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Pollination Potential of Thrips (Insecta: Thysanoptera) – an overview

R. Varatharajan¹, Shyam Maisnam², Chochong V. Shimray³ and R.R. Rachana⁴

Abstract

Thrips (Thysanoptera) are one of the pollinating insect groups. By virtue of their pollen feeding habit, thrips visit the flowers during anthesis and carry appreciable number of pollen grains and incidentally transfer them on to the stigma during their inter and intra movement between the flowers/florets/inflorescence. SEM study reveals that the body setae of thrips favour for fine attachment of pollen. The floral reward enhances the breeding potential of thrips and in return the flower is pollinated by the pollinivorous physopodans (thrips). Microsatellite DNA analysis of single pollen adhering to pollinators, density of thrips within the flowers, vector potentials of thrips and viable seed production after pollination further justify their dynamic role in pollen transfer. The intricacies between the flower and thrips observed by different researchers since 1914 have been briefly discussed in this review in the context of thripophily.

Key words: Thysanoptera, flower thrips, floral reward, pollen, vector, viable seed.

Introduction

The ecological service extended by thrips in flower pollination is referred to as "thripophily". The role of thrips in pollen transfer dynamics has been overlooked by many researchers due to their small size and weak flying ability, lack of specialized organ to carry pollen etc (Thien *et al.*, 2000). Their aggregation within the flower generally indicates them as pest rather than its status as a pollinator. However, during the last century a number of observations have been made on diverse plant species to establish the vector potential of thrips. Although literature pertaining to this topic is abundantly available for many

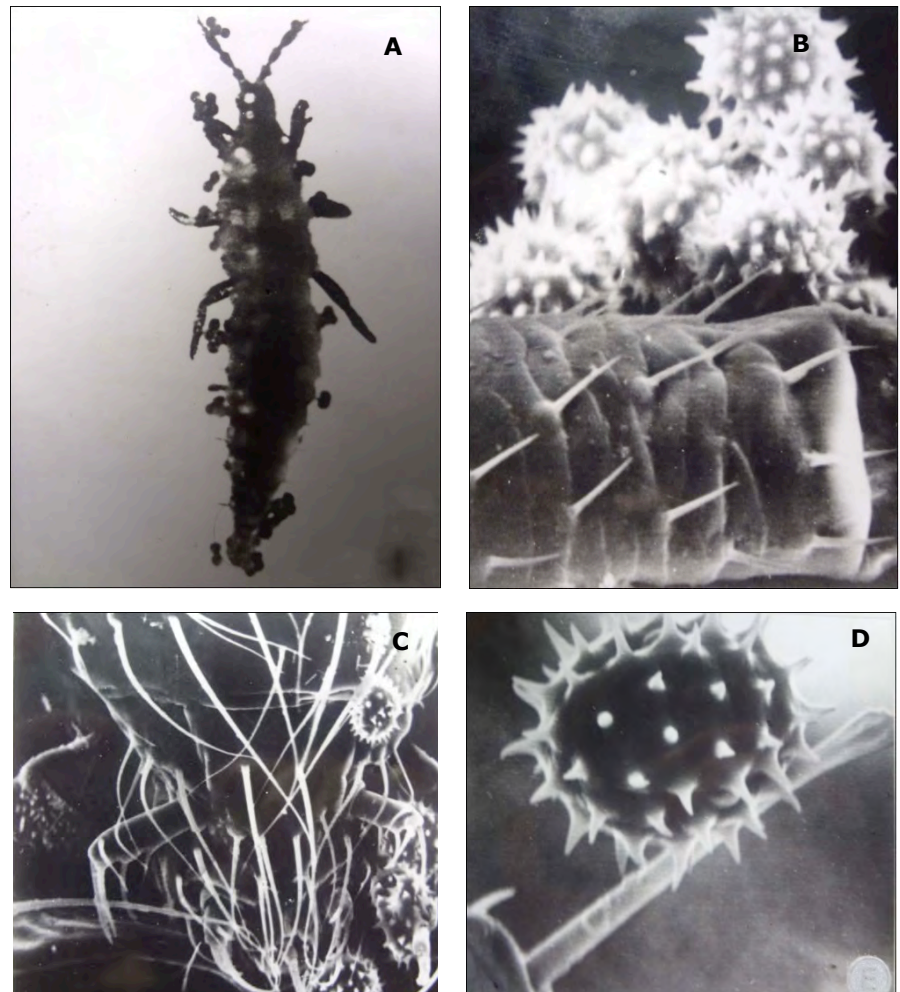


Fig 1. A - Light microscopic picture of a thrips larva carrying pollen loads (37x). B - SEM picture showing leg region of thrips with a cluster of pollen grains (1000x). C - SEM showing thrips mouth parts with the pollen grains of *Helianthus annuus* (750x). D - SEM photo of a single *H. annuus* pollen attached to thoracic seta of *Haplothrips* (2000x)

