Chapter 9

Use of Soil Analysis for Fertilizer Recommendation

Introduction

Fruit quality was affected by several factors including cultivar, rootstock, climate, soil, pests, irrigation and plant nutrition, then the effects of nutrition on fruit quality were important and well accepted. Additional, the nutrients in tangerine production had been taken into several considerations by local growers for a number of years. The management of plant nutrition and fertilizer application on farmer's knowkedge in traditional agriculture (see the Results in Chapter 3) has proved to increase the profitability and sustainability of the national citrus industry (Chang *et al*., 2006). Consequently, the optimum fertilization for nutrient status in their orchard is probably unbalanced or over an optimum range. This practice leads to inefficient and environmental unfriendly use of fertilizers. Therefore, the efficiency of fertilizer management was one of the key success factors to increase the competitive opportunity of tangerine production in the world market (Supakamnerd, 2004). More fertilizers, being left behind or reserve in soil than the standard values, may cause direct disadvantages to the plants as well as inhibit the availability of other nutrients.

Citrus tree nutritional status could be determined by using leaf and soil analysis. The leaf and soil sampling analysis showed the effectiveness of the fertilizer application program for the previous year. The analytical data of leaf and soil analysis were used to adjust the plant nutrition program for the following year. The soil analysis was a useful tool to evaluate soil nutritional status for fertilizer applications to the plants (Buasap, 2001). The fruit production research in Thailand generally do not engage soil analysis tool for application of fertilizer. The addition of fertilizer to most citrus crops may not afford high yield and quality of fruit. Therefore, this experiment aims to examine the effectiveness of soil analysis based fertilizer application on yield and quality of tangerine.

Materials and Methods

The experiment was conducted at 2 private orchards, where soil texture is loam and clay, located at Mae Soon Noi subdistrict, Fang district of Chiang Mai province. The study duration was during December 2005 – December 2007. Five-year-old tangerine trees of cv. Sainampueng were selected for the study.

Soil properties of each orchard was determined as a method previously described in Chapter 4 before the experimental trial inorder to obtain basic data for fertilizer application design.

The experiment was laid out in a completely randomized design (CRD) with five replications (trees). Six treatments of fertilizer application were as follows;

Treatment 1: Addition only the element that its concentration in soil was below the optimum level; soil application of macro-elements and foliar application of micro-element.

Treatment 2: Addition only the element that its concentration in soil was below the optimum level; soil application of both macro and micro-element.

Treatment 3: Adjustment of $N:P_2O_5:K_2O$ ratio as 4:2:5 in fertilizer and apply micro-elements by foliar application as in Treatment 1.

Treatment 4: Adjustment of $N:P_2O_5:K_2O$ ratio as 4:2:5 in fertilizer and apply micro-elements by soil application as in Treatment 2.

Treatment 5: Fertilizers application in accordance to farmer's practice.

Treatment 6: Similarity to treatment 5, except minor and micro-elements were soil application.

The 25 tangerine fruits per treatment were collected in the middle of the wet season (collected in August 26, 2006), cool dry season (collected in November 25, 2006) and hot dry season (collected in April 28, 2007) at the age of 10 months. The fruit qualities and nutrient concentration in fruit composition were determined (by the procedures) as previously described in Chapter 6.

The nutrient concentration in collected soil and 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 $p \leq 0.05$.

The data of applied fertilizer based on soil analysis (treatment 1, 2, 3 and 4) and fermer's procedure (treatment 5 and 6) were statistically analyzed using T-test.

The data of only the element that its concentration in soil was below the optimum level (treatment 1 and 2) and apply 4:2:5 ratio (treatment 3 and 4) were statistically analyzed using T-test.

Results and Discussion

1. Nutrient concentration in soil

1.1 Before experiment

The soil properties in loam soil before the experimental trial are shown in Table 9.1. The soil at the experimental site had optimum of pH at 6.06, with high OM (4.04 %). The soil macronutrient concentration showed low N (12.87 mg/kg) but high of P, K, Ca and Mg at 44.64, 470.68, 1,213.82, 158.40 mg/kg, respectively. The soil micronutrient concentration indicated high of Fe, Mn and Zn at 91.57, 30.97 and 6.0 mg/kg, respectively. However lower of Cu at 0.67 mg/kg and the absence of B was found.

The soil properties in clay soil before the experimental trial are shown in Table 9.2. The soil had optimum of pH at 6.13 and 3.01 % of OM. This is because of the organic fertilizer was applied last year. The soil macronutrient concentration bared low of N at 12.31 mg/kg but high of P, K, Ca and Mg at 198.05, 285.44, 1,439.80, 187.86 mg/kg, respectively. The soil micronutrient concentration showed high of Fe, Mn, Cu and Zn at 137.59, 18.11, 3.44 and 4.93 mg/kg, respectively. But B was not defected.

The soil properties in loam and clay soil came from chemical and organic fertilizer applied by growers (see Table 2 in Appendix).

Table 9.1 Properties of the loam soil before the experiment trial and their optimum nutrient concentration.

Nutrient	Soil nutrient concentration	Optimum concentration[1/]	Remark
pH	6.06	6.0-7.0	-
OM (%)	4.04	2.5-3.0	-
P (mg/kg)	44.64	26.0-42.0	-
K (mg/kg)	470.68	130	-
Ca (mg/kg)	1,213.82	1,040	-
Mg (mg/kg)	158.40	135	-
Fe (mg/kg)	91.57	11.0-16.0	-
Mn (mg/kg)	30.97	9.0-12.0	-
Cu (mg/kg)	0.67	0.9-1.2	added
Zn (mg/kg)	6.0	1.1-3.0	-
B (mg/kg)	0	0.6-1.2	added

[1/] Supakamnerd, 2005

The soil analysis in loam soil barely lower Cu and B but other nutrients showed in range of optimum nutrient concentration (Table 9.1), but N was fed on the soil because of the easy loss in the environment. As we know soil has much more K (Table 9.1) and the range of N, P to K is largely different. Thus in treatment 3 and 4, the fertilizer must apply only N and P. Therefore, the six treatments of fertilizer application were arranged as shown in Table 9.3.

Table 9.2 Properties of the clay soil before the experiment trial and their optimum nutrient concentration.

Nutrient	Soil nutrient concentration	Optimum concentration[1/]	Remark
pH	6.13	6.0-7.0	-
OM (%)	3.01	2.5-3.0	-
P (mg/kg)	198.05	26.0-42.0	-
K (mg/kg)	285.44	130	-
Ca (mg/kg)	1,439.80	1,040	-
Mg (mg/kg)	187.86	135	-
Fe (mg/kg)	137.59	11.0-16.0	-
Mn (mg/kg)	18.11	9.0-12.0	-
Cu (mg/kg)	3.44	0.9-1.2	-
Zn (mg/kg)	4.93	1.1-3.0	-
B (mg/kg)	0	0.6-1.2	added

[1/] Supakumnerd, 2005

The soil analysis in clay soil showed low values B while other nutrients were in range of optimum nutrient concentrations (Table 9.2), but N was fed on the soil because of the easy loss in the environment. As we know soil has much more K (Table 9.3) and the range of N, P to K is largely different. Thus in treatment 3 and 4, the fertilizer must apply only N and P. Therefore, the six treatments of fertilizer application were arranged as shown in Table 9.4.

