Chapter 6

Effect of day and night temperature on growth and flowering of *Curcuma alismatifolia* Gagnep.

6.1 Introduction

The genus *Curcuma* within the family Zingiberaceae has paramount importance as spice, medicines, dyes, cosmetics, starch and ornamentals. Many species that belong to the genus *Curcuma* are well known for their significant commercial and medicinal values. One of the most important species is *C. longa* within the genus which yields turmeric, one of the important coloring and aromatic ingredients of curry powders that is enormously used in Asian cuisines (Apavatjrut *et al*., 1999; Purseglove, 1974) and pharmaceutical industries, since it has been considered as an extremely important medicinal plant (Majeed *et al*., 1995). Some other species such as *C. aeruginosa*, *C. amada*, *C. angustifolia*, *C. caesia*, *C. elata*, *C. petiolata*, *C. rubescens*, *C. zanthorrhiza* and *C. zedoaria* have also received considerable attention as cut flowers and tropical glasshouse ornamentals. Among them, *C. alismatifolia* is recognized and popular in international trade as cut flower (Paisooksantivatana *et al*., 2001b).

A majority of these gingers are grown in Thailand. In their native habitat, most gingers emerge and grow during the rainy season, and dormancy ensue during the dry season. If rhizomes are dug and kept dry, they will remain dormant (Phongpreecha, 1997). In contrast to their native habitat, in temperate climates rhizomes enter dormancy when temperature decrease and days shorten (Hagiladi *et al*., 1997a).

Plants given the same average daily temperature (ADT) could show different growth patterns due to differences in day and night temperatures (DT and NT). Went (1944) introduced the term `thermoperiodism' to describe the effect of alternating DT and NT on various plant responses. This diurnal variation in temperature influenced internode length, plant height, petiole and flower stem length, chlorophyll content, leaf and shoot orientation and flowering (Myster and Moe, 1995). Erwin *et al*., (1989) suggested that stem elongation and leaf orientation of *Lilium longiflorum* were influenced more by the difference between DT and NT (DIF) rather than by absolute DT and NT. Many subsequent studies on a wide range of plant species, most of them performed out of horticultural interest, also concluded that DIF was a significant factor in determining stem extension responses. DIF has become a valuable concept in providing growers with a simple and effective way of calculating elongation responses to temperature (Erwin and Heins, 1995).

Smith and Langhans (1961) found that stem length increased as DT increased. Similarly, in *Lycopersicon esculentum* L., it was found that stem length increased as DT increased (Went, 1944). Stem elongation responses to DT and NT were also observed in *Fuchsia x hybrida* Hort. Ex Vilm. (Tageras, 1979).

Temperature was seemed to be the primary factor affecting bulb growth and it was commonly used to hasten or delay development (De Hertogh and Le Nard, 1993). For a curcuma to be used as a cut flower and pot plant, it had to be possible for growers to provide flowering plants within a specific time interval. Therefore, the objective of this study was to determine the effect of day and night temperature on growth, flowering, nitrogen and carbohydrate concentrations in *C. alismatifolia* Gagnep.

6.2 Materials and methods

Rhizomes of *C. alismatifolia* Gagnep. with four storage roots were planted in 6x8 inch of plastic bags using media containing soil : sand : rice husk ratio 1:1:1 (by volume). After planting, plants were placed in the growth chamber (Conther phytotron climate simulator) under 28 °C until shoots emerged. Then plants were transferred to growth chambers setting at day and night temperatures of 24/18, 30/18, 30/24 and 36/24 °C. All the other environmental conditions were kept constant in all treatments, including light intensity was set at 270 µmol photosynthetic photon flux, relative humidity at 70-80% and photoperiod 12 hrs. The experimental design was completely randomized design with 10 replications per treatment.

Data collection

Plant height, leaf length, leaf width, number of leaves per plant, number of plants per cluster, leaf area, dry weight of leaves, rhizome, new rhizome, storage roots, fibrous roots and spike were measured. Leaf color was measured using chlorophyll meter; Spad-502 (Minolta CO., LTD) at the first flower emergence.

