0	5.3	5.5	5.1 b
mean	4.0 A	4.4 AB	4.6 B	4.8 B	
Analysis of	variance		7		
P (Treati	ment)		< 0.01		
P (Harve	est)		< 0.05		
P (Treati	ment x Harv	est)	ns		
<sup>1</sup> LSD <sub>0.05</sub> (Tr	eatment) = 0	0.3, LSD <sub>0.05</sub> (Hai	rvest) = 0.5		

<sup>&</sup>lt;sup>1</sup>Different letters indicate significant difference at P < 0.05

**Table 4.3** The effect of B withdrawal on the number of pegs and pods of peanut at harvest 2 and harvest 3.

Treatment	I	H2	I	I3
-	Peg	Extended	Extended	Immature
		peg	peg	pod
BA/BA	6.3 a	9.4 c	25.8 b	22.5 c
BA/BD <sub>P</sub>	7.0 a	10.5 c	19.7 a	23.7 с
BA/BD <sub>F</sub>	7.8 a	7.4 b	41.3 c	8.5 b
BD/BD	26.3 b	0 a	55.0 d	0 a
Analysis of variance	3	4	F 165 7	
P (Treatment)	< 0.01	< 0.01	< 0.01	< 0.01
<sup>1</sup> LSD <sub>0.05</sub>	1.6	1.1	4.7	2.1

<sup>&</sup>lt;sup>1</sup>Different letters in each column indicate significant difference at P < 0.05

**Table 4.4** The effect of B withdrawal on the number of pods and % hollow heart in seed of peanut at harvest 4.

Treatment	Immature	Mature	Number of	1% Hollow
	pods/plant	pods/plant	seeds/plant	heart seed
BA/BA	13.8 a	20.3 с	37.7 с	0.5 a
BA/BD <sub>P</sub>	20.8 b	29.0 d	39.6 c	10.3 b
BA/BD <sub>F</sub>	68.3 d	9.0 b	15.0 b	53.4 c
BD/BD	55.8 c	4.3 a	4.3 a	85.4 d
	800	3		
Treatment	< 0.01	< 0.01	< 0.01	< 0.01
<sup>2</sup> LSD <sub>0.05</sub>	5.1	4.0	7.5	0.04

<sup>&</sup>lt;sup>1</sup>arcsin transformation before analysis of variance

 $<sup>^{2}</sup>$ Different letters indicate significant difference at P < 0.05

**Table 4.5** The effect of B withdrawal on dry weight (g plant<sup>-1</sup>) of reproductive parts of peanut.

T	]	H2	F	I3		H4	
Treatment	Peg	Extended	Extended	Immature	Immature	Shell	Seed
		peg	peg	pod	pod		
BA/BA	0.33 ab	5.15 c	1.10 a	19.96 d	1.17 a	32.39 c	23.54 c
BA/BD <sub>P</sub>	0.26 a	4.73 c	0.81 a	16.98 с	1.54 a	30.24 c	24.74 c
BA/BD <sub>F</sub>	0.39 b	2.47 b	2.53 b	6.47 b	5.12 c	6.38 b	4.08 b
BD/BD	1.82 c	0 a	2.33 b	0 a	3.14 b	1.76 a	0.96 a
Analysis of varia	ance	2		S 10			5101
P (Treatment)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
$^{1}LSD_{0.05}$	0.12	0.48	0.3	2.34	0.40	2.88	2.69

<sup>&</sup>lt;sup>1</sup>Different letters in each column indicate significant difference at P < 0.05



**Figure 4.7** The effect of B withdrawal on reproductive parts of peanut cv. Tainan 9 at harvest 4 (day 103).

- a) BA/BA (supplied with 10 µM B throughout)
- b) BA/B<sub>P</sub> (B withdrawal at pod set)
- c) BA/BD<sub>F</sub> (B withdrawal at flowering)
- d) BD/BD (supplied with 0µM B throughout)

Table 4.6 Boron concentration (mg B kg DW<sup>-1</sup>) in various parts of peanut. Data are means of 4 replications (SE).

Plant part			H1			I	H2	
	BA/BA	BA/BD <sub>P</sub>	BA/BD <sub>F</sub>	BD/BD	BA/BA	BA/BD <sub>P</sub>	BA/BD <sub>F</sub>	BD/BD
L22-L26 LL	yı V							77
pt pt								
L17-L21 LL	h	900						
pt st								
L9-L16 LL	9		1		49.0 (0.9)	44.8 (3.4)	15.4 (0.8)	9.7 (1.0)
td					25.9 (0.4)	27.2 (0.2)	14.0 (1.0)	8.5 (0.5)
st			A		22.3 (0.3)	23.6 (0.2)	10.4 (0.5)	9.1 (0.8)
L1-L8 LL	51.3 (1.3)	58.0 (1.7)	55.0 (1.5)	23.0 (1.0)	54.9 (2.2)	46.4 (3.6)	32.5 (0.6)	21.5 (2.3)
pt	30.2 (0.2)	26.4 (0.2)	28.9 (0.4)	20.3 (0.4)	26.2 (0.1)	26.5 (0)	22.2 (0.1)	19.0 (0.4)
st	28.9 (0.1)	29.8 (0.1)	27.4 (0.2)	20.1 (0.3)	19.7 (0.8)	21.0 (0.4)	14.7 (0.6)	11.2 (0.4)
Lateral branches	37.2 (0.8)	37.9 (0.9)	36.0 (0.8)	18.7 (1.6)	33.1 (0.5)	32.0 (1.4)	12.99 (0.3)	8.5 (0.2)
Flowers	46.2 (0)	43.6(0)	44.5 (2.4)	22.4 (0)				
Peg	n				29.6 (0.4)	28.8 (0.7)	7.4 (0.5)	6.1(0.5)
Extended peg					20.3 (0.4)	21.7 (0.2)	6.9 (0.2)	
Roots	28.2 (1.4)	26.3 (0.4)	26.5 (0.4)	18.0 (0.7)	24.1 (0.7)	24.0 (0.5)	17.3 (0.7)	13.9 (0.8)

Treatment: BA/BA - supplied with 10 µM B (B-adequate) throughout; BA/BD<sub>P</sub> - B withdrawal at pod set; BA/BD<sub>F</sub> - B withdrawal at Plant part: Leaf positions were numbered from the base of main stem. LL – leaflets of each leaf position; pt – petioles of each leaf position; st - stems below each leaf position

Harvest: H1 – flowering (25 days after germination); H2 – pod set (58 days after germination); H3 – grain filling (75 days after germination); H4 - grain maturity (103 days after germination)

