Chapter 3

Effects of Planting Dates and Night Break Treatments on Growth, Dry Matter and Rhizome Quality of *Curcuma alismatifolia* Gagnep.

3.1 Introduction

Since, night break is a tool for photoperiod control in a greenhouse mentioned in chapter 2. It was one of the most important factors involved in producing high flower yield, particularly when plant was grown off season. A day length extension (night break) with incandescent light was more effective in promoting flowering of long-day plants like *Hyoscyanuss niger*. Especially, the initiation phase of flowering required far-red phytochrome (Pfr) to be present, whereas the development phase proceeded more rapidly in the absence of Pfr (Downs and Thomas, 1982).

In *Curcuma alismatifolia,* some reports revealed that night break could improve quality of inflorescence for off season production (Changjeraja, 2009; Ruamrungsri *et al*., 2005; Wannakrairoj, 1996). However, there was not any report concerned with the effect of night break in regular season production. Therefore, this experiment was conducted to clarify the effect of night break under different planting dates (regular season and off season production), especially the influences on dry matter accumulation related to growth and quality of inflorescence and rhizome.

3.2 Materials and methods

3.2.1 Plant materials

Rhizomes of *Curcuma alismatifolia* cv. "Chiang Mai Pink" with the diameter of 1.5 - 2.0 cm, comprised of 4.0 storage roots were soaked in water for 3 days and replaced water daily in order to stimulate sprouting. Plants were grown in black plastic pots containing sand: rice husk: rice hull: soil in the ratio of 1:1:1:1 (by volume). After new shoots and roots emerged to about 1 inch, plants were transferred for application of treatments. There were 2 factors in this experiment. The first factor was three planting dates, i. e. 1) May 15, 2006, 2) December 15, 2006 and 3) May 15, 2007. The second factor was the night break treatment which was achieved by giving supplemental lighting during 08.00 - 10.00 pm for 2 hours using 100 watts incandescent lamp as a light source. Plants were supplied with chemical fertilizers 15:15:15 ($N:P_2O_5:K_2O$) at 7 g plant^{-1} until flowering then added with 13 : 13 : 21 ($N:P_2O_5:K_2O$) at 7 g plant^{-1} until senescence for twice a month.

3.2.2 Data collection

Plant height, number of leaves per plant, number of shoots per clump, leaf area, dry weight of leaves, rhizomes, storage roots and fibrous roots were determined. Leaf color was measured using chlorophyll meter (Spad-502; Minolta CO., LTD) at the different growth stages; L1: the first leaf fully expanded at 6-7 weeks after planting (WAP), L2: the second leaf fully expanded at 7-8 WAP, L3: the third leaf fully expanded at 8-9 WAP and L4: the forth leaf fully expanded at 9-10 WAP (Figure 3.1). The number of new rhizomes per clump, diameter of new rhizome, fresh and dry weight of new rhizome, number of storage roots per rhizome, the size of storage roots (length and diameter) and weight of storage roots were collected at harvested (Figure 3.2).

The experimental design used was a factorial in Completely Randomized Design (CRD) with four replications per treatment. Means of each pair of data combinations within the same stage were analyzed by using a statistical analysis program the Statistic 8 (SXW Tallahassee, FL, USA). The least significant difference (LSD) was used to interpret significant difference among the means (<0.05).

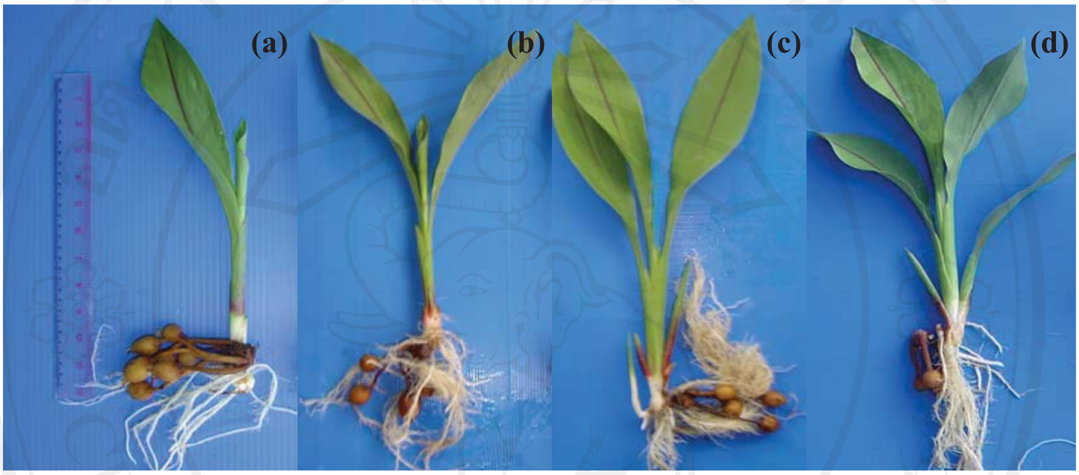

Figure 3.1 Plants measurement at four growth stages; (a) the 1^{st} fully expanded leaf (L1), (b) the 2^{nd} fully expanded leaf (L2), (c) the 3 rd fully expanded leaf (L3) and (d) the 4^{th} fully expanded leaf (L4).

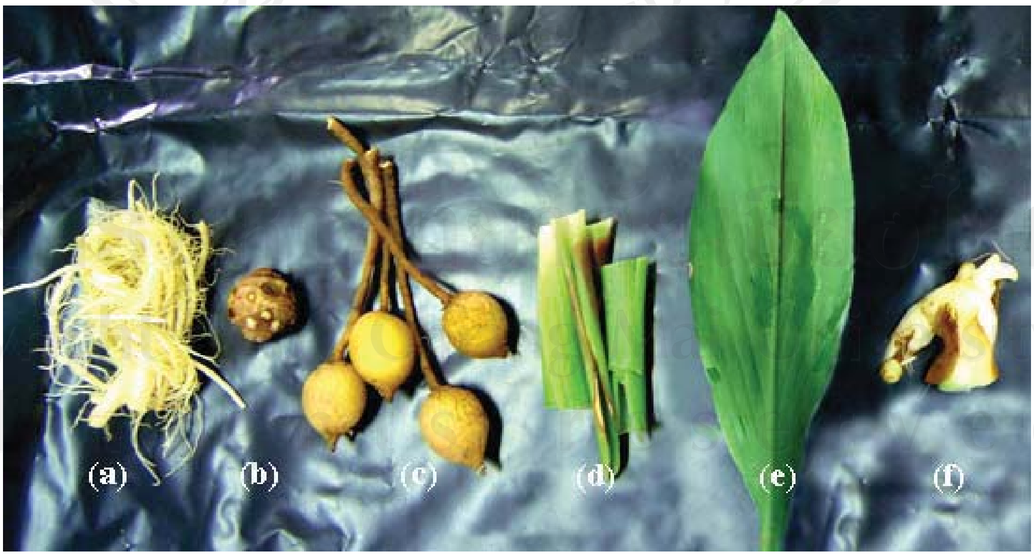

Figure 3.2 Plants measurement at four growth stages in different organs; (a) roots, (b) old rhizome, (c) old storage roots, (d and e) leaves and (f) new rhizome.

