

Population dynamics of Cowpea aphid, *Aphis craccivora* on exotic flowering leguminous plant *Gliricidia sepium*

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Abstract

Insect-plant interaction may have several unpredictable consequences, especially invasive, non-native plants in novel habitats beyond their original distribution. During flowering season of invasive Mexican Lilac (*Gliricidia sepium*) leguminous plant, Cowpea aphid (*Aphis craccivora*) attacks, populate, and excrete sticky secretion which could have inhibitory effect on both animals and plants. We studied population dynamics of different stages of *A. craccivora* on trunk, leaves, and different parts of flowers (corolla, calyx, and peduncle). Our observations revealed that during peak infection, large nymphs populate all studied plant parts except corolla. Small nymphs dominated corolla while the number of apterous, parthenogenetic females was constant on all plant parts. Apterous females were dominantly present on trunk. Winged adults were present on all plant parts in small proportion (3.34–5.51%). Results of the present study suggest that during peak infection proportion of small and large nymphs dominate the growing parts in inflorescence. Parthenogenetic females might be preferring corolla as oviposition sites. Results of the study will be helpful in understanding aphid and invasive plant interactions and their consequences.

Introduction

Animals and plants depend on each other for food, shelter, pollination, etc. Among different plant-animal interactions, parasitism is the most common insect-plant interaction (Price et al. 1980). Most insects are dependent on plants to complete their life cycle. However, exotic invasive plants could influence existing insect-plant interactions in native habitats (Sunny et al. 2015).

Several studies demonstrated that invasive plants change the role of associated insects in well-established processes in the ecosystem (Stout and Tiedeken 2017). Sometimes, native insects may adapt to exotic plant species. For example, the Green peach aphid (*Myzus persicae*) are adapted to feed on exotic tobacco species that have been introduced to Australia, and the native aphids adapted to exotic plants had higher fitness than the aphids collected from native tobacco species (Jiang et al. 2013). Exotic or invasive plants could serve as highly nutritious hosts for native insects (Bezemer et al. 2014). These newly established interactions between exotic plants and insects could positively or negatively influence the other associated elements in the ecosystem (Bezemer et al. 2014; Spafford et al. 2013). For instance, aphid attacks on exotic plants have several consequences on the plant life cycle, flowering, physiology, etc. (Aslam et al. 2013; Chrétien et al. 2022; Stone et al. 2013).

Latest reports suggest that the number of exotic or invasive plants is increasing in different parts of the globe at an alarming rate (Krupnick 2013; Sax and Gaines 2003). The invasion of exotic plants could severely impact native biodiversity (Spafford et al. 2013) and ecosystem functioning (Robertson and Coll 2019; Weidenhamer and Callaway 2010). Therefore, interactions between exotic plants and associated insects need to be studied, especially for the conservation of native biodiversity and for exploring bio-prospection opportunities such as the synthesis of nanoparticles for biomedical applications (Nguyen et al. 2023), herbicides (Duke et al. 2000), etc.

Recently, in India, Cowpea aphids infection (*Aphis craccivora*) has been reported on exotic, invasive Mexican lilac, *Gliricidia sepium* (Hedayetullah and Zaman 2018). *Aphis craccivora* is an anholocyclic cosmopolitan aphid that lives in small clusters and feeds on the young shoots of the plant. The aphid *A. craccivora* prefers hot, dry habitats and completes its lifecycle within 10 to 20 days (Obopile and Ositile 2010). The development of *A. craccivora* from the first instar to adulthood takes 3–5 days (Ofuya 1997). *Gliricidia sepium* is a leguminous, thornless tree native to Central America and Mexico, and used in agriculture and land management (Chalmers et al. 1992). In the northern Western Ghats of India, we observed fairly large populations of *G. sepium* distributed, especially in low vegetation and dry zones in and around the Pune district. The flowering season of this plant in the study area commences during the early summer months (February and March). Our twelve years of continuous observations in the study area revealed that Aphid *A. craccivora* infects *G. sepium* during the flowering season (Fig. 1A and B). During the infection period, *A. craccivora* excretes a watery sticky, liquid that inhibits the growth of other plants around *G. sepium* plants (personal observations). Moreover, the plant inflorescence has been considered a rat killer (“Undirmari” in Marathi) locally in India. The extract of *G. sepium* is reported to have insecticidal, antimicrobial, and nematocidal properties (Nazli et al. 2008). *Aphis craccivora* infection during the flowering season of *G. sepium* may have several consequences, including recruitment of ants and parasitoids, deterrence of other insects and rodents, plant growth inhibition, etc. Currently, it is unclear whether plant ingredients or aphid excreta are responsible for plant growth inhibition and insecticidal or rodenticidal properties. Therefore, the interaction between the aphid (*A. craccivora*) and the flowering stage of *G. sepium* need to be investigated.

