



Leafhoppers and their morphology, biology, ecology and contribution in ecosystem: A review paper

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Abstract

The present study was conducted at Anhui Agricultural University, Hefei, China during 2018 and was compiled as a review paper from internationally recognized published articles plus Annual/Environmental reports of documented organizations. Leafhoppers (Auchenorrhynca: Cicadellidae) are small, very active jumping insects that commonly feed on a variety of host plants. Leafhoppers are agricultural pests while some species are also vectors of many plant viruses. Around 25000 species of leafhoppers have been identified and described by the experts. The study on leafhoppers plays a vital role in understanding their roles in our agroecosystem. This review paper summarizes the basic information regarding the morphology, biology and ecology of leafhoppers.

Keywords: agricultural pest, auchenorrhynca, cicadellidae, leafhopper, vector

Introduction

Insect species of the animal kingdom that belongs to family Cicadellidae are commonly known as leafhoppers. They are found in various zones of the planet in tropical and subtropical ecosystems (Dietrich, 2005) [14]. These small insects known as hoppers have piercing-sucking type of mouthparts (Dietrich, 2004) [13] hence suck plant sap from trees, grasses and shrubs, also recognized as plant sap feeders (Wayadande & Nault, 1996) [48]. Adults and nymphs leafhoppers are very active and jumping insects (Dietrich, 2004) [13] as their hind legs are modified for jumping, and hind tibia are covered with enlarged setae that helps to spread a secretion over their bodies which act as a pheromones carrier (Stiller & Michael, 2009) [44] and water repellent.

Leafhoppers possess an incomplete metamorphosis. Some species of leafhoppers are cosmopolitan (Fletcher *et al.*, 1991) [19] and/or distributed worldwide at various climates and habitats may be due to which Cicadellidae is considered as one of the largest families of plant-feeding insects that possess more than 22000 described species (Derlink *et al.*, 2016) [12]. They are associated with a wide range of hosts. Some leafhoppers are pests while many are vectors of plant diseases (Nielson, 1979) [36], viruses and phytoplasmas (Stiller & Michael, 2009) [44]. Spreading of leafhoppers transmitted pathogens commonly depends on their gender status, abundance of insect vectors and their plant-to-plant movement (Power, 1987; Power, 1992; Hunt *et al.*, 1993) [41, 42, 26]. The populations of injurious leafhoppers can be controlled or reduced by using contact pesticide. The uses of insecticides against pest leafhoppers usually do not give the effective control of diseases (Paddick *et al.*, 1971; Paddick & French, 1972) [39, 38] because it needs to understand the population dynamics of insects that helps in proper timing of insecticides application (Broadbent, 1957; Perring *et al.*, 1999) [4, 40]. Some leafhoppers species can be controlled by using the resistant plant varieties and by removing the crop debris which they

usually use during overwintering. To control leafhoppers biologically, entomopathogenic fungi and parasitoids are used (Dietrich, 2004) [13].

Leafhoppers are the members of order Hemiptera followed by infraorder Cicadomorpha, superfamily Membracoidea and family Cicadellidae respectively. Leafhoppers are further placed in about 40 subfamilies (Web source A) [49]. Some species of leafhoppers are called sharpshooters (Wilson *et al.*, 2009) [57].

Morphological Description

Leafhoppers (Auchenorrhynca: Cicadellidae) are small wedge-shaped insects that ranges from 2 to 30 mm in length (Dietrich, 2004) [13]. Species of leafhoppers may be dorso-ventrally flattened, globular or elongated in appearance (Dietrich, 2004) [13]. Leafhoppers are very active insects. Wings and legs are used for locomotion. Adult leafhoppers can fly as they have two pairs of wings in which the front pair is mostly colored and thickened while immature leafhoppers do not have wings so they mostly jump or run sideways (Hammond, 2018) [25]. Before it was suggested that leafhoppers were brown earlier and green was the first acquired alternative color (Evans, 1966) [17]. Afterwards the evolutionary development has risen the insects with predominantly black and lack or have red, yellowish or sometimes bluish patterns/markings (Evans, 1988) [18]. Many leafhoppers are green or brown in color but some species are marked with a variety of colorful pattern (Dietrich, 2004) [13]. The hind tibia of leafhoppers possesses four rows of enlarged spine like setae. Tymbals are present at the base of leafhoppers' abdomen that vibrates and produces small sounds (Dietrich, 2004) [13]. Leafhoppers are blunt headed (Hammond, 2018) [25] and their head sometimes possess spines or some other ornamentation. One of the main distinguishing characteristics of leafhoppers subfamilies is the position of two lateral ocelli, when present (Evans, 1988) [18]. Other major

