# Plant Glandular Trichomes

## Chemical Factories with Many Potential Uses

*A John Peter and Thomas G Shanower*

**Most plants have hairs, called trichomes, on their surface that serve a number of functions ranging from protection against insect pests to heat and moisture conservation. In this article, some of the functions of plant glandular trichomes and their potential applications are discussed.**

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Most plants have hairs on their aerial surfaces, superficially similar to the hairs on the human body. These plant hairs, or trichomes, affect the plant in a number of ways. It has been suggested that plant hairs can change the optical properties of the leaf surface and could help to conserve heat and/or moisture. There are two main types of trichomes: glandular and non-glandular. Glandular trichomes contain or secrete a mixture of chemicals that have been found to have an enormous array of uses in the pesticide, pharmaceutical, and flavour/fragrance industries. Besides these industrial uses, glandular trichomes on some crop species confer resistance against insect pests. Thus, there is today an increasing interest in understanding the chemistry of glandular trichome exudates and taking advantage of their potential uses.

## Glandular Trichomes and the Pharmaceutical Industry

Glandular trichomes in *Mentha piperita* (peppermint) secrete I-menthone, which is converted to I-menthol, and the water soluble neomenthol-glucoside which is transported out of the gland. The possibility of manipulating the biosynthesis of I-menthol using recombinant DNA technology may be a boon to industries using menthol, such as cigarettes, liqueurs, perfumes, confectionery, cough drops and nasal inhalers.

Glandular trichomes on some crop plants confer resistance against insect pests.

*Plasmodium falciparum*, the human malarial parasite, has evolved resistance to several anti-malarial drugs. Chinese scientists have made good progress in identifying an anti-malarial chemical, artemisinin, from the glandular trichomes of the wormwood, *Artemisia annua*. In a recent study, artemisinin was found to cure 143 cases of chloroquine-resistant falciparum malaria and 141 cases of cerebral malaria. Of 2099 malarial cases tested (*P. vivax* and *P. falciparum* in a ratio of 3:1), all were cured after treatment with artemisinin. Body temperatures returned to normal within 72 hours of treatment and in addition to relieving the symptoms, artemisinin also eliminated the asexual parasite from the blood in less than 5 days after the beginning of the treatment. However, extraction of artemisinin from this herb poses problems. Maceration (i.e. grinding up) of tissues alters the originality of the compound due to the activation of oxidizing enzymes. Therefore, efforts are under progress to separate artemisinin from the glandular trichomes without maceration of whole tissues.

## Glandular Trichomes and Insect Resistance in Crops

Several crop species have glandular trichomes that either singly, or in combination with non-glandular trichomes, provide resistance to insect pests (*Figure 1*). Chemicals produced by

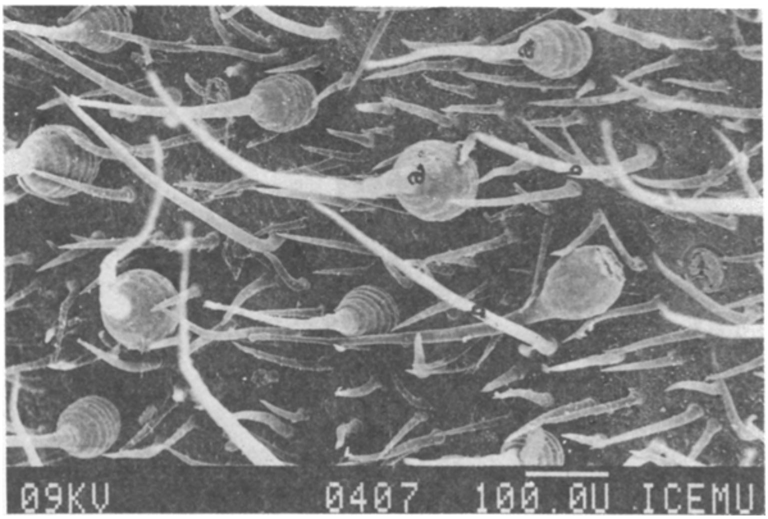


***Figure 1. Electron micrograph of cultivated pigeonpea pod surface showing:***

***a) glandular trichome which can secrete a clear viscous fluid at its tip. These exudates act like glue and trap small-sized insects.***

***b) non-glandular trichome which acts as a mechanical barrier to small-sized insects.***

glandular trichomes vary in the mechanisms by which they confer resistance, which include insecticidal and/or repellent effects, as well as behaviour-modifying effects such as feeding or oviposition inhibition.

Glandular trichomes on potato and tomato leaves release substances that react to form a sticky trap for small insects.

When brinjal or potato are cut and exposed to the air, the colour of the cut surface changes. Phenols in these cut pieces are oxidized by atmospheric oxygen and become black. Glandular trichomes on potato and tomato leaves release phenols and phenol oxidizing enzymes which react to form a sticky substance which hardens to entrap small–bodied insects. Aphids, for example, get coated with sticky phenols when they land on these plant surfaces. In the struggle to escape, they disrupt a second type of trichome which releases polyphenol oxidases (PPO). The PPOs oxidize the phenols into quinone, entrapping the aphids like hardening of cement, resulting in its death.