As a preliminary step to understanding severity of aphid infection on exotic *G. sepium*, susceptibility of different plant parts to aphid infection, and microhabitat selection by different life stages, we studied the populations of *A. craccivora* on infected flowering plants.

Material and method

We observed different stages of *A. craccivora* on *G. sepium* located on the Savitribai Phule Pune University campus. First, we identified different developmental stages of *A. craccivora* and categorised into four groups, Winged adult (W-adult), adult (apterous), and two groups of nymphs (Fig. 1). Nymphs were categorised into two groups, small nymphs (nymph-S) and large nymphs (nymph-L) based on their size, colour, and opacity (Fig. 1B, C, D, and E). Small nymphs were translucent and greenish in colour (1st and 2nd instar) while large nymphs were grey or brownish grey in colour (3rd and 4th instar) (Singh 1990). Different stages of aphids were photographed using the Oppo Find X3 Pro smartphone and a Mechanic stereo microscope attached to DX-480 camera.

We counted the number of individuals of different groups present on leaflets, trunks, and different parts of flowers (peduncle, calyx, and corolla) following the methodology described earlier (Hartnett and Bazzaz 1984). For this, we selected random trees (20 m apart from each other) on the campus and surrounding hill forest patches. We visited 18, 16, and 11 trees for observation of aphid infections on

leaflets, flowers, and trunks, respectively. We conducted the study from February 2023 to March 2023, from 10:00 a.m. to 4:00 p.m.

We observed aphids on the leaves and flowers of the plants with the help of magnifying glasses, scissors, forceps, and a Petri Dish. A random leaflet or flower of the infected tree was collected using scissors and forceps. The infected parts were observed with the naked eye and/or using a magnifying glass. The number of individuals from different groups of aphid life stages were observed and recorded. Multiple readings (at least 3 to 10) were taken from each plant. We also observed populations of aphids on different parts of the flower (corolla, calyx, and peduncle) independently. For each part of the flower, the number of individuals was counted separately. We observed aphids on the trunk of the tree using a scale box of 10 x 10 cm, and the number of aphids was counted and recorded.

The data collected was analysed and presented using Microsoft Excel. The association between different stages of the aphid *A. craccivora* and plant parts was analysed using cladistics analysis and the Brey-Curtis dissimilarity index. The statistical analysis was carried out using PAST 4.10 freeware.

Result

Overall, nymphs were predominantly present on the *Gliricidia sepium* trees, followed by hatchlings, adults, and W-adults (Fig. 2A). Winged adults were present on all plant parts in a small (less than 6%) proportion (Fig. 2B). Small nymphs were abundantly present on the corolla, while large nymphs populated the calyx (Fig. 2C). The proportion of small and large nymphs was similar on the peduncle, while large nymphs were dominated on the leaves, followed by small nymphs, apterous adults, and winged adults (Fig. 2B). On the trunk, only apterous adults and W-adults were observed. The proportion of parthenogenetic apterous adult females was more than 90% on the trunk (Fig. 2D).

