CHAPTER 5

On-field improvement of nitrogen fertilizer application in *Curcuma alismatifolia.*

5.1 Introduction

Nitrogen (N) fertilizer recommendations made without adequate knowledge of the N supply capability can lead to inefficient use of N. A major drawback of fertilizer application in agriculture is that only 30-50% of the applied N fertilizer is taken up by the crop plants (Smil, 1999; Cassman *et al*., 2002) while a significant amount of the applied N is lost from the agricultural fields. In the last decade, a wealth of studies has therefore addressed the consequences of intensive N supply, ranging from field studies (Chu *et al*., 2007) to laboratory experiments (Well *et al*., 2006).

Improving of N fertilizer application is important for the *Curcuma* crop, since growth, flower quality and rhizome yields respond to the amount of N applied and a deficiency of N can substantially reduce yields (Ohtake *et al*., 2006). As we explained in **Chapter 3**, there was a little information available concerning optimum rates and times of application or the most suitable forms of nitrogen fertilizer for *C. alismatifolia* production. However, in previous studies (**Chapter 4**), the amounts of nitrogen fertilizer 7.5 g N/plant was used to obtain high rhizome yields (more than

7,500 kg/ha). Nevertheless, the study did not include a direct comparison with methods of nitrogen application in commercial farm.

Therefore, the main objective in this experiment was to test the N rate applications by using the results following our research-based recommendations from **Chapter 4** compared with N rate in commercial-field from **Chapter 3** to obtain suitable on-farm nitrogen fertilizer rate in commercial field of *Curcuma* production.

5.2 Materials and methods

The field experiment was carried out on commercial *Curcuma* farm (selected from poor management farm in Chapter 3) at Chiang Mai province area in northern Thailand (Fig. 5.1).

Figure 5.1 Commercial *Curcuma* field in Chiang Mai area, northern Thailand.

Table 5.1 Chemical analysis of soil before planting from commercial *Curcuma* farms on Chiang Mai area, northern Thailand.

Element	Value obtained	Interpretation
Total Nitrogen (%)	0.05	Low
Available Phosphorus (mg/kg)	67.3	Low
Exchangeable Potassium (mg/kg)	33.6	Low
Exchangeable Calcium (mg/kg)	324.6	Low
Exchangeable Magnesium (mg/kg)	98.4	Low
pH (1: 2 soil: water)	6.6	pH 6.5 recommended [a]

[a] Whiley (1974)

The experiment was located within a block of commercial *Curcuma* farms. Chemical characteristics of the soil before planting were shown in Table 5.1. N fertilizer management on this experiment was separated by two treatments; N1 and N2 as shown in Table 5.2. Nitrogen application in N1 treatment was managed by the cooperating farmer as a part of his crop (1.95 g N/plant) while N2 treatment was managed by the using the results in Chapter 4 (7.5 g N/plant). Other essential elements were supplied equally for plants in each treatment group as = 15 g P_2O_5, 20 g K_2O, 0.25 g $MgSO_4$ and 0.54 g $CaSO_4$ per plant.

Table 5.2 Nitrogen fertilizer management in this experiment.

Growth stages (days after planting [DAP])	Nitrogen application (g N/plant)	
	N1	**N2**
Before planting (0 DAP)	0	1.20
1st fully-expanded leaf (45 DAP)	0	1.20
2nd fully-expanded leaf (60 DAP)	0	0
3rd fully-expanded leaf (75 DAP)	0	1.20
Pre-flowering stage (90 DAP)	1.95	0.98
Flowering stage (105 DAP)	0	0.98
Pre- resting stage (135 DAP)	0	0.98
Resting stage (165 DAP)	0	0.98
Harvesting stage (180 - 195 DAP)	0	0
Total N applied (g N/ plant/ crop)	**1.95**	**7.52**

Rhizomes of *C. alismatifolia* ‘Chiang Mai Pink’ with a diameter of about 1.8 - 2.0 cm were planted by hand to ensure uniform spacing, the planting depth being about 10 cm and the distance between plants along the row being 30 cm. The planting rate represented a density of approximately 62,500 plants/ha. Crop water requirements were completely satisfied by natural rainfall.

