The occurrence of crystals in a cynipid leaf gall
on Quercus turbinella

Kristalle in einer Cynipiden-Galle auf Blättern von Quercus turbinella

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(With 5 figures)

Received November 9, 1989

Keywords: Insect galls, Quercus turbinella, Atrusca caprone, Gall crystals, Cynipidae

Abstract

Crystals in insect gall tissue are variable and more rare than in other types of plant tissue. This is the first description of crystalline structures in Atrusca caprone (Hymenoptera: Cynipidae) leaf galls on Quercus turbinella. Crystals are only found in young galls which indicates that their production may have been influenced by larval activity.

Zusammenfassung

Kristalle in Geweben von Insektengallen sind variabel und erheblich seltener als in anderen Pflanzengeweben. Dieser Beitrag enthält die erste Beschreibung der Kristallstrukturen in von Atrusca caprone (Hymenoptera: Cynipidae) verursachten Blattgallen an Quercus turbinella. Kristalle finden sich nur in jungen Gallen, was darauf hindeutet, daß ihre Entstehung auf den Einfluß der Larven zurückgeht.

This is the first description of crystalline structures in a Atrusca caprone Weld (Hymenoptera: Cynipidae) leaf gall on Quercus turbinella Greene. Crystals have seldom been found in gall tissue (Dengg 1971, Rey & Moreau 1983.

Only one to two hundred of the 16 000 types of galls in the world have been adequately studied (Larew 1982). Among the insect galls the cynipid galls are well known for their abundance, species richness, and complex morphology, especially on Quercus and Rosa (e.g. Weld 1957, 1960. Bron-
In spite of several studies addressing cynipid galls' natural history (e.g. Shorthouse 1973, Collins et al. 1983), distribution (e.g. Askew 1961, Taper & Case 1987), and anatomy (e.g. Mani 1964, Larew 1982, Meyer 1987, and Meyer & Marequelle 1983 for reviews), the significance of the cynipid gall's complex morphology and anatomy are not well known (but see Cornell 1983).

Quercus turbinella is widely distributed in the chaparral vegetation of Arizona (McDougall 1973). Galls were found throughout the host plant distribution. They were more abundant between 1,200 and 1,500 meters altitude (adjacent to highways I-17, and 89A South). Galls were first observed in the beginning of June 1987 and by the end of September all of the galls were mature.

The cynipid galls occurred on the abaxial leaf surface, and were spherical, glabrous, and one-chambered with only one gall making larva per chamber. Galls varied from yellow to red. Most had red vertical stripes radiating upward from the base of the gall. Mature galls, from which the gall maker had emerged, had a mean diameter of 10.99 mm (S.E. = 0.42, n = 225). The mean gall wall thickness was 0.62 mm (S.E. = 0.04, n = 225). Kinsey (1930) and Larew (1982) describe the external and internal macroscopic appearance of the gall, and the cytology and anatomy of a structurally similar cynipid (Besbiscus mirabilis var. mirabilis [Kinsey] Weld) leaf gall on Quercus garryana Doug., respectively.

Young galls were solid, but the centrally located larval chamber became separated from the gall walls during gall development (Fig. 1). However, the larval chamber remained attached to the gall walls by numerous radiating strands (Fig. 1, 2, 3). Vascular bundles ran from the leaf base to the larval chamber and to the gall's outer shell. The mean length of the radiating strands was 5.66 mm (S.E. = 0.34, n = 225). Most of the strands were unicellular, occasionally branching or terminating before attachment, and were parenchymatous. Intra-cellular rosette-shaped crystals were found within and along these strands (Figs. 4, 5).

The occurrence of crystals in plant tissue has been described as unpredictable (Frey-Wyssling & Mühlethaler 1965, see also Schnepf 1971, Wergin & Newcomb 1970, Wergin et al. 1970). Crystals in gall tissue are variable and more rare than in other types of tissue (e.g. Dengg 1971, Küster 1930, Meyer & Marequelle 1983). They are localized in well defined regions of the galls, in general near conductive tissues (see Meyer & Marequelle 1983). Most of the few crystals described from galled tissue are formed by calcium oxalate. Calcium oxalate crystals are highly insoluble in water (solubility in grams per 100 ml of cold water is 0.0006713c, and 0.001495c in hot water (Hodgman 1948). However, the crystals of the present study were water soluble (H. Arnot, pers. comm.). The presence of water soluble crys-
Fig. 1 - 4. *Atrusca caprone* leaf gall on *Quercus turbinella*. 1. Cross-section of gall. 2. Strands radiating out to gall walls. 3. Cross section of strands and vascular bundle. The vascular bundles ran from the leaf base to the gall chamber which is positioned in the center of the gall, and to the gall walls. 4. Rosette-shaped crystals within strands. Arrow shows a well defined crystal and its radiating crystalline structures from the crystal center.
Crystals inside vacuoles of living cells is an apparent paradox due to the presence of water in the vacuoles. However, crystal formation and growth is also governed by the pH of the media. Thus, we suggest that the presence of the water-soluble crystals in aqueous cell media is due to cell pH. Crystals may, however, be dissolved during normal preparation techniques, in which AFA (Alcohol-Formalin-Acetic Acid) is frequently used. This probably explains why the crystals in question have not been previously reported.

Rey & Moreau (1983) studied the presence of paracrystalline inclusions in the nutritive cells of Diplolepis rosae Linnaeus (Cynipidae) galls on Rosa canina Linnaeus. Ultrafine enzymatic digestion bioassays indicated that the intra-cytoplasmatic paracrystals were of proteic nature. They stated that the paracrystals were probably related to the larval action which stimulates protein synthesis in the cells surrounding the consumed ones.
We found crystals only in immature galls. This was the stage of gall development during which the larvae were actively feeding. This suggests that crystal production may have been influenced by larval activity.

The importance of these crystals to the galling insect and/or plant is still unknown. Plant nutrients are concentrated in gall tissue (e.g. MANI 1964, LAREW 1982, ROHRFRITSCHE & SHORTHOUSE 1982). This may attract several gall herbivores, including predators and inquilines (FERNANDES et al. 1987) of the gall. