Chapter 4

RESULTS

4.1. Farmers' practices in tomato production

4.1.1. Plant density and yield

Data from the formal survey show that the farmers in San Sai and Chom Thong grew tomatoes in wide beds with close row spacing. The average spacing between rows and plants was 39 cm and 36 cm in San Sai, and 40 and 31 cm in Chom Thong. The population of tomatoes ranged from 32,680 - 36,040 plants/ha and the yield ranged from 33.0 - 19.3 t/ha, respectively (Table 2).

Table 2. The population and yield of tomato in the farmers' fields, April, 1990

Production area	No. of farmers	Bed width (cm)	Furrow width (cm)	Between rows (cm)	Between plants (cm)	Population (plant/ha)	Yield (t/ha)
San Sai	47	131	40	39	36	32,680	33.0
Chom Thong	47	134	45	40	31	36,040	19.3

4.1.2. Fertilizer application

Results from the survey indicated that the average potassium content from soil samples were 43.7 ppm (15 samples) and 48.3 ppm (13 samples) in San Sai and Chom Thong respectively. Most of the farmers, 78.8% in San Sai and 93.5% in Chom Thong, used manure in tomato production. In San Sai, farmers used an average of 100 kg/ha of N, 93 kg/ha of P_2O_5, and 113 kg/ha of K_2O, while in Chom Thong, the farmers used an average of 159 kg/ha of N, 124 kg/ha of P_2O_5 and 138 kg/ha of K_2O (Table 3).

Table 3. Fertilizer application in farmers' fields

Production area	Manure (%)	N (t/ha)	P_2O_5 (t/ha)	K_2O (t/ha)
San Sai	78.8	100	95	113
Chom Thong	93.5	159	124	138

4.1.3. Staking cultivation

Only 2% of the farmers in San Sai and 4% in Chom Thong used staking cultivation. When asked, only 30% and 26% of farmers in San Sai and Chom Thong said they were willing to use staking if staking was recommended to them. Most of the farmers, 41% in San Sai and 63% in Chom Thong, believed that using staking is too expensive for tomato production.

Based on the results from the formal survey, staking, plant density and K fertilizer seem to be the factors that affect the yield and quality of tomato in Chiang Mai valley.

This is the foundation for designing the treatments in the experiment.

4.2. Experimental results

4.2.1. Marketable yield

The marketable yield was significantly affected by plant spacing (P = 0.0012), but not by staking and K fertilizer (Appendix Table B-1 and C-1). A significant interaction effect on the marketable yield was also found between plant spacing and staking (P = 0.0475). Table 4 shows that when staking was implemented, plant spacing did not affect the marketable yield significantly, and when staking was not used, closer spacing i.e. 15 cm, resulted in significantly lower yields than the wider plant spacing, 30 and 45 cm. However, the marketable yields were not statistically different between 30 and 45 cm plant spacing. Table 4 also indicates that as the spacing increased, the effect of staking decreased. At 15 cm spacing, the yield from staking treatment was significantly higher than that from nonstaking treatment, but not at 30 and 45 cm plant spacing.

Table 4. Effects of staking and plant density on marketable yield averaged over the K fertilizer treatments

Plant spacing (cm)	Staking	Nonstaking
	---------- t/ha	-----------
15	58.42	45.62
30	62.18	58.45
45	64.94	62.88

$LSD_{.05}$ = 6.64 for pair comparison between or within staking and nonstaking treatments.

4.2.2. Unmarketable yield

In the case of unmarketable yield, statistical analysis shows that staking could reduce the unmarketable yield significantly as initially hypothesized (Table 5). Plant density and K did not have significant effects on the unmarketable yield. There was no interaction effect among three factors (Appendix Table B-2 and C-2).