Rainfall for the growing season (May - December) was 1126 mm, being distributed as follows (mm): May 46, June 123, July 114, August 471, September 196, October 170, November 0, and December 6. Macroclimate referred to meteorological data in 2010 automatically was recorded through regular seasons

(Appendix 3). *C. alismatifolia* would flower during July and August and would become dormant in November to December in the cool dry season. Rhizomes would be harvested in December and sold for export in January.

At flowering stage (105 days after planting), growth in terms of plant height, number of leaves per plant and numbers of new shoots per cluster were recorded. Fresh and dry weights of underground and aboveground parts were measured at sampling time using 20-plant samples from each treatment. Chlorophyll content (SPAD value) was measured using a SPAD meter (SPAD-502, Minolta, Japan) and leaf area was measured using a leaf area meter (LI-3100, LI-COR, Lincoln, NE). 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 qualities at harvesting stage were measured.

Data were analyzed for statistical significance using Statistic 8 analytical software (SXW Tallahassee, FL, USA). The Student's *t*-test was used to determine significant differences between the means in growth, yields and nitrogen concentration in plant tissues parameters.

5.3 Results

Plant growth, in terms of plant height, number of leaves per shoot, number of shoots per cluster, SPAD value and leaf area at flowering stage were shown in Table 5.3. The results showed that there was a higher number of shoots per cluster and SPAD value in N2 treatment than N1 treatment. However, plant height, number of leaves per shoot and leaf area were not significantly different by treatments (Table 5.3).

Table 5.3 Plant height, number of leaves per shoot, number of shoots per cluster, SPAD value, and total leaf area of *Curcuma* plants grown with different nitrogen application treatments at the flowering stage (105 days after planting).

Treatment	Plant height (cm)	No. of Leaves	NO. of shoots per cluster	SPAD value	Leaf area (cm^2)
N1	29.9 ± 0.6	3.55 ± 0.1	2.8 ± 0.1	45.2 ± 1.9	183.3 ± 7.4
N2	30.8 ± 0.6	3.7 ± 0.1	4.2 ± 0.2	51.4 ± 3.0	250.6 ± 11.3
t-test at $p < 0.05$	ns	ns	*	*	ns

Data were means ± SE (*n=20*). *; significant, ns = not significant.

Flower quality in terms of flower spike length, flower stalk length, and a number of green and pink bracts were not significantly different by treatments (Table 5.4).

Table 5.4 Flower quality of *Curcuma* plants grown with different nitrogen application treatments at the flowering stage (105 days after planting).

Treatment	Spike length (cm)	Flower stalk length (cm)	No. of green bracts	No. of pink bracts
N1	39.0 ± 0.6	14.4 ± 0.4	9.8 ± 0.1	16.3 ± 0.3
N2	41.0 ± 0.5	15.5 ± 0.2	9.5 ± 0.1	16.7 ± 0.2
t-test at $p < 0.05$	ns	ns	ns	ns

Data were means ± SE (*n=20*). *; significant, ns = not significant.

At flowering stage, there were higher fresh weight for underground parts, aboveground parts and total plant in plant supplied with N2 treatment than N1 treatment. Similarly in dry weight, there were higher underground parts dry weights in plant supplied with N2 than N1 treatment. However, aboveground parts and total plant dry weight were not affected by N treatment (Table 5.5).

Table 5.5 Fresh weight and dry weight of *Curcuma* plants grown with different nitrogen application treatments at the flowering stage (105 day after planting).

	Fresh weight (g)			Dry weight (g)		
Treatment	Under Ground parts	Above ground parts	Total plant	Under ground parts	Above ground parts	Total plant
N1	11.4 ± 0.3	63.5 ± 5.0	74.8 ± 5.1	1.6 ± 0.1	9.1± 0.8	10.6 ± 0.9
N2	20.4 ± 0.5	100.5±3.9	120.9±4.1	2.6 ± 0.1	12.3 ± 0.7	14.9 ± 0.8
t-test at $p< 0.05$	*	*	*	*	ns	ns

Data were means ± SE ($n=20$). *; significant, ns = not significant.

Table 5.6 Rhizome quality of *Curcuma* plants grown with different nitrogen application treatments at the harvest stage (180 days after planting).