3.3 Results

3.3.1 Plant growth and development

Main effects

Plant height of *C. alismatifolia* Gagnep. increased rapidly from 6 to 12 WAP when it was grown in May, 15, while it increased gradually when plant was grown in Nov, 15 and Dec, 15 (Figure 3.3a). The height of plants cultivated in May, 15 was significantly taller than that on Nov, 15 and Dec, 15 at 14 WAP (Table 3.1). Growing at during t the winter-time, especially Nov, 15 and Dec, 15; decreased plant height by 34.07 cm and 33.80 cm, respectively. Meanwhile, height of plant grown in May, 15 was the greatest of 58.86 cm. The number of leaves per plant rapidly increased from 6 to 12 WAP and remained static thereafter (Fig. 3.3b). Factorial treatments did not significantly affect the number of leaves per plant (Table 3.1). However, the number of shoots per clump of plant grown in November and December were significantly less than those grown in May. The average number of shoots per clump of plant grown in November and December were the same at 1.46, which were 30.74 % less than those grown in May (Fig. 3.3c and Table 3.1).

According to the night break effect, the treatment influenced on the height of *Curcuma alismatifolia*. Plants that received night break treatment were significantly taller than planting under control condition (no night break), which were 45.39 cm and 39.10 cm, respectively (Table 3.1). Meanwhile, number of shoots per clump between night break and no night break was not statistically different (1.69 and 1.47, respectively).

Interaction among factors

The interaction between two factors was determined at 14 WAP. There was no interaction between planting dates and night beak treatments on plant height, number of leaves per plant and number of shoots per clump (Appendix 1). These indicated that the planting dates were the major factor affecting the number of shoots per clump rather than night break treatments.

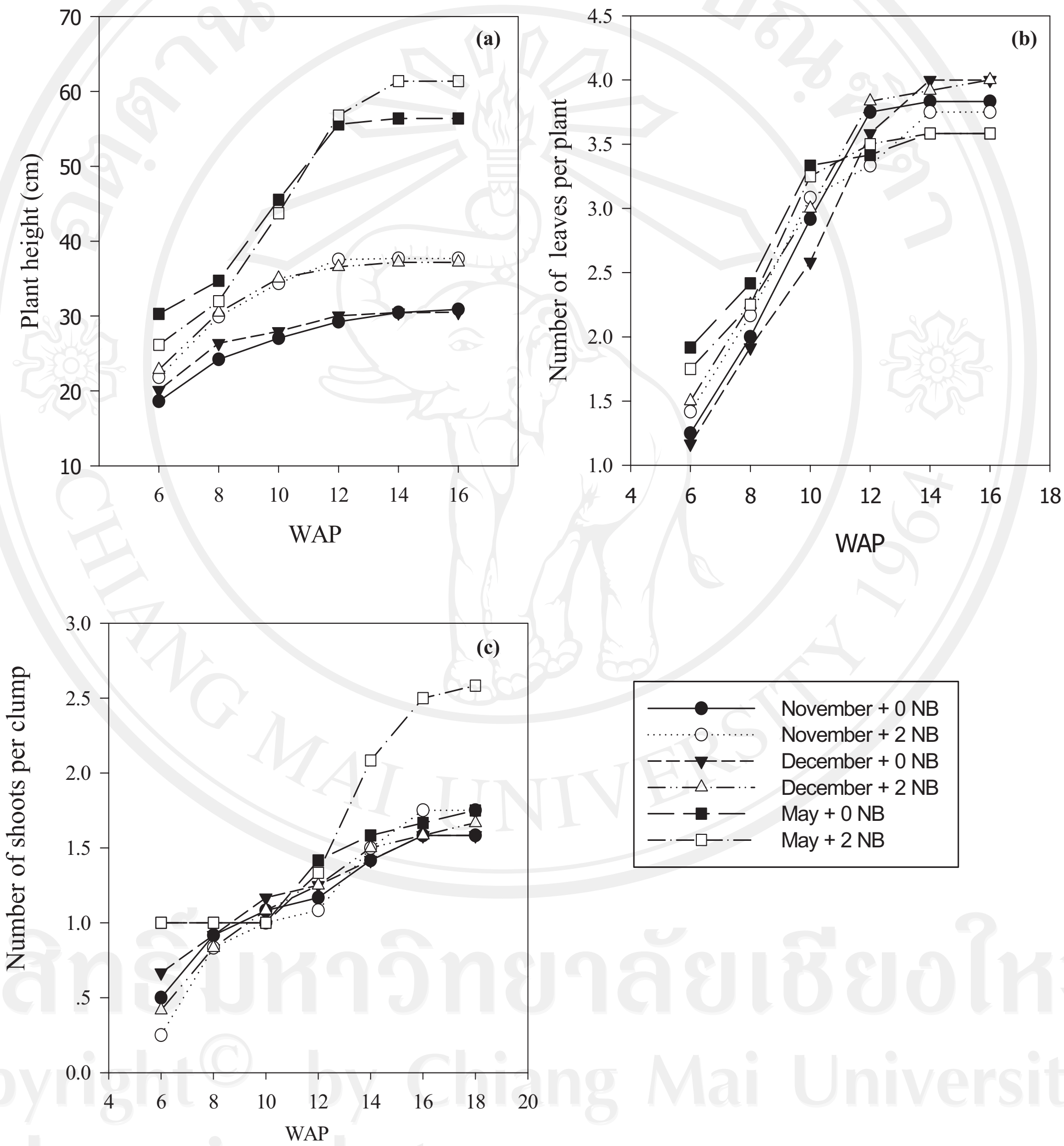

Figure 3.3 Growth of *Curcuma alismatifolia* Gagnep.; plant height (a), number of leaves per plant (b) and number of shoots per clump (c) of different treatments.

