Chapter 3

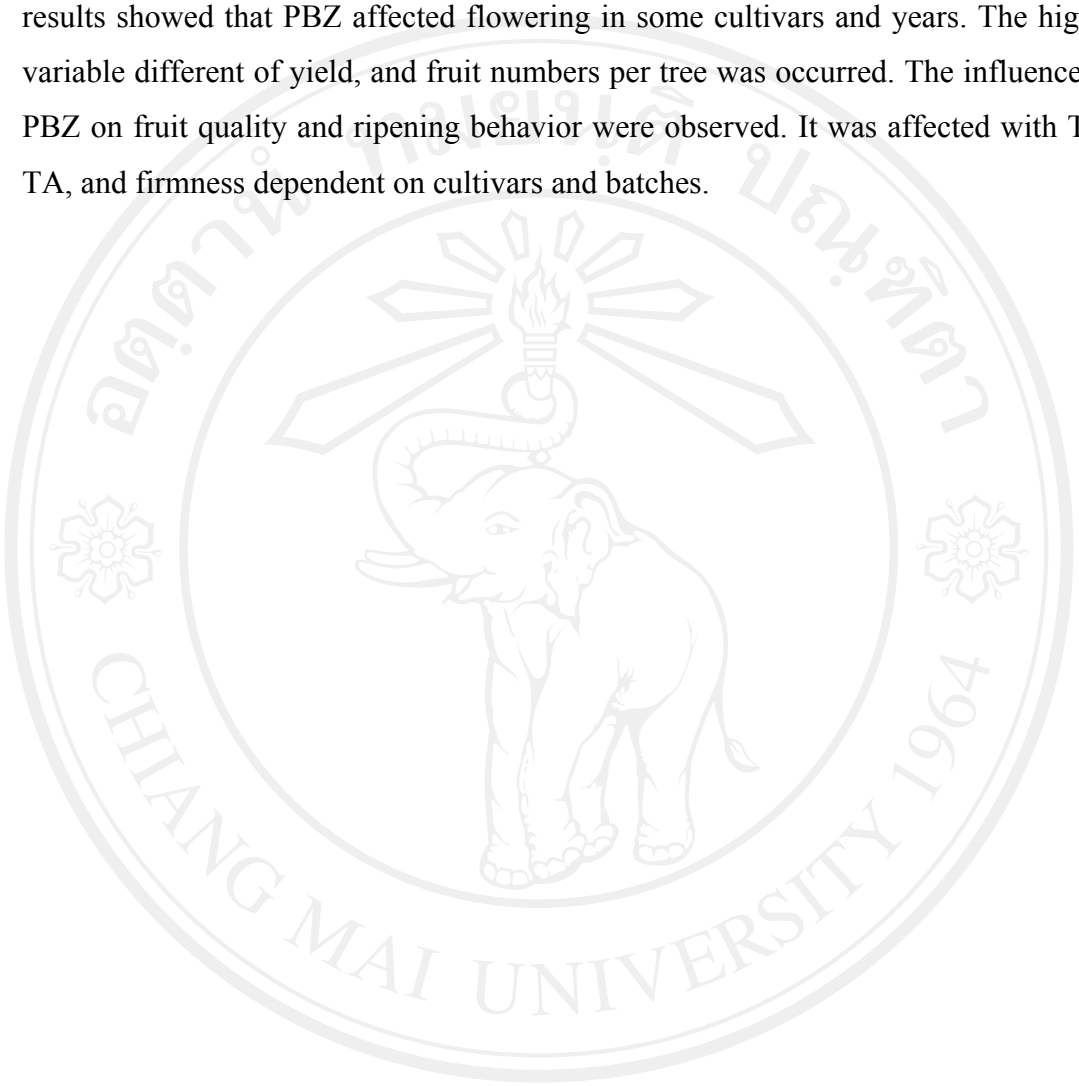
Effect of PBZ on Physico-Chemical Properties of Mango Fruits

3.1 Abstract

The objective of this study was to appraise the effect of PBZ (PBZ) on physical and chemical properties and postharvest ripening behaviour of mangoes cultivars 'Chok Anan' (CA), 'Nam Dok Mai' (ND), and Khiew Sawoey (KS). For inducing the off-season flowering in mango, the first experiment, PBZ was applied as a soil drench technique with concentration 0, 0.5 and 1.0 g *a.i*. per square meter and Pro-Ca 0.5 g *a.i*. per square meter on 8 years old trees of Chok Anan. The effect of the application at those concentrations was studied. The trees were investigated for two consecutive years in the term of physical and chemical properties. The results form the current experiment revealed that PBZ in different concentration had not significant effect with respect to the yield per tree, but there were significant with number of fruit per tree and the weight per fruit (for crop year 2004). Conversely, there was a statistically significant difference among the treatments in the term of the flowering, fruit proportion, fruit size distribution and the weight per fruit (for crop year 2005). In addition, fruit qualities in 2 stages (mature green and ripen) were compared with the control. PBZ in different concentration was affected with fruit quality parameters in both stages.

The second experiment, the Nam Dok Mai cultivar was only treated with PBZ 0, 1.0 g *a.i*. per square meter. In addition, Khiew Sawoey was also only applied by PBZ 0, 1.5 g *a.i*. per square meter on 16 - 17 years old trees. However, the Chok Anan was included, and only treated with PBZ 0, 1.0 g *a.i*. per square meter on 8 years old trees. All cultivars were used for studying the effect of PBZ on cultivar which compared between treated and untreated trees. The trees were assessed for three consecutive years in term percentage of flowering, fruit yield; numbers of fruits, fruit size distribution and fruit proportion. Mango fruits were harvested in full green

mature stage and ripen at 28 ± 2˚C, 58–83 % RH. The quality was determined in the term of total soluble solid (TSS), pH, total acid (TA), firmness (F) and colour. The results showed that PBZ affected flowering in some cultivars and years. The highest variable different of yield, and fruit numbers per tree was occurred. The influences of PBZ on fruit quality and ripening behavior were observed. It was affected with TSS, TA, and firmness dependent on cultivars and batches.



3.2 Introduction

Effects of off-season fruit production on fruit quality are expected to be markedly dependent on climate conditions during cultivation and planned harvest dates, respectively. PBZ a potent growth retardant has been connected with ripening in strawberry (Atkinson and Crisp, 1986), and mangoes (Singh and Dhillon, 1992; Kurian and Iyer, 1993).

The PBZ effects of fruits quality have been reported by Salazar-Garcia and Vazquez-Valdivia (1997) indicating that when the quality of PBZ treated 'Tommy Atkins' mango was observed over 3 years, only with low PBZ rate (2.5 and 5 g/tree) affected TSS of fruit juice, but the rates significantly higher at ≥ 10 g/tree. On the contrary, Yadava and Singh (1998) treated 'Dashehari' mango trees with PBZ at the ratio of 2, 4, and 6 g/tree as soil drench. Result showed that PBZ increased number of fruits and yield, maximum effect was found at 4 g/tree. Fruit firmness and pH were little affected by the treatments, but increased TSS and yellowness index. Whereas opposite findings for TSS were reported by Kurian and Iyer (1993) for 'Alphonso' mangoes. The experiment of Singh and Dhillon (1992) reported that the foliar and soil drench treatments of Cultar at 0, 10, 20, 40, and 60 g/tree in cv. 'Dusehri' did not significantly affect fruit weight and pulp stone ratio. Foliar application of Cultar increased the TSS of the fruit, whereas soil application of Cultar was less effective than foliar application increased the acid content of the fruit compared with the controls. Only the soil application of Cultar (20 g/tree) significantly increased the sugar acid ratio, compared with the controls and all other treatments, except foliar spray application (60 g/tree), which was at par. The increase in sugar acid ratio may be attributed to the decreased acid content of the fruit and increased TSS of the fruit. It was also reported that the fruit yield was significantly highest (27.2 kg/tree) with the soil application of Cultar (20 g/tree) as compared to all other treatments

Although the chemical has dramatic effects on reducing vegetative growth, its effects on mangoes fruits ripening are variable. It depends on mangoes cultivars, climate conditions during cultivation and planned harvest dates, respectively. The

present work aims to study the effect of PBZ as a preharvest treatment on postharvest ripening behaviour for a comprehensive databank on fruit quality of Northern Thai mangoes. Moreover, the potential of prohexadione-calcium as an alternative growth regulator was explored. It was applied by foliar spraying and compared to Chok Anan treated with PBZ and control treatments at D plot.

3.3 Methods and Materials

3.3.1 Application of paclobutrazol to mango trees

A field experiment was conducted at a mango orchard consisting of 8 year old mango trees (cultivar Chok Anan) located at Mae Jo University field (MJU), Chiang Mai province, Thailand (altitude 380 meters above sea level and the soil was Skeleti-Anthropic regosol). Other experiments were conducted at San Sai orchard (SS) (altitude 350 meters above sea level and the soil was sand), Chiang Mai province, Thailand consisting of 16-17 year old mango trees (cultivars Nam Dok Mai, Khiew Sawoey). PBZ-10 (WP) produced in China and distributed by WESCO Ltd, Bangkok, Thailand, was used as growth retardant and normally procured from Chiang Mai city market. PBZ was applied to the tree basin soil (under the canopy), called 'soil drench technique'. Trees in 5-10 replicates (1 tree represented 1 replicate) were maintained for each of the treatments in plot D and B (Figure 3.1, 9.1) at Mae Jo University field. Namely mango trees with two PBZ concentrations for each 10 replicates, 0.5 and 1.0 g *a.i.* per square meter, and a Prohexadione-Calcium (Pro-Ca) concentration for 5 replicates, 0.5 g *a.i.* per square meter, was applied by foliar spray to 'Chok Anan' for studying the effect of PBZ concentration on flowering and postharvest ripening behaviour for two consecutive years were performed from 2004 and 2005.

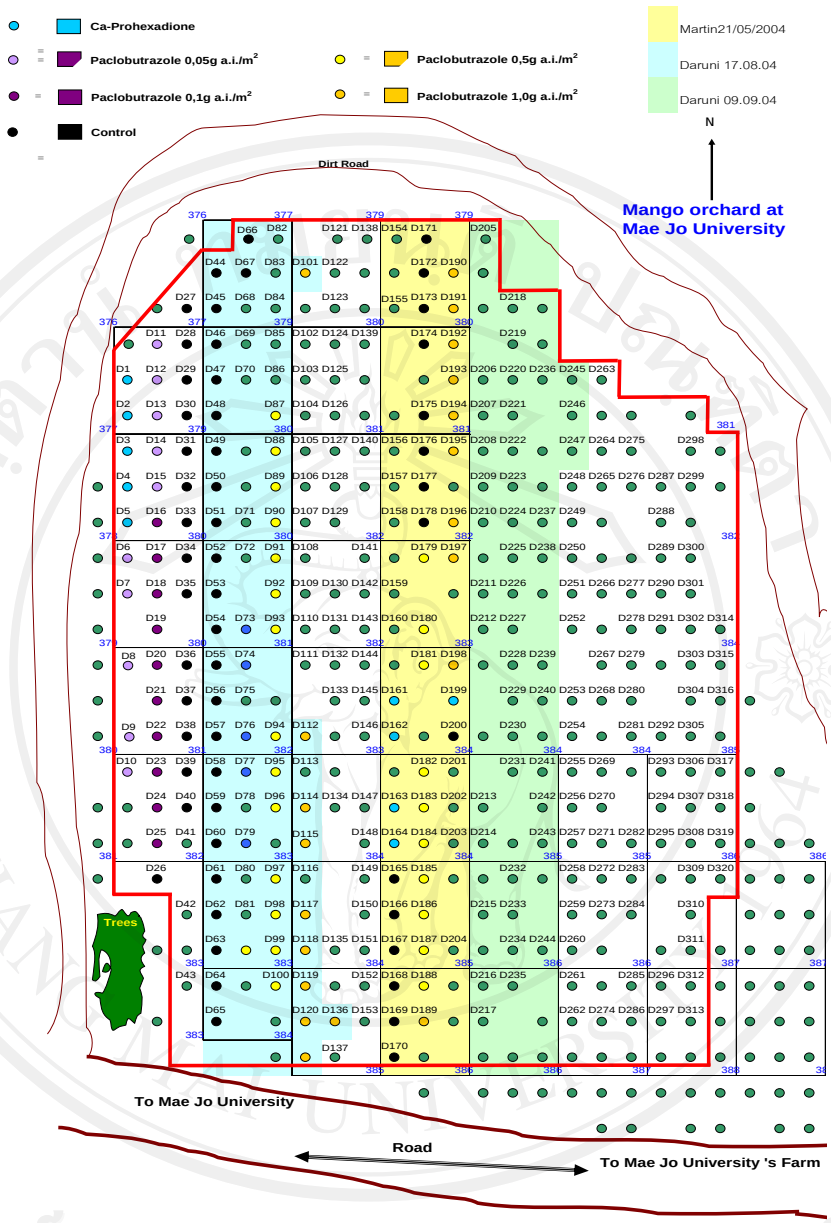


Figure 3.1 The map of mango orchard at Mea Jo University which used to practiced, according to D plot for studied the effect of the different PBZ concentration on mango cv. Chok Anan.

In addition, 'Nam Dok Mai' (5 trees) and 'Khiew Sawoey' (5 trees) cultivars in San Sai orchard (SS) were only treated PBZ with 1.0 and 1.5 g *a.i.* per square meter, respectively. As shown in Figure 3.2. These were merely studied the effect of cultivars in term of postharvest ripening behaviour also for three consecutive years were performed from 2004, 2005 and 2006.

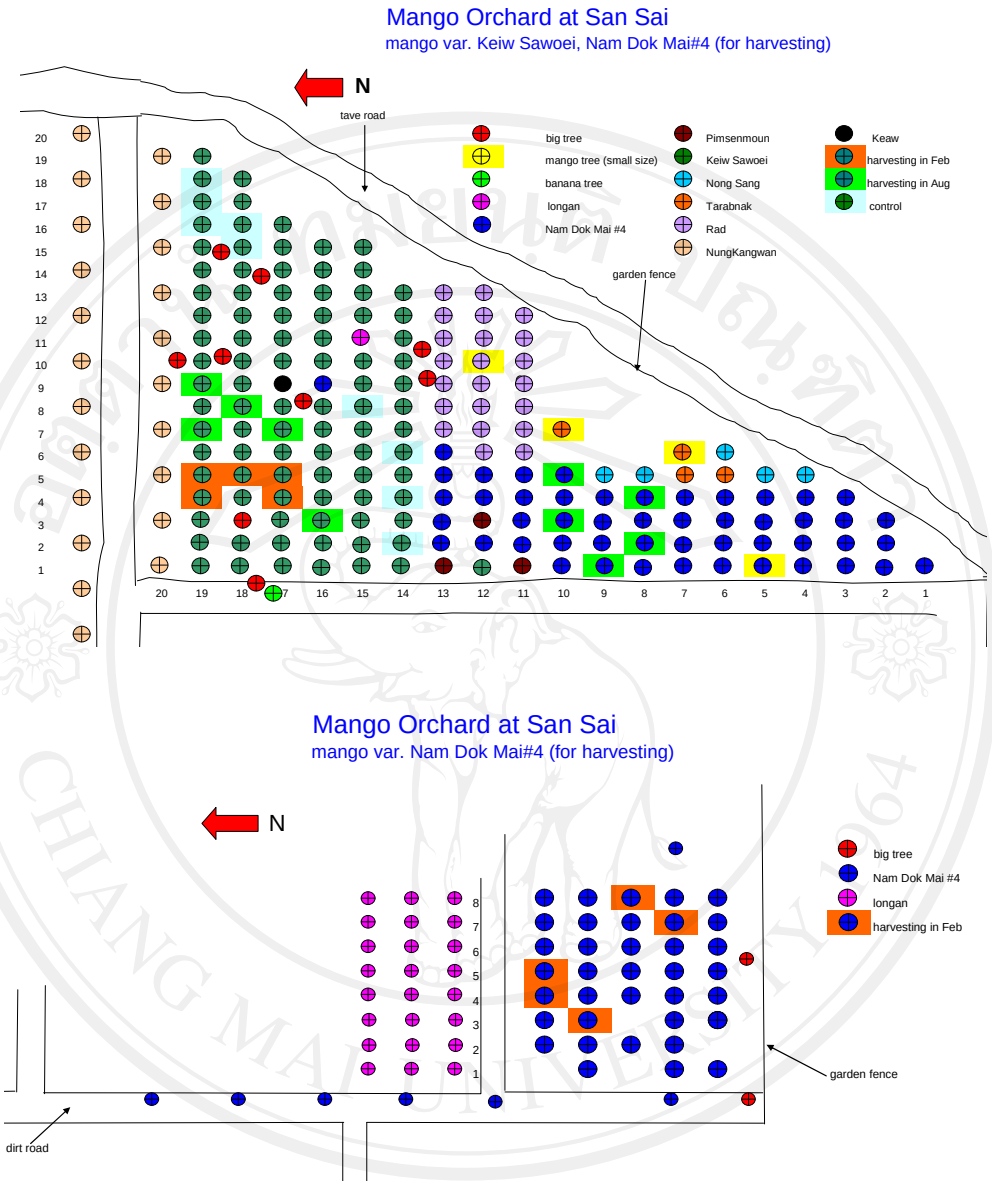


Figure 3.2 The map of mango orchard at San Sai which used to practiced two zones of mango cvs. Nam Dok Mai and Khiew Sawoey were obtained for studying the impact of PBZ on cultivar.

All of the controls were not treated. The trees were irrigated 3 times per week or more (35.87 L/tree/time) after application, depending on soil moisture until harvesting. Irrigation started right after flowering. The impact of PBZ concentration on the postharvest ripening behaviour of mango fruit was investigated by using experimental data from “Chok Anan” orchard and the impact of PBZ on that of three

mango cultivars can be investigated from all orchards. The full mature green fruits were collected and labeled systematically as follows:

TR	Cultivar	Year	Treatment	Conc. (g *a.i.*/m^2)	Plot
CA0-04	Chok Anan	2004	Control	0	D
CA1-04			Pro-Ca	0.5	D
CA2-04			PBZ	0.5	D
CA3-04			PBZ	1.0	D
CA0b-04	Chok Anan	2004	Control	0	B
CA3b-04			PBZ	1.0	B
KS0-04	Khiew Sawoey	2004	Control	0	SS
KS4-04			PBZ	1.5	SS
NM0-04	Nam Dok Mai	2004	Control	0	SS
NM3-04			PBZ	1.0	SS

3.3.2 Percentage of flowering and fruit yield

Twenty uniform terminal shoots of each tree were marked randomly before PBZ application for all treatments. After treatments, the percentage of flowered shoots was recorded at the beginning of flowering. At harvest, fruit production in term of number of fruits and weight of fruits per tree were also recorded for evaluated the fruit yield. The mango fruit samples were collected and brought to laboratory at Faculty of Agriculture, Chiang Mai University for further experiments.