flowering; BD/BD - supplied with 0 µM B (B-deficient) throughout

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		The second secon					The second secon	
Plant part			H3				H4	
	BA/BA	$BA/BD_P$	$\mathrm{BA/BD_F}$	BD/BD	BA/BA	$BA/BD_P$	BA/BD <sub>F</sub>	BD/BD
L22-L26 LL	T				46.7 (0.5)	17.6 (2.2)	8.9 (0.4)	10.6 (0.3)
d	) I				34.7 (0.1)	21.2 (0.1)	5.1(0)	5.8 (0)
st	1	ľ			35.4 (0.1)	16.6 (1.5)	8.2 (0.3)	5.5(0)
L17-L21 L	L 42.5 (1.5)	24.3 (1.2)	8.6 (0.4)	5.7 (0.4)	51.6 (2.4)	19.3 (0.1)	10.0 (0.4)	13.6 (0.4)
ď	t 27.7 (0)	16.7(0)	7.9 (0.1)	6.3 (0.3)	22.2 (0.1)	14.6 (0.1)	5.4 (0.1)	6.2(0)
st	30.3 (0.2)	20.8 (0)	6.9 (0.1)	7.2 (0.5)	22.1 (0.1)	17.3 (0.3)	5.5 (0.1)	6.1(0.1)
L9-L16 LI	(L 40.8 (0.5)	30.8 (1.2)	14.1 (1.2)	8.2 (0.7)	43.7 (2.3)	25.6 (0.6)	13.7 (0.6)	13.7 (0.6)
ď	t 24.3 (0)	20.9 (0.1)	9.1 (0.2)	6.4 (0.3)	21.4 (0.1)	18.6(0)	8.7 (0.2)	7.0 (0.1)
st	t 28.8 (0.7)	17.0 (0.3)	10.6 (0.9)	7.2 (0.1)	16.4(0.8)	18.8 (0.5)	6.1(0.1)	5.8 (0.1)
L1-L8 L	LL 55.1 (0.7)	39.6 (0.2)	28.1 (0.6)	18.4(0.7)	39.6 (0.9)	32.1 (0.4)	25.3 (0.6)	16.3 (0.1)
ď	t 25.1 (0.7)	23.6 (0.1)	20 (0.1)	13.5 (0.2)	23.9 (0.1)	21.5 (0.1)	19.9(0.1)	12.8 (0)
st	19.7 (0.7)	18.7 (0.1)	10.9 (0.6)	8.7 (0.4)	14.7 (0.6)	13.0 (0.1)	9.7 (0.1)	8.9 (0.2)
Lateral branches	es 26.6 (1.3)	20.4 (0.1)	11.1 (0.5)	8.9 (0.1)	28.3 (1.7)	15.5 (0.4)	7.4 (0.2)	7.0 (0.3)
Extended peg	30.4 (0.6)	23.2 (1.1)	5.5 (0.1)	4.7 (0.3)				
Immature pod	20.0 (0.7)	16.6 (0.4)	5.2 (0.1)		26.1 (1.2)	12.7 (1.3)	6.5 (0.4)	5.6 (0.4)
Mature pod					14.0 (0.2)	9.5 (1.0)	6.9 (0.2)	6.8(0.4)
Seed					21.6 (0.8)	13.2 (0.8)	4.6 (0.2)	3.8 (0.3)
Roots	28.5 (1.7)	20.1 (0.9)	14.9 (1.4)	11.1 (0.6)	25.3 (0.9)	16.7 (0.6)	9.6 (1.1)	9.9 (0.7)

Plant part: Leaf positions were numbered from the base of main stem. LL – leaflets of each leaf position; pt – petioles of each leaf position; st - stems below each leaf position

<u>Treatment</u>: BA/BA - supplied with 10  $\mu M$  B (B-adequate) throughout; BA/BD<sub>P</sub> - B withdrawal at pod set; BA/BD<sub>F</sub> - B withdrawal at flowering; BD/BD - supplied with 0 µM B (B-deficient) throughout

Harvest: H1 - flowering (25 days after germination); H2 - pod set (58 days after germination); H3 - grain filling (75 days after

germination); H4 - grain maturity (103 days after germination)

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Plant part			H1			1	H2	
	BA/BA	$BA/BD_{P}$	BA/BDF	BD/BD	BA/BA	RA/RD.	BA/BD	ממ/ממ
L22-L26 LL	0	5	•			дана	DANDUF	BU/BD
pt								
st								
L17-L21 LL	r	1				200		
pt								
st	h							
L9-L16 LL	t				98.9 (4.0)	92.7 (5.5)	38.8 (1.5)	28 4 (2 2)
pt					10.7 (0.4)	12.9 (0.3)	63(03)	4 9 (0 3)
st	000				26.6 (0.8)	26.3 (1.2)	12 2 (0.7)	119(16)
L1-L8 LL	40.0 (2.6)	48.9 (3.2)	44.9 (3.5)	21.5 (0.9)	44.4 (4.2)	399(36)	20 5 (0.7)	18 9 (7.2)
pt	4.4 (0.4)	3.9 (0.4)	4.6 (0.2)	4.0 (0.4)	54(03)	57(04)	44.0.1)	10.0 (2.3)
st	8.0(1.0)	7.8 (0.3)	7.3 (0.6)	4.8 (0.3)	24.1 (0.5)	25601)	20.7 (1.0)	4.4 (0.4)
Lateral branches	30.2 (5.0)	33.8 (6.8)	29.2 (5.4)	22.0 (3.6)	445 4 (25 1)	458 0 (42 9)	150 5 (0.6)	120 2 (21.5)
Flowers	4.7 (1.7)	4.4 (2.1)	3.7 (0.6)	2.5 (0.7)	(IIII)	(7.7.7)	(0.6) (.001	138.3 (21.3)
Peg	ni S			Taylor State of the State of th	(6.0) 9.6	72(11)	29(0.8)	11,000
Extended peg					103 6 (12 3)	104 6 (7 6)	17 0 (7 7)	11.2 (2.2)
Roots	24.0 (9.0)	22.1 (9.0)	24.7 (3.8)	20.5 (1.3)	49.1 (5.8)	63.2 (10.2)	40 5 (4 6)	(1, 4) 7 (6, 1)
Total	111.4 (9.0) 120.9	120.9	114.5	75.4 (3.8)	817.6 (50.1)	836.1 (62.1)	310.8	788 9 (62 7)
		(12.3)	(12.0)				(12.0)	700.7 (04.1)
							(14.0)	

Plant part: Leaf positions were numbered from the base of main stem. LL – leaflets of each leaf position; pt – petioles of each leaf position; st - stems below each leaf position

Treatment: BA/BA - supplied with 10 µM B (B-adequate) throughout; BA/BD<sub>P</sub> - B withdrawal at pod set; BA/BD<sub>F</sub> - B withdrawal at flowering; BD/BD - supplied with 0 µM B (B-deficient) throughout

Harvest: H1 - flowering (25 days after germination); H2 - pod set (58 days after germination); H3 - grain filling (75 days after germination); H4 - grain maturity (103 days after germination)

Plant part	,	I	H3			H4	4	
•	BA/BA	BA/BD <sub>P</sub>	BA/BD <sub>F</sub>	BD/BD	BA/BA	BA/BD <sub>P</sub>	BA/BD <sub>F</sub>	BD/BD
L22-L26 LL	A				33.4 (1.1)	15.4 (1.8)	15.5 (0.5)	19.6 (4.0)
pt					3.4 (0.1)	2.9 (0.1)	1.2(0.4)	1.8 (0.4)
st					4.5 (0.1)	3.0 (0.4)	3.6 (0.2)	3.7 (0.3)
L17-L21 LL	44.1 (2.5)	15.7 (0.9)	18.6 (0.8)	15.1 (0.8)	55.7 (1.3)	15.8 (1.9)	14.7 (1.6)	12.3 (1.6)
pt	5.0 (0.5)	3.7 (0.2)	3.4 (0.2)	3.1 (0.3)	4.1 (0.2)	3.2 (0.2)	2.9 (0.1)	3.5 (0.1)
st st	9.2 (0.7)	4.4 (0.6)	5.0 (0.3)	6.0 (0.4)	7.8 (0.2)	7.1 (0.2)	7.2 (0.3)	8.2 (0.1)
L9-L16 LL	96.5 (3.0)	68.6 (2.9)	33.7 (2.7)	6.1 (3.0)	92.4 (5.9)	62.3 (4.1)	32.6 (1.5)	9.4 (0.9)
pt	13.1 (0.3)	10.2 (0.4)	5.6 (0.9)	6.1 (1.0)	9.2 (0.5)	10.9 (0.6)	5.8 (0.3)	4.8 (0.2)
st	51.3 (2.4)	27.9 (1.6)	19.3 (2.2)	21.3 (2.0)	27.0 (0.3)	29.6 (0.8)	21.4 (1.3)	15.4 (0.5)
L1-L8 LL	42.7 (2.4)	26.7 (2.2)	21.5 (1.8)	14.8 (2.2)	11.5 (1.2)	11.1 (1.2)	7.9 (0.7)	6.9 (0.3)
pt	6.5 (0.2)	4.1 (0.4)	4.2 (0.9)	3.4 (0.6)	3.4 (0.2)	3.1 (0.3)	2.2 (0.2)	2.3 (0.1)
st	35.7 (2.3)	23.7 (0.4)	18.8 (1.9)	23.0 (2.5)	20.5 (0.5)	22.2 (0.2)	24.3 (0.4)	20.7 (0.4)
Lateral branches	615.1 (66.5)	353.2 (57.5)	312.9 (67.5)	305.6 (32.0)	856.8 (50.6)	525.3 (23.0)	279.6 (15.5)	295.8 (16.7)
Extended peg	29.4 (1.5)	14.2 (2.2)	16.2 (4.8)	10.7 (0.5)				
Immature pod	401.6 (50.2)	226.8 (6.7)	42.2 (5.2)		30.4 (2.8)	19.2 (0.8)	33.8 (4.0)	17.9 (2.6)
Shell					93.3 (8.5)	73.1 (7.8)	15.8 (0.9)	5.3 (0.5)
Seed					511.3 (18.9)	333.31 (37.2)	19.5 (2.1)	3.7 (0.2)
Roots	79.2 (13.0)	72.2 (6.4)	71.7 (11.4)	71.6 (4.1)	133.0 (14.8)	83.1 (4.4)	89.0 (8.4)	101.9 (5.3)
Total	1429.3	1032.2	572.9 (84.1)	508.2 (43.8)	1897 (68.0)	1220 (62.7)	576 (18.3)	533.2 (14.4)
	(126.1)	(74.7)						