Table 9.3 Application rate of fertilizers among the treatments which were conducted in loam soil.

Treatment	Quantity of fertilizer (g or ppm/tree/year)									
	N	P_2O_5	K_2O	Ca	Mg	Fe	Mn	Cu	Zn	B
1. Applied only nutrients which present below optimum level and foliar application of microelements	170 g	-	-	-	-	-	-	960 ppm	-	2,400 ppm
2. Applied only nutrients which present below optimum level and soil application of microelements	170 g	-	-	-	-	-	-	1.92 g	-	11.04 g
3. Adjustment N:P_2O_5:K_2O ratio of the soil (4:2:5) and foliar application of microelements	1,340 g	530 g	-	-	-	-	-	960 ppm	-	2,400 ppm
4. Adjustment N:P_2O_5:K_2O ratio of the soil (4:2:5) and soil application of microelements	1,340 g	530 g	-	-	-	-	-	1.92 g	-	11.04 g
5. Application of fertilizers in accordance with farmer's practice	895 g	665 g	920 g	2,400 ppm	2,400 ppm	-	-	-	2,400 ppm	2,400 ppm
6. Application of fertilizers in accordance with farmer's practice and soil application of microelements	895 g	665 g	920 g	11.04 g	11.04 g	-	-	-	11.04 g	11.04 g

Table 9.4 Application rate of fertilizers among the treatments which were conducted in clay soil.

Treatment	Quantity of fertilizer (g or ppm/tree/year)									
	N	P_2O_5	K_2O	Ca	Mg	Fe	Mn	Cu	Zn	B
1. Applied only nutrients which present below optimum level and foliar application of microelements	170 g	-	-	-	-	-	-	-	-	2,400 ppm
2. Applied only nutrients which present below optimum level and soil application of microelements	170 g	-	-	-	-	-	-	-	-	11.04 g
3. Adjustment N:P_2O_5:K_2O ratio of the soil (4:2:5) and foliar application of microelements	1,410 g	770 g	-	-	-	-	-	-	-	2,400 ppm
4. Adjustment N:P_2O_5:K_2O ratio of the soil (4:2:5) and soil application of microelements	1,410 g	770 g	-	-	-	-	-	-	-	11.04 g
5. Application of fertilizers in accordance with farmer's practice	895 g	665 g	920 g	2,400 ppm	2,400 ppm	-	-	-	2,400 ppm	2,400 ppm
6. Application of fertilizers in accordance with farmer's practice and soil application of microelements	895 g	665 g	920 g	11.04 g	11.04 g	-	-	-	11.04 g	11.04 g

1.2 After experiment

The values of most soil properties in loam soil was relativelt higher than those of at the beginning (Table 9.1) such as 6.07 - 6.13 of pH (Table 9.5), 4.29 - 4.58 % of OM (due to manure applied by grower); 17.2 – 19.4 mg/kg of N, 47.8 - 52.9 mg/kg of P, 475.9 – 481.2 mg/kg of K, 1,227.3 – 1,232.9 mg/kg of Ca, 159.1 – 162.1 mg/kg of Mg, 96.5 – 99.2 mg/kg of Fe, 32.4 – 34.6 mg/kg of Mn, 0.83 – 0.91 mg/kg of Cu, 6.72 – 8.02 mg/kg of Zn and 0 – 0.20 mg/kg of B. The increasing trend of nutrient concentration came directly from application rates of fertilizers in the treatments (Table 9.3), as well as dolomite, bio-fertilizer and pesticides given by the grower.

The values of all soil properties in clay soil increased after the experimental trial such as 6.16 - 6.18 of pH (Table 9.6), 3.24 – 3.41 % of OM (due to manure applied by grower); 13.5 – 15.1 mg/kg of N, 197.8 – 200.2 mg/kg of P, 287.1 – 290.7 mg/kg of K, 1,447.4 – 1,451.1 mg/kg of Ca, 187.2 – 189.0 mg/kg of Mg, 139.3 – 141.9 mg/kg of Fe, 17.5 – 18.2 mg/kg of Mn, 3.57 – 3.86 mg/kg of Cu, 4.68 – 4.90 mg/kg of Zn and 0 – 0.11 mg/kg of B. The rising of nutrient concentration came from application fertilizers in the treatments (Table 9.4), while the grower applied only dolomite, bio-fertilizer and pesticides.

The result indicated that the application fertilizers in the treatments were not different of the values of all soil properties in both soil areas. So, the growers used the soil analysis for the application of fertilizer in the both soil.

Table 9.5 Soil properties of the treatments after the experiment which was conducted in loam soil and at the optimum nutrient concentration.

Treatment	pH	OM (%)	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
			mg/kg									
1) 170 g N + 960 ppm Cu + 2,400 ppm B	6.07	4.42	17.9	50.9	478.5	1,229.6	159.1	97.2	33.0	0.83	6.72	0
2) 170 g N + 1.92 g Cu + 11.04 g B	6.08	4.30	17.2	47.8	476.3	1,227.3	161.5	96.5	32.6	0.85	7.23	0.13
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	6.13	4.58	19.4	48.1	475.9	1,228.4	159.7	98.1	33.7	0.91	6.84	0
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	6.11	4.29	18.9	51.5	480.4	1,230.5	162.1	97.9	32.4	0.87	7.14	0.05
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	6.12	4.51	18.3	52.9	479.3	1,232.9	161.8	98.8	34.6	0.83	7.75	0
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	6.11	4.46	18.8	50.2	481.2	1,331.1	160.2	99.2	32.8	0.86	8.02	0.20
Optimum concentration[1/]	6.0-7.0	2.5-3.0	20-60[2/]	26-42	130	1,040	135	11-16	9-12	0.9-1.2	1.1-3.0	0.6-1.2

[1/] Supakamnerd, 2005

[2/] Thaiagrotech, 2005

Table 9.6 Soil properties of the treatments after the experiment which was conducted in clay soil and at the optimum nutrient concentration.