species, there is no consolidated report highlighting the activities of thrips in floral systems, nor any review on the adaptive advantages that the thrips enjoy within the flower host. Considering these viewpoints, an attempt has been made to appraise the works that are available for different thrips as well as flower species along with some of our own observations.

The earliest documentation showing the evidence of association between thrips and flowers was that of thrips on convolvulus flowers recorded by Darwin (1876; 1877). But their involvement in pollination became evident only in 1914, when Shaw

observed thrips flying over sugar beet fields with considerable pollen loads. Active association of thrips in pollination has been well documented by Anand (1926) and Billes (1941) on cacao, Hagerup & Hagerup (1953) on *Erica tetralix* [Ericaceae], Lewis (1973) on sugarbeet, alfalfa, beans and a few legumes, Syed (1978) on oil palm,

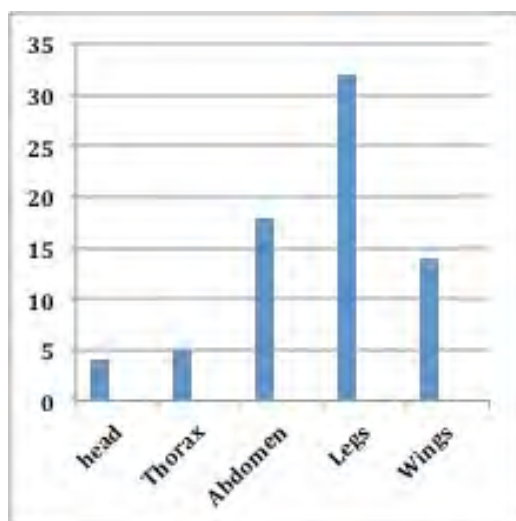
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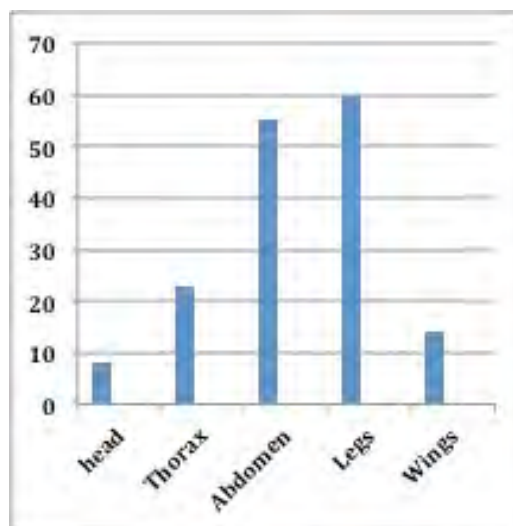
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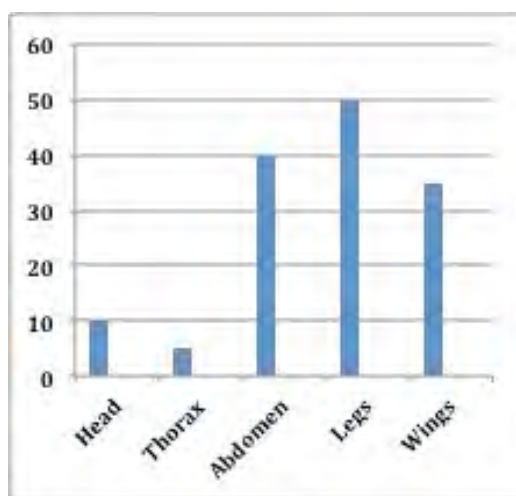
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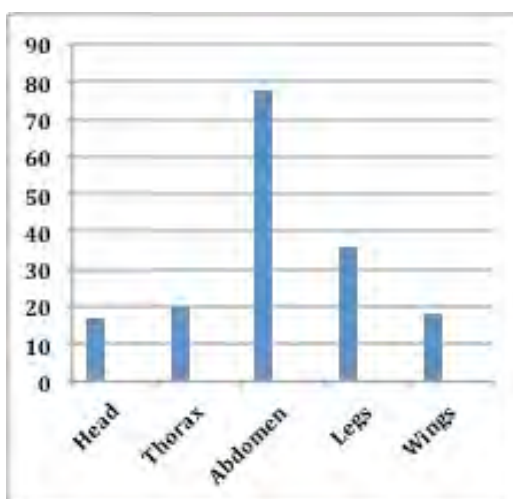
A. *Microcephalothrips abdominalis*