morphological features that differentiate species of leafhoppers include the setae arrangement on legs, venation in their wings and the male and female genitalia (Dietrich, 2004)^[13]. To protect themselves and their eggs from pathogens and predation, some leafhoppers' species produce brochosomes.

Behavior and Biology

Leafhoppers have many communication behaviors that include chemical communication systems like other insects. The male leafhoppers have special tymbals that vibrate (Ossiannilsson, 1949; Claridge, 1985a)^[37, 7]. These vibrating signals are transmitted through the substrate (Ichikawa and Ishii, 1974; Ichikawa, 1976; Ichikawa, 1979; Inoue, 1982; Claridge, 1985a; Claridge, 1985b)^[29, 27, 28, 30, 7, 8] mostly in bending waves (Cocroft *et al.*, 2000; Greenfield, 2002)^[9, 22]. Females of leafhoppers lack tymbal but often are able to make sounds through various stridulatory mechanisms (Gillham, 1992)^[20]. The production of sound through tymbal occurs in all superfamilies of Auchenorrhynca, even in Cicadoidea it is not present only in one sex as *Tettigarcta* females can also sing. So this feature might be acquired in early Mesozoic, if not Palaeozoic era (Evans, 1941)^[15]. During early Mesozoic times, some Auchenorrhynca were able to stridulate which is supposed due to some upper Triassic Homoptera like “*Eoscartoides bryani* Evans” possesses stridulatory areas on their proximal costal area of tegmina (Evans, 1961)^[16]. Many Auchenorrhynca possess a diverse range of vibrational or acoustic signals that are associated with various behaviors (Claridge, 1985a)^[7], but usually it is produced in pair formation and are called “calling signals” (Ichikawa, 1976; Claridge, 1983; Claridge, 1985a)^[27, 6, 7]. Generally a vibratory or auditory response is received by the calling male from the responding females, and the male usually continue duetting during their search for a stationary female. This behavior is in contrast with various acoustical insects in which the female finds the calling signals produced by stationary males (Bailey, 1991; Bailey, 2003)^[2, 3].

The maturity of leafhopper is fast because they are hemimetabolous insects (Dietrich, 2004)^[13] so they develop from nymph to adult without passing through pupal stage. Seasonal breeding, sexual reproduction and internal fertilization are the main reproduction characteristics of leafhoppers. In the late spring season, female leafhoppers after mating probably deposit eggs inside the stem or larger veins of the leaves of damaged plants either singly or in batches (Evans, 1988)^[18]. The eggs hatch in 6–9 days, and to become a fully grown adult, the emerged nymph usually needs to molt five times (Dietrich, 2004)^[13]. The white shed skin during the molting stage can easily be found attached on the lower side/underside of the leaves. Adult leafhoppers usually find non-cultivated fields/areas and crop debris near gardens to overwinter. The total expected life duration of leafhoppers from eggs to the fully grown adults varies from specie to specie (Dietrich, 2004)^[13]. Many overlapping generations may occur during one growing season.

Ecology

Leafhoppers are present worldwide from tropical regions and temperate grasslands (Morris, 1971; Waloff, 1980)^[33, 47],