Treatment	pH	OM (%)	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
			mg/kg									
1) 170 g N + 2,400 ppm B	6.16	3.24	14.2	198.9	288.4	1,449.6	188.5	141.9	18.1	3.57	4.74	0
2) 170 g N + 11.04 g B	6.18	3.30	13.5	197.8	287.6	1,451.1	187.6	139.3	17.9	3.65	4.82	0.06
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	6.16	3.41	14.7	198.1	288.9	1,447.4	189.0	140.0	18.2	3.71	4.68	0
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	6.17	3.29	15.1	199.5	287.1	1,450.2	187.2	139.7	18.0	3.77	4.77	0.04
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	6.18	3.35	14.6	199.1	289.3	1,448.2	187.6	141.1	17.5	3.60	4.71	0
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	6.17	3.26	14.8	200.2	290.7	1,449.3	188.4	140.5	18.1	3.86	4.90	0.11
Optimum concentration[1/]	6.0-7.0	2.5-3.0	20-60[2/]	26-42	130	1,040	135	11-16	9-12	0.9-1.2	1.1-3.0	0.6-1.2

[1/] Supakamnerd, 2005

[2/] Thaiagrotech, 2005

3. Nutrient concentration in leaf of tangerine

The nutrient concentrations in leaf of tangerine trees growing on loam and clay soil after the fertilizer application of six treatments showed in Table 9.7 and 9.8. The concentration of N, P, K, Ca and Mg were not significantly different among six fertilizer treatments. The tangerine trees did not respond to the quantity fertilization of N, P and K because of heavy consumption of P, K, Ca and Mg during growth and development of tangerine (Table 9.1, 9.2, 9.5 and 9.6). The micronutrient concentrations were significantly different among treatments because the micro-elements by foliar application were utilized better than soil application. Therefore, the treatments of foliar application of micro-element gave the highest rate of the micronutrient concentrations in soil application. The application of fertilizer in accordance to farmer's practice (treatment 5) gave the high micronutrient concentrations in leaf. This result may come from the foliar application of the most micronutrient by farmers (see Table 2 in Appendix).

After the nutrient content in leaf among treatments and adequate concentration in Taiwan (Table 9.7) were compared, it was found that most nutrients element concentration in leaf of all ratio appeared in range of the optimum level except K, Ca and Cu in both soil areas (Table 9.7 and 9.8). These three elements found rather than high concentration because of the extremely high K and Ca in soil (Table 9.5 and 9.6). It consequently caused luxury consumption by the tree (Osotsapar, 2000). Besides this, the grower also sprayed some pesticides with copper constituent (see the Results in Chapter 3).

The research results apparently showed that an addition of the only deficient elements gave nutrient elements for plant growth sufficiently.

Table 9.7 Nutrient concentration in leaf of tangerine cv. Sainampueng as affected by various fertilizer applications in loam soil.

Treatment	Concentration of macronutrient element (%)					Concentration of micronutrient element (ppm) [1/]				
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
1) 170 g N + 960 ppm Cu + 2,400 ppm B	2.95	0.14	2.18	5.89	0.37	79.3 a	57.6 a	60.2 b	25.7 bc	62.0 a
2) 170 g N + 1.92 g Cu + 11.04 g B	2.84	0.14	2.24	5.79	0.35	78.3 ab	55.4 b	44.8 d	24.7 c	55.7 b
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	2.91	0.15	2.21	5.73	0.34	77.5 ab	54.1 c	58.1 b	26.6 b	62.6 a
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	2.86	0.15	2.17	5.92	0.40	76.4 b	52.2 d	45.3 d	25.4 c	56.9 b
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	2.93	0.15	2.26	5.83	0.37	77.0 ab	58.0 a	74.4 a	27.9 a	63.8 a
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	2.86	0.15	2.24	5.85	0.35	75.6 b	54.3 c	52.1 c	26.1 b	58.5 b
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
$LSD_{0.05}$	ns	ns	ns	ns	ns	2.80	0.75	3.27	1.11	2.97
% CV	7.53	3.24	7.22	6.91	6.26	10.97	5.93	11.36	4.34	9.58

[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

Table 9.8 Nutrient concentration in leaf of tangerine cv. Sainampueng as affected by various fertilizer applications in clay soil.

Treatment	Concentration of macronutrient element (%)					Concentration of micronutrient element (ppm) [1/]				
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
1) 170 g N + 2,400 ppm B	2.68	0.13	1.85	5.63	0.36	73.4	49.7 b	75.6 bc	26.6 a	49.0 b
2) 170 g N + 11.04 g B	2.72	0.14	1.97	5.49	0.42	72.9	46.5 bc	73.3 c	25.0 b	42.8 d
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	2.85	0.15	1.91	5.50	0.34	70.5	47.6 b	74.7 bc	24.3 c	50.1 b
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	2.81	0.14	1.89	5.53	0.40	71.1	45.0 c	72.5 c	23.8 c	43.4 d
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	2.79	0.14	2.04	5.57	0.36	71.8	52.5 a	82.8 a	27.1 a	52.3 a
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	2.82	0.14	2.01	5.45	0.38	72.1	48.2 b	77.6 b	25.7 b	46.5 c
Nutrient standards										
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
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	1.63	4.01	0.68	1.75
% CV	9.63	2.78	11.75	12.12	6.16	13.81	8.82	13.14	12.86	13.35

[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

4. The quality and yield of tangerine fruit

From the overview in this experiment, the fertilizer applications are not different in quality and yield of tangerine fruits for both loam and clay soil in all harvesting season (Table 9.9-9.18), and it did not affect peel colour or juice colour (Table 9.21 and 9.27). While complained in each treatment, it showed applications fertilizers were different in the quality and yield of tangerine fruits (Table 9.19–9.30).

When studied in two 2 applications of microelements of each group; the addition of blow the optimum level suggestible by soil analysis and application fertilizer in accordance with the grower with foliar applications of microelements were better on growth, quality and yields of fruit than applied to the soil. But the adjustment of $N:P_2O_5:K_2O$ in chemical soil ratio of 4:2:5 was not different in the both applications of microelements.

The results of the experiment indicated that foliar application of microelements provided better fruit quality and yield than soil application. The result conformed to the effects of N, P, K and trace elements on quality and yield of tangerine in Chiang Kan and Ban Chong soil series (Sirinun, 1996; Vorapitirangsee, 2000). They found that the treatment of N, P and K plus trace element spray gave the best fruit quality. However, fertilizer applications to the soil were subjected to various fates including leach, runoff and fixation to forms which are not available to plants. Therefore, foliar application should be considered as a possible supplement to soil application for some nutrients. Thus, foliar application can reduce overall fertilizer application rate and energy use and can improve the uptake efficiency of micronutrients because they are directly absorbed into the leaves (Zekri and Obereza, 2008).

Table 9.9 Fruit size of tangerine cv. Sainampueng between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	6.18	6.13	6.19	6.27	6.26	6.36
Fertilizer application by farmer's practice (Treatment 5 and 6)	6.16	6.11	6.15	6.28	6.22	6.10
T - test	ns	ns	ns	ns	ns	ns
% CV	4.81	6.04	10.72	4.93	4.86	7.95
Applied only nutrients which present below optimum level (Treatment 1 and 2)	6.29	6.18 a	6.15	6.26	6.28	6.40
Adjustment $N:P_2O_5:K_2O$ ratio of the soil (4:2:5) (Treatment 3 and 4)	6.07	6.07 b	6.22	6.27	6.24	6.32
T - test	ns	*	ns	ns	ns	ns
% CV	4.52	4.35	9.14	4.64	4.58	6.92

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

ns not significant difference

Table 9.10 Peel thickness of tangerine cv. Sainampueng between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	1.32	1.26	2.54	1.40	1.39	2.36
Fertilizer application by farmer's practice (Treatment 5 and 6)	1.23	1.24	2.40	1.38	1.43	2.40
T - test	ns	ns	ns	ns	ns	ns
% CV	27.58	24.74	27.83	19.01	12.57	24.81
Applied only nutrients which present below optimum level (Treatment 1 and 2)	1.34	1.27	2.53	1.40	1.41	2.40
Adjustment $N:P_2O_5:K_2O$ ratio of the soil (4:2:5) (Treatment 3 and 4)	1.30	1.25	2.54	1.39	1.36	2.32
T - test	ns	ns	ns	ns	ns	ns
% CV	26.15	22.71	26.21	18.88	20.06	23.14

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

ns not significant difference

Table 9.11 Fruit weight of tangerine cv. Sainampueng between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	118.9	116.2	132.0 a	120.6	121.1	126.7
Fertilizer application by farmer's practice (Treatment 5 and 6)	118.0	115.8	124.0 b	120.6	119.8	119.1
T - test	ns	ns	*	ns	ns	ns
% CV	14.42	13.82	21.71	10.38	12.51	20.03
Applied only nutrients which present below optimum level (Treatment 1 and 2)	125.1	119.0	133.1	119.2	121.8	134.3
Adjustment $N:P_2O_5:K_2O$ ratio of the soil (4:2:5) (Treatment 3 and 4)	112.6	113.4	130.9	122.0	120.3	119.1
T - test	ns	ns	ns	ns	ns	ns
% CV	13.88	11.97	19.25	9.94	20.05	20.18

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

ns not significant difference

Table 9.12 Yield of tangerine cv. Sainampueng between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	14.4	29.9	8.51	24.8	56.9	12.4
Fertilizer application by farmer's practice (Treatment 5 and 6)	15.0	29.7	8.68	25.3	56.8	12.6
T - test	ns	ns	ns	ns	ns	ns
% CV	7.84	11.39	11.03	10.45	12.97	12.19
Applied only nutrients which present below optimum level (Treatment 1 and 2)	14.5	30.5	8.54	25.0	57.1	12.5
Adjustment N:P_2O_5:K_2O ratio of the soil (4:2:5) (Treatment 3 and 4)	14.3	29.2	8.47	24.3	56.6	12.3
T - test	ns	ns	ns	ns	ns	ns
% CV	6.76	10.83	10.72	10.22	11.47	12.03

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

ns not significant difference

Table 9.13 Juice percentage of tangerine cv. Sainampueng fruit between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	52.4	53.5 b	44.3	55.4	49.9	55.5
Fertilizer application by farmer's practice (Treatment 5 and 6)	53.5	55.9 a	44.7	56.4	44.1	54.5
T - test	ns	*	ns	ns	ns	ns
% CV	12.53	15.73	14.86	15.32	16.01	11.52
Applied only nutrients which present below optimum level (Treatment 1 and 2)	49.6 b	52.1 b	42.0	56.3	56.6 a	56.4
Adjustment $N:P_2O_5:K_2O$ ratio of the soil (4:2:5) (Treatment 3 and 4)	55.2 a	54.8 a	46.5	54.5	43.2 b	54.6
T - test	*	*	ns	ns	*	ns
% CV	11.98	14.57	13.45	14.74	15.26	10.78

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

ns not significant difference

Table 9.14 The pH of tangerine cv. Sainampueng juice between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	3.70	3.73	4.04	3.71	3.96	3.71
Fertilizer application by farmer's practice (Treatment 5 and 6)	3.73	3.69	4.07	3.73	4.08	3.73
T - test	ns	ns	ns	ns	ns	ns
% CV	2.01	1.84	6.72	0.98	2.07	12.22
Applied only nutrients which present below optimum level (Treatment 1 and 2)	3.70	3.73	4.01	3.67 b	3.70 b	3.70
Adjustment $N:P_2O_5:K_2O$ ratio of the soil (4:2:5) (Treatment 3 and 4)	3.70	3.72	4.06	3.76 a	4.21 a	3.72
T - test	ns	ns	ns	*	*	ns
% CV	1.72	1.46	5.08	0.63	15.35	11.95

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

ns not significant difference

Table 9.15 Vitamin C of tangerine cv. Sainampueng fruit between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	24.3	24.8	24.0	24.5	24.6	24.8
Fertilizer application by farmer's practice (Treatment 5 and 6)	24.3	24.9	24.0	24.5	24.4	24.8
T - test	ns	ns	ns	ns	ns	ns
% CV	1.47	2.08	1.21	1.41	2.28	7.83
Applied only nutrients which present below optimum level (Treatment 1 and 2)	24.3	24.9	24.0	24.5	24.8	24.8
Adjustment $N:P_2O_5:K_2O$ ratio of the soil (4:2:5) (Treatment 3 and 4)	24.3	24.7	24.0	24.5	24.4	24.8
T - test	ns	ns	ns	ns	ns	ns
% CV	1.15	1.68	1.03	1.29	1.83	7.74

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

ns not significant difference

Table 9.16 Total soluble solids (TSS) of tangerine cv. Sainampueng fruit between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	11.0	11.0	9.36	11.3	10.8	11.1
Fertilizer application by farmer's practice (Treatment 5 and 6)	11.0	11.1	9.04	11.6	11.6	11.7
T - test	ns	ns	ns	ns	ns	ns
% CV	6.22	6.92	13.68	5.85	7.74	10.87
Applied only nutrients which present below optimum level (Treatment 1 and 2)	11.1	10.9	9.54	11.3	11.1	11.1
Adjustment $N:P_2O_5:K_2O$ ratio of the soil (4:2:5) (Treatment 3 and 4)	10.8	11.1	9.18	11.2	10.4	11.1
T - test	ns	ns	ns	ns	ns	ns
% CV	5.84	6.32	11.64	5.64	7.17	10.44

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

ns not significant difference

Table 9.17 Titratable acidity (TA) of tangerine cv. Sainampueng fruit between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	0.57	0.58	0.73	0.54	0.60 b	0.53
Fertilizer application by farmer's practice (Treatment 5 and 6)	0.63	0.63	0.66	0.54	0.70 a	0.50
T - test	ns	ns	ns	ns	*	ns
% CV	8.69	11.65	22.75	11.79	12.21	12.02
Applied only nutrients which present below optimum level (Treatment 1 and 2)	0.56	0.57	0.74	0.55	0.54 b	0.54
Adjustment N:P_2O_5:K_2O ratio of the soil (4:2:5) (Treatment 3 and 4)	0.57	0.58	0.71	0.53	0.66 a	0.52
T - test	ns	ns	ns	ns	*	ns
% CV	8.39	10.89	20.09	11.55	11.75	11.63

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

ns not significant difference

Table 9.18 The TSS/TA ratio of tangerine cv. Sainampueng fruit between fertilizer application treatments.