Cluster analysis revealed that leaves and corolla had the most similar proportion of different stages of aphids (Fig. 10; Cophenetic correlation = 0.94). Similarly, the calyx and peduncle were situated in a clade with a similar proportion of different aphid stages and adults. Trunk emerged as an outgroup as only adult forms were observed (Fig. 2D).

Discussion

Studies on insect population dynamics are primarily important, especially in understanding insect-plant interactions. Population dynamics studies of pests and their host plants are important in determining the active stage of the insect, the severity of infection, vulnerable stage during plant development, and the insect's developmental stage that can be targeted while controlling the pest. The present study reports the population dynamics of different life stages of *A. craccivora* on different parts of *G. sepium*. The study revealed interesting facts about the stages and microhabitat selection by different stages of aphids during infection and discussed the possible causes and consequences. Aphid *A. craccivora* infects *G. sepium* mainly during the flowering season and damages the entire inflorescence. During the interaction,

aphids excrete an enormous amount of sticky liquid droplets that spread throughout entire plant and possibly hamper the physiology, growth, etc. of *G. sepium* (Goggin 2007).

During the present study, we observed the complete exploitation of *G. sepium* inflorescence by *A. craccivora*, eventually leading to the shedding of leaves and flowers. A month after complete shedding, *G. sepium* again started developing shoots but not blooming; suggesting that *A. craccivora* infection severely affects flowering and the life cycle. Aphid colony population structure may have multiple dimensions depending on the resources available and ecological conditions (Dixon 1985). One type of interaction between aphids and their host plants is mutualism, where the aphids benefit the plant by producing honeydew, a sugary substance that is excreted by the aphids as waste. Honeydew can serve as a food source for beneficial insects such as ants, wasps, and ladybirds, which in turn can help protect the plant from herbivores and pathogens (Stadler and Dixon 1998). Some studies have also suggested that the high sugar content of honeydew may provide a source of nutrition for the plant itself (Owen 1980). However, the feeding behaviour of aphids can also have negative effects on the host plant, including reduced plant growth, decreased photosynthesis, and increased susceptibility to pathogens and other stressors (Goggin 2007). Additionally, some aphid species can transmit plant viruses, which can have devastating impacts on crop yields (Ng and Perry 2004).

In the present study, we observed the distribution of different life stages of the aphid *A. craccivora* on the exotic plant *G. sepium* and found that all parts except the trunk were dominated by hatchlings and nymphs. *Gliridicia sepium* is a rapidly growing plant where young inflorescence buds are continuously present during the flowering season. These growing parts contain highly nutritious sap, which is an important source of food for hatchlings and nymphs. The young green parts of the inflorescence are soft and luscious, which are the major sites of initial attacks and settlements of aphids (Guerrieri and Digilio 2008). In the inflorescence of *G. sepium*, the peduncle and calyx are the softest young parts. Apparently, we observed large numbers of nymphs in these parts. Aphids are phloem-feeding insects that use their stylet mouthparts to pierce plant tissues and extract sap rich in sugars and nutrients. However, not all parts of a plant contain the same concentration of nutrients. For example, new growth and reproductive structures may have higher nutrient concentrations than older leaves (Guerrieri and Digilio 2008). Aphids have been shown to exhibit preferences for certain plant parts or species that have higher concentrations of the nutrients they require (Gianoli 2000). They can also respond to changes in nutrient availability by moving to other parts of the same plant or to nearby plants with higher nutrient concentrations (Grez and González 1995). Interestingly, we observed a greater number of hatchlings or small nymphs on the corolla than in any other part. The corolla of *G. sepium* lacks sap-containing green tissue necessary for fast-growing, large, voracious nymphs. On the other hand, large nymphs were predominantly present in the nearby tissue calyx. The density of large nymphs was low on the corolla as compared to the calyx. The occurrence of a large number of small nymphs on the corolla could be due to the fact that parthenogenic females might have a preference for the corolla as the birth sites.