Table 3.1 Effects of planting dates and night break treatments on growth of *Curcuma alismatifolia* at flowering stage (14 WAP).

Factors		Plant height (cm)	Number of leaves per plant	Number of shoots per clump
Planting date	Nov, 15	34.07b	3.79	1.46b
	Dec, 15	33.80b	3.96	1.46b
	May, 15	58.86a	3.58	1.83a
Night break	0 hour	39.10b	3.80	1.47
	2 hours	45.39a	3.75	1.69
Planting date		*	ns	*
Night break		*	ns	ns
Planting date x Night break		ns	ns	ns
CV%		9.01	7.99	17.71

Means within the factor in the same columns followed by different characters showed significantly different between treatments by LSD test at $P<0.05$.

ns : not significantly different.

3.3.2 Leaf area

Main effects

The result revealed that different planting dates significantly affected on leaf area of *C. alismatifolia*, especially at the L2 growth stage. Cultivating on May gained more leaf area of the plants than those grown on November and December, which were 122.80, 93.17 and 95.29 cm^2, respectively, only at L2 (Table 3.2). However, planting dates imposed no effect on leaf area in the L1, L3 and L4 growth stages. Meanwhile, night break treatments had no effect on leaf area at L1, L2 and L3 growth stages. However, it was noted that plants grown under night break treatment had more leaves area than those under control at L4 growth stage (Table 3.2).

Interaction among factors

It could be implied from interaction effect results that there was no interaction between planting dates and night break treatments on leaves area at any growth stages (Appendix 2).

Table 3.2 Effects of planting dates and night break treatments on leaf area of *Curcuma alismatifolia* at different growth stages.

Factors		Leaf area (cm^2)			
		L1	L2	L3	L4
Planting date	Nov, 15	64.75	93.17b	120.85	116.38
	Dec, 15	62.04	95.29b	123.42	114.44
	May, 15	73.84	122.80a	131.31	123.81
Night break	0 hour	67.36	105.18	121.70	112.21b
	2 hours	66.39	102.32	128.69	124.21a
Planting date		ns	*	ns	ns
Night break		ns	ns	ns	*
Planting date x Night break		ns	ns	ns	ns
CV%		15.38	6.20	12.75	10.89

Means within the factor in the same columns followed by different characters showed significantly different between treatments by LSD test at P <0.05.

ns : not significantly different.

3.3.3 Leaf color

Main effects

Planting dates significantly influenced on leaf color of *C. alismatifolia* at L1 and L4 growth stages, but they did not have any such effect at the L2 and L3 (Table 3.3). The leaves of plants grown in May, 15 showed to be darker than those grown in Nov, 15 and Dec, 15 at L1 stage. At the L4, leaf color of plant grown in

May, 15 and Nov, 15 was darker than that of Dec, 15. The leaf greenness values, determined by the chlorophyll meter, of all planting dates through L1-L4 growth stages were in the range of 45-58 (Table 3.3).

The night break treatments significantly affected on the greenness of leaves at L4 growth stage. Leaves under night break condition were paler than those of control, and greenness values were 56.08 and 48.88, respectively.

Interaction among factors

There was an interaction effect among factors on leaf color at L1, L2 and L4 growth stages, while there was no statistical difference in leaf color of *C. alismatifolia* at the L3 growth stage (Appendix 3).

Table 3.3 Effects of planting dates and night break treatments on leaf color of *Curcuma alismatifolia* at different growth stages.

Factors		Leaf color (SPAD unit)			
		L1	L2	L3	L4
Planting date	Nov, 15	51.44b	52.45	57.89	57.10a
	Dec, 15	54.6ab	57.82	53.07	45.09b
	May, 15	56.30a	55.51	56.75	55.25a
Night break	0 hour	54.06	55.52	57.80	56.08a
	2 hours	54.23	55.03	54.00	48.88b
Planting date		*	ns	ns	*
Night break		ns	ns	ns	*
Planting date x Night break		*	*	ns	*
CV%		6.78	7.57	8.06	6.34

Means within the factor in the same columns followed by different characters showed significantly different between treatments by LSD test at $P<0.05$.

ns: not significantly different.

3.3.4 Days to fully expanded leaves

Main effects

The different planting dates significantly affected on number of days to fully expanded leaves at L3 and L4. *C. alismatifolia* grown in May spent fewer days to have fully expanded leaves than did in November and December (Table 3.4). Night break treatments had no effect on the number of days required for such process.

Interaction among factors

The result revealed that either the planting dates or night break treatments did not contribute any combination effect on the number of days from planting until fully expanded leaves of *C. alismatifolia* at any of the L1, L2, L3 or L4 growth periods (Appendix 4).

Table 3.4 Effects of planting dates and night break treatments on day of fully expanded leaf of *Curcuma alismatifolia* at different growth stages.

Factors		Fully expanded leaf (Days)			
		L1	L2	L3	L4
Planting date	Nov, 15	40.50	51.87	64.62b	76.31b
	Dec, 15	40.00	50.75	65.00b	77.37b
	May, 15	42.32	51.06	61.00a	69.10a
Night break	0 hour	40.72	51.32	63.72	73.67
	2 hours	41.17	51.53	63.36	74.86
Planting date		ns	ns	*	*
Night break		ns	ns	ns	ns
Planting date x Night break		ns	ns	ns	ns
CV%		5.29	4.54	4.31	4.58

Means within the same columns followed by different characters showed significantly different between treatments by LSD test at $P<0.05$.

ns : not significantly different.

3.3.5 Inflorescence quality

Main effects

Referring to the determination on the effect of planting dates affected on inflorescence quality, it was found that *C. alismatifolia* planted in May, 15 gained significantly more inflorescence stalk length, spike length, number of pink bracts, number of green bracts and number of inflorescences per clump than the plants did in Nov, 15 and Dec, 15 (Table 3.5 and Fig. 3.4).

For effect of night break, inflorescence stalk length, spike length, number of pink bracts and number of inflorescences per clump increased when giving 2 hours of night break treatment, while number of green bracts showed no differences (Table 3.5).

Interaction among factors

It can be concluded from this study that supplemental lighting by night break combined with planting dates during May, 15 either, with or without night break was the most suitable condition for inflorescence quality improvement. Whereas, planting in Nov, 15 without night break gave the worst inflorescence quality (Fig. 3.4 and Appendix 5).