Treatment	Loam soil			Clay soil		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
Fertilizer application by soil analysis (Treatment 1, 2, 3 and 4)	19.6 a	19.1	12.9	20.9	18.3	20.9
Fertilizer application by farmer's practice (Treatment 5 and 6)	17.3 b	17.8	13.7	21.5	16.7	23.4
T - test	*	ns	ns	ns	ns	ns
% CV	8.62	12.79	13.04	10.11	11.63	11.39
Applied only nutrients which present below optimum level (Treatment 1 and 2)	20.1	19.1	12.9	20.6	20.7 a	20.6
Adjustment $N:P_2O_5:K_2O$ ratio of the soil (4:2:5) (Treatment 3 and 4)	19.0	19.1	12.9	21.1	15.9 b	21.2
T - test	ns	ns	ns	ns	*	ns
% CV	8.12	12.14	11.25	9.84	10.88	9.96

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

ns not significant difference

Table 9.19 Fruit size and peel thickness of tangerine cv. Sainampueng between fertilizer application treatments in loam soil.

Treatment	Fruit size (cm)[1/]			Peel thickness (mm)[1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	6.34 a	6.25 a	6.63 a	1.22 b	1.15 b	2.67 ab
2) 170 g N + 1.92 g Cu + 11.04 g B	6.23 ab	6.12 ab	5.66 b	1.56 a	1.40 a	2.39 ab
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	6.02 b	6.03 b	6.47 a	1.32 ab	1.30 ab	2.75 a
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	6.12 ab	6.08 b	5.97 b	1.28 ab	1.21 b	2.34 ab
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	6.34 a	6.22 ab	6.37 ab	1.31 ab	1.30 ab	2.70 a
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	6.05 b	5.99 b	5.93 b	1.15 b	1.18 b	2.10 b
$LSD_{0.05}$	0.26	0.15	0.49	0.31	0.17	0.57
% CV	4.65	4.48	8.87	26.75	23.62	26.71

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

Table 9.20 Fruit weight and yield of tangerine cv. Sainampueng between fertilizer application treatments in loam soil.

Treatment	Fruit weight (g)[1/]			Yield (kg/tree)[1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	126.7 a	120.8 a	136.3 a	14.7	30.9 a	8.62
2) 170 g N + 1.92 g Cu + 11.04 g B	123.5 ab	117.2 ab	129.8 b	14.3	30.1 ab	8.54
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	111.5 b	110.9 b	134.3 ab	14.5	28.6 b	8.47
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	113.7 b	115.8 ab	127.4 b	14.1	29.7 ab	8.47
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	129.7 a	121.6 a	125.7 bc	15.1	31.1 a	8.71
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	106.2 b	109.9 b	122.5 c	14.8	28.3 b	8.64
$LSD_{0.05}$	11.93	7.97	4.62	ns	2.01	ns
% CV	11.21	12.28	19.35	6.31	10.78	10.67

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.21 Peel colour and juice colour of tangerine cv. Sainampueng fruit between fertilizer application treatments in loam soil.

Treatment	Peel colour			Juice colour		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	9.4 GY[1] – 6.3 Y[2]	7.2 GY – 8.2 Y	9.7 GY – 8.0 Y	7.1 – 9.2 YR[3]	7.1 – 9.1YR	9.1 – 9.2 YR
2) 170 g N + 1.92 g Cu + 11.04 g B	9.3 GY – 8.2 Y	8.0 GY – 8.2 Y	6.9 GY – 8.0 Y	7.1 – 9.2 YR	7.1 – 9.1YR	9.1 – 9.2 YR
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	7.8 GY – 5.7 Y	7.2 GY – 8.2 Y	8.4 GY – 8.0 Y	7.1 – 9.2 YR	7.1 – 9.1YR	9.1 – 9.2 YR
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	9.3 GY – 8.2 Y	7.2 GY – 8.0 Y	9.3 GY – 8.0 Y	7.1 – 9.2 YR	7.1 – 9.1YR	9.1 – 9.2 YR
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	9.2 GY – 9.2 Y	7.2 GY – 8.0 Y	9.9 GY – 8.0 Y	7.1 – 9.2 YR	7.1 – 9.1YR	9.1 – 9.2 YR
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	6.9 GY – 8.0 Y	7.2 GY – 8.2 Y	7.2 GY – 8.0 Y	7.1 – 9.2 YR	7.1 – 9.1YR	9.1 – 9.2 YR

[1] GY was ratio of yellow and green

[2] Y was level of yellow

[3] YR was ratio of red and yellow

Table 9.22 Juice percentage and pH of juice of tangerine cv. Sainampueng fruit between fertilizer application treatments in loam soil.

Treatment	Juice percentage (%)[1/]			pH of juice[1]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	50.4 b	53.4 c	38.4 c	3.72 a	3.72 a	4.25 a
2) 170 g N + 1.92 g Cu + 11.04 g B	48.6 b	50.6 d	44.9 b	3.68 b	3.73 a	3.77 c
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	54.5 a	54.8 b	45.2 b	3.66 c	3.73 a	4.11 a
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	55.9 a	54.9 b	46.3 b	3.74 a	3.71 ab	4.01 b
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	53.2 a	55.8 a	37.8 c	3.73 a	3.69 b	4.18 ab
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	53.7 a	55.8 a	51.0 a	3.73 a	3.69 b	3.96 bc
$LSD_{0.05}$	2.77	0.72	1.49	0.03	0.02	0.20
% CV	11.75	14.83	12.95	1.37	1.66	5.42

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.23 Vitamin C and total soluble solids (TSS) of tangerine cv. Sainampueng fruit between fertilizer application treatments in loam soil.

