Review Article

Harnessing the Potential of Syrphids: Their Role as Bio-Agents and Pollinators

ABSTRACT

The agriculture sector has a major contribution to India's overall economy. However, crop production accounts with numerous constraints because of biotic and abiotic factors. Pest damage and pollination services are two crucial factors among several others. Integrated Pest Management techniques involving the use of natural enemies are now used to combat pests which are safer to pollinators too. Pollination is important in agriculture and is a fundamental pillar of crop production. Animals comprises arthropods, vertebrates and mammals provide pollination around 80 percent of all flowering plant species among which insects are the primary ones. Insect pollinators maintain a diverse range of orchard, agricultural, horticultural and forage crop production. Effective pollination leads to an increase in crop and seed production along with improvement in its quality. Bees are well-known pollinators among insects but there has been concern about their decline due to the rise of globalization, changes in the geography, and application of new agriculture practices. As a result, diversification systems for pollinators and pest control are becoming increasingly crucial. After bees, syrphids are a noteworthy category of pollinators. Syrphid flies (Syrphidae: Diptera) benefit ecosystems by pollinating crops and acting as predators simultaneously. Adult syrphids are significant pollinators with high floral visiting rates and pollen carrying capability, while young larvae serve as natural biological control agent (predator) to lower aphid numbers in the field. Syrphidae is one of the most varied families of true flies, with 200 genera consisting of over 6000 species being described globally. In India, 357 species under 69 genera haves been reported so far. The syrphidae family consists of three subfamilies: Syrphinae, Milesiinae and Microdontinae. The majority of syrphids that eat aphids belong to the subfamily Syrphinae. The vast majority of species are terrestrial, with only a few being aquatic or inhabiting exceptionally damp habitats. At least 25 percent of terrestrial species feed largely on aphids. In addition to bees, hoverflies have been identified as possible pollinators of a variety of wild plants. However, the larvae of various species inhabit diverse habitats where they act as predators of sucking pests (feeding upto 1200 aphids during this stage), as scavengers, as mycophagous insects and also survivors under heavily polluted water. Because of their diverse habitat, hover flies are less affected by urbanisation and modern agriculture. The immature larvae because of their resemblance with caterpillar, are occasionally misidentified as pests. They are vital to humans because they have multiple beneficial roles as pollinators, biological control agents, decomposers and bioindicators. The inclusion of extra floral assets to the crop is another conservation biological control approach for encouraging an array of natural enemies encompassing predatory pollinators like hoverflies. Even so, picking of flower species is mostly dependant on visiting interests with inadequate consideration paid to the relationship among these helpful insects liking and performance as well.

Key words: Syrphids, biocontrol, pollination, India, geography, urbanisation

Introduction

The Agriculture industry contributes the most to India's overall GDP (Arjun, 2013). However, crop production is hampered by numerous biotic as well as abiotic factors. Pest damage and pollination service are the two most critical factors. Pest damage has been a major issue since the beginning of mankind. Pesticides have mostly been used to combat them when they cross beyond the ETL. With the advancement of knowledge, pests are now dealt with using integrated pest management techniques. Utilising biologically controlled natural enemies is a significant as well as preferred approach in IPM as the crops and the environment have benefitted from it because of its specificity, and low toxicity towards non-target organisms, environment and human beings. Fruit and seeds cannot be produced without pollination, which is the movement of pollen from one flower to another. It also enhances the seed quality, improves hybrid seed development, and uniform crop ripening (Kearns *et al*., 1998). Pollination is critical for maintaining ecosystem balance and is a framework of agriculture production, connecting agriculture to the life cycle. Since plants are completely dependent on carriers to convey pollen at the time of cross pollination, pollinators play a crucial role in the process of crop yield. An increase in quality and quantity in pollination services has contributed significantly to the economic sector (Breeze *et al*., 2011; Gill *et al*., 2016; Hristov *et al*., 2020). Pollination by honey bees, native bees and flies generates billions of dollars each season and contributes between $ 361 and $ 577 billion to annual revenue worldwide (Lautenbach *et al*., 2012).

The first to demonstrate that flies are crucial to crop yield and pollination in India (Kapil and Jain, 1980). Among the most prevalent insects, are flies (Diptera) who have a long history of being associated with flowers. According to (Kevan and Baker, 1983) flies with lapping and suctorial mouthparts are thought to have been the earliest flowering plant pollinators. Certain significant fly families, including Syrphidae (flower flies), Bombyliidae (bee flies), Empididae (dance flies), Acroceridae (small-headed flies), Apioceridae (flower-loving flies) and Nemestrinidae (tangle-vein flies) have been known to exist since the late Jurassic or early Cretaceous period, according to fossil evidence (Mitra and Banerjee, 2007).

The main causes of declining wild bee pollinators are habitat degradation, landscape changes, modern agricultural techniques and acceleration in urbanization (Bates *et al*., 2011; Wahengbam *et al*., 2019). Certain hoverfly species have restricted distributed ranges due to their inclination towards particular habitats, whereas others exhibit extensive distribution ranges across various ecosystems (Sengupta *et al*., 2016). Since they don't sting like honeybees, flies play a vital part in ecosystem services by pollinating wild flowers and giving us fruits and basic cooking ingredients. According to (Hassan *et al*., 2019) syrphid flies also referred to as hoverflies or flower flies (Order-Diptera; Family-Syrphidae) and are the third most diversified taxon in the Neotropics (Amoros *et al*., 2014). While female hoverflies utilize pollen to complete their ovarian development (Doyle *et al*., 2020), adult hoverflies are able to hover on flowers, which serve as both mating locations and supplies of nectar and pollen (Kevan, 2002). The imagos also play a significant role in herb pollinator. Since, they significantly affect the density of aphid populations, which are a pest of several forest trees, field crops, vegetables, and flowers are considered a vital category of valuable insects (Speight and Lucas, 1992; Inouye *et al*., 2015). Aphids (Aphidoidea) and other soft bodied arthropods like thrips and caterpillars are mostly preyed upon by the Syrphinae, Pipizinae and Eristalinae larvae (Eristalinae to a lesser extent) (Skevington and Dang, 2002).

Historically, research has been concentrated on species that are exceptional at a single function such as honeybees for pollination or parasitoid wasps for pest management). While investigation on species capable of providing multiple services at the same time will be more efficient in today's time. Syrphid flies are one of the most well-known dual service suppliers (Syrphidae: Diptera) (Omkar, 2016). The flies are distributed globally except Antarctica with over 6000 species under 200 genera described globally till so far (Qiao *et al*., 2004; Brown *et al*., 2009; Thompson *et al*., 2010; Rotheray and Gilbert, 2011; Evenhuis and Pape, 2013; Miranda *et al*., 2013; Ghorpade, 2014; Anonymous, 2019). Out of which about 357 species of 69 genera have been documented in India (Pape and Thompson, 2016). India is home to a variety of these unique species. In addition to their strong ability for biological management of aphid pests to avert economic dangers (Colley and Luna, 2000), they have been identified as the second most important pollinators helping in cross pollination of a number of plants (Shah *et al.*, 2014). Within the suborder Cyclorrhapa of the order Diptera, the series Aschiza contains the superfamily Syrphoidae. The Syrphinae, Milesiinae and Microdontinae make up the Syrphidae family. Members of the Syrphinae make up a large proportion of aphidophagous syrphids (Joshi and Ballal, 2013).

