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An ecological study of sexual reproduction in *Cissus quadrangularis* L. and *Cissus vitifolia* L. (Vitaceae)

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ABSTRACT

C. quadrangularis and *C. vitifolia* are deciduous woody climbing shrubs which grow preferentially in habitats with water stress conditions. These species shed the leaves during dry season and produce leaves, bloom and fruit during wet season. In both, umbellate cymes with several flowers serve as units of attraction for flower foragers. The wasp, *Sphex* sp. is the exclusive pollinator for *C. quadrangularis* while butterflies are the pollinators for *C. vitifolia*. The flowers in these species are bisexual and offer both pollen and nectar but only nectar is collected by the wasp as well as butterflies. *C. vitifolia* is a potential nectar source for butterflies in habitats where water stress conditions exist. The two species of *Cissus* are the potential candidates as bio-carpet to control soil erosion, increase soil fertility and facilitate certain immigrant taxa to grow and build up their populations. In Oman, *C. quadrangularis* is a noxious weed and poses a huge menace due to its invasive nature and climbing habit preventing the growth and survival of other plants in the habitats where it occurs. Its proliferation in the habitats of its entire distribution range in the world appears to be a consequence of the function of both vegetative and sexual modes. Similar situation appears to be true in case of *C. vitifolia* in the habitats where it occurs in India.

Keywords: *Cissus quadrangularis*, *Cissus vitifolia*, hermaphrodites, wasps, butterflies, entomophily.

1. INTRODUCTION

The genus *Cissus* is the largest among all 14 genera classified under Vitaceae family (Wen 2007; Wen et al. 2007). It comprises of 350 species distributed throughout the world (Eggl 2002). Wen (2007) mentioned that this genus has about 135 species in Africa, 85 in Asia, 12 in Australia and 65 in the Neotropics. In this genus, the species represent climbing shrubs, small trees and herbs. These life forms have a perennial root stock with nodes or joined stem producing watery juices (Maurizio et al. 2007). They display remarkable morphological diversity and characterized by well-developed and undivided thick floral disks, tetramerous flowers and 1-seeded fruits (Wen 2007; Chen and Manchester 2011).

C. quadrangularis is native to tropical Africa, Arabia, India and Sri Lanka but it is now naturalized in Africa, Thailand, Vietnam, Indonesia, Singapore, the Philippines, Cuba, Jamaica, the Lesser Antilles, the United States and on several islands in the Pacific and Indian Oceans (Brink and Achigan-Dako 2012; Acevedo-Rodriguez and Strong 2012; Yeo et al. 2012). This species is used for the treatment of osteoporosis, diabetes, obesity, heart problems, and also for the stimulation of muscle growth in athletes (Brink and Achigan-Dako 2012). *C. vitiginea* L. is distributed in India and Sri Lanka (Shetty and Singh 2000). Different authors reported on the occurrence of this species in India. Pullaiah et al. (1998, 2000, 2002) reported that *C. vitiginea* occurs in Andhra Pradesh, Karnataka and Maharashtra. Khanna et al. (2001) reported that *C. vitiginea* occurs in Chhatisgarh. Meena (2016) reported that *C. vitiginea* occurs also in Madhya Pradesh. The two species have not been investigated for their floral biology and pollination thus far and it is in this context, the present study is carried out to report on the aspects of sexual reproduction in *Cissus quadrangularis* and *C. vitiginea*.

2. MATERIALS AND METHODS

Cissus quadrangularis growing at Modavalasa open habitats in Vizianagaram District and *C. vitiginea* growing abundantly at Dharmagiri and Talakona areas of Tirumala Hills in Seshachalam Hill Range in Chittoor District, Andhra Pradesh, India, were used for the studied aspects during March-September 2021. Both species occur in semi-dry and dry habitats with well drained soils. The habitat conditions were observed with reference to the occurrence and growth pattern of these two species. The plant characters were briefly recorded. The leaf shedding, leaf flushing, flowering and fruiting aspects were recorded for both species. Further, the floral characters, nectar production and flower visitor activity in relation to their role in pollination were observed in the field, detailed and discussed with the related works. In Oman, *C. quadrangularis* is documented as a noxious weed because it does not allow other plants growing in the same area, especially Acacias by covering them entirely due to its climbing habit (Osman 2001). Based on the literature regarding the plant species distribution in Oman, it is documented that *C. vitiginea* does not occur in this country.