B. *Thrips hawaiiensis*



C. *Megalurothrips distalis*



D. *Haplothrips gowdeyi*

Fig 2. Distribution pattern of Pollen on the body parts of thrips. (Margin figures indicate mean number of pollen grains observed on 20 individuals in each case)

Elaeis guinensis [Arecaceae], Mathur and Mohan Ram (1978) on *Lantana camara* [Verbenaceae], Rust (1980) on *Arisaema triphyllum* [Araceae], Appanah and Chen (1981) on *Dipterocarpus* [Dipterocarpaceae], Ananthakrishnan *et al.* (1981a; 1981b) on *Wedelia chinensis* [Asteraceae], Gopinathan and Varatharajan (1982) on *Ageratum conyzoides* [Asteraceae], Norton (1984) on certain tree flowers in the lowland forest of New Zealand, Kirk (1984) on *Echium platagineum* [Boraginaceae], Varatharajan *et al.* (1984) on *Cosmos bipinnatus* [Asteraceae], Velayudhan and Annadurai (1987) on *Solanum melongena* [Solanaceae], Gurusubramaniam (1989) on *Borreria hispida* (Rubiaceae), Webber and Grottsberger (1995) on *Bocageopsis multiflora* and *Oxandra euneura* [Annonaceae], Davies (1999) and Moog *et al.* (2002) on *Macaranga* sp. [Euphorbiaceae], Sakai (2001) on thrips pollination in the Androdioecious *Castilla elastica* (Moraceae) and Williams *et al.* (2001) on the rainforest tree flowers of *Wilkiea huegeliana*. A

classical example of thrips-flower association is the pollination of cycads by *Cycadothrips* in Australia, wherein members of this genus have been exclusively collected from the cycad genus *Macrozamia*, carrying appreciable pollen load and flying from male cone to female cone as a result of "thermogenesis" (Terry, 2001; Mound and Terry, 2001). Nyree *et al.* (2004) have collected a new species namely *Thrips antiaropsidis* which mediates pollen transfer among the flowers of *Antiaropsis decipiens* (Moraceae) in New Guinea. Other recent reports providing the evidence of thripophily include that of *Shorea acuminata* (Dipterocarpaceae) (Kondo *et al.*, 2011) and *Arctostaphylos pungens* (Ericaceae) by *Orothrips kelloggii*, *Oligothrips oreios* and *Frankliniella occidentalis* (Eliyahu *et al.*, 2015). The above citations not only highlight the role of thrips in the pollination biology of diverse species of plants but also reflect that thrips were one of the earliest insect groups involved in pollen transfer dynamics.

Pollination syndrome

Kirk (1997) has described the pollination syndromes of thrips pollinated flowers. Usually thrips inhabit medium sized flowers having sweet scent with or without nectar and the petal may be light shaded ranging from white to yellow colour. The pollen grains are small and dry and the floral structure is compact, globose, or urceolate with pollen chamber. These floral features have been observed in some of the plants belonging to the basal angiosperm families such as Asteraceae, Annonaceae, Fabaceae, Dipterocarpaceae, Ericaceae, Euphorbiaceae, Monimiaceae, Rubiaceae and Solanaceae etc. For instance, thrips pollinated flowers such as *Wedelia chinensis*, *Synedrella nodiflora*, *Vernonia cinerea*, *Ageratum conyzoides* and *Cosmos bipinnatus* (Asteraceae) (Ananthakrishnan, 1993); Amazonian flowers, *Bocageopsis multiflora* and *Oxandra euneura* (Annonaceae) (Webber & Gottsberger, 1995); blossoms of the common species in South-East Asia namely, *Macaranga velutiniflora* and *M. hullettii* (Euphorbiaceae) (Davies, 1999; Moog *et al.*, 2002); flowers of *Wilkiea huegeliana* (Monimiaceae), a rainforest tree in Queensland, Australia (Williams *et al.*, 2001) etc., exhibit typical syndromes as defined by Kirk (1997).

