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A Study of Fungal Galls and Ambrosia

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ABSTRACT: Gall is an outburst of tumourous out growth induced by various biological and physiological agents. Dispersal of plant galls whether passive or active, is greatly influenced by *geographical* routes or *barriers*. Routes i.e. plants favour dispersal and provide access to new areas. But the barriers i.e. insects or fungi limit dispersal of galls. So the plant galls biogeography is restricted and limited to certain areas only. Dispersal, population size and reproductive potentials are parts of ecological valence of the plants or animal. The ecological valence is a measure of the reaction of the species to the environmental influences. For the galls the ecological valence is narrow and they are stenotypes, occur under only well defined, limited set of conditions, such a species is too specialized to occur elsewhere. The fungal gall is unique when compare to insect gall. The present papers highlight the association and interlinking phenomenon of fungus in plant galls.

Keywords - Acacia leucophloea (Roxb.) Willd., Ambrosia, Excoecaria agallocha L., Oryza sativa L.

INTRODUCTION

Galls are pathologically developed cells, tissues and organs of plants, which arise mostly by *hypertrophy* and *hyperplasy*, usually under the influence of parasitic organisms[1]. They represent the growth reaction of the plant to the attack by a foreign organism and are related to the feeding activity and nutritional physiology of the concerned organism. The gall is thus, a product of interspecific association between a plant and another organism.Gall inducing fungi occur in certain major groups, causing galls on both domestic as well as wild plants. The gall inducing fungal parasites come under Plasmodio phoromycetes, Chytridiomycetes, Oomycetes, Homobasidiomycetes, and Ascomycetes. The fungal galls generally assume unlimited size and amorphous appearance because of the virtue of the fungal organisms permeating wider host tissues rendering them to undergo diffuse proliferation (Fig. 2).

Nearly 31 galls have been reported on various Indian taxa caused by fungi[[1]] (Table). This number excludes some other records of fungal galls reported by different Indian investigators[[2,3]]. Cecidogenous fungi occur in all major groups. Tiagi (1963) [[4]] in a brief review of abnormal growth due to parasitic fungi enumerates various cecidogenous fungi and their host plants. Among the Plasmodiophoromycetes, *Plasmodiophora brassicae* causes the well known 'club-root' gall on crucifers. *Sorodiscus radicicola* forms the convoluted, coral-like galls on the roots of *Gynandropsis gynandra* (Cleomaceae). This gall originates from the cortex, but establishes vascular connections with the stele of the root[[4]]. *Sorosphaera veronicae* incites shoot apical gall on *Veronica chamaedrys* (Scrophulariaceae).

Synchytrium is another potential cecidogenetic fungus of common occurrence. Krishnamurthy & Swamy (1981)[[5]] found a unique mechanism of galling by *Synchytrium* on *Alysicarpus* (Fabaceae). In this case, the gall arises as warty outgrowths in which several shoot-apices with tunica-corpus organization, leaf-primordia and procambia are formed. Later, this shoot-apical organizations of the gall disappear due to secondary infection by the fungal spores. In contrast to the usual callus-like nature of the fungal and bacterial galls, these authors claim some degree of controlled operation of growth and organisation in this particular gall. Many species of *Physoderma* of Chytridiomycetes are potential gall formers. They cause tumerous galls on *Limnanthemum* – Gentianaceae[[6]], *Aeschynomene* – Fabaceae[[3]] *Corchorus* – Tiliaceae[[7]]. Thus, the present study of fungal association in plant-galls forms a thrust area in biological sciences.

MATERIALS AND METHODS

The galls were collected from different forest area in various seasons. The plants were identified with the help of Flora of Madras Presidency[[8]]; Flora of Madras City and its neighbourhood[9] and Flora of Tamil Nadu[10]. Latest nomenclature of the plants was followed as per, "The Plant Book, by Mabberley (2005)"[[11]], the identification of plant galls with the help of Plant Galls of India and Ecology of Plant Galls by M. S. Mani[[1,12 & 13]].

