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MUTUALISTIC RELATIONSHIP- A MEANS OF INDIRECT PLANT DEFENSE VIA TRI-TROPHIC INTERACTIONS USING SEM

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ABSTRACT

A comparative study was conducted on members of Families Solanaceae (Tomato and Petunia)and Malvaceae (Okra) having glandular trichomes, thereby playing an important role in indirect plant defense against herbivores by making plant surfaces sticky which in turn adhere carrions on their surfaces by attracting mutualistic predatory arthropods (Order; Heteroptera). Maximizing plant defensive strategies are integral to effective integrated pest management. Indirect defenses including food provisioning and semichemical production, and improve biological control. Interactions between the two defensive strategies may be disruptive, complementary, or synergistic and are an important consideration for effective pest management programs. The key factor in this study is 'trichomes' which generally refer to outgrowths from the surfaces of leaves and other epidermal surfaces of plants ranging from small hairs to larger outgrowths like thorns. Glandular trichomes are plant structures which inhibit or entrap arthropods, protecting plants against herbivores, potentially at the cost of reducing natural enemy efficacy.

KEY WORDS: Top-down control, trichome, tri-trophic interaction, carrions

INTRODUCTION

Glandular trichomes represent an important first line of plant defense, forming a structural and chemical barrier against several environmental factors such as excessive light radiation, extreme temperatures and herbivory (Wagner, 1991; Werker, 2000). These glandular structures develop from protodermal cells and are widely distributed over the plant reproductive and vegetative organs (Werker et al., 1993). However, there are important morphological variations within each type of glandular trichome, in terms of the size and number of cells and the mode, chemical composition and function of secretions. A plethora of secondary metabolites, among them multiple alkaloids, terpenes, polyketides and phenolics, are believed to have evolved primarily as means of defense and many of them are trichome specific (Wang et al. 2001; Yazaki 2006; Schilmiller et al. 2008; Slocombe et al. 2008; Loreto et al. 2014; Kang et al. 2010b). Terpenes constitute the largest group of secondary metabolites with over 25 000 known structures that include toxins and deterrents against bacteria, fungi and animals (Gershenzon & Dudareva 2007). Terpenoid metabolism is highly active in glandular trichomes of many species including Family Solanaceae (Besser et al. 2009; Bleeker et al. 2012; Tissier et al. 2013). Acylsugars are insecticidal plant specialised metabolites produced in the Family Solanaceae (nightshade family). Petunia spp. synthesizes acylsugars that are structurally distinct from those of tomato (Nadakuduti et al., 2017). In theaerial organs of most terrestrial plants, including *Solanum lycopersicum* (tomato), the epidermis is patterned with trichomes, which are epidermal outgrowths with diverse roles in the defense against biotic and abiotic stresses. The epidermis also contains stomata, which are epidermal pores that regulate gas exchange and contribute directly to the control of water status. The cuticle that covers the surface of the epidermis is a hydrophobic layer, consisting of cutin and waxes, that prevents uncontrolled water loss (Riederer and Schreiber, 2001). As a result of their function in limiting water losses, specialised structures in the epidermis are promising targets to improve the drought tolerance and water use efficiency(WUE) of major crops (Antunes et al., 2012; Galmes et al., 2013; Franks et al., 2015). Trichomes in Solanum are multicellular and have been classified into eight different types according to the presence or absence of glandular cells, and the shape and number of cells (Luckwill, 1943; McDowell et al., 2011). On the contrary, *Abelmoschus esculentus* L. (Family Malvaceae), isa tall- growing, warm-season, annual crop cultivated inBrazil, southern USA and the West India for its long, manyseededpods, used as a vegetable. Thewhitefly(Hemiptera), causes severe damage to okraplants by feeding on sap, secreting honeydew andtransmitting viral diseases (Fishpool & Burban, 1994;Umaharan et al., 1998; Jose & Usha, 2003).

