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What's Hidden in a Gall? – An Entomological Perspective

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SUMMARY

Phytophagy of insects have evolved from biting and chewing to gall inducing in host plants. The reason behind development of such closed gall like environment for insects is probably for biological necessities such as nutrition, shelter and protection against natural enemies. Gall inducing insects have shown high degree of specialization while staying loyal to only one host species. They are able to alter plant's growth pattern by modifying their chemical profile and driving the plant to produce food source rich in nutrients and free from defensive chemicals, in a protected and isolated natural environment. The story and fascinating facts about these hidden insects and their evolving interactions have made them interesting to the naturalists.

INTRODUCTION

While wandering in your garden have you ever observed any plant part that is not usually found on that plant elsewhere but is very persistent and conspicuous only on your garden plant? Did it seem like a geometrical structure arising raised either from stem or leaves? There are high chances that you have encountered a home of a gall-producing insect and yes, their homes are usually referred as galls. The fundamental definition of gall states that any anomalous growth on plants usually caused by bacteria, viruses, fungi, algae, rotifers, copepods, insects or nematodes. But there is a prime difference between galls produced by micro-organisms and insects. Micro-organisms usually induce amorphous growths which are termed as tumors whereas insects incite symmetrical either radial or bilateral growths which have definitive shapes and termed as galls. Phytophagy by herbivorous insects is divided into five major guilds. They include chewing type, sucking type, miners, drillers and gall makers. Chewing and sucking type guilds are termed as ectophytic insects as they feed in open environment and miners, drillers and gall inducing insects are termed as endophytic insects as they feed in closed or confined environments. Gall inducing insects are considered as nature's most sophisticated insects as they have evolved in a way to utilize the underutilized niches resourcefully and efficiently by deceiving their host to provide food and nutrients directly to them.

Definition:

Galls are therefore, best modified natural symmetrical structures that are usually produced by the host to incorporate the alien organism *i.e.*, insect which has wiled the plant to accommodate it. Gall inducing insects are defined as those herbivores insects that compel the host to induce pathological modifications *i.e.*, galls, in the host tissue to complete their life cycle. This is designated as the most complex interaction between plants and insects in natural environment producing either hypertrophy or hyperplasia in plant tissues.

Evolution:

Gall inducing insects are abundant and evolved independently several times among various insect taxa. One theory states that gall inducing habit has been found to evolve from Leaf mining Diptera (e.g., Agromyzidae) and Microlepidoptera (e.g., Nepticulidae,

Stigmellidae), which over time evolved into this sophisticated concealed and protected environment for new food sources. Evolution from puncturing oviposition to galls is elucidated by the stem boring parasitic cynipids which are thought to be ancestors of modern gall inducers. During ovipositing near developing leaves, female cynipid adults might have released some stimulant combinations or maybe these stimulants were associated with cynipid larvae, ending in gall production.

Most of the gall inducers are found to be in 51 families spread among the following orders namely, Hemiptera, Thysanoptera (Tubulifera thrips), Coleoptera, Hymenoptera, Lepidoptera, Diptera and Eriophyoidea in Acarina. Plants belonging to Anacardiaceae, Asteraceae, Convolvulaceae, Combretaceae, Capparidaceae, Dipterocarpaceae, Euphorbiaceae, Fagaceae, Fabaceae, Lauraceae, Malvaceae, Moraceae, Myrtaceae, Rosaceae, and Salicaceae are found to host majority of gall inducing insects.

Key factors for gall induction:

The major key factors that trigger the gall induction and growth are feeding action of the insects, the saliva injected into the plant containing chemicals and probing the new meristem tissue for oviposition. Sub cellular chemistry in the host tissues are altered due to salivary chemicals and constant wounding of host plant due to feeding or oviposition initiates stress in the host. As a counter measure to neutralize the stress, plant moves the photoassimilates to the insect feeding site. As this process continues for extended period, a gall is produced. Puncturing for oviposition also induces galls. This gall ensured three major biological necessities viz., nutrition, shelter and protection from natural enemies either to the inducer or its progeny or both.