Serrato Paragus serratus formerly known as *Paragus* (*Pargus*) *serratus* and *Ischiodon scutellaris* were the first two species noted by Fabricius (1805) from Tranquebar, India. The first comprehensive papers on Indian syrphidae were published by Brunetti (1907a, 1907b and 1908). Herve-Bazin was later able to account some notable works on this particular insect (Sahayaraj, 2004). Several researchers (Joseph and Parui, 1927 and 1986; De Silva, 1961; Coe, 1964; Joseph, 1967; Nayar, 1968; Bhatia and Shaffi, 2004) have also been predisposed to work on Indian syrphidae. Recent contributions to the taxonomy of this family have been made by number of workers (Ghorpade, 1981 and 2014; Datta and Chakraborty, 1984 and 1986a; Mitra *et al*., 2004a; Mitra *et al*., 2004c; Mitra *et al*., 2005; Mukherjee *et al*., 2006; Mitra *et al*., 2008; Mengual and Ghorpade, 2010; Mitra *et al*., 2015; Sengupta *et al*., 2016). Few philopatric species might be employed as biodiversity indicators at the microhabitat level however hoverflies are often migratory species that make them ideal bioindicators on landscape scales, (Talasova *et al*., 2018). The data of a variety of biotic and abiotic variables pertaining to hoverfly communities have been broadly demonstrated supporting the idea of developing a number of conservation measures (Shebl *et al*., 2008) that can assist in preventing the extinction of numerous species of wild vegetation, protecting crop yield declines and maintaining ecological balance (Rotheray and Gilbert, 2011).

One of the most significant pollinators of cauliflowers is Diptera according to recent research by Sharma *et al* (1974); Kakkar, (1981), Tewari and Singh, (1983); Priti and Sihag, (1997). Goyal and co-workers in Himachal Pradesh discovered 71 insect species on carrot blossom in 1989 belonged to 31 families and 8 orders. Sihag, (1986) discovered that flies are the subsequent most efficient pollinators of carrots. After Hymenoptera, accounting maximum diversity even exceeding Hymenopterans in tropical areas, Diptera are most likely the subsequent prevalent order of flower visiting insects and pollinators (Inouye, 2001). The foremost distinguishing trait that sets these species apart is the emergence of spurious vein or false vein with some exceptions in genera *Graptomyza* and *Paragodon*. *Syritta flaviventris* on the other hand is located between the third (R4 + 5) and fourth (M1 + 2) longitudinal veins of the wings extending longitudinally and slightly diagonally (Vockeroth, 2001; Mitra *et al*., 2015; Sengupta *et al*., 2018).

In India honey bees are not that much attracted to cashew due to low nectar yields (Reddi, 1993). During the investigation he observed 37% of flies visiting cashew flowers compared to only 12% of bees. He claims that yield can be increased by maintaining fly population in cashew orchards. Dhara and Tandon (1993) discovered 60 percent Diptera species among the five major pollinator species of ber, *Zizyphus mauritiana*. Additionally, two species of fly pollinators in Gujarat were described by Mitra and co-workers (2002) for *Zizyphus mauritiana*. For pollination of mango blossoms Sharma along with his co-workers (1998) demonstrated a simple and rapid method of breeding flies.

One-third of all syrphid species are aphidophagous (aphid predating). Adult members of many of these species have developed specific aphid-finding mechanisms (such as ability to recognise pheromones on their prey), making aphidophagous syrphids possible biological measures for aphids in agricultural sector (Mizuno *et al*., 1997; Dib *et al*., 2010). The predatory nature of syrphid larvae has prompted research in to the possibility of using syrphids as a component in integrated pest management (IPM) program. IPM programs seek to incorporate a variety of pest control tactics in order to lower the usage of pesticides and minimize the harm caused by pests. Aphids are a crucial part of integrated pest management because they encourage natural enemies (such as syrphid larvae) to prey on or parasitize pests. This process is known as biological control. Although key objective of biological management is to minimize the damage done by pests to levels beneath the threshold for economic damage, even if the pest will not entirely disappear (Rotheray and Gilbert, 2011).

General biology

Hover flies like bees are beneficial to gardens and an important pollinator. The entire metamorphosis of a flower fly, including the egg, three larval stages, puparium and adult is involved in development (Graham and Gilbert, 2011). Females lay oblong, slightly curved eggs that are greyish to white measuring 1mm or less in length near or within aphid colonies and are commonly found singly near food for emerging larvae (Joshi and Ballal, 2013).

The appearance of syrphid larvae varies depending on the environment in which they feed (Brunetti, 1923). The majority of larvae resemble maggots with no actual legs that taper towards the head. With three larval instars, the maggots are predators of aphids (Graham and Gilbert, 2011). Depending on the stage and species, the size of the opaque skin and body content visible through thin integument ranges from 5 to 20 mm, and a variety of colours with majority having yellow longitudinal stripe on the back (Coe, 1964). Because of a slender, respiratory appendage at the back that can measure several times the length of the body, rat-tailed maggots are aquatic larvae of some species (e.g., *Eristalis tenax*). Certain species resemble molluscs are dome-shaped, spherical, and usually brown with patterns resembling a net or mesh that they use to dwell in ant nests and eat the ant brood (Mitra *et al*., 2015). Fly larvae have three pairs of abdominal appendages but no true legs. Prolegs are fleshy, leg-like appendages on the abdomen; nevertheless, most predaceous syrphids and aphid feeder larvae lack them, however the appearance of appendages might be given by the segmented, creviced body. Six different pairs of prolegs are present in the larvae of species (e.g., *Eristalis*) that feed on microorganisms and decomposing organic debris (Brunetti, 1907b and 1908). The lengthy breathing tube on the rear of drone fly larvae, often referred to as rattling maggots allows them to survive in extremely contaminated water (Anonymous, 2019b).

In most species, pupation takes place in the integument of the last instar, which hardens and takes on a teardrop form. Ant predator pupae, such as those of the (*Microdon* species) are similar in shape and size to larvae. Pupa are pear shaped, oblong and can be green or dark brown in colour (Bugg *et al*., 2008). The flies complete one or more generations in a year, depending on the species; some have a long flight season while others overwinter as adults. Not all hoverfly larvae are predators; some inhabit social insects as scavengers e.g., *Volucella* genus members found in bumblebee nests, *Microdon* genus members found in ant or termite nests and other species found in decaying plants (Datta and Chakraborty, 1985). Narcissus fly larvae feeds roots, stems and bulbs despite the fact that they do not result in significant losses (Lavoipierre, 2007).

Adults range in size from robust to slender (4-25mm) long. The broad head which has huge eyes and conspicuous antennae, is at least as wide as the abdomen. Many adults resemble wasps or stinging bees due to their black bodies with orange, yellow, or white bands or stripes, (Coe, 1964). While some species such as *Microdon* species are primarily blackish to brown or brilliant to dark greenish, others, like the brown, metallic blue or green, yellow species, are primarily brown. *Eristalis tenax* adults are hairy, stout, black and brown similar to male drones. The adults are frequently observed hovering and nectaring at flowers while larvae have a diverse diet (Knutsun *et al*., 1975) some feed on decaying organic materials while others are insectivorous (Brunetti, 1907b and 1908). Adults consume nectar and transport pollen from blossom to blossom while maggots feed on numerous sucking insect pests benefiting the crops with both pollination and prevention of pests (Schneider, 1969). *Eristalis tenax*, the drone flies, resemble wasps and bees through batasian mimicry yet do not harm other species (Golding *et al*., 2005; Thomson, 2013; Anonymous, 2019b). As syrphids have a diverse habitat which makes them less affected by landscape than bee pollinators. (Sommaggio, 1997; Sommaggio and Burgio, 2014; Zheng *et al*., 2019) established that syrphid species can be utilized as bio-indicators for calculating biodiversity loss and the success of restoration and conservation initiatives.

Economic Importance

Syrphidae are well known for providing environmental benefits. These small insects perform a crucial part in pollination and they pollinate numerous blossoms (Larson *et al*., 2001). Syrphidae also serves as biological control agents. Numerous larvae of the Syrphidae family fed on pest insects including leafhoppers, aphids and coccids. As a result, they have been discovered to control pest populations in agricultural fields (Bulganin *et al*., 2015). The predaceous larvae of *Episyrphus balteatus* are remarkable from an economic perspective because they effectively suppress aphids such as *Aphis gossypii* Glover, *Aphis craccivora* Koch, *Lipaphis erysimi* (Kalt.), *Myzus persicae* (Sulzer) and *Macrosiphoniella sanborni* (Gillete) acting as the predator's usual food source (Raina *et al*., 2005).