MATERIAL & METHODS

The experiment had been set up in natural (open field)and glass top wire house (controlled) conditions. Species of Family Solanaceae and Malvaceae like petunia (n=60; triplets), tomato (n=30; duplets) and okra (n=30; duplets) respectively were planted from seeds and saplingsgrown in field of new Botany Department, Lucknow University. These agriculturally and ornamentally important crops were harvested from a natural population growing in a totally sunny to partially shaded environment. Plants of all species were selected based on the presence of glandular trichomes and suitable growing seasons. To observe the impact of carrions on predator abundance, carrion attraction and herbivore addition experiment had been conducted on the plants. Specific herbivores were observed which fed upon the plant selectively.Weekly number estimates of herbivores(adults + nymphs), predators (adults + larvae) on the leaf surfaces (adaxial and abaxial) and on stems were obtained by visual inspections. The number of adaxial and abaxial trichomes was counted under a light microscope and scanning electron microscopy (SEM) was performed to compare the morphology of trichomes on different plants and followed the basic protocol for preparing sample.

Name of Plant	Variety	Family	Herbivore		Predator
Petunia spp.	Hybrid	Solanaceae	Tobacco budworm (Heliothis virescens)	Insecta Lepidoptera Noctuidae	Polistes spp. Wasps (Hymenoptera: Vespidae); Geocoris punctipes (Hemiptera:Lygaeid ae)
Tomato (*Solanum lycopesicum*)	Navodaya	Solanaceae	Two spotted spider mite (tetranychus urticae Koch) Microsiphum euphobiae	Arthropoda Chelicerata Arachnida	Predatory mites *Amblyseius*; the lady beetle, the minute pirate bug, *Orius*; the thrips etc.
Okra (*Abelmosch us esculentus*)	Mohanan	Malvaceae	Shoot and fruit bore(Earias sp.) White fly (*Aleyrodidae*) Fruit borer (*Helicoverpa armigera*)	Arthropoda Hemiptera Aleyrodida e	Chrysoperla spp. & Coccinellidae spp.

OBSERVATION & RESULT

All three plant species were observed in open field and controlled condition. In case of Petunia, due to presence of good number of glandular trichomes, entrapment of carrions was high which led to less herbivory which was not the same in case of okra and tomato, because they had less number of trichomes present on their surfaces which entrapped less carrions compared to petunia which led to high leaf damage in okra as well as attack of whitefly and fruit damage in tomato with the attack of borer. If we compare okra with tomato, the trichome density was more in tomato than in okra. On the other hand, in glass to wired house, carrion attraction was also monitored which led to their entrapment on plants, but as compared with open field experiment, less damage was noticed. So, carrion entrapment by plants can enhance top-down control of herbivore by increasing the densities of their natural enemies.

