CHAPTER 3

On-farm comparison of fertilizer application practices to assess nitrogen-use efficiency of *Curcuma alismatifolia* Gagnep.

3.1 Introduction

In Thailand, *Curcuma alismatifolia* Gagnep. is the second highest export-value flower plant after orchids, and trend of the exporting are increasing in every year (Taraka, 2004). Northern Thailand is predominantly *Curcuma* planting area in Thailand, especially in Chiang Mai province which has more than 23 hectares of *Curcuma* planting area (Taraka, 2004).

C. alismatifolia is an intensively-managed crop to maintain both high productivity and quality products. According to recommendations for Good Agricultural Practice (GAP), growers should apply 15 g of 16N–16P−16K fertilizer per plant per month from the two-leaf fully-expanded stage until the flowering stage and then 13N–13P–21K fertilizers during rhizome formation (Wichailak, 2005) by which total amounts is approximately 937 kg N/ha, 937 kg P/ha and 1,237 kg K/ha. However, the crop yield for exporting to the international market has uncertain quantity each year (Taraka, 2004) that may mainly be attributed to shortage of irrigation water, poor plant protection, inappropriate soil management, poor land preparation and imbalanced fertilizer use. Focusing on imbalanced fertilizer use, it has resulted not only in the reduction of crop production but also productivity of soil decelerated (Saleem, 1992), especially in nitrogen fertilizer which is one of the most important plant nutrients also in *Curcuma* plant. Ohtake *et al*. (2006) found that nitrogen fertilizers used in *C. alismatifolia* production are important, since growth, flower quality and rhizome yields responded to the amount of N applied and a deficiency of N could substantially reduce yields.

Research and experience of advanced countries have shown that key to increase per hectare yield lies in the proper use of fertilizers by the farmers (Nabi *et al*., 2006). Low crop productivity is primarily the result of outdated technology prevalent on farm sector, particularity among the farmers. The modern technology, such as the use of fertilizers are not properly diffused and widely adopted by the farmers (Khan, 2000). Nowadays, the farmers in Chiang Mai province are applying self-fertilizer technique based on their experience. This is due to lack of knowledge in the specific nitrogen fertilizer use. In addition, little information is available concerning optimum rates and times of application or the most suitable forms of nitrogen fertilizer for *Curcuma* production.

Therefore, the aim of this research was to study the effects of fertilizer managements on nitrogen-use efficiency of *Curcuma* production in Chiang Mai province area, northern Thailand. To accomplish this objective, fertilizer application practices in field and yield response were determined.

3.2 Materials and methods

The field experiments were carried out on 4 commercial *Curcuma* farms (designated site A, B, C and D) at Chiang Mai province area in northern Thailand (Fig. 3.1). The soil type on site A and B were clay loam while in site C and D were sandy clay loam.