Syrphid as bioagents

One long-term remedy to the pest control problem is the use of natural enemies as biological control agents. Natural enemies are able to adapt to the dynamics of pest populations and coevolve alongside pests (Omkar, 2016). For biological pest control of aphids, predatory syrphid larvae offer promising alternatives (Kotwal *et al*., 1984; Singh & Mishra, 1988; Radhakrishnan and Muraleedharan, 1993; Tenhumberg and Poehling, 1995; Brewer and Elliott, 2004; Freier *et al*., 2007; Haenke *et al*., 2009; Nelson *et al*., 2012). Since they proliferate quickly at high numbers, aphids are a challenging pest to control (Almohamad *et al*., 2009) causing immense economic harm to the global food production industry (Blackman and Eastop, 2017). One of the most significant aphid predators syrphids are recognised to control the prey population (Ssymank *et al*., 2008; Wenbin *et al*., 2009). The life stage and aphid density of aphidophagous syrphid larvae determined their voracity. In general, the most voracious is the third larval stage (Dib *et al*., 2010; Arcaya *et al*., 2017). An excellent characteristic of larval voracity is that it has tendency to rise with aphid density, potentially allowing syrphid larvae to modify their rates of prey consumption in response to variations in aphid population density (Hodgkiss *et al*., 2019). According to (Devi *et al*., 2011) different larval instars of *Episyrphus balteatus* consumed prey, *Liphaphis erysimi*, in rather different ways with the third instar larvae being the most voracious feeders. These results are corroborated by (Baskaran *et al*., 2009) which documented that the third instar larvae of four species of syrphids consumed the most amount of prey on *Aphis gossypii*. The larvae of the Syrphidae family are excellent natural enemies of aphids and other Homopteran insects because they are predators (Sommaggio, 1997; Sommaggio and Burgio, 2014; Beeraganni *et al*., 2018). Due to their predation on aphids, coccids, and other soft bodied insects certain syrphid fly larvae of the key genera *Sphaerophoria*, *Episyrphus*, *Syrphus* and *Baccha* are crucial as bio-control agents or for suppressing pest insects on a variety of crops (Chandler, 1968; Chambers *et al*., 1985; Chambers and Adams, 1986; Luna and Colley, 2000). In both the field and the lab, *Episyrphus balteatus* effectively inhibited *Liphaphis erysimi* (Devi *et al*., 2011).

Aphidophagous hover flies are viewed as essential natural adversaries of pests and prospective agents for use in biological management since aphids solely cause tens of millions of dollars in crop damage annually (Chamber, 1968). Programs for managing pests may benefit from the use of *Episyrphus* (Bhatti *et al*., 2022). In India 312 species of predatory syrphidae have been recorded (Ghorpade, 1981) and 169 species recorded in the western Himalaya (Shah *et al*., 2014). The two most significant aphid predators are syrphids and coccinellids (Khan *et al*., 2016). Nonetheless, there hasn't been much focus on research on syrphids in agro-ecosystems (Hopper *et al*., 2011). Farmers can better appreciate the predatory role of hoverflies by identifying and comprehending them. Hoverflies are also innocuous to plants and crops and can deter predators by mimicking the appearance of black and yellow striped wasps (Haenke *et al*., 2009). It was suggested to Kashmiri farmers that they employ insecticides against predatory syrphids in horticulture in a safer and more efficient manner (Abrol, 1993). Since they resemble miniature slugs or caterpillars, the larvae are sometimes mistaken for pests. They grope and find their food by lifting their heads and swinging back and forth, then they grip and suck the contents of the carcass and abandon it. Certain syrphid species recognize their prey by scent. Hundreds of aphids are consumed by a single larva in a month. Certain species have been reported to consume upto1200 aphids in their larval stages, hence controlling 70-100 % of the aphid population (Lavoipierre, 2007; Bugg *et al*., 2008).

According to (Asante, 1997) reported that 21% of the time, hover flies preyed on apple wooly aphids. Although *Aphelinus mali* has long been recognised as an effective bioagent for the apple wooly aphid, studies on predator exclusion studies in apple orchards have shown the significant functions played by other predators, including coccinelids, syrphids and mirids indicating that *A. malialone* did not significantly contribute to control (Walker, 1985). One of the vital natural enemies used to control aphids is *Eupeodes corollae* (Fabricius), a member of family Dipteranidae and order Diptera whose larvae feed on aphids (Wang *et al*., 2017). Previous studies have looked at the feeding, mating, and spawning habits of hoverflies as well as the spawning and larval predation habits of mature *Eupeodes corollae* adults (Karelin, 1980). However, the majority of researchers focus on taxonomic and molecular analysis of hoverflies, while a small number of researchers have conducted focused studies on hoverfly spawning locations (Marinoni and Thompson, 2003; Von *et al*., 2006).

Pollination by Syrphid flies

Syrphid flies represent the most important pollinators of a diverse range of flowers in the forest, agriculture and plants from the wild (Inouye *et al*., 2015; Doyle *et al*., 2020) and they can provide an equivalent quantity of pollination services like bees under certain circumstances (Ellis *et al*., 2017). Pollen is carried in greater quantities by bees while hover flies are capable to make up for this by making more visits (Wahengbam *et al*., 2019) because of morphological characteristics such as hairiness and size (Rader *et al*., 2011; Phillips *et al*., 2018). Despite these physical limitations, few syrphid species are just as successful at pollination as other insects, such as wild bees and honey bees (Rader *et al*., 2009; Rader *et al*., 2011; Rader *et al*., 2016) and can transport comparatively high quantities of pollen grains (Phillips *et al*., 2018). For instance, when visiting *Brassica rapa* var. *chinensis*, the syrphid species *Eristalis tenax* just likely to make contact with the stigmatic surfaces as honey bees, and both of them deposited a comparable quantity of pollen on the stigmas of virgin blossoms (Rader *et al*., 2009). However, since honey bees are more abundant, they are a more effective pollinator on the whole (Rader *et al*., 2009). While bees (Apidae and Halictidae) may solely transport viable pollen up to 300 meters, however few syrphidae species may transmit viable pollen up to 400 meters (Rader *et al*., 2011). At 200 m fly species of (Stratiomyidae and Syrphidae) families transport compared to bee species of (Apidae and Halictidae) families nevertheless, at 100 m, flies sustained substantially extra massive pollen than bees. These findings show that syrphid flies can effectively carry pollen and it may surpass honey bees

(Apidae) and they may even be able to do it over greater distances. Therefore, in an agricultural situation, a diverse array of pollinating insects with differing rates of dispersal can encourage pollen movement and gene flow across the landscape (Rader *et al*., 2011). Although most hover fly species are not picky eaters, some are, including *Cheilosia albitarsis* visit exclusively *Ranunculus repens* (Haslett, 1989). Flower colour, shape, pollen and nectar availability, shelter and prey availability all influence attractiveness (Sutherland *et al*., 1999; Colley and Luna, 2000). Syrphid flies are pollinators linked to the spring blooming season in the oriental region. They are extremely rare to be found in hot and arid regions of Asia during the summer and winter, when many species of flies like to visit white and yellow actinomorphic flowers (Sajjad and Saeed, 2010). Furthermore, there are differences in the way different species consume pollen. Large densely haired species long, spirally grooved bristles, short proboscis, and unbranched hairs ingested 99% of anemophilous pollens while small, sparsely haired species with unbranched hairs, simple bristles, and long proboscis ingested pollens only from nectar-bearing flowers. Most members of the Acroceridae and Syrphidae families use hairs with branching or curled tips to gather pollen (Holloway, 1976).

