**Review of Floral Biology and Insect Floral Visitors of Bottle Gourd (*Lagenaria siceraria*(Molina) Standley)**

**Abstract**

Pollination is vital for the survival of cross-pollinated plants, achieved through wind, water, and animal vectors. In animals, insects are the major vectors of pollination, including cucurbitaceous crops, where the bottle gourd is monoecious with the diurnal, crepuscular, and nocturnal habit of anthesis. In bottle gourd, staminate and pistillate flowers appear 55 to 83 days after planting on different nodes of the same plant with a ratio of 19:1 to 23:1. A meta-analysis of studies on insect floral visitors of bottle gourd revealed that 86 insect species consisting of 23 Hymenopterans, 22 Lepidopterans, 21 Dipterans, 11 Coleopterans, 4 Hemipterans, 2 Orthopterans, and 1 each of Odonatan, Thysanopteran, and Mantodean insects visited bottle gourd flowers.

**Keywords:** pollination**,** bottle gourd, floral biology, insect visitors.

**1. INTRODUCTION**

The bottle gourd, *Lagenaria siceraria* (Molina) Standley is one of the multipurpose Cucurbitaceous vegetables domesticated first in Southern Africa (Zhao et al., 2024), and its tender fruits are consumed as fresh vegetables. In contrast, dried fruits are used as storage jars, containers, bowls, musical instruments, and fishing floats (Ahuja et al., 2011). Additionally, it has numerous medicinal values, like a low-calorie vegetable rich in vitamins and minerals with antianxiety, antioxidant, antiurolithiatic, anthelmintic, antihyperlipidemic, antihyperglycemic, anticancer, anti-inflammatory, immunomodulator, and hepatoprotective properties. Moreover, the fruit pulp treats stomach acidity, indigestion, ulcers, hair disorders, diabetes, hypertension, and liver ailments (Zahoor et al., 2021). In addition, the vine is used as a rootstock, and its pollen is used for breeding seedless watermelons (Ulas et al., 2019; Sugiyama et al., 2014). Despite the huge benefits of bottle gourd, in India, the crop is cultivated in an area of 193 thousand hectares with a production of 3,171 thousand metric tons and a productivity of 366 metric tons per hectare (NHB, 2021). Bottle gourd is an exclusively cross-pollinated plant and its survival depends on its pollinators, especially insects. Hence, the following study was conducted to document various insect species visiting bottle gourd flowers.

**2. Floral biology of the bottle gourd**

Bottle gourd is monoecious, self-compatible, and highly cross-pollinated, requiring a protandrous plant, where staminate and pistillate flowers appear 55 to 83 days after planting on different nodes of the same plant with a ratio of 19:1 to 23:1 (Okunlola et al., 2022). Despite the staminate flowers appearing early at 55 to 59 days after planting with a long peduncle, 5 green sepals, 5 smaller white petals, and 3 fused stamens, they last for a short time (Sugiyama et al., 2014) compared with pistillate flowers, which appear 14 to 28 days later with a short peduncle, 5 green sepals, 5 larger white petals, 3 united carpels, and an inferior ovary (Okunlola et al., 2022; Khosa and Dhatt, 2015; Sugiyama et al., 2014; Morimoto et al., 2004; Stephens et al., 1994), and the flowers exhibit crepuscular blooming such as opening in late afternoon (Sugiyama et al., 2014; Shrivastava, 1990) and mostly in the night (Okunlola et al., 2022; Nandpuri and Singh, 1967; Theis et al., 2014). However, in south Indian conditions, anthesis (flower opening) takes place between 9 AM and 2 PM with the stigma remaining receptive for 24 h before and after anthesis (Joshi and Gaur, 1971), while in north Indian conditions, stigmatic receptivity lasts for 36 h before anthesis to 60 h after anthesis (Nandpuri and Singh, 1967). Furthermore, it is estimated to have high cross-pollination ability (Tiwari and Ram, 2009), where pollen grains are large and sticky, so wind and water are not involved in pollination. Hence, it depends entirely on the animals, especially insects, for pollination and successful fruit set (Morimoto et al., 2004; Okunlola et al., 2022).