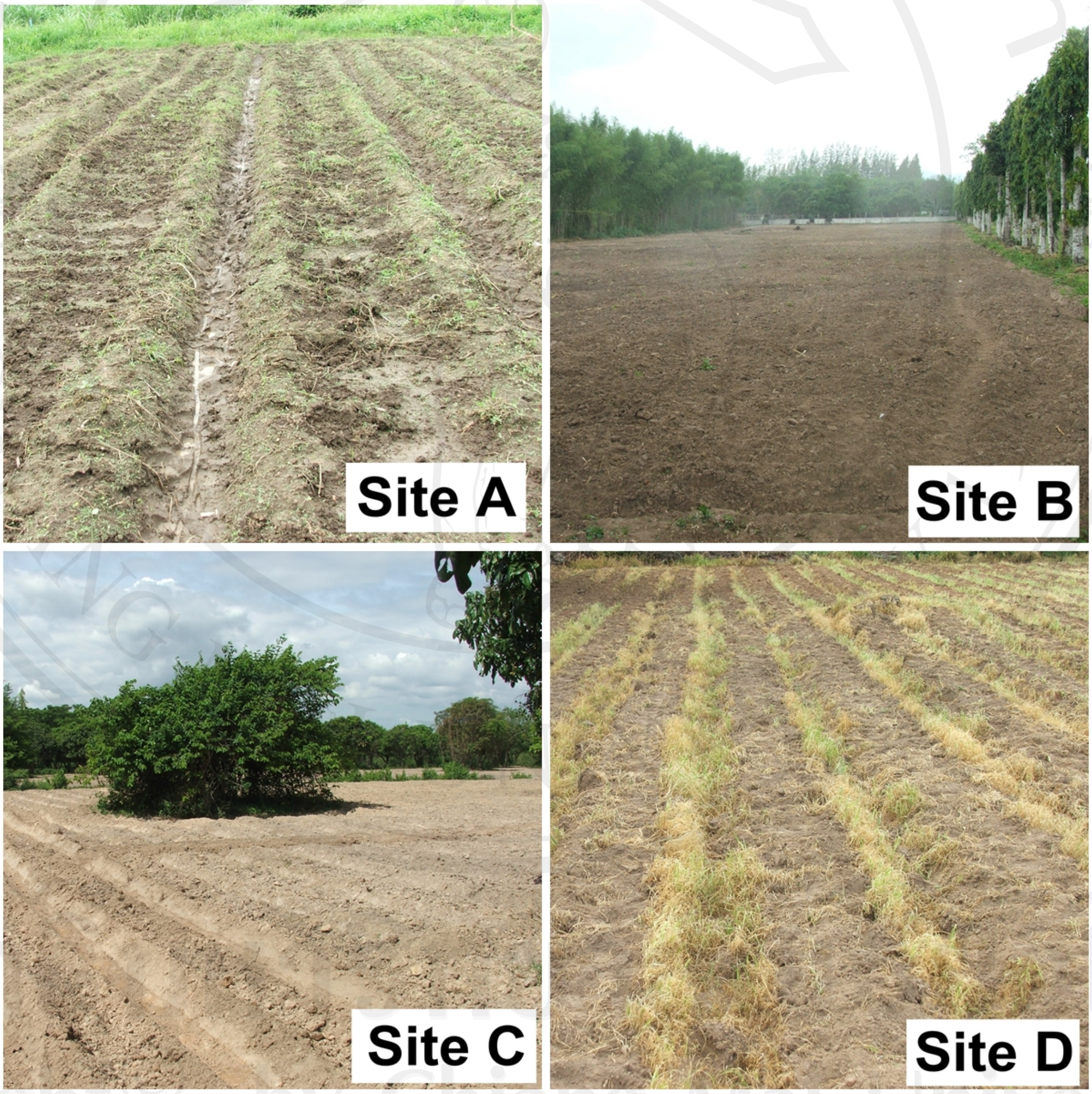

Figure 3.1 Experimental sites on Chiang Mai area, northern Thailand.

All commercial *Curcuma* farms were planted in May 2008 (regular growing season). Rhizomes of *C. alismatifolia* 'Chiang Mai Pink' with a diameter of about 1.8 -2.0 cm were planted, the planting depth being about 10 cm and the distance between plants along the row being 30 cm. The planting rate represents a density of approximately 62,500 plants/ha. Crop water requirements were completely satisfied by sprinkler irrigation on site A and by natural rainfall on sites B, C, and D (Appendix 1).

Table 3.1 Nitrogen fertilizer management in 4 commercial *Curcuma* farms at Chiang Mai area, northern Thailand.

Growth stages (days after planting [DAP])	Nitrogen application (g N/plant)			
	Site A	**Site B**	**Site C**	**Site D**
Before planting (0 DAP)	2.40	0	0	0
1st fully-expanded leaf (45 DAP)	2.40	2.25	0	0
2nd fully-expanded leaf (60 DAP)	0	0	1.50	0
3rd fully-expanded leaf (75 DAP)	2.40	2.25	0	0
Pre-flowering stage (90 DAP)	1.95	1.20	1.30	1.95
Flowering stage (105 DAP)	1.95	1.20	1.30	0
Pre- resting stage (135 DAP)	1.95	0	0	0
Resting stage (165 DAP)	1.95	0	0	0
Harvesting stage (180 - 195 DAP)	0	0	0	0
Total N applied (g N/ plant/ crop)	**15.00**	**6.90**	**4.10**	**1.95**

N fertilizer management in 4 commercial farms was shown in Table 3.1. The total amounts of nitrogen supplied were 15.0, 6.9, 4.1 and 1.95 g N/plant in site A, B, C and D, respectively. Total N P K fertilizers per plant were shown in Table 3.2.

Table 3.2 Details of total fertilizer (N, P, K) used in 4 commercial *Curcuma* farms at Chiang Mai area, northern Thailand.

Commercial farms	Fertilizer application (g/plant/crop)		
	N	P	K
Site A	15.00	15.00	19.80
Site B	6.90	11.70	11.70
Site C	4.10	4.10	5.70
Site D	1.95	1.95	3.15

Fertilizer management in each selected commercial farm was recorded throughout the crop season (Table 3.1). Soil mineral content and pH were measured at planting and harvesting stage. Growth in terms of plant height, number of leaves per plant and number of new shoots per cluster were measured. Fresh and dry weights of underground and aboveground parts were measured at sampling time, using 10-plant samples from each farm. The selected plant parts were collected for nitrogen analysis. The N concentration was determined by a modified indophenol method, using a Kjeldahl digested solution (Ohyama *et al*., 1991). The rhizome quality before planting and rhizome yield at harvesting stage were measured.

3.3 Results

3.3.1 Soil analysis

All experiments were located within a block of commercial *Curcuma* farms, N fertilizer and basal nutrients were managed by the cooperating farmer as a part of his crop. Chemical characteristics of the soil before planting were shown in Table 3.3.

Table 3.3 Chemical analysis of soil before planting from commercial *Curcuma* farms on Chiang Mai area, northern Thailand.

