Chapter 8

Effect of Fertilizer Ratio on Yield and Quality of Fruit

Introduction

In fruit tree production, success depends on several related factors. One key factor, essential for plant growth, is plant nutrition (Wanichkul, 2002). Plant nutrition management has generally proved important because of getting optimum productivity as well as the good fruit quality (Wangnai, 2002). The balance of nutrient refers to the supply of nutrients which plants need (Roy *et al*., 2003). Plant nutrient loss occurs in many ways such as supporting the vegetative growth and reproducing the fruit tree (Vosti *et al*., 2007). Excessive use of fertilizers, on the other hand resulting in direct disadvantages to the plants, may leave more nutrients accumulated in soil than the standard value and inhibit the availability of some other nutrients which is essential for the growth and development of plants. Excess P application through soil makes plants lack some micronutrients such as Zn which is important for oranges as well as Fe and Mn which may be affected in the same way. Plants may reveal the deficiency of these micronutrients although a high amount of them is detected in the soil.

Using chemical fertilizers may cause soil acidity. It obviously appears when plants lack Ca and Mg. When the nutrient balance is lost, plants suffer in at least 3 ways: 1) decrease the productivity, 2) reduces the fruit quality, 3) subject to attack by diseases and insect pests, therefore the total value of products may be lost with the improper application of fertilizers (Parkpian *et al*., 1995). The Department of Agriculture (2006a) has recently suggested 4 fertilizers application methods by: 1) using proper fertilizers according to the plant type, 2) using fertilizers in appropriate quantity ratio, 3) using fertilizers at the right time when plants need, and 4) considering the effects of nutrient balance in soil. The nutrients of which plants require are macronutrients including N, P, and K concurrence. For example, the citrus tree fertilization experiment might involve several ratio and application frequencies. The Department of Agriculture (2006a) recommended the base of fertilization 1:1:1 ratio for plant. The most accepted experimented ratio of 4:1:5 and 4:2:5 came from the analysis of nutrient content in tangerine fruits and yield, while the 3:1:3 ratio was

recommended by UNIDO/IFDC (1998) Bulletin SP-169 Nutrition of Florida Citrus Trees. Therefore, this experiment aims to find out the proper ratio of nitrogen, phosphorus, and potassium which is appropriate to quantity and quality of tangerine production.

Materials and Methods

The experiments were conducted by using one year air layering propagated tangerine cv. Sainampueng grown with fine sand in 40 cm diameter pots. The trees were grown in the experimental plot at the Department of Horticulture, Chiang Mai University, Thailand during April 2005 - October 2007.

Twenty Sainampueng trees were planted in sand culture for the experiment. For the first year, Sainampueng trees were daily irrigated with Hoagland solution, pH 6.5 (Hoagland and Arnon, 1952).

While in the 2nd year, 20 Sainampueng randomly selected in 4 treatments had been conducted, N:P_2O_5:K_2O ratio was issued as 4:1:5, 4:2:5, 1:1:1 and 3:1:3 in each treatment with 10 g everyday. The other elements were still performed by Hoagland and Arnon (1952) method. When fruit set happened, the amount were changed to 20 g.

In each treatment, 5 fruits were collected from the trees with the age of 2 (April 21, 2005), 5 (July 15, 2005), 8 (October 27, 2005) and 10 (December 24, 2005) months. The fruit qualities and nutrient concentration in fruit composition were determined (by the procedures) as previously described in Chapter 6.

The 50 leaves samplings with the 3rd collected leaf from shoot apex and 3-month-old leaf around the tree canopy were collected on May 21, 2005. The nutrient concentration in collected leaves were determined (by the procedures) as previously described in Chapter 4.

The data were statistically analyzed using ANOVA. A least significant difference (LSD) was used to test the effects of treatments when the F-test was statistically significant at $p \leq 0.05$.

Results and Discussion

1. Effect of nutrient ratio on flowering of tangerine

The tangerine trees flowered normally in February. There were 276 auxiliary clusters per tree, when the trees were inputted adjustment $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately as 4:2:5. While the flowers were adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately as 1:1:1, 4:1:5 and 3:1:3, respectively at 243, 184, and 136 auxiliary clusters per tree, respectively. Tangerine flowered last time in developing from flower to fruit for 4 weeks.

