Chapter 2

Review of literature

2.1 Origin and distribution of *C. alismatifolia* Gagnep.

The center of diversity of the genus *Curcuma* is in the continental monsoon in Asia, and Thailand seems to be one of the richest areas (Larsen and Larsen, 2006). It is in the tribe Hedychieae, family Zingiberaceae, consists of about 80 species. *Curcuma* is distributed throughout tropical Asia from Western India to South Asia, South China, South Asia, Papua New Guinea and northern Australia (Sirirugsa, 2006). *C. alismatifolia* belong to this genus with oblong leaves and pinkish inflorescence, lotus shape and has a long post harvest vase-life (Roh *et al*., 2006), that makes it good for cut-flowers. Plants usually lie dormant in October and November and will sprout again in April or May.

2.2 Economic important values

Drying the years from 1997 to 2004, Thailand exported a large the amount of *C. alismatifolia* rhizome and the number increased year by year as shown in Table 2.1. In 2004, the numbers of exported rhizomes was 3,870,068 which had a valued at about 24,871,170 baht. About one-third of them were exported to Germany, the remaining were to Japan, Portugal, the USA, Australia, Belgium, and Italy (Table 2.2). It was interesting that the numbers of inflorescences were increased in export from 2000 to 2004 and the value increased to about 400,000 baht in 2004 (Table 2.3). Belgium was the biggest importer for inflorescences in 2004, of 4,274 inflorescences with 381,230 baht in value (Table 2.3) (Department of Agricultural Extension, 2005).

Table 2.1 The number and economic values of exported *C. alismatifolia* rhizomes were exported from 1997 to 2004.

Year	Number (rhizomes)	Economic values (Baht)
1997	580,398	6,847,603.-
1998	1,344,103	24,355,450.-
1999	2,184,886	29,751,238.-
2000	2,884,367	26,515,360.-
2001	2,292,323	16,656,349.-
2002	2,080,976	16,870,588.-
2003	3,737,840	20,181,762.-
2004	3,870,068	24,871,170.-

Source: Department of Agricultural Extension, 2005.

Table 2.2 The number and economic values of exported *C. alismatifolia* rhizome, ranking by countries.

Country	Number (rhizomes)	Economic values (Baht)
Germany	1,180,485	7,818,895.-
Japan	835,414	4,449,962.-
Portugal	536,600	5,565,592.-
USA.	416,444	3,559,419.-
Australia	265,800	187.655.-
Belgium	137,759	1,460,400.-
Italy	100,886	645,475.-
Singapore	4,180	54,399.-
Korea	3,060	51,288.-
Netherland	60	600.-
Other	389,400	1,077,485.-
Total	3,870,068	24,871,170.-

Source: Department of Agricultural Extension, 2005.

Table 2.3 The number and economic values of exported *C. alismatifolia* inflorescences.

Year	Number (inflorescences)	Economic values (Baht)
2000	5,099	94,790.-
2001	11,325	51,371.-
2002	11,130	28,880.-
2003	25,954	51,055.-
2004	11,999	408,576.-

Source: Department of Agricultural Extension, 2005.

Table 2.4 The number and economic values of exported *C. alismatifolia* inflorescences, ranking by countries in 2004.

Country	Number (inflorescences)	Economic values (Baht)
Belgium	4,274	381,230.-
Japan	3,225	8,275.-
Spain	1,164	2,291.-
Saudi Arabia	1,080	3,625.-
Italy	1,046	6,020.-
Indonesia	130	1,300.-
India	115	2,125.-
Switzerland	80	580.-
Jordan	50	850.-
Cambodia	26	580.-
Other	805	1,700.-
Total	11,999	408,576.-

Source: Department of Agricultural Extension, 2005.

2.3 Morphology

2.3.1 Underground parts

Root system

The root systems of *C. alismatifolia* comprise of fibrous roots (Figure 2.1a) and contractile roots (Figure 2.1b). These are entirely adventitious. Fibrous roots initiate

and emerge from the base of storage roots and rhizome under high temperature and high humidity. The contractile roots thickened specialized root are emerged from the base of rhizomes and developed into the storage roots eventually.

