FUNGAL AND INSECT PARTICIPATION IN RED BULLET STEM GALLS OF WHITE OAK[1]

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ABSTRACT: The relationship between fungi and gall wasps in red bullet stem galls of white oak (*Quercus alba*) was investigated. Ten fungal species were isolated from the galls with a *Penicillium* sp. and a sterile hyaline form predominating. The *Penicillium* sp. was associated with gall breakdown, while the sterile hyaline fungus was found in the gall's trophic phase. Larvae of the cynipid gall wasp *Disholcaspis quercusglobulus* and the chalcid parasitoid *Torymus racemariae* were reared to adults on agar plates with the *Penicillium* sp.

Naturally occurring plant galls are a tissue outgrowth stimulated by the presence within the gall of a foreign parasitic organism such as an insect larva, bacterium, fungus, or virus. Gall tissue is unique only because it is unusually abundant, unusually placed, and unusually timed compared to "normal" plant development (Mani, 1964). The theoretical significance of the gall is "that the plant has successfully restricted the parasite . . . in space and time" (Mani, 1964). This restriction gives the plant means to reduce damage from its many potential parasites.

Mechanisms for gall formation are largely unknown. Elm leaf aphid galls seem to be induced to form not by some special stimulatory substance but by hypernutrition in the region of the parasite (Mani, 1964). It also may be that a parasite causes the secretion of plant growth hormones.

Oak stem galls can form in any part of a stem where the wasp's ovipositor can reach the vascular cambium. Cynipid wasp galls have a central capsule lined with schlerenchyma cells within which the parasite resides (Mani, 1964). Agamic females emerge from the galls in late fall (Krombein *et al.*, 1979).

A gall's life has been divided into three phases: 1) gall formation; 2) a trophic phase where parasite feeding and gall formation have stopped and the gall complex is dormant; and 3) post-maturity, where the gall breaks down to allow the parasite to escape.

Preliminary investigations of red bullet stem galls by one of us (D.R.D.)

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demonstrated that certain fungi were consistently present within the gall at certain phases of its history. While rearing gall wasp larvae, we observed a possible trophic relationship between the larvae and some of the fungi.

METHODS AND MATERIALS

The galls used in this study were the trophic phase of the red bullet stem gall of white oak (*Quercus alba* L.), formed by the cynipid wasp *Disholcaspis quercusglobulus* (Fitch) (Felt, 1940; Weld, 1959). Healthy galls range from 10-20 mm diameter, averaging 13 mm.

Whole trophic phase galls were collected from an infected white oak tree on the campus of DePauw University, Greencastle, Indiana in the fall and winter of 1975-1976 and kept refrigerated until used. The galls were washed in 100% ethanol, cut in half and placed on Petri plates containing a mixture of 5 g glucose, 1 g yeast extract, 20 g agar, and 1 l distilled water.

Uninjured larvae were removed from the gall's central chamber and placed on the agar plates to observe their interaction with the fungi contained within the galls. Plates were kept at room temperature (24-25°C).

RESULTS

Ten different fungi were isolated from the gall interiors. Two fungi (*Penicillium* sp. [70% of examined galls] and sterile hyaline form 1 [92% of galls]) were consistently present. The sterile hyaline fungus (probably a phycomycete) was isolated mainly from the interior of young galls while the *Penicillium* sp. was found primarily in older, more degenerate galls.

Larvae from the galls were successfully reared to normal adulthood on the dominant *Penicillium* sp.. Even though the larvae probably were in diapause when collected (fall and winter), fecal material was found on the agar plates and larvae were observed to eat the fungus. Larvae placed with the sterile hyaline form 1 survived, although there was no evidence of their having ingested the fungus. Larvae placed on the agar plates in November emerged in February, while those placed on the agar plates in February emerged in March and April.

Of 22 larvae reared to adult, four were Cynipidae [two *D. quercusglobulus* - the gall instigator, and two *Synergus campanula* (O.S.) - a gall inquiline (Krombein *et al.*, 1979)]. The remaining wasps were *Torymus racemariae* (Ashmead) (Torymidae), a parasitoid on stem galls. Both cynipid and chalcid wasp larvae ingested *Penicillium* sp.

DISCUSSION

Many plant galls are known to support complex trophic interactions between gall makers, inquilines, parasitoids, predators, and symbionts (Askew, 1961; Mani, 1964; Weis, 1982). Only two types of cynipid wasp galls, out of 43 different types inspected by Batra and Lichtwardt (1963), contained any fungi. Grundmann and Evans (1952) and Evans and Grundmann (1954) suggested that many cynipid wasp galls are also bacteriologically sterile. In contrast, we found that *Penicillium* sp. and sterile hyaline form 1 are an integral part of the red bullet stem gall complex, and the appearance of these fungi varied with the gall's age. The healthier a gall, the more likely it was to contain the sterile hyaline form 1 fungus. More degenerate looking galls contained mostly *Penicillium* sp.. As the gall must allow the parasite to leave in the post-maturity phase, perhaps the *Penicillium* sp. helps break down the gall so as to enable *D. quercusglobulus* to escape the gall's confinement. Batra and Lichtwardt (1963) commented that fungi from within hard galls frequently are saprophytic on insect excretia and may parasitize the gall tissues. Because wasp larvae ingested the *Penicillium* sp., perhaps the *Penicillium* sp. can serve as a supplemental food source. Such an arrangement would be easy to perpetuate as the developing female wasps need only incorporate the fungal spores in their reproductive tract and pass them along with the eggs during oviposition.

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LITERATURE CITED

Askew, R.R. 1961. On the biology of the inhabitants of oak galls of Cynipidae (Hymenoptera) in Britain. Trans. Soc. Brit. Entomol. 14: 237-268.

Batra, L.R. and **R.W. Lichtwardt.** 1963. Association of fungi with some insect galls. J. Kan. Entomol. Soc. 36: 262-278.

Evans, F.R. and **A.W. Grundmann.** 1954. Further observations on bacteriological sterility of the chamber of Cynipid-induced galls on *Quercus gambelii* Nutt. J. Kan. Entomol. Soc. 27: 148-151.

Felt, E. 1940. Plant Galls and Gall Makers. Comstock Publishers, New York. 364 pp.

Grundmann, A.W. and **F.R. Evans.** 1952. A study of the bacteria flora of certain gall wasps (Hymenoptera: Cynipidae) affecting scrub oak (*Quercus gambelii* Nutt.). J. Kan. Entomol. Soc. 25: 66-68.

Krombein, K.V., P.D. Hurd, Jr., D.R. Smith, and ***B.D. Burks*** (eds.). 1979. Catalog of Hymenoptera in American North of Mexico. Vol. 1 Smithsonian Institution Press. Washington, D.C. 1198 pp.

Mani, M.S. 1964. Ecology of Plant Galls. W. Junk. The Hague, Netherlands. 434 pp.

Weis, A.E. 1982. Use of a symbiotic fungus by the gall maker *Asteromyia carbonifera* to inhibit attack by the parasitoid *Torymus capite.* Ecology 63: 1602-1605.

Weld, L.H. 1959. Cynipid Galls of the Eastern United States. Ann Arbor, Michigan (privately printed). 124 pp + *30 pl.*