**3. Diversity of insect visitors to bottle gourd flowers**

The growth, development, and reproduction of living organisms are based on the type of food materials they consume (Wu, 2022), and many arthropod insects eat nectar and pollen (Rácz et al., 2023). Pollen is a male gamete with 54.22% carbohydrates, 21.30% proteins, and 5.31% lipids. At the same time, nectar is a complex, dynamic, energy-rich fluid containing sugars, amino acids, proteins, fatty acids, salts, vitamins, secondary metabolites, and water (Nicolson, 2022).

**3.1 Hymenoptera**

Hymenopteran insects have a division of labor (Grüter, 2020), where workers are actively engaged in food collection through their chewing and lapping mouthparts, which are exclusively meant for taking floral rewards such as nectar and pollen (Basari et al., 2021), which makes them the most efficient pollinators (Khalifa et al., 2021). Furthermore, at the time of the collection of floral rewards, the pollen grains stick to the body and are deposited on the stigma when landed on pistillate flowers. Additionally, the hymenopteran legs are modified to perform the function of pollen handling and packing (Portman et al., 2019). Despite the significant role of hymenopteran insects in pollination, a comprehensive review on hymenopteran floral visitors of bottle gourd (Morimoto et al., 2004; Srikanth et al., 2013; Manju et al., 2022; Sree Latha et al., 2018; Padhiyar and Patel, 2021; Subhakar and Sridevi, 2015; Rima, 2017; Saradar et al., 2024; Prajapati et al., 2021) revealed that 23 species visited bottle gourd flowers, with 11 insect species belonging to the Apidae family, 5 to Formicidae, 3 to Halictidae, and 1 to each Megachilidae, Ichneumonidae, Vespidae, and Scoliidae (Table 1).

**3.2 Lepidoptera**

Lepidopteran insects have egg, larvae, pupae, and adult stages (Sedlacek et al., 2018). In the larval stage, many insects are phytophagous (Wang et al., 2024) with their biting and chewing mouthparts (Liu and Jiang, 2023), but in the adult stage, the mouthparts are changed into the siphoning type (Guo et al., 2018). Despite this change, adults are confined to liquid food (Lehnert et al., 2016), and nectar is one of them (He et al., 2022). Hence, during the collection of nectar from the flower, the pollen grains stick to the body and get pollinated when landed on pistillate flowers. Moreover, studies on insect visitors to bottle-gourd flowers (Subhakar and Sridevi, 2015; Morimoto et al., 2004; Padhiyar and Patel, 2021; Srikanth et al., 2013; Thapa, 2006) revealed that 22 lepidopteran species visited bottle-gourd flowers, with 8 insect species belonging to the Sphingidae family and 5 to Pieridae, 2 to each Crambidae and Lycaenidae, and 1 to each Noctuidae, Pyralidae, Papilionidae, Hesperiidae, and Erebidae (Table 1).

**3.3 Diptera**

Dipteran insects undergo complete metamorphosis with eggs, larvae, pupa, and adult stages (Courtney et al., 2017). The larval stage is known as maggot, and in the adult stage, maggots transition from chewing mouthparts with hooks and spines (Bruno et al., 2020) that tear plant and animal tissues to sponging mouthparts with proboscis, specifically designed for consuming liquid food (Lehnert et al., 2022), where many adult dipterans feed on floral rewards such as nectar and pollen (Davis et al., 2023). Despite the hardy nature of pollen grains, pollen is crushed and swallowed by placing them between hardened plates of labella, and nectar is consumed with the help of the sucking pads of the proboscis (Sarwar, 2020). Furthermore, due to the stickiness of the pollen grains and the electrostatic forces of attraction (Khan et al., 2021), the pollen gets attached to the dipteran body and deposited on the stigma when it lands on the pistillate flowers. Moreover, the dipteran body has long bristles that provide more surface area for carrying more pollen grains (Cook et al., 2020). Hence, considering the significant role of dipteran insects in pollination, previous studies (Srikanth et al., 2013; Rima, 2017; Pramanik et al., 2023; Thapa, 2006) recorded 21 dipteran species as floral visitors of the bottle gourd. Among these, 10 species belong to the Syrphidae family, 2 to each Tephritidae, Stratiomyidae, Muscidae, and Calliphoridae family, and 1 to each Micropezidae, Lauxaniidae, and Micropezidae family (Table 1).