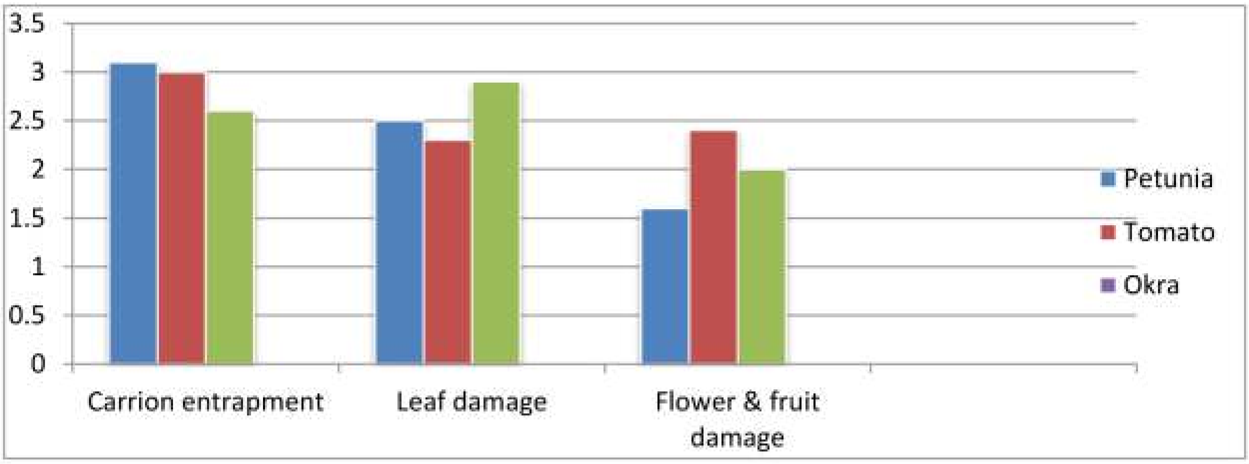

Fig. 1

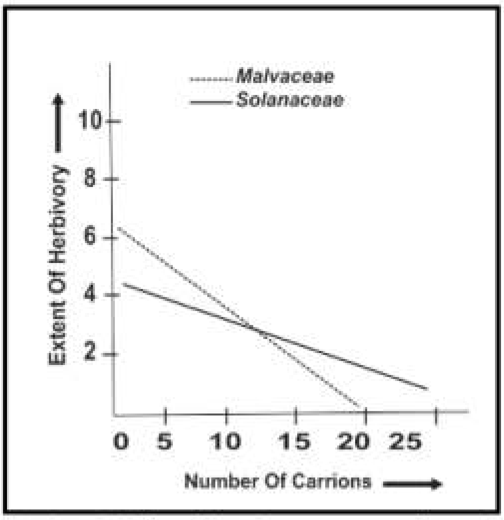

Fig. 2 Relationship between number of carrions and extent of herbivory in Family Malvaceae and Solanaceae