Treatment	Vitamin C (mg/100 ml)[1/]			TSS (°Brix)[1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	24.3	24.9	24.0	11.0 ab	10.9 b	10.08 a
2) 170 g N + 1.92 g Cu + 11.04 g B	24.3	24.8	24.0	11.2 ab	10.9 b	9.00 b
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	24.3	24.7	23.9	10.8 b	11.2 ab	9.40 ab
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	24.3	24.7	24.0	10.8 b	11.0 ab	8.95 b
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	24.2	24.8	24.0	11.3 a	11.3 a	9.62 ab
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	24.3	24.9	24.0	10.7 b	10.9 b	8.45 b
$LSD_{0.05}$	ns	ns	ns	0.40	0.36	1.01
% CV	1.28	1.43	1.10	5.16	5.81	12.15

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.24 Titratable acidity (TA) and TSS/TA ratio of tangerine cv. Sainampueng fruit between fertilizer application treatments in loam soil.

Treatment	TA (%)[1/]			TSS/TA ratio[1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	0.50 d	0.53 c	0.66 b	22.0 a	20.6 a	15.3 a
2) 170 g N + 1.92 g Cu + 11.04 g B	0.62 ab	0.61 ab	0.81 a	18.1 bc	17.9 b	12.3 bc
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	0.58 bc	0.57 b	0.73 ab	18.6 bc	19.7 a	12.9 b
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	0.56 c	0.59 b	0.69 a	19.3 b	18.9 ab	13.0 b
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	0.66 a	0.63 a	0.59 b	17.1 c	17.9 b	16.3 a
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	0.61 b	0.63 a	0.73 ab	17.5 c	17.3 b	11.6 c
$LSD_{0.05}$	0.04	0.03	0.13	1.52	2.21	1.17
% CV	8.17	10.50	20.75	7.47	11.72	11.32

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

Table 9.25 Fruit size and peel thickness of tangerine cv. Sainampueng between fertilizer application treatments in clay soil.

Treatment	Fruit size (cm) [1/]			Peel thickness (mm) [1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	6.22	6.21 ab	6.49 a	1.36	1.36	2.36 b
2) 170 g N + 11.04 g B	6.31	6.35 a	6.31 ab	1.44	1.45	2.44 ab
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	6.31	6.28 ab	6.49 a	1.35	1.32	2.08 c
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	6.23	6.20 ab	6.15 b	1.42	1.39	2.56 a
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	6.25	6.27 ab	6.35 a	1.39	1.44	2.30 b
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	6.31	6.18 b	5.85 c	1.37	1.41	2.50 ab
$LSD_{0.05}$	ns	0.16	0.23	ns	ns	0.17
% CV	4.52	4.42	7.54	18.76	19.94	23.56

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.26 Fruit weight and yield of tangerine cv. Sainampueng between fertilizer application treatments in clay soil.

Treatment	Fruit weight (g) [1/]			Yield (kg/tree) [1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	111.6 b	118.4 ab	132.3 a	25.2	56.4 b	12.7
2) 170 g N + 11.04 g B	126.8 a	125.2 a	136.2 a	24.8	57.8 a	12.3
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	128.9 a	123.1 ab	128.8 ab	24.7	57.3 ab	12.3
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	115.1 b	117.5 ab	109.3 bc	24.2	55.8 b	12.2
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	125.4 ab	124.0 a	120.5 ab	25.3	57.9 a	12.6
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	115.9 b	115.6 b	117.6 b	25.2	55.6 b	12.6
$LSD_{0.05}$	10.59	7.96	11.53	ns	1.32	ns
% CV	9.78	11.77	17.92	10.15	11.48	11.73

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.27 Peel colour and juice colour of tangerine cv. Sainampueng fruit between fertilizer application treatments in clay soil.

Treatment	Peel colour			Juice colour		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	8.2 – 1.5 GY[1/]	7.4 GY – 4.3 Y	7.2 GY – 5.7 Y	7.1 – 9.2 YR[3/]	6.4 – 7.1YR	9.1 – 9.2 YR
2) 170 g N + 11.04 g B	5.4 GY – 4.3 Y[2/]	7.4 GY – 5.6 Y	7.4 – 1.7 GY	7.1 – 9.2 YR	6.4 – 7.1YR	9.1 – 9.2 YR
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	8.3 – 5.4 GY	6.9 GY – 1.6 Y	8.7 – 1.8 GY	7.1 – 9.2 YR	6.4 – 7.1YR	9.1 – 9.2 YR
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	8.7 GY – 8.0 Y	6.9 GY – 1.4 Y	8.7 – 5.4 GY	7.1 – 9.2 YR	6.4 – 7.1YR	9.1 – 9.2 YR
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	8.3 – 1.8 GY	6.9 GY – 1.4 Y	8.7 GY – 5.7 Y	7.1 – 9.2 YR	6.4 – 7.1YR	9.1 – 9.2 YR
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	8.7 GY – 5.7 Y	6.9 GY – 1.4 Y	8.7 GY – 6.3 Y	7.1 – 9.2 YR	6.4 – 7.1YR	9.1 – 9.2 YR

[1/] GY was ratio of yellow and green

[2/] Y was level of yellow

[3/] YR was ratio of red and yellow

Table 9.28 Juice percentage and pH of juice of tangerine cv. Sainampueng fruit between fertilizer application treatments in clay soil.

Treatment	Juice percentage (%)[1/]			pH of juice[1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	56.0 ab	55.6 a	55.6 ab	3.67 c	3.72 d	3.72
2) 170 g N + 11.04 g B	55.8 ab	57.3 a	57.3 a	3.66 c	3.67 e	3.67
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	52.0 c	43.2 c	55.3 ab	3.80 a	4.18 b	3.71
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	56.7 ab	43.2 c	54.0 b	3.72 b	4.23 a	3.72
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	55.1 b	49.9 b	54.8 ab	3.72 b	4.16 b	3.73
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	57.3 a	38.3 d	54.4 b	3.74 b	3.99 c	3.73
$LSD_{0.05}$	1.82	1.75	2.24	0.02	0.03	ns
% CV	14.21	14.78	10.54	0.60	1.54	11.74

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.29 Vitamin C and total soluble solids (TSS) of tangerine cv. Sainampueng fruit between fertilizer application treatments in clay soil.

Treatment	Vitamin C (mg/100 ml) [1/]			TSS (°Brix) [1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	24.5	25.0 a	25.0	11.4 ab	10.9 c	10.9
2) 170 g N + 11.04 g B	24.5	24.5 b	24.5	11.3 ab	11.2 b	11.2
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	24.5	24.4 b	24.8	11.4 ab	10.5 c	11.1
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	24.4	24.4 b	24.7	11.0 b	10.2 c	11.0
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	24.5	24.4 b	24.8	11.4 ab	11.1 b	11.7
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	24.5	24.4 b	24.8	11.8 a	12.0 a	11.8
$LSD_{0.05}$	ns	0.18	ns	0.63	0.40	ns
% CV	1.26	1.62	7.52	5.60	6.93	10.23

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.30 Titratable acidity (TA) and TSS/TA ratio of tangerine cv. Sainampueng fruit between fertilizer application treatments in clay soil.