RESULTS

1. ***Acacia leucophloea*** (Roxb.) Willd. (Mimosoideae), is predominant thorny tree of the semiarid forests. Many insects and mites infest the various parts of the plant and produce many remarkable galls of high complexity caused by *Haphalophragmium ponderosum* (Uromycladium notabile) (Fungus).

Morphology of the gall (Fig. 1): Fungal gall on tender branches and fruits, huge, abundant, variously shaped, hard woody, indehiscent, solid, reddish-brown, smooth or warty, ridden gall; the galls persists for several years; almost entire tree bears galls of varying sizes and stages of development.

Fig. 1: ***Acacia leucophloea*** (Roxb.) Willd, Rinden Gall

Anatomy of the gall : The gall arises through extensive proliferation of the cortical as well as the vascular tissues. Since the fungus permeates freely and indefinitely, the gall tissues are rendered unlimited growth into huge amorphous body. The xylem tissue is thrown into twists and curls and also nodules due to hyperplasy and hypertrophy of the ground parenchyma. The fungal mycelium is intracellular and occupy the entire cell lumen. Locality: Javvadhu Hills – Eastern Ghats, Fairly common.

2. ***Aeschynomene indica*** Linn. (Papilionaceae) Gall maker: Fungus, Shrub.
Morphology of the gall : Shoot axis gall; Rinden gall; circular thick rind with central wide shallow depression. Gall pale green, smooth soft, indehiscent, solitary, 0.5 cm in diameter; occurs mostly on the aerial part of the stem.
Anatomy of the gall : The gall is cortical in origin. The stem has thin vascular cylinder and wide pith cavity. The cells external to the xylem cylinder, mostly the vascular cambium produces externally wide zone of parallel rows of compact cells. The fungal spores and mycelium are seen intercellular and intracellular spaces. The cortex has undergone limited proliferation and thin periderm is seen outer side. Xylem elements are much reduced in differentiation and remain in the primary state in the gall, whereas thick secondary growth is seen in the gall free part of the stem. Locality: Paddappai. Common.

3. ***Capparis*** sp. (Capparaceae), Fungal gall
Morphology of the gall: Foliar gall, visible on the lower side as dark, warty, hard irregular mass; gall sparse. Locality: Javadhu Foot Hills, Rare.

4. ***Connarus wightii*** Hook. f (Connaraceae), Shrub. Fungal gall
Morphology of the gall: Gall occurs on the veins petiole and tender stem. The foliar gall is epiphyllous, vermiform, spindle shaped, black, smooth, hard, indehiscent, along the veins and off the veins. Stem and petiole galls fusiform, spindle shaped cylindrical, extending vertically for long distance, black, smooth, hard, indehiscent, surface becomes warty in old galls.
Anatomy of the gall: In the vein gall, the ground tissue proliferates in random orientation producing large, compact, parenchyma cells. The fungus is restricted to the epidermis and a few subepidermal layers which become dark due to tannin accumulation. Perithecial cups are produced on the surface of the gall. The stem gall consists of peripheral cortical zone where fungus is accumulated. The cortical cells and pith cells proliferate extensively so that, the vascular bundles are separated from each other. Aecidia cup are seen in the cortical part of the stem. Locality: Courtallum foot hills. Fairly common, new record.

5. ***Excoecaria agallocha*** L. (Fig. 2) (Euphorbiaceae), Fungus, Mangrove tree.
Morphology of the gall: Stem gall; occurs on thick branches, trunk of the tree and tender shoots. Galls are very huge and abundant, ranging from small spherical lateral bulging to highly crowded, agglomerate huge mass of irregular shape and size. The trunk of the tree above the ground level is masked by large masses of irregular and agglomerated extensive gall. Gall surface has membranous flake; the mature gall is shining and brown.
Anatomy of the gall: The ground tissues undergo extensive and diffuse proliferation and the derivatives of cells spread in random directions. The vascular tissues, especially, the xylem elements are through into distorted fragments. The major portion of the gall comprises of highly dilated, less compact randomly oriented parenchyma cells harbouring the gall pathogen. Locality: Kodiakarai – Mangrove forest. Common, new record.