Table 5. The effects of staking on the unmarketable yield of tomato averaged over density and K fertilizer treatments

	Unmarketable yield (t/ha)
Staking	6.03
Nonstaking	8.57

$LSD_{.05}$ = 1.98

4.2.3. Number of fruits per plant

Spacing between plants had highly significant effects on the number of fruits per plant (P = 0.000). No clear response pattern of fruit numbers to staking and K fertilizer was observed. A significant interaction effect on the number of fruits was also found between plant spacing and K fertilizer (P = 0.0391, see Appendix Table B-3). The combination of 45 cm plant spacing and K(300) treatment produced the highest number of fruits, with an average of 51.44 fruits per plant, followed by the combination of 45 cm plant spacing and K(100) treatment, with an average of 46.57 fruits per plant. At any level of K fertilizer, the wider plant spacing produced more fruits than the closer one (Table 6). At plant spacing of 15 and 30 cm, K fertilizer did not significantly affect the fruit numbers. But at 45 cm plant spacing treatments, 300 kg/ha of K_2O treatment produced significantly more fruits than the other treatments.

Table 6. Effects of plant spacing and K fertilizer on the number of fruits per plant averaged over the staking treatments

Plant spacing (cm)	K treatment ($kg.K_2O/ha$)			
	K(0)	K(100)	K(200)	K(300)
15	13.93	14.69	14.11	14.90
30	30.86	29.58	32.21	29.83
45	42.46	46.57	42.12	51.44

$LSD_{.05}$ = 7.74 for comparison of the means of plant spacing treatment at the same or different levels of K treatments.

4.2.4. Average fruit weight

The average fruit weight was significantly affected by plant spacing, but it was unaffected by staking and K fertilizer. Spacing of 45 cm between plants yielded 58.95 g of average fruit weight, which is significantly greater than that from 15 cm plant spacing which yielded 51.25 g. The average fruit weight of 45 cm and 30 cm plant spacing were not statistically different, neither were 30 cm and 15 cm (Table 7). No significant interaction effects on the average fruit weight were found among the factors.

Table 7. Effects of plant spacing on fruit weight averaged over the staking and K fertilizer treatments

Plant spacing (cm)	Average fruit weight (g)
15	51.25
30	56.56
45	58.95

$LSD_{.05}$ = 5.54

4.2.5. The yield per plant

The yield per plant was affected only by the plant spacing in this experiment. The yield per plant increased as the plant spacing increased. The highest yield per plant, 1.99 kg/plant, was gained at 45 cm plant spacing, and the lowest yield per plant, 0.56 kg/plant, was produced at 15 cm plant spacing (Table 8). Staking and K fertilizer did not affect the average yield per plant. No interaction effects were found among three factors.

Table 8. Effects of plant spacing on the yield per plant averaged over staking and K fertilizer treatments

Plant spacing (cm)	Yield per plant (kg)
15	0.56
30	1.34
45	1.99

$LSD_{.05}$ = 0.11

4.2.6. Total acidity

Different effects of K fertilizer on total acidity were found (P = 0.0128). Total acidity from 200 and 300 kg/ha of K_2O treatments was significantly higher than that without K_2O treatment. However, the total acidity among all K_2O treatments [(100), K(200) and K(300)] was not statistically different (Table 9). Staking and plant spacing did not affect the total acidity of tomato fruits. No interaction effects were found among three factors.

Table 9. The effects of K fertilizer on the total acidity of tomatoes averaged over the staking and density treatments

K treatment (kg.K_2O/ha)	Total acidity (%)
K(0)	0.4231
K(100)	0.4386
K(200)	0.4586
K(300)	0.4568

$LSD_{.05}$ = 0.0236

4.2.7. Total solids

There was no striking effects on the total solid by staking, plant spacing and K fertilizer individually. But a significant interaction effect on the total solids was found between staking and K fertilizer (P = 0.034). Table 10 shows that in the nonstaking treatment, the total solids increased slightly as the K rate was raised. In the staking treatment, total solids did not change uniformly with the K increment. However, no significant difference between any pair of K treatments was found in both staking and nonstaking treatments. A multiple interaction effect on the total solids was observed among staking, plant spacing and K fertilizer (P = 0.0017). Because no main effect on the total solids was found, the multiple interaction is difficult to interpret (Appendix Table B-7).