Figure 2.1 Fibrous roots (a) and contractile roots (b) of *C. alismatifolia*.

Rhizome and Storage roots

Rhizome is modified from stem that is typically has short internodes, and it was ovule shapes (Fig. 2.2 a). Buds on rhizome will produce the following season leaves and inflorescence (Hagiladi *et al*., 1997). It is attached with storage roots (Fig. 2.2b), which play a role as storage organs with egg shape root end destinated as t-root (Hagiladi *et al*., 1997).

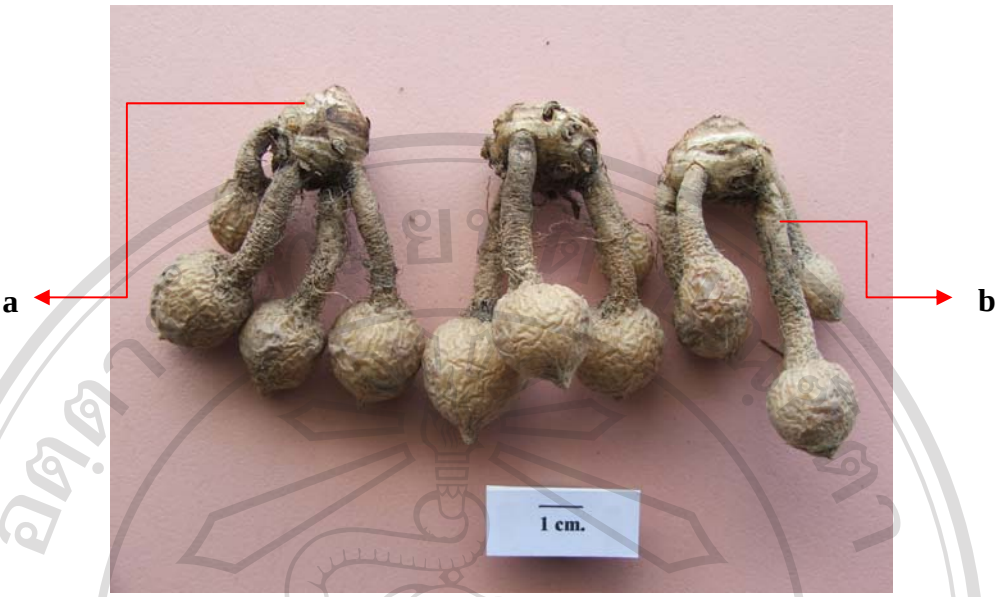

Figure 2.2 Rhizome (a) and storage roots (b) of *C. alismatifolia*.

2.3.2 Aerial parts

Pseudostem

Pseudostem comprises of bases of foliage leaves tightly wrap together with inflorescences stalk (Fig. 2.3a).

Leaves

The leaves are alternate and distichous, the base sheathing and the blade mostly elliptic with penni-parallel, strongly ascending veins (Fig. 2.3b). (Gerald, 1997)

a **b**

Figure 2.3 Pseudo-stem (a) and foliage leaves (b) of *C. alismatifolia*.

Inflorescence

Inflorescence is showy with almost indistinguishable tree flower (Hagiladi *et al*., 1997). The inflorescences comprise of long lasting coma bract in upper part with pink color and lower green bracts (Fig. 2.4a and 2.4b).

a **b**

Figure 2.4 Compact spike (a) and pink coma bracts in upper part (b) of plant.

Flower

True flowers that hide in the axils of the lower green bracts are bisexual, strongly zygomorphic, and often are associated with conspicuous floral bracts in a spike. The perianth is in two whorls, an herbaceous or membranous 3-lobed or spathaceous tubular calyx and a petaloid tubular corolla with 3 lobes. The androecium typically consists of 1 fertile stamen, a large opposing petaloid labellum representing 2 connate staminodia, and two smaller flanking petaloid staminodia. The gynoecium consists of a single compound pistil of 3 carpels, a single style nestled in a channel of the filament and anther of the fertile stamen and an inferior ovary with typically 3 locules, each containing numerous axile ovules. Rarely the ovary is unilocular with parietal placentation (Fig. 2.5) (Gerald, 1997).