Element and method of analysis	Optimum range[1/]	Value obtained			
		Site A	Site B	Site C	Site D
Total N (%)	3.0-4.5	0.15	0.02	0.1	0.05
Available P (mg/kg)	25-35	102.94	150.34	176.81	118.74
Exchangeable K (mg/kg)	200-300	122.14	52.35	30.01	48.16
Exchangeable Ca (mg/kg)	1500-2000	2125.98	505.25	662.73	531.5
Exchangeable Mg (mg/kg)	300-400	265.48	38.03	105.18	98.59
pH (1: 2 soil: water)	5.8-6.2	5.93	5.91	6.00	5.95

[1/] Tamimi *et al*. (1997)

3.3.2. Rhizome quality before planting

The rhizome quality before planting, in terms of rhizome fresh weight, number of storage roots, rhizome diameter, storage roots diameter and connecting roots length, was shown in Fig. 3.2. The lowest rhizome fresh weight was found in site B. The highest number and diameter of storage roots were observed for site A and not significantly different from site B and C while the highest of rhizome diameter were observed for site C and not significantly different from site A and B. Rhizome quality before planting, in terms of connecting roots length, was not significant among site experiments.

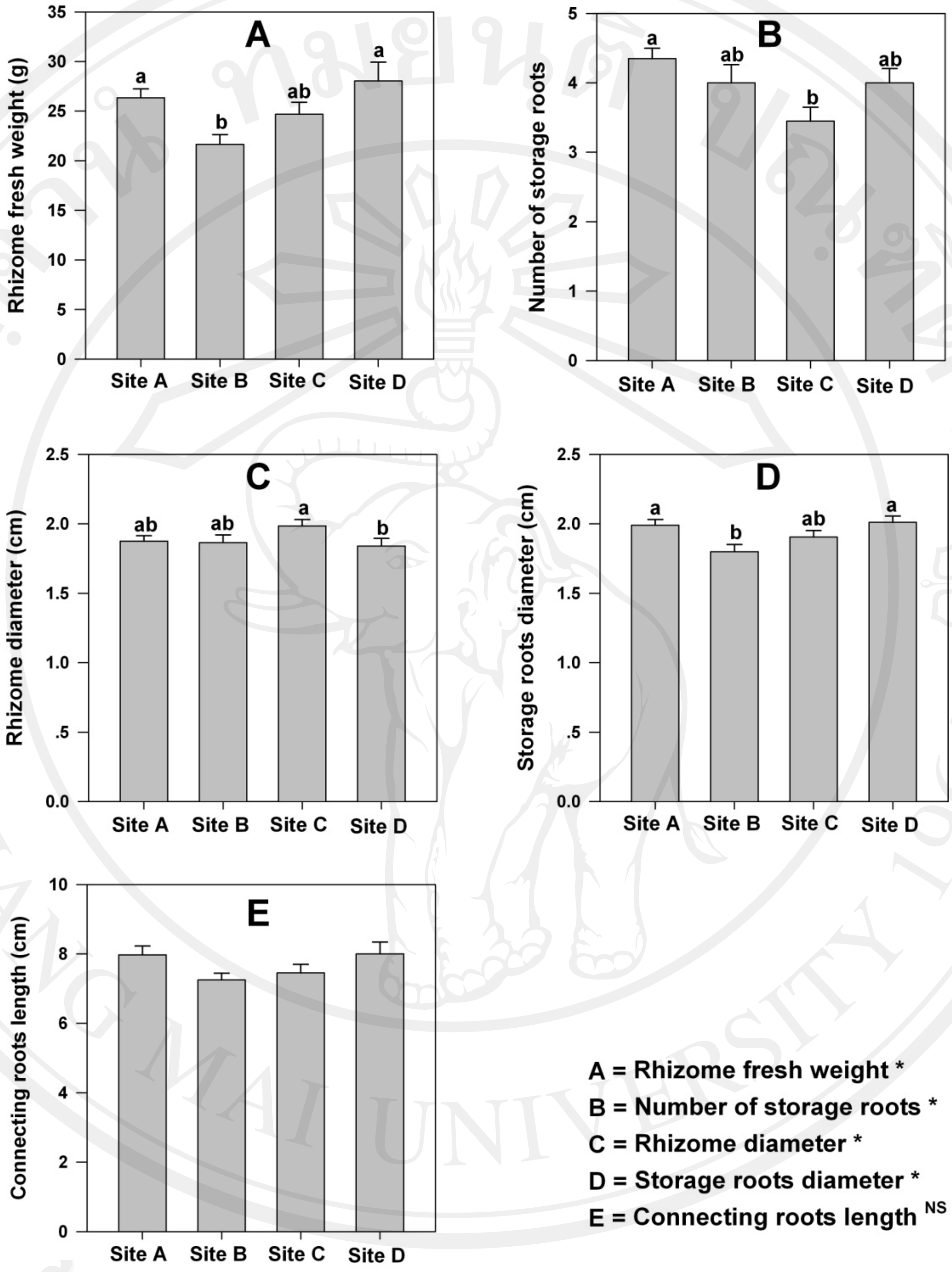

Figure 3.2 Rhizome quality in 4 commercial *Curcuma* farms at Chiang Mai area, northern Thailand before planting. The vertical bars represent the SE of the mean.*, significantly different among treatments at $p < 0.05$; NS= not significantly different.