It is well established that adult stages migrate in adverse conditions such as overcrowding (Dixon 1977). In the present study, we observed only adults stage in the trunk region. There are two types of aphid

migration: passive and active. Active migration occurs through flight or crawling (Emden and Harrington 2007). We observed both adults (winged and wingless) in trunk region, possibly in the process of emigration due to overcrowding. In the present study, we observed winged adults on all studied parts of *G. sepium*. Winged adult forms develop in overcrowded conditions (Dixon 1977). The occurrence of winged forms throughout the study confirms that the present study was carried out during the peak period of aphid infection on *G. sepium*. Another reason for the absence of both small and large nymphs in the trunk region could be the absence of sap-containing soft tissue, which is the most important for the settlement of larval stages of *A. craccivora*. Aphids feed on the sap of plants as their primary source of food. The sap contains essential nutrients such as sugars and amino acids that the aphids need for growth and reproduction (Dixon 1977).

Aphids are known for their remarkable ability to adapt to invasive plant species (Bai et al. 2010; Mathers et al. 2017). Invasive plants often lack natural enemies in their new range, which allows aphids to exploit them without competition. Moreover, aphid populations tend to be larger and more diverse on invasive plants than on native plants (Jiang et al. 2013). Invasive plants provide a more stable and predictable environment for aphids. Invasive plants often dominate their new range, creating a uniform and consistent habitat that is less prone to fluctuations in temperature and moisture (Muller-scharer 2004). The adaptations of aphid to resourceful exotic plants can also be explained by the Resource concentration hypothesis (RCH). RCH can help explain the distribution and abundance of aphids, as they are often found in high densities on patches of nutrient-rich plants (Grez and González 1995). Considering these facts, it seems that *A. craccivora* and *G. sepium* could provide excellent an model system for further ecological studies of invasive plant and insect interaction, and the impact of their interaction on associated flora and fauna. *Apis craccivora* is a serious pest of important leguminous plants, including cowpea and groundnut, and has the highest fitness among these plants (Singh 1990). Additionally, *G. sepium* provides an additional highly nutritious host plant to one of the serious pests, *A. craccivora*. Further, consequences regarding the invasion of *G. sepium* and adaptation of *A. craccivora* need to be evaluated for a better understanding of the invasion ecology of this plant.

Conclusion

We investigated the association between *A. craccivora* developmental stages and different parts of the invasive ecotoxic plant *G. sepium*. We found that aphids primarily infect the green parts of young inflorescences or shoots. The aphid has a high fecundity rate, as a result, it significantly damages the flowering tree. The occurrence of migratory adult stages on all the parts of tree indicates the severity of the infection. During peak infection, aphids excrete sticky, watery secretion, which may have several further ecological consequences, such as recruitment of other insects, interference in plant respiration, and possibly the death of rodents. Further studies on the biochemical composition of aphid excretion and its interaction with other organisms will be helpful to understand its ecological significance. The population data presented in the study will be useful to understand the interaction between *A. craccivora* and *G. sepium*.

Declarations

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Data availability

Data generated during the present study is included in the article.