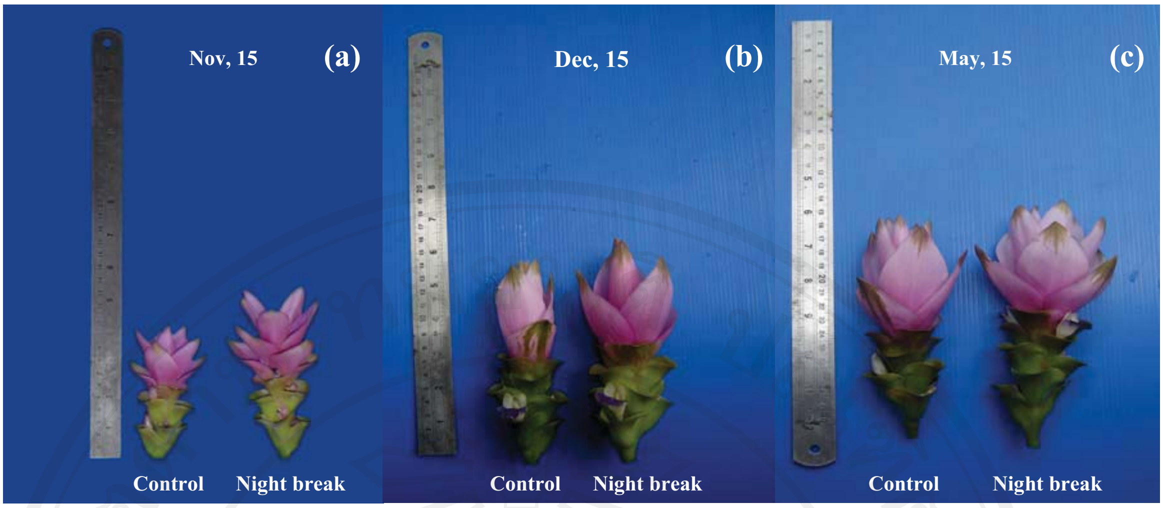

Figure 3.4 Inflorescence quality of *Curcuma alismatifolia* Gagnep. at different planting dates and night break conditions; 15 November 2006 (a), 15 December 2006 (b) and 15 May 2007 (c) from various treatments.

Table 3.5 Effects of planting dates and night break treatments on inflorescence quality attributes of *Curcuma alismatifolia* at flowering stage.

Factors		Spike length (cm)	Stalk length (cm)	Number of green bracts	Number of pink bracts	Number of inflorescences per clump	First floret opening (Days)
Planting date	Nov, 15	11.94b	27.88b	6.96b	9.79b	1.25b	103.29b
	Dec, 15	12.27b	29.89b	6.67b	11.58a	1.17b	102.42b
	May, 15	16.00a	45.40a	8.96a	11.87a	1.83a	91.08a
Night break	0 hour	11.99b	26.60b	7.44	10.33b	1.22b	103.17b
	2 hours	14.81a	42.17a	7.61	11.83a	1.61a	94.69a
Planting date		*	*	*	*	*	*
Night break		*	*	ns	*	*	*
Planting date x Night break		*	*	ns	*	ns	*
CV%		6.87	6.08	8.80	8.15	20.34	5.59

Means within the same columns followed by different characters showed significantly different between treatments by LSD test at $P<0.05$.
ns : not significantly different.

3.3.6 Changes of dry weight

3.3.6.1 Total leaves dry weight

Main effects

The result showed that different planting dates significantly affected on dry weight of leaves at L1 and L2 growth stages. Plants cultivated in May,15 accumulated more leaves dry weight than plants grown in Nov, 15 and Dec, 15 at the L1 and L2 (Table 3.6). For all planting dates through growth period (L1-L4), the total leaves dry weight generally increased with growing times.

Night break treatments did not influence total leaves dry weight at any growing periods from L1 to L4.

Interaction among factors

There was no interaction between 2 main factors, planting dates and night break treatments, on total leaves dry weight of *C. alismatifolia* (Fig. 3.5a and Appendix 6).

Table 3.6 Effects of planting dates and night break treatments on total leaves dry weight of *Curcuma alismatifolia* at different growth stages.

Factors		Dry weight of total leaves (g $plant^{-1}$)			
		L1	L2	L3	L4
Planting date	Nov, 15	1.31b	1.89b	4.14	4.38
	Dec, 15	1.23b	2.06b	3.95	4.46
	May, 15	1.91a	2.63a	4.43	4.83
Night break	0 hour	1.50	2.14	4.17	4.49
	2 hours	1.47	2.24	4.18	4.62
Planting date		*	*	ns	ns
Night break		ns	ns	ns	ns
Planting date x Night break		ns	ns	ns	ns
CV%		12.68	9.85	9.11	8.12

Means within the same columns followed by different characters showed significantly different between treatments by LSD test at $P < 0.05$.
ns : not significantly different.

3.3.6.2 Dry weight of old rhizomes

Main effects

The result suggested that both the planting dates and night break treatments did not statistically affect on dry weight of *C. alismatifolia* old rhizomes at L1-L4 growth stages (Table 3.7).

Interaction among factors

Planting dates and night break treatments showed no interaction on dry weight of *C. alismatifolia* old rhizomes throughout the growth periods (Fig. 3.5 b and Appendix 7).

Table 3.7 Effects of planting dates and night break treatments on old rhizomes dry weight of *Curcuma alismatifolia* at different growth stages.

Factors		Dry weight of old rhizomes (g plant^{-1})			
		L1	L2	L3	L4
Planting date	Nov, 15	2.47	2.37	2.02	1.89
	Dec, 15	2.51	2.40	2.14	1.80
	May, 15	2.46	2.41	2.26	1.85
Night break	0 hour	2.48	2.42	2.18	1.86
	2 hours	2.49	2.38	2.09	1.83
Planting date		ns	ns	ns	ns
Night break		ns	ns	ns	ns
Planting date x Night break		ns	ns	ns	ns
CV%		4.87	7.18	9.90	5.72

ns : not significantly different.

3.3.6.3 Dry weight of new rhizomes

Main effects

The result demonstrated that both the planting dates and night break treatments did not statistically affect on dry weight of *C. alismatifolia* new rhizomes at L1-L4 growth stages (Table 3.8).