3.3.3 Postharvest ripening condition

Mangoes of different cultivars 'Chok Anan' (CA) from Mae Jo University field, 'Nam Dok Mai' (NM) and 'Khiew Sawoey' (KS) from San Sai orchard were obtained. Approximately 20-30 kg of each cultivar were harvested per tree at their full mature green stage and washed. Were fruit yield was too low for analysis, samples had to be pooled within one treatment and used for bulk analysis. In a paper box, mango samples were placed in one layer and ripened. The incubating room was control the temperature at 28 ± 2 ˚C and 70 – 80 % relative humidity (RH). Samples

of approximate 2 kg were withdrawn randomly for daily quality analysis at Chiang Mai University, until the deteriorate fruit was found.

3.3.4 Physical properties analysis

(adapted from Vásquez-Caicedo *et al*., 2002 and Vásquez-Caicedo *et al*., 2004)

Size and Weight loss

The length (L), maximum width (W_{max}) and thickness (T_{max}), minimum width (W_{min}) and thickness (T_{min}) were measured using Vernier calipers and reported in centimeters. The weight loss is mainly due to the loss of water by transpiration. It ranged from 2-8 % during ripening is an important criterion for trader because it has a big impact on their income (Mahayothee, 2004). The weight of each fruit of mango was determined using a digital balance. The percentage of weight of weight loss at a particular ripening time was calculated based on the weight at the beginning of the ripening process.

Peel thickness

Peel, without flesh was measured for its thickness after manually peeled. The peel was cut at a square inch and carefully removed flesh using a knife, only the soft flesh that remained in the peel after peeling was taken away. The measurement was measured for 2 measurements from same piece using the Vernier calipers. The data was reported at least from 10 peel pieces per treatment.

Fruit mass and yield that referring to an edible part

Mango fruit weight was recorded individually. Fruits were peeled with a hand peeler, and removed flesh from the seed. The peel and seeds from all 15-20 mango fruits were collected respectively and recorded the corresponding combined weights in gram. The flesh weight was calculated as following equation:

$$W_{flesh} = W_{Unpeeled} - (W_{seeds} + W_{peel})$$

The weight yield of seeds, mesocarp and peel were expressed as a percentage of the total weight.

Peel colour

The peel colour of the whole fruit was evaluated by measuring the peel colour along the two sides of the fruits. For each measurement, the measuring head was placed on the fruit, completely covering the respective fruit surface for each measurement. Measure at least 15 points per treatment. A colorimeter was calibrated by using the white plate provided with the instrument (Minolta; CIELAB system; model CR 300, Japan). The L*, a*, and b*, where L* represents the brightness, a* the redness and b* the yellowness coordinates and the resulting hue angles (H°) and chroma values (C*) were recorded (Voss, 1992 and McGuire, 1992).

	Hue angle (H°)	=	arctan (b/a)
Formula in excel	H°	=	ARCTAN2 ([a];[b]) · 180/ PI()

	Chroma (C*)	=	$(a^2 + b^2)^{0.5}$
Formula in excel	C*	=	$([a]^2 + [b]^2)^{0.5}$

when [a] and [b] are cell addresses for the a* and b* value respectively

Flesh colour

The colour of flesh mango pulp was determined immediately as puree made by using a blender (Voss, 1992). The mango pulp was homogeneously distributed on a Petri-dish and places it on a white background (white paper) before measurement. The investigation took at least 5 repeated measurements from various places of this mango pulp. The L*, a*, and b*, where L* represents the brightness, a* the redness and b* the yellowness coordinates and the resulting hue angles (H°) and chroma

values (C*) are recorded. The rest of the puree was kept for further analysis (freeze one half at approx. – 80 °C, and refrigerate the rest).

Flesh firmness

Fruits were peeled and deseeded. The mesocarp was cut into cubes of 1 cm^3 require always fast work (for preventing the browning reactions). The resistance of the fruit sample to compression, shear and extrusion was recorded as load depending on the passed distance of the crosshead. A single layer of mesocarp cubes, approximately 40 g (±0.01g), was used in the Kramer shear cell (Instron model 3365, Instron company, University Ave, U.S.A), for each texture measurement. At least 3-5 measurements were performed per a fruit sample. The mesocarp firmness was recorded as maximum specific load F_{sp} (in N/100g), calculated from the maximum load F_{KSmax} (in N) and the sample weight W (in g):

$$F_{sp} = F_{KSmax} / W \cdot 100$$

3.3.5 The Chemical properties analysis

(adapted from Vásquez-Caicedo *et al*., 2002 and Vásquez-Caicedo *et al*., 2004)

pH – Value

The pH value is important as a measure of the active acidity which affects the flavor or palatability of the products. In this work, the glass electrode pH-meter was used regarding more reliable and faster than colorimetric method. The pH was measured for each sample as one of its quality attributes besides e.g. TA, IFU (International Federation of Fruit Juice Producers) method No.11 (1989) has to be applied, thus recording the pH of the undiluted sample at 20˚C with two places of decimals. Fruit tissue has to be thoroughly liquidized by fine grinding and homogenization for this purpose. It was determined using a pH–meter (Titrino, Metrohm Siam Ltd. Bangkok, Thailand).

Titratable Acidity (TA)

The pH-meter was calibrated using the buffers of pH = 4.0 and pH = 7.0. Both buffers were thermostatted at 20°C before calibration. The mango pulp sample was thermostatted at 20 ˚C. The mango pulp was weighed exactly (0.001g) 5 to 10 g in a beaker and add 50 ml distilled water (20°C). The sample was stirred for approximately 30 seconds to homogenize it, and measure the pH. Right after, the process was proceed to titrate with 0.1N NaOH to a pH of 8.1 (g $TA_{CA,pH8.1}$ /100 g), recording the lye volumes(V_{NaOH}) at pH 8.1. A magnetic stirrer was used for mixing the solution during titration. Titratable acidity was calculated according to IFU method No. 3 (1996)

Calculations: TA index, expressed as citric acid ($TA_{CA,pH\ 8.1}$):

$$\text{TA in g citric acid/100g} = \frac{0.064\ V_{NaOH,pH\ 8.1}\ cNaOH\ k\ 100}{W_{sample}}$$

with W_{sample} in g, V_{NaOH} in mL, cNaOH in mol/L. TA results are always reported indicating the acid referred to for calculation and the pH of the titration end-point, e.g. "...g/100g (citric acid, pH 8.1)".

Reference acid (H_2SO_4 in titrisol quality of the same normality as the NaOH titration solution to check the true NaOH concentration daily before use and to determine the respective factor k of the lye by titration of 10 mL reference acid with the NaOH solution: k = 10 mL z N acid / y mL z N NaOH (here: z = $[H^+]$ of acid = $[OH^-]$ of lye = 0.1 mol/L)

Total Soluble Solids (TSS)

The main soluble solids (TSS in ˚Brix) in mango pulp are referred to sugars, which indicate the sweetness of the fruit. It can be determined by refractometer. It is the most commonly used method in fruit processing for small scale. Juice from mango pulp was used to measure TSS. The digital refractometer (0-32 ˚Brix, model PR–32, ATAGO Co. Ltd., Tokyo, Japan) was utilized for the investigation done at Chiang

Mai University. The refractometer was calibrated with distilled water (0˚Brix) before each measurement. The mango pulp was controlled the temperature at 20˚C in a cooling bath. Three measurements were taken from each sample. The reading Brix (˚$Brix_{ref}$) was corrected for titratable acidity (TA) (mg citric acid/100g) (IFU No.8, 1991) Report TSS as corrected °Brix (°$Brix_{corr}$) at 20˚C.

°$Brix_{ref}$ = refractometer reading

°$Brix_{corr}$ = TSS (in g sucrose/100 g or °Brix)

= refractometer reading corrected for titratable acidity TA using TA according to IFU No.3 in g /100g calculated as citric acid with titration end-point pH 8.1

Sugar-Acid Ratio (TSS/TA)

Sugar-acid ratio indicates the sweetness and sourness of fruit, which has a direct impact on consumer's acceptance. It is used as an index of maturity in the tropical fruit processing industry (Mahayothee, 2004). It was calculated from:

TSS/TA = °$Brix_{corr}$ /TA using °$Brix_{corr}$ and TA as defined above

3.3.6 Statistical Analysis

The differences between treatments were determined with analysis of variance (ANOVA). This was performed by SPSS@ program (SPSS Inc., U.S.A) version 10.0 for Windows. Least significant differences (LSD) were calculated at $P \leq 0.05$, following with the significant F-tests for mean comparison.

3.4 Results

3.4.1 Effect of PBZ and Pro-Ca on fruit production and quality of mango cv. 'Chok Anan'

Flowering

There was a significant difference for the effect of PBZ application at different concentrations with the respect to percentage flowered (Table 3.1, 3.2) in both years 2004 and 2005. The trees were treated with the PBZ at the concentrations of 0.5 and 1.0 g *a.i*. per square meter. They produced a significantly higher percentage of tagged branches flowered at 35.00 percent (CA2-04), 41.67 percent (CA2-05) and 39.00 percent (CA3-05), respectively in both years. However, the flower panicles lengths were shortened and visibly compacted by high concentration of PBZ application (1.0 g *a.i.*/m^2) in both years. The Prohexadione-Calcium treatment (CA1-04, CA1-05) was not significantly difference found from the untreated trees.

Table 3.1 Effect of paclobutrazol in different concentrations on flowering of Chok Anan cultivar for year 2004 in D plot. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

TR	PBZ conc.	Flowered (%)	S.D.	n
CA0-04	0	6.00c	2.11	10
CA1-04	Pro-Ca	4.00c	2.23	5
CA2-04	0.5	35.00a	5.77	10
CA3-04	1.0	20.50b	5.50	10

Table 3.2 Effect of paclobutrazol in different concentrations on flowering of Chok Anan cultivar for year 2005 in D plot. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

TR	PBZ conc.	Flowered (%)	S.D.	n
CA0-05	0	2.50b	4.18	6
CA1-05	Pro-Ca	8.00b	17.89	5
CA2-05	0.5	41.67a	18.08	6
CA3-05	1.0	39.00a	15.16	6

In the case of the crop year 2004, it was treated with PBZ in mid of October 2003 (10th Oct 2003). The date of anthesis was 20th January 2004, which was also not different from that of the in-season mango (control trees). In addition of the crop year 2005, it was treated PBZ in the end of May (21st May 2004). The date of anthesis was on the 15th December 2004 that was about 2.5 months delayed. This means that it should be flowering in the mid of September. The date of anthesis as control (CA0-05) trees was on 25th January 2005. However, the applications of PBZ in crop year 2005 were shown that the flowering commenced 1 month earlier than control trees. Both years found that PBZ treatment induced slightly profuse flowering.

Fruit production

The trees were applied by PBZ and compared with the control trees. The results of fruit production in crop year 2004 indicated that none statistically significant difference of means value as yield per tree was obtained, but the number of fruits per tree and the average weight per fruit was significantly found (Table 3.3). The average of all treatments for yield per tree was 20.02 kg per tree. Moreover, the mean of all treatments for number of fruits per tree was 72.11 fruits. The average weight of fruit was 296.92 g per fruit. However, trees treated with high dosage of PBZ 1.0 g *a.i.* per square meter (CA3-04) had the highest weight of harvested fruit, when

compared to the others. The increase in fruit yield was caused by the increased number of fruit per tree but not because of a result of fruit size (Table 3.7). The date for harvesting was on 13th May 2004, which was as same as the main season.

Table 3.3 Effect of paclobutrazol in different concentrations on fruits production: yield per tree and number of fruits per tree in Chok Anan cultivar for year 2004 in D plot. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

		Production of mango fruits					
TR	PBZ conc.	Yield (kg/tree)	S.D.	No. of Fruits (number)	S.D.	Weight/fruit (g)	S.D.
CA0-04	0	20.03ns	9.41	64.75b	33.35	316.03a	30.99
CA1-04	Pro-Ca	16.50	9.95	51.80b	33.24	323.55a	51.90
CA2-04	0.5	18.84	11.28	69.00b	24.80	302.37a	49.58
CA3-04	1.0	25.90	11.56	108.75a	10.37	237.73b	28.80

ns = Non significant

Table 3.4 Effect of paclobutrazol in different concentrations on fruits production: yield per tree and number of fruits per tree in Chok Anan cultivar for year 2005 in D plot. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

		Production of mango fruits					
TR	PBZ conc.	Yield (kg/tree)	S.D.	No. of Fruits (number)	S.D.	Weight/fruit (g)	S.D.
CA0-05	0	45.00ns	14.99	156.25ns	74.41	301.51a	61.28
CA1-05	Pro-Ca	44.18	22.89	191.00	79.81	227.92b	22.34
CA2-05	0.5	38.59	13.06	195.88	62.89	196.53c	13.67
CA3-05	1.0	27.93	12.15	127.43	60.22	221.22b	21.21

ns = Non significant

For the crop year 2005, it was harvested on 28th-29th April 2005 that as same as main season, and the result was only showed non significant different of the yield. However, the PBZ treatments were significantly affected to the number of fruits per tree and the average weight per fruit (Table 3.4). The biggest fruit was obtained in untreated trees (CA0-05, 301.51 g/fruit) and the subordination treatments which treated PBZ and Pro-Ca were similar to fruit weight (average as 215.22 g/fruit). The mean value of all treatments for yield per tree was about 37.71 kg per tree. In addition, the average number of fruits per tree was 168.29 fruits. However at the second year, it was showed that trees treated with PBZ at high dosage 1.0 g *a.i.* per square meter (CA3-05) had the smallest weight of harvested fruit. The decrease in fruit number per tree and fewer yields per tree were caused by the increased weight per fruit, and inclusive a result of the big fruit size (Table 3.8).

Fruit proportion

The fruit proportion in crop year 2004 (Table 3.5) resulted that there was significantly different for the mean values in all parameters such as fruit weight, percentage of flesh, seed and peel. The biggest fruit weight occurred in Prohexadione-Calcium (CA1-04, 356.45 g) treatment. Nonetheless, the least fruit weight was found in high dose of PBZ application (CA3-04, 230.77 g) treatment. Moreover, the highest percentage of flesh fruit was observed in PBZ treatment as 0.5 g *a.i.* per square meter (CA2-04, 80.64 %), while the peel and seed were also lessen (10.67 % and 8.69 %), respectively.

Table 3.5 Effect of paclobutrazol in different concentrations on fruits proportion: fruit weight, flesh, seed and peel in percentage for Chok Anan cultivar for year 2004 in D plot. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

TR	PBZ Conc.	Weight [g]	S.D.	Flesh [%]	S.D.	Seed [%]	S.D.	Peel [%]	S.D.
CA0-04	0	279.02b	37.38	78.27b	2.29	9.39bc	1.64	12.34a	1.69
CA1-04	Pro-Ca	356.45a	68.11	74.90c	3.58	12.56a	1.77	12.55a	2.32
CA2-04	0.5	279.10b	39.91	80.64a	1.95	8.69c	1.65	10.67b	0.92
CA3-04	1.0	230.77c	31.68	77.14b	3.48	10.30b	2.15	12.57a	1.88

Table 3.6 Effect of paclobutrazol in different concentrations on fruits proportion: fruit weight, flesh, seed and peel in percentage for Chok Anan cultivar for year 2005 in D plot. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

TR	PBZ Conc.	Weight [g]	S.D.	Flesh [%]	S.D.	Seed [%]	S.D.	Peel [%]	S.D.
CA0-05	0	292.72a	54.50	78.51a	4.74	8.58d	2.34	12.91b	3.01
CA1-05	Pro-Ca	237.93b	30.81	74.92b	3.50	11.52b	3.46	13.56ab	1.38
CA2-05	0.5	203.46d	26.23	73.81b	4.36	12.81a	2.70	13.38ab	2.54
CA3-05	1.0	218.80c	41.93	75.13b	3.43	10.75c	2.00	14.13a	1.95

In addition of the crop year 2005 (Table 3.6), the results showed that it was significantly different in fruit proportion. The fruit weight of treated trees was smaller than untreated trees, while the peel and seed were also contrast. They gave the highest percentage of peel and seed (Table 3.6). As for the control (CA0-05) tree was found the heavy fruit of 292.72 g. Thus, it gave high percentage of flesh (78.51 %), less of peel (12.91 %) and seed (8.58 %) percentage. To summarize, Chok Anan for both

years gave higher flesh (edible part, more than 73 %) yield and thus, lowers waste percentages (seed and peel, less than 13 %). It was due to the slender shape and small size of seed.

Fruit size distribution

The effect of PBZ concentration on fruits size distribution such as length, width, and thickness in Chok Anan for crop years 2004 in D plot (Table 3.7) resulted that it was significantly different in all of the parameters. The longest length of fruit found in 0.5 g *a.i.* of Prohexadione-Calcium treatment (CA1-04, 11.84 cm). The 0.5 g *a.i.* of PBZ treatment (CA2-04, 11.29 cm) as the second order; control trees (CA0-04, 10.99 cm) and 1.0 g *a.i.* of PBZ (CA3-04, 10.33 cm) was obtained as the third and fourth order, respectively. High value of the maximum width (W_{max}) observed in Prohexadione-Calcium (CA1-04, 7.74 cm), and less value at 1.0 g *a.i.* of PBZ (CA3-04, 6.80 cm). Less value of the minimum width (W_{min}) found in 1.0 g *a.i.* of PBZ (CA3-04, 4.60 cm), and others treatment were not different value.