Treatment	TA (%)[1/]			TSS/TA ratio[1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	0.51b	0.52 d	0.52	22.4 b	21.0 a	21.0 c
2) 170 g N + 11.04 g B	0.59 a	0.55 d	0.55	19.2 c	20.4 a	20.4 c
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	0.57 a	0.63 c	0.55	20.0 c	16.7 c	20.2 c
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	0.48 b	0.68 b	0.49	22.9 ab	15.1 d	22.5 b
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	0.50 b	0.72 a	0.49	22.8 ab	15.4 d	23.9 a
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	0.50 b	0.67 b	0.50	23.6 a	17.9 b	23.6 a
$LSD_{0.05}$	0.05	0.03	ns	1.07	0.82	1.01
% CV	11.43	11.48	11.55	9.65	10.51	9.75

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

5. Nutrient content in tangerine fruit

The nutrient in fruits of tangerine trees growing on loam and clay soil showed in Table 9.31 – 9.38. The concentration of N, P, Ca, Mg, Fe, Mn, Cu, Zn and B were not significantly different among six fertilizer treatments except K. The tangerine trees did not respond to the quantity fertilization because of the heavy consumption of nutrients during growth and development of tangerine (Table 9.1, 9.2, 9.5 and 9.6). The K concentration in fruit was high among six fertilizer treatments because of the luxury consumption from high K concentration in both loam and clay soil (Table 9.5 and 9.6) (Osotsapar, 2000).

It was indicated that the application of fertilizer suggested by soil analysis and application fertilizer in accordance with the grower were not different in nutrient concentrations in fruits at all harvesting seasons. Because the nutrients in soil were available in high concentration (Table 9.1 and 9.2) for plant growth and developed fruit for best quality and yield. However, the concentration of input cost between the two approaches will be discussed in the next.

Table 9.31 Concentrations of nitrogen (N), phosphorus (P) and potassium (K) in tangerine cv. Sainampueng fruit as affected by various fertilizer application treatments in loam soil.

Treatment	Concentration of N (g/kg) [1/]			Concentration of P (g/kg)			Concentration of K (g/kg) [1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	1.66 b	1.68	1.34	0.18	0.19	0.15	1.70 b	1.71 b	1.37
2) 170 g N + 1.92 g Cu + 11.04 g B	1.70 ab	1.66	1.37	0.17	0.19	0.15	1.73 ab	1.73 ab	1.38
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	1.78 a	1.69	1.36	0.19	0.21	0.14	1.78 a	1.78 a	1.35
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	1.74 ab	1.66	1.36	0.18	0.19	0.15	1.78 a	1.67 b	1.39
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	1.66 b	1.65	1.35	0.18	0.18	0.16	1.73 ab	1.70 b	1.37
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	1.76 a	1.69	1.35	0.18	0.19	0.15	1.75 ab	1.71 b	1.37
$LSD_{0.05}$	0.09	ns	ns	ns	ns	ns	0.07	0.06	ns
% CV	12.76	9.53	7.67	11.84	16.71	13.22	8.05	11.86	8.73

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.32 Concentrations of calcium (Ca) and magnesium (Mg) in tangerine cv. Sainampueng fruit as affected by various fertilizer application treatments in loam soil.

Treatment	Concentration of Ca (g/kg)			Concentration of Mg (g/kg)		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	0.22	0.23	0.27	0.08	0.08	0.05
2) 170 g N + 1.92 g Cu + 11.04 g B	0.22	0.23	0.28	0.08	0.08	0.05
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	0.23	0.21	0.29	0.08	0.09	0.05
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	0.23	0.23	0.26	0.08	0.08	0.06
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	0.22	0.24	0.28	0.08	0.07	0.06
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	0.23	0.23	0.27	0.09	0.08	0.05
F-test	ns	ns	ns	ns	ns	ns
% CV	9.18	8.83	8.52	11.76	9.56	7.92

Table 9.33 Concentrations of iron (Fe), manganese (Mn) and copper (Cu) in tangerine cv. Sainampueng fruit as affected by various fertilizer application treatments in loam soil.

Treatment	Concentration of Fe (g/kg)			Concentration of Mn (g/kg) [1/]			Concentration of Cu (g/kg)		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	2.49	2.48	1.78	1.03	1.24	0.87 c	1.18	1.24	1.39
2) 170 g N + 1.92 g Cu + 11.04 g B	2.51	2.48	1.77	1.03	1.21	0.92 b	1.16	1.23	1.39
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	2.51	2.49	1.78	0.99	1.23	0.89 c	1.17	1.25	1.39
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	2.52	2.48	1.80	1.04	1.22	0.94 ab	1.16	1.24	1.41
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	2.49	2.49	1.79	1.02	1.23	0.95 a	1.16	1.23	1.41
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	2.50	2.48	1.78	1.04	1.24	0.90 bc	1.15	1.23	1.40
$LSD_{0.05}$	ns	ns	ns	ns	ns	0.02	ns	ns	ns
% CV	12.43	9.27	9.25	9.96	10.54	9.81	13.35	12.03	9.76

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.34 Concentrations of zinc (Zn) and boron (B) in tangerine cv. Sainampueng fruit as affected by various fertilizer application treatments in loam soil.

Treatment	Concentration of Zn (g/kg)			Concentration of B (g/kg)		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 960 ppm Cu + 2,400 ppm B	2.05	2.32	1.61	1.28	1.40	1.17
2) 170 g N + 1.92 g Cu + 11.04 g B	2.03	2.31	1.62	1.30	1.38	1.16
3) 1,340 g N + 530 g P_2O_5 + 960 ppm Cu + 2,400 ppm B	2.04	2.33	1.60	1.29	1.39	1.16
4) 1,340 g N + 530 g P_2O_5 + 1.92 g Cu + 11.04 g B	2.04	2.32	1.62	1.29	1.38	1.17
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	2.04	2.35	1.65	1.31	1.38	1.18
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	2.05	2.34	1.64	1.29	1.38	1.19
F-test	ns	ns	ns	ns	ns	ns
% CV	12.08	9.31	11.95	12.56	8.87	7.92

Table 9.35 Concentrations of nitrogen (N), phosphorus (P) and potassium (K) in tangerine cv. Sainampueng fruit as affected by various fertilizer application treatments in clay soil.

