Species

23(72), 2022

Monoecy and melittophily in *Cardiospermum halicacabum* L. (Sapindaceae)

Suvarna Raju P[1], Solomon Raju AJ[2]

To Cite:
Raju PS, Raju AJS. Monoecy and melittophily in *Cardiospermum halicacabum* L. (Sapindaceae). *Species*, 2022, 23(72), 326-330

Author Affiliation:
[1]Department of Health, Safety and Environmental Management, International College of Engineering and Management, Muscat, Sultanate of Oman, Oman
[2]Department of Environmental Sciences, Andhra University, Visakhapatnam 530 003, India

Corresponding author:
A.J. Solomon Raju,
Department of Environmental Sciences, Andhra University, Visakhapatnam 530 003, India
Email:solomonraju@gmail.com

Peer-Review History
Received: 15 April 2022
Reviewed & Revised: 20/April/2022 to 24/June/2022
Accepted: 27 June 2022
Published: 03 July 2022

Peer-Review Model
External peer-review was done through double-blind method.

ABSTRACT

Cardiospermum halicacabum propagates by perennial underground rootstock and by seed. It appears aggressively during rainy season but it extends its appearance until January. Root stock produces bushy growth, prolific leaf production, flowering and fruiting during wet and winter seasons. Seeds of the previous season germinate with the onset of wet season but they show leaf production and sexual reproduction events a bit later. The flowers are functionally unisexual although they have both male and female sex organs and characterize monoecious sexual system. Both flower sexes are borne on the same inflorescence. The monoecious sexual system facilitates only geitonogamy at plant level and xenogamy at population level. The flowers are pollinated by bees only and this plant species is melittophilous at the study site. Therefore, monoecious sexual system, mixed mating system and melittophily are functional and these three systems collectively contribute to the success of sexual reproduction in *C. halicacabum*. The ability of the plant to propagate from both seed and perennial root stock enables to invade different habitats presenting different environmental conditions.

Keywords: *Cardiospermum halicacabum*, monoecy, melittophily

1. INTRODUCTION

Cardiospermum is a genus of Sapindaceae family. It comprises of approximately 15 species of herbaceous climbers with tendrils distributed in the tropical and subtropical regions of America, India and Africa. The genus name has originated from two Greek words "*kardia*" and "*sperma*" which collectively mean heart-shaped seed (Ferrucci 1998; Ellis 1999). It is characterized by the production of unisexual flowers with a tetramerous corolla with scales adnate to the adaxial basal surface of petals, the presence of nectary with two or four protruding lobes, eight unequal stamens and schizocarp or capsular fruits (Solis and Ferrucci 2009). *Cardiospermum halicacabum* and *C. canescens* are distributed throughout India (Chetty et al. 2008). *C. halicacabum* is believed to be native to South and Central America but it is also distributed in the tropical regions of the Old World (Rojo and Pitarque 1999; Gildenhuys et al. 2013). It grows in different ecological settings but it prefers open places where sunlight directly strikes the foliage (Rojo and Pitargue 1999; Acevedo-Rodriquez 2005). It has gradually naturalized in

different habitats such as roadsides, pastures, forest margins, shrub lands and open lands (Wagner et al. 1999). *C. halicacabum* is reported to be raised as an ornamental for its papery capsules (Acevedo-Rodriquez 2005). *C. halicacabum* is bisexual and pollinated by different insects comprising of bees, wasps, flies and butterflies (PIER 2015). But, Rama Das et al. (1997) reported that *C. halicacabum* is monoecious and pollinated by bees, a wasp, a fly and a lycaenid butterfly. Solomon Raju et al. (2011) reported that *C. canescens* is pollinated by bees, a wasp, a hemipteran, and a pierid and a hesperiid butterfly. Viana and Kleinert (2006) noted that *C. integerrimum* is pollinated bees only. With this backdrop, the present study was conducted on *C. halicacabum* with reference to its sexual system, pollinators and pollination modes. The observations recorded are interpreted with the pertinent information as stated above.