Figure 2.5 True flower of *C. alismatifolia*.

Fruit and Seed

Fruit: Pisitil(s) compound; 1; 1-pistillate; with carpels united. Fruit pericarpium; capsule (Sput), or berry (not Spjut); loculicidal capsule; capsule not inflated; capsule without operculum; berry indehiscent; berry without central placental mss; without persistent central column; crowned by remains of perianth; many-seeded; many; with 3-carpellate, or 2-carpellate; with carpels united; with capels remaning united at maturity; with capels not radiating at maturity; with carpels remaining connected at style; without sterile carpels; not sulcate; apex not beaked; dehiscent, or indehiscent. Dehiscent unit seed(s). Dehiscent regulary, or irregularly; passively; and shedding seeds; without replum. Epicarp durable; without armature; smooth, or not smooth; warted; without wing(s); without apical respiratory hole. Endocarp present, or absent; not separating from exocarp; thin; not slitting into 1-seeded pyrenes; smooth; without wing; without operculum; without secretory cavities; without mechanism for seeding escape; without grooves; without longitudinal ridges. Funiculus short; short without seed bearing hooks (retinacula); not persisting in fruit after seed shed (Fig. 2.6a) (Kirkbride, 2007).

Seed: Aril present, or absent; a true aril; adnate to hilum; fleshy; of funicular origin; basal; does not aid in seed explusion from fruit; fimbriate-laciniate; lobed, or unlobed. Seed larger than minute; sub-circular, or angular; not bowl shaped; not nutlike; without winglike beak; without caudate appendage(s); at maturity with food reserves; with endosperm, or perispem; without canavanine. Sarcotesta absent. Testa present; without makedly different marginal tissue; without fleshy or leathery layer over hard layer; tight; surface unsmooth; surface with merged raised features; surface wrinkled; without crease or line separation cotyledons from hypocotyls-radicle; without notch along margin where cotyledons from hypocotyls-radicle tip approach each other; without glands; without bristle; glabrous; without wings; without collar; with operculum; colored; monochrome; firm(=cartilaginous); not becoming mucilaginous when wetted; surrounding food reserve. Endosperm development at first helobial, or cellular (latter); scant; hard, or mealy; smooth; with starch; without fatty acid containing cyclopropene; without apical lobes; without chlorophyll; without isodiametric faceted surface; without odor. Perisperm copious; hard on mealy; with starch; with compound starch grains; opaque. Embryo differentiated from food reserve; well developed; 1 per seed; partially filling testa (with food reserve); 0.8 times the length of food reserve; at one end of seed extending into a depression or cup; axile and centric; linear; straight; parallel to seed length; embedded in prisperm (with outer layer composed of endosperm); with cotyledons gradually connected to hypocotyls-radicle; without coleoptile; without coleorhizae; without simmondisn; without stomata; not green; with 1 cotyledon. Cotyledons one and terminal (but condition of plumule unknow); not modified into scutellum; not circinately coiled (Fig. 2.6b) (Kirkbride, 2007). A seed is like a grapes seed and dark brown color of seed coat in Finger 2.6c (Sirirugsa, 1990).

a

b

c

Figure 2.6 Fruit (a, b) and seed (c) of *C. alismatifolia*. (Kirkbride *et al*, 2007)

2.4 Cultivation

Generally, field preparation is made in March and planting taken place during April-May. Flowering occurs during July-September, when, plants bear 2-3 leaves. By October, aerial parts are withering and go to dormant in November. The new rhizomes are harvested in December-January and exported to the customer's countries during January to March (Department of Agriculture, 2006).