Fig. 2: ***Excoecaria agallocha*** L. Amorphous Rinden Gall

6. ***Hydnocarpus alpina*** Wt. (Bixaceae). Ascomycetous Fungus, Tree.
Gall morphology : Foliar gall, hypophyllous, black, corky, irregular patches, each spot surrounded by yellow well-defined halo formed by close aggregation of numerous ascocarps, as seen in abaxial surface. On the adaxial surface, each infected spot appears as shallow, cushion-like raised patches somewhat pale yellow in colour. Spots solitary or agglomerate. Each infected spot measures 0.5 – 1.0 cm in diameter. Distribution – diffuse.

The adaxial epidermal remains the same. The palisade mesophyll which is single layered multiples by periclinal division to form an elongate series of rectangular cells. The number of spongy cells also increases resulting in a compact arrangement of them. The abaxial epidermis protrudes, in the region of fructifications, becomes corky and breaks. The ascocarps are formed in the lower spongy mesophyll. Locality: Coonoor, Ooty. Rare, Endemic.

7. ***Jasminum trichotomum*** Heyne ex Roth. [Oleaceae] *Puccinia jasmine* DC (Fungi), Straggling shrub.
Morphology of the gall: Epiphyllous or hypophyllous blister gall of varying shape and size; bright yellow, smooth, solitary or more commonly agglomerate, indehiscent, diffuse.
Anatomy of the gall: The thick, undifferentiated leaf tissue undergoes vertical stretching and long files of compact oblong cells are produced giving rise to adaxial or abaxial bulging. The aecidial cups are seen both on the adaxial and abaxial side. The gall has scattered vascular strands. Locality: Kodaikanal.

8. ***Meliosoma wightii*** Planch (Sabiaceae), Phycomycetes (Fungus), Tree.
Gall morphology: Galls occur on all parts of the plant; they are of two types viz., organoid and histioid ones. The histioid type occurs on midrib, lateral veins, petiole and stems. These galls are irregularly globose, conspicuously rugose or tuberculate, hard, reddish brown, rinden galls; solitary, ranging in size from 0.5 mm to 3 – 5 cms in diameter. The gall on the midrib is elongated, cylindrical and parallel to the laminal surface with a pronounced vermiform swellings on the abaxial side. The organoid type occurs on the shoot apex coverting it into a huge and greatly swollen structure, composed of very thick leaf primordial and other appendages of the shoot.
Anatomical features (Normal leaf)
The vascular bundles 15 – 17 arranged in a broken ring and with the depression on the adaxial side. The bundles are collateral and separated by intervening radial files of parenchyma cells. External to the phloem each bundle has a sclerenchymatous cap. Both the adaxial and the abaxial epidermis consist of small papillate cells. Hypodermis is single layered and parenchymatous; it is followed by 3 – 4 rows of compactly arranged collenchymatous cells. The radial files of parenchyma at the vascular region show the presence of tanniferous contents in them.
Midrib gall:
The cecidogenesis is due to the proliferation of both the peripheral ground tissue and the adaxial epidermis. The adaxial epidermis of the normal leaf continues as the epidermis of the gall. This layer consists of slightly larger rectangular or barrel shaped cells. At certain places the parenchyma lying in between the collateral bundles also proliferates. The gall at maturity consists of large, polygonal and compactly disposed thin walled parenchyma cells with tanniniferous contents. No vascular elements are seen in the gall region. Mycelium is intercellular, sporangial sori are seen in the peripheral part of the gall and each sorus consists of a dense mass of sporangia formed by the sporangiophors.
Normal petiole

The epidermis consists of small papillate cells, followed by a single layer of hypodermis. The ground tissue is composed of large, compact, thin walled parenchyma cells. The vascular bundles 20 to 25 in number are arranged in a broken ring.