Nitrogen and carbohydrate analysis

Leave, rhizome, new rhizome, storage roots and spike from five plants of each treatment were sampled to determine the contents of soluble, non-soluble nitrogen, total nitrogen (Ohyama *et al*.,1985; 1986) and total non structural carbohydrates content (Smith *et al.*,1964).

6.3 Results and discussion

Plant growth

The results showed that plant height and leaf length of *C. alismatifolia* increased when plants were grown at the 36/24 °C (day/night temperature) compared with the other treatments (Table 6.1). Average daily temperature influenced internode length and thus the response to different day/night temperature (DIF) in many plants (Berghage, 1998). Sweet pepper seedling internode length was found to be correlated with average temperature, as well as, with DIF (Yaping and Heins, 1996). Similarly, poinsettia had an optimum average temperature for internode elongation at 24 °C, as well as a correlation with DIF (Berghage, 1998). In *Lilium longiflorum* Thunb. cv. 'Nellie White', plants were grown in different day/night temperature (DT/NT) environments to determine the anatomical basis for differential responses of stem elongation to DT and NT. *Lilium* plants were forced in 1986 and 1987 under 25 and 12 °C different DT/NT environments, respectively, with temperatures ranging from 14 to 30 °C. Parenchyma and epidermal cell length and width were measured in stem tissue (1987) and epidermal cell length and width were measured in leaf tissue (1986). Positive DIF at 6 °C was equally 24 °C (T3 vs T4) promoted plant height, number of leaves/plant and leave areas. However, when night temperature was 18 °C the same DIF interval did not affect these parameters, except for number of leaves/plant (Table 6.1). Indicating that the response of plant height and leave areas to DT related to optimal NT. The responses to DIF were rapid, and most plants responded to a change in DT and NT within 24 hrs. The effects of DIF on stem elongation and leaf expansion were a result of increased cellular elongation rather than division (Erwin and Heins, 1995). A physiological explanation for the effects of DIF suggested that DIF might elicit responses through affecting the concentration of endogenous gibberellins. Stem elongation was also sensitive to a temperature drop in the last 2 hrs of the night or the first 2 hrs of the day (Myster and Moe, 1995). Interaction between growth factors might be the reason that the effects of DIF and temperature drop on plant morphogenesis differed among research reports. Average daily temperature (ADT) could influence internode elongation in some species (Myster and Moe, 1995). The plant stem elongation rate was not constant during a day/night cycle and this knowledge could be used for control of plant morphogenesis and flowering by DT and NT alternations. This review showed that DIF and temperature drop could reduce or eliminate the use of growth retardants in many greenhouse crops (Myster and Moe, 1995).

The number of leaves per plant increased when plants grown under higher DT. Increasing of NT did not affect this parameter (T2 vs T3) (Table 6.1). Although, the day and night temperatures did not significantly affected leaf width or leaf length but the high day and night temperatures increased leaf areas of this plant (Table 6.1). Leaf expansion and orientation could also be affected by DIF (Erwin and Heins, 1995). However, it was depended on plant species. Leaf area of *Solanum tuberosum* plantlets (Kozii *et al*., 1995) and *Brassica* transplants (Bakken and Flones, 1995) was reduced when grown with a negative DIF. Likewise, Yaping and Heins (1996) reported that leaf area of sweet pepper seedling was highly correlated with DIF. In contrast, leaf area of Easter lily was correlated with night temperature and not with