Foraging behaviour of *E. balteatus* revealed a liking for greater nectar amounts while showing no behavioural changes in response to rising pollen percentages (Sutherland *et al*., 1999). Hover fly adult is dependent on floral sources for energy in the form of nectar rich in proteins, lipids and pollens rich in vitamins (Faegri and vander, 2013). Plant characteristics, body size, and evolutionary relatedness all affect floral visitation. Based upon plant traits an analysis of flower visiting rates in three sub families; Eristalinae, Pipizinae and Syrphinae showed that the number of visits in Eristalinae rose with plant height. Larger species were shown to be independent of floral size, while the size of the inflorescence was found to be positively correlated with tiny species across all three subfamilies. All subfamilies have different preferences for flower colours such as Eristalinae highly favour white and yellow flowers, while Syrphinae don't care what colour flowers are (Klecka *et al*., 2018). These pollinators influence the fruit quality and setting. *Eristalis tenax* pollinates sweet pepper, resulting in an increase in seed set and fruit weight, which confers beneficial qualities (Jarlan *et al*., 1996).

In Himachal Pradesh, many species of dipterans belonging to the genera *Musca* sp, *Orthellia* sp (Family: Muscidae), *Eristalis* (Family: Syrphidae), *Scaeva* (Syrphidae) were observed (Mishra and Kumar, 1993). During the study, it was recorded that *Sphaerophoria*, *Episyrphus, Ischiodon*, *Mezanostoma* belonging to family Syrphidae were the frequent visitors to mustard proved to be the dominant pollinator after bees. After Hymenoptera, Diptera was discovered to be the most significant pollinator of onions (Kumar *et al*., 1985). Among onion flower visitors (Priti, 1998) Dipteran species out number Hymenopterans in strength. Even in Apples syrphids (Diptera) are thought to represent the key insect pollinators (McGregor, 1976; Free, 1993; Bangyu *et al*., 1997; Batra, 1997).

In a study investigated by (Kumar *et al*., 2017) examined the distribution of major syrphid fly species in western Uttar Pradesh and discovered that marmalade hoverfly, also recognised as *Episyrphus balteatus* (De Geer) hovered adjacent to flowers of a variety of plants such as mustard, beans, chrysanthemum, brinjal, and marigold. This kind of insect has also been mentioned by numerous authors from all across India. Additionally, Himachal, Punjab, Jachh, Southern India, Maharastra and Karnataka have recorded its cases (Lingappa *et al*., 2004). In the Meerut region, other species i.e. *Ischiodon scutellaris* was discovered hovering near the flowers of various plants such as cowpea, marigold, mustard, paper flower, mango and tomato. Karnataka has also yielded reports of this species (Lingappa *et al*., 2004; Puttannavar, 2004). It was found that *Eristalis taphicus* hovered about the blossoms of a variety of plants such as mustard, rose, brinjal, mango, paper flower, marigold, candytuft, coriander and tomato. Hovering near the blossoms of various plants such as cowpea, marigold, candytuft and tomato were found to be *Paragus sp*. This finding is consistent with the findings of Joshi and his co-workers (1997) who isolated syrphid species from various parts of India. *Eristalis tenax* was discovered hovered about the blossoms of various plants including mustard, mango, paper flower, marigold, candytuft and tomato. *Syrphus* sp. was discovered hovered over cowpea, mustard, rose, marigold and tomato. There have also been reports of this species from India (Bisht *et al*., 2001; Prabhakar and Roy, 2010). Hovering around the blooms of a variety of host plants such as chickpea, paper flower and marigold were observed to be Bombyliidae. A high diversity of insects belonging to Diptera and Hymenoptera group has been recorded to pollinate some major crops. More studies on this should be conducted to record the maximum diversity, their host range and behaviour.

Promoting Syrphid Flies

The advancement and maintenance of ecologically useful species relies on techniques in agriculture, topography and vegetation. Dispersal of organism and declination of pollinators is greatly caused by global warming (Wahengbam *et al*., 2019). The use of flowering vegetation closest to crops is a prudent biological management method that enhances natural enemies' performance (Landis *et al*., 2000). The significance of floral resources for an array of natural enemies, including various parasitoid species and predators like coccinellidae, chrysopidae and syrphidae has been thoroughly documented (Jervis *et al*., 1993; Al-Doghairi and cranshaw, 1999). Several studies have found that Diptera family makes a positive contribution through the inclusion of blossoming plants to the crop which significantly enhance their time period and effectiveness causes reduction in aphid density and crop damage (Hickman and Wratten, 1996; Pineda and Garcia, 2008b; Haenke *et al*., 2009). Pollinator friendly plants on farms provide beneficial ecosystem services. Establishing sweet alyssum in apple growing fields and collards increases syrphid populations that assists in pollination and decreased aphid infestation (Ribeiro & Gontijo, 2017). In California, it has been observed that growing 1 to 2 alyssums per 50 lettuce transplants effectively lures aphid predators (Brennan, 2015). Lettuce aphid is effectively controlled by increased syrphid population by the presence of blossoming plant strips including coriander and chrysanthemum in iceberg lettuce (Pascual *et al*., 2006). Syrphid fly population densities are negative via temperature and humidity but positive with flower abundance (Sajjad *et al*., 2010). Dispersal of syrphid flies is affected by landscape and barriers so to achieve a better ecosystem service, advantageous to pollinators, efficient planning of farm layout should be done. After realising that pollination serves as the several vital services creating adequate techniques to conserve these pollinators biodiversity and their diverse group rendering free services to the human beings through habitat conservation and urban planning should be in main focus which ultimately results in improving food security (Mitra and Banerjee, 2007).

Conclusion

The most extensively utilized form of chemical management delivers greater economic returns in addition to some other inputs however has recently been critiqued for its negative impacts, particularly for disrupting the harmony of the environment. Syrphidae are biotic predatory insects as well as significant pollinators second to bees. The fly not only pollinates flowers by hovering over them but their larva is also predaceous on sucking insect pests. Open blooms pollinated by bees occasionally generate smaller number of seeds each plant than syrphid pollinated flowers. Syrphid flies can outnumber bees at flowers. If there are no bees, these little flies can completely pollinate some flat, open and easily accessible blooms. Some crops can be pollinated almost as effectively by syrphid flies as bees. Adopting fly- friendly agricultural measures to promote population will ensure ecologically friendly pest management besides enhancing the quality of numerous plant features such as fruit setting, seed weight, productivity, and so on through pollination. However, if the dual effect of syrphids is properly exploited and their incorporation into IPM practices turns out well, there could possibly be a monetary incentive to take in to consideration their inclusion in an area beside their sole service giving contemporaries (e.g. honey bee). Syrphids with their twin functions in pollination and pest management, could be valuable allies in efforts to establish agriculture sustainability.

References

Abrol, D.P. 1993. Insect pollination and crop production in Jammu and Kashmir. *Current Science* **65**(3): 265–269.

Al-Doghairi, M.A. and Cranshaw, W.S. 1999. Surveys on visitation of flowering landscape plants by common biological control agents in Colorado. *Journal of the Kansas Entomological Society* **72**: 190–196.

Almohamad, R., Verheggen, F.J., Haubruge, É. 2009. Searching and oviposition behaviour of aphidophagous hoverflies (Diptera: Syrphidae): A review. *Biotechnol*ogy, *Agronomy, Society and Environment* **13**(3): 467–481.

Amorós, J.R., Pineda, A., Fereres, A., Marcos, M.Á. 2014. Feeding preferences of the aphidophagous hoverfly, *Sphaerophoria rueppellii* affect the performance of its offspring. *Biocontrol* **59**(4): 1-9.

Anonymous. 2019a.Hoverfly. https://www.britannica.com/animal/hover-fly.Date of Accessed: 11/26/2019.

Anonymous. 2019b. Drone Flies. https://www.fs.fed.us/wildflowers/pollinators/pollinator-of-the month/drone_flies.shtml Date of accessed: 27/11/2019.