2. Effect of nutrient ratio on fruit growth of tangerine

The adjusted ratio of $N:P_2O_5:K_2O$ to approximately 4:1:5, 4:2:5, 1:1:1, and 3:1:3 resulted in no differences in the increase of fruit size and fruit weight. The peel thickness was decreased when the fruit had more age (Figure 8.1, 8.2 and 8.3).

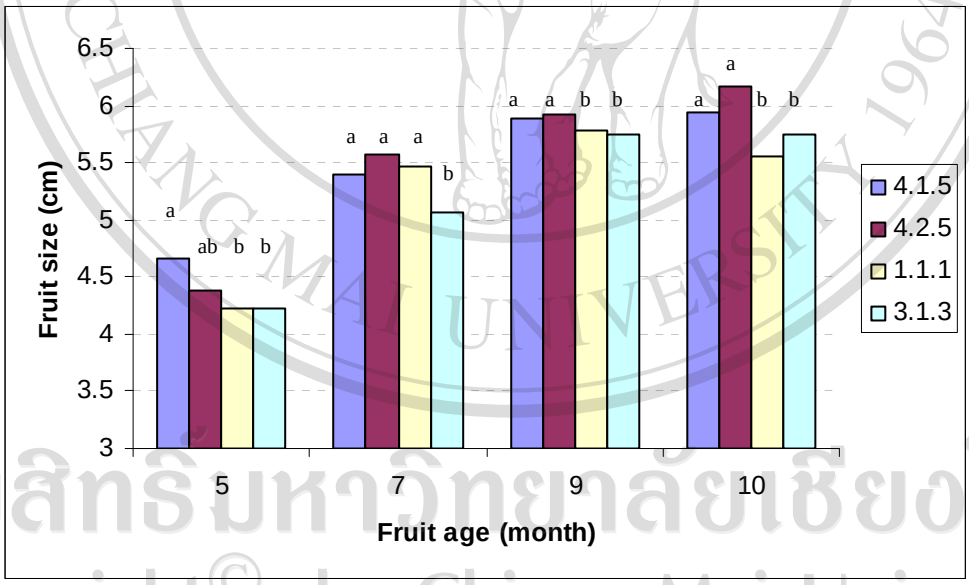

Figure 8.1 The effect of adjusted nutrient ratio of the fertilizer on fruit size of tangerine cv. Sainampueng.

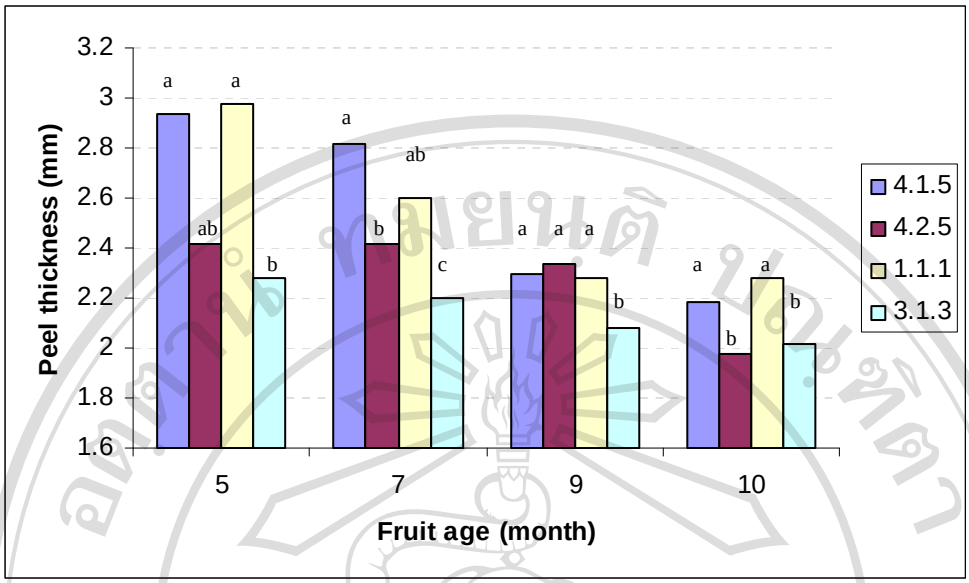

Figure 8.2 The effect of adjusted nutrient ratio of the fertilizer on peel thickness of tangerine cv. Sainampueng.