2. MATERIALS AND METHODS

A wild patch of *Cardiospermum halicacabum* growing at Rushikonda, Visakhapatnam suburban area was used for this study conducted during May 2021 to January 2022. It is a herbaceous climbing vine which uses tendrils as support to climb the associated plant species and in the process affecting their proper growth and sexual reproduction as well. The timing of mature buds unfolding into flowers was recorded by tagging ten inflorescences on different plants. The floral structural characters and nectar production, the placement of flowers on the inflorescence and the traits of stamens and pistil were recorded in detail to evaluate the adaptability of flowers to probing flower-visitors which collect forage and effect pollination. The schedule of visitation to flowers by insect visitors was noted. The insect visitors included only bees which sought both pollen and nectar. Their flower approach, probing manner and their contact with floral sex organs was observed in the field to evaluate their role in pollination. Fruit characters are briefly mentioned.

3. OBSERVATIONS

Cardiospermum halicacabum is a perennial creeping and climbing many-branched vine. It uses bi-forked axillary tendrils for climbing on other nearby plants. The leaves are borne alternate and biternately compound, papery-thin with triangular outline and serrate margins; the terminal leaf let is larger than the lateral leaflets. The plant propagates by seed and by underground root stock; vegetative growth begins as soon as monsoon rains fall in May/June. The plants produced from seeds take 3-4 weeks to complete vegetative growth and initiate flowering and extend the same until January. The underground root stock produces new plants which initiate flowering early to those produced from the seed. In both types of plants, new branches and inflorescences add continuously until December/January. Therefore, aerial parts of the plants begin to wither and finally shed them to the ground. The flowers are borne in trichasial compound cymes which arise from leaf axils and each trichasial cyme collectively consisting of 9 flowers is subtended by two bracts which are modified into terminal tendrils. In each 3-flowered cyme, only a single bud matures at a time but once the trichasial cymes commence their flowering, it continuously produces flowers for 4-5 days. The flowers are pedicellate, small, milky white, odorless, zygomorphic and monoecious. In each 3-flowered cyme, both staminate (Figure 1e,f) and pistillate flowers are produced (Figure 1a,b); if the first flower is staminate then the other two flowers represent one staminate and one pistillate sex but if the first flower is pistillate then the other two flowers represent staminate sex only. The staminate and pistillate flowers are produced on the same day on different cymes of trichasial cyme. In both sexes, the calyx has four light green concave sepals in two rows, the outer row with two ciliate circular sepals and the inner row with two inner glabrous ovate sepals. The corolla has four free obovate whitish petals placed alternate to the position of sepals. Four scales (two anterior and two posterior) positioned inside the corolla cover the erect stamens and the pistil. The two anterior scales are connate basally and sparsely villous; they are white but their apical portion is yellow and possess a white, deltoid and hairy appendage which is deflected towards the anthers positioned on the posterior side. Two posterior scales are free throughout, white, sparsely hairy and lack appendages; they appear like a hood which encloses the stamens. In staminate flowers, the stamens are 8, free and vary in length which can be differentiated into long, medium and short ones. The long and short stamens are 3 each while medium stamens are 2. All eight stamens in staminate flowers are fertile and dehisce by longitudinal slits an hour after flower-opening while all eight stamens in pistillate flowers are not fertile, inconspicuous, attached to the ovary lobes basally and do not dehisce at all throughout flower-life. The pollen grains are monads in staminate flowers (Figure 1g). In both flower sexes, the filaments of stamens are hairy. The ovary is a rudimentary pistillode in staminate flowers while it is trigonous, hairy with 3 carpels which are united and each carpel is 1-ovuled in pistillate flowers (Figure 1d). The style is short and columnar with 3-lobed densely villous stigma (Figure 1c). A nectary disc with 2 broad and 2 small glands is present at the flower base. The nectar secreted by this disc is escorted by the erect anterior and posterior scales. The fruit is an inflated dehiscent spherical capsular balloon which is 3-loculed and each locule with one black hard seed with white heart-shaped hilum; it is dispersed easily by wind and also by water.

ISSN 2319–5746 EISSN 2319–5754 I OPEN ACCESS

Figure 1. *Cardiospermum halicacabum*: a. Pistillate flower, b. Position of stamens and 3-lobed stigma in pistillate flower, c. Pistil, d. Ovules, e. Staminate flower, f. Close-up view of stamens, g. Pollen grain, h. *Apis florea* collecting nectar, i. *Trigona iridipennis* collecting pollen, j. *Ceratina* sp. collecting pollen.