Planting area

Criteria of area selection for growing curcuma are given below. Land on which curcuma has never been planted previously. On land where plants that are known as hosts to diseases affected curcuma have never been planted for at least two years, such as those in the ginger family, egg plant, potato, sesame and tobacco. Land must be free of nematodes. If land has been planted with curcuma, it should be rotated with other crops for at least three years before returning to curcuma again. Land to be planted with curcuma should not be contaminated with rhizome rot or wilt disease. The soil should be well-drained. Transportation should be convenient and it should be possible to send the products promptly to the market (Department of Agriculture, 2006).

Soil Preparation

The soil should be sandy loam, of medium fertility, with good water drainage and soil acidity of 6.5-7.0. There are two ways of raising curcuma, i.e., planting in the field and planting in plastic bags (Department of Agriculture, 2006).

Field Planting: Select disease free rhizome of the desired cultivar with diameter is not less than 1 cm. Analyze soil conditions and adjust pH to 6.5-7.0. Adjust alkaline soil by adding sulfur and avoid planting in alkaline soil as curcuma will exhibit symptoms of macro nutrient deficiency. The plant will be stunted, leaves become yellow and the flowers pale. Plow the land once; leave it exposed to the sun for 20-30 days and then harrow, collecting whatever rubbish leftover. As a preventive measure against rhizome rot, urea mixed with lime in the ratio of 1:10 is applied at the rate 10,000 rhizomes per rai before harrowing. The land is bedded, compacted, watered well and covered with plastic sheet for 15 days. Sub-divide the beds into small plots

of about 400 m^2 and provide adequate drainage channels. In between the sub-divisions, of about 1 m wide, plant crops that are not alternate host of rhizome rot such as maize, sorghum, mungbean and lemongrass to prevent spreading of the disease. Within the sub-division, raise the level by 20-30 cm and 1.0-1.2 m wide, providing a 0.5 m wide path for walking space. Do not prepare the soil too deeply as the storage roots will grown down too deep and will get damaged when harvested, which would be undesirable for the export market.

Plastic Bag Planting: Potting material (sand : rice husk or coconut coir dust : rice husk charcoal at a ratio of 1 : 1 : 1) is filled into a black plastic bag sized 15 x 30 cm and placed on a sheet of clear plastic on a raised platform of 20 cm high (Department of Agriculture, 2006).

Rhizome for planting preparation

Select only disease-free rhizome, unaffected with nematodes and that come from disease-free planting fields. Grade rhizomes according to size, such as large (with diameter larger than 1.5 cm), medium (with a diameter of 1-1.5 cm) and small (with a diameter less than 1.0 cm). Place the selected rhizomes in germination boxes, having sand or rice husk charcoal or coconut dust as planting material. Maintain the humidity at 70% and partial sunlight to stimulate uniform sprouting. Select rhizome of equal size for planting in the same field (Department of Agriculture, 2006).

Planting of curcuma

There are two types of planting, namely:

Planting in the field: Planting distance depends on the size of the rhizome, as follows: large (30x30 cm or 10,000 rhizome per rai), medium (25x25 cm or 15,000 rhizome per rai) and small (20x20 cm or 20,000 rhizome per rai). Before planting, place 15 g of 15-15-15 or 16-16-16 fertilizer in the bottom of the planting pit. Placeing one rhizome 7-10 cm deep; covers it with soil and with straw on top or plastic sheet to conserve moisture (Department of Agriculture, 2006).

Planting in plastic bags: Planting the sprouted rhizome close to the soil surface with upright shoot, this will result in inducing flowers about two weeks earlier than

usual. After which covers it with soil thinly in order to protect the shoot from burning (Department of Agriculture, 2006).

Water application

The water should be clean with no contamination of any organic matter or toxic inorganic matters. The pH of the water should be in the range of 5.5-6.5 (Department of Agriculture, 2006).