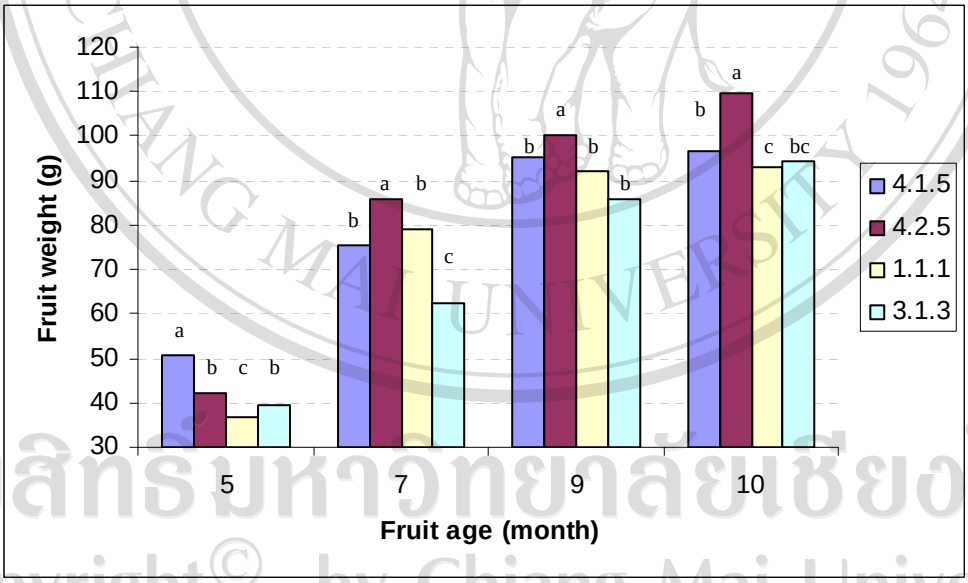

Figure 8.3 The effect of adjusted nutrient ratio of the fertilizer on fruit weight of tangerine cv. Sainampueng.

Peel's colour was changed from green to greenish yellow at the age 9 to 10 months. In the fruit maturation, chlorophyll pigments disappear from the flavedo and carotenoid pigments are revealed (Charles and Coggins, 1986).

As shown in Table 8.1, the ratio of 4:2:5 provided the biggest fruit and more fruit weight than any other ratio, because it would give the most suitable nutrients for fruit growth. It was expected that the 4:2:5 would increase peel thickness because nitrogen is generally seen to result in increasing peel thickness, but this was not observed. (Mongi *et al.*, 2008).

From this experiment, it was found that the fruit size is so small that it can hardly sell in the market as the standard. It might result from insufficient amounts of nutrients as the plant needed.

The adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately 4:2:5 gave the highest yield (Table 8.1). This result came from a better flowering and fruit set. The percentage of combined variance (% CV) was high because in April, the tangerine fruits were fallen and twigs were broken from a storm and heavy rain in Chiang Mai and there was a high rainfall distribution from July to September. In 4- to 6-month-old tangerine fruit, this period was the start of fruit enlargement and tangerine tree using more nutrients to grow. The nutrients resevered in leaf are the main sources for fruit growth (Menzel *et al*., 1988). In the cell enlargement period there is a corresponding stretching. When the rainfall and fruit enlargement coincide, tangerine fruit would quickly absorb nutrients and water to the fruit sac. This action affects the enlargement rate of the pulp which becomes greater than that of the peel, so that the peel splits (Geisel, 2008). Thus, the variability of yield was more than normal.

Table 8.1 Effect of adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer on fruit size, peel thickness, fruit weight of 10-month-old tangerine cv. Sainampueng fruit.

Treatment	Fruit size (cm)	Peel thickness (mm)	Fruit weight (g)	Yield (kg/tree)
4:1:5	5.94 b	2.18	96.8 b	1.32 c
4:2:5	6.16 a	2.07	109.8 a	2.15 a
1:1:1	5.79 b	2.02	92.9 c	1.73 b
3:1:3	5.75 b	1.98	94.5 bc	1.48 c
$LSD_{0.05}$	0.21	ns	5.32	0.37
% CV	7.26	11.56	6.92	19.88

* Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

3. Effect of nutrient ratio on fruit quality of tangerine

It was found that the adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately 4:1:5, 4:2:5, 1:1:1, and 3:1:3 increased juice percentage, pH of juice, TSS, TSS/TA ratio, and vitamin C when the fruit approached maturity (Figure 8.4, 8.5, 8.6, 8.7, 8.8 and 8.9). TA of juice was contrastive.