Treatment	Concentration of N (g/kg) [1/]			Concentration of P (g/kg)			Concentration of K (g/kg) [1/]		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	1.59	1.65	1.31 c	0.18	0.19	0.17	1.64 a	1.73 ab	1.50
2) 170 g N + 11.04 g B	1.56	1.64	1.32 c	0.17	0.19	0.16	1.60 b	1.68 b	1.47
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	1.56	1.63	1.34 b	0.17	0.19	0.17	1.58 b	1.70 ab	1.49
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	1.59	1.64	1.35 bc	0.17	0.20	0.18	1.64 ab	1.72 ab	1.51
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	1.58	1.63	1.40 a	0.17	0.19	0.17	1.61 b	1.69 ab	1.47
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	1.60	1.64	1.41 a	0.18	0.20	0.18	1.65 a	1.74 a	1.48
$LSD_{0.05}$	ns	ns	0.02	ns	ns	ns	0.03	0.05	ns
% CV	14.43	9.85	6.84	13.21	11.59	12.76	7.89	9.66	9.04

[1/] Means within the same column followed by different alphabets were significantly different at $P \leq 0.05$ by LSD

[ns] not significant difference

Table 9.36 Concentrations of calcium (Ca) and magnesium (Mg) in tangerine cv. Sainampueng fruit as affected by various fertilizer application treatments in clay soil.

Treatment	Concentration of Ca (g/kg)			Concentration of Mg (g/kg)		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	0.22	0.26	0.26	0.09	0.08	0.07
2) 170 g N + 11.04 g B	0.21	0.25	0.25	0.08	0.08	0.07
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	0.21	0.26	0.26	0.08	0.08	0.06
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	0.22	0.26	0.26	0.08	0.08	0.06
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	0.23	0.26	0.27	0.09	0.09	0.07
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	0.22	0.26	0.27	0.08	0.08	0.06
F-test	ns	ns	ns	ns	ns	ns
% CV	11.54	9.35	8.26	10.37	8.14	8.65

Table 9.37 Concentrations of Iron (Fe), manganese (Mn) and copper (Cu) in tangerine cv. Sainampueng fruit as affected by various fertilizer application treatments in clay soil.

Treatment	Concentration of Fe (g/kg)			Concentration of Mn (g/kg)			Concentration of Cu (g/kg)		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	2.03	2.01	1.97	1.05	1.06	1.03	1.24	1.18	1.13
2) 170 g N + 11.04 g B	2.01	2.00	1.98	1.04	1.04	1.03	1.26	1.18	1.11
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	1.99	2.03	2.01	1.01	1.05	1.01	1.24	1.17	1.10
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	1.98	2.01	1.98	1.03	1.03	1.00	1.25	1.16	1.12
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	2.03	2.03	2.01	1.04	1.05	1.01	1.25	1.15	1.14
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	2.02	2.02	2.00	1.04	1.04	1.02	1.26	1.16	1.12
F-test	ns	ns	ns	ns	ns	ns	ns	ns	ns
% CV	10.83	9.68	11.04	8.75	11.43	10.81	8.47	9.85	9.79

Table 9.38 Concentrations of zinc (Zn) and boron (B) in tangerine cv. Sainampueng fruit as affected by various fertilizer application treatments in clay soil.

Treatment	Concentration of Zn (g/kg)			Concentration of B (g/kg)		
	Hot dry season	Cool dry season	Wet season	Hot dry season	Cool dry season	Wet season
1) 170 g N + 2,400 ppm B	2.23	1.97	2.04	1.25	1.28	1.21
2) 170 g N + 11.04 g B	2.21	1.98	2.05	1.24	1.27	1.19
3) 1,410 g N + 770 g P_2O_5 + 2,400 ppm B	2.22	1.99	2.02	1.23	1.30	1.22
4) 1,410 g N + 770 g P_2O_5 + 11.04 g B	2.20	1.97	2.03	1.21	1.28	1.20
5) 895 g N + 665 g P_2O_5 + 920 g K_2O + 2,400 ppm Ca + 2,400 ppm Mg + 2,400 ppm Zn + 2,400 ppm B	2.22	2.01	2.06	1.23	1.30	1.21
6) 895 g N + 665 g P_2O_5 + 920 g K_2O + 11.04 g Ca + 11.04 g Mg + 11.04 g Zn + 11.04 g B	2.23	2.00	2.05	1.20	1.29	1.21
F-test	ns	ns	ns	ns	ns	ns
% CV	9.07	9.53	10.05	9.89	10.64	9.27

Treatment 1 was considered as the most suitable method because the general fruit quality and yield were better than with other treatments. Besides, the amount of fertilizers used (Table 9.2 and 9.5) and its cost were much chcapter than other treatments (Table 9.39).

It is strongly suggested that nutrient management is important and considered as the basic practices for fruit tree production. The optimum concentration of nutrients encourages healthy growth, high yield and good quality of the products (Wangnai, 2002; Kumlung *et al*., 2003). Excessive amount of fertilizer application decreases the quality of fruit (Mongi *et al*., 2008). The farmer experiences alone were ineffective to manage the crop because there is a tendency to apply more fertilizer than needed. This over application caused more expenses (Poovarodom *et al*., 1998). The yield and quality of fruit of treatment 1 was as high as the other treatments but required less amount nutrient.

Conclusions and Recommendations

The fertilizer management programme should be applied fertilizer the basis of soil nutrient analysis. The fertilizer was applied once a month only for nutrients which present below optimum level. Soil application was used for N, P and K, and foliar application for all other elements. It provided better results for farmer's practices with not only the high yield but also the quality of fruit, including fruit size (6.21-6.63 cm), fruit weight (111.6-136.3 g), juice percentage (50.4-56.0 %), vitamin C (24.0-25.0 mg/100 ml of juice), TSS (10.08-11.4 $^{\circ}$Brix), TA (0.50-0.66 %) and TSS/TA ratio (15.3-22.4) as well as yields (30.9-56.4 kg/tree). It also reduced input cost (69.87-126.50 baht/1 kg of yield/year) in both loam and clay soil for every harvesting season.

Table 9.39 The expense of fertilizer applied in the treatments of the tangerine cv. Sainampueng experimented in loam and clay soil.

Treatment	Loam soil			Clay soil		
	Expense (baht/tree/year)	Yield (kg/tree/year)	Average (baht/kg/year)	Expense (baht/tree/year)	Yield (kg/tree/year)	Average (baht/kg/year)
1. Applied only nutrients which present below optimum level and foliar application of microelements	480	54.22	8.85	480	94.3	5.09
2. Applied only nutrients which present below optimum level and soil application of microelements	480	52.94	9.07	480	94.9	5.06
3. Adjustment N:P_2O_5:K_2O ratio of the soil (4:2:5) and foliar application of microelements	3,463	51.57	67.15	4,710	94.3	49.95
4. Adjustment N:P_2O_5:K_2O ratio of the soil (4:2:5) and soil application of microelements	3,463	52.27	66.25	4,710	92.2	51.08
5. Application of fertilizers in accordance with farmer's practice	7,003	54.91	127.54	7,003	95.8	73.10
6. Application of fertilizers in accordance with farmer's practice and soil application of microelements	7,003	51.74	135.35	7,003	93.4	74.98