Table 3.7 Effect of paclobutrazol in different concentrations on fruits size distribution: length, width, and thickness in Chok Anan cultivar for year 2004 in D plot. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

TR	PBZ conc.	Length [cm]	S.D.	W_{max} [cm]	S.D.	W_{min} [cm]	S.D.	T_{max} [cm]	S.D.	T_{min} [cm]	S.D.
CA0-04	0	10.99c	0.50	7.40ab	0.47	5.27a	0.48	6.54b	0.40	4.91a	0.45
CA1-04	Pro-Ca	11.84a	0.74	7.64a	0.83	5.01a	0.57	6.79a	0.47	4.52b	0.44
CA2-04	0.5	11.29b	0.65	7.31b	0.47	5.07a	0.84	6.33c	0.31	4.29c	0.25
CA3-04	1.0	10.33d	0.52	6.80c	0.32	4.60b	0.33	6.06d	0.36	4.33c	0.33

Table 3.8 Effect of paclobutrazol in different concentrations on fruits size distribution: length, width, and thickness in Chok Anan cultivar for year 2005 in D plot. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

TR	PBZ conc.	Length [cm]	S.D.	W_{max} [cm]	S.D.	W_{min} [cm]	S.D.	T_{max} [cm]	S.D.	T_{min} [cm]	S.D.
CA0-05	0	11.75ns	0.76	7.53a	0.59	4.90a	0.50	6.43a	0.46	4.66	3.64
CA1-05	Pro-Ca	11.22	0.49	7.01b	0.37	4.63b	0.38	5.98b	0.31	3.95	0.30
CA2-05	0.5	11.44	9.48	6.68c	0.32	4.70b	0.35	5.74c	0.23	4.10	0.31
CA3-05	1.0	10.72	0.72	6.78c	0.50	4.59b	0.43	5.82c	0.44	3.97	0.38

ns = Non significant

Furthermore, the maximum and minimum thickness of fruit found also the least value in 1.0 g *a.i.* of PBZ (CA3-04, 6.06 cm (T_{max}), 4.33 cm (T_{min})). For the crop year 2005 (Table 3.8), Chok Anan in D plot resulted non significant difference as for the length of fruit, and the minimum thickness of fruit. However, the maximum and minimum width, or the maximum thicknesses of fruit were only significant. In addition of the least value of their found also in 0.5 and 1.0 g *a.i.* of PBZ (CA2-05, 6.68 cm (W_{max},) 4.70 cm (W_{min},) 5.74 cm (T_{max}); CA3-05, 6.78 cm (W_{max}), 4.59 cm (W_{min}), 5.82 cm (T_{max})). Moreover, the control trees (CA0-05) revealed higher the maximum and minimum width, or the maximum thicknesses of fruit were 7.53, 4.90, and 6.43 cm, respectively.

Peel thickness

The impact of PBZ concentration on the thickness of peels in both years (2004, 2005) for cultivar 'Chok Anan' in D plot which was compared at each stages (mature green and ripen) between untreated trees and treated trees was recorded non significant difference (Figure 3.3, 3.4). The thickness of peels was observed in range of 0.10-0.12 cm in mature green stage and it was reduced to 0.06-0.08 cm in fully ripe stage. When mangoes ripe, the thick of peels were spared near 2 times.

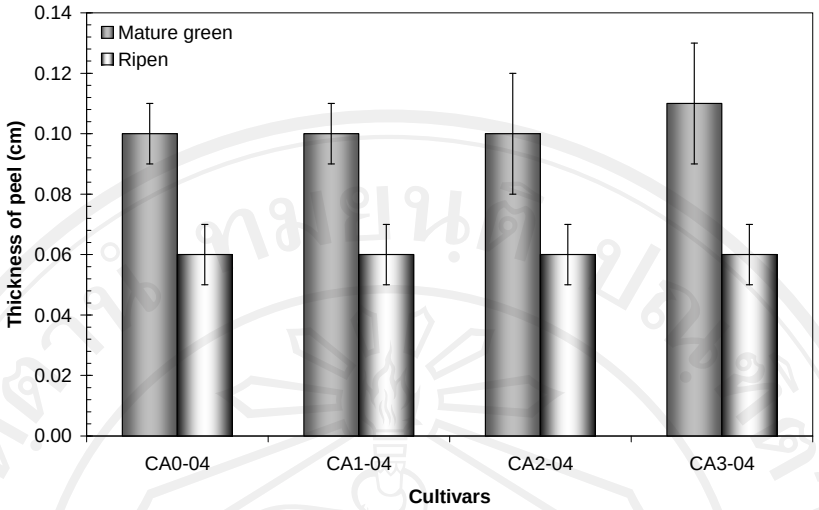


Figure 3.3 The comparison thickness of peels for Chok Anan cultivar between mature green and fully ripe stage which treated with paclobutrazol in different concentrations and Pro-Ca in year 2004.

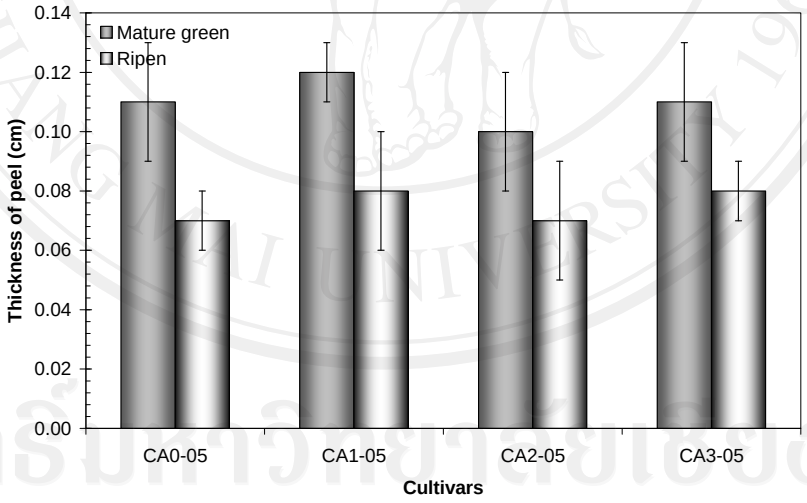


Figure 3.4 The comparison thickness of peels for Chok Anan cultivar between mature green and fully ripe stage which treated by paclobutrazol at different concentrations and Pro-Ca in year 2005.

Firmness, Total soluble solid (TSS), Titratable acidity (TA), pH, and Sugar-acid ratio (TSS/TA)

For Chok Anan in crop year 2004, all fruit qualitative parameters at mature green (at harvested) stage were significantly affected by PBZ, except pH value (Table 3.9). The highest firmness value was obtained in treated trees by PBZ (CA2-04), and Prohexadione-Calcium (CA1-04). Total soluble solid (TSS) and titratable acidity were higher in the treated trees (CA2-04, CA3-04), but lower sugar-acid ratio. As the fully ripe stage, the fruit treated with prohexadione-Calcium (CA1-04) was still hardened, as the firmness was fallen negligible. The lower total soluble solid (TSS) and pH value were also observed. However, titratable acidity (TA) and sugar-acid ratio had not significantly affected with all concentration.

In crop year 2005, the data showed that all postharvest fruit quality parameters were statistically significant difference among the PBZ treated groups and Prohexadione-Calcium in mature green stage (Table 3.10). Firmness was harder for those treated with Prohexadione-Calcium (CA1-05). Trees treated with PBZ and control was subordinated. The untreated trees (CA0-05) had the highest sugar-acid ratio, pH, and total soluble solid. Furthermore, the statistic significant difference was observed in total soluble solid, pH, and sugar-acid ratio among all treatment for the fully ripe stage (Table 3.10). The highest value for all parameters was found in the treated trees with high dose of PBZ 1.0 g *a.i.* per square meter (CA3-05). The TSS and sugar-acid ratio was fluctuating while increasing the concentration of PBZ in both mature green and fully ripe stages. Total soluble solid in mature green stage for crop year 2004 was rather higher than the crop year 2005. Moreover, titratable acidity was about 2 times lower. Fruit firmness in the fully ripe stage for crop year 2005 was 2 times harder than in that of the crop year 2004. Total soluble solid and titratable acidity were negligibly deferent.

Peel and flesh colour

For Chok Anan in crop year 2004, the results indicated that the mean value of the colour of peel and flesh in mature green stage (at harvested) were statistically significant different. The Peel colour of the treated trees with Prohexadione-Calcium (CA1-04) was measured with L, C*, and H* parameters (Table 3.11). All treatments in mature green showed a desirable deep yellow-green colour of the peel. As for the flesh colour, the highest amount of L, C*, and H* were obtained as the treated trees with high dose of PBZ 1.0 g *a.i.* per square meter (CA3-04). By the way, all treatments in mature green showed the considerable palest greenish-yellow colour of the flesh. Nevertheless, Peel colour at the fully ripe stage was changed to light yellow for all treatments; therefore, they were statistically significant difference of the average value. The flesh colour for all treatments was similar to the peel which showed a desirable light yellow colour. When there were compared with hue sequence and hue angle orientation on a CIELAB diagram, not much difference on colour shade was found. In crop year 2005 (Table 3.12), the results indicated that the peel and flesh colour in mature green stage was rather similar with the crop year 2004. Respect to the fully ripe stage, it also was not different. However, only a few fruits that showed a deep greenish-yellow of peel and the deep yellow of flesh were different.

Table 3.9 Effect of paclobutrazol in different concentrations on fruits quality: Firmness, TSS, TA, pH, and TSS/TA in Chok Anan cultivar for year 2004 in D plot at mature green and fully ripe stage. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

Stage	TR	PBZ conc.	Fruit quality									
			Firmness	S.D.	TSS	S.D.	TA	S.D.	pH	S.D.	TSS/TA	S.D.
Mature green	CA0-04	0	8513.40b	466.5	9.00b	0.12	0.43b	0.00	3.28ns	0.07	20.90a	0.17
	CA1-04	Pro-Ca	9403.60a	692.8	9.00b	0.10	0.41b	0.00	3.32	0.09	21.83a	0.03
	CA2-04	0.5	9306.00a	649.5	9.26a	0.09	0.55a	0.02	3.31	0.02	16.92b	0.58
	CA3-04	1.0	7187.40c	275.8	9.20ab	0.29	0.63a	0.08	3.30	0.03	14.78b	1.87
Fully ripe	CA0-04	0	868.40b	415.34	18.70a	0.00	0.48ns	0.00	3.91a	0.08	38.96ns	0.22
	CA1-04	Pro-Ca	6157.40a	946.82	13.56d	0.09	0.47	0.12	3.78b	0.03	40.13	10.49
	CA2-04	0.5	654.60b	91.03	18.24b	0.11	0.44	0.00	3.87ab	0.06	41.69	0.28
	CA3-04	1.0	566.00b	65.87	17.50c	0.12	0.44	0.00	3.91a	0.03	39.73	0.14

Firmness= N/100g Fw; TSS= g/100g Fw; TA= g/100g Fw; ns = Non significant

Table 3.10 Effect of paclobutrazol in different concentrations on fruits quality: Firmness, TSS, TA, pH, and TSS/TA in Chok Anan cultivar for year 2005 in D plot at mature green and fully ripe stage. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

Stage	TR	PBZ conc.	Fruit quality									
			Firmness	S.D.	TSS	S.D.	TA	S.D.	pH	S.D.	TSS/TA	S.D.
Mature green	CA0-05	0	7845.85b	388.42	7.82a	0.59	0.70b	0.04	3.55a	0.04	11.26a	0.52
	CA1-05	Pro-Ca	8813.30a	506.82	5.67c	0.06	0.80a	0.02	3.32c	0.02	7.07b	0.20
	CA2-05	0.5	8229.74b	724.42	5.75c	0.58	0.80a	0.09	3.35bc	0.22	7.28b	1.64
	CA3-05	1.0	8189.10b	404.98	6.57b	0.60	0.82a	0.11	3.47ab	0.14	8.08b	1.40
Fully ripe	CA0-05	0	2998.44ns	804.57	15.09b	0.23	0.53ns	0.12	3.87b	0.25	29.74ab	6.39
	CA1-05	Pro-Ca	3091.14	797.63	14.88b	0.14	0.62	0.03	3.93b	0.14	24.25b	1.03
	CA2-05	0.5	3798.06	1335.3	15.37a	0.38	0.53	0.13	3.81b	0.35	30.36ab	7.11
	CA3-05	1.0	3404.71	1051.1	15.48a	0.36	0.47	0.15	4.22a	0.20	35.29a	8.29

Firmness= N/100g Fw; TSS= g/100g Fw; TA= g/100g Fw; ns = Non significant

Table 3.11 Effect of paclobutrazol in different concentrations on fruits quality: colour of peel and fresh in Chok Anan cultivar for year 2004 in D plot at mature green and fully ripe stage. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

Stage	TR	PBZ conc.	Peel						Flesh					
			L	S.D.	C*	S.D.	H*	S.D.	L	S.D.	C*	S.D.	H*	S.D.
Mature green	CA0-04	0	58.58ab	7.66	39.70ab	4.63	114.11b	3.61	81.97a	2.47	35.89c	1.07	100.80b	0.15
	CA1-04	Pro-Ca	62.58a	2.52	41.33a	2.14	116.19a	2.58	75.87b	3.33	34.16d	1.29	101.67a	0.44
	CA2-04	0.5	54.84b	8.19	37.22b	4.76	116.58a	3.37	75.53b	6.78	37.70b	2.86	100.64b	0.41
	CA3-04	1.0	55.24b	9.94	37.28b	5.57	115.17ab	2.77	84.35a	1.56	41.30a	1.55	100.46b	0.50
Fully ripe	CA0-04	0	73.96a	3.36	52.21b	3.98	95.03b	6.42	71.66a	2.30	67.21ns	5.15	94.32a	0.95
	CA1-04	Pro-Ca	64.20b	5.85	44.98c	6.23	102.06a	11.62	69.68ab	3.81	64.29	4.12	93.50b	0.44
	CA2-04	0.5	73.07a	4.91	52.15b	5.50	92.81b	8.19	69.33ab	5.16	64.29	6.50	94.40a	0.67
	CA3-04	1.0	74.85a	1.41	55.95a	3.35	90.84b	2.11	67.45b	3.11	63.95	4.82	94.27a	0.76

ns = Non significant

Table 3.12 Effect of paclobutrazol in different concentrations on fruits quality: colour of peel and fresh in Chok Anan cultivar for year 2005 in D plot at mature green and fully ripe stage. Means within columns followed by different letters in the same column are significantly different at $P \leq 0.05$ according to LSD test.

Stage	TR	PBZ conc.	Peel						Flesh					
			L	S.D.	C*	S.D.	H*	S.D.	L	S.D.	C*	S.D.	H*	S.D.
Mature green	CA0-05	0	62.07a	3.04	37.02ns	2.57	114.52b	9.25	76.54bc	2.51	33.25c	1.94	108.02ab	0.81
	CA1-05	Pro-Ca	60.68a	2.48	36.37	2.55	117.93a	1.82	77.43b	2.62	35.39b	1.31	108.68b	1.48
	CA2-05	0.5	57.10b	2.45	37.22	3.03	117.44a	1.85	75.89c	2.41	36.52a	1.69	109.35a	2.17
	CA3-05	1.0	57.21b	3.22	37.23	2.97	117.57a	2.36	79.10a	3.02	36.50a	2.21	106.50b	5.86
Fully ripe	CA0-05	0	70.38a	5.19	42.60ab	5.6	100.37b	9.83	74.20b	6.66	48.67b	6.88	93.17b	2.25
	CA1-05	Pro-Ca	65.47bc	5.35	40.74b	6.32	110.84a	4.95	81.02a	1.62	49.58b	1.74	95.09a	0.76
	CA2-05	0.5	64.40c	6.38	41.28b	7.75	107.62a	11.05	74.14b	6.74	51.86ab	5.07	94.62a	3.33
	CA3-05	1.0	67.67ab	7.47	45.45a	6.53	102.29b	9.52	72.81b	5.11	54.40a	10.11	92.99b	3.05

ns = Non significant

3.4.2 Effect of PBZ on fruit production and quality of three mango cultivars

Flowering

The effect of PBZ on different mangoes cultivars was studied such as 'Chok Anan', 'Nam Dok Mai', and 'Khiew Sawoey' which separately compared within each cultivar between untreated (control) and treated trees for each year. In crop year 2004, the percentage of flowering recorded for Chok Anan cultivar was significantly different of average values (Table 3.13). The tree was applied PBZ on 24th April 2004 and the date of the anthesis was on 07th July 2004. However, the date of anthesis for the control trees was on 25th January 2004. The highest average flowering was observed with the control trees (CA0b-04, 77.5 %) as compared to the treated trees (CA3b-04, 15.0 %). Besides, the flowerings of 2 representative trees in the control were only recorded. While the tress treated with PBZ as Nam Dok Mai (NM3-04) and Khiew Sawoey (KS4-04) had the flowering in 89.0 % and 95.0 %, respectively (Table 3.13). The date of PBZ application was on 10 November 2003 (NM3-04) and 20th October 2003 (KS4-04), respectively. They were observed that the flowering was on 01st February 2004 and 23rd January 2004. The flowering of the main season is also during this period (December-January). Nevertheless, it was not flowering in untreated trees.

Table 3.13 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to flowering for year 2004 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar

TR	PBZ conc.	Plot	Flowered (%)	S.D.	n
CA0b-04	0	MJU, B	77.50a	10.61	2
CA3b-04	1.0	MJU, B	15.00b	4.12	5
NM0-04	0	SS	-	-	-
NM3-04	1.0	SS	89.00	11.94	5
KS0-04	0	SS	-	-	-
KS4-04	1.5	SS	95.00	5.00	5

Table 3.14 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to flowering for year 2005 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plot	Flowered (%)	S.D.	n
CA0b-05	0	MJU,B	71.67ns	2.89	3
CA3bY-05	1.0	MJU,B	75.00	18.71	5
NM0-05	0	SS	80.00ns	7.91	5
NM3-05	1.0	SS	88.00	10.37	5
KS0-05	0	SS	78.60b	8.05	5
KS4-05	1.5	SS	92.00a	8.37	5

ns = Non significant

Table 3.15 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to flowering for year 2006 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plot	Flowered (%)	S.D.	n
CA0b-06	0	MJU,B	77.00ns	8.54	3
CA3bY-06	1.0	MJU,B	67.00	8.37	5
CA3bB-06	1.0	MJU,B	68.00	10.98	5
NM0-06	0	SS	80.00ns	5.00	3
NM3-06	1.0	SS	81.67	7.64	3
KS0-06	0	SS	73.33ns	2.89	3
KS4-06	1.5	SS	80.00	5.00	3

ns = Non significant

In addition of the crop year 2005, Khiew Sawoey was applied by PBZ on 22nd August 2004. The date of anthesis was on 13rd January 2005. It was only significantly affected by PBZ application compared with the control trees, while it flowered on 16th January 2005. Trees treated with PBZ gave the highest of flowering as 92 % (Table 3.14). On the other hand, Chok Anan and Nam Dok Mai were treated on 15th July 2004 and 28th August 2004, respectively. In addition of the date of anthesis was on 30th December 2004 and 30th January 2005. They were not statistically significant

difference of the mean value. Otherwise, solitarily Chok Anan in both years (2004, 2005) which treated by PBZ was occurred excessive shortening and visible compactness of panicles.