Petiole gall

Galling is due to the proliferation of both the peripheral ground parenchyma and also the interfascicular parenchyma. There is a marked reduction in the number of vascular bundles from 25 to 10. On account of excessive proliferation of the interfascicular parenchyma, the vascular bundles become elongated or distorted. The gall parenchyma is compact and composed of polygonal parenchyma cells with tanniniferous contents. The outer surface of the gall is undulate. The gall epidermis is made up of small papillate cells. Locality : Dodabetta. Rare, New record.

9. ***Polygonum glabrum*** Willd. (*Polygonum chinense* Linn.), (Polygonaceae), Ustilaginales (Fungus), Herb

Gall morphology : '*Cauliflorus gall'* Flower gall, Gall occurs on the pedicel of the flower or on the ovary. In the cyme, several individual floral stalks and ovaries are infected and sometimes, a group of galls fuse to form an irregular mass. The gall on the pedicel is cylindrical , globular or irregular in size. The ovary gall is conical or cylindrical. Both types of gall are light brown when young and black on maturation. The full grown gall bursts open liberating black, powdery mass of fungal spores. In the case of pedicel gall, the flower occurs on the summit of the gall with its floral organs intact. However, no seed is formed in the flower whose pedicel is galled. In the ovary gall, no seeds and stamens are found which are aborted in the early stage of infection.

The cells of the infected pedicel proliferate diffusely and the cells are also much dilated. All the cells of the proliferated pedicel are filled with fungal spores. In the case of ovary gall, the chamber of the carpel is obliterated due to proliferation of the cells of the ovary wall. The gall consists of compact thin walled parenchyma cells harbouring dense masses of fungal spores. The cells are disintegrated at later stage, so that, the ovary appears as dilated sac of spores. The style and stamens get aborted in the floral galls. Both in the pedicel and ovary galls, the perianth members are not affected. **Locality** : Marappalam, Ooty. Kodaikannal, Bodimettu foot hills.

10. ***Schefflera stellata*** (Gaertn.) Harms (Araliaceae), Fungus,Tree.

Morphology of the gall: Foliar gall; black, circular, swollen patches with yellow margin; large, solitary, not abundant. Locality: Silathoranum – Tirupathi foot hills.

Table : The frequency of Galls by Fungi on different organs of plants

Organisms	Lamina	Vein/ Petiole	Bud	Stem	Root	Flower	Inflorescence	Ovary	Fruit	Total	%
Fungi	**7**	**2**	**7**	**20**	**1**	**3**	**-**	**-**	**1**	**41**	**4.1**

Of the 6 fungal galls studied, 3 galls are found to be new records. They are fungal leaf galls on *Hydnocarpus alpine*; shoot apex, vein or midrib gall on *Meliosma wightii* and floral gall on *Polygonum glabrum*. The general growth responses of plants infected with the funfal parasites are an exaggeration or an inhibition of normal morphogenetic processes. The degree of perfection found in the insect galls is lacking in fungal galls. The symmetry and histological differentiation do not go hand in hand, and this renders the fungal galls to assume unlimited size and amorphous form.

In *Polygonum glabrum* gall occurs on the pedicel of th flower and ovary. In the case of pedicel gall although the normal flower occurs on the summit of this gall, it does not set seeds, so also in the ovary galls. Stamens get aborted during the early stage of infection.

The fungal galls on *Meliosma* are remarkable in the sense that they are of either organoid or histoid type.

The 'Witches' broom type of gall occurring on the fern *Arachnioides* and *Pteris* deserves a special mention here. Although, the gall occurs either on the rachis or pinna it receives the same quantum of vascular supply as that of the normal part. In this case there is no anatomical clue for the gall causing agent.

In this connection, it may be mentioned that Sinnott (1960) [14] is of the opinion that it is not always obligatory that there should be gall causing agent for cecidogenesis. On the contrary, he opines that the development of galls in certain ferns may be due to some nutritional disorders in the plant metabolism.

Association of fungus with the larval cavity has been observed in some of the floral galls investigated. The fungi isolated from the galls of *Ipomoea sepiaria* and *Clerodendrum inerme* which sporulated in culture were identified as *Cladosporium* sp. and *Alternaria* sp. respectively. A comparative account of morphological feature of the hyphae of *Cladosporium* and *Alternaria* under different conditions were observed and also of the Blasto-conidial type of Deuteromycetes isolated from *Tournefortia heyneana* (Lourdusamy, 1982) [15].