DIF (Erwin *et al*., 1989). The emergence of new leaves of the winter barley (*Hordeum vulgare* L.) cultivar Kikai Hadaka, grown at constant temperatures between 12.5 to 27.5 °C was a linear function of time at all temperature regimes. The leaf emergence rate increased with increasing temperature until an optimum temperature of 22.5 °C and reached its' maximum and then decreased with further increasing temperatures, but not significantly when compared with the peak (Tamaki *et al*., 2002). The result in *Arabidopsis thaliana* Ler. suggested that the final leaf length decreased with increasing night temperature due to a combination of reduced elongation period and reduced elongation rate. Final stem length increased with increasing day temperature due to increased elongation rate, and decreased with increasing night temperature due to a decrease in elongation period. Under night temperature at 27 °C, however, stem elongation rate increased greatly, resulting in the same final stem length as under night temperature at 12 °C. A linear regression analysis was performed to clarify the relationship between final leaf length, final stem length and flowering time with DIF (day temperature minus night temperature) and/or ADT (average daily temperature). For all three variables, the effect of DIF depended on ADT. The relationship of final stem length with DIF also depended on the temperature range. (Thingnaes *et al*., 2003). Grafted cv. Fuerte and cv. Hass avocado plants were grown for 81 days in growth chambers at day/night temperatures of 17/10, 21/14, 25/18, 29/22, 33/26 and 37/30 °C. Stem diameter, length of side branches, the number of leaves, leaf area and plant height, were all greater in the 21/14 to 33/26 °C temperature range, than that at temperatures of 17/10 °C and especially 37/30 °C, which restricted growth in both cultivars.

The result from present experiment showed that leaf chlorophyll of plants were not significantly difference. This was different from the result in *Fuchsia* (*Fuchsia x hybrida* Hort. Ex Vilm.) and *Dendranthema* which total leaf chlorophyll increased as DIF increased (Erwin and Heins, 1995). Reduced leaf chlorophyll resulted in visibly chlorotic plants in negative DIF environments. For examples, sweet pepper leaf reflectance at 550 nm decreased as DIF increased (Berghage, 1998; Yaping and Heins, 1996). DIF induced leaf chlorosis was often reversible, with plants greening rapidly after removal from the negative DIF environment (Erwin and Heins, 1995).

Dry-weight of plant parts

Dry-weight of leaves, fibrous roots and spike stalk were also the greatest in plants growing at 36/24 °C day/night temperature, compared with the other treatments. Plants were grown at 24/18 °C had higher dry weight of storage roots than the plants grown at the other temperatures. The dry weight of rhizome in plant grown at 24/18 and 30/18 °C day/night temperature was higher than the other treatments. Dry weight of mother rhizome and storage roots at planting was about 0.20 g and 22.00 g, respectively. The results indicated that high temperature accelerated the decreasing of rhizome and storage roots dry weight. This may be related to the photorespiration increased with increased temperature (Al-Hamdani and Todd, 1990). Thermoperiod refers to daily temperature change. Plants produce maximum growth when they are being exposed to a day temperature that is about 5.5 to 8 °C higher than the night temperature. This allows the plant to photosynthesize and respire during an optimum daytime temperature and to curtail the rate of respiration during a cooler night.

Table 6.1 Growth of *C. alismatifolia* under different growing day-night temperatures at 12 WAP.

Day-night temperature (°C)	Plant height (cm) [1/]	Number of leaves per plant[1/]	Leaf width (cm) [2/]	Leaf length (cm) [1/]	Number of plants per luster[2/]	Leaf area[1/]	Leaf color[2/]
24/18	34.50 c	3.30 c	4.08	21.25 b	1.80	217.80 b	56.56
30/18	28.80 c	4.20 b	4.39	19.85 b	1.90	276.00 b	44.64
30/24	44.75 b	3.70 bc	4.77	25.05 a	2.00	283.00 b	44.45
36/24	54.30 a	4.90 a	4.83	25.85 a	1.10	482.60 a	49.58
$LSD_{.05}$	6.94	0.58	ns	2.12	ns	157.53	ns

[1/] Values within columns followed by different letters were significantly different at $P<0.05$.

[2/] ns: not significantly different

High temperatures cause increased respiration sometimes above the rate of photosynthesis. This means that the products of photosynthesis are being used more rapidly than they are being produced. For growth to occur photosynthesis must be greater than respiration. Roberts (1943) suggested that the temperature during the night rather than the day largely determined the response of plants to temperature. Went (1944) made detailed observations on the effect of night temperature on stem extension rate of tomato (*Lycopersicon esculentum* Mill.). A Kentucky wonder variety of *Phaseolus vulgaris* was grown under controlled environmental conditions. The finding for tomato, chili pepper and tobacco that night temperature was the most critical factor influencing developmental processes was observed to apply to beans as well (Viglierchio and Went, 1957). The day/night temperature did not significantly affect spike dry weight (Table 6.2).