3.3.3 Growth of plants

Plant growth, in terms of plant height, number of leaves per plant and number of shoots per cluster, were shown in Fig. 3.3 and 3.4. The results showed that there was a greater plant height in site B and D than site A and C. The highest number of leaves per plant was observed in site D while the highest number of new shoots per cluster was observed in site B.

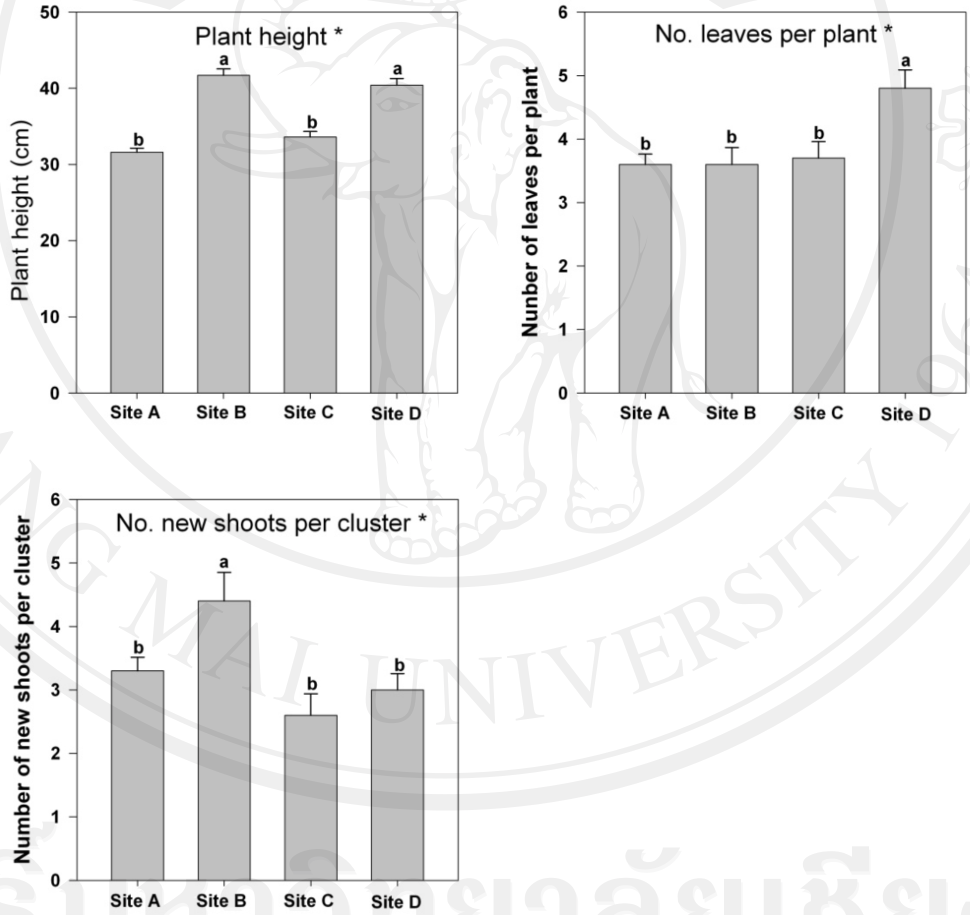

Figure 3.3 Growth of *C. alismatifolia* in 4 commercial *Curcuma* farms at Chiang Mai area, northern Thailand (at flowering stage). The vertical bars represent the SE of the mean.*, significantly different among treatments at $p < 0.05$; NS= not significantly different.