Synchronous development

The duration of development of the flower thrips from egg to larva has been found synchronized with the time sequences of floral development of the flower host. This has been observed in some of the examined pollination systems. For instance, *Thrips hawaiiensis* takes about 11 days to develop up to second instar from egg, which is almost equivalent to the floral development of *Cosmos bipinnatus* up to seed setting stage (Varatharajan, 1984). Similarly, the growth period of the blossoms of *Dolichos lablab* and the life cycle duration of *Megalurothrips distalis* have been found to correspond with each other (Vellayudhan & Annadurai, 1987). Yet another species, *Microcephalothrips abdominalis* inhabiting exclusively on the flowers of Asteraceae not only indicated a synchronous development with its flower host, *Wedelia chinensis* but also the ability to build-up its population in tune with flower density (Ananthakrishnan *et al.*, 1981a). The centripetal development of the capitulum as seen in Asteraceae, shows a sequential and continuous availability of pollen and nectar, thus ensuring the growth of the pollinator. Thrips sometimes inhabit the flower at a late bud stage. Eggs laid at this stage develop up to the adult stage at the time of seed-setting, whereas the eggs laid after anthesis grow up to pre-pupa or pupa, which would metamorphose into adult through soil pupation as in the case of *Thrips hawaiiensis* inhabiting the Lecythidaceae flowers of *Couropita guianensis* (Varatharajan & Daniel, 1984). As early as in 1983, Bawa observed that the flower thrips that breed in the tropics could be predicted to have

shorter life cycle in comparison to thrips that dwell in long-lived temperate flowers. Thus in a number of cases the duration on growth and development of thrips synchronizes well with the floral development; thereby thrips efficiently use the flower for their growth and survival.

Floral reward

Anthophilous thrips primarily feed on pollen and nectar. The mouthparts of thrips are unique with only functional left mandible which is used for piercing the pollen and nectar gland to suck the contents. Pollen and nectar are essential components promoting growth and breeding competence of thrips. By virtue of their small size (0.5 to 2mm body length), flower thrips reach up to the secretory tissue of the nectar gland and suck the floral exudation (Gopinathan & Varatharajan, 1982). Thrips can enter even unopened buds but their peak density has been observed during pollen dehiscence of flowers (Kirk, 1987a). In cycads too, Terry *et al.*, (2005) noted the presence of over 50,000 thrips in some of the male cones especially during pollen dehiscence. Flower inhabiting terebrantian species belonging to the genera such as *Ceratothripoides*, *Frankliniella*, *Megalurothrips*, *Microcephalothrips*, *Thrips* etc., oviposit their eggs into the floral parts. Such concealed micro-niches protect the early life stages of thrips (Ananthakrishnan, 1993).

Pollen as food

Nutrition plays a vital role in insect reproduction and especially adequate concentrations of nutritionally important substances like proteins, amino acids, lipids, and carbohydrates in their diet influence insect growth and reproduction (Engelmann, 1970). Among them, the diet rich in protein and free amino acid have been related to egg maturation and egg production of pollen feeding insects (Haydak, 1970; Gilbert, 1972; Stanley & Linskens, 1974; Kevan & Baker, 1983). This is true with flower thrips, which are mostly pollen feeders (Andrewartha, 1935; Grinfel'd, 1959; Priesner, 1960; Laughlin, 1977). They puncture the pollen coat and drain the grains (Kirk, 1985; 1997) and their pollen consumption has been to the extent of 843 pollen grains per thrips per day. In yet another observation, Kirk (1987b) has reported that a single second instar larva of *Thrips imaginis* could consume as many as 1626 pollen grains/day (Mound, 2004). Grimaldi & Engel (2005) were of the view that pollen feeding had evolved several times in thrips and due to this phenomenon, they could be considered as valuable pollinators by virtue of their association with a wide range of flowers in nature. This seems to be plausible because thrips are Palaeozoic in origin (Kukalova-Peck, 1991; Labandeira & Seposki, 1993) and the basal groups of Thysanoptera predate predominantly angiosperms and even certain specific cycads (Terry, 2001 & 2002).