Table 6.2 Dry weight of *C. alismatifolia* under different growing day-night temperatures at 12 WAP.

Day-night temperature (°C)	Dry weight (g)						
	Leaves[1/]	Old-rhizome[1/]	Old-storage roots[1/]	Fibrous roots[1/]	Spike[2/]	Spike stalk[1/]	Total[1/]
24/18	2.10 b	0.85 a	9.82 a	0.74 b	0.88	0.72 b	15.11 a
30/18	2.47 b	0.86 a	7.22 b	0.78 b	0.94	0.63 b	12.90 b
30/24	2.31 b	0.64 b	8.63 b	0.79 b	0.83	0.79 b	13.99 b
36/24	5.48 a	0.49 b	3.38 c	1.23 a	0.65	1.55 a	12.78 b
$LSD_{.05}$	1.10	0.16	2.45	0.38	ns	0.16	2.51

[1/] Values within columns followed by different letters were significantly different at $P<0.05$.

[2/] ns: not significantly different

Inflorescence of plants grown under 30/24 and 36/24 °C day/night temperature produced the percentage of flowering at 90 and 100%, respectively. Low DT/NT at 24/18 °C decreased flowering percentage of this plant (Table 6.3). Number of pink bracts and flower stalk length of plant grown at 36/24 °C day/night temperature were greater than plants grown in the other treatments. The DT and NT did not significantly affect spike width, spike length or number of green bract.