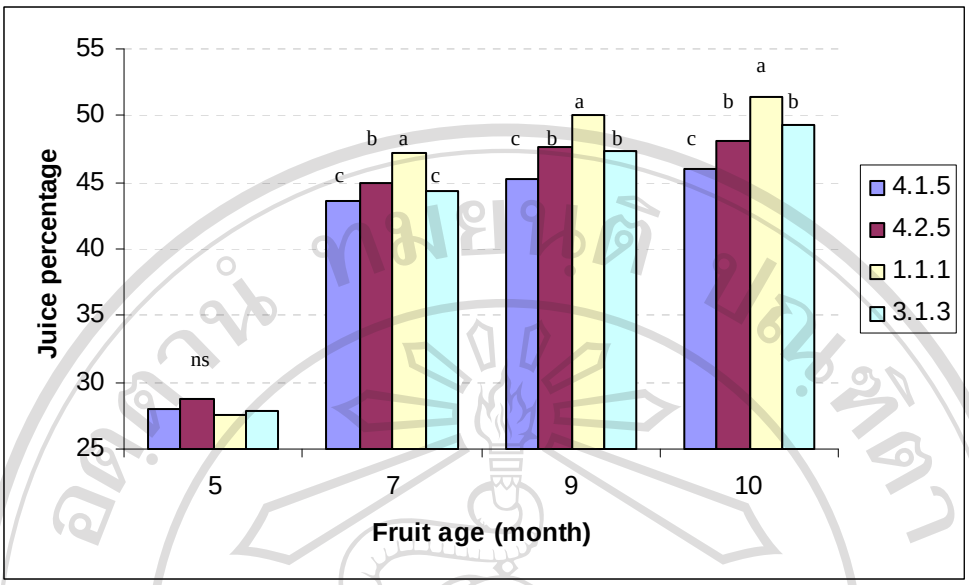

Figure 8.4 The effect of adjusted nutrient ratio of the fertilizer on juice percentage of tangerine cv. Sainampueng.

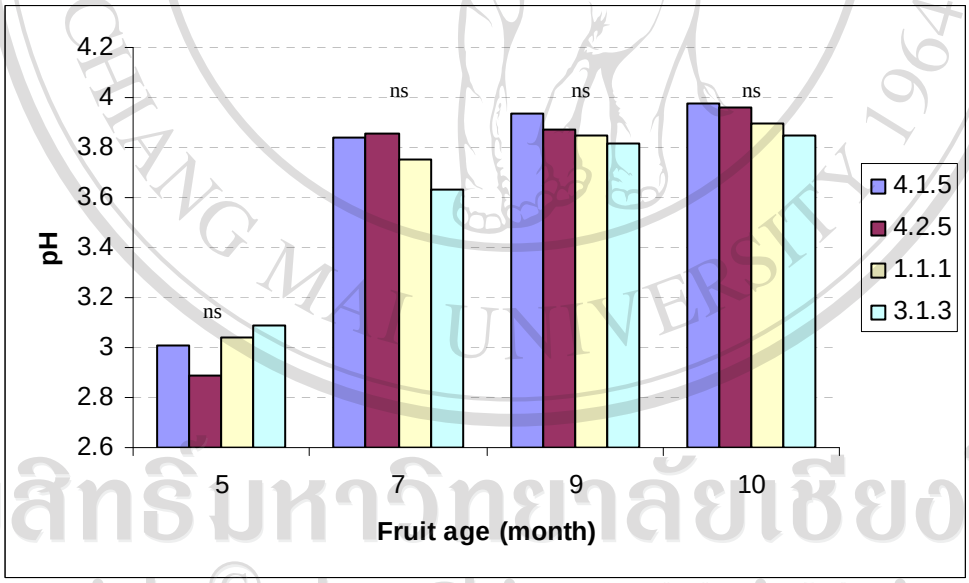

Figure 8.5 The effect of adjusted nutrient ratio of the fertilizer on pH of tangerine cv. Sainampueng juice.

