ANALYSIS

Vol. 21, Issue 67, 2020

ISSN 2319–5746 EISSN 2319–5754

Species

Break-down of sphingophily and its affect on sexual reproduction in *Crinum latifolium* L. (Amaryllidaceae), a dry season bloomer in the Araku valley of northern Eastern Ghats, Andhra Pradesh

Solomon Raju AJ[1], **Lakshminarayana G**[2], **Ch. Prasada Rao**[3], **Dileepu Kumar B**[4], **K. Venkata Ramana**[5], **Santhi Kumari M**[6], **Prasad KBJ**[7]

[1,4-7]Department of Environmental Sciences, Andhra University, Visakhapatnam 530 003, India

[2]Department of Environmental Sciences, Gayathri Vidya Parishad College for Degree & P.G. Courses (Autonomous), M.V.P. Colony, Visakhapatnam 530 017, India

[3,5]Department of Botany, Andhra University, Visakhapatnam 530 003, India

[4]Department of Botany, M.R. College (Autonomous), Vizianagaram 535 003, India

✉**Corresponding author**:
A.J. Solomon Raju, Mobile: 91-9866256682, email:solomonraju@gmail.com

Article History
Received: 07 January 2020
Accepted: 20 February 2020
Published: February 2020

Citation
Solomon Raju AJ, Lakshminarayana G, Ch. Prasada Rao, Dileepu Kumar B, K. Venkata Ramana, Santhi Kumari M, Prasad KBJ. Break-down of sphingophily and its affect on sexual reproduction in *Crinum latifolium* L. (Amaryllidaceae), a dry season bloomer in the Araku valley of northern Eastern Ghats, Andhra Pradesh. *Species*, 2020, 21(67), 120-125

ABSTRACT

C. latifolium is a deciduous perennial bulbous herb and blooms during March-May. It is functionally hermaphroditic, dichogamous and herkogamous. The floral characteristics such as white flowers, perianth tube with copious nectar, sweet fragrance and crepuscular anthesis characterize the syndrome of sphingophily but the flowers were never visited by hawk moths or other insects and fruit set is totally lacking. The absence of pollinator activity and lack of fruit set indicate that the plant is an obligate-outcrosser. But, bulbils as asexual mode of reproduction is functional for its multiplication and population expansion. However, asexual reproduction is deleterious for the long-time survival and sustainability of the plant species. Nevertheless, it can be used as a valued dry season blooming ornamental geophyte due to its attractive white, showy and sweet fragrant flowers.

Key words:

Crinum latifolium, geophyte, ornamental, hermaphroditism, dichogamy, herkogamy, sphingophily.

1. INTRODUCTION

The genus *Crinum* belongs to sub-tribe Crininae, tribe Amaryllideae, sub-family Amaryllidoideae of the family Amaryllidaceae (APG IV 2016). It has wide geographical distribution throughout the tropics, subtropics and warm temperate regions of the world (Mabberly 1990). The genus name originated from the Greek word "Krinon" meaning white lily and is related to a group of mostly southern African endemic genera constituting the Amaryllidaceae (Meerow and Snijman 1998). *Crinum* genus comprises of about 130 species distributed in Africa, America and southern Asia and Australia but most of the species are distributed in Africa where twenty two species of this genus are endemic. The species of this genus occupy different habitats such as seasonally dry places, short-lived water pools, river banks and coastal areas (Snijman and Linder 1996). They are valued as ornamentals due to their showy flowers and also traded for traditional medicine (Refaat et al. 2012).