Arcaya, E., Pérez, B.C., Mengual, X., Zubcoff, J.J., Rojo, S. 2017. Life table and predation rates of the syrphid fly, *Allograpta exotica*, a control agent of the cowpea aphid, *Aphis craccivora*. *Biological Control* **115**: 74–84.

Arjun, K.M. 2013. Indian Agriculture- status, importance and role in indian economy. *International Journal of Agriculture and Food Science Technology* **4**(4): 343-346.

Asante, S.K. 1997. Natural enemies of the woolly apple aphid, *Eriosoma lanigerum* (Hausmann) (Hemiptera: Aphididae): A review of the world literature. *Plant Protection Quarterly* **12**(4): 166-172.

Bangyu, K., Tan, K., Haiou, K. 1997. *Present situation and expectancy of utilizing Honey bees for pollination in the mountain areas of China*, a report submitted to ICIMOD. Kathmandu, Nepal.

Baskaran, R.K., Sasikumar, S., Rajavel, D.S., Suresh, K. 2009. Biology and Predatory potential of aphidophagous syrphids on guava aphid, *Aphis gossypii* (Glover) (Hemiptera: Aphididae). *Journal of Biological Control* **23**(1): 53:56.

Bates, A.J., Sadler, J.P., Fairbrass, A.J., Falk, S.J., Hale, J.D., Matthews, T.J. 2011. Changing bee and hoverfly pollinator assemblages along an urban-rural gradient. *Plos one* **6**(8): e23459.

Batra, S.W. 1997. Solitary bees for orchard pollination. In *Pennsylvania Fruit News*, April.

Beeraganni, K.M., Radadia, G.G., Shinde, C.U. 2018. Comaprative morphometrics of three aphidophagous syrphids occurring in Navsari region. *International Journal of Pure Applied Biosciences* **6**(1): 948-953.

Bhatia, H.L., Shaffi, M. 2004. Life histories of some Indian Syrphidae. *Indian Journal of Agricultural Science* **2**: 543-570.

Bhatti, A.A., Manvi K., Slathia, N. 2022. Genomic characterization of *Episyrphus balteatus* (Diptera: Syrphidae) from outer and lower Himalayas, India. *Indian Journal of Ecology* **49**(2): 515-520.

Bisht, R.S., Rana, D.S., Mishra, P.N. 2001. Bio-ecology of predators and parasitoids of aphids in Garhwal hills. *Journal of Aphidology* **15**: 125-128.

Blackman, R.L. and Eastop, V.F. 2017. Taxonomic issues in Aphids as Crop Pests. CABI, Wallingford. 1-29.

Breeze, T.D., Bailey, A.P., Balcombe, K.G., Potts, S.G. 2011. Pollination services in the UK: How important are honeybees? *Agriculture Ecosystems and Environment* **142**(3-4): 137-143.

Brennan, E. 2015. Efficient intercropping for biological control of aphids in transplanted organic lettuce. e-Organic article. http://articles.extension.org/pages/72642/efficient-intercropping-for-biological-control-ofaphids-in-transplanted-organic-lettuce.

Brewer, M.J. and Elliott, N.C. 2004. Biological control of cereal aphids in North America and mediating effects of host plant and habitat manipulations. *Annual Review of Entomology* **49**(1): 219–242.

Brown, B.V., Borkent, A., Cumming, J.M., Wood, D.M., Woodley, N.E., Zumbado, M.A. 2009. Manual of Central American Diptera. NRC Research Press, Ottawa, Ontario, canada. **1**: 714.

Brunetti E. 1907a. Notes on Oriental Diptera II. Preliminary report on a collection from Simla. *Records of the Indian Museum* 1: 166-170.

Brunetti, E. 1907b. Notes on the Oriental Syrphidae. Part I. *Records of the Indian Museum* 1: 379-380.

Brunetti, E. 1908. Notes on Oriental Syrphidae with descriptions of new species. Part I. *Records of the Indian Museum* **2**: 49-96.

Brunetti, E. 1923. Family Syrphidae. In, The Fauna of British India. **3**(23-342): 406-415.

Bugg, R.L., Colfer, R.G., Chaney, W.E., Smith, H.A., Cannon, J. 2008. Flower flies (Syrphidae) and other biological control agents for aphids in vegetable crops.

Bulganin, M., Sankarsan, R., Imtiaz, I., Maitree, G. 2015. A review of the hover flies (Syrphidae: Diptera) from India. *International Journal of Fauna and Biological Studies* **2**(3): 61-73.

Chamber, R.J. 1968. Preliminary experiments on the potential of hover flies (Diptera: Syrphidae) for the control of aphids under glass house. *Entomophaga* **31**: 197-200.

Chamber, R.J., Sunderland, K.D., Stacey, D.L., Wyatt, I.J. 1985. Control of Cereal aphids in winter wheat by natural enemies, aphid specific predators, parasitoids and pathogenic fungi. *Annals of Applied Biology* **108**(2): 219-231.

Chamber, R.J. and Adams, T.H. 1986. Quantification of the impact of hoverflies (Diptera: Syrphidae) on cereal aphids in winter wheat: An analysis of field populations. *Journal of Applied Ecology* **23**(3): 895-904.

Chandler, A.F. 1968. The relationship between aphid infestations and oviposition by aphidophagous (Diptera: Syrphidae). *Annals of Applied Biology* **61**: 425-434.

Coe, R.L. 1964. Diptera from Nepal. Syrphidae. *Bulletin of the British Museum, Natural History Entomology* **15**: 255-290.

Colley, M.R., and Luna, J.M. 2000. Relative attractiveness of potential beneficial insectary plants to aphidophagous hoverflies (Diptera: Syrphidae). *Environmental Entomology* **29**(5): 1054-1059.

Datta, M. and Chakraborti, M. 1984. On a collection of Flower flies, (Diptera: Syrphidae) with new records from Jammu and Kashmir. *Records of the Zoological Survey of India* **81**: 237-253.

Datta, M. and Chakraborti, M. 1985. Insecta: Diptera. In fauna of Namdapha Arunachal Pradesh. *Records of the Zoological Survey of India* **82**(1-4): 231-252.

Datta, M. and Chakraborti, M. 1986a. On collection of flower flies, (Diptera: Syrphidae) from south India. *Records of the Zoological Survey of India* **83**: 53-67.

Devi, Y.R., Kalita, J., Singh, T.K. 2011. Biological control potential of an aphidophagous syrphid, *Episyrphus balteatus*, De-Geer (Diptera: Syrphidae) on mustard aphid, *Lipaphis erysimi* (Kalt.) (Homoptera: Aphididae) on cabbage ecosystem in Manipur. *Journal of Experimental Sciences* **2**(12): 13-16.

De-Silva, M.D. 1961. A preliminary list of the native parasites and predators of insect pests in Ceylon. *Tropical agriculturist* **117**: 115-141.

Dhara, J.B. and Tandon, P.L. 1993. Insect pollinator activity on ber, *Zizyphus mauritiana* (Lamk). *Proceedings of the International Symposium on Pollination in Tropics*. Pub. IUSSI-Indian Chapter.

Dib, H., Simon, S., Sauphanor, B. and Capowiez, Y. 2010. The role of natural enemies on the population dynamics of the rosy apple aphid, *Dysaphis plantaginea passerini* (Hemiptera: Aphididae) in organic apple orchards in south-eastern France. *Biological Control* **55**: 97–109.

Doyle, T., Hawkes, W.L., Massy, R., Powney, G.D., Menz, M.H., Wotton, K.R. 2020. Pollination by hoverflies in the Anthropocene. *Proceedings of the Royal Society*. *Biological Sciences* **287**.

Ellis, C.R., Feltham, H., Park, K., Hanley, N., Goulson, D. 2017. Seasonal complementary in pollinators of soft-fruit crops. *Basic and Applied Ecology* **19**: 45-55.