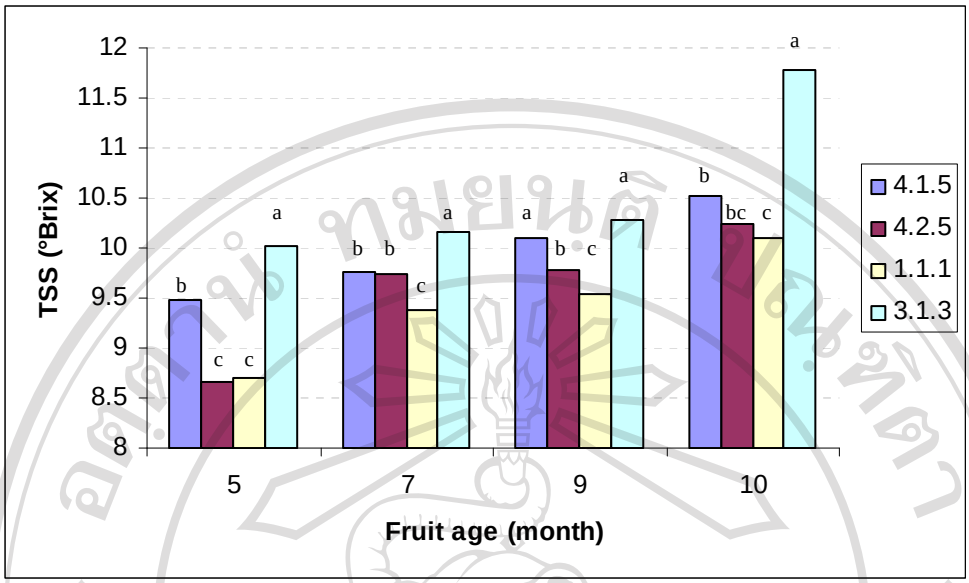

Figure 8.6 The effect of adjusted nutrient ratio of the fertilizer on TSS of tangerine cv. Sainampueng fruit.

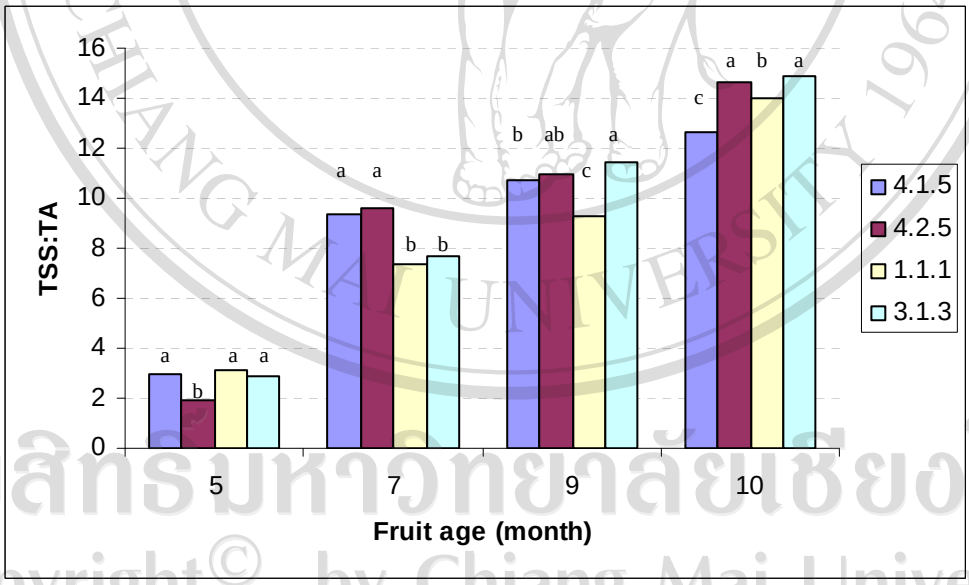

Figure 8.7 The effect of adjusted nutrient ratio of the fertilizer on TSS:TA ratio of tangerine cv. Sainampueng fruit.