In Amaryllidaceae, moth pollination is an important strategy in several genera that produce white, long-tubed crateriform flowers (Grant 1983). In the genus *Crinum*, the flowers exhibit the characteristics such as long perianth tube, strong sweet fragrance, dusk to evening anthesis conform to sphingophily (Kwembeya et al. 2007). *Crinum* species with white and sweet scented flowers are pollinated by butterflies and honey-sucking birds (Singh 1981). *C. variabile* is hermaphroditic, protandrous, out-crossing and displays the characteristics of sphingophily. They include the white perianth with a slender long tube containing abundant nectar, heavy sweet fragrance and crepuscular anthesis. This species is pollinated by the hawk moth, *Hyles lineata* in the Cape region of South Africa (Manning and Snijman 2002). Likewise, the hermaphroditic species, *C. flaccidum* with crepuscular anthesis is also pollinated by hawk moths in Australia (Howell and Prakash 1990). *C. erubescens* is a hermaphroditic, outcrossing, protandrous and crepuscular in anthesis; it is pollinated at night by hawk moths (Manasse and Stanton 1991). In *C. flaccidum* and *C. variabile*, the honey bees collect pollen from freshly dehisced anthers but do not visit older flowers with receptive stigmas indicating that they are unlikely to play an important role in pollination (Howell and Prakash 1990; Manning and Snijman 2002). *C. bulbispermum* is a hermaphrodite and pollinated by the hawk moth, *Agrius convolvuli* in South Africa (Laura and Johnson 2005). *C. latifolium* is native to tropical Asia but distributed throughout Sri Lanka, India and Myanmar, Malaysia and Africa (Afroz et al. 2018). Its taxonomic characters are briefly provided by Yakandawala and Samarakoon (2006) but there is no information on its floral biology and pollination ecology despite its common occurrence across India and use as ornamental bulbous herb. Therefore, the present study is contemplated to provide the floral and pollination aspects of *C. latifolium* growing abundantly on a slanting rocky terrain supporting a few sparsely distributed tree species with seasonal sparse herbaceous vegetation near Chaparai, a picnic spot in Araku valley which is a part of northern Eastern Ghats forest of Andhra Pradesh, India.

2. MATERIALS AND METHODS

The Chaparai location (18.2924°N, 82.7977°E, 1168 m) is a beautiful water cascade with its endless streams that cut across big rock formations and surrounded by forest area in the Araku valley of northern Eastern Ghats forest of Andhra Pradesh, India. The study area is about 15 km away from Araku valley and located opposite to Chaparai water cascade which is separated by Araku-Paderu road. The study location is characteristically a slanting rocky terrain consisting of a few sparsely distributed tree species and herbaceous flora that thrive well only during rainy season. However, a few grass species grow throughout the year. In this location, *Crinum latifolium* L. grows abundantly and appears almost as pure mono-stands with flowering during dry season. These mono-stands were used to record flowering, floral biology and pollination aspects during April-June of 2018 and 2019. With previous

knowledge on the flowering season of this species, regular field visits were made about two months prior to commencement of flowering and continued until two months after the cessation of flowering. During flowering season, the plant life form, leaf and flower aspects were observed in detail with reference to sexual system, pollination mode and pollination syndrome and recorded systematically. The inflorescence type, the number of flowers produced per inflorescence, flower-opening time and flower lifespan were recorded. Ten mature buds on five plants were tagged and followed to record the daily schedule of flower-opening time. The same buds were followed to record the time and mode of anther dehiscence. Ten mature buds were tagged, bagged and followed for three days to measure the volume of nectar secreted by them. Later, the average volume of nectar produced per flower was recorded and expressed in µl. Simultaneously, nectar sugar concentration was also recorded using a Hand Sugar Refractometer (Erma, Japan). The stigma receptivity was observed by H_2O_2 test as given in Dafni et al. (2005). The observations for flower-foragers were made from morning to evening at weekly intervals throughout the flowering season. But, the flowers were never foraged by any insects. Fruiting aspects were not recorded due to lack of fruit set by the entire population. Keeping the absence of foraging activity of insects on the flowers in view, the entire study area was surveyed to note whether insects were using the flowers of other species in the surrounding vegetation. But, co-flowering plant species and insect species were totally absent during the flowering season of *C. latifolium* at the study area.