Evenhuis, N.L. and Pape, T. 2013. Systema Dipterorum, Version [1.5]. http://www.diptera.org/ [Accessed: 8 May 2014].

Fabricius, J.C. 1805. Systema antliatorum secundum ordines, genera, species. Brusvigae. **37**: 3-30.

Faegri, K and Vander, P.L. 2013. Principles of pollination ecology. Pergamon Press, Federal Rupublic of Germany. p-239.

Free, J.B. 1993. *Insect pollination of crops* (3rd edn). Academic Press, London.

Freier, B., Triltsch, H., Mowes, M., Moll, E. 2007. The potential of predators in natural control of aphids in wheat: results of a ten-year field study in two German landscapes. *Biocontrol* **52**: 775-788.

Ghorpade, K.D. 1981. An anomalous new *Episyrphus* (Diptera: Syrphidae) from Madagascar. *Colemania* **1**: 89-94.

Ghorpadé, K. 2014. An updated checklist of the hover-flies (Diptera-Syrphidae) recorded in the Indian subcontinent. *Colemania* **44**: 1-30.

Ghorpade, K. 2014. On the Hover-flies (Diptera:Syrphidae) preserved in the collection of the Punjab University, Chandigarh, and further notes on those from the Indian Punjab and north west India. *Colemania* **46**: 1-17.

Gill, R.J., Baldock, K.C., Brown, M.J., Cresswell, J.E., Dicks, L.V., Fountain, M.T., Garratt, M.P., Gough, L.A., Heard, M.S., Holland, J.M. 2016. Protecting an ecosystem service: Approaches to understanding and mitigating threats to wild insect pollinators. *Advances in Ecological Research* **54**: 135-206.

Golding, Y., Edmunds, M., Ennos, A.R. 2005. Flight behaviour during foraging of the social wasp, *Vespula vulgaris* (Hymenoptera: Vespidae) and four mimetic hoverflies (Diptera: Syrphidae) *Sericomyia silentis*, *Myathropa florea*, *Helophilus sp*. and *Syrphus sp*. *Journal of Experimental Biol*ogy **208**(23): 4523-4527.

Goyal, N.P., Singh, M., Kandoria, J.L. 1989. Role of insect pollination in seed production of carrot, *Daucus carota* Linn. *Indian Bee Journal* **51**(3): 89-93.

Graham, E.R. and Gilbert, F. 2011. The Natural History of Hoverflies. First edition, Forest Text Publisher, Iver United Kingdom. 334.

Haenke, S., Scheid, B., Schaefer, M., Tscharntke, T., Theis, C. 2009. Increasing syrphid fly diversity and density in sown flower strips with in simple and complex landscapes. *Journal of Applied Ecology* **46**: 1106-1114.

Haslett, J.R. 1989. Interpreting patterns of resource utilization randomness and selectivity in pollen feeding by adult hoverflies. *Oecologia* **78**(4): 433-442.

Hassan, M.A., Bodlah, I., Bodlah, M.A., Hussain, R. 2019. New records of the genus Ceriana Rafinesque, 1815 (Diptera: Syrphidae) from Pakistan. *Munis Entomology and Zoology* **14**(1): 185-187.

Hickman, J.M. and Wratten, S.D. 1996. Use of *Phacelia tanacetifolia* strips to enhance biological control of aphids by hoverfly larvae in cereal fields. *Journal of Economic Entomology* **89**: 832–840.

Hodgkiss, D., Brown, M.F., Fountain, M.T. 2019. The effect of within crop floral resources on pollination, aphid control and fruit quality in commercial strawberry. *Agriculture Ecosystems and Environment* **275**: 112-122.

Holloway, B.A. 1976. Pollen feeding in hover-flies (Diptera: Syrphidae). *New Zealand journal of zoology* **3**(4): 339-350.

Hopper, J.V., Nelson, E.H., Daane, K.M., Mills, N.J. 2011. Growth development and consumption by four syrphid species associated with the lettuce aphid, *Nasonovia ribisnigri* in California. *Biological Control*.

Hristov, P., Neov, B., Shumkova, R., Palova, N. 2020. Significance of Apoidea as main pollinators. Ecological and economic impact and implications for human nutrition. *Diversity* **12**(7): 280.

Inouye, D.W. 2001. Pollinators the role of. *Enclycopedia of Biodiversity* **4**: 723-730.

Inouye, D., Larson, B., Symank, A., Kevan, P. 2015. Flies and flowers: ecology of foraging and pollination. *Journal of Pollination Ecology* **16**: 115-133.

Jarlan, A., Oliveira, D.D., Gingras, J. 1996. Pollination of sweet pepper, *Capsicum annuum* (L.) in greenhouse by the syrphid fly, *Eristalis tenax* (L.). *In VII International Symposium on Pollination* **437**: 335-340.

Jervis, M.A., Kidd, N.A., Fitton, M.G., Huddleston, T., Dawah, H.A. 1993. Flower visiting by hymenopteran parasitoids. *Journal of Natural History* **27**(1): 67-105.

Joseph, A.N. and Parui, P. 1927a. Diptera from NEFA and Assam foothills Part I. Kameng Frontier Division and Assam foothills. *Records of the Zoological Survey of India* **66**: 63-74.

Joseph, A.N. 1967. A new Indian species of *Sphaerophoria st*. *Fargeau* and *Serville* (Diptera: Syrphidae). *Bulletin of Entomology* **8**(2):79-80.

Joseph, A.N. and Parui, P. 1986. Diptera from silent valley. *Records of the Zoological Survey of India* **84**: 157-164.

Joshi, S., Venkaesan, T., Rao, N.S. 1997. Host range and predatory fauna of *Aphis craccivora* Koch (Homoptera: Aphididae) in Bangalore, Karnataka. *Journal of Biological Control* **11**: 59-63.

Joshi, S. and Ballal, C.R. 2013. Syrphid predators for biological control of aphids. *Journal of Biological Control* **27**(3): 151-170.

Kakkar, K.L. 1981. Foraging behaviour of insect pollinators of cauliflower bloom. *Indian Journal of Ecology* **8**(1): 126-130.

Kapil, R.P. and Jain, K.L. 1980. Biology and utilization of insect pollinators from crop production. Final Tech report. HAU. Hisar. 81.

Karelin, V.D. 1980. Conditions for the use of syrphids. *Zashchita Rastenii* **1**: 40-41.

Kearns, C.A., Inouye, D.W., Waser, N.M. 1998. Endangered mutualisms the conservation of plant-pollinator interactions. *Annual Review of Ecology and Systematics* **29**: 83-112.

Kevan, P.G. and Baker, H.G. 1983. Insects as flower visitors and pollinators. *Annual Review of Entomology* **28**: 407-453.

Kevan, P.G. 2002. Flowers pollination and the associated diversity of flies. *Biodiversity* **3**(4): 16-18.

Khan, A.A., Shah, M.A., Majid, S. 2016. Functional response of four syrphid predators associated with green apple aphid (Hemiptera: Aphididae) in Laboratory. *Journal of Economic Entomology* **109**(1): 78-83.

Klecka, J., Hadrava, J., Biella, P., Akter, A. 2018. Flower visitation by hoverflies (Diptera: Syrphidae) in a temperate plant-pollinator network. *PeerJ* **6**: e6025.

Knutson, L.V., Thompson, F.C., Vockeroth, J.R., Hardy, M.D. 1975. A catalogue of the Diptera of the oriental region. 2: 459.

Kotwal, D.R., Bhalla, D.P., Verma, A.K. 1984. Natural enemies of cabbage aphid, *Brevicoryne brassicae* (Linn.) in the mid-hill regions of Himachal Pradesh. *Indian Journal of Agricultural Science* **54**: 1011-1012.