Interaction among factors

Planting dates and night break treatments showed no interaction on dry weight of *C. alismatifolia* new rhizomes throughout the growth periods (Fig. 3.5 c and Appendix 8).

Table 3.8 Effects of planting dates and night break treatments on new rhizomes dry weight of *Curcuma alismatifolia* at different growth stages.

Factors		Dry weight of new rhizomes (g plant^{-1})			
		L1	L2	L3	L4
Planting date	Nov, 15	0.37	0.43	0.52	0.66
	Dec, 15	0.34	0.47	0.51	0.57
	May, 15	0.39	0.42	0.47	0.63
Night break	0 hour	0.37	0.44	0.51	0.60
	2 hours	0.36	0.45	0.51	0.64
Planting date		ns	ns	ns	ns
Night break		ns	ns	ns	ns
Planting date x Night break		ns	ns	ns	ns
CV%		22.66	15.09	17.79	20.13

ns : not significantly different.

3.3.6.4 Dry weight of storage roots

Main effects

The result demonstrated that planting dates did not affect on dry weight of old storage roots in L1-L4 growth stages of *C. alismatifolia* (Table 3.9). In general, dry weight of storage roots decreased from L1 to L4 growth stages (Table 3.9).

The storage roots dry weight of plant in the control treatment was significantly lower than that in the night break treatment for 2 hours at the L1 growth stage, where the values were 5.71 and 6.97 g plant^{-1}, respectively.

Interaction among factors

Planting dates and night break treatments interaction did not have any effect on the dry weight of storage roots of *C. alismatifolia* (Fig. 3.5 d and Appendix 9).

Table 3.9 Effects of planting dates and night break treatments on storage roots dry weight of *Curcuma alismatifolia* at different growth stages.

Factors		Dry weight of storage roots (g plant^{-1})			
		L1	L2	L3	L4
Planting date	Nov, 15	6.24	5.57	4.49	3.63
	Dec, 15	6.29	6.11	4.46	3.95
	May, 15	6.49	6.08	4.68	3.54
Night break	0 hour	5.71b	5.63	4.56	3.86
	2 hours	6.97a	6.22	4.52	3.56
Planting date		ns	ns	ns	ns
Night break		*	ns	ns	ns
Planting date x Night break		ns	ns	ns	ns
CV%		11.27	14.24	22.39	13.78

Means within the same columns followed by different characters showed significantly different between treatments by LSD test at $P<0.05$.
ns : not significantly different.

3.3.6.5 Dry weight of fibrous roots

Main Effects

The result showed that there was a significant difference in the dry weight of fibrous roots between treatments at the L2 growth stage (Table 3.10). Plants cultivated at May, 15 produced more fibrous roots dry weight than that grown on Nov, 15 and Dec, 15, in which the dry weights were 0.58, 0.41 and 0.44 g plant^{-1}, respectively.

Night break treatments significantly increased fibrous roots dry weight of *C. alismatifolia* at the L1 growth stage (0.39 g plant^{-1}) as compared with that in the control treatment (0.32 g plant^{-1}).

Interaction among factors

The 2 main factors of planting dates and night break treatments did not interact with dry weight of fibrous roots (Fig. 3.4 e and Appendix 10).

Table 3.10 Effects of planting dates and night break treatments on fibrous roots dry weight of *Curcuma alismatifolia* at different growth stages.

Factors		Dry weight of fibrous roots (g plant^{-1})			
		L1	L2	L3	L4
Planting date	Nov, 15	0.34	0.41b	0.70	2.29
	Dec, 15	0.33	0.44b	0.70	1.79
	May, 15	0.40	0.58a	0.68	1.91
Night break	0 hour	0.32b	0.46	0.74	2.15
	2 hours	0.39a	0.49	0.65	1.97
Planting date		ns	*	ns	ns
Night break		*	ns	ns	ns
Planting date x Night break		ns	ns	ns	ns
CV%		18.73	16.88	21.02	28.12

Means within the same columns followed by different characters showed significantly different between treatments by LSD test at P <0.05.
ns : not significantly different.

3.3.6.6 Total dry weight

Main Effects

The result showed that there was a significant difference in the total dry weight between treatments at the L1 and L2 growth stages (Table 3.11). Plants cultivated at May, 15 produced more total dry weights than that grown on Nov, 15 and Dec, 15, in which the total dry weight were, 12.00, 11.00 and 10.98 g $plant^{-1}$, respectively.

Night break treatments significantly increased total dry weight of *C. alismatifolia* at the L1 growth stage (11.98 g $plant^{-1}$) as compared with that in the control treatment (10.68 g $plant^{-1}$).

Interaction among factors

The 2 main factors of planting dates and night break treatments did not interact with total dry weight (Fig. 3.4 f and Appendix 11).

Table 3.11 Effects of planting dates and night break treatments on total dry weight of *Curcuma alismatifolia* at different growth stages.

Factors		Total dry weight (g $plant^{-1}$)			
		L1	L2	L3	L4
Planting date	Nov, 15	11.00b	11.03b	13.61	14.69
	Dec, 15	10.98b	11.77ab	13.50	14.54
	May, 15	12.00a	12.30a	14.44	14.86
Night break	0 hour	10.68b	11.44	13.92	14.86
	2 hours	11.98a	11.97	13.78	14.54
Planting date		*	*	ns	ns
Night break		*	ns	ns	ns
Planting date x Night break		ns	ns	ns	ns
CV%		5.21	7.88	7.64	6.00

Means within the same columns followed by different characters showed significantly different between treatments by LSD test at $P<0.05$.
ns : not significantly different.