A part of the crop year 2006, three cultivars were investigated that the flowering was not significantly different as compared within each cultivars. The flowering was shown in rage of 67.0 – 82.0 % (Table 3.15). However, the treated trees in Chok Anan, Nam Dok Mai and Khiew Sawoey were negligible recorded difference as compared to control trees. There were treated PBZ on 27th July 2005 (CA3bY-06), 03rd September 2005 (NM3-06), and 20th August 2005 (KS4-06). The dates of anthesis were on 11st January 2006, 13rd January 2006, and 27th January 2006, respectively. It was noticed that in the control tress, they flowered 2 or 3 days earlier from the treated trees. Three years of Chok Anan at B plot has slightly profuse flowering, the visibly compact flowering and shortening of panicles. For Nam Dok Mai and Khiew Sawoey, the malformation was not obtained.

Fruit production

The responses yield production in Nam Dok Mai and Khiew Sawoey were most evident in PBZ treatment for three consecutive years (Table 3.16, 3.17, 3.18). The harvesting date of Nam Dok Mai was on 21st May 2004 (NM3-04), 18th May 2005 (NM0-05), 11st May 2005 (NM3-05), 03rd June 2006 (NM0-06 and NM3-06). Khiew Sawoey was harvested on 21st May 2004 (KS4-04), 18th May 2005 (KS0-05), 16th May 2005 (KS4-05), and 19th May 2006 (KS0-06, KS4-06), respectively. They were only functioned in increasing fruit number rather than enlarging the average fruit weight. Notwithstanding, Nam Dok Mai cultivar was obtained conversely. It means that the yield per tree, the number of fruit, and the average weight per fruit were also upward increased. By the way, the average weight per fruit for the treated trees in Khiew Sawoey cultivar was performed lower than control trees. PBZ had not significant effect with respect to the fruit yield of Khiew Sawoey for two consecutive years. However, trees treated with PBZ (both cvs. Nam Dok Mai and Khiew Sawoey) had the high weight of harvested fruit. The increase in fruit number per tree was

caused by adding PBZ and also increased yield weight, together with fruit size (Table 3.23, 3.24). Moreover, Chok Anan cultivar for crop year 2004 was not found fruits in the treated trees, because of the lower flowering occurred in Table 3.13 and after fruit set two weeks later, all fruits were dropped off the trees. However, Nam Dok Mai and Khiew Sawoey had not fruit in the control because they had not flowering before. Moreover, the average of the yield in Chok Anan which applied by PBZ was happened to be lower than control trees (average of all 15.64 kg/tree) for three years. It was harvested on 13rd May 2004 (CA0b-04).

Table 3.16 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits production: yield per tree and number of fruits per tree for year 2004 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plots	Production of mango fruits					
			Yield (kg/tree)	S.D.	No. of Fruits (number)	S.D.	Weight/ fruit (g)	S.D.
CA0b-04	0	MJU,B	17.80	6.65	63.00	5.66	278.93	80.46
CA3b-04	1.0	MJU,B	-	-	-	-	-	-
NM0-04	0	SS	-	-	-	-	-	-
NM3-04	1.0	SS	27.58	4.66	86.60	15.31	318.91	8.69
KS0-04	0	SS	-	-	-	-	-	-
KS4-04	1.5	SS	24.90	2.23	86.00	5.24	289.53	18.44

Table 3.17 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits production: yield per tree and number of fruits per tree for year 2005 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plots	Production of mango fruits					
			Yield (kg/tree)	S.D.	No. of Fruits (number)	S.D.	Weight/ fruit (g)	S.D.
CA0b-05	0	MJU,B	23.83a	6.01	88.33ns	19.40	269.85ns	28.78
CA3bY-05	1.0	MJU,B	13.80b	3.17	61.20	25.92	230.73	24.69
NM0-05	0	SS	16.67b	3.51	65.00b	14.11	256.61ns	11.46
NM3-05	1.0	SS	47.80a	11.19	181.40a	30.02	261.21	26.78
KS0-05	0	SS	23.25ns	15.44	92.00ns	21.43	257.17a	24.87
KS4-05	1.5	SS	24.00	5.05	114.80	15.14	207.69b	20.84

ns = Non significant

In addition of the number of fruit per tree and the average weight per fruit were also observed in the trees treated with PBZ lower than the untreated trees. On the other hand, all cultivars and all treatments in three consecutive years were indicated that the average weight per fruit was increased more than 200 g/fruit (Table 3.16, 3.17, 3.18). The date of Chok Anan for harvesting was on 21st May 2005 (CA0b-05), 14th May 2005 (CA3bY-05), 26th May 2006 (CA0b-06, CA3bY-06, CA3bB-06), respectively.

Table 3.18 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits production: yield per tree and number of fruits per tree for year 2006 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plots	Production of mango fruits					
			Yield (kg/tree)	S.D.	No. of Fruits (number)	S.D.	Weight/ fruit (g)	S.D.
CA0b-06	0	MJU,B	17.55ns	16.33	74.50ns	36.06	224.70ns	25.17
CA3bY-06	1.0	MJU,B	15.10	5.71	69.00	22.12	216.04	29.68
CA3bB-06	1.0	MJU,B	18.02	8.45	83.80	36.12	219.37	37.33
NM0-06	0	SS	12.50b	3.54	61.00b	12.73	209.95ns	17.36
NM3-06	1.0	SS	23.37a	0.99	96.67a	4.72	244.02	24.23
KS0-06	0	SS	14.10b	1.27	55.00b	11.31	271.79ns	31.58
KS4-06	1.5	SS	23.97a	2.14	105.67a	17.62	226.26	24.77

ns = Non significant

Fruit proportion

As for the crop year 2004, the results showed that the fruit weight was occurred in rang of 246.0 – 414.0 g, and also gave higher flesh (edible part, more than 69 %) yield which also then gave a lower waste percentages (seed and peel, less than 16.3 %, Table 3.19). Therefore, Nam Dok Mai cultivar was showed that fruits treated with PBZ retained a heavier size than it did with the control. It gave higher edible part yield (more than 77.0 %) and lower waste percentages (Table 3.20, 3.21) in both crop years 2005 and 2006. The fruit weight of Khiew Sawoey cultivar in crop year 2005 and 2006 was not statistically significant difference among the mean values. However, the waste percentage of peel was significantly different to the control trees which they were higher than the treated trees. The lowest percentage of seed was observed in Nam Dok Mai cultivar for three consecutive years. Conversely, the highest percentage of seed was found in Khiew Sawoey cultivar for three consecutive years (Table 3.19, 3.20, 3.21).

Table 3.19 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits proportion: fruit weight, flesh, seed and peel in percentage for year 2004 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plots	Weight [g]	S.D.	Flesh [%]	S.D.	Seed [%]	S.D.	Peel [%]	S.D.
CA0b-04	0	MJU,B	413.51	86.16	81.13	3.93	8.69	2.78	10.18	1.47
CA3b-04	1.0	MJU,B	-	-	-	-	-	-	-	-
NM0-04	0	SS	-	-	-	-	-	-	-	-
NM3-04	1.0	SS	254.04	45.84	77.52	2.04	8.59	1.56	13.98	1.13
KS0-04	0	SS	-	-	-	-	-	-	-	-
KS4-04	1.5	SS	246.70	66.84	69.96	2.89	14.03	2.34	16.21	1.13

Table 3.20 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits proportion: fruit weight, flesh, seed and peel in percentage for year 2005 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plots	Weight [g]	S.D.	Flesh [%]	S.D.	Seed [%]	S.D.	Peel [%]	S.D.
CA0b-05	0	MJU,B	254.96a	34.28	75.60a	1.83	10.73ns	1.80	13.67b	1.22
CA3bY-05	1.0	MJU,B	217.59b	64.53	73.45b	3.31	10.98	2.31	15.56a	1.82
NM0-05	0	SS	204.96b	64.74	75.79b	3.13	9.42ns	1.79	14.79a	2.74
NM3-05	1.0	SS	302.27a	68.05	77.76a	6.15	9.05	5.69	13.19b	1.87
KS0-05	0	SS	226.92ns	65.39	69.09ns	4.16	14.76ns	2.36	16.14a	2.82
KS4-05	1.5	SS	212.78	60.09	66.57	17.48	18.56	17.42	14.87b	2.80

ns = Non significant

Table 3.21 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits proportion: fruit weight, flesh, seed and peel in percentage for year 2006 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plots	Weight [g]	S.D.	Flesh [%]	S.D.	Seed [%]	S.D.	Peel [%]	S.D.
CA0b-06	0	MJU,B	213.00b	27.29	73.44ns	1.60	11.85ab	1.41	14.70ab	0.70
CA3bY-06	1.0	MJU,B	231.89a	33.78	73.35	2.60	11.30b	1.91	15.35a	1.43
CA3bB-06	1.0	MJU,B	207.01b	25.94	73.37	3.23	12.29a	1.72	14.35b	1.89
NM0-06	0	SS	269.70b	44.98	78.07ns	1.99	7.87ns	1.04	14.06ns	1.63
NM3-06	1.0	SS	300.36a	50.88	78.47	1.22	7.64	1.06	13.89	0.86
KS0-06	0	SS	325.32ns	82.25	70.36ns	4.33	14.48ns	3.54	15.16a	1.69
KS4-06	1.5	SS	327.14	67.92	72.05	3.01	13.69	2.90	14.27b	1.14

ns = Non significant

Fruit size distribution

The effect of paclobutrazol on mango cultivars to fruits size distribution such as length, width, and thickness in Chok Anan for crop years 2004 in B plot (Table 3.22) was only observed in control trees. Conversely, Nam Dok Mai and Khiew Sawoey in SS plot were only found in the treated trees (NM3-04, KS4-04).

Table 3.22 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits size distribution: length, width, and thickness for year 2004 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plots	Length [cm]	S.D.	W_{max} [cm]	S.D.	W_{min} [cm]	S.D.	T_{max} [cm]	S.D.	T_{min} [cm]	S.D.
CA0b-04	0	MJU,B	12.50	1.08	8.33	0.71	5.57	0.38	7.02	0.55	5.42	0.31
CA3b-04	1.0	MJU,B	-	-	-	-	-	-	-	-	-	-
NM0-04	0	SS	-	-	-	-	-	-	-	-	-	-
NM3-04	1.0	SS	12.41	1.18	6.65	0.44	3.59	0.65	6.24	0.35	3.23	0.49
KS0-04	0	SS	-	-	-	-	-	-	-	-	-	-
KS4-04	1.5	SS	12.21	1.65	6.34	0.53	4.79	0.46	5.84	0.50	4.55	0.48

Table 3.23 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits size distribution: length, width, and thickness for year 2005 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plots	Length [cm]	S.D.	W_{max} [cm]	S.D.	W_{min} [cm]	S.D.	T_{max} [cm]	S.D.	T_{min} [cm]	S.D.
CA0b-05	0	MJU,B	10.90a	0.52	7.00ns	0.38	5.39a	0.39	6.07a	0.30	4.71a	0.37
CA3bY-05	1.0	MJU,B	10.38b	1.32	6.81	0.71	4.82b	0.51	5.83b	0.59	4.30b	0.47
NM0-05	0	SS	11.45b	1.58	6.10b	0.65	4.10b	0.81	5.69b	0.82	3.54b	0.53
NM3-05	1.0	SS	13.52a	1.57	7.03a	0.57	4.94a	0.45	6.27a	0.47	3.95a	0.33
KS0-05	0	SS	12.06ns	1.39	6.08ns	0.57	4.81a	0.58	5.62ns	0.53	3.86ns	0.55
KS4-05	1.5	SS	11.65	1.53	6.08	0.45	4.51b	0.52	5.67	0.42	3.72	0.45

ns = Non significant

Table 3.24 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits size distribution: length, width, and thickness for year 2006 in B and SS plots. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared in each cultivar.

TR	PBZ conc.	Plots	Length [cm]	S.D.	W_{max} [cm]	S.D.	W_{min} [cm]	S.D.	T_{max} [cm]	S.D.	T_{min} [cm]	S.D.
CA0b-06	0	MJU,B	10.92a	0.68	6.87ns	0.39	5.52ns	0.38	6.04b	0.38	4.76ns	0.36
CA3bY-06	1.0	MJU,B	11.03a	0.77	8.08	7.48	5.40	0.83	6.24a	0.28	4.88	0.36
CA3bB-06	1.0	MJU,B	10.54b	0.54	6.68	0.31	5.35	0.37	5.90b	0.44	4.79	0.27
NM0-06	0	SS	12.64ns	1.39	6.52ns	0.65	5.10ns	0.40	6.08ns	0.32	4.55ns	0.35
NM3-06	1.0	SS	12.93	1.16	6.72	0.82	5.00	0.49	6.20	0.31	4.40	0.40
KS0-06	0	SS	14.57b	0.85	7.10ns	0.43	5.92ns	0.43	6.46ns	0.46	4.95a	0.43
KS4-06	1.5	SS	15.17a	0.79	7.05	0.40	5.97	0.39	6.30	0.39	4.69b	0.32

ns = Non significant

For the crop year 2005 (Table 3.23), Chok Anan cultivar was found a statistically significant difference in all parameters, except the maximum width (W_{max}). All parameters tested with the control trees (CA0b-05) were higher than the treated trees (CA3b-05). Nam Dok Mai cultivar was significantly different in all parameters. The highest of all variances was evaluated in the treated trees (NM3-05). Therefore, Khiew Sawoey was only significant in the minimum width (W_{min}), and the high value was found in the control trees (KS4-05). In the crop year 2006 (Table 3.24), Chok Anan was significantly different in the length and the maximum thicknesses (T_{max}) of fruits. The highest value of both parameters was occurred in the treated trees (CA3bY-06). In addition, Nam Dok Mai was not significantly affected to all parameters. Moreover, Khiew Sawoey had significant effect only with the length and the minimum thickness (T_{min}). The highest values of the length, and the minimum thickness were obtained in the treated and untreated trees, respectively.

Peel thickness

The impact of paclobutrazol on mango cultivars to the thickness of peels in both years (2005, 2006) for all cultivar 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' in B and SS plot which was compared to each stage of ripening (mature green and ripen) between untreated trees and treated trees were not statistically significant difference for three years in each cultivars (Figure 3.6, 3.7). The thickness of peels was observed in the range of 0.09-0.13 cm in mature green stage and it was thinned to 0.06-0.09 cm when mangoes ripen, including the crop year 2004 (Figure 3.5).

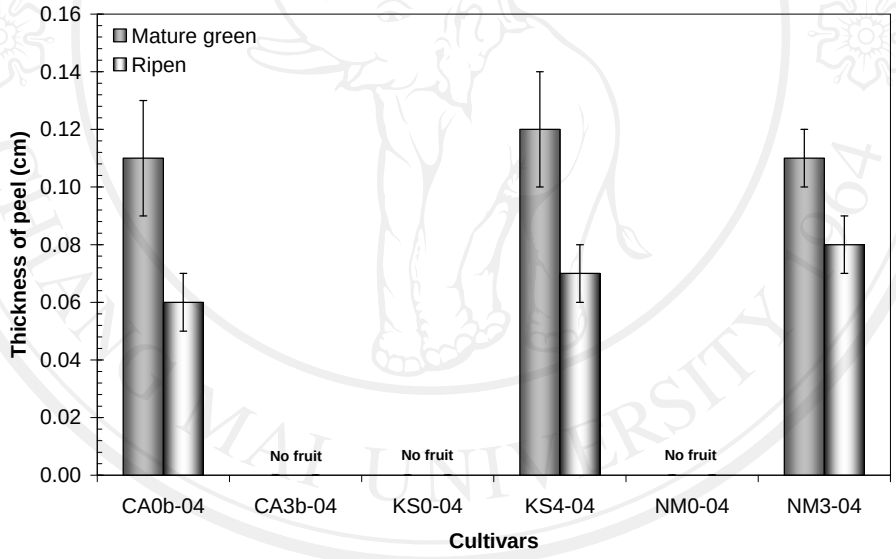


Figure 3.5 The comparison thickness of peel in different cultivars Chok Anan, Nam Dok Mai, and Khiew Sawoey between mature green and fully ripe stage which treated with paclobutrazol in year 2004.

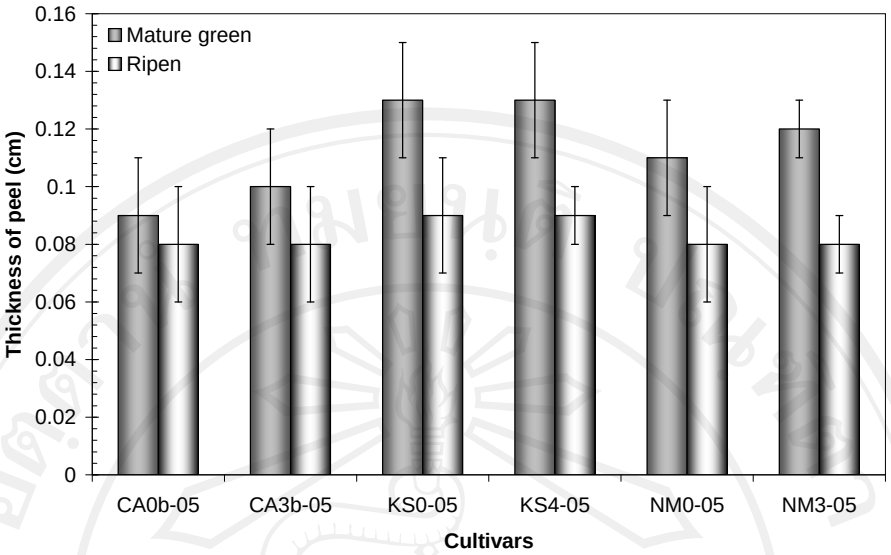


Figure 3.6 The comparison thickness of peel in different cultivars Chok Anan, Nam Dok Mai, and Khiew Sawoey between mature green and fully ripe stage which treated with paclobutrazol in year 2005.