The effectiveness of pollen and nectar on growth and egg maturation of thrips has also been studied in common flower dwelling form such as *Thrips hawaiiensis*, wherein its fecundity rate increased with pollen diet; on the contrary, pollen free diet (PFD) significantly reduced its egg output. It is not only the pollen diet but pollen grains of different flower species have been found to influence the fecundity. For instance, the mean fecundity rate of *T. hawaiiensis* was 64 and 31, when reared separately on the pollen grains of *Helianthus annuus* and *Lantana camara*, whereas individuals reared on PFD exhibited 15.2 and 9.7 eggs, respectively. The PFD included stigma, style and small florets excluding pollen (Varatharajan *et al.*, 1999). Murai and Ishii (1982) devised a simple method to culture flower thrips, with which they have demonstrated variation in fecundity of thrips by rearing them on a combination of diets like pollen + honey + water which gave substantially higher fecundity than pollen + honey as well as pollen grains alone. All these observations unambiguously demonstrate the nutritive significance of pollen for the flower visiting thysanoptera.

Pollen carrying capacity (PCC)

The movement of thrips within the flower enables them to get dusted with pollen on their body surface. Thrips carry pollen grains on their legs, wings and setae of the abdominal segments (Fig. 1). Presence of setae on the body surface enables them to carry appreciable pollen load. Among the examined terebrantians, *Thrips hawaiiensis* could carry a maximum of 172 pollen grains, while that of *Microcephalothrips abdominalis* was about 95 grains per individual. However, their average PCC would range from 15 to 30 pollen grains per individual (Varatharajan, 1984). But the tubuliferan, *Dolichothrips* has been reported to carry 268 pollen per individual (Moog *et al.*, 2002). The increased efficiency of PCC may be attributed to the greater surface area and body length of thrips (Ananthakrishnan, 1982). Although PCC of the pollinator is an index reflecting its efficiency, but carrying single viable pollen and effectively transferring it to the receptive stigma will also reveal the success of pollination. Variation in term of PCC appeared not only between thrips species but also among the body parts of the same individual. Such differences were evident in terms of pollen count on the head, thorax, abdomen, legs and wings (Fig.2). The dissimilarity of pollen load of the same thrips species carrying pollens of different flower species may be attributed to difference in the ornamentation of pollen exine, besides the degree of pollen production in the respective flowers. For example, pollen production in *Ageratum conyzoides* has been found to vary from 18,954 to 26,208 per capitulum (Gopinathan *et al.*, 1981) and in *Synedrella nodiflora* it ranged from 5536 to 5716 per capitulum

(Varatharajan *et al.*, 1984). It would mean that higher the pollen production greater the level of PCC. In addition, the PCC could also depend upon the pollen surface and architecture. For example, pollen grains of *Helianthus annuus* have exines which facilitates attachment on the body setae of thrips, while that of *Solanum melongena* is devoid of such marked exines as a result PCC of thrips has been found appreciably low (Velayudhan & Annadurai, 1987). The mode of pollen attachment on thrips body revealed that solitary grain was localized on a seta, while pollen clusters got attached on the wings, legs and other body parts (Fig. 1).

Pollen dispersal and transfer mechanism

The ornamentation and sticky surface of the pollen facilitate the thrips to carry pollen in perceptible amount. Pollen grains attached to the body setae, wings and legs of thrips are dispersed on the stigma by way of their active movement, rubbing the abdomen on the stigmatic surface, cleansing of their body parts with their hind legs and also by their wing combing mechanism (Ananthakrishnan, 1982). Thrips movement within the flower involves frequent spreading and shaking of wings, body grooming and trivial flight take-off from the florets etc. In many flowers, stigma is very prominent and that is being used by thrips for landing and take-off. During this process, thrips places the pollen directly on the stigma (Kirk, 1997). The impressive petal colour and corolla tube of a small flower form an ideal site to attract thrips for oviposition, enabling the emerging larvae to become dusted with pollen in their upward and downward movement eventually leading to pollination. It is also significant to mention here that thrips prefer landing on the flower invariably when the stigma is at the receptive stage (Mathur & Mohan Ram, 1978; Ananthakrishnan, 1993). Syed (1978) observed that individuals of *T. hawaiiensis* appear on the oil palm as soon as the male flowers open. With the process of anthesis, thrips population gradually increases and attains the saturation level, which coincides with the receptive stage of stigma. This saturation level induces thrips to take off from male to female flowers of oil palm along with considerable load of fresh pollen, resulting in pollen transfer. Similarly, Terry (2001, 2002) observed the occurrence of thousands of individuals on the male cone which carry the pollen load and fly towards female cone due to "thermogenesis" as a result of crowding effect. Estimates of total thrips visitation and pollen loads indicated a pollen delivery of >5700 grains per ovule in a single afternoon, thereby establishing *Cycadothrips albrechti* as the sole pollinator of the cycad plant Terry *et al.* (2005). Flower thrips are either oligo or polyphagous in habit bearing a few species which appear to have an extremely narrow host range. As for instance, it is not uncommon to see the species such as *Dichromothrips nakahari*, *Megalurothrips distalis*,