Figure 1. *Crinum latifolium*: a. Habitat, b. Vegetative phase, c-f. Anthesis stages, g. Habitat after natural fire, h. Re-growth from root stock after natural fire.

3. RESULTS

Crinum latifolium is a deciduous rosette-like stout perennial herb that springs up from an underground bulb, produces leaves and flowers during March-May (Figure 1a,b). The leaves are basal, typically long, strap-shaped and arranged spirally. The peduncle is about 1 m long, emerges from the bulbous base and tipped with an involucre comprising of two contortedly arranged bracts called spathes. The spathes are fleshy, vigorous and thick prior to opening and wither during anthesis appearing dry and papery. An umbel-like inflorescence consisting of 10-12 buds emerges out of the spathes; all buds are open within 2 days. The buds are pedicellate, green and 3-4 cm long. The anthesis is crepuscular, the perianth part gradually bulges and open during 1500-1700 h exposing the sex organs (Figure 1c-f). The stamens and stigma are spatially separated with the stigma extending beyond the height of the stamens. The mature buds begin nectar secretion and continues its production until the evening of the 2nd day of flower life. Individual flowers produce a total volume of 2.3 to 3.1 µl of nectar with 21-27% sugar concentration. The flowers are sweet scented, red to pink to white, funnel-shaped and bisexual. The perianth tube is short and the upper lobes are reflexed than the lower lobes

enabling the flower strongly zygomorphic. The stamens are six and inserted at the throat of the perianth tube; their filaments are long, free, filiform and spreading with 10-12 mm long linear dorsifixed, versatile, introrse dithecous anthers with longitudinal dehiscence taking place prior to the attainment of stigma receptivity indicating strong protandry. The pollen grains are monads, heteropolar, unicolpate, pseudo-operculate and elliptic with spinulose exine surface. The ovary is syncarpous with three carpels and ovules arranged on axile placentation. The style is greenish to white at the base, purple distally, filiform, declinate and ends with purple capitate stigma which attains receptivity on the morning of the following day and remain receptive until the dusk hours of the 3rd day. But, flowers remain open throughout their lifespan and wither by the dawn of the 4th day.

In the habitat of *C. latifolium*, herbaceous plant species growing along with this plant species are only grasses. The tree species growing in the same habitat were either in leafless or leaf-flushing phase without any flowering. Further, the areas nearby also displayed the same situation. The flowers of *C. latifolium* were never visited by any insect species during day and night. Field observations made during the flowering season of this plant species showed that the habitat and its surroundings were totally devoid of any flower-visiting insect species because of lack of floral resources to support their forage requirements. The study found that *C. latifolium* is experiencing the non-availability of its pollinators. None of the plants in the study area set fruit indicating that this species is an obligate-outcrosser. In this area, the plant multiplies by producing bulbs underground and expands its area of occupancy and re-growth also occurs from sub-surface root stock, which was found to be very quick following natural fire (Figure 1g,h). Therefore, the sexual mode of reproduction is totally absent in *C. latifolium* growing in this area.

4. DISCUSSION

Snijman and Linder (1996) reported that *Crinum* species are very versatile to grow in different habitats. They grow in seasonally dry places, ephemeral pools, rainforests, river banks and coastal areas. In this study, *C. latifolium* is found to grow in slant rocky terrain with little soil content with a few sparsely distributed tree species and seasonal herbaceous flora. Hutchinson (1964) reported that *Crinum* species are perennial herbaceous plants and bloom during May, June or August. Manning and Snijman (2002) reported that *C. variabile* flowers in late summer towards the end of the dry season in the Cape region of South Africa. Manasse and Stanton (1991) mentioned that *C. erubescens* flowers during August-December as these authors carried out pollination experiments at that time. Afroz et al. (2018) reported that *C. latifolium* flowers during May-September in Bangladesh. At the study area, *C. latifolium* is a deciduous perennial bulbous herb and blooms during March-May where there co-flowering plant species do not exist. Each plant produces a single pedunculate umbel-like inflorescence with more than ten flowers that open within two days. The flowers emerge from a pair of contortedly arranged bracts resembling spathes.