Kumar, J., Misra, R.C., Gupta, J.K. 1985. The effect of mode of pollination on *Allium* species with observation on insects as pollinators. *Journal of apicultural Research* **24**(1): 62-66.

Kumar, D., Prasad, C.S., Kumar, S., Singh, R. 2017. Isolation, identification and occurrence of major syrphid fly species of various agricultural, horticultural, medicinal and oil seed crops in Western Uttar Pradesh. *Journal of Entomology and Zoology Studies* **5**(3): 844-850.

Landis, D.A., Wratten, S.D., Gurr, G.M. 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review of Entomology* **45**: 175–201.

Larson, B.M., Kevan, P.G., Inouye, D.W. 2001. Flies and flowers: Taxonomic Diversity of anthophiles and pollinators. *The Canadian Entomologist* **133**: 439-465.

Lautenbach, S., Seppelt, R., Liebscher, J., Dormann, C.F. 2012. Spatial and temporal trends of global pollination benefit. **7**(4): e35954.

Lavoipierre, F. 2007. Garden Allies: Hover Flies. Pacific Horticulture Society, newsletter issued April 7th.

Lingappa, S., Patil, R.K., Tippannavar, P.S., Balikai, R.A., Kumar, P. 2004. Development strategies for the management of woolly aphid, *C. lanigera* Z. (Homoptera: Aphidiadae) on sugarcane. Project Report Submitted to the Department of Agriculture, Government of Karnataka. 46-53.

Luna, J. and Colley. M.R. 2000. Enhancement of biological control with beneficial insectary plantings. Organic Farming Foundation Project Report. 98-27.

Marinoni, L. and Thompson, F.C. 2003. Flower flies of southern Brazil (Diptera: Syrphidae). Part I. Introduction and new species. *Studia Dipterologica* **10**(2): 565-578.

McGregor, S.E. 1976. *Insect pollination of cultivated crop plants*. Washington, DC: United States Department of Agriculture.

Mengual, X. and Ghorpade, K. 2010. The flower fly genus *Eosphaerophoria* Frey (Diptera: Syrphidae). *Zoo Keys* **33**: 39-80.

Miranda, G.F., Young, A.D., Locke, M.M., Marshall, S.A., Skevington, J.H., Thompson, F.C. 2013. Key to the genera of Nearctic Syrphidae. *Canadian Journal of Arthropod Identification* **23**: 1–351.

Mishra, R.C. and Kumar, J. 1993. Status of research in Pollination biology in Himachal Pradesh. *Proceedings of the International Symposium on Pollination in Tropics*. Pub. IUSSI-Indian Chapter. pp. 279-295.

Mitra, B., Bhattacharjee, K., Parui, P., Mukherjee, M. 2002. Insect pollinators of Sarpgandha plant from South 24 Parganas, West Bengal. *BIONOTES* **4**(3): 67.

Mitra, B., Parui, P., Banerjee, D., Sharma, R.M. 2004a. On a collection of Diptera from Kalatop Khajjiar Wildlife Sanctuary, Himachal Pradesh. Himalayan Chemistry and Pharmacy Bulletin. **21**: 31-35.

Mitra, B., Parui, P., Sharma, R.M., Banerjee, D., Mehta, H.S. 2004c. Diptera fauna of chandigarh. *Journal of Interacademicia* **8**(3): 393-423.

Mitra, B., Parui, P., Banerjee, D., Mukherjee, M., Bhattacharya, K. 2005. A report on flies (Diptera: Insecta) as flower visitors and pollinators of Kolkata and its adjoining areas. *Records of the Zoological Survey of India* **105**(34): 120.

Mitra, B. and Banerjee, D. 2007. Fly Pollinators: Assessing their value in biodiversity conservation and food security in india. *Records of the zoological Survey of India* **l07**(Part-l): 33-48.

Mitra, B., Mukherjee, M., Banerjee, D. 2008. A check list of hoverflies (Diptera: Syrphidae) of Eastern Himalayas. *Records of the Indian Museum Zoological Survey of India* **284**: 1-47.

Mitra, B., Roy, S., Imam, I., Ghosh, M. 2015. A review of the hover flies (Syrphidae: Diptera) from India. *International Journal of Fauna and Biological Studies* **2**(3): 61-73.

Mizuno, M., Itioka, T., Tatematsu, Y. Itô, Y. 1997. Food utilization of aphidophagous hoverfly larvae (Diptera: Syrphidae, Chamaemyiidae) on herbaceous plants in an urban habitat. *Ecological Research* **12**: 239-248.

Mukherjee, M., Parui, P., Mitra, B. 2006. Diptera: Syrphidae. In Fauna of Nagaland. State fauna series. **12**: 185-192.

Mukherjee, M., Parui, P., Mitra, B. 2006. Insecta (Diptera: Syrphidae). Fauna of Arunachal Pradesh. State fauna series. **13**(2): 331-354.

Nayar, J.L. 1968. A contribution to our knowledge of high altitude Diptera, Cyclorrhapha: Syrphidae from north west Himalaya, Part I-Subfamily Syrphinae. Agra University. *Journal of Research Science* **16**: 121-131.

Nelson, E.H., Hogg, B.N., Mills, N.J., Daane, K.M. 2012. Syrphid flies suppress lettuce aphids. *Biocontrol* **57**: 819-826.

Omkar, G.M. 2016. Syrphid Flies (the Hovering Agents). Academic Press, San Diego, CA.

Pape, T. and Thompson, F.C. 2016. Systema Dipterorum Version 2.0, Jan 2011. In, Species 2000 & ITIS Catalogue of Life.

Pascual, M.J., Lacasa, A., Gonzalez, A., Varo, P. and Garcia, M.J. 2006. Effect of flowering plant strips on aphid and syrphid populations in lettuce. *European Journal of agronomy* **24**(2): 182-185.

Phillips, B.B., Williams, A., Osborne, J.L., Shaw, R.F. 2018. Shared traits make flies and bees' effective pollinators of oilseed rape (*Brassica napus* L.). *Basic and Applied Ecology* **32**: 66-76.

Pineda, A. and Garcia, M. 2008b. Seasonal abundance of aphidophagous hoverflies (Diptera: Syrphidae) and their population levels in and outside Mediterranean sweet pepper greenhouses. *Annals of the Entomological Society of America* **101**(2): 384-391.

Prabhakar, A.K. and Roy, S.P. 2010. Biodiversity of aphids and their coccinellid and syrphid predators on vegetable crops of North-East Bihar (India). *Proceedings of the Zoological Society of India* **9**: 41-50.

Priti. 1998. Abundance and pollination efficiency of insect visitors of onion bloom. *Indian Bee Journal* **60**(2): 75-78.

Priti and Sihag, R.C. 1997. Diversity, visitation frequency, foraging behaviour and pollinating efficiency of insect pollinators on cauliflower, *Brassica oleracea* L. var. *botrytis* cv. Hazipur local blossoms. *Indian bee Journal* **59**(4): 230-237.

Puttannavar, M. 2004. Bio-ecology and management of woolly aphid, *C. lanigera* Z. (Homoptera: Aphididae). M. Sc. Thesis, University of Agricultural Sciences.

Qiao, G.X., Zhang, G.X., Simon, J.C., Dedryver, C.A., Rispe, C., Hullé, M. 2004. Preliminary study of aphid diversity in China: taxonomic and geographic variation.

Rader, R., Howlett, B.G., Cunningham, S.A., Westcott, D.A., Newstrom, L.E., Walker, M.K. 2009. Alternative pollinator taxa are equally efficient but not as effective as the honeybee in a mass flowering crop. *Journal of Applied Ecology* **46**(5): 1080-1087.

Rader, R., Edwards, W., Westcott, D.A., Cunningham, S.A., Howlett, B.G. 2011. Pollen transport differs among bees and flies in a human-modified landscape. *Diversity and Distributions* **17**(3): 519-529.