Microcephalothrips abdominalis on the members of the plant families viz., Orchidaceae, Fabaceae and Asteraceae, respectively. When there is a significant density of a flower species, the blossom inhabiting thysanopterans can be observed in large numbers. In fact, this feature facilitates them to carry invariably homogenous cluster of pollen belonging to a particular plant species as they rarely forage unrelated plant hosts due to their weak flying ability. In other words, the polylectic habit of collecting pollen from many unrelated species appears to be uncommon among thrips as this practice leads to incompatible pollen transfer. Further, the microsatellite DNA analysis of single pollen adhering to individuals involved in pollen transfer confirms the efficiency of thrips in pollination as in the case of *Shorea acuminata* (Dipterocarpaceae), a typical tropical rainforest tree wherein 60% of the flower visiting insects are only thrips. Based on the positive inputs of the above investigation along with direct observation of the floral systems, Kondo *et al.*, (2011) rated thrips as primary pollinators, in spite of their minute size. In this context, it would be pertinent to state the view expressed by Faegri and van der Pijl (1979) that there is every reason to presume that [thrips] and other small and insignificant, unobtrusive animals may prove to be of much greater importance than hitherto suspected".

Viable seed production

The number of viable seeds produced is generally considered as a measure of effective pollination. Comparative studies of thrips pollination along with other major pollinators like bees and butterflies, besides self pollination of flowers indicated that the role of thrips cannot be underscored in pollination. Experiments conducted with flowers of Asteraceae, Fabaceae and Solanaceae that were covered by net, proved unambiguously that the rate of seed setting in thrips associated self fertile flower ranged from 50 to 70% (Varatharajan *et al.*, 1984; Ananthakrishnan, 1993). But, flowers devoid of any insects could produce only 25 to 45% seeds through autogamy, suggesting that association of thrips in the former enabled to enhance the viable seed production. Mound and Terry (2001) examined the interaction between the desert cycad, *Macrozamia macdonnellii* and the insect, *Cycadothrips albrechti* with the aim to determine the pollination potential of thrips in cycads. Their observations revealed that *C. albrechti* delivered adequate quantum of pollen grains so as to achieve effective fertilization leading to viable seed production to the extent of 60%. Moog *et al.* (2002) while working with the dioecious ant plant *Macaranga hullettii* (Euphorbiaceae), clearly demonstrated that the thrips moved from staminate to pistillate trees over a distance of 25m with pollen and that resulted in the seed set of 80%. The inflorescences which were bagged within the net that allowed only the tiny

thrips to pollinate also showed substantial production of viable seeds.

Conservation of the Pollinator

It has been assessed that the density as well as diversity of pollinating species gradually dwindles due to indiscriminate use of synthetic chemicals (Claire *et al.*, 2002) and environmental degradation (Mustajarvi *et al.*, 2001). In certain cases, shifting cultivation and removal of specific plant hosts under the cultivable areas indirectly reduce the pollinator density. Habitat fragmentation can clearly disrupt plant-pollinator interaction and threaten the local persistence of plant and pollinator (Kunte, 2000). However, analysis of this issue in the context of thrips, revealed that thrips are not affected much because of their adaptations like laying eggs within the plant tissue, occurring in a concealed microenvironment, quick life cycle, appreciable fecundity due to pollen diet, oligophagous feeding habit, escaping tactics from the natural enemies and so on. Nevertheless, protecting the habitat of the flora will unquestionably minimize the incidence of species loss. It is very clear from the described account that the pollination system comprising of thrips and the flower, functions well within the framework of mutualism. The floral reward enhances the chances of thrips survival and in turn, the pollinivorous thrips ensure pollination of the flower.

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(* original paper not referred & the sources are Lewis, T, 1973 & Ananthakrishnan, T.N, 1984).