Kasetsart J. (Nat. Sci.) 41 : 621 - 632 (2007)

The Effects of Calcium and Boron Sprays on the Incidence of Translucent Flesh Disorder and Gamboge Disorder in Mangosteen (*Garcinia mangostana* L.)

Surachart Pechkeo[1*], Sayan Sdoodee[1] and Chairatna Nilnond[2]

ABSTRACT

Two experimental sites to investigate the effects of Ca and B sprays on the incidence of TFD and GD in mangosteen fruits were established at Nakhon Si Thammarat, southern Thailand. The experiment was designed as factorial design with 2 main factors: 1) fruit positions (outer and inner canopy) and 2) concentrations of Ca and B sprayed (wt/vol) (control (no spray), 5% $CaCl_2$, 10% $CaCl_2$, 5% $CaCl_2$+0.5 mg kg^{-1}B and 10% $CaCl_2$+0.5 mg kg^{-1}B). Ten treatments with 3 replications were completely randomized under field condition. The mangosteen fruits were sprayed at 6, 7 and 8 weeks after blooming. Soil sampling was taken at 2 depths; 0-15 and 15-30 cm, from soil surface around the middle of the tree canopy at blooming period and analyzed for some important chemical and physical properties. Leaves were sampled at blooming and harvesting periods while fruits were sampled at harvesting period. Ca and B concentrations of the leaf, peel and flesh of all treatments were analyzed. Results indicated that the soil textures varied from sandy loam to clay, and the natural soil in mangosteen orchards were very strongly acid to very extremely acid (pH 3.92-4.92, soil:water = 1:5) with very low essential nutrient levels for plant growth. The applications of $CaCl_2$ and H_3BO_3 could increase Ca and B concentrations in peel and flesh of mangosteen fruits. Spraying with 10% $CaCl_2$ could also increase the percentages of normal fruits (NF), whereas the percentages of defected fruits (TFD and GD) decreased. Spraying 10% $CaCl_2$+0.5 mg kg^{-1}B enhanced the efficiency of Ca to increase the ratio of NF:TFD and GD.

Key words: calcium, boron, translucent flesh disorder, gamboge disorder, mangosteen (*Garcinia mangostana* L.)

INTRODUCTION

In southern Thailand, mangosteen (*Garcinia mangostana* L) is an important fruit and the export markets are promising. The incidences of translucent flesh disorder (TFD) and gamboge disorder (GD) are both major problems of mangosteen fruit production in humid tropics (Yaacob and Tindall, 1995). TFD and GD are physiological disorders of mangosteen fruits, TFD

1 Department of Plant Science, Faculty of Natural Resources, Prince of Songkla University, Hat Yai, Songkhla, 90112, Thailand.
2 Department of Earth Science, Faculty of Natural Resources, Prince of Songkla University, Hat Yai, Songkhla, 90112, Thailand.
* Corresponding author, e-mail: surachart.p@psu.ac.th

Received date : 26/04/07 Accepted date : 20/07/07

shows as water soaking of the flesh, wheareas, GD is a yellow gum in the rind or in the flesh (Pankasemsuk, *et al.*, 1996). The incidences of TFD and GD were caused by excess water during the pre-harvesting period, and they usually lead to fruit crack (Luckanatinvong, 1996). Chutinunthakun (2001) found that the threshold of TFD and GD incidence of mangosteen fruits subjected to excess water was around 9 weeks after blooming. Sdoodee and Limpun-Udom (2002) reported that the water could penetrate fruit rind and caused TFD and GD.

Kheoruenromn (1990) suggested that Ca deficiency might cause fruit-crack with relating to excess water in plant. Osotsapar (2000) reported that Ca could prevent fruit-crack. Limpun-Udom (2001) found that Ca and B concentrations in the peel and Ca concentration in the flesh of normal mangosteen fruit (NF) were high compared with TFD and GD fruits, whereas B concentration in the flesh of NF fruits were lower than those of TFD and GD fruits. An important role of B is to support Ca function in plant (Lim *et al.*, 2001). Boron deficiency results to limit plant growth and yield, although B deficiency does not cause visible symptom in plant (Osotsapar, 2000). Callan (1986) and Meheriuk *et al.* (1991) indicated that the application of $CaCl_2$, $Ca(OH_2)$ and H_3BO_3 compounds spraying during pre-harvesting stage could reduce fruits splitting in cherry. In addition, the impacts of excess water and the imbalance of deficiency essential nutrient in mangosteen tree might cause TFD and GD fruits. Therefore, fruit disorder symptoms need to be investigated as a guideline for fertilizer management to improve the mangosteen production.

This research was aimed to investigate the influenced of Ca and B spraying on the incidence of TFD and GD in mangosteen fruits.

MATERIALS AND METHODS

The experimental site

Two experiments were conducted at mangosteen orchards in Thung Song district, Nakhon Si Thammarat province, southern Thailand; (8°12’45”N, 99°42’00”E (site 1) and 8°10’45”N, 99°43’45”E (site 2)) (Figure 1).

The experimental design in filed

The experiments at site 1 and 2 were designed as factorial design with 2 main factors: 1) fruit positions (outer and inner canopy) and 2) concentration of Ca and B sprayed (wt/vol) (control (no spray), 5% $CaCl_2$, 10% $CaCl_2$, 5% $CaCl_2$+0.5 mg kg^{-1}B and 10% $CaCl_2$+0.5 mg kg^{-1}B). Ten treatments with 3 replications (1 tree/ replication), were completely randomized under field condition. Six mangosteen trees aged 15 years (at site 1 and 2) were used and sprayed 6, 7 and 8 weeks after blooming (Figure 2A and 2B).

Soil management

Soil sampling (4 soil cores/tree) were taken at 2 depths: 0-15 and 15-30 cm, from soil surface around the middle of tree canopy at the blooming period. The soils were air-dried, passed through a 2 mm sieve and analyzed for some chemical and physical properties as follow: soil texture (hydrometer) (Gee and Bauder, 1986), soil pH (soil:water = 1:5) (Mclean, 1982), soil electrical conductivity (EC) (soil:water = 1:5) (Rhoades, 1982), soil organic matter (OM) (rapid wet oxidation of Walkley and Black) (Nelson and Sommers, 1982), total N (kjeldahl) (Dennis, 1982), exchangeable cations; Ca, Mg and K (1M ammonium acetate pH 7.0) (Thomas, 1982), available P (bray 2) (Olsen and Sommers, 1982), available S [0.01 M $Ca(H_2PO_4)_2$] (Tabatabai, 1982) and available B (azomethine-H) (Aitken, *et al.*, 1987).