**3.4 Coleoptera**

Many coleopteran insects are phytophagous (Dedyukhin, 2015) and have biting and chewing mouthparts in the grub and adult stages (Liu and Tong, 2023). Additionally, many insects feed on floral petals, nectar, and pollen (Saravy et al., 2021; Batelka and Prokop, 2021). Due to this anthophilous nature, many coleopteran insects visit flowers and act as pollination vectors. Furthermore, previous studies (Morimoto et al., 2004; Prajapati et al., 2021; Srikanth et al., 2013; Rima, 2017; Dasgupta et al., 2018) recorded 11 coleopteran insect species visiting bottle gourd flowers, with 4 species belonging to the Chrysomelidae and Coccinellidae families and 1 to each the Meloidae, Nitidulidae, and Melolonthidae (Table 1).

**3.5 Hemiptera**

Hemipteran insects have piercing and sucking mouthparts in the nymph and adult stages. In piercing and sucking mouthparts, stylets are modified to puncture the plant tissue (Wang et al., 2020). Apart from this, some hemipteran insects also feed on floral nectar (Zhu et al., 2014), which makes the vectors of pollination (Garcia et al., 2023). Furthermore, studies on the insect visitors to bottle gourd flowers (Prajapati et al., 2021; Shrivastava, 1990; Rima, 2017) recorded 4 hemipteran species belonging to the family Pentatomidae, Pyrrhocoridae, Miridae, and Aphididae visited bottle gourd flowers (Table 1).

**3.6 Orthoptera**

Orthopteran nymphs and adults have biting and chewing mouthparts with a phytophagous nature (El Harche et al., 2024). In addition, orthopteran insects also feed on nectar and pollen, enabling them to visit flowers (Rácz et al., 2023). Furthermore, previous studies (Padhiyar and Patel, 2021; Subhakar and Sridevi, 2015) stated that *Phaneroptera falcata* of the Tettigoniidae family and *Hieroglyphus banian* of the Acrididae family visited bottle gourd flowers (Table 1).

**3.7 Thysanoptera**

Thysanopteran nymphs and adults have asymmetrical, rasping, and sucking mouthparts with plant sap as their major food (Singh and Rachana, 2020). Additionally, thrips eat pollen grains that make them visit flowers (Visschers et al., 2023). Furthermore, Rima (2017) stated that *Megalurothrips usitatus* of the Thripidae family visited bottle-gourd flowers (Table 1).

**3.8 Mantidae**

Mantises have mandibulate mouthparts with predatory behavior (Gao et al., 2021). In addition, some insect species eat pollen grains. Hence, due to their pollen-feeding nature (Lanna et al., 2021), they visit flowers and act as pollination vectors. Furthermore, Subhakar and Sridevi (2015) stated that *Mantis religiosa*of the Mantidae family visited bottle gourd flowers (Table 1).

**Conclusion**

Bottle gourd is monoecious with diurnal, crepuscular, and nocturnal habitats of anthesis. Studies on bottle-gourd insect floral visitors revealed that in the blooming period, 86 insect species visited bottle-gourd flowers. However, every insect floral visitor is not involved in pollination; hence, to know which insect contributes more to bottle gourd pollination, studies will be conducted on the pollination biology of the dominant visitor of bottle gourd flowers.