Fertilizer Application

Field Planting: After the first pair of opened leaves, apply around the plant with a high nitrogen fertilizer such as 21-7-14, 15-0-0 or 16-16-16 at 15 g/plant once a month and water after each application. Next, at flowering apply 13-13-21 fertilizer at 15 g/plant once a month. Foliar fertilizer is also given, such as calcium, magnesium, boron, zinc and copper whenever the leaves shown to the yellowing due to micro elements deficiency. When new rhizome develops, high phosphorus and potassium fertilizers are given such as 8-16-24, 14-14-21 or 13-13-21 at 15 g/plant once a month.

Plastic Bag Planting: The amount of fertilizer used for each bag planting should be less per application but more frequent, i.e at 7-10 g/bag every three weeks (Department of Agriculture, 2006).

H.M. the King's Initiative Centre for Flower and Fruit Propagation, Chiang Mai University, has developed a liquid fertilizer named "Banrai's Centre; BC-1", that It comprised of nitrogen (200 mg/l), phosphorus (50 mg/l) and potassium (200 mg/l). This formula can promote number of plants per cluster and rhizome quality of *C. alismatifolia* (Ruamrungsri *et al*., 2005).

Pest Control

Diseases: The causal pathogen of wilt or rot is bacteria (*Ralstonia solanacearum*). At stem; disease begins with the lower leaves which will roll due to lack of water and clearly prominent in the morning. The base of the plant and the new growth will appear succulent and leaf roll will spread to the upper parts, ant the whole plant. At a severe stage, the plant will fold over and will come off the ground easily

when pulled. Finally the plant dries up, succumbs and dies. The disease also causes rhizomes and roots parts to become succulent too. In particular, the young rhizome does not only become succulent but also the flesh becomes transparent glassy. Feeding roots indicated dark brown rot. As disease progresses, rhizomes and roots become darker and emit a rotting smell. Eventually, when squeezed, the rhizome will exude milky white liquid through cracks. Transmission occurs through infected rhizome, scraps and pieces of plant parts debris previously infected and leftover. Soil and water will harbor the pathogen and eventually enter into the tubers through surface cuts, natural inlets or otherwise. The bacterial pathogen is most damaging in a soil having pH of 6.8 and is less damaging at pH 4.3. Infection period; infection will be severe in the rainy season is full of moisture and has temperature of 25-35^{o}C, The presence of nematodes will exacerbate the problem. (Department of Agriculture, 2006).

Insects: Fortunately, very few insects infest curcuma. The most common ones are leaf roller and grasshopper that damage the leaves and can easily be controlled by synthetic pyrethroid such as cypermethrin. Red spider mites cause spotting to the colorful bracts and can be controlled by propagate and dicofol. Wetting agents should be added to every spray.

Nematodes: Nematode is an important factor in spreading the wilt disease and is commonly found in sandy soil. Control manure can be made by rotate crops that are not susceptible to the disease, such as peanuts, lemon grass, kenaf but not chili, egg plant, tomato, cucurbits, mungbean, coriander, okra, celery, kale and papaya, either before or after planting curcuma. Addition of organic matters, such as manure, fresh manure and humus improve the physical properties of the soil, as well as, increase microorganisms that are antagonistic to nematodes. Collect nematode infected rhizome and roots in order to dispose of the the planting land by burying or burning (Department of Agriculture, 2006).

Harvesting

Cultivation of curcuma for cut flower or for rhizome productions have to be done separately. Rhizomes for planting must have the floral buds nipped off, therefore there won't be any flowers at harvest.

Harvesting of Flowers: Cut the flower when there are 4-6 bracts opened and two flowers bloomed. Cut only in the morning, but the plants must be watered adequately before cutting. Hold the base of peduncle low down with the fingers, twist and pull up with leave attached. Soak in clean water and cover the flowers with a plastic bag. Before transportation the basal end of the peduncle should be wrapped in cotton wool and dipped in disinfectant solution of 50-100 mg Clorox per liter of water. Pack it in a plastic bag with the flower end opened then place it in a carton box, and store in a 15^{o}C cool room to transportation.