Plant analysis and fruit quality assessment

Ten leaves/tree (1 tree/replication) were taken for leaf samples at the blooming period. Ten leaves and 10 fruits/replication were taken for leaf and fruit samples of the 10 treatments at the harvesting period (12^{th}-13^{th} weeks of blooming).

Mangosteen leaves and fruits were cleaned by using deionized water, oven-dried by 68-80°C for 24-48 hours, passing through a 1-mm sieve and analysis for total Ca (wet digestion) and total B (azomethine-H) (Maneepong, 1994). The percentages of normal fruits:defect fruits (TFD and GD) in each treatment were assessed.

RESULTS AND DISCUSSION

Soil analysis

Soil chemical properties of two experimental sites are shown in Figure 3. Soil texture was sandy loam to sandy clay loam at site 1, while at site 2 was clay. The surface soils at site

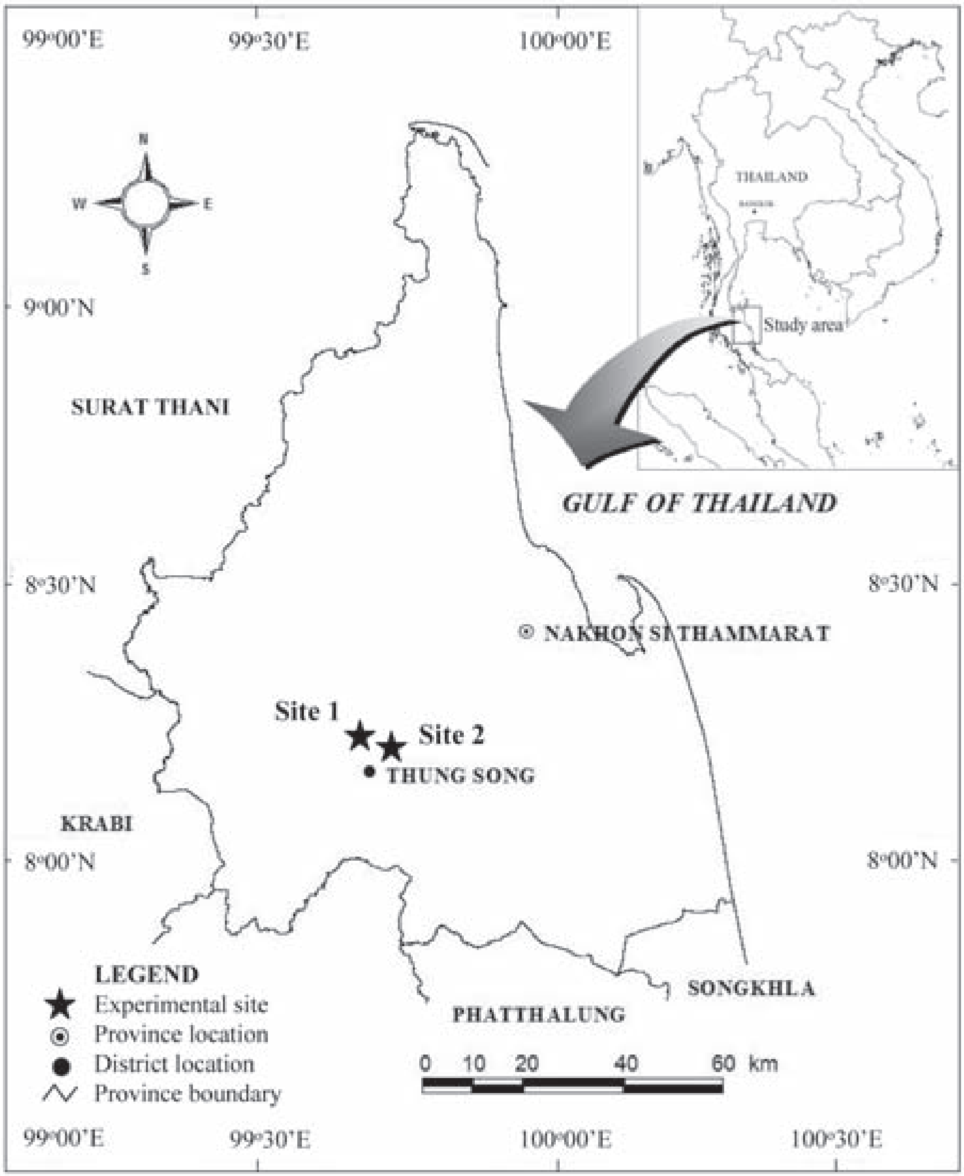

Figure 1 The experimental sites at Thung Song district, Nakhon Si Thammarat province, southern Thailand.

1 were extremely acid to very strongly acid with soil pH (soil:water = 1:5) ranging from 4.28-4.92 and were very extremely acid to extremely acid with soil pH ranging from 3.92-4.19 at site 2 (Figure 3A). Nilnond *et al*. (1995) and Pechkeo (1999) reported that pH of mangosteen soils in southern Thailand were low (3.50-5.72). At both sites, soil were very low in electrical conductivity content (0.04-0.19 dS m^{-1} (Figure 3B), exchangeable Ca (0.03-0.63 $cmol_c$ kg^{-1}) (Figure 3G) and exchangeable Mg (0.02-0.23 $cmol_c$ kg^{-1}) (Figure 3H) and low to very low in total N (0.71-1.29 g kg^{-1}) (Figure 3D), available S (4.14-10.62 mg kg^{-1}) (Figure 3I) and available B (0.45-0.89 mg kg^{-1}) (Figure 3J), low to medium in organic matter (9.44-19.78 g kg^{-1}) (Figure 3C) and exchangeable K (0.18-0.42 $cmol_c$ kg^{-1}) (Figure 3F), while available P (5.99-99.00 mg kg^{-1}) were

Figure 2 $CaCl_2$ and H_3BO_3 compounds spraying on mangosteen fruits. [(A) Before sprayed and (B) After sprayed].