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**Table 1. Insect visitors of the bottle gourd flower**

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| S.NO | Scientific name | Family | Oder | References |
| 1 | *Apis mellifera* Linnaeus, 1758 | Apidae | Hymenoptera | Morimoto et al., 2004 |
| 2 | *Apis dorsata* Fabricius, 1793 | Apidae | Hymenoptera | Srikanth et al., 2013 |
| 3 | *Apis cerana* Fabricius, 1793 | Apidae | Hymenoptera | Manju et al., 2022 |
| 4 | *Amegilla zonata* (Linnaeus, 1758) | Apidae | Hymenoptera | Srikanth et al., 2013 |
| 5 | *Ceratina binghami* Cockerell, 1908 | Apidae | Hymenoptera | Srikanth et al., 2013 |
| 6 | *Ceratina hieroglyphica* Smith, 1854 | Apidae | Hymenoptera | Srikanth et al., 2013 |
| 7 | *Tetragonula iridipennis* (Smith, 1854) | Apidae | Hymenoptera | Sree Latha et al., 2018 |
| 8 | *Xylocopa* sp. | Apidae | Hymenoptera | Padhiyar and Patel, 2021 |
| 9 | *Xylocopa fenestrata*(Fabricius, 1798) | Apidae | Hymenoptera | Bhardwaj et al., 2012 |
| 10 | *Xylocopa virginica*(Linnaeus, 1771) | Apidae | Hymenoptera | Bhardwaj et al., 2012 |
| 11 | *Anthophora* sp. | Apidae | Hymenoptera | Morimoto et al., 2004 |
| 12 | *Camponotus compressus* (Fabricius, 1787) | Formicidae | Hymenoptera | Padhiyar and Patel, 2021 |
| 13 | *Camponotus pennsylvanicus*(De Geer, 1773) | Formicidae | Hymenoptera | Alim et al., 2023 |
| 14 | *Oecophylla smaragdina* (Fabricius, 1775) | Formicidae | Hymenoptera | Subhakar and Sridevi, 2015 |
| 15 | *Formica* sp. | Formicidae | Hymenoptera | Rima, 2017 |
| 16 | *Trichomyrmex* sp. | Formicidae | Hymenoptera | Saradar et al., 2024 |
| 17 | *Nomia elliotii* (Smith, 1875) | Halictidae | Hymenoptera | Srikanth et al., 2013 |
| 18 | *Nomia iridescens* (Smith, 1857) | Halictidae | Hymenoptera | Srikanth et al., 2013 |
| 19 | *Halictus* sp. | Halictidae | Hymenoptera | Srikanth et al., 2013 |
| 20 | *Megachile (Eutricharaea)* sp. | Megachilidae | Hymenoptera | Prajapati et al., 2021 |
| 21 | *Xanthopimpla stemmator*(Thunberg, 1822) | Ichneumonidae | Hymenoptera | Bhardwaj et al., 2012 |
| 22 | *Polistes* sp. | Vespidae | Hymenoptera | Bhardwaj et al., 2012 |
| 23 | *Scolia* sp. | Scoliidae | Hymenoptera | Bhardwaj et al., 2012 |
| 24 | *Hippotion celerio* (Linnaeus, 1758) | Sphingidae | Lepidoptera | Morimoto et al., 2004 |
| 25 | *Agrius convolvuli* (Linnaeus, 1758) | Sphingidae | Lepidoptera | Morimoto et al., 2004 |
| 26 | *Acosmeryx shervillii*Boisduval, 1875 | Sphingidae | Lepidoptera | Lu et al., 2021 |
| 27 | *Pergesa acteus*(Cramer, 1779) | Sphingidae | Lepidoptera | Lu et al., 2021 |
| 28 | *Psilogramma discistriga*Walker, 1856 | Sphingidae | Lepidoptera | Lu et al., 2021 |