Harvesting of Rhizome: The growing curcuma bed has to be well watered one day prior to harvesting. Dig up the rhizomes when the leaves are still attached to indicating their presence. Wash out the soil. Separate the rhizomes from the cluster with a pair of disinfected (70% alcohol) pruning shears, dress them by clipping out the unhealthy roots and rhizomes. Group the rhizomes according to their size, then treat then with the insecticide and fungicide solution. Place the healthy ones in a basket and wash out the soil with water spray. Grade the individual rhizomes according to size and then treat them with an insecticide and fungicide solution. Allow them to dry out in the shade for 14 days and then store in a well ventilated and shaded place (Department of Agriculture, 2006).

In seasonal and off-season planting

In season planting can be made in three periods, namely:

Early-season Planting: Rhizome must be pre-germinated before planting by soaking them in water to stimulate shoot emergence. Planting starts from February to March. Early flowering occurs in May and sale of rhizomes can begin in December (Department of Agricultural and Extension, 2005).

Mid-season Planting: Planting is made during April and May depening on normal rainfall. *C. alismatifolia* will flower during July and August (about 2 ½ -3 months after planting) and will dormant during November and December in the cool season. Rhizomes are harvested in December and sold for export in January (Department of Agricultural Extension, 2005).

Late-season Planting: Rhizomes are planted from late June to July. The advantage of this late planting is that the soil had adequate time to dry in the sun, and

to control soil borne pathogens, resulting in minimizing the risk of infections but the rhizome has only 5-6 months of accumulate reserve food. Management of adequate water and fertilizer is crucial. The harvested rhizome has short swollen root that store food, which is the most suitable for export. The rhizome must be carefully kept in order to avoid drying out before planting (Department of Agricultural Extension, 2005; Vichailak, 2006).

Off-season planting:

The objectives of the off-season planting are to: *(i)* avoid surpluses of the in-season cut flower or rhizome production, to avoid danger of epidemics, and to increase farmer's income, *(ii*) satisfy customers at the time of their needs; and *(iii)* guarantee employment throughout the year. In *Zingiber mioga*, experimental commercial planting is being undertaken in Australia and New Zealand in the hope of supplying the lucrative Japanese off-season with high quality products (Kamenetsky, 200). In *C. alismatifolia*; in-season flowers are produced during the rainy season (from June to August), requiring longday condition. There are no flower developed after September when shortday condition commenced. All of the above ground parts wither and die down, and rhizomes enter dormancy period until next rainy season. Providing additional light can break such dormancy. The most effective is 3 hours of intermittent light in the middle of the night. It should be started soon after daylength is shortened (21th September). In this way, plants will continue to produce flowers all the way up to the New Year day, provided that enough humidity and nutrients are given (Chomchalow, 2007). The off-season flowering of *Curcuma alismatifolia* were studied at Chiang Mai province in Thailand. Plants were grown under different night break treatments combined with varried planting dates, i.e., August 9, September 9, October 9 and November 9. Plant growth and flower qualities were similar with and without the night break treatment on planting date of August 9. However, delayed growing in September to October needed the night break treatment to promote flowering and maintain flower qualities (Ruamrungsri *et al*., 2006).

2.5 Physiology of rhizome and contractile root formation

Rhizome formation: Leopold (1964) reported that the bulb formation had four steps: The first step was called "Induction". It was to construct and translate the

hormone. Next, the second step, so called “Differentiation” was the growth of tissue to becomestorage part tissue. The third step, called “Development” which was enlarging the size of rhizome or bulb. The final, “Ripening” step, was reaching the full size of rhizome or bulb and changes the biochemistry in rhizome or bulb. Each rhizome of curcuma has many lateral buds, which grows above ground. In general, the outdoor growing period is seven to eight months, and flowering takes place for two to three months. Flowering initiates new rhizome formation (Paz and Kuehny, 2007). In potatoes, tuber formation is a complex developmental process that requires the interaction of the environmental, biochemical, and genetic factors (Ewing and Struik, 1922).