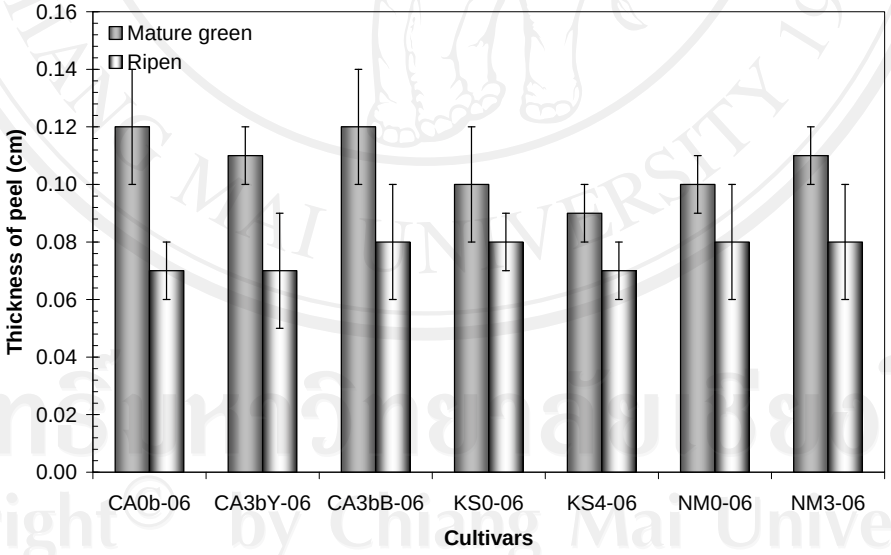


Figure 3.7 The comparison thickness of peel in different cultivars Chok Anan, Nam Dok Mai, and Khiew Sawoey between mature green and fully ripe stage which treated with paclobutrazol in year 2006.

Firmness, Total soluble solid (TSS), Titratable acidity (TA), pH, and Sugar-acid ratio (TSS/TA)

In crop year 2004 (Table 3.25), only control sample of Chok Anan cultivar gave fruits. However, Nam Dok Mai and Khiew Sawoey which were treated with PBZ produced fruits but not for the control. Firmness was decreased more than 10 times in fully ripe stage for all treatments when compared with initial harvested (mature green) value. Total soluble solid was increased about 2 times. Titratable acidity and pH were slightly changed. Sugar-acid ratio was raised nearly 2 times for Nam Dok Mai and Khiew Sawoey, except Chok Anan in control (CA0-04) was increased about 4 times.

In crop year 2005 (Table 3.26), Chok Anan in mature green was significantly different only in firmness value, that was harder in the control (CA0-05). For Nam Dok Mai was statistically significant difference as for total soluble solid, titratable acidity, and pH. Khiew Sawoey was only significant different in total soluble solid. In the fully ripe stage, Chok Anan was only significant in firmness, and the control (CA0-05) was harder than other treatments. Nam Dok Mai was significantly different in all parameters. Trees treated with PBZ (NM3-05) had the highest firmness and sugar-acid ratio, for other parameters, they were lower than control (NM0-05). Total soluble solid and sugar-acid ratio in Khiew Sawoey was significant different. High sugar-acid ratio was caused by the increased total soluble solid and the decreased titratable acidity.

For the crop year 2006 (Table 3.27), Chok Anan cultivar in mature green stage for the total soluble solid and pH were significantly difference of mean value. The highest value was observed in control (CA0b-06) sample. Nam Dok Mai and Khiew Sawoey were only significantly difference in titratable acidity and pH, respectively. In the fully ripe stage, Chok Anan was statistically significant difference for total soluble solid, titratable acidity, and pH. The highest amount was observed as in the control (CA0b-06). Nam Dok Mai had high firmness in control (NM0-06). Khiew Sawoey was significantly different for all parameters. The highest total soluble solid,

sugar-acid ratio and pH were as in the control (KS0-06). Higher firmness and titratable acidity were found with the treated trees with PBZ (KS4-06) than the others.

Peel and fresh colour

For the crop year 2004 (Table 3.28), peel colour in mature green stage of Chok Anan and Nam Dok Mai were yellow-green colour, but Khiew Sawoey had deep yellowish-green colour. Flesh colour of all cultivars was all the same, greenish-yellow colour. In the fully ripe stage, Chok Anan and Nam Dok Mai were greenish-yellow for peel, except Khiew Sawoey was still yellow-green of peel. However, the flesh colour for all cultivars was rather in the same shade as yellow colour.

The crop year 2005 (Table 3.29) in mature green stage the results indicated that Chok Anan was statistically significant difference as L, C*, and H* for peel. Flesh was only different as for L values. Nam Dok Mai also was significant difference in H* of peel and C* for flesh. A part of Khiew Sawoey was significantly different in L and H* of peel and H* as for flesh. However, peel colour in mature green for Chok Anan and Nam Dok Mai was greenish-yellow colour, but Khiew Sawoey was dark yellowish-green. Flesh colour of all cultivars and treatments were similarly as in yellow shade. All values were compared with hue sequence and hue angle orientation on a CIELAB diagram and not much different was found in colour shade. In fully ripe stage, peel colour of Chok Anan in control (CA0-05) was orange-yellow colour, for the trees treated with PBZ (CA3bY-05) were yellow colour. Peel colour in Nam Dok Mai between control and other treatments was presented the same colour as in yellow shade. Peel colour of Khiew Sawoey was not changed; it was still dark yellowish-green. However, the flesh colour of all cultivars and treatments in fully ripe was dull yellow colour.

The fruit in crop year 2006 (Table 3.30), peel colour of Chok Anan and Nam Dok Mai in mature green was yellow-green colour. Khiew Sawoey was yellowish-green. However, flesh colour of all cultivars and treatments in mature green was not much different as colour shade when compared with hue sequence and hue angle

orientation on a CIELAB diagram. They were greenish-yellow colour. For fully ripe stage, peel colour in Chok Anan was statistically significant difference of hue mean value. However, it was yellow colour as same as a CIELAB system. Nam Dok Mai and Khiew Sawoey had the same yellow-green colour of peel. Furthermore, flesh colour of all cultivars and treatments in fully ripe was not much different as colour shade when compared with hue sequence and hue angle orientation on a CIELAB diagram. They were yellow colour.

Table 3.25 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits quality: Firmness, TSS, TA, pH, and TSS/TA for year 2004 in B and SS plots at mature green and fully ripe stage. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared within each cultivar.

Stage	TR	PBZ conc.	Fruit quality									
			Firmness	S.D.	TSS	S.D.	TA	S.D.	pH	S.D.	TSS/TA	S.D.
Mature green	CA0b-04	0	9163.40	451.28	8.99	0.10	0.79	0.16	3.40	0.06	10.91	2.24
	CA3b-04	1.0	-	-	-	-	-	-	-	-	-	-
	NM0-04	0	-	-	-	-	-	-	-	-	-	-
	NM3-04	1.0	6324.00	314.88	11.67	0.13	1.03	0.00	3.50	0.01	11.31	0.05
	KS0-04	0	-	-	-	-	-	-	-	-	-	-
	KS4-04	1.5	7831.20	534.04	12.84	0.35	0.50	0.01	4.36	0.01	25.46	0.43
Fully ripe	CA0b-04	0	676.00	66.82	20.55	0.07	0.45	0.00	3.67	0.01	45.48	0.28
	CA3b-04	1.0	-	-	-	-	-	-	-	-	-	-
	NM0-04	0	-	-	-	-	-	-	-	-	-	-
	NM3-04	1.0	735.40	242.42	20.50	0.15	0.89	0.00	3.61	0.01	23.08	0.09
	KS0-04	0	-	-	-	-	-	-	-	-	-	-
	KS4-04	1.5	881.80	223.48	23.53	0.13	0.52	0.03	4.32	0.01	44.77	1.50

Firmness= N/100g Fw; TSS= g/100g Fw; TA= g/100g Fw;

Table 3.26 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits quality: Firmness, TSS, TA, pH, and TSS/TA for year 2005 in B and SS plots at mature green and fully ripe stage. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared within each cultivar.

Stage	TR	PBZ conc.	Fruit quality									
			Firmness	S.D.	TSS	S.D.	TA	S.D.	pH	S.D.	TSS/TA	S.D.
Mature green	CA0b-05	0	6943.80a	960.6	10.10ns	1.00	0.76ns	0.04	3.80ns	0.13	13.29ns	1.65
	CA3bY-05	1.0	4249.40b	753.15	10.12	0.62	0.75	0.14	3.65	0.10	13.83	2.45
	NM0-05	0	4862.40ns	568.77	11.58a	0.30	1.66b	0.17	3.27a	0.05	7.03ns	0.66
	NM3-05	1.0	5227.00	603.32	10.52b	0.34	1.70a	0.15	2.94b	0.02	6.25	0.60
	KS0-05	0	5776.93ns	422.49	13.44b	1.05	0.56ns	0.01	4.13ns	0.09	23.81ns	1.68
	KS4-05	1.5	5644.84	797.55	14.55a	0.62	0.69	0.15	4.06	0.16	22.20	5.35
Fully ripe	CA0b-05	0	1003.53a	170.69	18.93ns	1.01	0.72ns	0.13	4.06ns	0.18	27.25ns	5.02
	CA3bY-05	1.0	506.24b	167.07	17.63	1.40	0.70	0.07	3.92	0.09	25.53	4.42
	NM0-05	0	585.33b	86.56	16.34a	0.81	1.39a	0.19	3.54a	0.17	11.98b	2.14
	NM3-05	1.0	1304.92a	524.8	15.64b	0.46	1.10b	0.08	3.36b	0.07	14.35a	1.18
	KS0-05	0	958.80ns	320.01	20.30a	0.35	0.56ns	0.06	4.18ns	0.04	36.79a	3.19
	KS4-05	1.5	847.20	149.82	19.36b	0.57	0.60	0.05	4.16	0.08	31.78b	3.41

Firmness= N/100g Fw; TSS= g/100g Fw; TA= g/100g Fw; ns = Non significant

Table 3.27 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits quality: Firmness, TSS, TA, pH, and TSS/TA for year 2006 in B and SS plots at mature green and fully ripe stage. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared within each cultivar.

Stage	TR	PBZ conc.	Fruit quality									
			Firmness	S.D.	TSS	S.D.	TA	S.D.	pH	S.D.	TSS/TA	S.D.
Mature green	CA0b-06	0	8360.40ns	698.16	9.33a	0.22	0.73ns	0.00	4.06a	0.01	12.80ns	0.04
	CA3bY-06	1.0	6839.33	467.96	8.72ab	1.52	0.75	0.09	3.55b	0.10	11.88	2.63
	CA3bB-06	1.0	6971.15	660.38	7.85b	0.61	0.67	0.12	3.72b	0.17	12.23	3.17
	NM0-06	0	4618.80ns	204.65	9.24ns	0.14	2.18a	0.00	2.89ns	0.00	4.24ns	0.01
	NM3-06	1.0	4471.07	363.03	9.50	0.39	1.94b	0.10	2.89	0.09	4.91	0.40
	KS0-06	0	6400.75ns	334.94	9.54ns	0.19	0.44ns	0.06	4.03a	0.01	21.68ns	3.00
	KS4-06	1.5	6365.20	500.35	9.58	0.33	0.54	0.07	3.91b	0.09	17.88	2.80
Fully ripe	CA0b-06	0	463.00ns	74.72	19.68a	0.13	0.63a	0.00	4.10a	0.00	31.14ns	0.21
	CA3bY-06	1.0	402.85	74.96	15.84c	0.72	0.54ab	0.04	3.81b	0.07	29.32	2.40
	CA3bB-06	1.0	416.62	55.04	17.73b	1.83	0.45b	0.07	3.98a	0.16	38.97	14.06
	NM0-06	0	358.60a	60.12	16.80ns	0.06	1.23ns	0.00	3.22ns	0.01	13.68ns	0.01
	NM3-06	1.0	294.80b	49.65	16.11	0.65	1.03	0.13	3.39	0.22	15.76	1.90
	KS0-06	0	846.40b	76.59	17.99a	0.10	0.30b	0.01	4.16a	0.01	59.69a	0.81
	KS4-06	1.5	1234.86a	390.17	16.61b	1.21	0.44a	0.05	4.06b	0.04	40.77b	6.97

Firmness= N/100g Fw; TSS= g/100g Fw; TA= g/100g Fw; ns = Non significant

Table 3.28 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits quality: colour of peel and fresh for year 2004 in B and SS plots at mature green and fully ripe stage. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared within each cultivar.

Stage	TR	PBZ conc.	Peel						Flesh					
			L	S.D.	C*	S.D.	H*	S.D.	L	S.D.	C*	S.D.	H*	S.D.
Mature green	CA0b-04	0	63.82	4.22	40.97	2.28	115.98	2.24	78.66	3.42	32.82	1.08	105.84	0.34
	CA3b-04	1.0	-	-	-	-	-	-	-	-	-	-	-	-
	NM0-04	0	-	-	-	-	-	-	-	-	-	-	-	-
	NM3-04	1.0	62.60	1.66	37.63	1.61	118.54	2.53	80.70	3.79	48.37	3.97	99.61	0.78
	KS0-04	0	-	-	-	-	-	-	-	-	-	-	-	-
	KS4-04	1.5	51.15	2.36	20.88	1.77	129.45	3.55	80.69	1.99	44.37	2.20	102.91	0.70
Fully ripe	CA0b-04	0	65.36	6.75	46.84	7.87	105.30	8.47	68.91	4.16	61.82	5.71	95.21	0.75
	CA3b-04	1.0	-	-	-	-	-	-	-	-	-	-	-	-
	NM0-04	0	-	-	-	-	-	-	-	-	-	-	-	-
	NM3-04	1.0	64.32	2.76	41.22	2.90	110.20	3.91	65.26	4.58	58.95	6.56	93.97	2.07
	KS0-04	0	-	-	-	-	-	-	-	-	-	-	-	-
	KS4-04	1.5	50.58	4.05	25.99	5.90	123.00	5.27	68.20	2.42	53.44	2.38	98.28	0.82

Table 3.29 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits quality: colour of peel and fresh for year 2005 in B and SS plots at mature green and fully ripe stage. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared within each cultivar.

Stage	TR	PBZ conc.	Peel						Flesh					
			L	S.D.	C*	S.D.	H*	S.D.	L	S.D.	C*	S.D.	H*	S.D.
Mature green	CA0b-05	0	74.70a	3.12	44.54a	2.97	97.87b	4.27	82.54a	3.24	36.52ns	2.01	95.83ns	1.28
	CA3bY-05	1.0	65.42b	9.92	38.45b	4.16	103.08a	9.88	80.86b	2.55	37.13	2.35	95.87	2.48
	NM0-05	0	66.80ns	4.77	34.81ns	2.86	110.64a	4.85	81.54ns	4.75	36.25a	7.70	100.45ns	5.96
	NM3-05	1.0	69.61	2.92	34.20	2.10	106.71b	2.32	80.89	2.56	28.33b	1.54	101.54	0.75
	KS0-05	0	46.66a	2.52	16.90ns	2.28	124.05b	2.47	79.00ns	2.41	39.88ns	5.58	105.26a	3.02
	KS4-05	1.5	45.02b	2.74	16.66	4.96	128.83a	4.63	78.31	2.27	39.57	5.74	101.45b	1.90
Fully ripe	CA0b-05	0	77.07a	1.63	50.49a	3.42	87.77b	2.83	71.53b	6.54	49.10b	8.02	95.55b	1.71
	CA3bY-05	1.0	71.51b	4.94	47.16b	3.25	94.38a	8.97	76.99a	6.57	61.57a	6.8	97.16a	3.42
	NM0-05	0	66.36ns	4.50	34.49b	3.00	111.02a	4.92	76.85ns	3.17	40.30b	4.73	97.94ns	0.83
	NM3-05	1.0	67.19	1.80	37.11a	1.59	107.48b	2.56	75.67	4.07	52.77a	5.07	98.17	0.85
	KS0-05	0	48.99a	2.09	15.98b	3.66	121.82ns	9.42	68.96ns	4.06	51.36b	7.38	98.21a	1.20
	KS4-05	1.5	45.72b	3.02	18.68a	5.16	126.08	10.32	70.42	7.48	66.87a	11.27	95.76b	1.62

ns = Non significant

Table 3.30 Impact of paclobutrazol on mango cvs. 'Chok Anan', 'Nam Dok Mai' and 'Khiew Sawoey' to fruits quality: colour of pee; and fresh for year 2006 in B and SS plots at mature green and fully ripe stage. Means within columns followed by different letters in the same column and each cultivar are significantly different at $P \leq 0.05$ according to LSD test as compared within each cultivar.