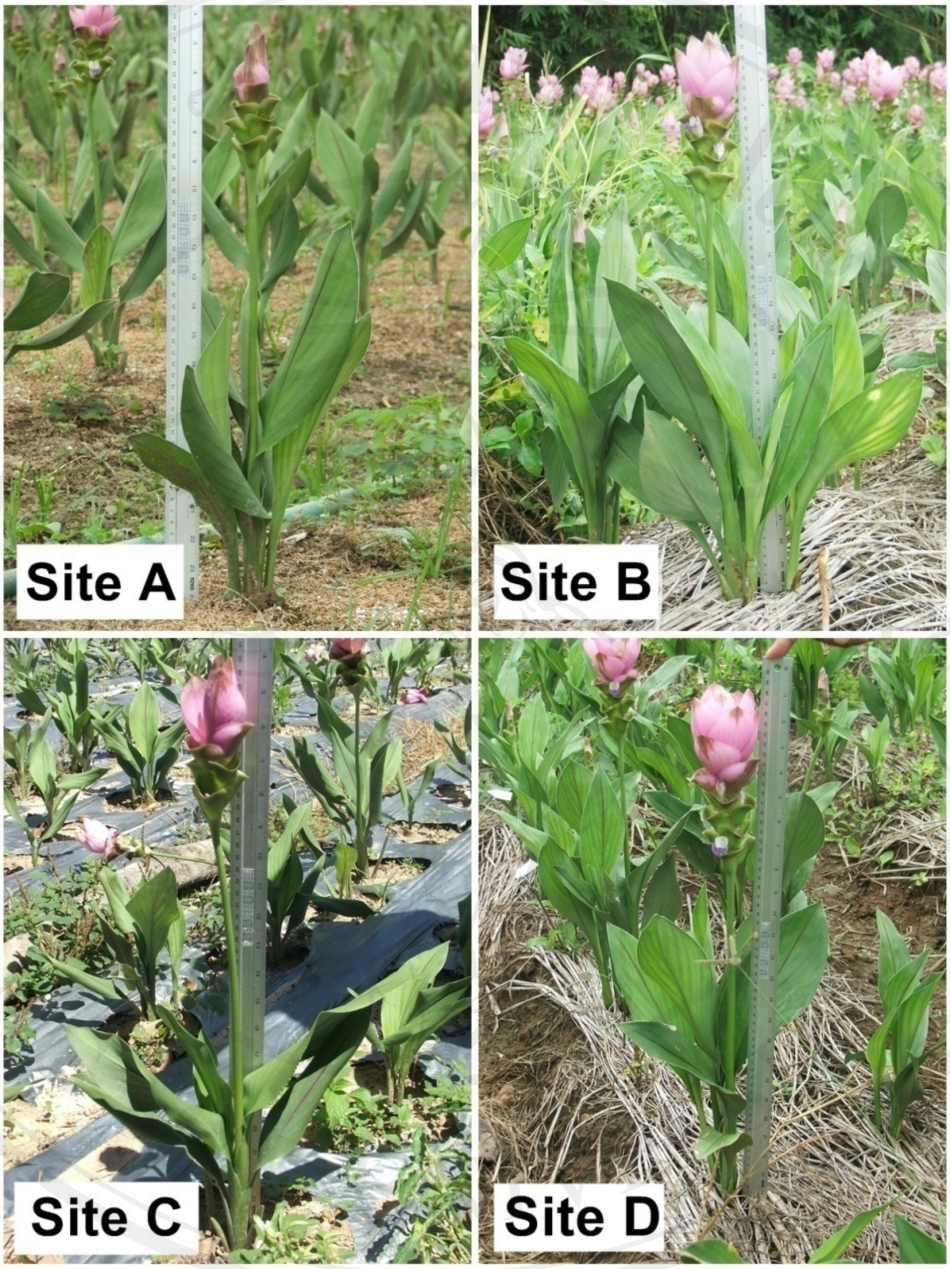

Figure 3.4 Growth of *C. alismatifolia* in 4 commercial *Curcuma* farms at Chiang Mai area, northern Thailand (at flowering stage).

At flowering stage, the highest dry weight for underground parts was 6.43 g for site B and the lowest was 3.60 g for site C. Aboveground parts dry weight was not affected by N fertilizer. However, there were higher total plant dry weights in plants grown in site A, B and D than site C (Fig. 3.5).