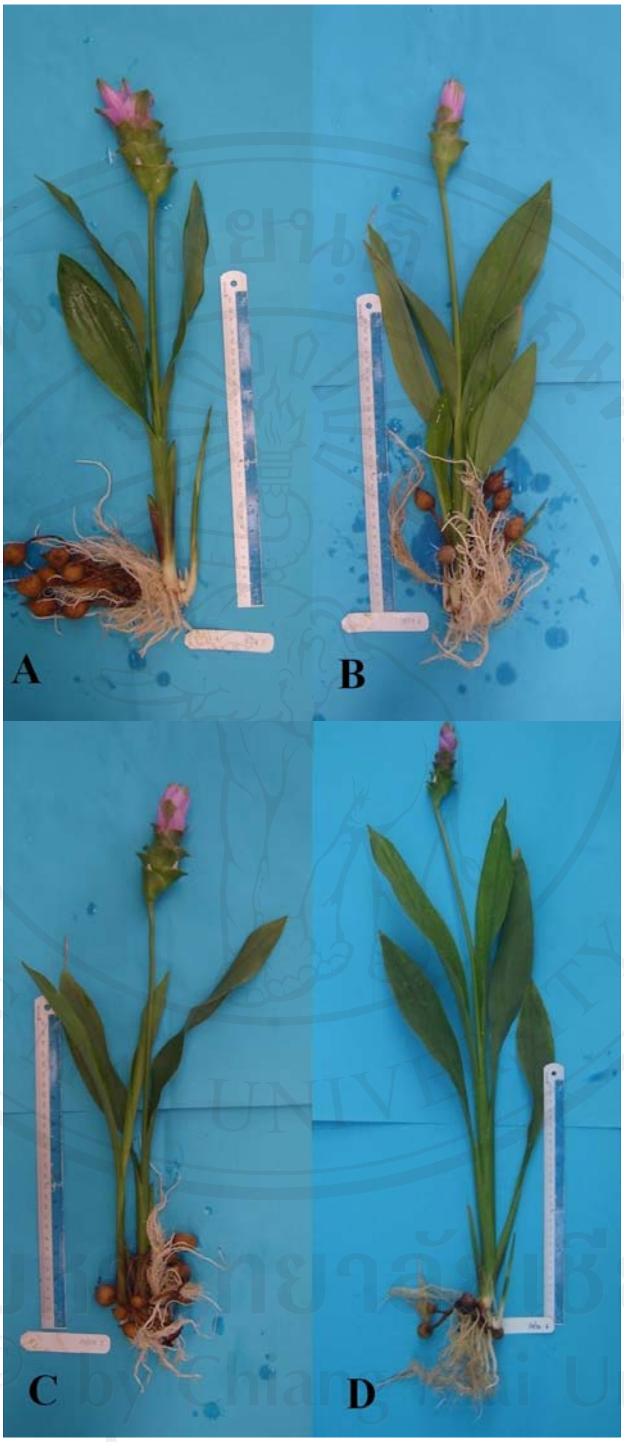

Figure 6.1 Growth of *C. alismatifolia* under different growing day and night temperatures at 12 WAP.

Ison and Humphreys, (1984) reported that floral initiation of *Stylosanthes guianensis* cv. Schofield grown at a photoperiod marginal for flowering (12–11.75 hrs) was promoted by a combination of low day (25 °C) and low night (16 or 21 °C) temperatures, while completely inhibited by a 35 °C day temperature. Additionally, earliness of floral initiation under naturally decreasing daylength was negatively related to temperature regime over the range of 35/30 to 20/15 °C (day/night).

C. alismatifolia grown at 30/18 and 36/24 °C had the percentage of flowering approximately 100% (Table 6.3). Depending on the situation and specific plant, the effect of temperature could either speed up or slow down the transition from vegetative to reproductive (flowering) (http://extension.oregonstate.ded/mg/botany/light.htm., 2006). The transition to flowering was accelerated by increasing night temperature. A linear regression analysis was performed to clarify the relationship between final leaf length, final stem length and flowering time with DIF (day temperature (DT) minus night temperature (NT)) and/or ADT (average daily temperature). For all three variables, the effect of DIF depended on ADT. The relationship of final stem length with DIF also depended on the temperature range. Increased cell volume in flower stems developing at DT/NT 22/12 °C gave rise to longer and thicker stems compared with stems developing at DT/NT 12/22 °C. The result from GC–MS analysis (gas chromatography–mass spectrometry) showed that the endogenous level of IAA was 56 % higher in stems grown under positive DIF (22/12 °C) compared with negative DIF (12/22 °C). However, only the level of non-bioactive GA_{29} was affected by these temperature treatments (Thingnaes *et al*., 2003).

Table 6.3 Flower quality of *C. alismatifolia* under different growing day-night temperatures at 12 WAP.

Day-night temperature (°C)	Spike width (cm) $^{2/}$	Spike length (cm) $^{2/}$	Spike stalk length (cm) $^{1/}$	Number of green bract$^{2/}$	Number of pink bract$^{1/}$	Percentage of flowering
24/18	5.65	12.05	22.10 d	9.40	8.50 b	80.00
30/18	5.40	12.45	30.35 c	8.40	7.80 b	100.00
30/24	5.20	11.15	39.15 b	8.80	8.50 b	90.00
36/24	5.37	11.50	53.80 a	9.30	9.60 a	100.00
LSD$_{.05}$	ns	ns	4.84	ns	0.75	-

$^{1/}$Values within columns followed by different letters were significantly different at $P<0.05$.

$^{2/}$ns: not significantly different

Nitrogen and total non structural carbohydrates.

Nitrogen fractions (insoluble and soluble nitrogen), total nitrogen, TNC concentrations and C:N ratio in leaf of plants grown under different day and night temperatures were shown in Table 6.4. The plant grown at 36/24 °C temperature gave higher insoluble nitrogen, total nitrogen and TNC than the other treatments (i.e. 73.77, 83.30 and 293.02 mg/plant). The plants were grown at 30/18 °C temperature gave higher soluble nitrogen (i.e. 12.37mg/plant) than the others. The DT and NT did not significantly affect C:N ratio (Table 6.4).

Table 6.4 Insoluble nitrogen, soluble nitrogen, total nitrogen, TNC concentrations and C:N ratio in leaves of *C. alismatifolia* under different growing temperatures 12 WAP.