Stage	TR	PBZ conc.	Peel						Flesh					
			L	S.D.	C*	S.D.	H*	S.D.	L	S.D.	C*	S.D.	H*	S.D.
Mature green	CA0b-06	0	56.13a	2.18	40.99a	3.04	120.50ns	1.62	79.81ns	2.82	44.81a	2.23	103.62b	0.30
	CA3bY-06	1.0	55.02a	1.47	37.86b	2.67	120.49	2.65	77.14	3.06	41.89b	3.09	105.34ab	1.51
	CA3bB-06	1.0	52.99b	4.03	37.15b	2.92	121.00	2.69	77.92	2.90	42.21ab	2.70	106.58a	2.88
	NM0-06	0	53.76ns	3.22	36.73ns	2.31	118.49ns	2.19	78.98ns	2.83	33.91b	0.84	107.71a	0.20
	NM3-06	1.0	55.01	3.75	35.98	3.93	120.38	3.59	80.99	2.85	40.55a	3.19	106.49b	1.00
	KS0-06	0	49.61a	1.89	25.06ns	4.29	128.54ns	3.85	75.78a	1.33	36.59ns	1.39	111.86b	0.17
	KS4-06	1.5	47.01b	2.53	25.33	5.03	126.68	4.35	71.47b	3.40	37.14	1.10	114.42a	1.21
Fully ripe	CA0b-06	0	72.13ns	2.64	58.64ns	2.87	98.34ab	2.21	75.62a	3.57	59.87ns	5.97	99.90ns	0.75
	CA3bY-06	1.0	70.08	12.35	56.41	3.43	97.00b	2.95	69.42b	5.26	58.78	6.65	99.83	0.85
	CA3bB-06	1.0	69.51	4.18	56.3	4.38	99.00a	2.55	72.59ab	2.58	61.28	4.92	99.08	0.86
	NM0-06	0	53.17ns	3.26	36.05ns	2.76	117.68ns	1.89	54.71b	3.21	35.36b	0.86	103.74ns	1.66
	NM3-06	1.0	52.58	4.02	38.09	3.31	116.20	2.24	64.60a	9.79	46.56a	8.09	103.77	3.73
	KS0-06	0	54.06a	4.12	34.73ns	3.83	121.64ns	3.19	62.67ns	5.40	57.72ns	5.34	99.95b	0.46
	KS4-06	1.5	50.17b	3.86	31.15	5.49	122.66	4.26	61.90	8.79	56.81	5.51	101.55a	1.34

ns = Non significant

3.4.3 Postharvest ripening behavior

Criteria indicating of full ripeness

Firmness, sugar-acid ratio (TSS/TA) and total soluble solid (TSS) were used to mark the full ripening stage. When total soluble solid (TSS) had reached its plateau, the full maturity stage can be indicated. The sugar-acid ratio (TSS/TA) started to increase during the stage of ripening. By the way, the firmness rapidly declined at the initial low levels of sugar-acid ratio (TSS/TA) and remained almost constant until fruits reached their fully ripe stage. However, the indicator used for full ripening fruit should be more than 2 parameters better than one solely parameter such as total soluble solid (TSS), firmness, titratable acidity (TA), pH and sugar-acid ratio. For example in Figure 3.8 shows the criterion for mango cultivar Chok Anan (CA0b-06, CA3bY-06, CA3bB-06), Khiew Sawoey (KS0-05, KS4-05) and Nam Dok Mai (NM0-06, NM3-06) were ripened in 2 days after harvesting. Total soluble solid (TSS) was found rapid increasing at the initial until full ripe stage and rather inclined constant after full maturity and in relation to ripening time (Figure 3.8A). Fruits firmness sharply decreased at the initial and rather constant after fully ripe (Figure 3.8C). Sugar-acid ratio was obtained rising (Figure 3.8B). Fruit firmness was sharply declined within 2 initial days of ripening and almost remained constant through the ripening period. The specific ripening kinetics for this quality attributes predominantly related to eating quality allowed to unambiguously specify the full maturity stage, providing that the postharvest ripening process can be completely observed. Moreover, the several factors may be affected to the graphical characteristic such as: the fruit reached over-ripe stage before studying, the short ripening time for studying, and the immature fruit used for studying, etc.

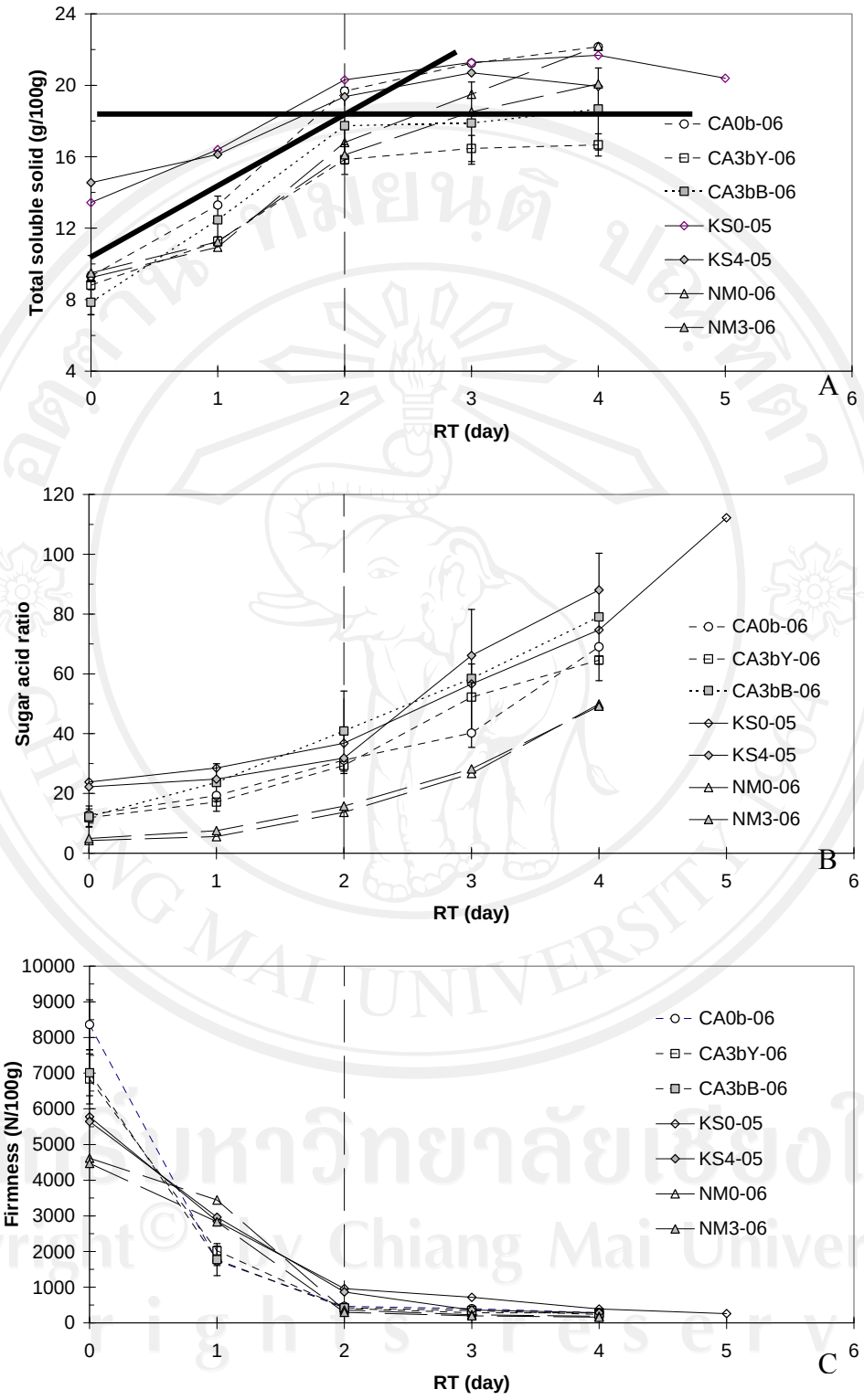


Figure 3.8 The indicating of full maturity of cvs. CA, KS, and NM. The vertical line represents the ripening time to reached them full ripening at 28±2 ˚C, 58-83 % RH.

The optimum time required to reach the full ripeness according to the criteria mentioned is summarized in Table 3.31, 3.32, 3.33 and 3.34 for all three cultivars under temperature about 28±2˚C, 58-83 %RH condition without accelerators. Mango cultivar Chok Anan with treated PBZ in different concentrations (Table 3.31) for D plot. As studying the impact of PBZ required, the process took 6-7 days to reach the full ripeness, while cultivar Chok Anan which was only treated 1.0 g *a.i.* PBZ (Table 3.32) in B plot for studying the impact of PBZ on different mango cultivar was compared within each cultivar between control and treatment for each year. It required 2-5 days for full ripeness. Nam Dok Mai and Khiew Sawoey required 1-3 days and 2-4 days reaching the full ripeness respectively. The values of quality parameters at the full ripening stages of all three cultivars ripened at 28±2˚C, 58-83 %RH were presented in Table 3.21, 3.22, 3.25, 3.26 and 3.27, respectively.

Table 3.31 Treatments, harvesting time, ripening conditions and ripening time of the investigation of fruit lots at D plot.

TR	PBZ conc.	Harvesting time	Ripening conditions		Ripening time (days)
			Temp (˚C)	RH (%)	
CA0-04	0	13 May 2004	26-30	65-82	6
CA1-04	Pro-Ca	13 May 2004	26-30	65-82	6
CA2-04	0.5	13 May 2004	26-30	65-82	6
CA3-04	1.0	13 May 2004	26-30	65-82	6
CA0-05	0	28 April 2005	26-28	58-75	7
CA1-05	Pro-Ca	29 April 2005	26-28	58-75	7
CA2-05	0.5	29 April 2005	26-28	58-75	7
CA3-05	1.0	29 April 2005	26-28	58-75	7

Table 3.32 Treatments, harvesting time, ripening conditions and ripening time of the investigation of fruit lots at B plot.

TR	PBZ conc.	Harvesting time	Ripening conditions		Ripening time (days)
			Temp (˚C)	RH (%)	
CA0b-04	0	13 May 2004	26-30	65-82	5 to 6
CA3b-04	1.0	-	-	-	-
CA0b-05	0	21 May 2005	27-28	65-80	2
CA3bY-05	1.0	14 May 2005	26-29	68-79	2
CA0b-06	0	26 May 2006	28-29	71-76	2
CA3bY-06	1.0	26 May 2006	28-29	71-76	2
CA3bB-06	1.0	26 May 2006	28-29	71-76	2

Table 3.33 Treatments, harvesting time, ripening conditions and ripening time of the investigation of fruit lots at SS plot.

TR	PBZ conc.	Harvesting time	Ripening conditions		Ripening time (days)
			Temp (˚C)	RH (%)	
NM0-04	0	-	-	-	-
NM3-04	1.0	21 May 2004	27-30	67-83	3
NM0-05	0	18 May 2005	28-29	67-80	1 to 2
NM3-05	1.0	11 May 2005	26-29	68-79	2
NM0-06	0	03 June 2006	28-29	72-73	2
NM3b-06	1.0	03 June 2006	28-29	72-73	2

Table 3.34 Treatments, harvesting time, ripening conditions and ripening time of the investigation of fruit lots at SS plot.

TR	PBZ conc.	Harvesting time	Ripening conditions		Ripening time (days)
			Temp (˚C)	RH (%)	
KS0-04	0	-	-	-	-
KS4-04	1.5	21 May 2004	27-30	67-83	4
KS0-05	0	18 May 2005	28-29	67-80	2
KS4-05	1.5	16 May 2005	26-28	67-79	2
KS0-06	0	19 May 2006	23-27	72-78	4
KS4-06	1.5	19 May 2006	23-27	72-78	4

Weight loss

The weight loss of fruit is caused by evaporation of water. The effect of PBZ on weight loss was not found. The investigations showed that the weight loss of the observing three cultivars during ripening process advanced almost linearly until over-ripe (Figure 3.9). The different of temperature, maturity of fruit and relative humidity during ripening affected the ripening behavior of the fruit. The weight loss in cultivar Nam Dok Mai and Khiew Sawoey were clearly occurred. Chok Anan cultivars in plot D (CA0-04,...CA0-05,…) reached full ripening stage after 7 days, this cultivar led to weight loss of about 4 – 7 %. Furthermore, Nam Dok Mai, Khiew Sawoey and Chok Anan in B plot (CA0b…CA3b…) were reduced in weight loss, the values ranged between 2 – 5 %. The different harvesting date of the fruits had also affected to the weight loss.

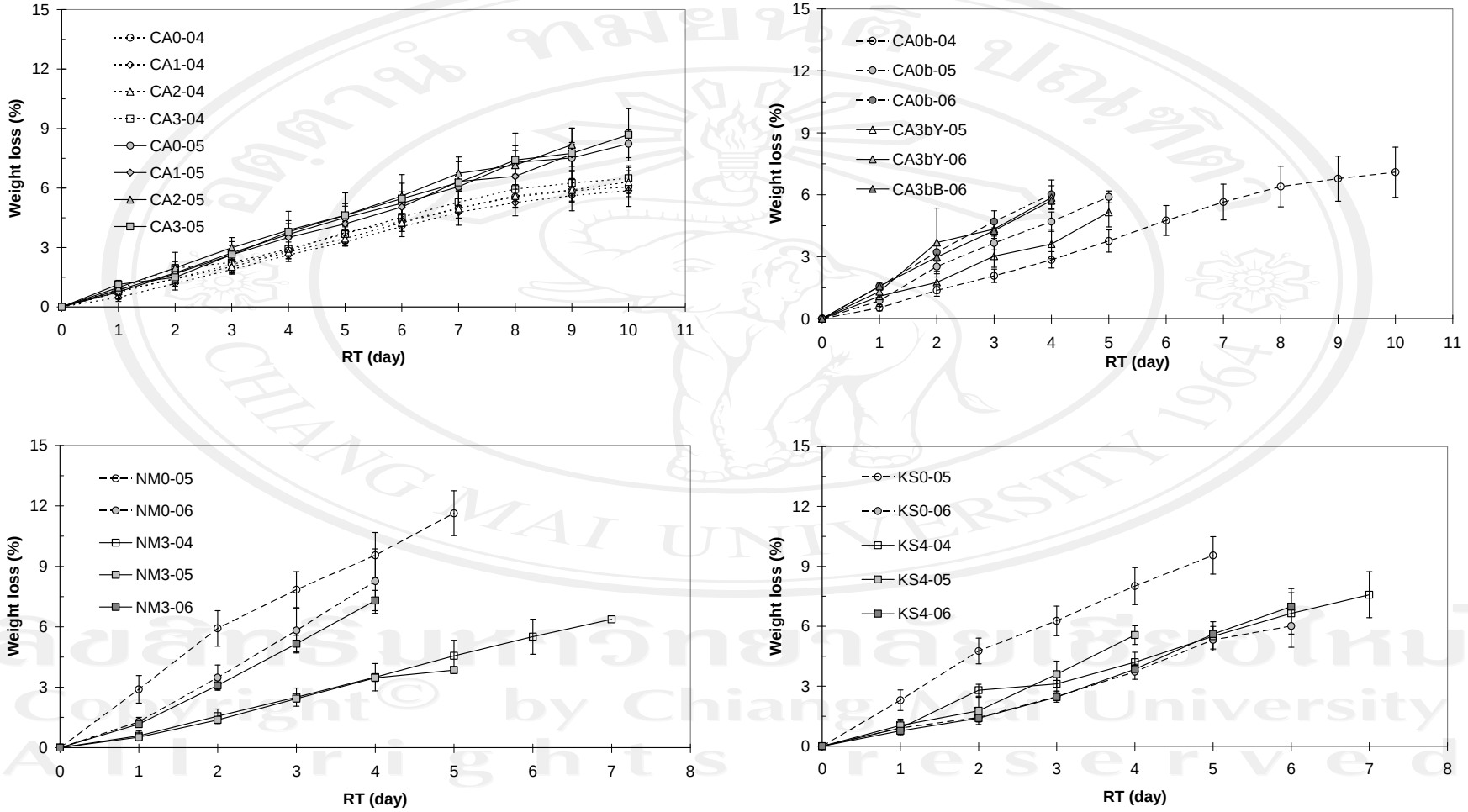


Figure 3.9 Weight losses in mango cvs. Chok Anan, Nam Dok Mai and Khiew Sawoey during postharvest ripening

Flesh firmness

Fruit firmness of almost all cultivars was rapidly decreased during the 2 initial days of ripening, except Chok Anan in D plot (CA0-04…CA0-05…) was declined in the 6 -7 days of the ripening process (Figure 3.10). At the 5 – 6 initial days of this cultivar in D plot the firmness was rather constant or negligible change. However, the reduction of fruit firmness after the full ripe stage it trended as same as others. The initial value of fruit firmness was differed for each cultivar and each batch. However, Chok Anan was hardened when compared to the beginning of the ripening process in each cultivar.

Total soluble solid (TSS), Titratable acidity (TA), pH-value

The investigation of total soluble solid in Chok Anan at D plot for crop year 2004 was higher than in 2005. TSS in control tree for year 2004 was higher than treated trees after full ripe stage, but it was opposed for crop year 2005. TSS values in Chok Anan in both crop years were lower than 10 g/100g fresh weight (Figure 3.11). In addition of Chok Anan in B plot, it was also found that the TSS in control tree was higher than treated trees. Nam Dok Mai and Khiew Sawoey had stronger TSS in control trees. However, TSS for all cultivars increases rapidly at the beginning and inclined constantly after full ripe stage.

TA was slowly decreased in all cultivars, except Nam Dok Mai cultivar was rather strongly declined (Figure 3.12). Chok Anan at D plot in crop year 2005 was higher than the crop year 2004. The result was followed with TSS (Figure 3.11) as describe above. Nam Dok Mai had high value of TA at the beginning of the ripening process in range of 1.0 – 2.5 g/100g fresh weight, for the other cultivars TA was below 1.0 g/100g fresh weight. Furthermore, the lower TA was observed in Khiew Sawoey as the range of 0.45 – 0.70 g/100g fresh weight.

pH values of the fruit pulp increased throughout the ripening process for all cultivars irrespective of treatment (Figure 3.13). The highest pH value was occurred

in Khiew Sawoey cultivar as the range of 4.0 – 4.5, but the lower pH was in Nam Dok Mai between 3.0 – 3.5. Consistent with the TA developed in Chok Anan for both crop years was obtained. Moreover, total soluble solid (TSS), titratable acidity (TA), pH and sugar-acid ratio are important sensory attributes crucial to consumers' acceptance of fruits and fruit products.

Sugar-acid ratio was extremely rising to a final ratio of high value after full ripe stage in all cultivars and treatments.

Peel and flesh Colour

Hue of peel value indicated that the peel colour of mango development during the ripening process was specific to the cultivar (Figure 3.14). Peel colour of Khiew Sawoey was observed the high hue value in range of 120º – 130º at the beginning of the ripening process that showed a desirable yellowish-green to yellow-green colour. Furthermore, the peel colour of the other cultivars was occurred below 120º at the beginning of the ripening process that showed a desirable greenish-yellow colour. However, the hue of peel colour for all cultivars was developed to yellow colour that indicated in the rank of 80º - 90º. In addition of peel colour is a major parameter influencing consumer behavior, the cultivar that changes a vehement yellow or orange colour would be more an attractive.