Plant part: Leaf positions were numbered from the base of main stem. LL - leaflets of each leaf position; pt - petioles of each leaf position; st - stems below each leaf position

<u>Treatment</u>: BA/BA – supplied with 10 μM B (B-adequate) throughout; BA/BD<sub>P</sub> – B withdrawal at pod set; BA/BD<sub>F</sub> – B withdrawal at flowering; BD/BD - supplied with 0 μM B (B-deficient) throughout

Harvest: H1 – flowering (25 days after germination); H2 – pod set (58 days after germination); H3 – grain filling (75 days after

germination); H4 - grain maturity (103 days after germination)

# 4.3.2 Experiment 2: Confirming B remobilization using tracer B (10B)

## 4.3.2.1 Experiment 2.1: <sup>10</sup>B-foliar application

Boron deficiency did not significantly affect the dry weight of the whole shoot, root and lateral branches at harvest 1 (before foliar <sup>10</sup>B application), or at 1-day after foliar treatment (Figure 4.8). By H3 (V10, 13 days after foliar B application), however, foliar <sup>10</sup>B application significantly increased (P < 0.05) dry matter of the whole shoot of B-adequate plants and lateral branches of B-deficient plants. It was found that B-adequate peanut plants which were supplied with foliar <sup>10</sup>B had higher total shoot dry weight than plants without foliar application while having no significant effect on the dry weight of other plant parts. Root dry matter, on the other hand, was not affected either by root or foliar B application.

The percentage of  $^{10}$ B abundance in plant parts at harvest 1 (before  $^{10}$ B treatment) in all treatments was similar to the natural abundance that has been reported by Brown *et al.* (1992) (19.19 %  $\pm$  0.19 %) (Figure 4.9). At harvest 2 (1 day after  $^{10}$ B was applied to leaf 1 – leaf 4 (L1 – L4) of peanut plants), the percent abundance of  $^{10}$ B in leaflets + petioles of treated leaves increased to 33.4  $\pm$  2.7 % in BD + F  $^{10}$ B and 28.8  $\pm$  1.5 % in BA + F  $^{10}$ F. There were also small increases in  $^{10}$ B abundance in the stem below leaf 1 – leaf 4, leaflets + petioles of leaf 5 – leaf 7 and lateral branches of both B-deficient and B-adequate plants treated with  $^{10}$ B (BD + F  $^{10}$ B and BA + F  $^{10}$ B). No change in  $^{10}$ B was detected in the roots. By H3, 13 days after  $^{10}$ B was applied, the percent abundance of  $^{10}$ B in L1 – L4 (LL+pt) declined from H2 but increased in new plant parts (L8 – L11 (LL+pt), L8 – L11 (st) and flowers) in both BD + F  $^{10}$ B and BA + F  $^{10}$ B. In contrast, the percent abundance of  $^{10}$ B of the

various plant parts in BD + NF  $^{10}$ B and BA + NF  $^{10}$ B all remained in the same range as the natural abundance.



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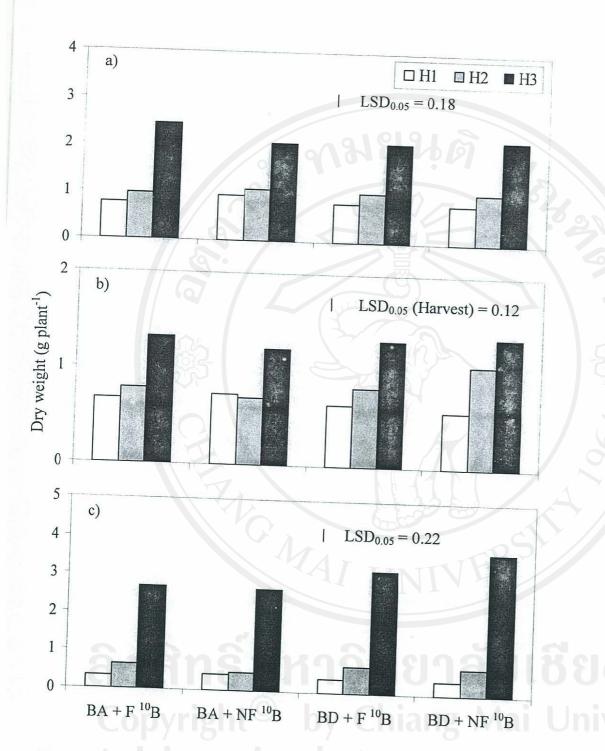
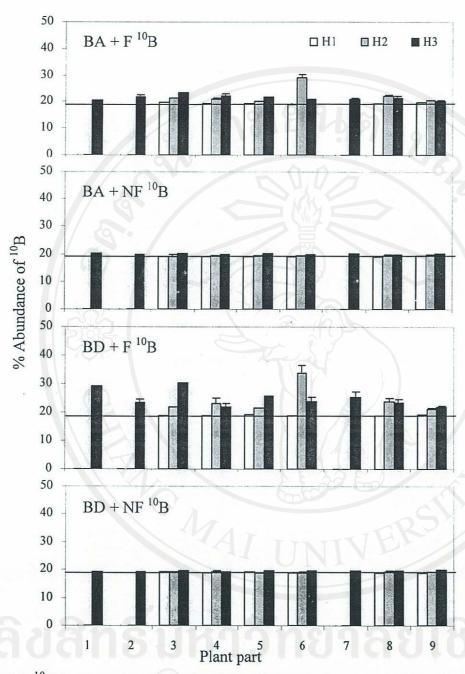


Figure 4.8 The effect of foliar B on dry weight of peanut cv. Tainan 9. a) Total shoot dry weight, b) Root dry weight and c) Lateral branch dry weight. Bars indicate means of 4 replicates.

Treatments: BA + F  $^{10}$ B - supplied 10  $\mu$ M B to rooting medium with foliar  $^{10}$ B BA + NF  $^{10}$ B - supplied 10  $\mu$ M B to rooting medium without foliar  $^{10}$ B BD + F  $^{10}$ B - supplied nil B to rooting medium with foliar  $^{10}$ B BD + NF  $^{10}$ B - supplied nil B to rooting medium without foliar  $^{10}$ B



**Figure 4.9** <sup>10</sup>B isotope abundance in parts of peanut plants cv. Tainan 9. Bars are means of four replicates. Error bars represent standard errors. The values without error bars are from four pooled samples. The horizontal line is the natural abundance of B (19.19%).

