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Anthophorid bee-pollination and autochory in *Trichodesma indicum* (L.) R.Br. (Boraginaceae)

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ABSTRACT

Trichodesma indicum is an annual wet season herb. The flowers are white, hermaphroditic, nectariferous, and specially adapted for pollination by Anthophorid bees. Protandry is functional but it facilitates the occurrence of both self- and cross-pollinations. Fruits produce 1 to 4 nutlets which are enclosed by accrescent papery calyx. They split open when mature and dry to disperse seeds, indicating the function of autochory.

Key words: *Trichodesma indicum*, hermaphrodism, Anthophorid bee-pollination, autochory

1. INTRODUCTION

The genus *Trichodesma* (Family Boraginaceae, sub-family Boraginoideae) has about 40-45 species (Zhu et al. 1995) distributed mainly in the western and central Asia with a few species in Africa and Australia (Weigend et al. 2013). It is characterized by coiled cymose inflorescences, setae with multi-celluar bases, spirally twisted connective of the anthers and fruits developing into 4-nutlets (Retief and Van, 2002). Dukas and Dafni (1990) reported that *T. africana* and *T. boissieri* flowers are protandrous, pollen is dispersed in the hollow cone head in the male phase and the stigma extends beyond the connectives in the female phase. These two species are buzz-pollinated by Anthophorid bees but different species are involved, *Anthophora tarsalis* in case of *T. africana* and *Anthophora* and *Amegilla* in case of *T. boissieri*; the Megachilid bee, *Hoptilis* sp. also pollinates *T. africana*. Shivanna (2014) reported that *T. zeylanicum* is an obligate autogamous species and autogamy occurs due to non-exposure of anthers and stigma for flower foragers. *T. indicum* is native to Kenya, Tanzania and Mauritis in Africa, and in Afghanistan, Pakistan, India and the Philippines in Asia. It grows naturally in low elevations of sandy soils, waste places, roadsides and open sunny soils (Verdcourt, 1991; Chiu-Mei and Kun-Cheng, 2014). It is protandrous, facultative xenogamous and buzz-pollinated sternotribically by two *Anthophora* bee species; other bees *Chrysis* sp. and *Colletes* sp., and small butterflies also visit the flowers but they are neither pollen carriers nor pollinators (Ahmed et al. 1995). But, Verma et al. (2008) reported that *T. indicum* is a cross-pollinated species. Keeping in view the

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paucity of pollination ecology information on *Trichodesma* genus and contradictory reports on the mating system of *T. indicum*, the present study made an attempt to detail more on pollination ecology of *T. indicum*.

2. MATERIALS AND METHODS

Trichodesma indicum plants growing in agricultural fields where vegetables are cultivated in Duvvada and Atchutapuram areas of Visakhapatnam, Andhra Pradesh, India, were selected for study during 2020-2021. Vegetative growth, flowering period and fruiting ecology were examined continually from the time of appearance of plants during wet season. Floral details with reference to sexual system, nectar production and pollination were examined in detail. The foraging bees visiting the flowers were observed for the probing behavior for nectar and pollen collection and their role in pollination and fertilization for fruit and seed set. Fruit characters and seed dispersal mode were observed in the field.

3. RESULTS AND DISCUSSION

Trichodesma indicum is an erect, many-branched, hispid annual herb. It grows in dry to semi-dry open habitats during wet season. The flowering occurs from August to November (Figure 1a). Leaves are sessile, hairy, opposite, alternate, lanceolate. Flowers are solitary borne in leaf axils, pedicellate, actinomorphic and bisexual (Figure 1b). Calyx is green, short-tubed and 5-lobed, hairy with lanceolate sepal lobes and pointed apically. Corolla is short-tubed with 5 white petals which are completely fused, funnel-shaped and the tip of each petal is long tailed and curved. Stamens are 5, each with a short hairy filament with white lanceolate densely villose, introrse anthers forming into a unified projecting cone around the style with appendages twisted apically consisting of a central pore; they are inserted at basal part of corolla tube. The pistil consists of 4-celled ovary with one ovule in each cell, simple gynobasic style and sub-globose stigma.

Figure 1. *Trichodesma indicum*: a. Plant in flowering phase, b. Flower, c. *Anthophora bicincta* approaching to collect nectar

Ahmed et al. (1995) reported that *T. indicum* shows anthesis mostly during late evening and early morning hours. The mature buds open during early morning hours. But, in this study, the anthers dehisce by longitudinal slits during mature flower bud stage; at this time, the stigma is placed below the twisted part of the cone. The pollen grains are powdery, radially symmetrical, tricolporate, sub-spheroidal and 8-10 μm in size. The anther cone appendages slightly untwist enabling the apical pore to become wide open in the late evening of the day of anthesis by which time the anthers turn brown and shed most of the pollen. The stigma then matures and gradually grows out of the cone pore by showing receptivity which extends until the evening of the next day. The corolla together with the stamina cone and appendages fades and falls off any time on the 3rd day. But, the pistil remains in place if fertilized and initiates fruit growth and development, which is quite visible after 5 days from the day of fall of corolla. Nectaries situated at the base of the ovary secrete nectar which gradually accumulates in the short corolla tube; the nectar is secreted from mature bud stage and it is available throughout the duration of flower life if not collected by insect visitors.