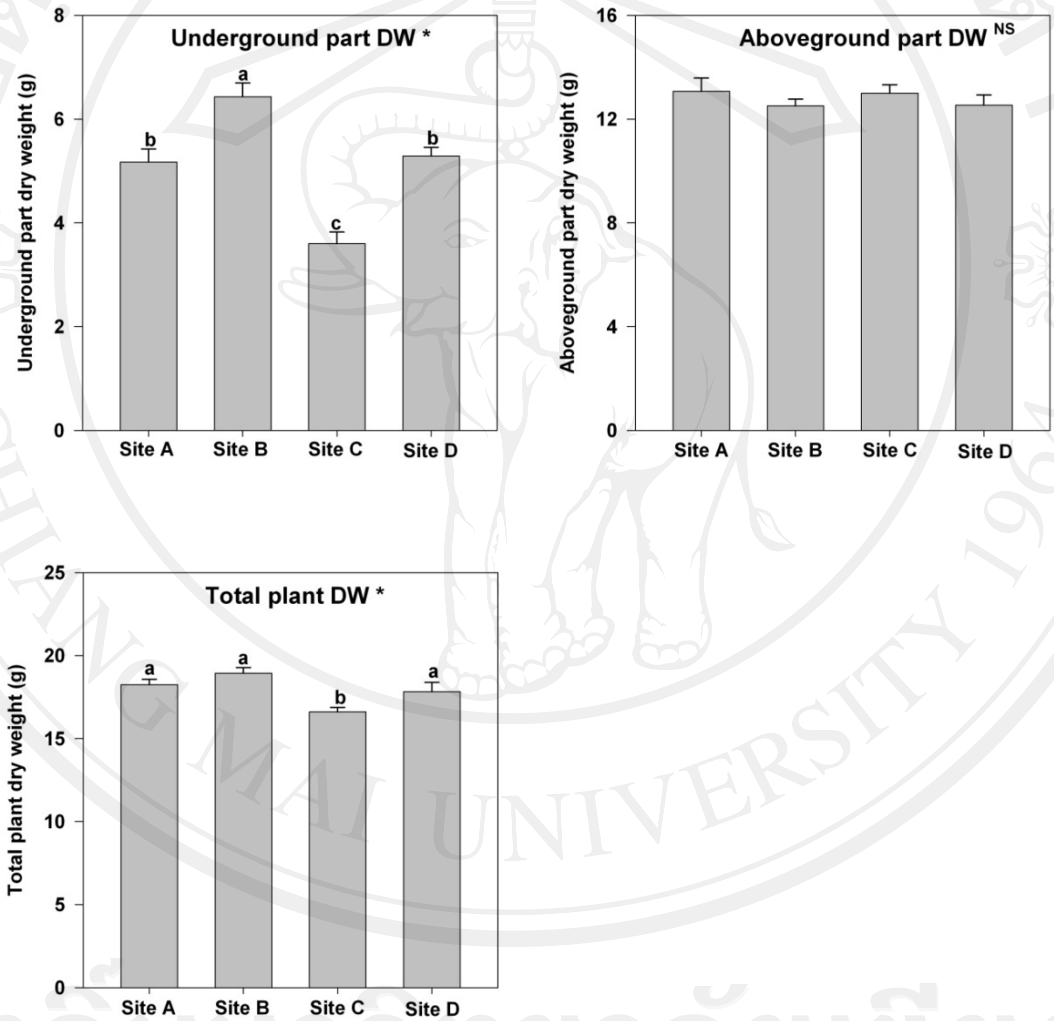

Figure 3.5 Dry matter of *C. alismatifolia* (flowering stage) in 4 commercial farms at Chiang Mai area, northern Thailand. The vertical bars represent the SE of the mean.*, significantly different among treatments at $p < 0.05$; NS= not significantly different.

3.3.4 Flower quality

Stalk lengths were longest in the plants grown in site B (44.2 cm) than in those grown in site A, C and D (Fig. 3.6). Flower spike length was not significantly different among site experiments. The number of green bracts was lowest in plants grown in site D while the number of pink bracts was lowest in plants grown in site C**.**

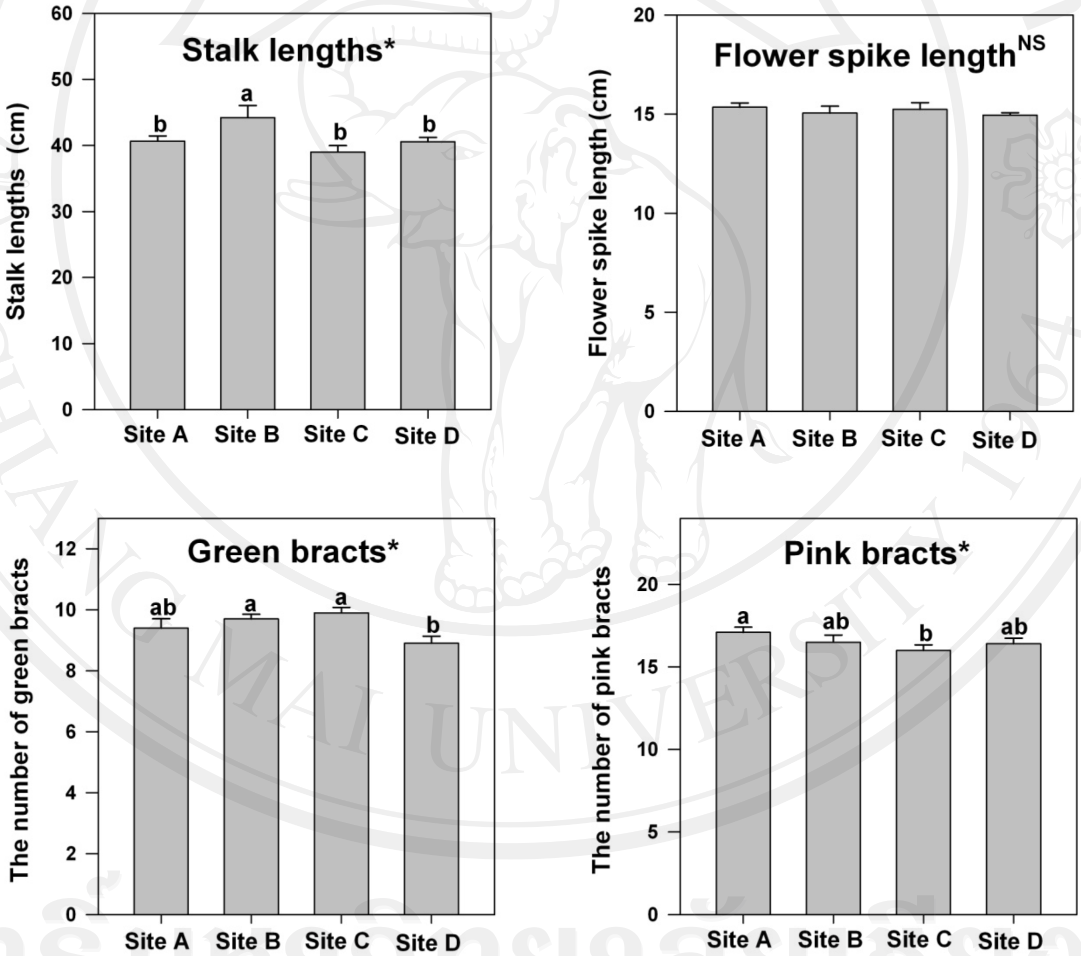

Figure 3.6 Flower quality of *C. alismatifolia* (flowering stage) in 4 commercial farms at Chiang Mai area, northern Thailand. The vertical bars represent the SE of the mean.*, significantly different among treatments at $p < 0.05$; NS= not significantly different.