Rader, R., Bartomeus, I., Garibaldi, L.A., Garratt. M.P., Howlett, B.G., Winfree, R. 2016. Non-bee insects are important contributors to global crop pollination. *Proceedings of the National Academy of Sciences* **113**(1): 146-151.

Radhakrishnan, B. and Muraleedharan, N. 1993. Bio-ecology of six species of syrphid predators of the tea aphid, *Toxoptera aurantia* in southern india. *Entomon* **18**: 175-180.

Raina, N., Samuel, I.J., Dass., Singh, R. 2005. Feeding potential and its effect on development of an aphid predator, *Episyrphus balteatus* (De Geer). (Diptera: Syrphidae) vis-a-vis variable prey densities. *Journal of Aphidology* **19**: 93-100.

Reddi, E.U. 1993. Pollination studies of cashew in India: An overview. *Proceedings of the International Symposium on Pollination in Tropics*. 321-324.

Ribeiro, A.L. and Gontijo, L.M. 2017. Alyssum flowers promote biological control of collard pests. *Biological Control* **62**(2): 185-196.

Rotheray, G.E. and Gilbert, F. 2011. The natural history of Hoverflies. Forrest Text Publisher, Iver, United Kingdom.

Sahayaraj, K. 2004. Indian insect predators in biological control. Daya publishing house. Delhi, India. **1**: 336.

Sajjad, A. and Saeed, S. 2010. Floral host plant range of syrphid flies (Syrphidae: Diptera) under natural conditions in southern Punjab, Pakistan. *Pakistan Journal of Botany* **42**(2): 1187-1200.

Sajjad, A., Saeed, S., Ashfaq, M. 2010. Seasonal variation in abundance and composition of Hoverfly (Diptera: Syrphidae) communities in Multan, Pakistan. *Pakistan Journal of Zoology* **42**(2): 105-115.

Schneider, E. 1969. Bionomics and physiology of aphidophagous Syrphidae. *Annual Review of Entomology* **14**: 103-123.

Sengupta, J., Naskar, A., Maity, A., Hazra, S., Banerjee, D. 2016. New distributional records and annotated keys of hoverflies (Diptera: Syrphidae) from Himachal Pradesh, India. *Journal of Advanced Zoology* **37**(1): 31-54.

Sengupta, J., Naskar, A., Maity, A., Homechaudhuri, S., Banerjee, D. 2018. A taxonomic account of Hoverflies (Diptera: Syrphidae) with 4 new records from cold dry zones of Himachal Pradesh, India. *International Journal of Advancement in Life Sciences Research* **1**(4): 13-30.

Shah, G.M., Ulfat Jan., Aijaz, A.W. 2014. A checklist of hoverflies (Diptera: Syrphidae) in the western Himalaya, India. *Acta Zoologica Academiae Scientiarum Hungaricae* **60**(4): 283-305.

Sharma, P.L., Dhaliwal, H.S., Kakar, K.L. 1974. Insect visitors and pollinators of cauliflower, *Brassica oleracea* var. *botrytis* seed crop bloom. *Himachal Journal of Agricultural Research* **2**: 74-78.

Sharma, S., Abbas, S.R., Shukla, R.P. 1998. An easy & quick method of breeding flies for pollination of mango blossoms. *Insect Environment* **4**(3): 76-77.

Shebl, M.A., Kamel, S.M., Hashesh, T.A., Osman, M.A. 2008. Seasonal abundance of leaf cutting bees, *Megachile minutissima* (Megachilidae, Hymenoptera). *World Journal of Agricultural Science* **4**: 280-287.

Sihag, R.C. 1986. Insect pollination increases seed production in cruciferous and umbelliferous crops. *Journal of apiculture Research* **25**(2): 121-126.

Singh, R. and Mishra, S. 1988. Development of a syrphid fly, *Ischiodon scutellaris* (Fabr.) on *Rhopalosiphum maidis* (Fitch). *Journal of Aphidology* **2**(1-2): 28-34.

Skevington, J.H. and Dang, P.T. 2002. Exploring the diversity of flies (Diptera). *Biodiversity* **3**(4): 3-27.

Sommaggio, D. 1997. Syrphidae. Can they be used as environmental bioindicators? *Agriculture Ecosystems and Environment* **74**: 343-356.

Sommaggio, D. and Burgio, G. 2014. The use of Syrphidae as functional bioindicator to compare vineyards with different managements. *Bulletin of Insectology* **67**(1): 147-156.

Speight, M.C. and Lucas, J.A. 1992. Liechtenstei Syrphidae (Diptera). Berichte der Botanisch Zoologischen Gesellschaft Liechtenstein-Sargans Werdenberg. **19**: 327 - 463.

Ssymank, A., Kearns, C.A., Pape, T., Thompson, F.C. 2008. Pollinating flies (Diptera): A major contribution to plant diversity and agricultural production. *Biodiversity* **9**(1-2): 86-89.

Sutherland, J.P., Sullivan, M.S., Poppy, G.M. 1999. The influence of floral character on the foraging behaviour of the hoverfly, *Episyrphus balteatus*. *Entomologia Experimentalis et Applicata* **93**(2): 157-164.

Talasova, A., Straka, J., Hadrava, J., Benda, D., Kocourek, F., Kazda, J. 2018. High degree of philopatry is required for mobile insects used as local indicators in biodiversity studies. *Ecological Indicators* **94**: 99-103.

Tenhumberg, B. and Poehling, H.M. 1995. Syrphids as natural enemies of cereal aphids in Germany. Aspects of their biology and efficacy in different years and regions. *Agriculture, Ecosystems and Environment* **52**(1): 39-43.

Tewari, G.N. and Singh, K. 1983. Studies on insect pollinators in relation to seed production in cauliflower, *Brassica oleracea* var. *botrytis* Linn. *Indian Bee Journal* **45**(2-3): 54-55.

Thompson, F., Rotheray, G., Zumbado, M. 2010. Syrphidae (flower flies). Manual of Central American Diptera. NRC Research Press, Ottawa, Canada. **2**.

Thomson, R. 2013. Insecta. Part-C (Diptera: Syrphidae). *Zoological Record* **149**(13C): 383-398.

Vockeroth, J.R. 2001. The flower flies of the subfamily Syrphinae of Canada, Alaska, Greenland. Diptera: Syrphidae. *The Insects and Arachnids of Canada* **1**: 12-16.

Von, C.D., Rowe, C.A., Heie, O.E. 2006. A test of morphological hypotheses for tribal and sub-tribal relationships of Aphidinae (Insecta: Hemiptera: Aphididae) using DNA sequences. *Molecular Phylogenetics and Evolution* **38**(2): 316-329.

Wahengbam, J., Raut, A., Banu, N. 2019. Syrphid fly: A potential bioagents and pollinators. *Think India Journal* **22**: 34.

Wahengbam, J., Raut, A., Pal, S., Banu, N. 2019. Role of bumble bee in pollination. *Annals of Biology* **35**(2): 290-295.

Walker, J.T. 1985. The influence of temperature and natural enemies on population development of woolly apple aphid, *Eriosoma lanigerum* (Hausmann) (Doctoral dissertation, Washington State University).

Wang, B., Liu, Y., Wang, G.R. 2017. Chemosensory genes in the antennal transcriptome of two syrphid species, *Episyrphus balteatus* and *Eupeodes corollae* (Diptera: Syrphidae). *BMC Genomics* **1**: 586.

Wenbin, L., Minli, W., Zhenmin, L. 2009. Research advances in Syrphidae in China. *Chinese Bulletin of Entomology* **46**(6): 861-865.

Zheng, Z., Liu, H., Wang, X., Wu, X., Chen, Y., Deng, J., Chen, X., Li, Y., Pu, D. 2019. Development and reproduction of the hoverfly, *Eupeodes corollae* (Diptera: Syrphidae). *Journal of Earth Sciences & Environmental Studies* **4**(4): 654-660.