Ethical approval

Not applicable

Consent to participate

Not applicable

Conflict of interest

We declare no conflict of interest regarding the publication of this article

Consent to publish

Not applicable

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Figures

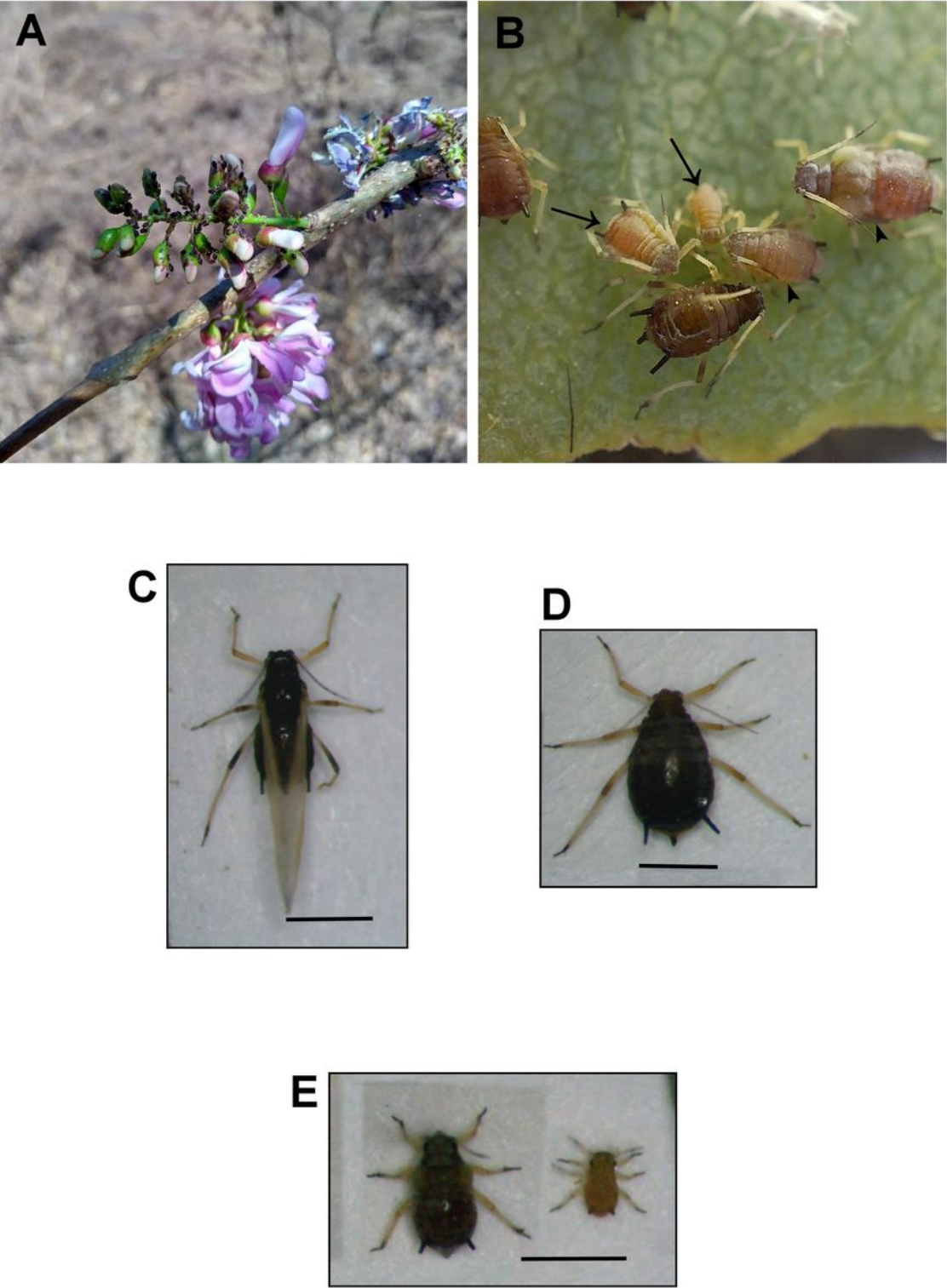


Figure 1

(A) Inflorescence of *Gliricidia sepium* infected with aphid *Aphis craccivora*. (B) Different stages of aphids on *G. sepium*. Arrow indicate small nymphs and arrowhead indicate large nymphs. (C) Winged adult. (D) Apterous adult. (E) Large and small sized nymphs. Scale bar = 1 mm