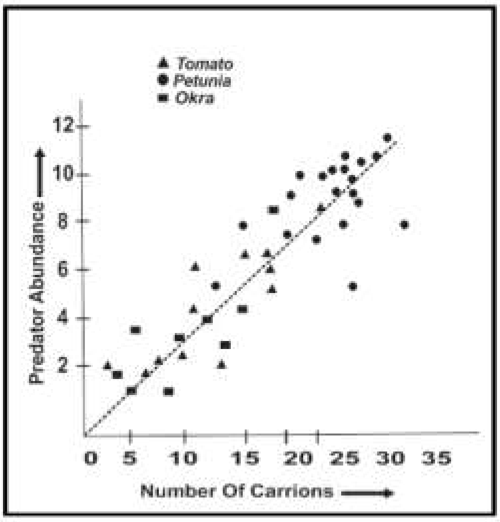

Fig. 3 Relationship between number of carrions and predator abundance

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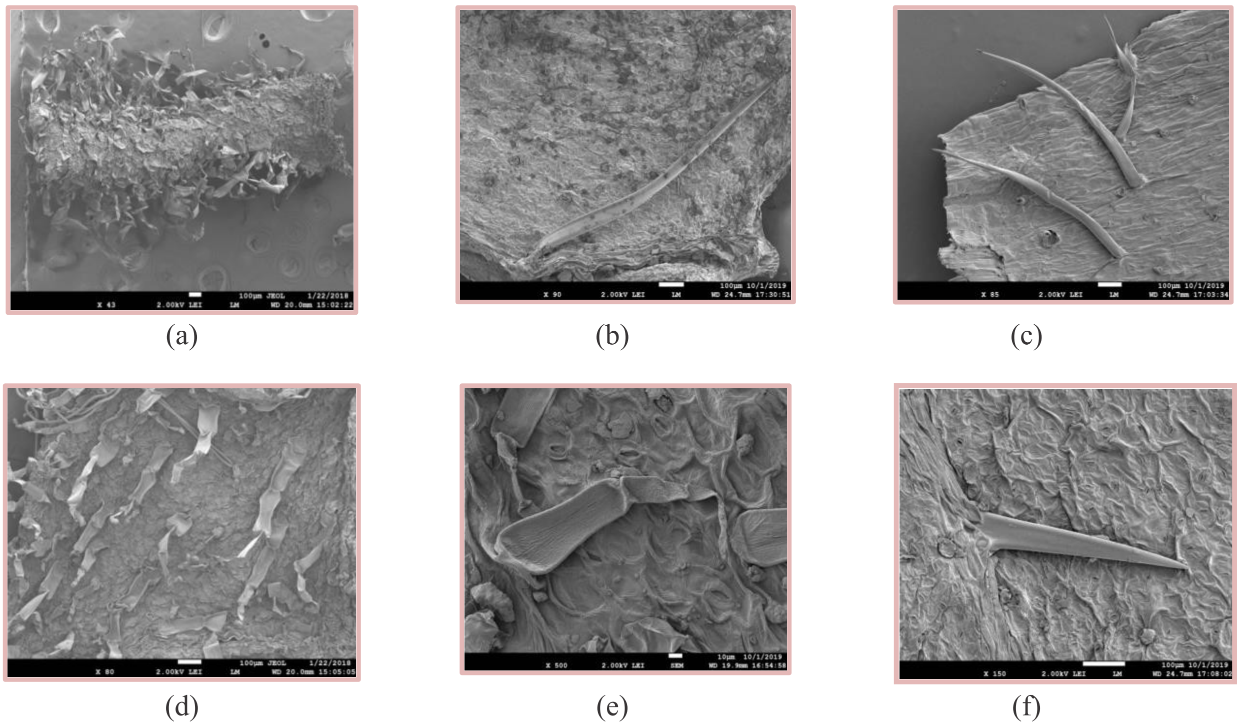
DISCUSSION

This study represents *mutualistic relationship* of plants having glandular trichomes or stickyness with arthropods. Ecological interactions are an integral component of various species for their fitness in the ecosystems. About 20-30% of vascular plants are estimated to produce glandular trichomes which are the sticky parts of the plant. 'Proto-carnivory' is a phenomenon in which plants derive nutrients by attracting, trapping or killing invertebrates. Protocarnivorous plants trap and kill insects but lack the ability to either directly digest or absorb nutrients from its prey like carnivorous plants. The morphological adaptations such as sticky trichomes of proto-carnivorous plants parallel the trap structures of confirmed carnivorous plants.Trichome-based resistance in tomato plants offers a feasible approach to reduce pesticide applications (Simmonsand Gurr 2004; Alba et al. 2009; Kang et al. 2010b). Trichome morphology, density and chemical composition are important mechanisms of defense to prevent or decrease herbivore damage.Trichomes in *Solanum* are multicellular and have been classified into eight different types according to the presence or absence of glandular cells, and the shape and number of cells (Luckwill, 1943; McDowell et al., 2011). Glandular trichomes may also be ecologically important due to their possible influence on some components of plant fitness (i.e. survival). For instance, plants that are exposed to harsh environmental conditions, such as those featuring high rates of herbivory or high solar radiation and temperatures, may present higher trichome density (Bosabalidis and Kokkini, 1997; Fernandes et al., 2016; Tattini et al., 2000; Tozin et al., 2017). It has been suggested that trichome secretion plays a protective role for the plant photosynthetic tissue which can be studied through metabolites analysis.



SEM images showing the number of trichomes and stomata; (a) Petunia stem, (b) Tomato stem, (c) Okra stem, (d) Petunia leaf, (e) Tomato leaf and (f) Okra leaf.

CONCLUSION

Therefore, study concluded that carrion entrapment by plants can enhance top-down control of herbivore by increasing the densities of their natural enemies. When protein is costly for plants to produce, carbon rich glandular exudates or hooked trichomes -'tourist' traps could be relatively cheap means of providing protein rich food for predators. The mutualistic relationship between the sticky plant and predatory arthropods can provide the indirect defense to the plant following tri-trophic interaction. This type of indirect defense can be an addition to pest management application in agricultural sector.

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