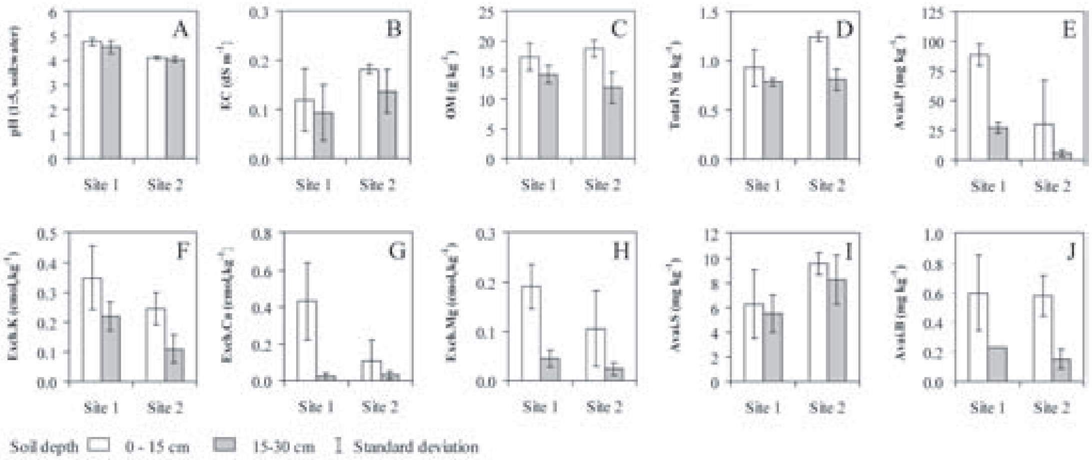

Figure 3 Average values of some soil chemical properties in experimental site.
[(A) Soil pH (B) Soil EC (C) Organic matter (D) Total nitrogen (E) Available phosphorus (F) Exchangeable potassium (G) Exchangeable calcium (H) Exchangeable magnesium (I) Available sulphur and (J) Available boron].

ranged from low to very high levels (Figure 3E) (Division of Land Use Planning, Department of Land Development, 1992). The essential nutrients in mangosteen soils were low for plant growth. Heavy rain may cause nutrients leaching from soils (Moncharoen, 2002) and the strongly acid soil condition could reduce an availability of some nutrients for plant growth (Department of Soil Science, 1998). Phosphorus was high accumulated in the soil, because it was fixed in the soil. The nutrient contents in mangosteen soils in southern Thailand as reported by Nilnond *et al*. (1995) and Pechkeo (1999) were as follow: available P and S (2.45-61.69 and 1.85-15.32 mg kg^{-1}, respectively) exchangeable K, Ca and Mg (0.10-0.26, 0.09-2.43 and 0.05-0.50 $cmol_c$ kg^{-1}, respectively) and extractable B (0.16-0.84 mg kg^{-1}).

Effects of Ca and B on fruit quality

The application of 10% $CaCl_2$ by spraying at the outer canopy could increase the highest ratio of NF:TFD and GD as 75.25±21.32:10.19±13.02:14.56±17.60 at site 1 and 77.11±24.53:5.18±8.93:17.71±21.80 at site 2, respectively (Figure 4 and 5).

The application of 10% $CaCl_2$ by spraying at the inner canopy could increase the highest ratio of NF:TFD and GD at site 1 as 86.94±15.20:6.11±9.93:9.72±12.40, respecttively, while at site 2, 5% $CaCl_2$ spraying gave the highest ratio of NF:TFD and GD as 84.17±18.61:10.83±14.72:5.00±15.81, respectively (Figures 4 and 5).

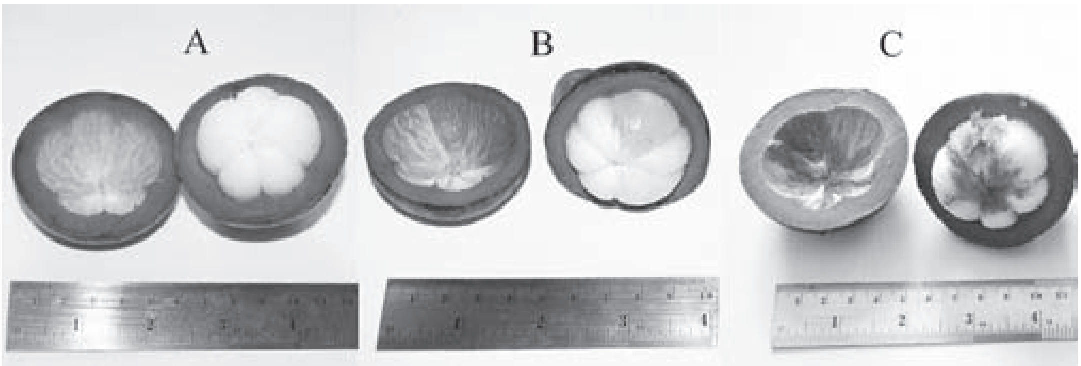

Figure 4 Mangosteen fruits at the harvesting period. [(A) NF fruit (B) TFD fruit and (C) GD fruit].

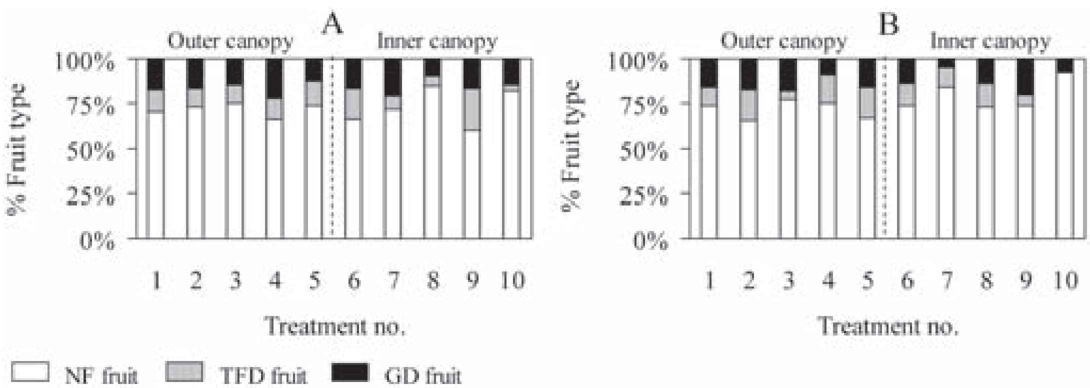

Figure 5 The percentages of mangosteen fruit qualities at the harvesting period, NF:TFD:GD fruits. [(A) Experimental site 1 and (B) Experimental site 2].

