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Ecological aspects of sexual reproduction in Stinking Passion Flower, *Passiflora foetida* L. (Passifloraceae)

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ABSTRACT

Passiflora foetida is an annual or perennial herbaceous climber. The flowers are large, hermaphroditic, nectariferous and fragrance with specialized bracts that protect the buds and flowers from florivores and also protect fruits during their maturation stage from frugivores while trapping insects for use as nutrients. The flowers are protandrous which promotes cross-pollination, but the flowers also display spontaneous autogamy. The plant is characteristically melittophilous with carpenter bees as the most appropriate and effective pollinators. The floral functional traits such as hermaphroditism, nectar production, tri-fid style movements, protandry and mixed mating system encourage both self- and cross-pollination in the presence or absence of pollen vectors and hence, these traits enable the plant to grow as a highly successful invasive weed mainly in tropical regions.

Key words: *Passiflora foetida*, carnivory, carpenter bees, honey bees, melittophily.

1. INTRODUCTION

Passiflora foetida is an evergreen creeping vine native to Americas but it has been introduced into tropical parts in South Asia, Southeast Asia, Africa, Hawaii and Maldives. The genus name is a mix of two Latin terms *passio-onis* meaning passion and *flos-oris* which refers to the flower structure where the first Spanish missionaries saw the instruments of Passion of Christ. The species name is a Latin epithet which refers to the stinking smell of the crushed leaves. The species is commonly called Passion Flower which refers to the *passion* of Jesus Christ in Christian theology. *Passion* word comes from the Latin *passio* word which refers to *suffering*. Spanish Christian missionaries adopted the unique features of this plant as the symbols of crucifixion days of Jesus. In *P. foetida*, the pointed tips of palmate leaves are used to refer to Holy Lance, the tendrils to the whips used in the flagellation of Jesus, the ten sepals and petals to the ten faithful apostles excluding St. Peter, who denied Christ 3 times and Judas Iscariot, who betrayed him, the numerous white radial filaments in the flower to the crown of thorns, tulip-shaped ovary together with its receptable to the Holy Grail, 3 stigmas to 3 nails and the 5 anthers to 5 hammers/wounds of which 4 by the nails and 1 by the

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lance, white color with light bluish or purplish tinge to Heaven and Purity, and the open state of the flower for 3 days to symbolize the 3 years of Christ ministry. Carvalho et al. (2011) reported that farmers from northeastern Brazil treat *P. foetida* as a toxic plant (Gandhi & Sirisha, 2021). High levels of cyanide present in its fresh leaves is poisonous to goats if the latter ingests them, mostly during the dry period. Radhamani et al. (1995) documented that *P. foetida* bracts exude a sticky substance which contains digestive enzymes. The insects that land on its bracts die subsequently. The insectivorous function of bracts is reported to minimize predation of young flowers and fruits by insects. Yoshitaka and Nguyen (2007) reported that in *P. foetida*, the young leaves and plant tips are edible. In Vietnamese folk medicine, its dry leaves are used in tea making to get relief from sleeping problems and treat itching and cough problems. The fruits contain a mildly sweet and delicately flavoured bluish-white pulp which is edible. Despite the importance of *P. foetida* in traditional medicine and its toxic effects on goats and insects, it has not been investigated for its sexual reproduction and regeneration aspects. However, there is some piece-meal information on the pollinators of *P. foetida* distributed naturally in different geographic regions (Raju et al., 2021). Janzen (1968) reported that *Ptiloglossa* species act as pollinators in Central America. Gottsberger et al. (1988) reported that *P. foetida* is pollinated by *Centris* and *Xylocopa* in Brazil. Frankie et al. (1983) also reported that *Ptiloglossa* displays floral constancy to *P. foetida* flowers. Amela Garcia and Hoc (1998) noted that *P. foetida* is a self-compatible species and pollinated by *Ptiloglossa tarsata* and *Pseudaugochloropsis* sp. with the former species as main pollinator and the latter species as a rare pollinator in Argentina. Amela Garcia and Hoc (2001) reported that *P. foetida* is pollinated by medium-sized *Ptiloglossa tarsata*; it is the most important pollinator and its matinal activity is correlated with the early and short period of anthesis. Hammer (1987) reported that *P. foetida* is visited by *Apis mellifera* and *Xylocopa vanpuncta*; the former is not the effective pollinator because it collects pollen before the stigmas display receptivity to pollen while the latter is the effective pollinator because it is large-bodied which brushes the anthers and stigmas to access nectar. Kishore et al. (2010) reported that *P. foetida* is pollinated by *Apis mellifera* and *A. cerana* in Mizoram, India. With this backdrop, the present study made an attempt to provide floral traits, pollinators and ecological value of *Passiflora foetida* growing wild in Visakhapatnam, India.