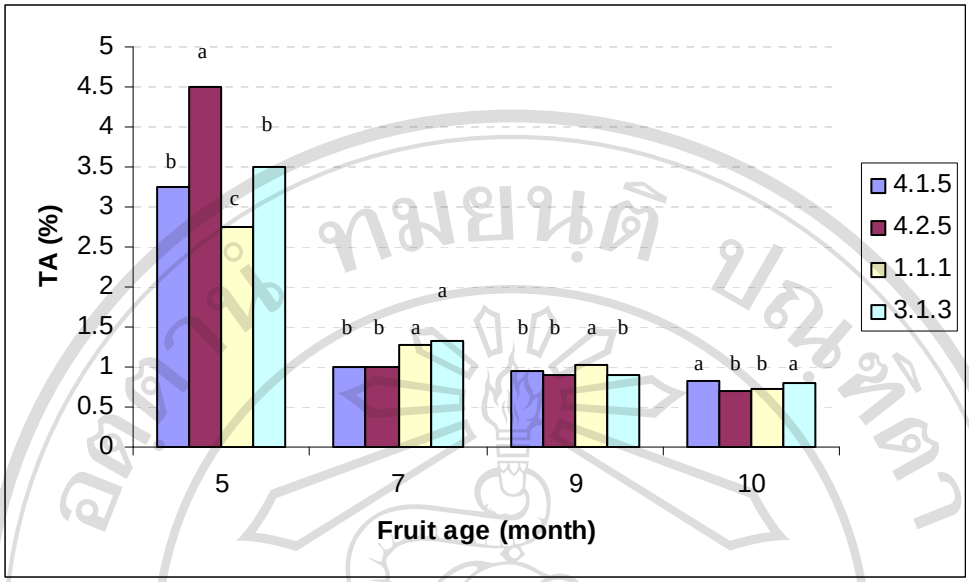

Figure 8.8 The effect of adjusted nutrient ratio of the fertilizer on TA of tangerine cv. Sainampueng fruit.

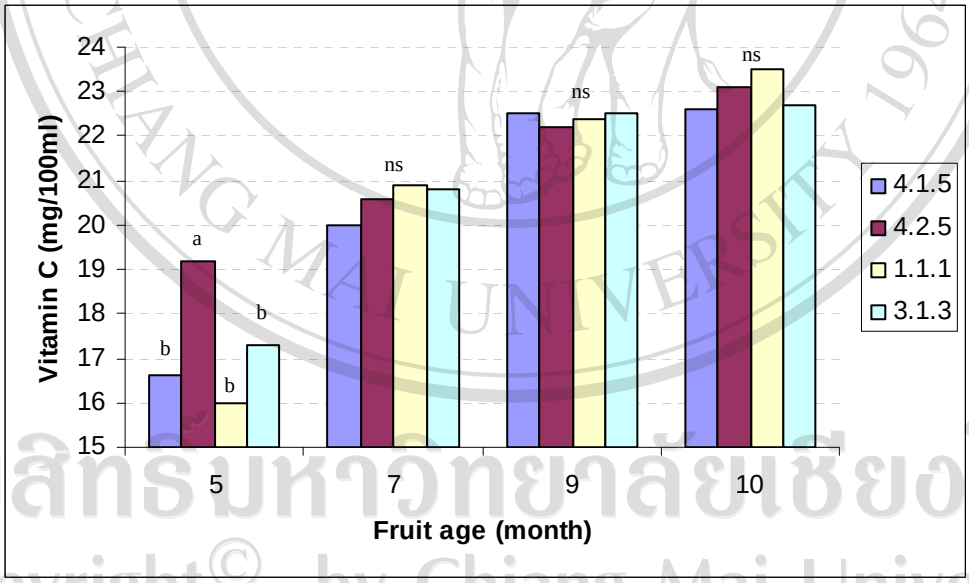

Figure 8.9 The effect of adjusted nutrient ratio of the fertilizer on vitamin C of tangerine cv. Sainampueng fruit.

Colour of juice from all treatments of fertilizer ratio was changed from yellow to reddish yellow at 9- to 10-month-old.

As shown in Table 8.2, all ratios of the fertilizer applied to tangerine fruit at the age 10 months gave significantly different results in juice percentage, TSS, TA, and TSS/TA ratio.

Table 8.2 Effect of adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer on juice percentage, pH of juice, TSS, TA, TSS/TA ratio and vitamin C of 10-month-old tangerine cv. Sainampueng fruit.

Treatment	Juice percentage	pH of juice	TSS (°Brix)	TA (%)	TSS/TA ratio	Vitamin C (mg/100 ml)
4:1:5	46.0 c	3.98	10.52 b	0.83 a	12.68 c	22.6
4:2:5	48.1 b	3.96	10.24 b	0.70 b	14.67 a	23.1
1:1:1	51.4 a	3.90	10.10 b	0.72 b	14.03 b	23.5
3:1:3	49.3 b	3.85	11.78 a	0.79 a	14.91 a	22.7
$LSD_{0.05}$	1.52	ns	0.67	0.06	0.43	ns
%CV	7.38	9.51	8.47	8.36	9.79	10.35

* Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

In the experiment, the adjusted $N:P_2O_5:K_2O$ ratios affected growth and quality of tangerine fruit. The ratio not only afforded large fruit size but also caused thickness of peel. The taste of orange was different in each ratio and fruit age. As the standard of tangerine quality in Thailand, the quality of mandarin had juice percentage (50 %), TSS (12 °Brix), TA (0.6-1.0 %), and the TSS/TA ratio (12/1 or 13/1) (Ministry of Agriculture and Cooperatives, 2002). In the comparison of both qualities, it was found that the quality from this experiment had more the ratio of TSS/TA, but lower juice percentage, TSS, and TA than the tangerine standard.