<u>Treatments</u>: BA + F  $^{10}$ B - supplied 10  $\mu$ M B to rooting medium with foliar  $^{10}$ B, BA + NF  $^{10}$ B - supplied 10  $\mu$ M B to rooting medium without foliar  $^{10}$ B, BD + F  $^{10}$ B - supplied nil B to rooting medium with foliar  $^{10}$ B, BD + NF  $^{10}$ B - supplied nil B to rooting medium without foliar  $^{10}$ B <u>Plant part</u>: 1) Leaf 8 – Leaf 11 (stems), 2) Leaf 8 – Leaf 11 (leaflets + petioles), 3) Leaf 5 – Leaf 7 (stems), 4) Leaf 5 – Leaf 7 (leaflets + petioles), 5) Leaf 1 – Leaf 4 (stems), 6) Leaf 1 – Leaf 4 (leaflets + petioles) 7) Flowers 8) Lateral branches and 9) Roots. <u>Harvests</u>: H1- before foliar  $^{10}$ B application, H2 – 1 day after  $^{10}$ B application and H3 – 13 days

after <sup>10</sup>B application.

# 4.3.2.2 Experiment 2.2: <sup>10</sup>B applied to the roots

Peanut plants which were grown continuously in B-deficient solution ( $^{10}BD \rightarrow ^{11}BD$ ) showed the first B deficiency symptoms during vegetative growth (40 days after germination) as water-soaked areas in the young leaves (Figure 10a). This was followed by stunting of shoots and roots at harvest 2 (45 days after germination) (Figure 10b), with very few new leaves at harvest 3 (77 days after germination) (Figure 4.11). The symptoms of B deficiency also occurred, but less severe and appeared 10 days later, in plants which had been transferred from B-sufficient to B-deficient solution ( $^{10}BA \rightarrow ^{11}BD$ ).

At harvest 1 (V<sub>5</sub>: 10 days after treatment), peanut plants were not affected by B treatments. When B was withdrawn from the nutrient solution, by harvest 2 (flowering; 20 days after withdrawal B) and harvest 3 (pod filling; 51 days after withdrawal B) plant height and root length of peanut in B-deficient treatments ( $^{10}$ BD  $\rightarrow$   $^{11}$ BD and  $^{10}$ BA  $\rightarrow$   $^{11}$ BD) were lower than B-adequate plant ( $^{10}$ BA  $\rightarrow$   $^{11}$ BA) (Figure 4.11). After considering plant growth in terms of dry matter accumulation, it was found that plant dry weight was not affected by B treatment at harvest 1 and harvest 2, but by harvest 3 it was depressed in both B-deficient conditions ( $^{10}$ BA  $\rightarrow$   $^{11}$ BD and  $^{10}$ BD  $\rightarrow$   $^{11}$ BD) (Table 4.8). Moreover, it was found that plant growth was inhibited in plants which were supplied with 0.1  $\mu$ M B throughout the experiment ( $^{10}$ BD  $\rightarrow$   $^{11}$ BD). The height and root length of these plants remained unchanged after harvest 2. Besides, the number of new leaves and the number of lateral branches were not influenced by B treatment at harvests 1 and 2, but at harvest 3 plants which were supplied with 0.1  $\mu$ M B throughout the experiment ( $^{10}$ BD  $\rightarrow$   $^{11}$ BD) produced more

lateral branches (Figure 4.11). The number of new leaves produced between harvests was about the same among the B treatments between harvest 1 and harvest 2, which was about 4 leaves in 10 days. In the 32 days between harvest 2 and harvest 3, there were clear effects of B on the production of new leaves (Figure 4.11). More than 6 leaves were produced between harvests 2 and 3 in the B adequate plants ( $^{11}BA \rightarrow ^{10}BA$ ), but B withdrawal ( $^{11}BA \rightarrow ^{10}BD$ ) depressed the number of new leaves to fewer than 4. The plants that were kept in B deficiency throughout ( $^{11}BD \rightarrow ^{10}BD$ ) produced fewer than 2 leaves in the same period.

At flowering (H2; 30 days after withdrawal of B), peanut plants which received 10  $\mu$ M B in the first period ( $^{10}$ BA  $\rightarrow$   $^{11}$ BD) were able to produce flowers but in fewer number than plants which received 10  $\mu$ M B continuously ( $^{10}$ BA  $\rightarrow$   $^{11}$ BA). Moreover, only a very small number of these flowers developed to pegs, and none progressed to pods. Plants grown in continuous 0.1  $\mu$ M B ( $^{10}$ BD  $\rightarrow$   $^{11}$ BD) produced some flowers, but they were abnormal and did not develop into pegs or pods (Table 4.9, Figure 4.12).

The data on percent abundance of <sup>10</sup>B isotope (Figure 4.13) and <sup>10</sup>B content (Table 4.10) showed the movement of <sup>10</sup>B which the plants had received in the first period of growth, being transferred to new tissues. This apparent remobilization of <sup>10</sup>B occurred in plants with all three external B treatments. The % abundance of <sup>10</sup>B and <sup>10</sup>B content declined in old plants parts, to appear in new growth such as new leaves, flowers, pegs and pods. In B-sufficient plants (<sup>10</sup>BA → <sup>11</sup>BA), the <sup>10</sup>B abundance and <sup>10</sup>B content declined from harvest 1 through 3 in leaves 1-6 (including stems + petioles), to be found in flowers in harvest 2 and pegs and pods by harvest 3.

In B-deficient plants ( $^{10}BD \rightarrow ^{11}BD$ ) the  $^{10}B$  taken up earlier was found in the flowers by harvest 2, but no other reproductive tissue. The  $^{10}B$  content in flowers of  $^{10}BA \rightarrow ^{11}BD$  plants was equal to those in  $^{10}BA \rightarrow ^{11}BA$  plants while the %  $^{10}B$  abundance in the flowers in the B deficient plants was about twice as much as that in B-sufficient plants. An even higher percent  $^{10}B$  abundance was found in the new tissues of flowers (harvest 2) and pegs (harvest 3) of those plants to which its B supply was withdrawn ( $^{10}BA \rightarrow ^{11}BD$ ).

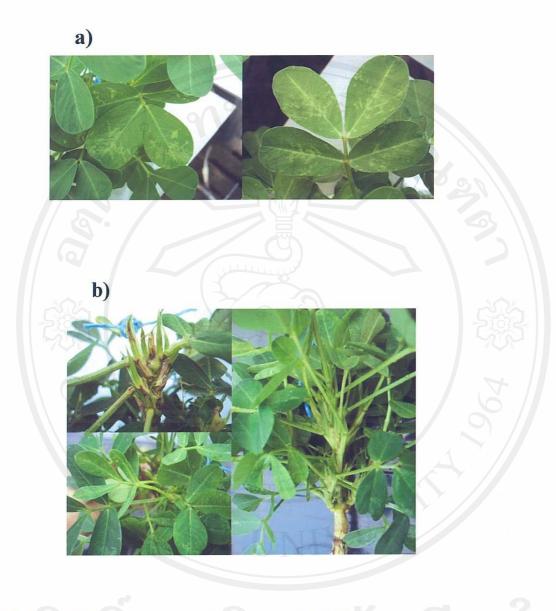
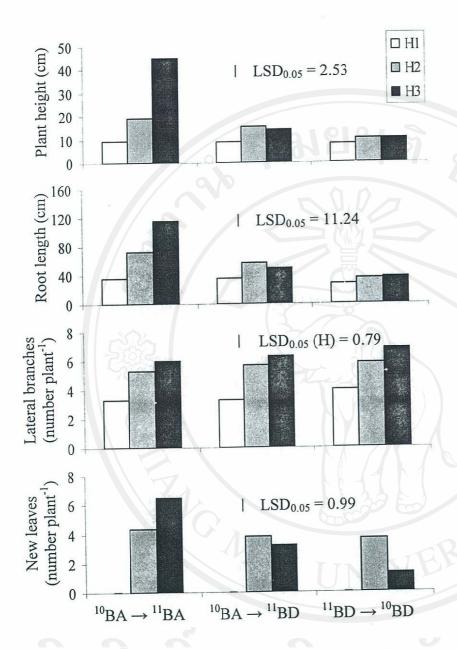


Figure 4.10 Boron deficiency symptoms in peanut cv. TAG 24.