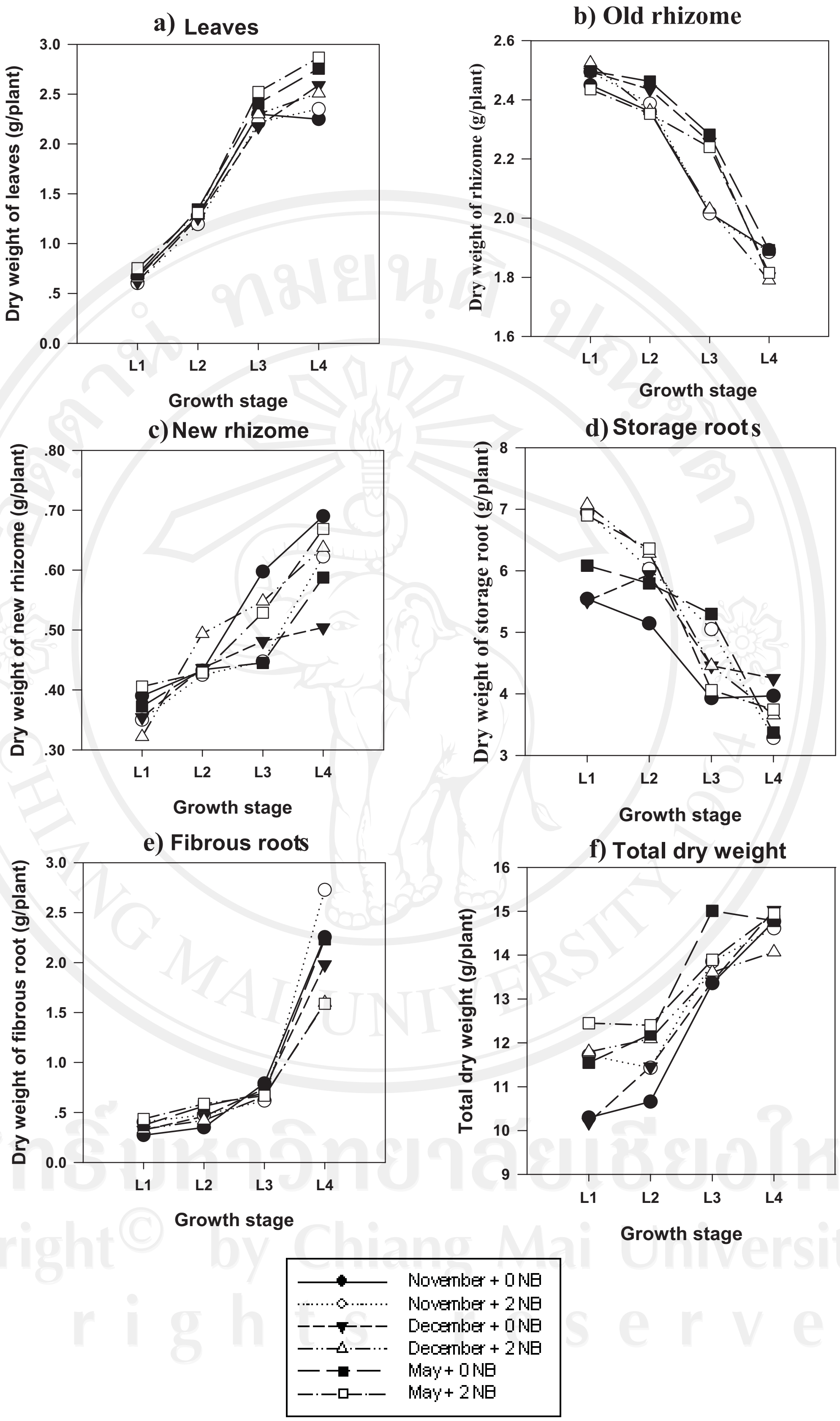

Figure 3.5 Dry weight of *Curcuma alismatifolia* Gagnep. at L1 to L4 growth stages; a) leaves, b) rhizome, c) new rhizome, d) storage roots, e) fibrous roots and f) total dry weight of different treatments.

3.3.6.7 Rhizome quality

Main effects

Planting dates significantly affected on rhizome quality, in terms of the number of new rhizomes and new rhizome diameter, but did not affect on number of new storage roots of *C. alismatifolia* (Fig. 3.6 and Table 3.12). Planting date in May, 15 gave more new rhizomes, where its diameter was larger than that plant grown in Nov, 15 and Dec, 15 (Table 3.12).

Night break treatments had pronounced effect on the number of new storage roots. Supplemental lighting for 2 hours caused the decrease of new storage roots number as compared with that of control (Fig. 3.6 and Table 3.12).

Interaction among factors

The interaction of planting dates and night break treatments was found in the number of new rhizomes, but the opposite results were found on the number of storage roots and size of new rhizome diameter (Appendix 12).

Table 3.12 Effects of planting dates and night break treatments on rhizomes quality attributes of *Curcuma alismatifolia* at dormancy stage.

Factors		Rhizomes quality		
		Number of new rhizomes	Number of new storage roots	Rhizomes diameter (cm)
Planting date	Nov, 15	2.71b	4.10	2.05b
	Dec, 15	2.29b	3.51	2.00b
	May, 15	4.12a	4.93	2.46a
Night break	0 hour	2.97	7.54a	2.24
	2 hours	3.11	0.82b	2.10
Planting date		*	ns	*
Night break		ns	*	ns
Planting date x night break		*	ns	ns
CV%		14.36	27.09	7.67

Means within the same columns followed by different characters showed significantly different between treatments by LSD test at $P<0.05$.
ns : not significantly different.

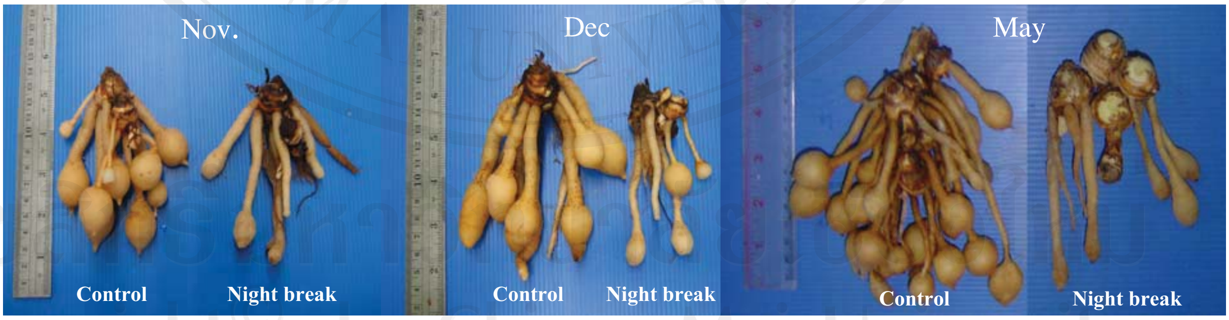

Figure 3.6 Rhizomes quality of *Curcuma alismatifolia* Gagnep. at dormancy stage from different planting dates and night break conditions; 15 November 2006 (a), 15 December 2006 (b) and 15 May 2007 (c) from different treatments.