Crinum variabile with a slender white perianth with basal tube containing plentiful nectar, heavy sweet fragrance and crepuscular anthesis displays the syndrome of sphingophily and accordingly it is pollinated by the hawk moth, *Hyles lineata* in the Cape region of South Africa (Manning and Snijman 2002). *C. flaccidum* in Australia, *C. erubescens* in Panama and *C. bulbispermum* in South Africa, with similar sphingophilous characteristics have been reported to be pollinated by hawk moths (Howell and Prakash 1990; Manasse and Stanton 1991; Laura and Johnson 2005). In the present study, *C. latifolium* also exhibits similar sphingophilous characteristics but it is not visited by hawk moths or even by honey bees as reported in *C. variabile* (Manning and Snijman 2002). There are no co-flowering plant species in the habitat of *C. latifolium* during dry season indicating that this species alone does not support the nectar requirement of hawk moths and the absence of their foraging activity indicate that the habitat does not provide the larval food plants for hawk moths so that the adult ones can use appropriate flowers as and when available in the same habitat. In this context, it is pertinent to state the finding by Manning and Snijman (2002) that *C. variabile* in the Cape region is pollinated only by a single hawk moth species and there is a shortage of appropriate larval food plants for hawk moths. Therefore, sphingophilous pollination syndrome is not functional in *C. latifolium* in the absence of hawk moth foraging activity.

Crinum variabile, C. flaccidum, C. erubescens and *C. bulbispermum* have been reported to be hermaphroditic, weakly or strongly protandrous and sex organs spatially separated to promote out-crossing (Manning and Snijman 2002; Howell and Prakash 1990; Manasse and Stanton 1991; Laura and Johnson 2005). In the present study also, *C. latifolium* is functionally hermaphroditic with sexual functions temporally separated by strong protandry and sex organs spatially separated by the position of stigma beyond the height of declinate stamens. These sexual functional characteristics indicate that *C. latifolium* is typically an out-crossing species adapted for pollination by hawk moths. In the absence of hawk moth foraging activity, its flowers are not pollinated by any insect species and hence, there is no fruit set from any flower of any individual of this species. Yakandawala and Samarakoon (2006) based on taxonomic study reported *that C. latifolium* lacks fruit development in Sri Lanka, indicating that this plant species is also not pollinated by hawk moths in that country. These findings indicate that *C. latifolium* is an obligate out-crosser and there is absolutely a break-down of sphingophily which could be attributable to the non-availability of sufficient floral nectar from different floral species during dry season and to the shortage or non-availability of sufficient larval food plants for their breeding and multiplication

in the study region. Therefore, *C. latifolium* at the study region is left with the option of only asexual reproduction through bulbils for its propagation and population expansion but this reproductive mode is deleterious for its long time survival and sustainability.

Refaat et al. (2012) reported that *Crinum* species are valuable as ornamentals due to their showy and fragrant flowers, and also have importance in traditional medicine. The present study suggests that *C. latifolium* can also be promoted as an ornamental due to its white, showy and sweet fragrant flowers. Its flowering during summer season is an additional advantage because the plant with bright green foliage and flowers on a long peduncle is quite attractive and provides aesthetic joy. Therefore, it can be cultivated in urban parks, gardens and root-top gardens as a valuable ornamental geophyte.