Day-night temperature (°C)	nitrogen (mg/plant)			TNC (mg/plant) [1]	C:N ratio [2]
	Insoluble [1]	Soluble [2]	Total [2]		
24/18	40.59 b	3.70 c	43.55 b	149.61 b	2.80: 1
30/18	22.57 b	12.37 a	34.89 b	140.73 b	3.97: 1
30/24	27.67 b	8.12 b	35.79 b	76.22 b	2.10: 1
36/24	73.77 a	3.70 c	83.30 a	293.02 a	3.54: 1
LSD$_{.05}$	30.56	2.14	28.23	127.82	ns

[1] Values within columns followed by different letters were significantly different at P<0.05.

[2] ns: not significantly different

The plant grown at 24/18 °C temperature gave higher insoluble nitrogen and total nitrogen concentration (i.e. 285.98 and 288.92 mg/plant) than the plant grown at the other treatments. The insoluble nitrogen in storage roots of plant grown at 30/18 °C was greater than that in the plant grown at the other treatments. Day and night temperature did not significantly affect TNC and C:N ratio in storage roots (Table 6.5).

Table 6.5 Insoluble nitrogen, soluble nitrogen, total nitrogen, TNC concentrations and C:N ratio in storage roots of *C. alismatifolia* under different growing temperatures 12 WAP.

Day-night temperature (°C)	nitrogen (mg/plant)			TNC (mg/plant) [1/]	C:N ratio[1/]
	Insoluble[2/]	Soluble[2/]	Total[2/]		
24/18	285.98 a	4.91 b	288.92 a	209.91	1.06 :1
30/18	24.95 b	73.29 a	57.78 b	169.15	3.10 :1
30/24	130.53 ab	23.81 b	154.35 ab	411.92	4.70 :1
36/24	54.67 b	12.00 b	66.68 b	133.11	2.63 :1
LSD$_{.05}$	154.58	2.16	160.19	ns	ns

[1/] Values within columns followed by different letters were significantly different at P<0.05.

[2/] ns: not significantly different

Day/night temperature did not significantly affect insoluble, soluble or total nitrogen, TNC concentration and C:N ratio in rhizome (Table 6.6).

Table 6.6 Insoluble nitrogen, soluble nitrogen, total nitrogen, TNC concentrations and C:N ratio in mother rhizome of *C. alismatifolia* under different growing temperatures 12 WAP.

Day-night temperature (°C)	nitrogen (mg/plant)			TNC	C:N
	Insoluble[2/]	Soluble[1/]	Total[2/]	(mg/plant) [2/]	ratio[2/]
24/18	25.27	2.18	27.02	26.42	1.31:1
30/18	18.79	4.39	23.18	21.59	1.22:1
30/24	17.95	2.82	20.98	16.35	0.99:1
36/24	13.49	1.82	15.32	24.29	2.27:1
LSD$_{.05}$	ns	ns	ns	ns	ns

[1/] Values within columns followed by different letters were significantly different at P<0.05.

[2/] ns: not significantly different

Insoluble nitrogen, soluble nitrogen and total nitrogen concentrations in plant grown at 36/24 °C were higher than that in the plant grown in the other treatments. The plant grown at 24/18 °C and 36/24 °C day/night temperatures gave the highest TNC concentration, while the plant grown at 24/18 °C day/night temperature gave the highest C:N ratio in new rhizome (Table 6.7).

Table 6.7 Insoluble nitrogen, soluble nitrogen, total nitrogen, TNC concentrations and C:N ratio in new rhizome of *C. alismatifolia* under different growing temperatures 12 WAP.

Day-night temperature (°C)	nitrogen (mg/plant)			TNC (mg/plant)[1/]	C:N ratio[1/]
	Insoluble[2/]	Soluble[1/]	Total[2/]		
24/18	18.51 ab	1.46 ab	19.96 b	50.47 a	2.79:1 a
30/18	5.90 b	1.19 b	7.09 c	3.79 c	0.55:1 b
30/24	8.91 b	0.60 b	9.51 c	20.47 b	2.25:1 ab
36/24	24.02 a	2.55 a	26.58 a	42.70 a	2.61:1 b
LSD.$_{05}$	16.06	1.27	15.15	14.34	0.62

[1/] Values within columns followed by different letters were significantly different at P<0.05.