Leaf Ca and B concentrations

Leaf Ca and B concentrations in mangosteen of the outer and inner canopy trees were not significantly different leaf Ca concentrations of the outer canopy. At site 1&2 were 11.51-12.50 and 7.79-9.31 g kg^{-1}, respectively, while the inner canopy leaves were 12.18-13.35 and 7.65-9.45 g kg^{-1}, respectively (Table 1 and 2). Calcium concentrations of the inner canopy leaves tended to be higher than those of the outer canopy leaves. The application of $CaCl_2$ and H_3BO_3, accumulation of Ca was higher than the application of $CaCl_2$ alone, as reported by Poowarodom *et al*. (2002). In durian, Ca concentration in leaf increased with leaf age (Poowarodom *et al*., 2000). Calcium was an highly immobile nutrient (Marschner, 1995), accumulation of Ca was higher in the mature leaves than young leaves.

At site 1&2 boron concentrations of the outer canopy leaves were 28.07-42.97 and 30.51-34.86 mg kg^{-1}, respectively, and the inner canopy leaf were 26.59-33.58 and 30.44-34.87 mg kg^{-1}, respectively (Table 1 and 2). The results showed that B of the outer canopy leaf was higher than that of the inner canopy leaf.

Peel Ca and B concentrations

Table 3 shows Ca concentrations in mangosteen peel at the harvesting period to be not significantly different between outer and inner canopy fruits. In NF fruits of the outer canopy, spraying of 10% $CaCl_2$ gave the highest Ca concentration (1.94±0.14 g kg^{-1}) at site 1, while 5% $CaCl_2$+0.5 mg kg^{-1}B sprayed gave the highest Ca concentration (1.30±0.35 g kg^{-1}) at site 2. In NF fruits of the inner canopy, spraying of 10% $CaCl_2$+0.5 mg kg^{-1}B gave the highest Ca concentration (1.88±0.51 g kg^{-1}) at site 1, and 10% $CaCl_2$ spraying gave the highest Ca concentration (1.10±0.15 g kg^{-1}) at site 2. Calcium concentrations in peel of NF fruits were higher than TFD and GD fruits at both sites. It was found that spraying with $CaCl_2$ and H_3BO_3 Ca concentration in the peel was likely to be higher than spraying with $CaCl_2$, especially in the inner canopy fruits.

Table 4 shows that B concentrations in mangosteen peel at the harvesting period to be not significantly different between outer and inner canopy fruits. In NF fruits of the outer canopy, control treatment (no nutrients spraying) gave the highest B concentration (6.70±0.51 mg kg^{-1}) at site 1, while 5% $CaCl_2$+0.5 mg kg^{-1}B spraying gave the highest B concentration (12.36±3.90 mg kg^{-1}) at site 2. In NF fruits of the inner canopy, spraying of 10% $CaCl_2$+0.5 mg kg^{-1}B gave the highest B concentration (7.75±1.76 mg kg^{-1}) at site 1, and the control gave the highest B concentration (7.55±3.23 mg kg^{-1}) at site 2. The NF fruits peels, B concentrations were higher than TFD and GD fruits (all canopy fruits), suggesting that spraying with 5% $CaCl_2$+0.5 mg kg^{-1}B resulted in higher B concentration in peel than the other applications.

Flesh Ca and B concentrations

Calcium concentrations in mangosteen flesh are shown in Table 5. Flesh Ca concentrations in mangosteen at harvesting period were not significantly different between outer and inner canopy fruits. In NF fruits of the outer canopy,

Table 1 Concentrations of calcium and boron in mangosteen leaf at blooming period.

Leaf positions	Leaf Ca concentrations (g kg^{-1})		Leaf B concentrations (mg kg^{-1})	
	Site 1	Site 2	Site 1	Site 2
Outer canopy	9.38 ± 0.92	6.78 ± 0.91	26.65 ± 4.86	31.30 ± 6.20
Inner canopy	10.09 ± 1.63	7.30 ± 0.74	27.30 ± 2.45	37.45 ± 1.60
T-test	NS	NS	NS	NS

Remark: NS = No significant difference

Table 2 Concentrations of calcium and boron in mangosteen leaf at harvesting period.

Treatments	Leaf Ca concentrations (g kg^{-1})						Leaf B concentrations (mg kg^{-1})					
	Site 1			Site 2			Site 1			Site 2		
	Outer canopy	Inner canopy	T-test	Outer canopy	Inner canopy	T-test	Outer canopy	Inner canopy	T-test	Outer canopy	Inner canopy	T-test
Control	12.22 ± 1.14	12.18 ± 2.70	NS	7.84 ± 0.42	8.45 ± 1.03	NS	42.98 ± 8.44^{a}	33.59 ± 5.79	NS	32.92 ± 2.92	30.44 ± 3.97	NS
5% $CaCl_2$	12.28 ± 1.38	12.21 ± 1.87	NS	8.03 ± 1.15	8.21 ± 1.70	NS	34.80 ± 1.94^{ab}	29.76 ± 4.41	NS	34.87 ± 2.35	30.76 ± 5.44	NS
10% $CaCl_2$	11.52 ± 1.46	13.35 ± 3.20	NS	7.79 ± 0.21	9.45 ± 2.45	NS	28.08 ± 5.71^{b}	27.77 ± 2.41	NS	33.08 ± 8.94	34.52 ± 2.96	NS
5% $CaCl_2$±0.5 mg kg^{-1} B	11.71 ± 2.10	12.82 ± 2.23	NS	9.32 ± 0.77	8.40 ± 1.61	NS	32.99 ± 4.14^{b}	26.59 ± 3.36	NS	30.52 ± 2.90	34.87 ± 8.75	NS
10% $CaCl_2$±0.5 mg kg^{-1}B	12.51 ± 2.40	12.42 ± 1.40	NS	8.48 ± 1.80	7.66 ± 0.38	NS	30.21 ± 1.24^{b}	29.74 ± 3.77	NS	33.19 ± 8.65	34.84 ± 5.20	NS
F-test	NS	NS		NS	NS		*	NS		NS	NS	
% C.V.	14.62	18.76		12.48	18.90		14.86	13.92		18.07	16.97	

Remark: Values in the same column followed by different letters are significantly different at the probability level $P < 0.05$
* = Significant difference at $P < 0.05$
NS = No significant difference

Table 3 Concentration of calcium in mangosteen peel at harvesting period.