2. MATERIALS AND METHODS

Wild mats of *Passiflora foetida* climber growing Kailasagiri, Visakhapatnam, India, were used for conducting the present study during July 2021 to October 2021. It is a herbaceous vine which uses taller plants for climbing, in the absence of which it either climbs over the smaller plants or lands on the ground covering the latter completely. The solitary mature buds produced from the axils of leaves were marked and followed to note the timing of anthesis and anther dehiscence. Since the flowers are highly specialized, the floral features were carefully observed and noted systematically in order to describe sexual system and pollination system. The flowers were also observed for nectar content. The flower visitors included only carpenter bees and honey bees. They were observed for their flower probing behaviour and the forage collected by them. At the same time, the role of these foragers was assessed to note them as main or supplementary pollinators. Fruit and seed traits and the role of floral bracts as defense for fruits during their growth, development and maturing phases were also recorded. Lastly, fruit dispersal and seed dispsersal aspects were briefly observed and the findings were accordingly recorded.

3. RESULTS AND DISCUSSION

Passiflora foetida is a herbaceous evergreen climber with white hairy, thin, wiry stems emitting unpleasant odor. It uses axillary tendrils which are produced at the axils of leaves for climbing. It displays either an annual or a perennial life cycle in permanently wet or moist habitats while it grows as an annual in habitats or locations with distinct dry season. It grows best in locations where taller host plants exist but in locations where such host plants do not exist, this plant forms mats over low-growing plants or over ground. The flowering is very prominent during wet season and sparse flowering other seasons subject to the availability moisture in the soil. In the same habitat, *P. foetida* var. *alba* also grows and it is distributed intermingled with each other but the variety *alba* is rare (Figure 1a-c). But, Da Costa Sacco (1980) noted that *P. foetida* blooms and fruits during October-February in Brazil while Deginani (1998) mentioned that this species flowers and fruits throughout the year with main flowering from September to May in Argentina. In *P. foetida*, the leaves are petiolate, palmate, 3-5 lobed, hairy and denticulate with setaceous hairs tipped with glands. The flowers are solitary, large, white, fragrant, hermaphroditic, nectariferous, protandrous and axillary in position with involucres of finely pinnatifid bracteoles containing capillary glandular segments. The calyx is short-tubed and saucer-shaped with 5 ovate to lanceolate sepals. The corolla consists of 5 free white petals with pinkish base and open completely in flat state. The stamens are 5, radiating, open downwards and the anthers produce abundant pollen. The ovary is globose, seated on androgynophore and extends into tri-fid style basally united and apically tipped with a clavate stigma (Vanderplank 1996). The stigma attains receptivity to pollen only during open state of the flower (Cox 1957). The stamens, tri-fid style and stigmas are seated above the white crown of