forests to high elevations and latitudes. Leafhoppers have herbivores (Taft and Dietrich, 2017)^[46] nature hence their trophic strategy (food habits) is that all leafhoppers suck the plant fluid with their piercing-sucking mouthparts (Dietrich, 2004)^[13]. Some leafhoppers species exist worldwide usually feed on a diverse range of plants while many species have a particular host plant (DeLong, 1948; Brown *et al.*, 1992; Whitcomb *et al.*, 1987; Whitcomb and Hicks, 1988; Nickel & Remane, 2002)^[11, 5, 56, 55, 34]. As far as predation of leafhoppers is concerned, they are fast movers and can easily dodge their predators. Some leafhoppers emit a distress call that causes their predators to drop them. Some of them have bright coloration which is suggested to be toxic but this information has not been reported yet (Hammond, 2018)^[25]. Many insects like Hymenoptera, Tyrannidae and some small birds are known predators of leafhopper (Rasmussen, 1941)^[43]. Adults and nymphs are parasitized by pipunculid flies, dryinid wasp and epipyropid moths while mymarid and trichogrammatid wasp is the egg parasitoids of leafhoppers. The oldest Cicadellidae fossils are traced back to lower Cretaceous period (Dietrich, 2004)^[13].

Leafhoppers have many associations like some species of genus *Anteon*, *Aphelopus* and *Gonatopus* are larval parasitoids of Cicadellidae. Their major role in the ecosystem is that they are the carrier of many plant diseases. Leafhoppers transmit bacteria, viruses and phytoplasmas (Lee *et al.*, 2000; Grylls, 1979; Gray & Banerjee, 1999; Backus *et al.*, 2005; Weintraub & Beanland, 2006)^[31, 23, 21, 1, 54]. They sometimes directly injured the plants by feeding while sometimes indirectly by transmitting plant pathogens (Nielson, 1968; Weintraub & Beanland, 2006)^[35, 54]. For protection against various predators, some leafhoppers like Australian *Kahaono montana* Evans usually build silk nests on underside of leaves of the same trees they live in (Gurr & Fletcher, 2011)^[24].

Evolution and Systematics

In taxonomic classification, leafhoppers were considered before in order Homoptera of class hexapoda, but due to more finding and modern researches by taxonomists they are now grouped together in order Hemiptera. The three superfamilies; Cercopoidea that includes spittlebugs and froghoppers, Cicadoidea which includes cicadas and Membracoidea are considered monophyletic. The closely related living insects of leafhoppers are the members of the families like Membracidae, Aetalionidae, Melizoderidae and Myerslopiidae (David, 1995; web source C)^[50, 51].

Leafhoppers have functional adaptations. The cicadas' wings shed the water and dirt with the help of nano scale protrusions which is surrounded by air pockets. The air pockets buoy droplets of water (web source D & E)^[52, 53].

The surface microstructures that has induced the self-cleaning effect on the cicada wings has inspired high interest to create super hydrophobic coatings that helps in the prevention of erosion, accumulation of bacteria and contamination. Even the natural microstructures on cicada wings and moth eyes both have different biological functionalities but they show high similarity in their structures, both consists of non-close-packed (ncp), nipple shaped hexagonally ordered protrusions with sub-300-nm-scale dimensions. Scientists have been

inspired by this similarity in generating the self-cleaning antireflection coatings (ARCs) (Sun *et al.*, 2008; Web source D & E) [45, 52, 53].

Contributions in Ecosystem

Leafhoppers contribute our ecosystem both positively as well as negatively. Positive contribution is that many predators feed on leafhoppers hence they are a good food source for small predators (Hammond, 2018) [25]. While negative impact is that many leafhoppers species are pests in agriculture (Day & Fletcher, 1994) [10] that includes potato leafhopper, beet leafhopper, two-spotted leafhopper, common brown leafhoppers, corn leafhopper, white apple leafhopper, green rice leafhopper, grape leafhoppers, glassy-winged sharpshooter (Dietrich, 2004) [13]. Leafhoppers carry many diseases from plant to plant which is the main cause of crop damage but sometimes they also damage crops directly by their feeding as well (Grylls, 1979; Gray & Banerjee, 1999; Backus *et al.*, 2005; Weintraub & Beanland, 2006) [23, 21, 1, 54]. Population of leafhoppers increases so fast that they can quickly become a problem (Hammond, 2018) [25].

Conclusion

From present description, it is concluded that wide variety of leafhoppers found across the globe. Ecological and geographical differences are the cause of diversity in leafhoppers fauna. Keeping in view of the importance of leafhoppers in our ecosystem, people must have an adequate knowledge and information about their species, biology, nature of damage and control strategies. Their presence in crop fields needs proper attention. New species of leafhoppers and their importance in agriculture and integrated pest management needs to be discovered further.

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