Treatments	Fruit positions	Peel Ca concentrations (g kg^{-1})									
		Site 1					Site 2				
		NF	TFD	GB	F-test	%C.V.	NF	TFD	GB	F-test	%C.V.
Control	Outer canopy	1.18 ± 0.33	1.12 ± 0.09	1.68 ± 0.54	NS	29.06	0.92 ± 0.08	0.80 ± 0.13	0.97 ± 0.00	NS	12.16
	Inner canopy	1.35 ± 0.32	1.08 ± 0.18	1.12 ± 0.34	NS	23.08	0.85 ± 0.08	0.74 ± 0.16	0.68 ± 0.16	NS	18.37
	T-test	NS	NS	NS			NS	NS	NS		
5% $CaCl_2$	Outer canopy	1.74 ± 0.37	1.54 ± 0.25	1.32 ± 0.00	NS	20.38	1.14 ± 0.17	0.94 ± 0.00	1.12 ± 0.08	NS	12.19
	Inner canopy	1.45 ± 0.44	1.32 ± 0.32	1.27 ± 0.32	NS	26.09	1.04 ± 0.15	0.94 ± 0.31	ND	NS	26.58
	T-test	NS	NS	NS			NS	NS	-		
10% $CaCl_2$	Outer canopy	1.94 ± 0.14^{a}	1.63 ± 0.21^{b}	1.71 ± 0.46^{ab}	*	17.52	1.22 ± 0.12	0.85 ± 0.06	1.02 ± 0.00	NS	11.71
	Inner canopy	1.60 ± 0.30	1.64 ± 0.61	1.08 ± 0.24	NS	18.44	1.10 ± 0.15	0.78 ± 0.00	1.03 ± 0.08	NS	11.63
	T-test	NS	NS	NS			NS	NS	NS		
5% $CaCl_2$±0.5 mg kg^{-1}B	Outer canopy	1.74 ± 0.44	1.69 ± 0.23	1.69 ± 0.02	NS	22.63	1.30 ± 0.35	0.80 ± 0.11	0.91 ± 0.00	NS	24.84
	Inner canopy	1.53 ± 0.22	1.26 ± 0.49	1.25 ± 0.33	NS	20.92	1.05 ± 0.28	0.90 ± 0.23	1.04 ± 0.00	NS	26.78
	T-test	NS	NS	NS			NS	NS	NS		
10% $CaCl_2$±0.5 mg kg^{-1}B	Outer canopy	1.75 ± 0.26^{a}	1.37 ± 0.05^{b}	2.03 ± 0.44^{a}	*	19.19	1.08 ± 0.17	0.93 ± 0.26	0.80 ± 0.17	NS	22.05
	Inner canopy	1.88 ± 0.51	1.74 ± 0.59	1.44 ± 0.27	NS	23.80	1.05 ± 0.15	0.89 ± 0.00	1.21 ± 0.00	NS	13.86
	T-test	NS	NS	NS			NS	NS	NS		

Remark: Values in the same row followed by different letters are significantly different at the probability level $P < 0.05$
* = Significant difference at $P < 0.05$
NF = normal fruit; TFD = translucent flesh disorder fruit; GD = gamboge disorder fruit
NS = No significant difference; ND = Not detected

Table 4 Concentration of boron in mangosteen peel at harvesting period.

Treatments	Fruit positions	Peel B concentrations (mg kg^{-1})									
		Site 1					Site 2				
		NF	TFD	GB	F-test	%C.V.	NF	TFD	GB	F-test	%C.V.
Control	Outer canopy	6.70 ± 0.51	4.99 ± 1.26	5.35 ± 2.44	NS	28.42	5.25 ± 4.63	3.45 ± 1.23	3.23 ± 0.00	NS	80.92
	Inner canopy	3.72 ± 1.59	5.45 ± 1.07	3.39 ± 2.24	NS	36.66	7.55 ± 3.23^{a}	3.81 ± 1.06^{ab}	2.03 ± 0.74^{b}	*	44.99
	T-test	*	NS	NS			NS	NS	NS		
5% $CaCl_2$	Outer canopy	6.14 ± 0.85	6.70 ± 0.97	4.30 ± 0.00	NS	14.82	5.47 ± 1.64	3.58 ± 0.00	3.12 ± 0.42	NS	28.59
	Inner canopy	3.82 ± 1.46	3.93 ± 0.48	5.20 ± 1.45	NS	30.14	7.99 ± 3.97	4.28 ± 0.99	ND	NS	61.93
	T-test	NS	*	NS			NS	NS	-		
10% $CaCl_2$	Outer canopy	4.01 ± 0.62	6.41 ± 1.52	4.63 ± 1.20	NS	23.41	6.88 ± 4.28	3.05 ± 1.26	3.58 ± 2.49	NS	68.84
	Inner canopy	4.78 ± 0.45	3.57 ± 2.50	9.18 ± 6.39	NS	60.52	6.32 ± 1.18	5.68 ± 0.00	3.59 ± 1.41	NS	25.63
	T-test	NS	NS	NS			NS	NS	NS		
5% $CaCl_2$±0.5 mg kg^{-1}B	Outer canopy	5.84 ± 2.26	7.37 ± 1.01	4.29 ± 0.51	NS	26.21	12.36 ± 3.90^{a}	3.59 ± 1.55^{b}	1.81 ± 0.00^{b}	*	41.88
	Inner canopy	6.04 ± 1.32	4.86 ± 1.22	5.34 ± 0.49	NS	21.38	7.41 ± 4.56	5.84 ± 1.73	4.99 ± 0.00	NS	59.39
	T-test	NS	NS	NS			NS	NS	NS		
10% $CaCl_2$±0.5 mg kg^{-1}B	Outer canopy	5.25 ± 0.28	4.75 ± 1.39	6.13 ± 1.76	NS	24.34	7.55 ± 4.18	2.88 ± 0.94	1.27 ± 0.26	NS	64.22
	Inner canopy	7.75 ± 1.76	4.97 ± 0.99	4.87 ± 0.69	NS	21.35	5.82 ± 3.94	3.59 ± 0.00	3.58 ± 0.00	NS	80.01
	T-test	NS	NS	NS			NS	NS	NS		

Remark: Values in the same row followed by different letters are significantly different at probability level P < 0.05
* = Significant difference at P < 0.05
NF = normal fruit; TFD = translucent flesh disorder fruit; GD = gamboge disorder fruit
NS = No significant difference; ND = Not detected

Table 5 Concentration of calcium in mangosteen flesh at harvesting period.