3. RESULTS

***Cissus quadrangularis* L.:** *Cissus quadrangularis* is an evergreen perennial climbing shrub with 4-winged thick and fleshy stem (Figure 1a). It climbs over shrubs and trees covering them almost completely and blocks light penetration restricting the proper growth and regeneration of local plants. It is a fast-growing aggressive species which spreads vertically as well as horizontally forming impenetrable monospecific stands which out-compete the local flora. It grows well in habitats with water stress conditions. It propagates by both sexual and asexual means; the former mode involves seed while the latter mode involves stem cuttings or fragments. Leaf shedding occurs during dry season while leaf flushing and flowering during rainy season. The leaves are petiolate, simple, thick, coriaceous, broadly ovate or reniform with obtuse apex. They appear at the nodes and each leaf has a tendril springing up from the other side of the node. The inflorescence is pedunculate with small and glabrous umbellate cymes; it produces small white, yellowish or greenish bisexual flowers (Figure 1b). The calyx is tubate with 4 inconspicuous reddish pink lobes. The petals are greenish yellow, ovate and recurved. The stamens are 4 with creamy white anthers. The ovary is glabrous, 2-celled and each cell with 2 ovules; the style is slender and subulate with a small stigma. The fruit is a globular succulent red berry with black smooth seeds.

The flowers are open during 0630-0830 h. The petals fall off from the calyx cup soon after anthesis. The anthers dehisce during mature bud stage by longitudinal slits. Nectar is secreted in traces by an 4-lobed nectar disc present at the ovary base. The calyx is persistent and houses the growing fruit while the stamens and stigma falls off any day during 4th to 7th day. The flowers were visited during day time exclusively by a wasp, *Sphex* sp. (Figure 1c) throughout the day for nectar collection. But, its foraging activity is more during forenoon period. Since the petals fall off soon after flower-opening, the calyx cup provides easy access to nectar for this wasp and the latter while probing the flower effect pollination. The wasp is a swift flier and collected nectar from several flowers of the same cyme in a single visit and hops between different cymes of the same and different conspecific plants.



Figure 1. *Cissus quadrangularis*: a. Habit, b. Inflorescence, c. *Sphex* sp. collecting nectar.



Figure 2. *Cissus vitiginea*: a. Plant form, b. Inflorescence, c. *Pachliopta Hector*, d. *Papilio demoleus*, e. *Cepora nerissa*, f. *Phalanta phalantha*

Cissus vitiginea L.: It is a climbing liana with blackish to reddish bark and densely pubescent branchlets (Figure 2a). Leaves are petiolate, simple, broadly cordate, 3-5 lobed with irregularly toothed margins and acute apex. The stem, leaves and inflorescence are densely covered with short gray hairs. It is leafless during dry season and produces new foliage following the first monsoon showers in late May/June. The flowering occurs during late July-late September at population level but individual liana blooms for about 4 weeks only. The flowers are pedicellate, pale green and borne in axillary pedunculate umbellate cymes consisting of 30-45 flowers as flat-topped clusters (Figure 2b). They are small, tetramerous and bisexual. The calyx is small, pubescent and cup-shaped with 4 inconspicuous lobes. The corolla is gamopetalous and 4 valvate light green petals with hood-like apex. The stamens are 4, fertile with slender green filaments and oblong introrse dithecous anthers. The ovary is bicarpellary bilocular syncarpous with 2 ovules in each locule. The style is short with minute sub-capitate dry type non-papillate stigma. Fruit is berry, blue black, pendulous and 1-seeded but occasionally it is 2-seeded.

The flowers are open during 0700-0830 h. The petals fall off from the calyx cup soon after anthesis. The anthers dehisce during mature bud stage by longitudinal slits. The stigma is receptive after anthesis and extends its receptivity until the evening of the next day. Nectar is secreted in traces by an annual disc present at the flower base, which is partly fused with the petals, stamens and ovary. The calyx is persistent and houses the growing fruit while the stamens and stigma falls off any day during 4th to 7th day.