Table 10. Effects of staking, and K fertilizer on the total solids (%) of tomato averaged over the plant spacing treatment

	K treatment (kg.K_2O/ha)				$LSD_{.05}$
	K(0)	K(100)	K(200)	K(300)	
Staking	5.085	5.191	4.793	4.952	NS
Nonstaking	5.003	5.049	5.203	5.319	NS

NS = Nonsignificant

4.2.8. Soluble solid

Similar to the total solids, three factors, i.e., staking, density and K fertilizer, did not affect the soluble solids individually. But staking and K fertilizer had significant interation effect on the soluble solids ($P = 0.0393$). Also staking, plant spacing and K fertilizer had multiple interaction effect on the soluble solids ($P = 0.0422$, see Appendix Table B-8). Table 11 indicates that as the K rate increased, soluble solids increased slightly. But there was no statistical difference among them. Within the staking treatment, no regular change and no statistical difference were found between any pair of K treatments.

Table 11. Effects of staking, and K fertilizer on soluble solids (°Brix) of tomato averaged over the plant spacing treatment

	K treatment (kg.K_2O/ha)				$LSD_{.05}$
	K(0)	K(100)	K(200)	K(300)	
Staking	5.12	5.33	5.05	5.17	NS
Nonstaking	5.19	5.14	5.23	5.31	NS

NS = Nonsignificant

4.2.9. pH value

In this study, no significant effects of staking, plant density and K fertilizer on pH value were noticed separately, even though some difference occurred among the treatments. Also no interaction effects were found among three factors (Table 12).

Table 12. Effects of staking, plant spacing and K fertilizer on pH value of tomato juice

K treatment ($kg.K_2O/ha$)	Staking			Nonstaking		
	15 cm	30 cm	45 cm	15 cm	30 cm	45 cm
K(0)	4.32	4.29	4.31	4.31	4.29	4.34
K(100)	4.27	4.30	4.30	4.34	4.30	4.31
K(200)	4.29	4.31	4.33	4.32	4.29	4.25
K(300)	4.27	4.30	4.31	4.24	4.27	4.33

$LSD_{.05}$ = 0.067

4.2.10. Fruit color and pulp color

It was observed that the different rates of K fertilizer affected the fruit color. Even though a blotchy ripening was found in every treatment, the fruit color, however, developed better in the higher rate of K fertilizer treatments. The difference between the K(0) and K(300) treatments was very obvious. Unfortunately, in this experiment, the color appearance of fruits was not quantitatively determined.

Pulp colors did not differ qualitatively between different treatments. Table 3 shows that the tomato pulps from all the treatments were red in color, with only some difference occurring in the value (lightness) and the chroma (saturation), but they were all aceptable for processing. Munsell Color is a subjetive determination method. It is psychologically influenced, and the results recorded from it could not be used for the statistical analysis.

Table 13. Effects of staking, plant spacing and K fertilizer on tomato pulp color[a]

K treatment ($kg.K_2O/ha$)		Staking 15 cm	Staking 30 cm	Staking 45 cm	Nonstaking 15 cm	Nonstaking 30 cm	Nonstaking 45 cm
K(0)	Rep I	5R,5/12[b]	5R,6/8	5R,5/12	5R,6/10	5R,6/10	5R,6/8
	Rep II	5R,6/10	5R,5/12	5R,6/12	5R,5/12	5R,6/12	5R,5/12
	Rep III	5R,5/14	5R,5/12	5R,6/10	5R,7/8	5R,6/10	5R,6/10
K(100)	Rep I	5R,6/11	5R,6/10	5R,5/8	5R,6/9	5R,6/10	5R,6/10
	Rep II	5R,5/12	5R,5/12	5R,5/14	5R,6/12	5R,5/14	5R,6/12
	Rep III	5R,6/12	5R,6/12	5R,5/12	5R,6/10	5R,5/12	5R,5/10
K(200)	Rep I	5R,6/10	5R,6/11	5R,6/11	5R,6/10	5R,5/10	5R,6/10
	Rep II	5R,5/12	5R,5/10	5R,5/12	5R,5/12	5R,5/12	5R,5/12
	Rep III	5R,6/10	5R,5/12	5R,6/10	5R,6/12	5R,5/10	5R,5/12
K(300)	Rep I	5R,6/11	5R,5/10	5R,6/10	5R,6/10	5R,6/12	5R,6/10
	Rep II	5R,5/10	5R,6/10	5R,5/14	5R,5/10	5R,5/12	5R,5/10
	Rep III	5R,5/12	5R,5/10	5R,6/12	5R,5/10	5R,6/10	5R,6/12

[a]The pulp color was measured by using the Munsell Color Charts.