Treatments	Fruit positions	Flesh Ca concentrations (g kg^{-1})									
		Site 1					Site 2				
		NF	TFD	GB	F-test	%C.V.	NF	TFD	GB	F-test	%C.V.
Control	Outer canopy	1.19 ± 0.08	1.07 ± 0.55	1.54 ± 0.64	NS	38.55	0.89 ± 0.14	0.79 ± 0.04	1.73 ± 0.00	NS	36.92
	Inner canopy	1.05 ± 0.12	0.98 ± 0.15	0.65 ± 0.00	NS	13.68	0.94 ± 0.18	0.93 ± 0.23	0.84 ± 0.03	NS	18.93
	T-test	NS	NS	NS			NS	NS	NS		
5% $CaCl_2$	Outer canopy	1.44 ± 0.11	1.56 ± 0.85	1.81 ± 1.22	NS	48.78	1.01 ± 0.11	ND	1.11 ± 0.05	NS	40.37
	Inner canopy	2.09 ± 0.91	1.24 ± 0.07	1.32 ± 0.17	NS	36.95	0.75 ± 0.23	1.23 ± 0.19	ND	NS	28.58
	T-test	NS	NS	NS			NS	-	-		
10% $CaCl_2$	Outer canopy	2.11 ± 0.42^{a}	0.91 ± 0.08^{b}	1.35 ± 0.47^{ab}	*	26.23	0.89 ± 0.15	1.12 ± 0.15	1.29 ± 0.43	NS	24.14
	Inner canopy	1.34 ± 0.32	1.51 ± 0.93	1.40 ± 0.22	NS	37.63	1.10 ± 0.21	1.01 ± 0.00	1.03 ± 0.32	NS	25.50
	T-test	NS	NS	NS			NS	NS	NS		
5% $CaCl_2$±0.5 mg kg^{-1}B	Outer canopy	1.24 ± 0.28	1.50 ± 0.75	1.47 ± 0.36	NS	36.18	1.06 ± 0.39	1.21 ± 0.20	0.93 ± 0.17	NS	26.40
	Inner canopy	1.47 ± 0.65	2.16 ± 0.29	1.05 ± 0.07	NS	29.35	1.02 ± 0.14	0.80 ± 0.00	0.86 ± 0.00	NS	15.19
	T-test	NS	NS	NS			NS	NS	NS		
10% $CaCl_2$±0.5 mg kg^{-1}B	Outer canopy	1.50 ± 0.50	1.40 ± 0.44	1.40 ± 0.55	NS	34.90	1.26 ± 0.21	1.03 ± 0.28	1.03 ± 0.00	NS	22.01
	Inner canopy	1.46 ± 0.78	1.22 ± 0.01	1.20 ± 0.56	NS	47.16	0.91 ± 0.09^{b}	0.73 ± 0.02^{c}	1.65 ± 0.00^{a}	**	7.26
	T-test	NS	NS	NS			NS	NS	NS		

Remark: Values in the same row followed by different letters are significantly different at the probability level P < 0.05 or P < 0.01
* = Significant difference at P < 0.05 ** = Significant difference at P < 0.01
NF = normal fruit; TFD = translucent flesh disorder fruit; GD = gamboge disorder fruit
NS = No significant difference; ND = Not detected

spraying of 10% $CaCl_2$ gave the highest Ca concentration (2.11±0.42 g kg^{-1}) at site 1, while 10% $CaCl_2$+0.5 mg kg^{-1}B spraying gave the highest Ca concentration (1.26±0.21 g kg^{-1}) at site 2. In NF fruits of the inner canopy, spraying of 5% $CaCl_2$ gave the highest Ca concentration (2.09±0.91 g kg^{-1}) at site 1, and 10% $CaCl_2$ spraying gave the highest Ca concentration (1.10±0.21 g kg^{-1}) at site 2. Calcium concentrations in flesh of NF fruits were higher than TFD and GD fruits, especially of that inner canopy fruits, suggesting that $CaCl_2$ compounds spraying was likely to increase Ca concentration in flesh greater than other applications.

Boron concentrations in mangosteen flesh one shown in Table 6. Flesh B concentrations of outer and inner canopy fruits at harvesting period were not significantly different. In NF fruits of the outer canopy, control treatment gave the highest B concentration (4.51±1.17 and 7.27±1.03 mg kg^{-1}) at site 1 and 2. In NF fruits of the inner canopy, spraying of 10% $CaCl_2$+0.5 mg kg^{-1}B gave the highest B concentration (8.77±3.61 mg kg^{-1}) at site 1, and the control gave the highest B concentration (7.00±0.77 mg kg^{-1}) at site 2. The NF fruits flesh, B concentrations was lower than TFD and GD fruits (all canopy fruits). These results suggested that 10% $CaCl_2$+0.5 mg kg^{-1}B spraying resulted in higher B concentration in flesh than the other applications at outer canopy, and 5% $CaCl_2$+0.5 mg kg^{-1}B at inner canopy fruits.

Effects of Ca and B on the improvement of mangosteen fruit quality

Calcium and B were phloem immobile nutrients, therefore, they were not directly transferred from leaves to fruits (Osotsapar, 2000). Calcium is an essential element, and its function was to strengthen

Table 6 Concentration of boron in mangosteen flesh at harvesting period.