3.3.5 Yield and rhizome quality

At the harvest stage, yields in terms of rhizome fresh weight per clump and rhizome quality in terms of rhizome diameter and storage roots diameter were greatest when plant were grown in site B and C as supplied with 6.90 g N/plant, and 4.10 g N/plant respectively (Table 3.4). The lowest plant yield (105.73g) was observed in site D where plant was supplied with 1.95 g N/plant.

Table 3.4 Effects of rate of nitrogen application on yield and rhizome quality of *C. alismatifolia* in commercial farms.

Commercial farms	N Applied (g/plant)	Yield (g) (Rhizomes FW)	Rhizome diameter (cm)	Storage roots diameter (cm)
Site A	15.00	156.26b	1.56b	1.51c
Site B	6.90	245.04a	1.73a	1.87a
Site C	4.10	251.67a	1.87a	1.94a
Site D	1.95	105.73c	1.72ab	1.69b
Significance		*	*	*

Means within column followed by different letters are significantly different ($p < 0.05$), NS = not significant.

The soil pH value at harvesting stage was of the greatest decreasing in plants grown in site C (Table 3.5).

Table 3.5 Chemical analysis of soil at harvesting stage from the commercial *Curcuma* farms at Chiang Mai area, northern Thailand.

Element and method of analysis	Value obtained			
	Site A	Site B	Site C	Site D
Total N (%)	0.05	0.06	0.06	0.05
Available P (mg/kg)	307.13	281.12	286.32	275.91
Exchangeable K (mg/kg)	212.44	83.13	181.65	55.42
Exchangeable Ca (mg/kg)	692.31	568.24	816.38	642.68
Exchangeable Mg (mg/kg)	62.34	36.25	62.34	41.47
pH (1: 2 soil: water)	5.78	5.17	4.55	4.63

3.3.6 Nitrogen concentration

Nitrogen concentrations in plant tissue were shown in Table 3.6. Before planting, the highest N concentration in mother rhizome and storage roots was found in site B (7.32% and 2.18% respectively) while the lowest was found in site D (3.43% and 0.83% respectively). At the flowering stage, the high concentration of N in mother rhizome, storage roots and new rhizome were found in site B while there was decreasing trend of N concentration in leaves (from site A to site D) with decrease of N supplied (from 15 g/plant to 1.95 g/plant). At the harvest stage, the highest (2.93%) and lowest (1.92%) N concentration in new rhizomes were obtained when plants were grown in site C and site D, respectively, while the highest and lowest N concentration in new storage roots were found in site A and site C, respectively.

Table 3.6 Effects of rate of nitrogen application on nitrogen concentration of *C. alismatifolia* in commercial farms.

		Nitrogen concentration in plant organ (%)								
		Before planting		Flowering stage					Harvesting stage	
Commercial farms	N applied (g/plant)	rhizome	storage roots	rhizome	storage roots	new rhizome	leaves	Inflores-cence	new rhizome	new storage roots
Site A	15.00	4.09b	0.88b	2.66a	1.07b	2.42b	1.95a	1.18b	2.37bc	0.93a
Site B	6.90	7.32a	2.18a	2.72a	1.28a	2.73a	1.86b	1.15b	2.75ab	0.85b
Site C	4.10	6.30a	1.13b	2.73a	0.69c	2.64a	1.86b	1.35a	2.93a	0.76c
Site D	1.95	3.43b	0.83b	1.68b	0.55d	1.36c	1.43c	0.93c	1.92c	0.84b
Significance		*	*	*	*	*	*	*	*	*

Means within columns followed by different letters are significantly different ($p < 0.05$), NS = not significant.

3.4 Discussion

The results of our study indicate that the better plant growth, in terms of plant height and number of new shoots per cluster, was observed in site B (6.9 g N/plant supplied) than the other sites and the same results were also found in flower quality in terms of stalk lengths (44.2 cm) that may be due to site B had a higher decreasing percentage of mature rhizome-N from planting stage to flowering stage (63%) than other sites (site A 35%, site C 57% and site D 51%). These observations suggested that there was a better transfer of N assimilates from roots to aboveground tissues in plant grown at site B than other sites. According to Tapun and Ruamrungsri (2006), N concentrations in both mother rhizome and storage roots changed during plant growth and development. Between planting to shoot growth and two fully-expanded leaves, the N concentration in mother rhizome increased due to the remobilization from storage roots and some N was transported to shoot.