The flowers were visited during day time exclusively by butterflies. The butterflies included 9 species representing Papilionidae, Pieridae and Nymphalidae. The papilionids were *Pachliopta Hector* (Figure 2c), *Papilio polytes*, *P. demoleus* (Figure 2d), *P. aristolochiae* and *Graphium agamemnon*. The pierids were *Catopsilia pyranthe*, *Cepora nerissa* (Figure 2e) and *Eurema hecabe*. The nymphalid was *Phalanta phalantha* (Figure 2f). Of these, the individuals of papilionid butterflies were more than those of other families at the flowers throughout the flowering season. The foraging activity of these butterflies gradually increased from morning to noon and gradually decreased towards the evening. This foraging trend was observed almost throughout the flowering season. The butterflies accessed the nectar with great ease due to exposure of nectar in cup-shaped flowers which was further facilitated by the fall of petals soon after anthesis. They landed on the top of the flowering cymes before inserting their proboscis into the flower for nectar collection during which only the proboscis of the butterflies contacted the stamens and stigma affect pollination. The butterflies tended to move frequently between clusters of flowers on the same plant and on different plants; this inter-plant nectar feeding activity was

considered to be promoting cross-pollination. The study showed that Papilionids and then Pierids play an important role in the pollination of *C. vitiginea*.

4. DISCUSSION

Cissus quadrangularis and *C. vitiginea* are deciduous perennial climbing plants which shed leaves during dry season and leaf flushing and flowering during rainy season. Both species grow well on well-drained soils in dry and semi-dry habitats in the study areas. De Santo et al. (1987) reported that *C. quadrangularis* is highly resistant to water loss and possesses parenchyma which stores water abundantly. Brink and Achigan-Dako (2012) reported that *C. quadrangularis* is cactus-like with succulent stems and uses Crassulacean Acid Metabolism photosynthetic pathway to minimize water loss and survive well in habitats with water stress and drought conditions. In the present study, both *C. quadrangularis* and *C. vitiginea* grow in semi-dry and dry habitats where soil is wet only during rainy season. Since water stress is acute during dry season, these species shed their leaves in this season and start producing leaves with the onset of rainy season and commence flowering at the at peak leaf flushing period. The flowering and fruiting events are tailored to suit the period of water availability. Similar situation is reported in *C. quadrangularis* growing in Africa (India Biodiversity 2018).

In both *C. quadrangularis* and *C. vitiginea*, the small flat-topped clusters of flowers borne in umbellate cymes collectively serve as units of attraction to flower-visitors. Despite the production of flowers massively and the flowers offering both pollen and nectar in both species, *C. quadrangularis* is visited and pollinated by only a single wasp species, *Sphex* sp. and *C. vitiginea* by a few butterfly species. The study indicates that *C. quadrangularis* despite producing attractive flowers is unable to be visited by different insect species and *Sphex* wasp is the sole pollinator for this species in the study habitat. On the contrary, *C. vitiginea* is visited and pollinated by Papilionid, Pieridae and Nymphalidae butterflies. As the flowers display the functionality of stigma receptivity for two days, the pollination occurs on both days when visited by butterflies. Since there are no other insects visiting the flowers of this plant species, it is treated to be typically psychophilous. Therefore, both the species of *Cissus* are insect pollinated and agree with the report by Rossetto et al. (2002) that Vitaceae members are usually entomophilous and it is reported in *Vitis vinifera*, *Leea indica*, *L. macrophylla*, *Cissus adnata* and *C. woodrowii*. Nevertheless, both *Cissus* species appear to be important for planting/cultivation in habitats with water stress conditions and also in ecologically degraded habitats so that soil fertility can be restored and soil erosion controlled. Finally, their growth in such habitats provides the preparatory ground for the natural immigration of taxa by seed to facilitate the return of biodiversity in such habitats.

5. CONCLUSIONS

C. quadrangularis and *C. vitiginea* are climbing shrubs and display phenological events in quick succession, one after the other, leaf fall during dry season and leaf flushing, flowering and fruiting during wet season. In both, the flowers are not very prominent but their presentation as umbellate cymes in aggregation attracts certain locally available insect species, the wasp, *Sphex* sp. to *C. quadrangularis*, and papilionid, pierid and nymphalid butterflies to *C. vitiginea*. The flowers in these species are bisexual and offer both pollen and nectar but only nectar is collected by the wasp and butterflies. The study indicates that both plant species are entomophilous. *C. vitiginea* is a potential nectar source for butterflies in habitats where water stress conditions exist. The preferential growth of these two species in soils with water stress conditions is an important adaptation and hence they can be used for soil erosion control, charging the soil with fertility and facilitating the growth and survival of immigrant taxa.

Authors' contributions

All authors contributed equally.

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Ethical approval

Cissus quadrangularis was observed from Modavalasa open habitats in Vizianagaram District and *C. vitiginea* was observed from Dharmagiri and Talakona areas of Tirumala Hills in Seshachalam Hill Range in Chittoor District, Andhra Pradesh, India. The ethical guidelines are followed in the study for species observation & identification.

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.

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