Kumar et al. (2020) reported that in Boraginaceae family, many species are bisexual while some species are dioecious. Pollination is mostly entomophilous involving bees and other insects. Dukas and Dafni (1990) reported that *T. africana* and *T.*

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boissieri flowers are nectariferous, protandrous, in the male stage pollen is dispersed in the hollow cone head, and in the female stage the stigma extends beyond the connectives. Both species are buzz-pollinated by Anthophorid bees, *Anthophora tarsalis* in case of *T. africana* and *Anthophora* sp. and *Amegilla* sp. in case of *T. boissieri*; *T. africana* is also pollinated by Megachilid bee, *Hoptilis* sp. Shivanna (2014) reported that *T. zeylanicum* is an obligate autogamous species and autogamy occurs due to non-exposure of anthers and stigma for flower foragers. *T. indicum* is protandrous, facultative xenogamous and buzz-pollinated sternotribically by two *Anthophora* bee species; other bees *Chrysis* sp. and *Colletes* sp., and small butterflies also visit the flowers but they are neither pollen carriers nor pollinators (Ahmed et al. 1995). Later, Verma et al. (2008) reported that *T. indicum* is a cross-pollinated species. The present study finds that *T. indicum* flowers attract only Anthophorid bees, *Anthophora bicincta* (Figure 1c) and *Anthophora* sp. during day time. They land on the corolla/anther cone and scrape the dehisced anthers to collect pollen. Since the flowers are protandrous and dehisce before anthesis, the pollen is readily available for collection by these bees. During pollen collection, the ventral side of the bee is usually brushed with the pollen and the head, legs and wings are also slightly coated with pollen grains. The bees also probe the flower base by inserting their tongue into the maroon colored grooves present at the corolla base to access nectar seated around the ovary base. The maroon grooves appear to act as nectar guide to guide the bees to access the nectar. The protandrous flowers with stigma inside the cone represent staminate phase while the flowers with stigma protruded out of the apical pore of the cone and appendages represent pistillate phase. The bees which visit staminate phase flowers act as pollen carriers only while those visiting the pistillate phase flowers act as both pollen carriers and pollinators. Since staminate and pistillate phase flowers are available simultaneously at plant level, the bees could contribute to self- as well as cross-pollinations. This study and other studies (Ahmed et al. 1995; Verma et al. 2008) indicate that *T. indicum* is specialized for pollination by Anthophorid bees only. This study does not find the function of buzz-pollination as the anthers are not poricidal and anther sacs are completely filled with pollen unlike in buzz-pollinated flowers such as *Cassia* and *Solanum*. Further, the function of bisexual flowers in *T. indicum* indicates that it is facultative xenogamous agreeing to the report by Ahmed et al. (1995).

In *T. physaloides* and *T. ambacense*, fruits produce a single mature nutlet. Fruits with single nutlets together with the accrescent calyx and style disperse from the parent plant. The production of a single nutlet against the production of four ovules per ovary is a result of abortion of the other three ovules, the function of which is considered to be an adaptation for anemochory because the fruiting calyx with a single nutlet acquires light weight which facilitates easy dispersal by wind. Further, the papery accrescent calyx increases the nutlet buoyancy in air current which in turn increases dispersal distance (Casper and Weins, 1981; Retief and Van, 2002). In this study, *T. indicum* the fruit is ellipsoid with persistent style and enclosed by accrescent papery calyx; the nutlet production varies from 1 to 4, but mostly 3-4 are produced per fruit. The mature and dry fruits split into four nutlets leaving a tetrangular central vertical column. The nutlets are ovoid, compressed, rugosely pitted on the inner surface and smooth and shiny on the outer surface. Fruit splitting and sequential seed dispersal occurs as and when fruit is mature and dry but fruit/seed dispersal by autochory is more effective during late winter and dry season. Seeds germinate following the first rains in June and produce new plants; with the completion of vegetative growth, they flower and fruit continually until November but flowering and fruiting is a continuous process in habitats where soil is wet and charged with nutrients.

4. CONCLUSIONS

Trichodesma indicum is an annual herb growing in dry to semi-dry open habitats during wet season. The flowers are white, bisexual, nectariferous, protandrous and adapted for pollination by Anthophorid bees indicating that the plant has a highly specialized pollination system. The protandrous condition is strikingly prominent but facilitates both self- and cross-pollinations. Fruit is ellipsoid in shape with a persistent style and enclosed by accrescent papery calyx. Each fruit produces 1 to 4 nutlets and splits open when mature and dry, leaving a tetrangular central vertical column; this mode of fruit split is an indication of function of autochory.

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Authors' contributions

Both authors contributed equally.

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Ethical approval
The ethical guidelines for plants & plant materials are followed in the study for species collection & identification.

Conflicts of interest:
The authors declare no conflict of interest.

Data and materials availability
All data associated with this study are present in the paper.

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