3.4 Discussion

3.4.1 Growth of plant

The plant growth, in terms of, plant height and number of shoots per clump, leaves area, leaf color and day to fully expanded leaf were significantly affected by planting dates. When plant was grown in May, 15, it produced greater plant height and shoots number than that grown in November, 15 and December, 15. Due to the proper planting dates, plant probably received comparatively favorable environment for promoting vegetative growth. The planting seasons affected many aspects of growth, which was grown in regular season production and in off-seasonal production. In the North of Thailand, the weather in May to September had a high average temperature at approximately 28 ^{o}C, 80 % RH and 13 hours of day length while the weather changed to 22 ^{o}C, 70 % RH and 11 hours of sunshine in winter (October to February) (Chidburee, 2008). The decrease in temperature, % RH and photoperiod in winter might have caused low photosynthesis in the off-season plant, which brought about the reduction in food reserve thus, the off-season planting curcuma (November and December) exhibited a shorter plant. Similar to Thomas and Vince-prue, (1997) reported that the main factors, which regulated these different phenomena, should be changes of climate, such as day length, temperature and % RH. In order to overcome the unfavorable environmental conditions, plants were adapted by various survival strategies. Similarly, corn grown before or after the optimum date resulted in reduced leaf area index, total dry matter production, and grain yield (Swanson and Wilhelm 1996). Ribeiro *et al.* (2009) reported that sweet orange trees grown in different seasons, plant showed to have higher photosynthesis and stomatal aperture in summer season as compared with that in winter season. The seasonal regulation of photosynthesis was the source-sink relation (Iglesias *et al.*, 2002). In addition, planting dates did not statistically affect the number of leaves per plant, but significantly affected leaf area, leaf color and days to fully expanded leaves at some growth stages, where plant grown in May gave better results than that grown in November and December. Similarly, Ruamrungsri *et al*. (2007) reported that growth of *C. alismatifolia* was different when plant grown in different planting dates.

The night interrupts for 2 hours of lighting promoted plant height, leaves area (at L4) and leaf color (at L4). It might be due to photosynthesis period was extended under this condition, brought about the increase of photoassimilates for promoting these growth parameters. The greater effect on plant height could be due to the red: far red (R:FR) ratio, an increase in FR (or low R:FR) in the light environment caused marked increases in extension growth rates of stems or petioles in some species. Rapidly elongating cells needed more carbohydrates, such as reducing sugars, that were readily available for metabolism to meet increased demand for synthesis of structural material, such as cell walls, and to maintain cell turgidity during elongation (Ranwala *et al.,* 2002). Hoddinott (1983) had showed that phytochrome regulated sugar translocation in light quality-regulated growth responses. Another possibility was that the relationship between gibberellins (GA) and light in the control of stem elongation. Talon and Zeevaart (1990) suggested that photoperiod might control petiole and stem elongation by regulating GA metabolism. The photoperiod modulated GA metabolism mainly through the rate of conversion of GA_{53}. As a result of long day induction, GA_1 accumulated at its highest level in shoot tips which, in turn, resulted in stem elongation. In addition, long day also appeared to increase the sensitivity of the tissue to GA, and this effect was presumably responsible for the photoperiodic after effected on stem elongation in *Silene* (Talon and Zeevaart, 1990).

Chidburee *et al.* (2007) illustrated that the height of plant grown in 13 hours day length was greater than that grown in 7 and 10 hours. Similarly, Kuehny *et al.* (2002) also found that in *Curcuma* species; such as *C. alismatifolia*, *C. petiolata*, *C. thorelii*, *C. cordata* and *Kaempferia* sp.; showed the greater development on plant height, leaves and rhizomes numbers when increasing day length from 8 and 12 hours to 16 and 20 hours. Hamamoto *et al.* (2007) reported that night break treatments promoted the height, weight, and leaf area growth of spinach cultivars.

The interaction of planting dates and night break treatments was not different in vegetative growth, i.e. height, number of leaves per plant, number of shoots per clump, leaf area and days of fully expanded leaves of *C. alismatifolia* Gagnep. However, leaf color was significantly different as due to the interaction between planting dates and night break treatments at L1, L2 and L4 growth stages.

Vegetative growth was triggered by photoperiod and temperature (Dahl, 1995). Changes in day length or photoperiod functioned as the timer and trigger that activated or stopped physiological process initiating growth and flowering and activated the process of hardening for resistance to low temperature in the fall and winter (Dahl, 1995). In addition, the environmental conditions as related to the macroclimate were quite different between seasons. In regular season (May, 15) provided sufficient sunshine duration about 13 hours, average temperature of 27.6 ^{o}C and with 77.6 % RH, which were suitable for growth and development. In contrast, plant grown in the off-season (Nov, 15 and Dec, 15), when the temperature was ranging 24.7 - 25.1 ^{o}C, with about 11.4 and 11.8 hours of sunshine duration, and 70.7 to

72.4 % RH, respectively (Appendix 13), which were not suitable for growth and development of this plant. The study showed that supplementary lighting had a significant and beneficial effect on plant growth during both winter planting dates (Nov, 15 and Dec, 15) but did not effect on plant growth during regular planting date (May, 15) that provided a critical and sufficient environmental factors that were suitable for growth of *Curcuma*. This might be due to the reason for no interaction between planting dates and night break treatments. Besides, plant growth and development were influenced by physical, chemical and biological components in the plants environment. Any factor in the plants' environment that was less than optimum, whether it was deficient, in excess or incorrect proportion, would prevent proper plant growth (Westwood, 1978).

3.4.2 Inflorescence quality

It was found that planting date in May, 15 produced significantly greater flower stalk length, spike length, number of pink bracts, number of green bracts and number of inflorescences per clump than the plants grown in Nov, 15 and Dec, 15.

The night break treatment increased flower stalk length, spike length, number of pink bracts and number of inflorescences per clump, while number of green bracts was not different. Ruamrungsri *et al.* (2005) reported that the increase of day length by night break for 2 hours was able to activate flower quality improvement when planting in off-season (low temperature and short day length conditions), and it was not statistically different when planted in regular season. This indicated that there were multi-factors affected quality attributes of inflorescence. The present results found here were also similar to those reported by Ruamrungsri *et al.* (2005). This suggested that photoperiod was the major effect that retarded inflorescence quality and the night break treatment could compensate the long day for promoting inflorescence quality under the same low temperature in off-season.