| 29 | *Psilogramma increta* (Walker, 1865) | Sphingidae | Lepidoptera | Lu et al., 2021 |
| 30 | *Theretra tibetiana*Vaglia & Haxaire, 2010 | Sphingidae | Lepidoptera | Lu et al., 2021 |
| 31 | *Theretra silhetensis*Walker, 1856 | Sphingidae | Lepidoptera | Lu et al., 2021 |
| 32 | *Pieris brassicae* (Linnaeus, 1758) | Pieridae | Lepidoptera | Subhakar and Sridevi, 2015 |
| 33 | *Belenois creona* (Cramer, 1776) | Pieridae | Lepidoptera | Morimoto et al., 2004 |
| 34 | *Eurema hecabe* (Linnaeus, 1758) | Pieridae | Lepidoptera | Padhiyar and Patel, 2021 |
| 35 | *Delias eucharis* (Drury, 1773) | Pieridae | Lepidoptera | Subhakar and Sridevi, 2015 |
| 36 | *Danaus chrysippus*(Linnaeus, 1758) | Pieridae | Lepidoptera | Srikanth et al., 2013 |
| 37 | *Spoladea recurvalis* (Fabricius, 1775) | Crambidae | Lepidoptera | Padhiyar and Patel, 2021 |
| 38 | *Diaphania indica* (Saunders, 1851) | Crambidae | Lepidoptera | Subhakar and Sridevi, 2015 |
| 39 | *Lampides boeticus*(Linnaeus, 1767) | Lycaenidae | Lepidoptera | Thapa, 2006 |
| 40 | *Anthene lunulate* (Trimen, 1894) | Lycaenidae | Lepidoptera | Morimoto et al., 2004 |
| 41 | *Anadevidia peponis* (Fabricius, 1775) | Noctuidae | Lepidoptera | Subhakar and Sridevi, 2015 |
| 42 | *Arthroschista hilaralis* (Walker, 1859) | Pyralidae | Lepidoptera | Subhakar and Sridevi, 2015 |
| 43 | *Pachliopta hector* (Linnaeus, 1758) | Papilionidae | Lepidoptera | Srikanth et al., 2013 |
| 44 | *Gorgyra johnstoni* (Butler, 1894) | Hesperiidae | Lepidoptera | Morimoto et al., 2004 |
| 45 | *Dysgonia* sp. | Erebidae | Lepidoptera | Srikanth et al., 2013 |
| 46 | *Paragus yerburiensis* Stuckenberg, 1954 | Syrphidae | Diptera | Srikanth et al., 2013 |
| 47 | *Scaeva pyrastri* (Linnaeus, 1758) | Syrphidae | Diptera | Rima, 2017 |
| 48 | *Paragus crenulatus*Thomson, 1869 | Syrphidae | Diptera | Srikanth et al., 2013 |
| 49 | *Paragus serratus*(Fabricius, 1805) | Syrphidae | Diptera | Srikanth et al., 2013 |
| 50 | *Dideopsis aegrota* (Fabricius, 1805) | Syrphidae | Diptera | Pramanik et al., 2023 |
| 51 | *Episyrphus balteatus* (De Geer, 1776) | Syrphidae | Diptera | Pramanik et al., 2023 |
| 52 | *Ischiodon scutellaris* (Fabricius, 1805) | Syrphidae | Diptera | Pramanik et al., 2023 |
| 53 | *Eristalinus megacephalus* (Rossi, 1794) | Syrphidae | Diptera | Pramanik et al., 2023 |
| 54 | *Mesembrius bengalensis* (Wiedemann, 1819) | Syrphidae | Diptera | Pramanik et al., 2023 |
| 55 | *Syrphus* sp. | Syrphidae | Diptera | Thapa, 2006 |
| 56 | *Bactrocera cucurbitae* (Coquillett, 1899) | Tephritidae | Diptera | Rima, 2017 |
| 57 | *Platensina acrostacta* (Wiedemann, 1824) | Tephritidae | Diptera | Pramanik et al., 2023 |
| 58 | *Hermetia* sp. | Stratiomyidae | Diptera | Srikanth et al., 2013 |