Contractile root formation: The major function of contractile roots appears to be the positioning of the storage organ at a level in the soil for optimal growth and survival of the species. Rimbach (1929) has shown that contractile roots are present in 450 species among 315 generas of gymnospermous, monocotyledonous, and dicotyledonous families. Roots contraction can occur in tap, lateral, or adventitious roots. In *Crocus sativus*, the total number of basal roots are unaffected by planting depth, but the number of contractile roots are decreased in corms planted at 20 cm compared to those at 5 cm (Negbi *et al.*, 1989). In *Gladiolus*, the greatest numbers of contractile roots are produced at 5 cm planting depth and the number decrease in corms placed at 0, 15, and 30 corm (Iziro and Hori, 1963). Halevy (1986a,b) also found that the number of contractile roots decreased when the planting depth of *Gladiolus* corms increased. Moreover, he found that only small- and medium-sized corms produced contractile roots. Large corms did not produce contractile roots at any planting depth, but divided into two or more smaller corms in which it was needed to elucidate the control mechanism of cellular contraction.

2.5.1 Environmental factors affecting the rhizome formation

Usually, bulbous plants form bulbs and go to dormancy under unappropriate temperature, day length and dry conditions. Because the induction of dormancy in bulbous plants always follows bulb formation, even now the relationship between the induction of bulb formation and bulb dormancy is yet unclear (Machara *et al*., 1987). In potatoes, tuber formation is the determinant process in the formation

of harvestable products of potatoes (Struik *et al.*, 1999). The mechanisms of dormancy induction in these geophytes are poorly understood, because there are few plants in which dormancy induction was reported to be strictly regulated by environmental factors; photoperiod and temperature (Ewing and Struik, 1992). Ornamental gingers and curcuma are most commonly propagated by rhizomes-underground storage organs that serve as a major source of water and carbohydrates (Paz and Kuehny, 2007). In contrast to their native habitats, rhizome in temperate climates enter dormancy in winter in response to short days and low temperature (Paz and Kuehny, 2007).

2.5.2 Effect of day length or photoperiod

Daylength and photoperiod is one of the most important environmental stimuli regulating many physiological and developmental processes including flowering, seed germination, asexual reproduction and formation of storage organs in higher plants (Thomas and Vince-Prue, 1997). Shanmugand and Muthuwamy (1974) found that long day condition increased N, K, Ca, Mg and carbohydrate concentration in leaves of *Chrsysanthemum indicum*. Kuehny *et al*. (2002) reported that plant height of *C. alismatifolia* increased wiht length of photoperiods up to 20 hrs. The number of leaves also increased at 16 to 20 hrs of photoperiods. Perception of day length is accomplished by leaves and one or more stimuli are then translocated to the responsive regions for growth and development induction (Thomas and Vince-Prue, 1997). In *Achimenes*, rhizome development seems to be correlated to shoot growth. Daylength hardly influences number of rhizome, however, in some cultivars the number and fresh weight of rhizome increase in short daylength (Vlahos, 1991). It is well known that growth of plants is affected by both external and internal factors, e.g. by light, water, nutrients, hormones etc. (Lawlor and Lawlor, 1995). The formation of certain plant organs, including tubers, bulbs and flower buds, is controlled by photoperiod. Potatoes (*Solanum tuberosum* L.) and Jerusalem artichoke (*Helianthus tuberosus* L.) tubers are formed under short days (Koda and Okazawa, 1988). Tuberization of potatoes plants is strongly influenced by day length, in which short day in general promoting tuber formation (Ewing, 1995). Under conditions of a short-day photoperiod and cool temperature, a transmissible signal is activated that initiated

cell division and expansion and a change in the orientation of cell growth in the subapical region of the stolon tip (Ewing and Struik, 1992; Xu *et al*., 1998).

Short days (SD) (in fact long nights) are tuber-inducing in tuber-bearing *Solanum* species, provided that the night temperature is adequately low. Daylength is detected in the leaves of the potato plants. Under SD conditions a tuber-inducing factor is probably synthesized or activated in the leaves and transported basipetally via the phloem (Gregory, 1956). Aamlid (1992) reported that in *Poa pratensis* L., rhizome formation and elongation were stimulated by long days, and more strongly, by high day temperature, but a greater proportion of the rhizomes formed aerial tillers in short days.