Treatments	Fruit positions	Flesh B concentrations (mg kg^{-1})									
		Site 1					Site 2				
		NF	TFD	GB	F-test	%C.V.	NF	TFD	GB	F-test	%C.V.
Control	Outer canopy	4.51 ± 1.17	6.34 ± 2.76	6.66 ± 2.75	NS	40.24	7.27 ± 1.03	6.18 ± 1.23	3.30 ± 0.00	NS	18.19
	Inner canopy	3.42 ± 0.24^c	11.75 ± 1.45^a	8.86 ± 0.00^b	*	13.41	7.00 ± 0.77	10.35 ± 2.22	8.12 ± 1.46	NS	18.84
	T-test	NS	*	NS			NS	*	*		
5% $CaCl_2$	Outer canopy	3.51 ± 1.58	4.98 ± 1.67	7.78 ± 0.72	NS	29.02	6.62 ± 0.89	ND	6.62 ± 2.32	NS	30.65
	Inner canopy	9.68 ± 3.59	11.35 ± 1.10	13.09 ± 2.00	NS	23.24	7.07 ± 1.04	8.97 ± 1.32	ND	NS	20.97
	T-test	NS	*	*			NS	-	-		
10% $CaCl_2$	Outer canopy	5.14 ± 2.34	3.92 ± 1.06	6.95 ± 0.63	NS	29.15	5.47 ± 1.26	6.43 ± 2.03	9.21 ± 1.62	NS	23.14
	Inner canopy	8.03 ± 1.86	8.87 ± 1.16	11.19 ± 1.96	NS	19.00	4.76 ± 2.02	2.53 ± 0.00	7.31 ± 0.68	NS	27.19
	T-test	NS	*	NS			NS	NS	NS		
5% $CaCl_2$±0.5 mg kg^{-1}B	Outer canopy	2.77 ± 1.35	5.33 ± 2.35	6.35 ± 1.71	NS	38.46	5.57 ± 2.02	4.99 ± 2.95	8.32 ± 0.38	NS	37.55
	Inner canopy	6.13 ± 1.00	9.15 ± 0.89	7.17 ± 2.90	NS	27.19	4.23 ± 1.46	9.07 ± 0.00	9.56 ± 0.00	NS	23.35
	T-test	*	NS	NS			NS	NS	NS		
10% $CaCl_2$±0.5 mg kg^{-1}B	Outer canopy	3.02 ± 1.44^b	10.18 ± 1.05^a	9.99 ± 3.56^a	*	29.77	6.46 ± 1.36	9.86 ± 1.27	9.84 ± 0.00	NS	15.64
	Inner canopy	8.77 ± 3.61	7.98 ± 0.17	6.39 ± 1.96	NS	34.78	2.07 ± 0.88^b	7.79 ± 1.44^a	8.09 ± 0.00^a	*	22.06
	T-test	NS	NS	NS			*	NS	NS		

Remark: Values in the same row followed by different letters are significantly different at $P<0.05$ or $P<0.01$
* = Significant difference at $P < 0.05$
** = Significant difference at $P < 0.01$
NF = normal fruit; TFD = translucent flesh disorder fruit; GD = gamboge disorder fruit
NS = No significant difference; ND = Not detected

peel cells (Sutthipradit, 1993), while B is a support Ca function in plant (Lim *et al*., 2001). Therefore, nutrient spraying is an alternative method for increasing peel and flesh Ca and B concentration on transferring through fruit layer. Table 3, 4, 5 and 6 show Ca concentration in fruits to increase with spraying of $CaCl_2$ and H_3BO_3 compounds. Ten percent $CaCl_2$ spraying during 6-8 weeks of mangosteen fruit development reduced the number of TFD and GD fruits (all canopy fruits), and the percentages of NF fruits were higher than TFD and GD fruits (all canopy fruits) (Figure 5). The percent reduction of fruits splitting in Shogun mandarin (Sdoodee and Chiarawipa, 2005) and longkong (Rattanapong, 1995) was reported. Calcium concentrations in TFD and GD fruits were lower than NF fruits. Spraying of 10% $CaCl_2$+0.5 mg kg^{-1}B to mangosteen fruit was likely to increase the ratio of NF:TFD and GD. It showed that B might have a synergistic effect on Ca function to increase the ratio of mangosteen fruit qualities (NF:TFD:GD). Therefore, this study suggested that Ca and B sprayed could be used as an alternative method to reduce the incidence of TFD and GD in mangosteen fruits.

CONCLUSIONS

The mangosteen soil at Thung Song district, Nakhon Si Thammarat province was very extremely acid to very strongly acid, and low essential nutrients for mangosteen growth. The application of $CaCl_2$ and H_3BO_3 compounds by spraying could increase Ca and B concentrations in peel and flesh of mangosteen fruits. Spraying with 10% $CaCl_2$, the percentage of normal fruits increased, whereas the percentages of defect fruits (TFD and GD) decreased. Ten percents of $CaCl_2$+0.5 mg kg^{-1}B spraying could enhance the efficiency of Ca to increase the ratio of NF:TFD and GD.

ACKNOWLEDGEMENTS

We wish to thank Commission of Higher Education, Ministry of Education and Graduate School, Prince of Songkla University for financial support in this study.

LITERATURE CITED

Aitken, R.L., A.J. Jeffery and B.L. Compton. 1987. Evaluation of selected extractants for boron in some Queensland soils. **Aust. J. Soil Res.** 25: 263-273.

Callan, N.W. 1986. Calcium hydroxide reduces splitting of "Lambert" sweet cherry. **J. Amer. Soc. Hort. Sci.** 111(2): 173-175.

Chutinuntakun, T. 2001. **Prevention of the Incidence of Translucent Flesh Disorder and Internal Gumming Fruits in Mangosteen (*Garcinia mangostana* L.) and Screening Techniques.** M.Sc. Thesis. Prince of Songkla University, Songkhla.

Dennis, R.K. 1982. Nitrogen-availability, pp. 711-733. *In* A.L. Page, R.H. Miller and D.R. Keeney (eds.). **Methods of Soil Analysis Part 2: Chemical and Microbiological Properties.** 2nd ed. Madison Publisher Wisconsin.

Department of Soil Science. 1998. **Principles of Soil Science.** 8th ed. Kasetsart University, Thailand. 547 p.