- a) water soaked young leaves
  b) stunted shoots
- A lights reserved



**Figure 4.11** Plant height (cm), root length (cm), number of lateral branches/plant and number of new leaves/plant of peanut (cv. TAG 24) which were grown with different B status. H1: V<sub>5</sub> (before withdrawal B), H2: R<sub>1</sub> (flowering; 10 days after withdrawal of B), H3: R<sub>5</sub> (41 days after withdrawal of B).

<u>Treatment</u>:  $^{10}\text{BA} \rightarrow ^{11}\text{BA}$  – seedlings (1-week-old) grown in basal solution culture containing 10  $\mu\text{M}$   $^{10}\text{B}$  and transferred into solution culture with 10  $\mu\text{M}$   $^{11}\text{B}$ ,  $^{10}\text{BA} \rightarrow ^{11}\text{BD}$  – seedlings (1-week-old) grown in basal solution culture containing 10  $\mu\text{M}$   $^{10}\text{B}$  and transferred into solution culture with 0.1  $\mu\text{M}$   $^{11}\text{B}$ ,  $^{10}\text{BD} \rightarrow ^{11}\text{BD}$  – seedlings (1-week-old) grown in basal solution culture containing 0.1  $\mu\text{M}$   $^{10}\text{B}$  and transferred into solution culture with 0.1  $\mu\text{M}$   $^{11}\text{B}$ 

**Table 4.8** Dry weight (g plant<sup>-1</sup>) of peanut (cv. TAG 24). Data are means of three replicates.

		Dry weight (g plant <sup>-1</sup> )				
Treatment <sup>1</sup>	Harvest	Main stem	Root	Lateral branches		
$^{10}\text{BA} \rightarrow ^{11}\text{BA}$	H1	0.55 a	0.33 a	0.20 a		
	H2	1.29 b	0.84 bc	3.15 cd		
	Н3	3.10 e	3.13 f	15.71 f		
$^{10}\mathrm{BA} \rightarrow ^{11}\mathrm{BD}$	<b>Н</b> 1	0.55 a	0.33 a	0.20 a		
	H2	1.18 b	0.70 b	2.49 bc		
	Н3	2.49 d	2.49 e	6.6 e		
$^{10}\mathrm{BD} \rightarrow ^{11}\mathrm{BD}$	Н1	0.54 a	0.34 a	0.26 a		
	H2	1.46 b	1.01 c	1.89 b		
	Н3	1.99 c	1.90 d	4.04 d		
Analysis of varia	nce	AIII	NIVE			
P(Treatment)		<0.01	<0.01	<0.01		
P(Harvest)		<0.01	<0.01	<0.01		
P(TxH)		<0.01 (0.31)	<0.01 (0.24)	<0.01 (1.22)		

<sup>&</sup>lt;sup>1</sup>Treatment see Figure 4.6.

Different letters in each column indicate significant difference at P < 0.05 based on LSD (value in parentheses).

**Table 4.9** Reproductive growth of peanut (cv. TAG 24) grown with adequate or deficient <sup>10</sup>B and then transferred into <sup>11</sup>B.

	Flov	wers	Pe	egs	Po	ods
Treatment <sup>1</sup>	Number/	DW	<sup>2</sup> Number/	$^{2}\mathrm{DW}$	Number/	DW
Troutinont	plant	(g plant <sup>-1</sup> )	plant	(g plant <sup>-1</sup> )	plant	(g plant <sup>-1</sup> )
$^{10}\text{BA} \rightarrow ^{11}\text{BA}$	32.50 b	0.049 b	34.17 c	1.336 c	0.86 b	0 o 19 b
$^{10}\mathrm{BA} \rightarrow ^{11}\mathrm{BD}$	22.50 b	0.039 b	1.0 b	0.015 b	0 a	0 a
$^{10}BD \rightarrow ^{11}BD$	9.33 a	0.015 a	0 a	0 a	0 a	0 a
Analysis of varia	ance		(3)			30
P (T)	< 0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
$^{3}LSD_{0.05}$	10.82	0.011	0.05	0.008	0.25	6.94

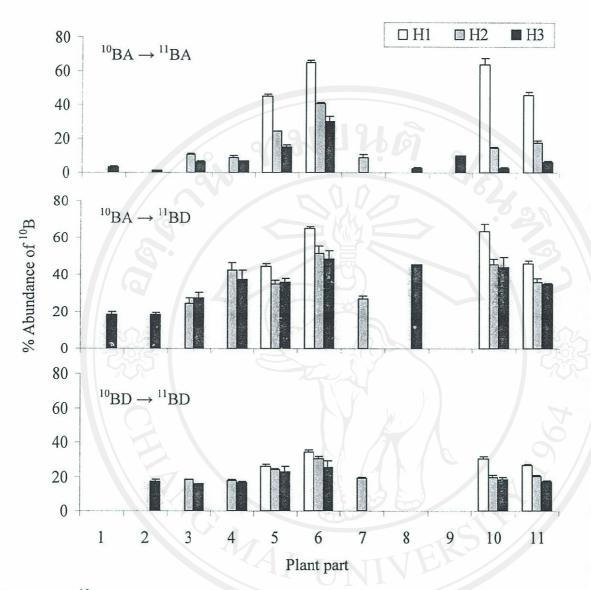
<sup>&</sup>lt;sup>1</sup>Treatment see Figure 4.6.

<sup>&</sup>lt;sup>2</sup>The data were transformed with arcsin before analysis of variance

 $<sup>^{3}</sup>$ Different letters in each column indicate significant difference at P < 0.05



- a)  $^{10}BA \rightarrow ^{11}BA$  (transferred from solution culture with 10  $\mu M$   $^{10}B$  to 10  $\mu M$   $^{11}B)$
- b)  $^{10}BA \rightarrow ^{11}BD$  (transferred from solution culture with 10  $\mu M$   $^{10}B$  to 0.1  $\mu M$   $^{11}B)$
- c)  $^{10}BD \rightarrow ^{11}BD$  (transferred from solution culture with 0.1  $\mu M$   $^{10}B$  to 0.1  $\mu M$   $^{11}B$ )



**Figure 4.13** <sup>10</sup>B isotope abundance in parts of peanut plants cv. TAG 24 (Experiment 2.2). Bars are means of three replicates. Error bars represent standard errors. The values without error bars are from four pooled samples.

Plant part: 1) Leaf 12 – Leaf 15 (petioles + stems), 2) Leaf 12 – Leaf 15 (leaflets), 3) Leaf 7 – Leaf 11 (petioles + stems), 4) Leaf 7 – Leaf 11 (leaflets), 5) Leaf 1 – Leaf 6 (petioles + stems), 6) Leaf 1 – Leaf 6 (leaflets), 7) Flowers 8) pegs, 9) pods, 10) Lateral branches and 11) Roots. (See diagram of peanut growth in Figure 4.7) Harvests: H1- V<sub>5</sub>, H2 –R<sub>1</sub>: Flowering and H3 – R<sub>5</sub>: pod filling.

**Table 4.10**  $^{10}$ B content (µg plant<sup>-1</sup>) of peanut cv. TAG 24. Values are means of three replicates  $\pm$  SE.