The large, fleshy, pouch gall on *Garuga pinnata* (Fig. 3 & 4) has wide larval chamber; we have observed nearly six successories and some ants in the gall cavity. The tree is deciduous and shed leaves bearing the gall. The entire floor around the tree is covered with the leaves and galls. These galls are again invaded by saprophytic fungi and insects. It is not easy to distinguish the inquilines, parasites, predators and other inhabitants in the gall. However, a mini food-web is recognizable in the gall both in fresh condition and later in dry condition.

Fig. 3: ***Garuga pinnata*** Roxb. *Cupular covering growth rostrate pouch*

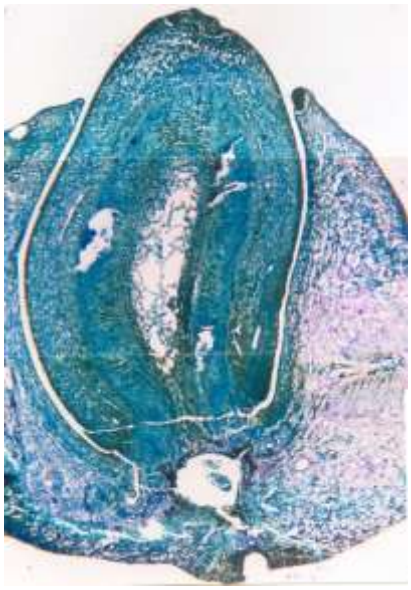

Fig. 4: L.S. of Gall

Many rust fungal galls are also common in India. Gymnosporangium causes the large galls on red-cedar and the galls are popularly known as '*cedar-apples*'. Uromyces, Aecidium and *Haphalophragmium ponderosum* cause woody galls on different host plants. The fungus *Haphalophragmium ponderosum* produces huge and abundant galls on all tender branches and fruits of *Acacia leucophloea* (Mimosoideae, Fig. 1). In the stem gall of *Haphalophragmium* on *Acacia leucophloea* (Mimosoideae) unusual types of tracheary elements with altered orientation were observed [16 & 17]. A fungal gall on paddy grains caused by *Ustilago* sp. (Fig. 5,6,7,8 & 9) is an edible gall. Recently amazingly huge, massive, highly lobed grayish brown gall on the branches and also on the trunks of *Excoecaria agallocha* (Euphorbiaceae) was recorded from Vedaraniyam mangrove forests (Fig. 2). The gall is caused by an unknown fungus (Amerjothy, 2005)[18]. A spindle form vein gall was also recorded on *Connarus wightii* (Connaraceae).