4. Nutrient ratio and nutrient content of tangerine

It was found that the fruits from all treatments of fertilizer ratio had a heavy demand of N and K when during fruit enlargement stage (Figure 8.10). After that, the

fruit higher demand of K than N when fruits approached maturity. The same result was found in Fe, Cu, and B (Figure 8.10). The fruits need less quantity of P, Ca, Mg, Mn, and Zn but these nutrients were demanded slightly higher when the fruit had more age. This result shows the same analysis of nutrient element concentration during the fruit growth in Shokun tangerine as Supakamnerd *et al*. (2005). Typically, the Shokun fruits had more nutrient element when fruit aged and they had demand in the vicinity of N and K at set fruit to 5 months of age. After that, the fruit higher demand of K than N when fruits approached maturity.

The adjusted $N:P_2O_5:K_2O$ ratio had the effect of pulling the nutrient from the tree into the fruit for growing and improving quality. The nutrient content in the ratio 4:2:5 was better than ratio 1:1:1. It was showed that the normal fertilizer formulas used by many orchardists are not the suitable ratio for fruit growing.

While the comparison of the nutrient content in leaf between the adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately (4:1:5, 4:2:5, 1:1:1, and 3:1:3) and adequate concentration, it was found that most nutrients element concentration in leaf of all fertilizer treatments ratio had optimum level except the low N (Table 8.3). It could be leach quickly because N is easy to dissolve (Suksawat, 2001). The root could not absorb the N into the plant in time. The results reflected that the quantity of fertilizer at all ratios had sufficient nutrient for plant growth. The amount of P was not significantly different among the treatments. The adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately 1:1:1 resulted in high P concentration in soil but it was not be able to absorb by plant. It affected the absorbability of Fe and Zn, so the concentration of Fe and Zn in leaf was less than other ratio (Table 8.3).