		11							
Dlant nort	yı I	$^{''}BA \rightarrow ^{''}BA$	_		$^{10}\text{BA} \rightarrow ^{11}\text{BD}$	\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\		$10^{8} D \rightarrow 11^{8} D$	
r raint part	HI	HZ	H3	H1	H2	H3	O HI	H2	H3
L12-L15 (LL)	h r	S	$1.2 \pm 0.2$	7		$0.6 \pm 0.1$			
L12-L15 (pt+st)			$0.6 \pm 0.1$			$0.2 \pm 0.0$			$0.3 \pm 0.1$
L7-L11 (LL)		$2.8 \pm 0.3$	$2.8\pm0.1$		$2.9 \pm 0.3$	$4.5 \pm 0.9$		$1.4 \pm 0.2$	$1.6 \pm 0.3$
L7-L11(pt+st)		$1.6 \pm 0.1$	$1.9 \pm 0.2$		$1.3 \pm 0.2$	$1.3 \pm 0.2$		$0.9 \pm 0.2$	$1.0 \pm 0.3$
L1-L6 (LL)	$15.7 \pm 0.6$	$7.3 \pm 0.2$	$6.6 \pm 0.2$	$15.7 \pm 0.6$	<b>7.8</b> ± 0.6	$5.7 \pm 0.4$	$3.4 \pm 0.3$	$2.6 \pm 0.1$	$2.2 \pm 0.1$
L1-L6(pt+st)	$4.1 \pm 0.3$	$2.7 \pm 0.4$	$2.1 \pm 0.1$	$4.1 \pm 0.3$	$3.4 \pm 0.5$	$2.4 \pm 1.4$	$2.1\pm0.2$	1.4 ± 0.1	$1.5 \pm 0.4$
Flowers		$1.0\pm0.2$			$0.7 \pm 0.1$			$0.1 \pm 0.0$	
Pegs			$2.0 \pm 0.3$			$0.6 \pm 0.0$			
Pods			$2.0 \pm 0.2$						
Lateral branches	$9.4 \pm 0.9$	$12.6 \pm 0.1$	$18.7 \pm 2.6$	$9.4 \pm 0.9$	$14.2\pm1.0$	$18.0 \pm 2.7$	$3.0 \pm 0.3$	$3.6 \pm 0.1$	4.7 ± 1.2
Roots	$8.0 \pm 0.6$	$10.1 \pm 0.6$	$6.0 \pm 0.5$	$8.0 \pm 0.8$	$10.2 \pm 0.6$	$7.5 \pm 0.3$	$4.4 \pm 0.3$	$4.1 \pm 0.2$	$3.7 \pm 0.8$
total	$37.3 \pm 2.0$	$37.3 \pm 2.0$ $38.0 \pm 1.4$	$43.9 \pm 2.8$	$37.3 \pm 2.0$	$40.3 \pm 2.7$	$40.0 \pm 2.5$	$12.9 \pm 0.9$ $14.1 \pm 0.5$	$14.1 \pm 0.5$	$15.1 \pm 1.9$
			The second secon						

#### 4.3.3 Experiment 3: Boron mobility in two peanut cultivars

No effect of B treatment was evident in the two peanut cultivars at harvest 1 and harvest 2, except some minor cultivar differences (Tables 4.11, 4.12). By harvest 3 (83 days after germination), differential response to B between the two cultivars became evident (Table 4.13). The main stem dry weight of both cultivars was not affected by foliar B treatment while it was found that Tainan 9 had higher total main stem dry weight than TAG 24. Besides, it was also found that foliar B treatment had no effect on dry weights of roots and lateral branches of Tainan 9 while they increased these parameters in TAG 24. The two peanut cultivars responded differently to the foliar B application (P < 0.05-0.01) in the dry weight of immature pods, number of immature pods, pods/plant and % hollow heart. Comparison of the seed yield and % hollow heart seed of both cultivars showed that Tainan 9 had greater seed yield but of a lower quality (higher % hollow heart) than TAG 24. The data was also showed that foliar B increased seed yield and reduced the percentage of seed with hollow heart (Table 4.13).

The B concentration in most organs of TAG 24 was higher than in Tainan 9 at harvests 1 and 2 while they were similar at harvest 3. At harvest 1, the B concentration among plant parts was similar, which were found in both cultivars. After the end of foliar B treatment (harvest 2), the B concentration in treated leaves had increased from  $16.9 \pm 0.8$  to  $23.2 \pm 1.6$  mg B kg DW<sup>-1</sup> in Tainan 9 and from 27.4  $\pm$  0.3 to  $37.2 \pm 1.3$  mg B kg DW<sup>-1</sup> in TAG 24. However, it decreased about 40% in TAG 24 after 16 days following treatment (harvest 3) while it was not changed in Tainan 9. Excluding the B-treated leaves, the B concentration in both Tainan 9 and TAG 24 had minor changes in some tissues during harvest 1 to harvest 3 in both BD +

F and BD + NF. At harvest 3, most parts of Tainan 9 and a few parts of TAG 24 plants treated with foliar B had significantly higher B concentrations than in untreated plants, including new parts (Table 4.13).

At harvest 2 (at the end of foliar B application), the B content in treated leaves had increased about 1.5 times in Tainan 9 and almost 3 times in TAG 24 (Figure 4.14). After that (harvest 3), B in treated leaves decreased about 18% for Tainan 9, and decreased to the same level as before foliar treatment for TAG 24. The B content was found in the greater amount in seeds of both cultivars compared with no foliar Foliar treatment increased B content in the other reproductive parts, (immature pod and shell + hypanthium) of TAG 24 while had no effects to Tainan 9. By contrast, the B content of the new vegetative growth, L16-L18, of both cultivars given foliar B was elevated relative to the untreated plants (Figure 4.15). The B content of organs formed prior to foliar treatment varied with cultivar and foliar treatment. Tainan 9 had higher B contents in most vegetative parts but lower B contents in reproductive parts compared with TAG 24. At harvest 3, Tainan 9, treated with foliar B, accumulated B in some parts formed prior to foliar treatment [L12-L15 (LL+pt), L1-L6 (LL+pt), L1-L6 (st) and roots] whereas in the others [L12-L15 (st), L1-L11 (st) and pegs] B content was not significantly different among harvests and In. TAG 24, B in most tissues was not significant different among harvests, except for roots which accumulated B at harvest 3 (Figure 4.15).

**Table 4.11** Vegetative and reproductive growth of 2 peanut cultivars before foliar B application (H1: 60 days after germination).

			Dry weigh	nt (g plant <sup>-1</sup> )		D
Treatment	Cultivar	Total	Root	Lateral	Peg	Peg number
		shoot		branch		number
BD+F	Tainan 9	2.9	0.88	6.1	0.12	3.3
	TAG 24	1.7	0.80	2.6	0.14	5.7
BD+NF	Tainan 9	2.9	0.89	5.4	0.16	3.2
	TAG 24	1.9	0.76	2.7	0.18	5
Analysis of	variance		S			1
P(Cultiva	ar)	< 0.01	ns	< 0.01	ns	< 0.01
		(0.3)		(0.6)		(0.6)
P(Treatm	ent)	ns	ns	ns	ns	ns
P(CVxT)		ns	ns	ns	ns	ns

Values in parentheses are respective LSD (P<0.05)

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**Table 4.12** The effect of foliar B application on vegetative and reproductive growth of 2 peanut cultivars at the end of foliar B application (H2: 67 days after germination).

			Dry weigh	nt (g plant <sup>-1</sup> )		Peg
Treatment	Cultivar	Total	Root	Lateral	Peg	number
		shoot		branches		namoer
BD+F	Tainan 9	3.1	0.85	6	2.6	3.7
	TAG 24	1.8	0.89	3	2.9	5.7
BD+NF	Tainan 9	3.2	0.95	5.6	3.2	3.2
	TAG 24	1.9	0.82	2.8	3	5.5
Analysis of	variance		8,	- 73		
P(Cultiv	ar)	< 0.01	ns	< 0.01	ns	< 0.01
		(0.5)		(0.8)		(0.9)
P(Treatn	ment)	ns	ns	ns	ns	ns
P(CVxT		ns	ns	ns	ns	ns

Values in parentheses are respective LSD (P<0.05)

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Table 4.13 The effect of foliar B application on vegetative and reproductive growth of 2 peanut cultivars at 83 days after germination (H3: grain maturity).