Fig. 5: Oryza sativa L. Seed Galls

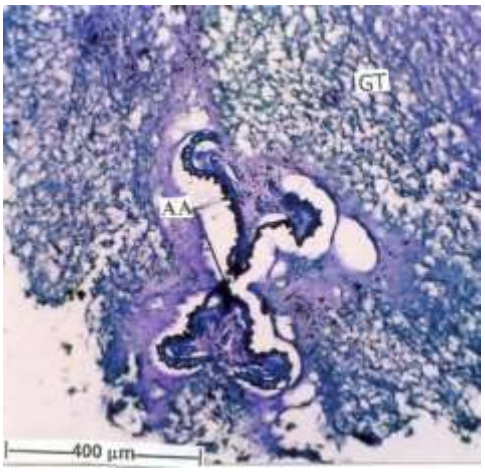

Fig. 6: T.S. of Seed Gall

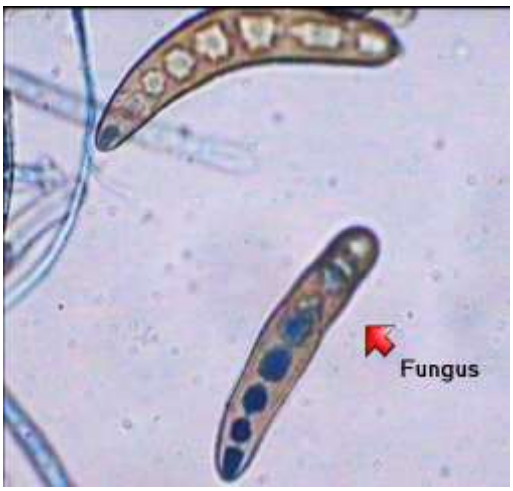

Fig. 7: Fungus Enlarged

Fig. 8: Sectional View of Seed Gall

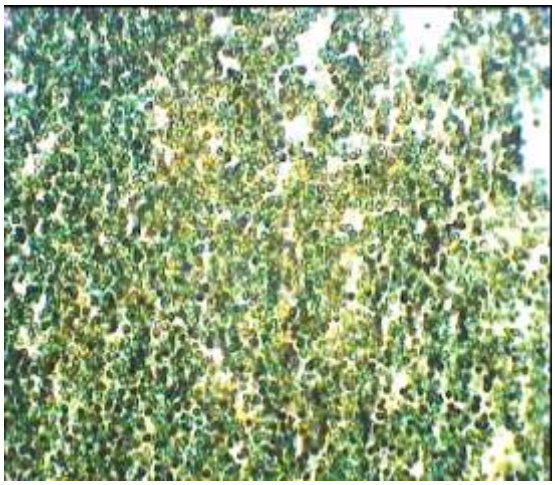

Fig. 9: Fungal Spores Enlarged

The fungal galls are less common as compared to the insect galls. The fungal galls are unorganized and indefinite in shape and size. A gall on aerial parts of *Jasminum trichotomum* is caused by *Puccinia jasmini*. On *Acacia leucophloea* a fungus, Uromlycladium, causes huge gall of varying size and shape which are abundant in the scrub forest. On *Connarus wightii* diffused fusiform shoot axis gall produced by an unknown fungus.

DISCUSSION

Many galls induced by the larvae belonging the group Itonididae, a fungus called Ambrosia is invariably associated in the larval chamber. Such a gall with the fungus in the gall chamber is termed "*ambrosia gall*". Cecidologists believe that the fungus - gall tissue – insect larva form a complex system of symbiotic relations. The galls induced by the insect *Asphondylia* on various host plants is said to invariably harbour the ambrosia fungus in the larval chamber. In a survey made by the author, galls induced by different species of *Asphondylia* were recorded on *Dicerma biarticulatum*, *Ipomoea staphylina* (Fig. 10), *Morinda pubescens* (Fig. 11), *Rivea hypocrateriformis* and *Tectona grandis*. Among these galls, only *Dicerma biarticulatum* (Leguminosae) and *Ipomoea staphylina* were found to bear Ambrosia fungus. It seems most probable that the spores of the fungus are carried with the eggs of the insect and as the larva hatches out and enters the plant tissue, the spores are also carried with the larva. As the gall grows, the fungus occupies the larval cavity deriving nutrition from the gall tissue. The larva feeds on the spores of the fungus. While this symbiotic relationship is believed to be the common phenomenon in the ambrosia galls, views incongruous to this concept have been expressed by Ross (1932)[19]. It is claimed that the fungus found in certain galls are mere inquiline similar to other insect inquilines without any biological relationships with the larva.