Yields	Treatment N1 (1.95 g N/plant)	Treatment N2 (7.5 g N/plant)	*t*-test[1/]
New rhizomes			
total numbers	4.1 + 0.3	6.5 + 0.5	*
diameter (cm)	1.7 + 0.1	1.7 + 0.1	ns
New storage roots			
total numbers	5.3 + 0.3	5.8 + 0.5	ns
diameter (cm)	1.7 + 0.1	2.0 + 0.1	ns
length (cm)	7.1 + 0.2	7.0 + 0.2	ns
Total rhizome yields			
fresh weight (g)	152.5 + 7.8	240.4 + 23.0	*
dry weight (g)	31.9 + 1.3	49.5 + 4.5	*

[1/] Significant by Student's *t*-test at $p < 0.05$. Data were means ± SE (*n=10)*

At harvest stage, yields in terms of number of new rhizomes (Fig. 5.2), rhizome fresh weight and dry weight were greatest when plants were supplied with N2 treatment (Table 5.6). New rhizomes diameter and new storage roots quality were not affected by N treatment.

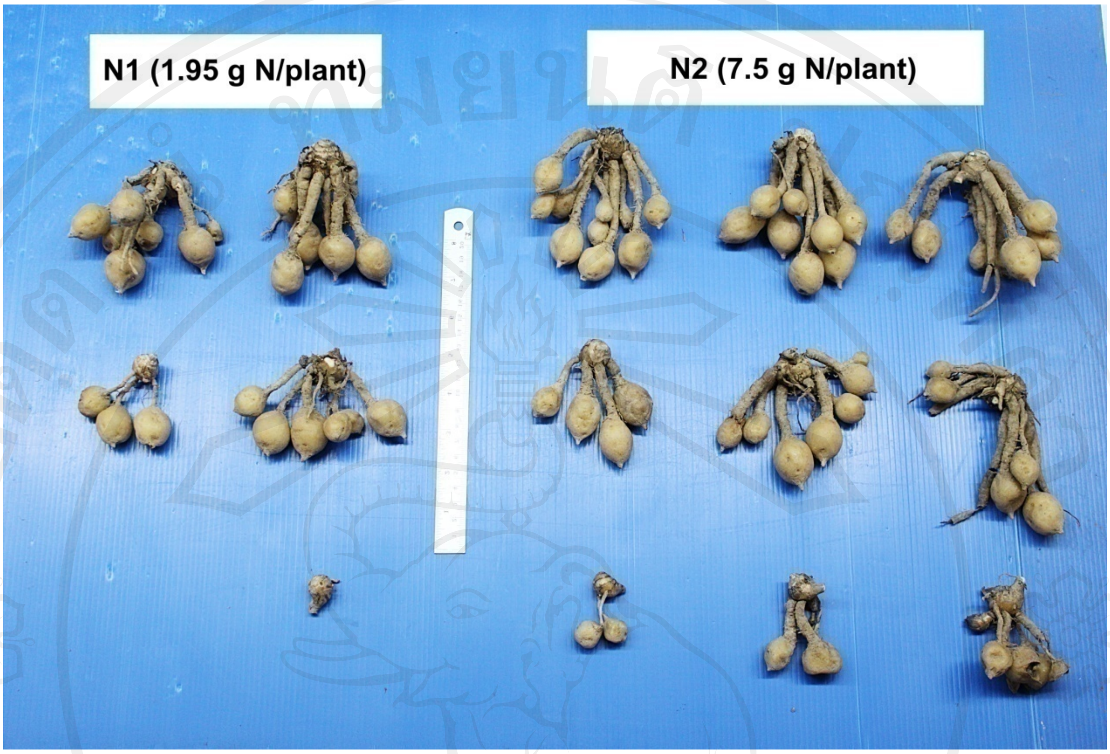

Figure 5.2 Number of new rhizome of *Curcuma* plant grown with different nitrogen application treatments at the harvest stage (180 days after planting).

Nitrogen concentrations in plant tissue were shown in Table 5.7. Before planting, there were no significant differences in N concentration in mature rhizome and storage roots between N treatments. At the flowering stage, the higher concentration of N in underground parts, 1st leaf from bottom, and 2nd leaf from bottom were found in N2 treatment compared with N1 treatment, while there were no significant differences in aboveground part and 3rd leaf from bottom. At the harvest stage, plants supplied with N2 treatment give the higher N concentration in total rhizome than N1 treatment (Table 5.7).