The result of plant growth indicated that N application method by site A might be over-fertilizer rate since it reduced plant height, number of leaves per plant and number of new shoots per cluster. Moreover, the mineral element concentration in soil was also higher than the other sites. At flowering, the N in mother rhizomes and storage roots decreased whereas the most of N were accumulated in leaves and some inflorescence (Tapun and Ruamrungsri 2006). Mills and Jones (1996) found that in the early stages of growth, concentrations would be high throughout the plant. As plants mature, the concentrations of nitrogen in these organs fell, and were usually independent of the initial external supply of nitrogen. If the development of a plant was restricted by low levels of external factors, such as other nutrients, water or temperature, internal concentration of nitrogen might rise.

In general, the concentration of nitrogen in a plant will be expected to rise, along with growth and yields, with increases in nitrogen supply (Hanway *el at*., 1963). Similarly in our results, the increases of nitrogen supply at site A (15 g N/plant) gave the highest nitrogen concentration in rhizome and leaves at flowering stage and in storage roots at harvesting stage. However, the yields of site A, i.e., underground dry weight, rhizome fresh weight, rhizome diameter and storage roots diameter were lower than those of site B and C (6.9 and 4.1 g N/plant respectively) (Table 3.4, Fig. 3.5), this indicated that the rate of N supply at 15 g N/plant was too high for site A where the nutrient in soil was high (Table 3.3). In addition, the lowest yield was observed in site D with the lowest N supplied rate (1.95 g N/plant) that may be due to a deficiency of nitrogen in plant; this was supported by the lower concentration of nitrogen in almost plant parts when compared with the other sites at the same stage (Table 3.6). Deficiency of nitrogen or another nutrient was associated with suboptimum development of a plant, as reflected by the appearance of symptoms of deficiency, the suppression of yields or to the response of plants after the accumulation of the deficient nutrient following its application as a fertilizer. Ruamrungsri *et al*., (2006) also found that nitrogen deficiency in curcuma resulted in stunt growth, the decrease of leaf area, leaf yellowing and low flower quality.

The greatest nitrogen concentration in new rhizome at harvesting stage was found in plant grown at site B and site C (Table 3.6), suggesting that nitrogen supply at 4.1 – 6.9 g N/plant was enough to be utilized for plant growth and final yields. In addition, there was found that initial nitrogen of rhizome before planting in site B and C also higher than other sites (Table 3.6).

In the present study, at site C which gave the highest yield, there was the greatest decreasing in soil pH value (Table 3.5), maximum yields being associated with end of season pH as 4.55. In general, an excess of cation over anion leads to a decrease in pH, suggesting that supplied N in site C caused a release of more hydrogen ions in root zone than other sites which led to the increased acidity (lowering the pH). Although there was a little research conducted on the effects of soil pH on *Curcuma* production, but Whiley (1974) suggested pH 6.5 as an optimum value for ginger production. These results suggest that *Curcuma* may be more tolerant to low pH than has previously been supposed in ginger. Lee and Asher (1981) also showed that in ginger, there was a tendency in nitrogen treatments which gave the largest yield increases to cause the greatest depression in soil pH during the growing season.

Nitrogen supply at the planting stage was made at site A only and the rhizome yield was still lower when compared with site B and site C. This result indicated that it was unnecessary to supply N at the planting stage of *Curcuma*, suggesting that the N source from mature rhizome and in soil might be sufficient for growth and development of *Curcuma* plant at early stage. Khuankaew (2010) reported that during early stages of plant growth, the original nitrogen in old rhizome and old storage roots was transported to aboveground parts which the nitrogen absorbed in this stage was recovered in new organs.

Nitrogen management in site D gave the lowest rhizome yields. This result may be because there was only one time N application in pre-flowering stage (Table 3.1), suggesting that in this experiment, the nitrogen use efficiency of *Curcuma* could be improved greatly by the use of split applications in appropriate amount, and the results from site B and C of the present study fully confirm this suggestion (Table 3.1 and 3.4). The results of Lee *et al*. (1981a) suggested that with 10 applications of nitrogen, the size of which was varied according to seasonal demand, maximum yields of ginger could be obtained. In the present study, according to system of split applications, rhizome yields still appeared to be increasing up to 3- 4 split applications (in site B and C). Moreover, original N in rhizome before planting might played and importance role in *Curcuma* growth and yield since higher N in original rhizome of site B and C could lead to the greater final yield than the other sites.

3.5 Conclusion

Fertilizer management in commercial *Curcuma* farm varied widely from one individual to another. The highest and lowest nitrogen supply at 15 and 1.95 g N/plant was not suitable for *Curcuma* production since the rhizome yield was decreased in plant grown in site A and site D. The nitrogen rate of 4.1 – 6.9 g N/plant was required for maximum rhizome yields as shown in site B and site C. Nitrogen supply was related to nitrogen concentration in plant parts at different growth stages. Soil analysis data should be used for fertilizer application management. Further research is needed to establish nitrogen critical level and to assess nitrogen status in plant that will lead to evaluation of nitrogen requirement in *Curcuma*.