| 59 | *Sargus metallinus*Fabricius, 1805 | Stratiomyidae | Diptera | Pramanik et al., 2023 |
| 60 | *Musca domestica* Linnaeus, 1758 | Muscidae | Diptera | Pramanik et al., 2023 |
| 61 | *Atherigona orientalis* Schiner, 1868 | Muscidae | Diptera | Pramanik et al., 2023 |
| 62 | *Lucilia porphyrina* (Walker, 1856) | Calliphoridae | Diptera | Pramanik et al., 2023 |
| 63 | *Lucilia cuprina* (Wiedemann, 1830) | Calliphoridae | Diptera | Pramanik et al., 2023 |
| 64 | *Mimegralla albimana* (Doleschall, 1856) | Micropezidae | Diptera | Pramanik et al., 2023 |
| 65 | *Homoneura bengalensis* (Macquart,1843) | Lauxaniidae | Diptera | Pramanik et al., 2023 |
| 66 | *Mimegralla albimana* (Doleschall, 1856) | Micropezidae | Diptera | Pramanik et al., 2023 |
| 67 | *Aulacophora semipalliata* Fairmaire, 1891 | Chrysomelidae | Coleoptera | Morimoto et al., 2004 |
| 68 | *Aulacophora intermedia* Jacoby, 1892 | Chrysomelidae | Coleoptera | Prajapati et al., 2021 |
| 69 | *Aulacophora foveicollis* (Lucas, 1849) | Chrysomelidae | Coleoptera | Srikanth et al., 2013 |
| 70 | *Diabrotica undecimpunctata* Mannerheim, 1843 | Chrysomelidae | Coleoptera | Rima, 2017 |
| 71 | *Coccinella septempunctata* Linnaeus, 1758 | Coccinellidae | Coleoptera | Rima, 2017 |
| 72 | *Cheilomenes sexmaculata* (Fabricius, 1781) | Coccinellidae | Coleoptera | Prajapati et al., 2021 |
| 73 | *Illeis cincta* (Fabricius, 1798) | Coccinellidae | Coleoptera | Prajapati et al., 2021 |
| 74 | *Coccinella transversalis* Fabricus, 1781 | Coccinellidae | Coleoptera | Prajapati et al., 2021 |
| 75 | *Coryna* sp. | Meloidae | Coleoptera | Morimoto et al., 2004 |
| 76 | *Epuraea (Haptoncus) motschulskyi* (Reitter) | Nitidulidae | Coleoptera | Dasgupta et al., 2018 |
| 77 | *Cyclocephala paraguayensis*Arrow, 1903 | Melolonthidae | Coleoptera | Favaris et al., 2020 |
| 78 | *Nezara viridula* (Linnaeus, 1758) | Pentatomidae | Hemiptera | Prajapati et al., 2021 |
| 79 | *Dysdercus cingulatus* (Fabricius, 1775) | Pyrrhocoridae | Hemiptera | Prajapati et al., 2021 |
| 80 | *Nesidiocoris tenuis* (Reuter, 1895) | Miridae | Hemiptera | Shrivastava, 1990 |
| 81 | *Therioaphis trifolii*(Monell, 1882) | Aphididae | Hemiptera | Rima, 2017 |
| 82 | *Phaneroptera falcata* (Poda, 1761) | Tettigoniidae | Orthoptera | Padhiyar and Patel, 2021 |
| 83 | *Hieroglyphus banian* (Fabricius, 1798) | Acrididae | Orthoptera | Subhakar and Sridevi, 2015 |
| 84 | *Diplacodes trivialis* (Rambur, 1842) | Libellulidae | Odonata | Padhiyar and Patel, 2021 |
| 85 | *Megalurothrips usitatus* (Bagnall, 1913) | Thripidae | Thysanoptera | Rima, 2017 |
| 86 | *Mantis religiosa*(Linnaeus, 1758) | Mantidae | Mantodea | Subhakar and Sridevi, 2015 |