As galls provide nutrition, gall acts as a reservoir for different nutrients and energy which are used by the insect for its development. Vascular tissues in host plant can also be induced to produce galls for supply of nutrients as well as water to the residing insect. There are basically two types of feeding action in gall producing insect *viz.*, piercing and sucking by hemipteroid stock and biting and chewing by coleopteroid stock. Immature larvae of Cecidomyiidae, Hemiptera, and Acarina feed subtly by wounding the tissues and sucking the sap whereas in Thysanoptera, harsh rasping of tissues with asymmetrical mouthparts takes place followed by sucking the sap. In case of higher insect orders like Tenthredinidae of Hymenoptera having well developed mandibles, chew and feed the plant cells directly.

The symmetrical galls are mostly unique to each species and produce definitive shapes. Few examples of special gall shapes recorded in India are listed in table 1. In gall inducing taxa, Eriophyoidea, Thysanoptera, and Hemiptera (Aphidoidea, Coccoidea), the gall inducer, the female adult and its progeny finds shelter whereas in gall-inducing taxa of the higher orders, Lepidoptera, Diptera and Hymenoptera, only single larva resides in the gall.

Table 1. Few examples of gall shapes recorded in India

Gall shape	**Host and location**	**Gall inducing insect**
Cylinder–piston galls	Leaflets of *Acacia ferruginea* (Mimosaceae)	*Contarinia manii* (Diptera: Cecidomyiidae)
Sea-urchin-shaped galls	Vegetative shoot-apical meristems of *Hopea ponga* (Dipterocarpaceae)	*Mangalorea hopeae* (Hemiptera: Beesoniidae)
Fir-cone-like galls	Vegetative shoot apical meristems of *Mangifera indica*	*Apsylla cistellata* (Hemiptera: Calophyidae)
Soft, parenchymatous galls	leaves of *Achyranthes aspera* (Amaranthaceae)	*Bemisia tabaci* (Hemiptera: Aleyrodidae)

Marginal leaf roll	Leaves of *Piper nigrum* (Piperaceae)	*Gynaikothrips chavicae* (Thysanoptera: Phlaeothripidae)
Echinate shaped galls	Leaves of *Ficus benghalensis* (Moraceae)	*Chrysocharis echinata* (Hymenoptera: Eulophidae)

Source: Raman (2010) and Aneesha and Roopavathy (2019)

Gall inducing insects are strongly restricted to one species of host plant. However, few insects have shown exceptions by shifting from preferred hosts. Ex. gall inducing tephritids (Diptera). Main reasons for exhibiting host shift behavior are changes in host-plant chemistry, competitive interactions for best host resources and escaping from the natural enemies. Generally, simple and closed communities of single insect and plant occurs but it was recorded that numerous cynipid species induce complex closed communities consisting gall inducers, inquilines and parasitoids on plant, *Quercus* species.

Economic importance:

Even though, the plants attacked by gall inducing stress experience a slight level of stress, overall metabolism is usually unaffected except in the place where gall develops. These plants rarely suffer extensive damage or death. One established example of gall-inducing insect causing serious concern is rice gall midge, *Orseolia oryzae* (Diptera: Cecidomyiidae). It has inflicted considerable economic losses to rice production. Recent outbreak of Eucalyptus gall wasp, *Leptocybe invasa* (Hymenoptera: Eulophidae) on Eucalyptus and Erythrina gall wasp, *Quadrastichus erythrinae* (Hymenoptera: Eulophidae) on Erythrinae has evoked serious concern in the world. Besides inflicting damage to economically important plants, few galls induced by gall forming insects were found to be useful for their medicinal properties. Eg. Galls induced by *Cynips tinctoria* (Hymenoptera: Cynipidae), on leaves of *Quercus infectoria*, have potential anti-inflammatory capability and alpha-glycosidae inhibitory activity. Their specificity towards single host species is inspiring their potential as biocontrol agents of weeds and invasive plants. There also have been recorded as bioindicators of environmental health and quality.

CONCLUSION

Galls, even though appears as simple outgrowths in nature, careful examination has revealed phenomenal complexity in structure and architectural design which has always kept the naturalists engaging on further research. Gall inducing insects are found to be most revolutionary as they are able to control and divert the host plant metabolites for their own benefit. These insects exhibit both negative and beneficial uses, however, the beneficial uses always outweighs over economic damage. Evolution of these insects has shown a fascinating intimate interaction between plants and insect, that's hidden from the world.

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