Trantment	Cultivos			Dry weigh	Dry weight (g plant <sup>-1</sup> )			9	Number per plant	olant
Heatment		Main	Root	Lateral	Immature	Shell	Seed	Immature	Pod	% Hollow
		stem		branches	pod			pod		heart seed
BD+F	Tainan 9	3.7	1.0	7.0	0.45	1.8	6.5	7.5	5.8	17.8
	TAG 24	1.4	1.5	6.5	0.28	1.9	4.2	8.3	12	7.7
BD+NF	Tainan 9	3.5	1.0	7.5	0.13	1.4	3.6	6.5	4.5	63.1
	TAG 24	1.2	6.0	4.9	0.20	1.6	3.1	6.5	8.9	38.8
Analysis of variance	variance	l i			Buch				21	
P(Cultivar)	var)	<0.01	su	<0.01	ns	ns	<0.05	ns	< 0.01	< 0.01
		(0.4)					(1.1)			
P(Treatment)	ment)	su	< 0.05	su	<0.01	ns	<0.01	< 0.05	< 0.01	< 0.01
							(1.1)			
P(CVxT)		ns	< 0.05	<0.01	<0.01	ns	ns	< 0.05	< 0.05	< 0.01
			(0.3)	(0.9)	(0.08)			(1.4)	(1.8)	(4.0)
ית) עט ז יידי יידי יידי יידי יידי יידי יידי י	141	7 1 17	(30,00,00)	1						

Values in parentheses are respective LSD (P<0.05)

Table 4.14 Boron concentration (mg B kg DW<sup>-1</sup>) in various parts of two peanut cultivars with and without foliar B.

Cultivar	Dlant nart	3	BD+F		G	BD+NF	
		HI	H2	H3 CH	HI	H2	H3
Tainan 9	L16-L18	200	1	$19.2 \pm 1.8$			$15.0 \pm 0.0$
	L12-L15 (LL+pt)	$18.3 \pm 0.3$	$18.1\pm1.0$	$19.7 \pm 2.0$	$15.0 \pm 0.7$	$15.7 \pm 0.8$	$16.5 \pm 1.6$
	L12-L15 (st)	$13.6 \pm 0.9$	$14.3 \pm 1.5$	$17.4 \pm 1.9$	$12.0 \pm 0.2$	$12.5 \pm 0.2$	$8.5 \pm 0.6$
	L7-L11 (LL+pt)	$16.9 \pm 0.8$	$23.2 \pm 1.6$	$22.3 \pm 2.4$	$17.1 \pm 0.2$	$17.8\pm1.1$	$18.0 \pm 0.9$
	L7-L11 (st)	$8.2 \pm 0.4$	$10.1 \pm 0.4$	$10.5 \pm 1.8$	$8.6 \pm 0.5$	8.7 ± 0.8	$9.2 \pm 1.2$
	L1-L6 (LL+pt)	$19.3 \pm 0.7$	$19.6 \pm 0.7$	$21.4 \pm 1.6$	$18.4 \pm 0.2$	$19.1 \pm 0.9$	$16.9 \pm 1.9$
	L1-L6 (st)	$9.2 \pm 0.3$	$9.2 \pm 0.5$	$11.6 \pm 1.1$	$9.2 \pm 0.1$	$9.1 \pm 0.1$	$9.2 \pm 0.7$
	Peg	$18.1 \pm 0.0$	$12.1 \pm 2.0$		$18.1\pm0.0$	$9.8 \pm 0.5$	
	Immature pod			$11.8 \pm 1.2$			$10.0 \pm 1.7$
	Shell + hypanthium			$10.8 \pm 0.4$			$9.3 \pm 1.0$
	Seed O pas			$9.6 \pm 0.1$			$6.8 \pm 0.1$
	Roots	$13.6 \pm 0.4$	$13.8 \pm 0.0$	$15.3 \pm 1.4$	$14.0 \pm 0.0$	$13.9 \pm 0.1$	$12.7 \pm 0.9$

Values are means of three replications ± SE

Table 4.14 (Continued)

Flant part  L16-L18  L12-L15 (LL+pt)  L12-L15 (st)  L7-L11 (LL+pt)  L7-L11 (st)  L7-L11 (st)  L1-L6 (st)  Reg  L1-L6 (st)  Inmature pod  Shell + hypanthium  Seed	;			BD+F			BD+NF	
L16-L18  L12-L15 (LL+pt)  L12-L15 (st)  L12-L15 (st)  L7-L11 (LL+pt)  L7-L11 (st)  L7-L11 (st)  L1-L6 (LL+pt)  20.2 ± 0.8  L1-L6 (st)  Peg  Inmature pod  Shell + hypanthium  Seed	Cultivars	Plant part	HI	HZ	H3	HI X	H2	H3
LL+pt) $22.7 \pm 1.1$ st) $21.9 \pm 0.0$ L+pt) $27.4 \pm 0.3$ t) $27.4 \pm 0.3$ t) $21.8 \pm 0.0$ t) $20.2 \pm 0.8$ 16.4 ± 1.8 16.8 ± 1.2 pod panthium	TAG 24	L16-L18	n		$18.0 \pm 0.0$	97		
st) 21.9 ± 0.0 L+pt) 27.4 ± 0.3 t) 21.8 ± 0.0 2+pt) 20.2 ± 0.8 16.4 ± 1.8 16.8 ± 1.2 pod panthium		L12-L15 (LL+pt)	$22.7 \pm 1.1$	$22.9 \pm 1.2$	$16.5 \pm 1.2$	$24.3 \pm 1.1$	$24.6\pm1.0$	$16.0\pm1.0$
L+pt) 27.4 ± 0.3 t) 21.8 ± 0.0 2-pt) 20.2 ± 0.8 16.4 ± 1.8 16.8 ± 1.2 pod panthium		L12-L15 (st)	$21.9 \pm 0.0$	$22.0\pm0.0$	$15.1 \pm 0.0$	$21.0\pm0.0$	$22.1 \pm 0.0$	$16.1\pm0.0$
t) 21.8 ± 0.0 J-pt) 20.2 ± 0.8 16.4 ± 1.8 16.8 ± 1.2 pod panthium		L7-L11 (LL+pt)	$27.4 \pm 0.3$	$37.2 \pm 1.3$	$22.5 \pm 0.6$	$27.8 \pm 0.5$	$27.6 \pm 0.7$	$21.7 \pm 1.9$
20.2 $\pm$ 0.8 16.4 $\pm$ 1.8 16.8 $\pm$ 1.2 pod panthium		L7-L11 (st)	$21.8 \pm 0.0$	$16.3 \pm 0.0$	$11.8 \pm 0.8$	$22.0\pm0.0$	$22.3 \pm 0.0$	$11.6 \pm 1.4$
16.4 $\pm$ 1.8  16.8 $\pm$ 1.2  pod  panthium		L1-L6 (LL+pt)	$20.2 \pm 0.8$	$20.2 \pm 0.8$	$26.2 \pm 0.0$	$22.7 \pm 0.0$	$22.8 \pm 0.0$	$23.0 \pm 1.6$
$16.8 \pm 1.2$ $pod$ $panthium$		L1-L6 (st)	$16.4 \pm 1.8$	$16.4 \pm 1.8$	$11.5 \pm 1.2$	$16.6 \pm 0.5$	$16.6 \pm 0.4$	$11.6 \pm 1.1$
ture pod + hypanthium		Peg	$16.8 \pm 1.2$	$14.7 \pm 0.8$		$16.5 \pm 1.3$	$14.8 \pm 0.9$	
+ hypanthium		Immature pod	<b>8 1 1 1 1 1 1 1 1 1 1</b>		$14.4 \pm 0.3$			$13.9 \pm 0.3$
30+3918 Me		Shell + hypanthium			$10.3 \pm 0.3$			$9.2 \pm 0.7$
165+05		Seed			$8.6 \pm 0.4$			$7.0 \pm 0.4$
10.7 ± 0.7		Roots	$16.5 \pm 0.5$	$15.5 \pm 1.3$	$12.5 \pm 0.6$	$16.5 \pm 0.6$	$16.9 \pm 0.4$	$14.3 \pm 0.9$