The flowers were foraged exclusively by 3 species of bees, namely, *Apis florea* (Figure 1h), *Trigona iridipennis* (Figure 1i) and *Ceratina* sp. (Figure 1j) for pollen and nectar from 0800 h to 1700 h. The yellow portion of the anterior scales against white portion of all scales and white petals is quite prominent and acts as nectar guide for the probing bees. The bees visited both flower sexes indiscriminately for forage collection; their visits to staminate flowers were rewarded with both pollen and nectar while their visits to pistillate flowers were rewarded with only nectar because the anthers are indehiscent. Their indiscriminate visits to both flower sexes invariably effect either self- and/or cross- pollination.

4. DISCUSSION

Cardiospermum halicacabum is a seasonal climber which appears during rainy season but flowering and fruiting extends into January. The inflorescence is a compound 9-flowered trichasial cyme in this species but it is a 6-flowered dichasial cyme (Solomon Raju et al. 2011). The flowering pattern of the trichasial cyme with gradual anthesis over a few days is an indication of "steady state" flowering as stated for Bignoniaceae members by Gentry (1974). PIER (2015) reported that *C. halicacabum* is hermaphroditic. In the present study, it is found that *C. halicacabum* flowers are morphologically hermaphroditic but functionally unisexual. Because, the ovary is rudimentary in staminate flowers and the anthers are not dehiscent in pistillate flowers. Both staminate and pistillate flowers are produced in each inflorescence indicating that the plant is functionally monoecious. Monoecious sexual system is also functional in other species of Sapindaceae family, *Cardiospermum canescens* (Solomon Raju et al. 2011), *Sapindus emarginatus* (Subba Reddi et al. 1983) and *Allophylus serratus* (Solomon Raju et al. 1998). The occurrence of staminate and pistillate flowers within the same inflorescence or at plant level provides opportunities for self-pollination through geitonogamy and cross-pollination through xenogamy. Rama Das et al. (1997) reported that these two modes of pollination are functional in *C. halicacabum*. The number of staminate and pistillate flowers produced each day and the steady state of flowering pattern are the driving factors for the promotion of cross-pollination by flower-visitors. The flowers being white equipped with a nectar guide represented by posterior scales could attract only three species of bees at the study site although there are several other wild bees and insects present in the same site habitat. The bees recorded on *C. halicacabum* at the study site utilize this floral source regularly with concentrated forage collection activity during peak flowering phase at population level. Rama Das et al. (1997) reported that *C. halicacabum* is pollinated by the bees recorded in the present study and also by the wasp, *Vespa* sp., the fly *Eristalinus quinquestratus* and the lycaenid butterfly *Euchrysops cnejus*. PIER (2015) reported that *C. halicacabum* is pollinated by bees, wasps, flies and butterflies. But, in the present study, bees visiting the flowers of *C. halicacabum* collect the floral reward(s) indiscriminately from both staminate and pistillate flowers and in this process they invariably effect pollination. Solomon Raju et al. (2011) reported that *C. canescens* is pollinated by bees *Apis cerana, A. florea, Trigona iridipennis,* the wasp *Rhynchium* sp., the hemipteran *Lygaeus* sp., the pierid butterfly *Cepora nerissa* and hesperiid butterfly *Borbo cinnara*. Viana and Kleinert (2006) noted that *C. integerrimum* is pollinated bees of *Apis mellifera, Trigonoa spinipes* and *Xylocopa* sp. The present study and other studies on *Cardiospermum* species indicate that this genus is typically

ISSN 2319–5746 EISSN 2319–5754 I OPEN ACCESS

entomophilous. Therefore, the functionality of monoecy, mixed mating system and entomophily (melittophily) ensures the success of sexual reproduction in *C. halicacabum* and invasion of habitats with different environmental conditions.

5. CONCLUSIONS

Cardiospermum halicacabum is a herbaceous climbing vine which propagates by perennial underground rootstock and by seed. It is a prolific vine and appears aggressively during rainy season but it extends its appearance until January. Root stock produces bushy growth, prolific leaf production, flowering and fruiting during wet and winter seasons. Seeds of the previous season germinate with the onset of wet season but they show leaf production and sexual reproduction events a bit later. The flowers are functionally unisexual although they have both male and female sex organs. The flowers with rudimentary pistil and well developed fertile stamens with dehiscent anthers act as staminate sex while those with well-developed pistil and inconspicuous stamens with indehiscent anthers act as pistillate sex. Both flower sexes occur in 3-flowered cymes. The presence of both staminate and pistillate flowers on the same plant is the characteristic of monoecy and this sexual system does not facilitate the occurrence of autogamy but facilitates geitonogamy in addition to xenogamy. The flowers are pollinated by bees only and this plant species is melittophilous at the study site. Therefore, monoecious sexual system, mixed mating system and melittophily are functional and these three systems collectively contribute to the success of sexual reproduction in *C. halicacabum.* The ability of the plant to propagate from both seed and perennial root stock enables to invade different habitats presenting different environmental conditions.