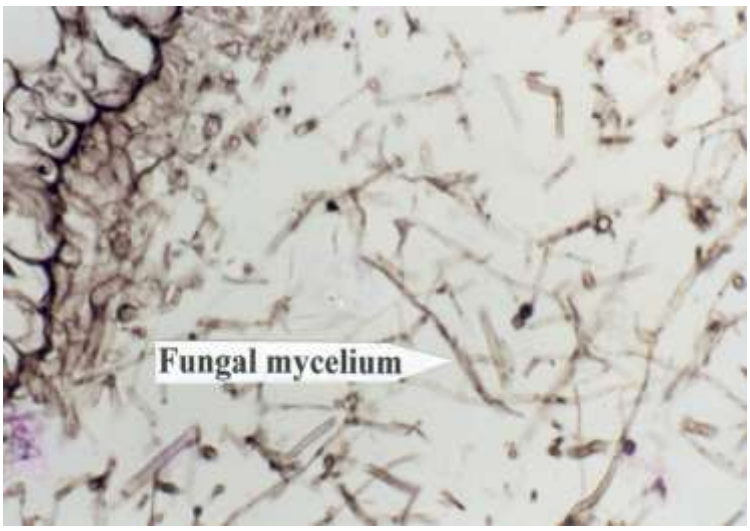

Fig. 10: *Ipomoea staphylina* Roem. & Schultes Fungal Mycelium Enlarged

Fig. 11: ***Morinda pubescens*** J.E. Smith Flower Gall

Albugo is remarkable for causing very pronounced hypertrophies and abnormal growths on several host plants. The *coralloid gall* on *Ipomoea pes-tigridis* (Convolvulaceae) caused by *Albugo* is one of the most interesting fungal galls[20]. Since there is also association of a mite with this gall, Mani (1973) [1] considers that the original incitant of the gall is *Eriophyes sp*. and the fungus is a secondary associate. The nodulated gall on *Ipomoea indica* (Convolvulaceae) and the *Cerebriform* gall on *Ipomoea pentaphylla* (Convolvulaceae) are also considered to be caused by *Albugo* [21, 22], whereas Mani (1973) [1] records them as mite galls. In all these cases not only the ground tissues, but also the formative and vascular tissues prolifeate and form typical *histioid galls*.

In the present survey, many galls of *Asphondylia* were found to lack any fungal association. Thus, the gall insect larvae thrive well without the fungus and the galls also develop normally. This observation lends support to the view of Ross (1932)[19]. However, this subject remains inconclusive due to lack of more studies and experimental evidences.

In the fungal galls, the position of the pathogen in the stem does not seem to be specific nor specific to any tissues. Unless prevented by a mechanical barrier, the mycelium, otherwise, spreads freely to various tissues randomly, and stimulates them to proliferate to different degrees (Akai, 1951)[23]. Thus, more than one type of tissue of the stem may contribute to the cecidogenesis of the shoot axis galls of fungal origin.

In addition to the above recorded information there is a great wealth of knowledge concerning the medicinal, narcotic and other properties of plant galls that is still transmitted orally from generation to generation by tribal societies [24]. The use of modern isolation techniques and pharmacological testing procedure means that new plant galls (phytodrugs) usually find their way into medicine as purified substances rather than in the form of galenical preparations.

Other than the afore mentioned fungal group, there are many galls that serve as saprophytic medium for growth of the fungi. These saprophytic secondary invader fungi grow either on the surface or inside the larval chamber and flourish well deriving nutrition from the dead gall tissues.

CONCLUSION

The general growth responses of plants infected with the fungal parasites include an exaggeration or an inhibition of normal morphogenetic processes. The insect galls are self-limiting outgrowths in which the behaviour of the insects is important and additional factor playing key role in cecidogenesis. Thus, in the insect galls greater precision of stimulation in time and space could be effected. In contrast to the insect galls, the fungal galls may not combine symmetry and histological differentiation to the degree of perfection as found among the insect galls. The fungal pathogen occupies more area of host tissues and it is in direct contact with the individual cells, thereby having direct influence over the physiological activities of the host tissues. All these aspects render the fungal galls to assume unlimited size and amorphous form. Nevertheless, examples of fungal galls are available which display considerable degree of cells specialization distinct from those of normal organs. Comparative analyses of galls of bacterial and fungal origin on one hand and insects / mites on the other, are likely to offer wealth of information on the role and the nature of the cecidogenetic stimulus and its diffusion gradients during the development of galls. Based on the previous and present investigation of the detailed information about the fungal gall and ambrosia gall, it is slightly correlated with the behaviours of lichens and mycorrhizal association in plants. But still it is chain of continuing controversial conclusion about the fungal association in plant galls. Hope in future it will give better picture among the role of fungus association in plant galls.

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