2.5.3 Effect of light quality

For most geophytes, rooting takes place in the absence of light. No marked effects have been observed in which nonplanted and/or rooted bulbs of many genera are exposed to light (De Hertogh, unpublished). Red light is important for the development of the photosynthetic apparatus of plants and may increase starch accumulation in several plant species by inhibiting the translocation of photosynthates out of leaves (Saebo *et al*., 1995). Thomas and Vince-Prue (1997) revealed that red light (R) was more effective than other wavelength regions such as blue, green or far-red (FR) light in night break treatment of potatoes and begonia. Giving a red light pulse in the middle of dark period to plants grown in short day led to inhibition of flowering in short day plant, promotion of long day plant and inhibitor of tuberization.

2.5.4 Effect of temperature and humidity

Temperature: Hartsema (1961) clearly established that temperature was a critical factor in the control of growth and development of flower bulbs. This was not only true for floral development, but also for root growth. Temperature is the primary factor that affects ginger's sprouting and growth, and it is commonly used to hasten or delay its development (Paz and Kuehny, 2007).

Humidity: Moisture interacts markedly with temperature and strongly influences the development of certain root and foliage diseases. The importance of these interactions depends to a large extent on the species and/or cultivar. Most flower

bulbs require excellent drainage either in the field or in the containers. This is related to the aeration of the soil or planting medium and moisture content. Blaauw (1938) showed that the level of water table had a significant effect on root development of *Tulipa*, *Hyachinthus*, and *Iris hollandica*. Generally, a water level of 60 cm produced the highest root dry weight.

2.5.5 Effect of plant growth regulator

Halevy and Biran (1975) have reviewed most of the plant growth regulator research on tuberization of *Dahlia*. They concluded that daminozide and ethephon promoted the tuberization process in whole plants and inhibited it in budless cuttings. Abscisic acid (ABA) enhanced, while gibberellic acid (GA_3) inhibited, tuberization regardless of the organs used. Short days increased the levels of endogenous ABA and endogenous ethylene. They reached the peak between the second and third week after the state of short days. Under the experimental conditions, hormones are used with Dahlia cuttings to promote rooting, but no concentration ranges are reported (Langeslag, 1988).

2.6 Rhizome formation *in vitro*

Propagation through auxillary bud multiplication is an easy and safe method in order to obtain uniformity, and it also assures a consistent production of true-to-type plants within a short span of time. Currently, interest *in vitro* propagation is directed at rhizome or storage organ induction for efficient acclimatization and to minimize injury during transportation. Microrhizomes have good potential to be used by commercial growers as they are disease-free planting materials, can be produced *in vitro* irrespective of seasonal fluctuations and are easily transferable and sown like seeds. In addition to that, these organs be easily can transported across the national borders, as they do not require any culture medium or any other special measures. Only a few reports are available and are still in progress (Sunitibala *et al*., 2001). The initiation of other storage organs *in vitro*, such as *Solanum* tubers and bulbs, corms of several species, and rhizome of ginger have shown requirements for growth regulators (Ewing 1987; Hussey, 1982). Nayak and Naik (2005) reported that factors,

such as concentration of sucrose and BA in the medium, as well as, photoperiod and their interaction, were found to have a significant effect in the induction of microrhizomes. Sucrose was the most effective in rhizome formation, followed by photoperiod and BA in the medium. The concentration of sucrose (6-8%) is one of the important factors for rhizome formation *in vitro* of *Globba malaccensis* (Chidburee *et al*., 2003). In *Dioscorea bulbifera*, 8% of sucrose concentration on MS medium induced rhizome formation (Forsyth and Staden, 1984). Garner and Blake (1989) also improved tuberization in potatoes by increasing sucrose level from 4 to 8%. Marlin (2005) showed that the optimal microrhizome formation of ginger was stimulated at 3% of sucrose.