Authors contributions

Both authors contributed equally.

Ethical approval

Cardiospermum halicacabum was observed Rushikonda, Visakhapatnam, India. The ethical guidelines for plants & plant materials are followed in the study for sample collection & identification.

Funding

This study has not received any external funding.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Acevedo-Rodriguez, P. 2005. Vines and climbing plants of Puerto Rico and the Virgin Islands. Contributions from the United States National Herbarium 51. Pp. 483.
2. Chetty, K.M., Sivaji, K. and Tulasi Rao, K. 2008. Flowering plants of Chittoor district Andhra Pradesh, 3.India. Students Offset Printers, Tirupati.
3. Ellis, B.W. 4.1999. Taylor's Guide to Annuals: How to select and grow more than 400 annuals, biennials, and5. tender perennials. Houghton Mifflin Company.
4. Ferrucci, M.S. 1998. *Cardiospermum cuchujaquense* (Sapindaceae), a new species from Sonora, Mexico. Novon 8: 235-238.
5. Gentry, A.H. 1974. Flowering phenology and diversity in tropical Bignoniaceae. Biotropica 6: 64-68.
6. Gildenhuys, E., Ellis, A.G., Carroll, S.P. and Le Roux, J.J. 2013. The ecology, biogeography, history and future of two globally important weeds: *Cardiospermum halicacabum* Linn. and *C. grandiflorum* Sw. NeoBota 19: 45-65.
7. PIER 2015. Pacific Islands Ecosystems at Rick, University of Hawaii, Honolulu, USA.
8. Rama Das, K., Subba Reddi, C., Solomon Raju, A.J. and Atluri, J.B. 1997. Sexual system and pollination ecology of *Cardiospermum halicacabum* L. (Sapindaceae). J. Palynol. 94: 333-341.
9. Rojo, J.P. and Pitargue, F.C. 1999. *Cardiospermum halicacabum* L. In: Plant Resources of South-East Asia No. 12(1): Medicinal and poisonous plants 1. L.S. de Padua, N. Bunyapraphatsara and R.H.M.J. Lemmens (Eds.), pp. 176-178, Backhuys Publisher, Leiden, The Netherlands.
10. Solis, S.M. and Ferrucci, M.S. 2009. Morpho-anatomy and ontogeny of the floral nectaries of *Cardiospermum*

ISSN 2319–5746 EISSN 2319–5754 I OPEN ACCESS

grandiflorum and *Urvillea chacoensis* (Sapindaceae). Ann. Bot. Fennici 46: 485-495.

11. Solomon Raju, A.J., Subba Reddi, C. and Rama Das, K. 1998. Temporal dioecism and pollination by wasps and bees in *Allophylus serratus* (Roxb.) Radlk. (Sapindaceae). Pl. Sp. Biol. 13: 1-5.
12. Solomon Raju, A.J., Ramana, K.V., Govinda Rao, N. and Varalakshmi, P. 2011. Monoecy and entomophily in *Cardiospermum canescens* Wall. (Sapindaceae), a medicinally valuable herbaceous vine. Curr. Sci. 101: 617-619.
13. Subba Reddi, C., Reddi, E.U.B., Reddi, N.S. and Reddi, P.S. 1983. Reproductive ecology of *Sapindus emarginatus* Vahl. (Sapindaceae). Proc. Indian Nat. Sci. Acad. 49: 57-72.
14. Viana, B.F. and Kleinert, A.M. 2006. Structure of bee-flower system in the coastal sand dune of Abaete, northeastern Brazil. Rev. Brasil. Entomol. 50: 53-63.
15. Wagner, W.L., Herbst, D.R. and Sohmer, S.H. 1999. Manual of the flowering plants of Hawaii. University of Hawaii Press/Bishop Museum Press, Honolulu, Hawaii, USA. pp.1919.

ISSN 2319–5746 EISSN 2319–5754 I OPEN ACCESS