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fringy filaments with pinkish base. The study found that *P. foetida* flowers are open with sunrise and close by early afternoon. Knight and Sauls (1994) documented that in *P. foetida*, the style shows rhythmic movements by curvature during flower life. Based on style curvature trait, the flowers have been categorized into 3 types, namely, completed curved, partially curved and straight style. In the first type, the style curvature facilitates the stigmatic lobes close to the anthers. In the second type, the style shows partial curvature with stigmas placed above the anthers. In the third type, the style is straight althrough the flower life. In this study, the first and second type flowers have been observed but the style curvature appears to be a function time within the duration of open state of flower life. In the second type flowers, the styles in straight position are also close to the anthers. These two types of style positions facilitate spontaneous autogamy but its occurrence is not definite. The fruit is an indehiscent small, globose berry, yellowish-orange during growing and maturing state and red when ripe. It is caged by pinnate persistent laciniate bracts of the flower. An anonymous report indicates that these bracts are carnivorous and secrete a sticky nectar and nitrogenase enzyme to lure bugs or insects in order to dissolve and use them as nutrient source. Radhamani et al. (1995) reported that the bracts of the flowers covered by hairs exude a sticky fluid which is aimed at attracting small insects. The insects that come in contact with this fluid get stuck and digested to nutrient-rich slimy substance by proteases and acid phosphatases and in this context this plant is stated to be a carnivorous plant. In this study, it is opined that these floral bracts defend buds, flowers and fruits from florivores and frugivores. The fruits produce numerous oval flattened black seeds which are embedded in fruit pulp. The birds feed on fruit pulp and in this process, the contribute to seed dispersal. MacDougal (1994) reported that *P. foetida* reproduces exclusively by seed which is probably disseminated by small mammals. The viable seeds survive in the soil after many years of dormancy.

Figure 1. *Passiflora foetida* - flowering: a. & b. c. *P. foetida* var. *alba*

Different authors reported on the pollinators of *P. foetida* in different geographic regions. It is pollinated by *Ptiloglossa* bees in Central America (Janzen 1968; Frankie et al. 1983), *P. tarsata* and *Pseudaugochloropsis* bees in Argentina (Amela Garcia and Hoc 1998; 2001), Centris and Xylocopa bees in Brazil (Gottsberger et al. 1988), *Apis mellifera* and *Xylocopa vanpuncta* bees in Florida, USA (Hammer 1987) and *Apis mellifera* and *A. cerana* bees in Mizoram, India (Kishore et al. 2010). Among these authors, Hammer (1987) noted that *X. vanpuncta* is the most effective pollinator of *P. foetida* while stating that *A. mellifera* is not the pollinator due to its pollen collection behavior. The present study observed that *Xylocopa* and *Apis* bees visit the flowers of *P. foetida*; the former bee is only nectar-forager while the latter ones are both pollen and nectar foragers. Among these bees, *Xylocopa* is the appropriate and efficient pollinator while *Apis* bees are supplementary pollinators as they tended to concentrate more on pollen collection rather than on nectar. Therefore, the reports by all authors stated above and the present study confirm that *P. foetida* is characteristically a melittophilous species and relies on bees for pollination in all areas of its distribution.

Amela Garcia et al. (2000) reported that *P. foetida* produces fruits by spontaneous and induced self-pollination, geitonogamous and natural pollination. The seeds produced in all these modes of pollination are viable and show germination after two months from the date of sowing. This report indicates that *P. foetida* is a self-compatible species with mixed mating system which is advantageous for the plant to grow in different habitats in the presence or absence of pollen vectors and extend its distribution in tropical latitudes as a very successful invasive species. From ecology point of view, its ability to grow as an annual in dry habitats, also as a perennial in wet habitats qualifies it as an important species for consideration in eco-restoration programs. Further, this species can be cultivated as a ground cover to regulate soil erosion and as an ornamental for improving the aesthetic value of the landscape.

4. CONCLUSIONS

Passiflora foetida is an annual or perennial herbaceous climber which flowers and fruits mainly during wet season with the ability to extend these events year-long depending on the soil moisture status. The flowers are large, hermaphroditic, nectariferous and

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fragrance with specialized bracts that protect the buds and flowers from florivores and also protect fruits during their maturation stage from frugivores. The protandry functional in this species minimizes self-pollination and maximizes cross-pollination, but the flower attains spontaneous autogamy also due to tri-fid style movements which enable contact with the anthers of the same flower. The plant is typically melittophilous with carpenter bees as the most appropriate and effective pollinators. The floral functional traits such as hermaphroditism, nectar production, tri-fid style movements, protandry and mixed mating system encourage both self- and cross-pollination in the presence or absence of pollen vectors and hence, these traits enable the plant to grow as a highly successful invasive weed mainly in tropical regions.

Authors contributions:

Both authors contributed equally.

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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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