The flesh colour was showed a considerable greenish-yellow colour to pale yellow (100º - 115º) at the beginning of the ripening process for all cultivars and treatments (Figure 3.15). They were trended to more or less deep yellow colour that indicated in the rank of 88º - 96º.

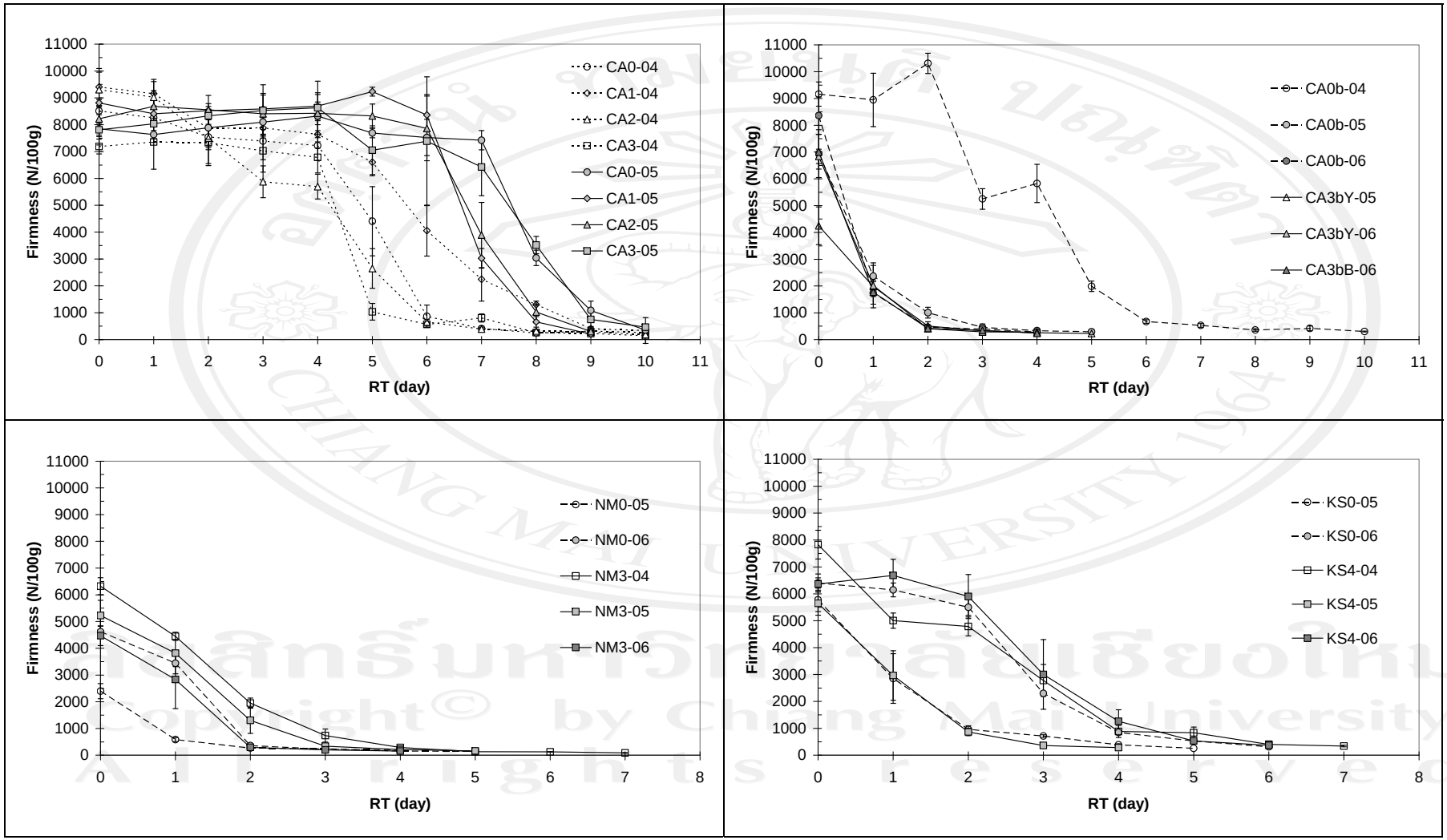


Figure 3.10 Changes in flesh firmness in mango cvs. Chok Anan, Nam Dok Mai and Khiew Sawoey during postharvest ripening

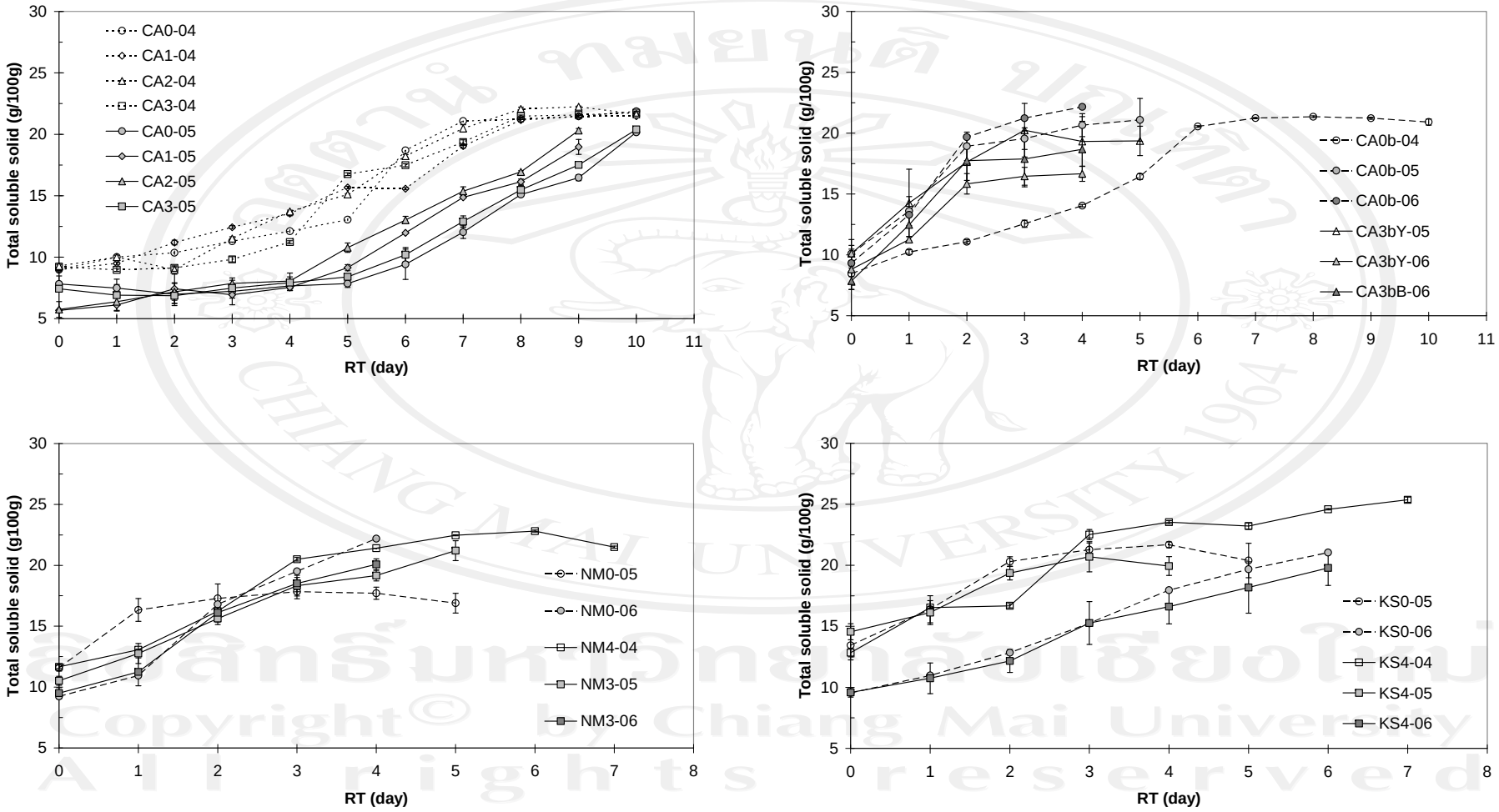


Figure 3.11 General changes in TSS for mango cvs. Chok Anan, Nam Dok Mai and Khiew Sawoey during postharvest ripening

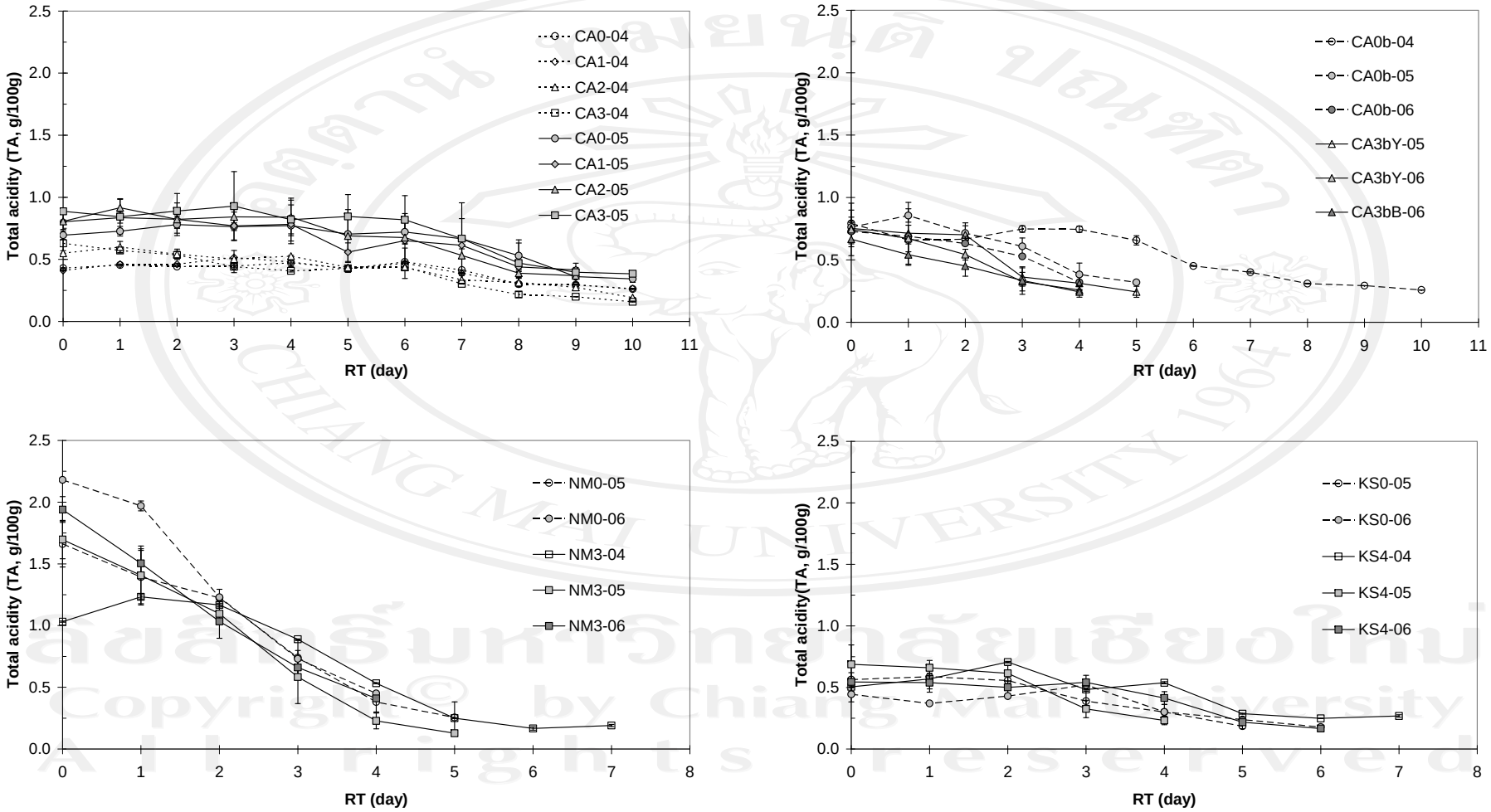


Figure 3.12 Changes in TA of mango cvs. Chok Anan, Nam Dok Mai and Khiew Sawoey during postharvest ripening

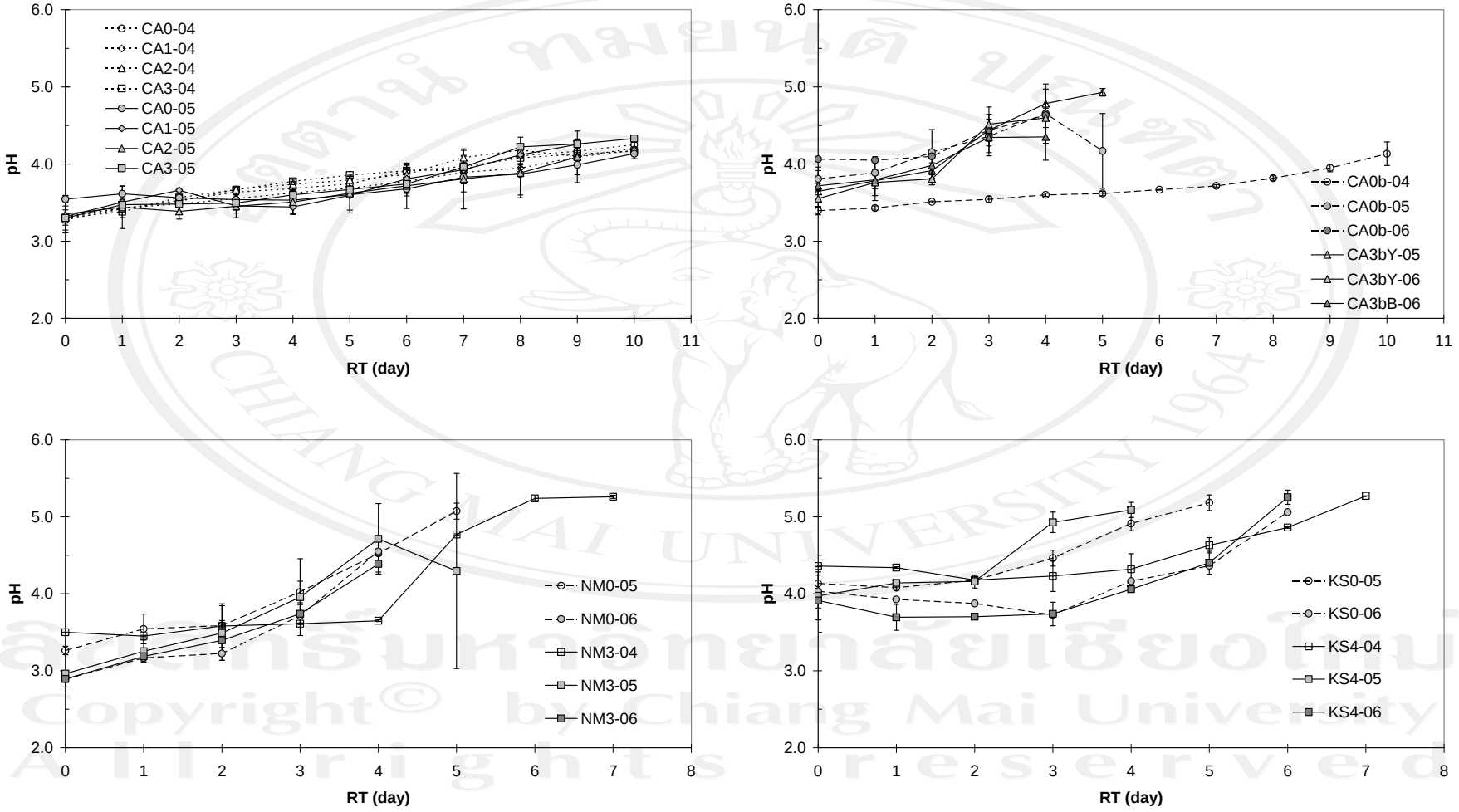


Figure 3.13 General changes in pH of mango cvs. Chok Anan, Nam Dok Mai and Khiew Sawoey during postharvest ripening