[2/] ns: not significantly different

The plant grown at 30/18 °C gave higher soluble nitrogen concentration (i.e. 4.72 mg/plant) than the other treatments. The plant grown at 36/24 °C temperature gave higher TNC concentration and C:N ratio in spike (i.e. 43.27 mg/plant and 4.61:1, respectively) than the plant grown at the other treatments. Day/night temperature did not significantly affect insoluble or total nitrogen concentrations in spike (Table 6.8). In onion bulbs (*Allium cepa* L. cv. Creamgold), grown in a phytotron from seed, had a dry weight, as percentage of fresh weight, that decreased as growth temperatures increased from 22/16 to 33/28 °C day/night. There were no significant differences between growth temperatures in fructose, sucrose or fructan contents, but glucose content was higher at high temperatures. There was no correlation of total carbohydrate content with growth temperature. The sum of fructose, glucose and sucrose per unit tissue water was constant between temperatures, suggesting that the mono- and disaccharide contents probably controlled the bulb water content. These results from controlled-environment tests, predicted that the best yield in the field of dry weight as a percentage of fresh weight would be obtained by low growing temperatures (Steer, 1982).

Table 6.8 Insoluble nitrogen, soluble nitrogen, total nitrogen, TNC concentrations and C:N ratio in spike of *C. alismatifolia* under different growing temperatures 12 WAP.

Day-night temperature (°C)	nitrogen (mg/plant)			TNC (mg/plant)[1/]	C:N ratio[1/]
	Insoluble[2/]	Soluble[1/]	Total[2/]		
24/18	11.96	0.59 c	12.43	21.29 c	1.88:1 b
30/18	8.44	4.72 a	13.16	42.35 ab	3.31:1 ab
30/24	12.49	3.10 b	15.60	28.89 bc	2.17:1 b
36/24	9.28	1.51 c	10.79	43.27 a	4.61:1 a
LSD.$_{05}$	ns	2.13	ns	14.29	1.76

[1/] Values within columns followed by different letters were significantly different at P<0.05.

[2/] ns: not significantly different

Whole plant

Insoluble and total nitrogen concentrations in plant grown at 24/18 °C day/night were higher than that in the plant grown at the other treatments. The plant grown at 30/18 °C day/night temperature gave the highest soluble nitrogen concentration, while the plant grown at 30/24 and 36/24 °C day/night temperatures gave the highest C:N ratio. Day/night temperature did not significantly affect TNC of whole plant (Table 6.9).

Table 6.9 Insoluble nitrogen, soluble nitrogen, total nitrogen, TNC concentrations and C:N ratio in whole plant of *C. alismatifolia* under different growing temperatures 12 WAP.

Day-night temperature (°C)	nitrogen (g/plant)			TNC	C:N
	Insoluble[1/]	Soluble[2/]	Total[1/]	(mg/plant)[1/]	ratio[1/]
24/18	382.30 a	9.59 c	391.90 a	457.71	1.44:1 b
30/18	84.60 b	58.27 a	136.12 b	377.62	2.82:1 b
30/24	197.57 b	38.47 ab	236.04 b	553.86	3.16:1 a
36/24	164.28 b	27.47 bc	191.75 b	536.40	3.29:1 a
LSD$_{.05}$	102.97	17.79	89.88	ns	1.18

[1/] Values within columns followed by different letters were significantly different at P<0.05.

[2/] ns: not significantly different

6.1 Conclusion

Day temperature promoted growth and flowering of *C. alismatifolia* during vegetative stage. It was also promoted plant height, number of leaves per plant, leaf length, number of plants per cluster, leaf area and spike stalk. The optimum temperature at 36/24 °C gave the best quality of spike of *C. alismatifolia*. Low temperature increased insoluble-N-fraction and total nitrogen but decreased TNC and C:N ratio in plant. In leaves, high day and night temperature increased insoluble-N-fraction and total nitrogen and TNC.