Division of Land Use Planning, Department of Land Development. 1992. **Qualitative Land Evaluations.** Ministry of Agriculture and Co-operatives, Thailand. 65 p.

Gee, G.W. and J.W. Bauder. 1986. Particle-size analysis, pp. 383-412. *In* A. Klute (ed.). **Method of Soil Analysis Part 1: Physical and Mineralogical Methods.** Madison Publisher. Wisconsin.

Kheoruenromn, I. 1990. **Soil of Thailand.** Department of Soil Science, Kasetsart University, Bangkok.

Lim, M., S. Sdoodee, S. Chanawerawan and C. Onthong. 2001. Growth pattern and phonological development of longkong (*Aglai dookoo* Griff.). **Songklanakarin J. Sci. Technol.** 23(4): 467-478.

Limpun-Udom, S. 2001. **Influence of Water on the Incidence of Translucent Flesh Disorder in Mangosteen (*Garcinia mangostana* L.) Fruits.** M.Sc. Thesis. Prince of Songkla University, Songkhla.

Luckanathinvong, V. 1996. **The Study on Chemical Composition, Cell Viability and Influence of Water on Translucent Flesh Disorder in Mangosteen (*Garcinia mangostana* L.).** M.Sc. Thesis. Kasetsart University, Bangkok.

Maneepong, S. 1994. **Soil and Plant Analysis.** Department of Earth Science, Faculty of Natural Resources, Prince of Songkla University, Songkhla. 200 p.

Marschner, H. 1995. **Mineral Nutrition of Higher Plants.** 2nd ed. Acadamic Press. New York. 889 p.

Mclean, E.O. 1982. Soil pH and lime requirement, pp. 199-224. *In* A.L. Page, R.H. Miller and D.R. Keeney (eds.). **Methods of Soil Analysis Part 2: Chemical and Microbiological Properties.** 2nd ed. Madison Publisher. Wisconsin.

Meheriuk, M., G.H. Neilsen and D.L. Mekenzic. 1991. Incidence of rain splitting in sweet cherries treated with calcium or coating materials. **Can. J. Plant Sci.** 71(1): 231-234.

Moncharoen, P. 2002. **Soil Analysis Interpretation for Soil Improvement and Fertilizer Recommendation.** Department of Land Development, Ministry of Agriculture and Co-operatives, Thailand. 216 p.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon and organic matter, pp. 539-579. *In* A.L. Page, R.H. Miller and D.R. Keeney (eds.). **Methods of Soil Analysis Part 2: Chemical and Microbiological Properties**. 2nd ed. Madison Publisher Wisconsin.

Nilnond, C., W. Jatupote, W. Leowarin and S. Yong. 1995. Chemical fertility status of some growing mangosteen soil in southern Thailand. **Songklanakarin J. Sci. Technol.** 17(4): 381-393.

Olsen, S.R. and L.E. Sommers. 1982. Phosphorus, pp. 403-430. *In* A.L. Page, R.H. Miller and D.R. Keeney (eds.). **Methods of Soil Analysis Part 2: Chemical and Microbio-logical Properties.** 2nd ed. Madison Publisher Wisconsin.

Osotsapar, Y. 2000. **Plant Nutritions.** Department of Soil science, Faculty of Agriculture, Kasetsart University, Bangkok. 424 p.

Pankasemsuk, T., J.O. Garner, F.B. Mattar and J.L. Silva. 1996. Translucent flesh disorder of mangosteen fruit (*Garcinia mangostana* L.). **HortScience** 31(1): 112-113.

Pechkeo, S. 1999. **Research report: Land Potential for Mangosteen Cultivation in Southern Thailand; Some Soil Properties of Mangosteen Soil in Southern Thailand; Some Soil Properties of Mangosteen Soil in Namom District, Songkhla Province**. Department of Earth Science, Faculty of Natural Resources, Prince of Songkla University, Songkhla.

Poowarodom, S., P. Kanyawongha, P. Lertrat and N. Boonplang. 2002. Leaf age and position on mineral composition of mangosteen leaves, paper no. 2272. *In* **Transection of the 17th World Congress of Soil Science, Symposium no.16.** 14-21 August, Bangkok.

Poowarodom, S., N. Tawinteung, S. Mairaing, J. Prasittikhet and P. Ketsayom. 2000. Seasonal variations in nutrient concentrations of durian (*Durio zibethinus* Murr.) leaves. **Acta Hort.** 564: 235-242.

Rattanapong, J. 1995. **Feasibility Study to Alleviate the Fruit-crack of Longkong**

(*Lansium domestticum* Corr.) by Calcium Chloride Application. M.Sc. Thesis. Prince of Songkla University, Songkhla.

Rhoades, J.D. 1982. Soluble salts, pp. 167-179. *In* A.L. Page, R.H. Miller and D.R. Keeney (eds.). **Methods of Soil Analysis Part 2: Chemical and Microbio-logical Properties.** 2nd ed. Madison Publisher. Wisconsin.

Sdoodee, S. and R. Chiarawipa. 2005. Fruit splitting occurrence of Shogun mandarin (*Citrus reticulate* Blanco cv. Shogun) in southern Thailand and alleviation by calcium and boron sprays. **Songklanakarin J. Sci. Technol.** 27(4): 719-730.

Sdoodee, S. and S. Limpun-Udom. 2002. Effect of excess water on the incidence of translucent flesh disorder in mangosteen (*Garcinia mangostana* L.) **Acta Hort.** 575: 813-820.

Sutthipradit, S. 1993. **Soil Fertility.** Department of Earth Science, Faculty of Natural Resources, Prince of Songkla University, Songkhla. 349 p.

Tabatabai, M.A. 1982. Sulfur, pp. 501-538. *In* A.L. Page, R.H. Miller and D.R. Keeney (eds.). **Methods of Soil Analysis Part 2: Chemical and Microbiological Properties.** 2nd ed. Madison Publisher. Wisconsin.

Thomas, G.W. 1982. Exchangeable cations, pp. 159-165. *In* A.L. Page, R.H. Miller and D.R. Keeney (eds.). **Methods of Soil Analysis Part 2: Chemical and Microbiological Properties.** 2nd ed. Madison Publisher Wisconsin.

Yaacob, O. and H.D. Tindall. 1995. **Mangosteen Cultivation.** FAO. Rome. 103 p.