[b]R, one of the five principal hues, namely red, yellow, green, blue, and purple. 5R means midway in the red section of the spectrum. It is a pure red free from purple yellow. The number above the line in the fraction is the value (brilliance or lightness) that indicates the intensity of the black constituent of the color, scaling from 0 - 10. Zero is absolute black and 10 is absolute white. The number below the line in the denominator is chroma (strength or saturation), which expresses the strength or degree of departure of a particular hue from a neutral gray of the same value, scaling from 0 - 14 or further (Gould, 1974).

4.3. Results of plant nutrition analysis

K, Ca, Mg in tomato leaves and K residual in the soil after harvest were analyzed in order to understand the relationships among the elements and their effects on the yield and the quality of tomato fruits.

4.3.1. Nutrition contents in tomato leaves

4.3.1.1. Potassium Potassium content in plant leaves from the first sampling collected one day before the second dressing, did not respond well to the K fertilizer application (Table 14). The uptake of K from K(300), K(200), K(0) treatments were not statistically different, but the uptake of K from K(100) treatment was significantly lower than those from the former three treatments, including K(0), the control treatment.

Potassium content in tomato leaves from the second sampling collected two weeks after the second dressing (flowering stage) was affected by the different K treatments (Table 14). K uptake between K(200) and K(300) treatments were not significantly different. K contents from these two treatments were significantly greater than K(100) and K(0) treatments. Significant difference of K content was also observed between K(100) and K(0) treatments.

4.3.1.2. Calcium and Magnesium Calcium and Magnesium were not tested factors in the experiment. Lime was applied in the experimental plots at a rate of 1,250 kg/ha. Magnesium was not applied at all. In the light of plant leaves analysis, Ca and Mg absorbed by the plants were associated with the potassium applications. More Ca and Mg were taken up by plants at K(200) treatment (Table 14).

4.3.2. Relations between nutrient uptake and the total yield

Even though the percentage K of tomato leaves was significantly different from one level of K application to the another, the total yield did not show any response to the application of K level (Table 14).

Table 14. Relationships between K, Ca and Mg in tomato leaves and total fruit yield[a]

K treatment ($kg.K_2O/ha$)	Nutrients in plant (%)						Total yield (t/ha)
	K		Ca		Mg		
	1st S[b].	2nd S.	1st S.	2nd S.	1st S.	2nd S.	
K(0)	3.794	3.409	3.042	3.526	0.423	0.477	66.11
K(100)	3.509	3.798	2.944	3.412	0.518	0.492	64.40
K(200)	3.852	4.081	3.564	3.827	0.448	0.535	65.98
K(300)	3.856	4.071	2.104	2.422	0.471	0.489	66.80
$LSD_{.05}$	0.235	0.242	0.171	0.263	NS	0.032	NS

NS = Nonsignificant

[a]The methods of analysis for K, Ca and Mg were explained before

[b]S = sampling

4.3.3. Potassium residual in the soil

Analysis of variance on the potassium residuals in the soil shows that the potassium residuals were very significantly different among the K treatments (Table 15). The higher rate of K treatment, the higher K residual in the soil. But the residual between K(0) and K(100) was not significantly different.

Table 15. K residuals of different K treatment in the soil after harvest[a]

K treatment ($kg.K_2O/ha$)	K residual in the soil (ppm)
K(0)	66.44
K(100)	81.28
K(200)	105.70
K(300)	150.40

$LSD_{.05}$ = 14.52

[a]K was extracted with 1N NH_4OAc pH = 7.