Values are means of three replications ± SE

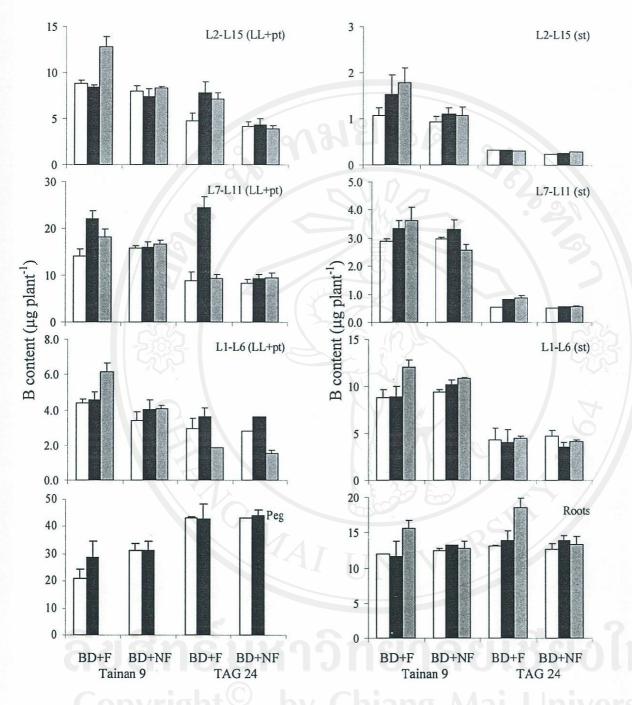


Figure 4.14 Boron content ( $\mu g$  plant<sup>-1</sup>) of older plant parts developed before foliar treatment of 2 peanut cultivars. Bars are means of three replications with error bars as SE.  $\square$  H1  $\blacksquare$  H2  $\blacksquare$  H3

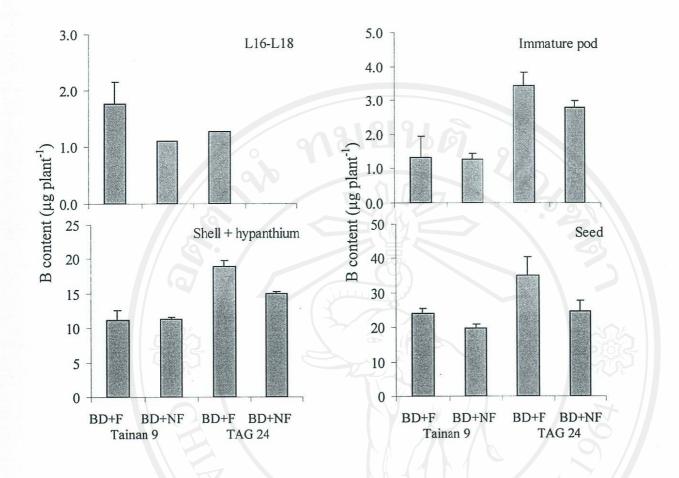


Figure 4.15 Boron content (μg plant<sup>-1</sup>) of plant organs formed after foliar treatment of 2 peanut cultivars. Bars are means of three replications with error bars as SE.

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#### 4.4. Discussion

The evidence of partly B retranslocation in peanut was proved in all experiments conducted in this Chapter. These evidence included, the retranslocation of B from the older parts to the younger and reproductive organs in Experiment 1, the <sup>10</sup>B could be moved out the treated leaves to non-treated and new tissues (Experiment 2.1), the retranslocation of <sup>10</sup>B accumulated previously to newly growth (Experiment 2.2), and the movement of foliar treated to new parts of both peanut cultivars (Tainan 9 and TAG 24) in Experiment 3.

In Experiment 1, B treatment affected growth of peanut plants after mid reproductive stage. Boron deficiency condition raised root dry weight at harvest 2 (pod set stage), and including lateral branch dry weight at harvest 3 (grain filling) and harvest 4 (grain maturity). For reproductive parts of peanut, B deficient reduced seed yield and their quality. It was found that longer period of B-adequate condition reduced the effect of B-deficient in later period, indicated by the percentage of hollow heart in seed of BA/BDP was lower than in BA/BDF. In this study, B deficiency symptoms occurred on leaves during plants was in reproductive stage with B concentration was lower than 9 mg B kg DW-1. This was quite low when compared to previous report of Bell et al. (1990) which were found the critical B concentration for diagnosis of B deficiency was 12 mg B kg<sup>-1</sup>. The declination of B content in some older parts at harvest 4 (Table 4.7), leaflets, petioles and stems of L1-L8, may be caused of the loss of dry weight (Figure 4.3). Plants which were supplied with Badequate for longer period affected the amount of B stored in plants. Moreover, B could move from accumulated parts to the others including new vegetative and reproductive organ. Match and Ochiai (2005) suggested that B retranslocation in

plant was not restricted to reproductive organs, but also in vegetative organs. However, the detection of previous taken-up B in the younger tissues did not always indicate the retranslocation in phloem system because several amount of water-soluble B may contain in the stem and some of B might donate B to the xylem fluid (Matoh and Ochiai, 2005).

Thellier and collaborator (1979) reported the technique for study of B by using stable isotopes of B. Later, tracer experiments are widespread in both root (Marentes et al., 1997; Bellaloui and Brown, 1998; Matoh and Ochiai 2005) and foliar application (Perica et al., 2001; Letho et al., 2000; Letho et al., 2004a; Letho et al., 2004b), and provided many reports with more direct evidence for translocation of B within plants (Brown et al., 1992). Accordingly, this study consisted of both tracer applications for proving our previous study of B mobility in peanut. It was clear that foliar <sup>10</sup>B could be moved out from treated leaves to the other parts of peanut. The <sup>10</sup>B abundance of them in both BD and BA was decreased while there was <sup>10</sup>B in nontreated and new tissues. Due to the prevention during foliar application, it was certain that <sup>10</sup>B did not come from the contamination. From the root application experiment could be proved the retranslocation of accumulated B which plants received at the first period of their growth. It was found that the percent abundance of <sup>10</sup>B and <sup>10</sup>B content of leaves 1 - 6 was decreased and there was <sup>10</sup>B in the newly growth (new leaves and reproductive organs) of all treatments when plants grew until R<sub>1</sub> and R<sub>5</sub>. The decreasing of <sup>10</sup>B in stems + petioles of L1 - L6 may be a consequence of stored B in tissues reloaded into their xylem (Raven, 1980; Shelp et al., 1998). Huang et al. (2001) demonstrated that a substantial amount of B in the lower parts is transported to reproductive organ, developing ears, even though concurrent B from the rooting solution is the major source of B. Moreover, plants which were grown in B withdrawal condition could use the retantslocated-B for produce the flowers but it was not enough for the later stage.

There were cultivar differences on growth of both peanut cultivars. It may be belonging to cultivar characteristics. Both Tainan 9 and TAG 24 are Spanish botanical type. Tainan 9 is imported cultivar from Taiwan since B.C. 1972, medium seeded, high yielding (Vorasoot *et al.*, 2003). TAG 24 is semi-dwarf commercial cultivar of Australia with high yield (Patil *et al.*, 1995; Basu and Nautiyal, 2004). Foliar application affected dry matter of root and lateral branches of TAG 24. So, it could be suggested that TAG 24 responded to foliar B. Reproductive growth of both cultivars responded to foliar B application than vegetative stage. Foliar B increased number of immature pod, dry weight of immature pod, pod dry weight and seed yield. Moreover, it reduced percentage of hollow heart seed. For movement of foliar treated B, it could be suggested that it could move out treated leaves and distributed to new parts. Both cultivars showed the appearance of B mobility although it seemed to be greater retranslocation in TAG 24 than in Tainan 9.

In conclusion, the evidence gained from this Chapter was strong enough for indicating that B could be retranslocated in peanut with regardless external supply and plant cultivars. Although the retranslocated B was only minor amount, but it was significance.