5. CONCLUSION

C. latifolium is a deciduous perennial bulbous herb and blooms during March-May. Individual plants produce a single pedunculate umbel-like inflorescence with more than ten flowers. It is functionally hermaphroditic with sexual functions temporally separated by strong protandry and sex organs spatially separated by the position of stigma beyond the height of declinate stamens. The floral characteristics such as white flowers, perianth tube with copious nectar, sweet fragrance and crepuscular anthesis display the syndrome of sphingophily but the flowers were never visited by hawk moths or any other insect species and there is no fruit set. The absence of pollinator activity and lack of fruit set indicate that *C. latifolium* is an obligate-outcrosser but the break-down of sphingophily led to failure of fruit or seed set through sexual reproduction. But, the plant uses bulbils as asexual mode of reproduction for its multiplication and population expansion. However, the total reliability on asexual reproduction is deleterious for *C. latifolium* for its long-time survival and sustainability. Nevertheless, it can be used as a valued dry season blooming ornamental geophyte due to its attractive white, showy and sweet fragrant flowers.

Acknowledgement

We thank the Andhra University, Visakhapatnam, for providing all physical facilities to carry out this research work.

Authors contributions:

All authors contributed equally.

Funding:

This study has not received any external funding.

Conflict of Interest:

The authors declare that there are no conflicts of interests.

REFERENCE

1. Afroz, S.A., Rahman, M.O. and Hassan, M.A. 2018. Taxonomic revision of the genus Crinum L. (Liliaceae) of Bangladesh. Bangladesh J. Plant Taxon 25: 257-271.
2. APG 2016. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Bot. J. Linn. Soc. 181: 1-20.
3. Dafni, A., Kevan, P.G. and Husband, B.C. 2005. Practical Pollination Biology. Enviroquest Ltd., Ontario, 583pp.
4. Grant, V. 1983. The systematic and geographical distribution of hawk moth flowers in the temperate North American flora. Bot. Gaz. 114: 439-449.
5. Howell, G. and Prakash, N. 1990. Embryology and reproductive ecology of the Darling lily, Crinum flaccidum Herbert. Austr. J. Bot. 38: 433-444.
6. Hutchinson, J. 1964. The Genera of flowering plants. Vol. 1, The Clarendon Press, Oxford, 516pp.
7. Kwembeya, E.G., Bjora, C.S., Stedje, B. and Nordal, I. 2007. Phylogenetic relationships in the genus Crinum (Amaryllidaceae) with emphasis on tropical African species: evidence from trnL-F and nuclear ITS DNA sequence data. Taxon 56: 801-810.
8. Laura, A.S. and Johnson, S.D. 2005. The flower and the fly. Nat. Hist. Magazine Inc. March 2005.
9. Mabberly, D.J. 1990. The plant book. Cambridge University Press, 706pp.
10. Manasse, R.S. and Stanton, M.L. 1991. The influence of the mating system on seed size variation in Crinum erubescens (Amaryllidaceae). Evolution 45: 883-890.
11. Manning, J.C. and Snijman, D. 2002. Hawkmoth-pollination in Crinum variabile (Amaryllidaceae) and the biogeography of sphingophily in southern African Amaryllidaceae. South Afr. J. Bot. 68: 212-216.
12. Meerow, A. W. and Snijman, D.A. 1998. Families and genera of vascular plants. Springer-Verlag, Berlin, Vol. III: 83-110.
13. Refaat, J., Kamel, M.S., Ramadan, M.A. and Ali, A.A. 2012. Crinum: an endless source of bioactive principles: a review.

Part 1 - Crinum alkaloids: Lycorine-type alkaloids. Intl. J. Pharm. Res. 3: 1883-1890.

14. Singh, V. 1981. Taxonomy of Angiosperms. Deep and Deep Publications, New Delhi, 489pp.
15. Snijman, D.A. and Linder, H.P. 1996. Phylogenetic relationships, seed characters, and dispersal system evolution in Amaryllideae (Amaryllidaceae). Ann. Mo. Bot. Gard. 83: 362-386.
16. Yakandawala, D.M.D. and Samarakoon, T.M. 2006. An empirical study on the taxonomy of Crinum zeylanicum (L.) L. and Crinum latifolium L. (Amaryllidaceae) occurring in Sri Lanka. Cey. J. Sci. (Bio. Sci.) 35: 53-72.