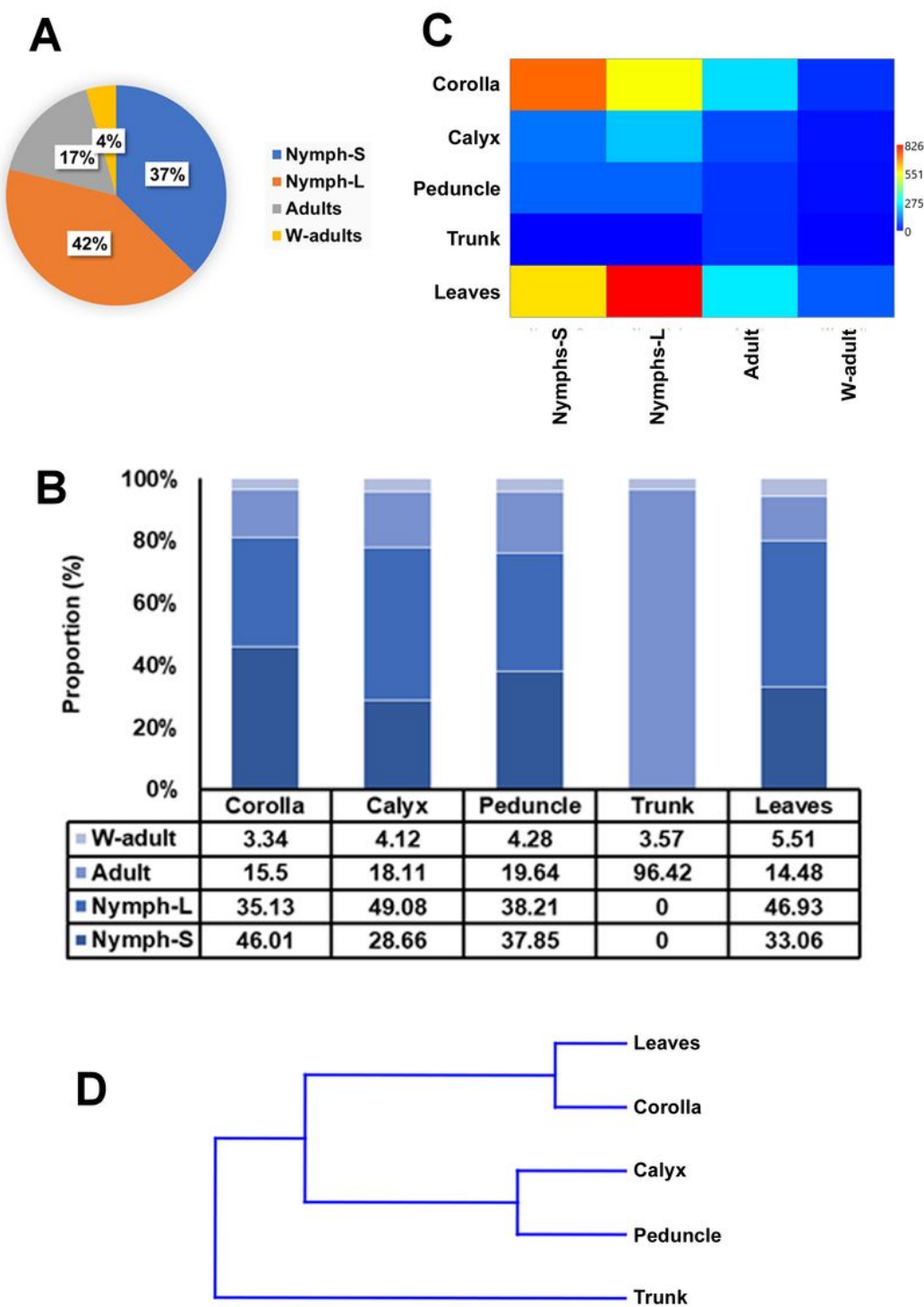


Figure 2

Proportion of *Aphis craccivora* adults and nymphs on different parts of *Gliricidia sepium* plant. (A) Overall proportion of different life forms observed during study. (B) Detailed proportion of W-adult, adult, nymph-S, and nymph-L on corolla, calyx, peduncle, leaves, and trunk. (C) Heatmap depicting the comparative density of different life forms on *G. sepium* plant parts. (D) Association of different life forms of *A. craccivora* and different plant parts using Cladistic analysis and Brey-curtis dissimilarity index.