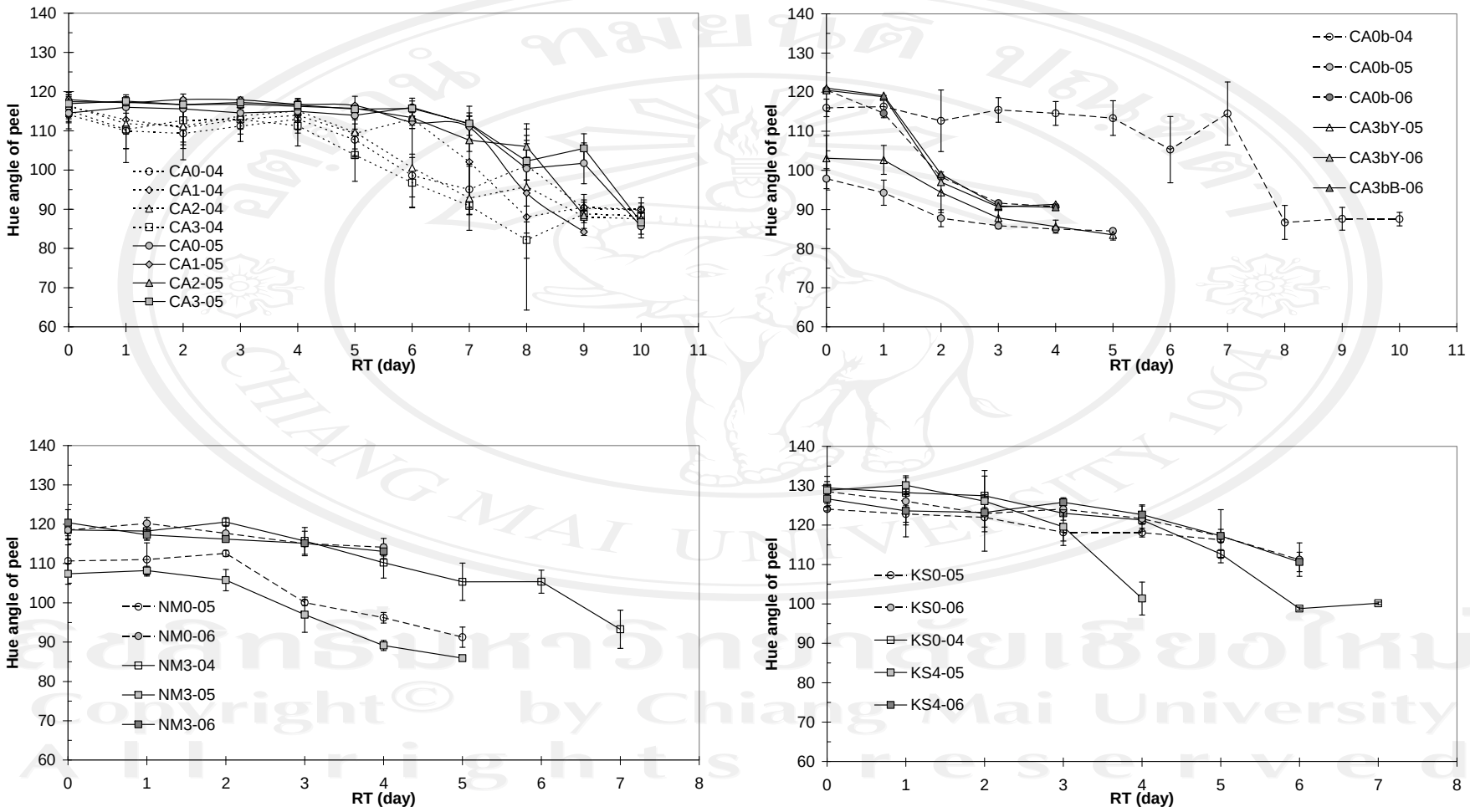


Figure 3.14 General changes in hue of peel mango cvs. Chok Anan, Nam Dok Mai and Khiew Sawoey during postharvest ripening

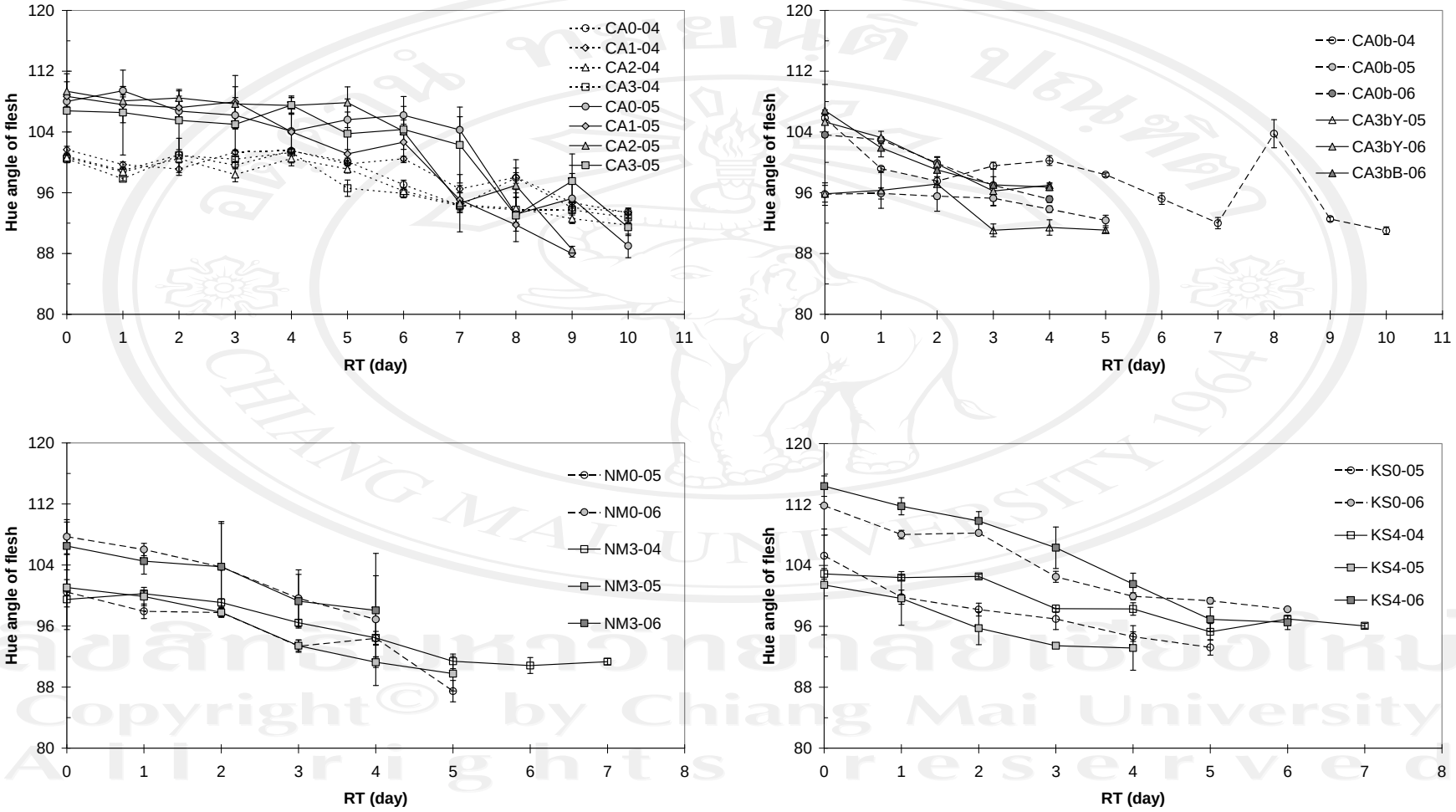


Figure 3.15 Flesh colour development (hue) in mango cvs. Chok Anan, Nam Dok Mai and Khiew Sawoey during postharvest ripening

3.5 Discussion

3.5.1 Effect of the different paclobutrazol concentration

In this case, the study was only observed in Chok Anan cultivar at D plot that resulted non significant difference of the date (period) to flower between in-season and off-season mango, but they was significantly different of the flowering percent in each concentration. The normal flowering period for mangoes in Thailand is between Decembers through January. In addition, low temperature of 15 ˚C day and 10 degree night was reported to completely inhibit vegetative growth of Nam Dok Mai mango trees, enhanced carbohydrate accumulation within different parts of the trees, and induced flowering (Whiley *et al*., 1989). Davenport and Nunez-Elisea (1997) found that the minimum temperature of 18 ˚C or less are considered being favorable for the induction of flowering mango.

However, the flowering percentage was not related to the yield per tree because there was only recorded the percentage of flowered shoots at the first time of flowering. On the other hand, it was found that the mango tree had the second or the third time of flowering. The yield was collected that included for all of the flowering.

The weather in north region of Thailand is one impediment of the mango flowering, because it is very fluctuating, especially at night and day the temperature was very different during the studying. However, Phavaphutanon *et al*. (2000) reported that Nam Dok Mai mangoes grown in the low land production system were very responsive to the first time of PBZ application. Vegetative growth was completely inhibited and off-season flowering could achieve during a rainy season without inductive conditions such as low temperature or water stress. Moreover, the mango trees should have the new vegetative flushes until the leaves changes to purple colour, it is the better time for applied PBZ as describe by Tongumpai (1999) and Nartvaranant *et al*. (2000). This was a problem and could be a reason why late application of PBZ is needed. The lack of response for flowering found in crop year 2005 of Chok Anan occurred in spite of having drenched beyond the dates. It may be

due to rainy season inducing the buds to flushes instead of flowers. The results of an experiment by Burondkar and Gunjate (1993) also reported that PBZ application increased the number of flowering shoots due to lower vegetative growth and higher food reserves in the tree. A higher accumulation of food reserves in the shoot prior to flowering was observed by Stassen and Janse Van Vuuren (1997); Phavaphutanon *et* a*l*. (2000).

Mango growth and development are strongly influenced by the environment (Whiley *et al*., 1989; and Nunez-Elisea *et al*., 1993). The success in production off-season mango is also dependent on other factors such as climatic conditions, mango cultivars, location, and orchard management and most importantly the experience of mango growers.

Harvesting period was not significance from the control (in-season). The fruit production was observed high amount of the fruit numbers per tree in the treated trees and the weight of yields per tree as following together. By the way, it was decreased the weight per fruit. In crop year 2004 the treated trees with high doses of PBZ gave the fruit weight below 250 g/fruit, but only control trees in crop year 2005 was higher than 300 g/fruit. Furthermore, the small size was occurred in the treated trees with PBZ. The fruit proportions in averages were gave the flesh percent higher than 75 %, the waste of seed and peel below 14 %. PBZ was not effect on the thickness of peel. Kurian and Iyer (1992, 1993) reported that the higher doses of PBZ application reduced fruit size. As for Singh and Dhillon (1992) reported that the fruit yield was significantly higher (27.2 kg/tree) with the soil application of Cultar (20 g/tree) as compared to all other treatments. Furthermore, PBZ enhanced fruit set (Steffens and Wang, 1986) that means it should have higher fruit numbers per tree.

According to Salazar-Garcia and Vazquez-Valdivia (1996) reported that when ‘Tommy Atkins’ mango was applied by PBZ at 0, 2.5, 5, 10, 15, 20 and 40 g per tree, all PBZ rates decreased average fruit weight (398 to 301 g). Control trees produced the heaviest fruit (401 g). Fruit diameter was closely related to fruit weight and again the smallest values were for PBZ levels of 15 g per tree and above. Moreover,

Yeshitela *et al*. (2004) reported that when ten-year-old 'Tommy Atkins' mango trees in the Rift Valley of Ethiopia was treated with PBZ by soil drench and spray at 0, 2.75, 5.50, 8.25 g *a.i.* per tree, the main effect of method and dose of PBZ application was significantly affected the total fruit numbers at harvest. The results showed that higher numbers of fruit were obtained from soil drenching than spray applications. Applications of 8.25 g *a.i.* per tree PBZ increased the weight of harvested fruit by 152.87% when compared with the control. Average weight of fruit was not significantly affected by PBZ application. Voon *et al*. (1991) found that the work conducted with Cultar by ICI agrochemicals and various co-operators in Thailand, Malaysia and Indonesia. Fruit numbers were increased significantly. Nonetheless, Fruit size was usually not affected but in some cases increased. They also explained that fruit size is related more to fruit load on the tree than to the direct effect of Cultar. To sustain yield increases, it is important that nutrients, irrigation and management are provided. It is also important not to over crop and this can be achieved by applying optimal Cultar doses for each cultivar per tree size. Furthermore, Khader (1989) illustrated that when PBZ (PP333) was applied as foliar spray at 250, 500, 1000, 2000 or 3000 mg/L in 'Dashehari' mango (*Mangifera indica* L.) tree, the concentrations of 2000 and 3000 mg/L treatments were significantly higher (9.1-9.3) in TSS values but total acidity values were lower than the control at the beginning of the harvest. A similar trend was found with the sugar acid ratio with the significant higher values in fruits when treated with 2000 or 3000 mg/L PP333. However, all treatments having a uniform level of ascorbic acid at harvest were observed.

It was studied on Chok Anan in D plot about the impact of PBZ in different concentration. The high concentration of PBZ clearly affected to fruit firmness at mature green and full ripe stage in crop year 2004 of Chok Anan at D plot, Prohexadione-Calcium was also obtained. PBZ was impacted to sugar-acid ratio that showed the relative of the basic test and palatability of the fruits (Mahayothee, 2004). The striking of TSS, TA and pH was also occurred. There were not clear about the effect of PBZ on peel and flesh colour development.

3.5.2 Effect of paclobutrazol on different mango cultivars

In this experiment, the effect of PBZ on different mango cultivars was investigated. Nam Dok Mai and Khiew Sawoey were very responsive to the first time of PBZ application, the flowerings could be achieved. Chok Anan was found less flower, it may be due to the usage high dose of PBZ (1.0 g *a.i.*) making them stun. The flowers and panicles were compacted and shortened. This reason Chok Anan was not fruit set and fruit production in crop year 2004. The next 2 consecutive years of Chok Anan were responded to PBZ application, but the flowers and panicles were still compacted and shortened. Generally, Chok Anan is known to be easily induced off-season flower. Kurian and Iyer (1992) reported that the PBZ at the highest doses decreased pollen fertility. The date of anthesis of all cultivars and all treatments were not significant difference for shooting when compared with control trees (in-season). The success in production off-season mango in north part of Thailand is still difficult, because of the several factors is affected as describe above.

The fruit production was significant only in the fruit numbers per tree, especially in the treated trees were found higher fruit per tree. However, the high difference of the fruit yields per tree or the fruit numbers per tree and others was obtained for each treatment that means the data have high variation for each treatment. Thus, the usage of the statistical analysis was shown not significant difference of the mean value. Therefore, the data looks like differences in some cases. However, it was directly affected by treatments. The fruit weight per tree of all cultivars was decreased for the treated trees in the 2 consecutive crop years later. Nam Dok Mai was highly responded with PBZ better than other cultivars. Three consecutive years of Khiew Sawoey had the percent of flesh below than 70 % and other cultivars were higher than 75 %. The big seed was found in Khiew Sawoey, but the small (flat shape) seed was in Nam Dok Mai. Chok Anan cultivar shortened in fruit length. Non significant of the thickness of peel in all cultivars was obtained when compared with treated trees and untreated trees for each cultivar in each crop year.

With reference to González and Blaikie (2003) they found that the second involved applying PBZ as a soil drench around the trunk of the tree. Commercial fruit yield of PBZ-treated trees was 2-3 times higher than that of control or mango flowering treatment (MFT). Fruit yield was enhanced considerably by PBZ at 2.5 or 5.0 g per tree, but 10 g per tree, it reduced yield. Alar at 3000 mg/L slightly enhanced yield and higher doses of PBZ (10 g) reduced fruit size (Kurian and Iyer, 1993).

Winston (1992) found that PBZ was applied after harvest as a foliar spray, a band along the drip line, or a collar drench in trials over 3 years on 3-, 4-, and 5-year-old trees of mango *cv. Kensington Pride*. In particular, collar drenches of 4 and 8 mL *a.i.*/tree, applied for 2 consecutive years, reduced summer growth. Flowering and cropping were significantly increased by PBZ in a year of inadequate winter stress, while a trend towards increased yield was noted under more normal conditions. Yield increases were due to fruit numbers rather than size. Dose of PBZ > 4 mL *a.i.*/tree caused unacceptable compaction of flower panicles.

In term of different mango cultivars, the PBZ was affected to fruit firmness for Nam Dok Mai and Khiew Sawoey. Firmness value could be referring to the fiber that obtained in mango flesh. The sourness found in Nam Dok Mai, but the sweetness occurred in Khiew Sawoey and Chok Anan, respectively. By analogy, Kurian and Iyer (1992) found that the highest doses of PBZ application adversely affected TSS of fruit juice while the lowest concentration of the chemical resulted in on significant increase in TSS. Other physico-chemical characters of fruits such as acidity of fruit juice, pulp to skin or pulp to stone ratio etc., were not much affected by PBZ treatments. The change of peel and flesh colour was also not clear by the impact of PBZ. It may be due to dependent of cultivar. Salazar-Garcia and Vazquez-Valdivia (1996) reported that TSS of Tommy Atkins fruit juice were not affected compared with the controls at low rates of PBZ (2.5 and 5 g per tree), but they were significantly higher for trees treated with 10 g PBZ per tree or above. TA for fruits from control and 10 g PBZ per tree gave intermediate values (0.18 and 0.19%). Fruits from trees treated with PBZ at 5 g per trees had the highest acidity (0.29%) and the lowest acidity which corresponded to fruits of treatments with 2.5 and 20 g PBZ per tree

(0.15 and 0.14%, respectively). Kurian and Iyer (1993) found that the higher doses of PBZ (10 g) gave an adversely effects to the TSS of fruits while the sugar acid ratio was lower.

3.5.3 Postharvest ripening behavior

Three parameters were selected to indicate of full ripe stage could be accepted such as TSS, sugar-acid ratio and firmness. By analogy, Mahayothee (2004) found that the firmness, TSS/TA and TSS were used to define the full ripening of the three cultivars (Chok Anan, Nam Dok Mai and Keaw). The criterion used is the ripening time when TSS had approximately reached its plateau, and the TSS/TA started to substantially increase. Moreover, firmness was also considered, since significant changes in firmness generally occurred until a time, when it remained somewhat constant. The variation of quality parameters in each cultivar was followed as same as the theoretical. Furthermore, the TA of Nam Dok Mai at the initial was very high values and strongly decreased to other cultivars until full ripe it still high. That was sour and it had relative to the low sugar-acid ratio value that was reported by Mahayothee (2004) However, the development of peel colour depended on the cultivar. Moreover, PBZ was not affected to the ripening process period for all cultivars. Therefore, Rizzolo *et al*. (1997) said that PBZ enhanced the ripening processes, which are associated with volatile evolution at harvest. Also Steffens and Wang (1986) indicated that PBZ has been widely shown to be active in controlling the vegetative growth of mango fruit corps, generally it reduces ethylene production, delays fruit maturation and ripening, enhances fruit set and limits water loss. According to Burondkar and Gunjate (1993) reported that when PBZ was treated at 500, 1000 and 2000 ppm as foliar and 5 g and 10 g per tree by soil drench with Alphonso mango, none of the PBZ treatments impaired and improved any of the fruit quality attributes, the data pertaining to chemical composition of ripe mango fruit. Also Kurian and Iyer (1993) found that the higher doses of PBZ (10 g) delayed the maturing of mango fruits on the trees and the ripening of harvested fruits

3.6 Conclusion

PBZ could not be succeeded to induce mango flowering out of season. However, it could help and enhance the percentage of flowering. PBZ was affected with the number of fruit per tree and it caused to the average of the weight per fruit, yield per tree, and fruit size. The influences of PBZ on fruit quality parameters were observed in some parameters such as: TSS, TA, and firmness. Furthermore, it depended on cultivars, batches, and including several factors such as climatic conditions; mango cultivars; location; mango healthy; orchard management and most importantly the experience of mango growers.