Table 5.7 Nitrogen concentration (%) in *Curcuma* plant parts grown in different nitrogen application treatments at each growth stage.

Growing stage / Plant parts	Treatment N1 (1.95 g N/plant)	Treatment N2 (7.5 g N/plant)	*t-test*[1/]
Planting stage			
mature rhizome	3.28 ± 0.09	3.25 ± 0.11	ns
storages roots	0.98 ± 0.04	1.04 ± 0.05	ns
Flowering stage			
underground parts	1.26 ± 0.05	1.48 ± 0.09	*
aboveground part	1.06 ± 0.03	1.11 ± 0.03	ns
1st leaf from bottom	1.01 ± 0.05	1.23 ± 0.12	*
2nd leaf from bottom	1.04 ± 0.01	1.26 ± 0.02	*
3rd leaf from bottom	1.18 ± 0.02	1.31± 0.02	ns
Harvest stage			
total rhizome	1.91 ± 0.04	2.54 ± 0.07	*

[1/] Significant by Student's *t*-test at $p < 0.05$. Data were means ± SE (*n=20)*

5.4 Discussion

Efficient application of nitrogen is important for achieving quality and yield goals in *C. alismatifolia*. In our experiment, insufficient N results in **Chapter 3** reduced rhizome quality and yield. However, excessive N led to yield reduction and increased input costs in *Curcuma* plant as our results in **Chapter 4**. Therefore, in this chapter, we tested appropriate N rates obtained from **Chapter 4** compared with insufficient N applied by farmer's method in commercial farm. The results of our study indicated that when compared with farmer method (N1), plant supplied with N rate following our research based recommendations (N2) gave the higher results in terms of number of shoots per cluster, SPAD value (Table 5.3), fresh weight and dry weight of underground parts (Table 5.4), number of new rhizomes and fresh and dry weight of total yields (Table 5.6). This may be due to an insufficient supply of nitrogen in plant grown with N1 treatment which was supported by the lower concentration of nitrogen in underground parts, the 1st and the 2nd leaf from the bottom, and total rhizome parts when plants were grown with the N1 treatment (Table 5.7). Ohtake *et al*. (2006) reported that lack of N supply decreased total N concentration, total amino acids and protein concentrations in both rhizome and storage root. In addition, growth in terms of the number of new shoot and leaves per plants were decreased when *Curcuma* plants were cultured in N-free solution compared with culture in complete solution (Ruamrungsri *et al*., 2006).

However, our results showed that there were no significant differences in flower quality. This may be mainly due to there were no significant differences in leaf area, number of leaves in the 1st-order shoot, aboveground parts dry weight at flowering stage. These results may indicate that different N treatments in this experiment did not affect the aboveground part qualities at flowering stage. Thus, the above mentioned results might possibly be explained by the nitrogen concentration in plant tissue since there were equal nitrogen concentrations in mature rhizome and storage roots at planting stage and also in aboveground parts at flowering stage (Table 5.7). N utilization in *Cucmama* roots was complicated since their roots were divided into two parts, rhizome and storage roots, with both parts play an important role on preserving food and essential minerals including nitrogen for their growth and development. In our results, it seemed to be that the growth of *Cucuma* from the planting stage to flowering stage were served by original nitrogen in mature rhizome and storage roots, and after flowering stage, most of growth would respond to external nitrogen supply. Similar results were reported by Ruamrungsri *et al*. (2006) who showed that continuous supply of N fertilizer from flowering to pre-harvest is very important in promoting growth and development of *Curcuma* plant.