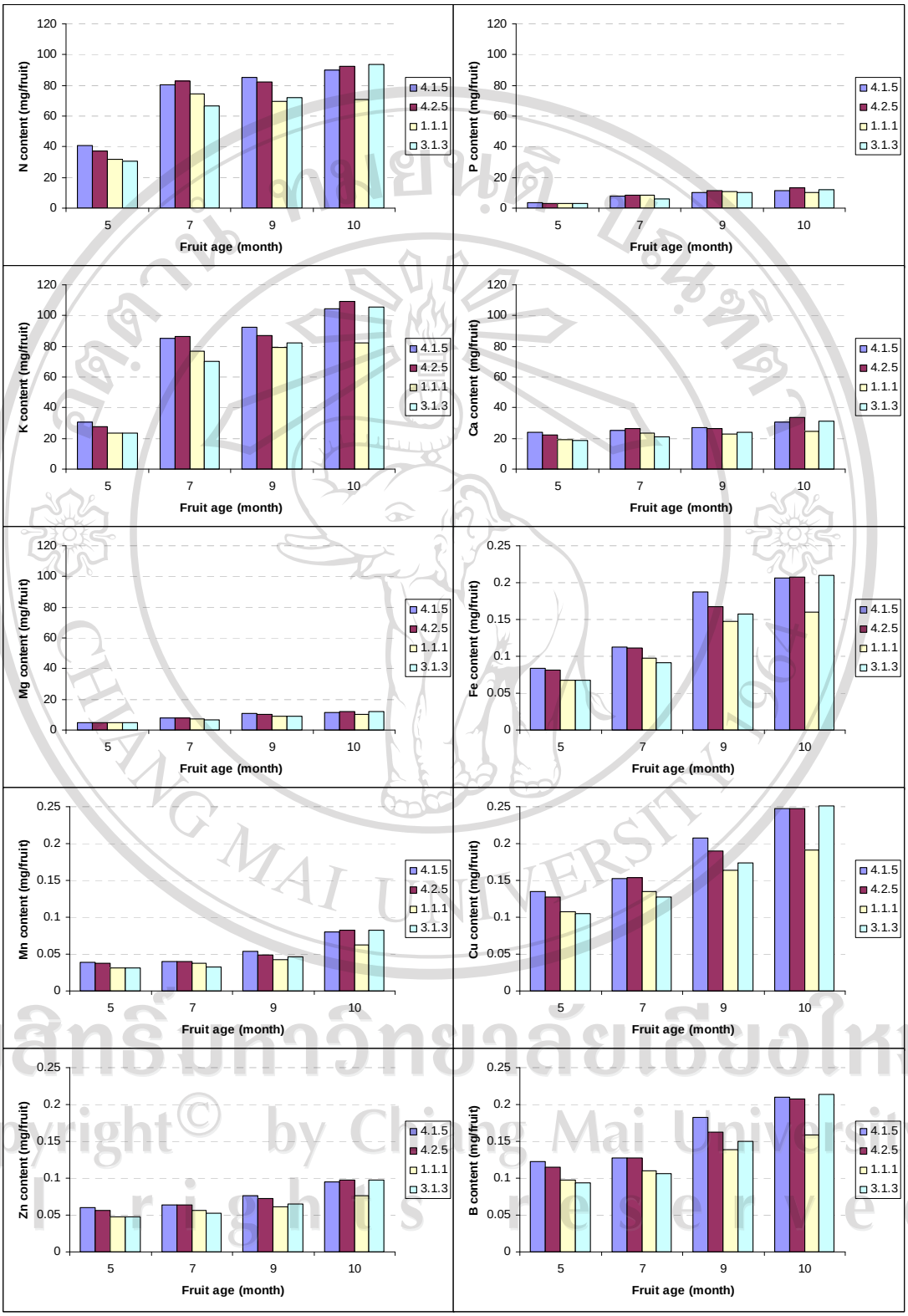

Figure 8.10 The effect of adjusted nutrient ratio of the fertilizer on nutrient content in tangerine cv. Sainampueng fruit.

Table 8.3 Effect of adjusted $N:P_2O_5:K_2O$ ratio on nutrient concentration in leaf of 10 months old tangerine cv. Sainampueng fruit.

Treatment	Concentration of macronutrient element (%)[1/]					Concentration of micronutrient element (ppm)[1/]				
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
4 : 1 : 5	2.47 a	0.14	1.65 a	2.69	0.40 a	115.5 b	39.5 b	75.0 b	12.5 c	32.2 a
4 : 2 : 5	2.43 ab	0.14	1.53 ab	2.73	0.37 b	123.5 a	44.0 a	90.5 a	14.5 b	29.4 ab
1 : 1 : 1	2.36 b	0.16	1.44 b	2.75	0.35 b	105.1 c	34.0 c	70.5 b	16.0 ab	27.1 b
3 : 1 : 3	2.40 ab	0.15	1.48 b	2.67	0.35 b	117.0 ab	32.0 c	84.5 a	16.5 a	28.0 b
$LSD_{0.05}$	0.08	ns	0.15	ns	0.02	6.67	4.43	6.09	1.86	2.97
% CV	8.71	3.24	10.91	5.15	5.75	5.58	2.76	9.63	4.34	11.40
Adequate concentration										
Taiwan[2/]	2.9-3.1	0.12-0.18	1.4-1.7	2.5-4.5	0.26-0.5	60-120	25-200	25-100	5-16	25-150

[1/] Means followed by different letters within columns are significantly different at the 5 % level by $LSD_{0.05}$

[2/] source: Chang *et al*., 1992

[ns] not significant difference

From the synthesis data of blossoming, fruit growth, yield, nutrient concentrations in fruit and leaf, it was found that the appropriate ratio for tangerine production was 4:2:5. The ratio had come from the analysis of nutrient content in mature fruit of mandarin (Supakamnerd *et al*. 2005). The given fertilizer by product assessment on tree in nearly demand of tangerine tree resulted in the best growth of fruit. When the quality of fruit was considering the adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately as 3:1:3 gave better quality fruit than other ratios.

Conclusions and Recommendations

In sand culture, the adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately 4:2:5 provided the best growth of fruit. It was given the bigger fruit size, higher weight and yield. Besides, the nutrient concentrations in fruit at this ratio were higher than others. The adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately 3:1:3 provided the best quality of fruit. However, the adjusted $N:P_2O_5:K_2O$ ratio of the fertilizer to approximately 4:2:5 could be used in all fruit growth periods. The feeding of too much P had not resulted in growth and increased quality of fruit and this increased the cost of fertilizing because the P was extremely expensive.