Glandular trichomes in tomato produce large quantities of 2-tridecanone, 2-unidecanone and a viscous mixture of acylsugars which confer resistance against some tomato-feeding insects. These trichomes also release volatile chemicals. One of these volatile compounds, E-beta farnesene, prevents aphids from landing on the plant. Glandular trichomes in catmint (*Nepeta* sp.) produce nepetalactone, closely related to the aphid sex pheromone, nepetalactol. Nepetalactone can be reduced to the corresponding nepetalactol. Scientists in the U.S.A. and U.K. are trying to increase the biosynthesis of nepetalactone to use nepetalactols in pheromone traps for monitoring of the aphid population. The resinous material secreted by the glandular trichome of some plants coats the plant surface, particularly on immature tissues, to avoid insect infestation. For example, larvae of cottonweed leaf beetle avoid feeding on the resin-covered leaves of *Populus deltoides*.

Glandular trichomes contain or secrete chemicals that have many uses in the pesticide, pharmaceutical and flavour/ fragrance industries.

## Research on Trichomes at ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics, headquartered near Hyderabad, is a non-profit agricultural research organization, with a global mandate to improve chickpea (chana dal), groundnut, pigeonpea (toor dal) sorghum and pearl millet, and cropping systems in the semi-arid tropics. Research on the role of glandular trichomes of chickpea and pigeonpea in insect resistance is currently in progress at ICRISAT.

Chickpea trichome exudates contain acidic chemicals such as malic acid, oxalic acid and succinic acid. Oxalic acid has an antibiotic effect on the larvae of pod borer, *Helicoverpa armigera*, which results in reduced pod damage. Similarly, several wild pigeonpea species limit the establishment of the pod borer. A dense mat of non-glandular trichomes in these species prevents the small larvae from feeding on the pods (*Figure 2*). Scientists at ICRISAT are investigating the possiblity of using these insect resistance mechanisms to develop cultivars less susceptible to insect pests.

While effective at conferring resistance to insect pests, glandular trichomes and their chemical exudates may also be harmful to insect predators and parasites. These natural enemies of the insect pests of crop plants search for their hosts or prey on the plant surface. The movement of the predators and parasites on the plant surface may be inhibited by trichomes, or they may be repelled by the exudates. Hence, natural enemies either avoid such cultivars or terminate their searching mode and move to a different host plant. For example, the tiny parasitic wasp,

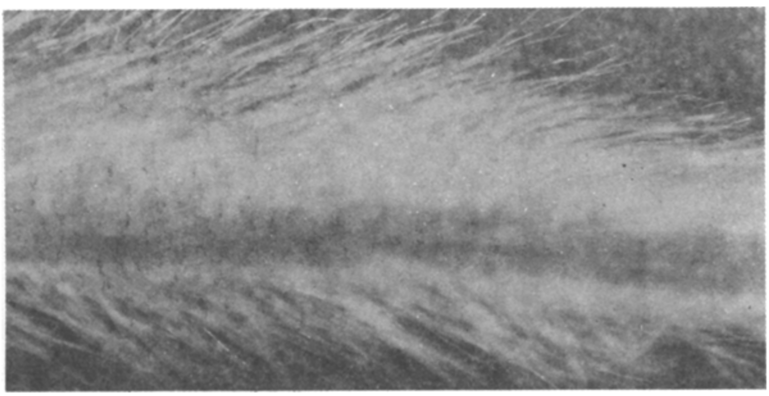

*Figure 2. Stereomicroscopic photograph showing a highly hairy pod surface of wild pigeonpea, Cajanus scarabaeoides. This dense mat of non-glandular trichome prevents the first instar larva of pod borer from reaching the seeds. Thus, larva coming out of the egg desiccates and dies due to starvation.*

*Trichogramma,* parasitizes and kills *Helicoverpa* eggs in cotton fields. The wasps however, are incapable of parasitizing *Helicoverpa* eggs on pigeonpea and chickpea, perhaps due to the trichomal exudates.

## The Future of Glandular Trichome Research and Application

Plant glandular trichomes function either as repositories or releasing sites of various chemicals. Interest in producing these chemicals in cell or tissue culture systems has increased in recent years. However, this approach has not been too successful due to the lack of knowledge about the genes that control the synthesis of these chemicals. The lack of success in artemisinin production employing cell and tissue cultures is a notable example of such problems.

On the other hand, scientists have been successful in transferring glandular trichome-based insect tolerance to tomato and potato cultivars using conventional breeding techniques. However, conventional breeding may not always transfer the desired characters from parents to the offspring. Sometimes, it also transfers undesired characters. For example, in an attempt to develop an insect tolerant pigeonpea by crossing the cultivated with wild pigeonpea, the $F_1$ (progeny) generation had pods with dense trichomes (desired character) but with small seeds (undesired character).

Usually, 1-3 genes control the expression of plant trichomes. Understanding these genes sufficiently to manipulate and transfer them to desired plants could lead to significant progress in obtaining crops with desired types of trichomes. The knowledge generated could also be used to support biotechnological improvements. Single gene changes using recombinant DNA techniques is an alternative approach. Such attempts may require the use of trichome-specific promotor elements which will probably be available in the near future.

## Suggested Reading


- Juniper B E and T R E Southwood. *Insects and the Plant Surface.* Edward Arnold Publishers Ltd. London. UK, 1986.
- Peter A J, Shanower T J and Romeis. The Role of Plant Trichomes in Insect Resistance: A selective Review. *Phytophaga.* 7.pp. 41–63, 1995.



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