The underground dry weight at the flowering stage (105 DAP) was significantly higher in plant supplied with N2 treatments (7.5 g N/plant) (Table 5.5). This may be explained by the relationship of the yield and the concentration of N in the 1st fully-expanded leaf since there was higher N concentration in the 1st leaf of N2 (1.23%) than N1 (1.01%) treatment (Table 5.7). In addition, leaf N concentration obtained in N2 (1.23%) treatment on this stage was lower than the N critical level in **Chapter 4** (1.51%), suggesting that it may be mainly due to environmental effects since at the same N supply rate (7.5 g N/plant) and the same growth stage (105 DAP), in **Chapter 4** gave the higher results in underground dry weight (4.6 g, Table 4.9) than in this experiment (2.6 g, Table 5.5). Westerveld *et al.* (2003) reported that several environmental factors could affect the results of plant analysis such as soil type, soil moisture content, fertilizer source and climate. Thus, the usage of N critical value will have to be concerned on many factors such as growth stage, plant part, differences between crops and species, environmental variability and nutrient interactions for evaluation of N status which would lead to estimate N fertilizer requirements by a precise matching of supply to demand.

At the harvest stage, yield of fresh *Curcuma* rhizomes was significantly higher when plants were applied with total nitrogen at 470 kg/ha (N2) than 120 kg N/ha (N1) (Fig. 5.3), and this amounts were in the range of 340 –830 kg/ha which Lee (1975) recommended to ginger industry for highest commercial yields of fresh rhizomes. Thus, in our experiment, we concluded that N supply at 7.5 g N/plant or 470 kg N/ha (N2 treatment) could be suitable for rhizome production in *Curcuma* plants.

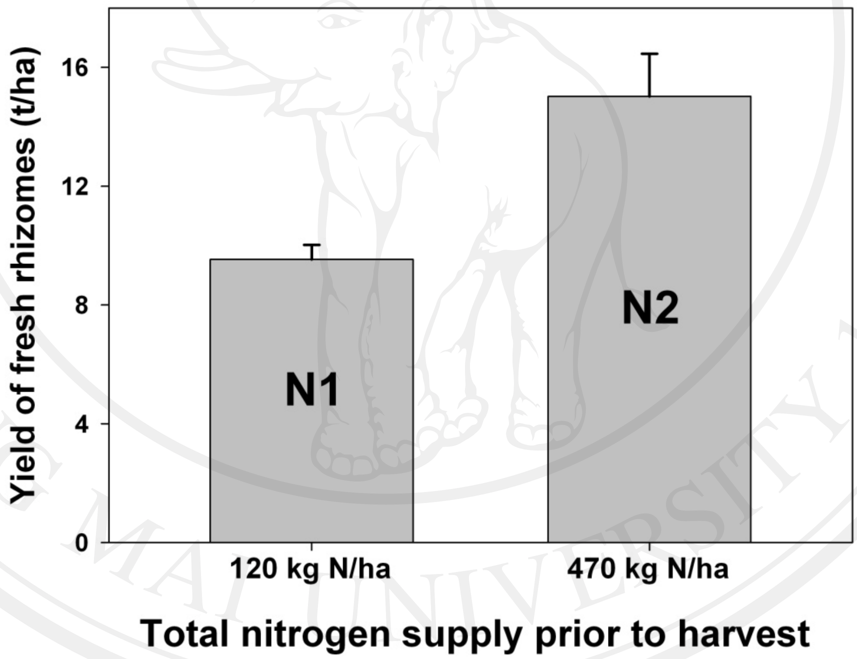

Figure 5.3 Effects of nitrogen supply on the yield of fresh rhizomes of *Curcuma* plant at harvest stage (180 DAP).

5.5 Conclusion

Optimal nitrogen fertilization is essential for achieving commercial rhizome production and results in maximum economic return. In this experiment, we evaluated the performance of yield and growth of *Curcuma* plant based on recommended N rate from **Chapter 4**, compared with N rate of farmer in commercial filed. It is concluded that insufficient nitrogen application of farmer's method (N1= 1.95 g N/plant) reduced both plant growth and rhizome yield while optimizing crop nitrogen management was found in N2 treatment (7.5 g N/plant) since higher rhizome yields were obtained. Therefore, this experiment confirmed that the N rate recommendation could improve rhizome yield of *Curcuma* in commercial-field production. Further study may try to test this fertilizer nitrogen rate by varying from field-to-field and from year-to-year to find out the variation in both crop nitrogen demand and nitrogen supply. The relationship between yield and N fertilizer need may be more appropriate for long-term, large-scale analyses for making fertilizer N recommendations for specific fields.