Furthermore, flower quality parameters, such as inflorescence stalk length, spike length, number of pink bracts and number of inflorescences per clump, of long day was greater and heavier than those of short day condition. Schneider *et al.* (1967) reported that a daylength extension with a mixture of R and FR, from an incandescent lamp, could be given when the light period was of sufficient duration to allow flower initiation and to accelerate flowering. In later studies Shillo and Halevy (1981 and1976) suggested that long day promoted flowering indirectly by extending the period of flower development, thus increasing the total solar irradiance absorbed by the plants and the total photosynthates available to the plants at the sensitive stages of early flower development.

The present study indicated that photoperiod might have both direct and indirect effects on growth and development of *C. alismatifolia* Gagnep. Long day specifically and directly promoted flower growth, and short day directly promoted underground growth (new rhizomes and storage roots). Similarly, a result was observed by Shillo and Halevy (1981) on gladiolus. The distribution pattern of assimilates during development of gladiolus was demonstrated by Robinson *et al.* (1980) which found that there were two competing sinks the inflorescence and the new corm. The inflorescence constituted to be the main sink until anthesis, and the corm was the main sink after blooming. Results of the present study confirmed their results, and suggested that long day conditions strengthened the sink activity of the flower by encouraging the distribution of dry matter towards the flower and away from the rhizome. The flower was the main sink during the period of accelerated flower development (from spike emergence to anthesis), both under short day and long day conditions. However, under long day condition there was almost no increase in dry weight of the rhizome during this period, and the preference of dry matter allocation to the flower was increased. It seemed that short day specifically promoted growth and sink activity of the rhizome, thus increasing the competition for assimilates between the flower and the rhizome. Shillo and Halevy (1981) suggested that in case where assimilate supply was limited, e.g. when gladiolus were grown in winter at high densities, the diversion of metabolites to the corm under natural short days during the sensitive stages of flower development might reduce flower quality and increase flower abortion.

3.4.3 Rhizome quality

Planting dates significantly affected on rhizome quality parameters on the extent of the number of new rhizomes and new rhizomes diameter, but did not influence the number of new storage roots. Planting date in May, 15 induced the plant to produce more new rhizomes and having its diameter bigger than plant grown in Nov, 15 and Dec, 15. However, the off-season production reduced rhizome quality of this plant (Ruamrungsri *et al*., 2006).

Night break treatments affected the number of new storage roots of *C. alismatifolia* Gagnep. Supplemental lighting for 2 hours caused the decrease in new storage roots number as compared with control. Similar to the study of Payakaihapon (2006) which supported that night break treatment for *C. alismatifolia* grown in October decreased the number of storage roots compared with natural condition. Changjeraja *et al.* (2008) reported that *C. alismatifolia* grown at 14 hours did not produce new storage roots at flowering stage, while the plants grown at 6 and 10 hours of photoperiods formed new storage roots normally.

The interaction of planting dates and night break treatments was found in the number of new rhizomes, but the opposite results were obtained on number of storage roots and size of new rhizome diameter. However, cultivating on May, 15 without night break treatment seemed to be advantages for the best rhizome quality. In that, the number of new rhizomes, number of new storage roots and maximum diameter of new rhizomes were 3.42 rhizomes, 9.50 storage roots and 2.50 cm, respectively. Off-season planting with night break, even though the plant could develop inflorescence quality attributes as previously mentioned, the rhizome quality features were somewhat decreased, as new rhizomes were small and number of storage roots were lacking or nearly disappeared. This was probably because of short day length during off-season planting caused photosynthesis capacity to be less than the longer daytime in regular season. Although night break for 2 hours could increase day length for photosynthesis, all synthetic components might have been used for shoot growth and inflorescence development rather than storing in the new rhizome, and thus the new rhizomes became smaller in size. Supporting report was found in the study of Hagiladi *et al.* (1997) that increased light for 10 hours to *C. alismatifolia* compared with natural condition (in short day), the shoot that received more light produced more flowers than that exposed to short day length, but the numbers of storage roots were less.

3.4.4 Dry weight of plant

The result demonstrated that different planting dates significantly affected dry weight of total leaves in L1 and L2 growth stages. Plants cultivated in May gained slightly more total leaves dry weight and fibrous roots dry weight than plants grown in Nov, 15 and Dec, 15. Generally, total leaves dry matter increased from L1 to L4 growth stages. The addition in the leaves and fibrous roots partitioning that occurred from L1 to L4 was probably an indication for the importance of the rhizome as a primary source of assimilates for initial growth of the plant. In that, it might be due to the translocation of food reserve from sources (old rhizome and old storage roots) to sink (leaves and fibrous roots) that occurred during these stages. There were the reductions in dry weight of old rhizome and old storage roots, but were not statistically different. Similarly, Goenaga (1995) reported that growing Taro in early season, the plants allocated a greater percentage of dry matter to leaves and petioles where these organs were accounted for over 40 % of the total dry matter at 82 day after planting. As plants matured, the partitioning ratio decreased significantly for leaves, petioles and roots, which it changed little in corm, but increased significantly in the cormels of suckers.

Night break treatments did not influence on dry weight of total leaves of *C. alismatifolia* Gagnep. The rhizome dry weights were not statistically different at either growing period from L1 to L4. However, the no night break treatment significantly decreased dry weight of old storage roots as compared with the night break for 2 hours in the L1 growth stage, which were 5.71 and 6.97 g plant^{-1}, respectively, On the other hand, the fibrous roots dry weight increased at the L1 growth stage (0.39 g plant^{-1}) compared with that of control treatment (0.32 g plant^{-1}).

However, due to the night break treatment significantly increased inflorescence size and number, therefore, it could be speculated that the dry weight of inflorescence were also affected. Similar patterns of changes in leaves dry weight and fibrous roots were also at the greatest in *C. alismatifolia* growing at 14 hours (Changjeraja *et al.*, 2008).

There was no interaction between planting dates and night break treatments on total leaves dry weight, dry weight of storage roots or dry weight of fibrous roots. The interaction of these factors on dry weight was needed to be further investigated.

3.5 Conclusion

The off-season planting, on November, 15 and December, 15, decreased plant growth and inflorescence quality of *C. alismatifolia*, includes plant height, number of leaves per plant, number of shoots per clump, inflorescence quality and rhizome quality. Supplemental lighting by 2 hours night break treatment was able to promote plant growth and to improve inflorescence quality attributes of the plant. However, the night break treatment during regular planting season (May, 15) did not have any effect on any parameters, as the climatic condition was probably suitable for maximum growth and development of *C. alismatifolia*.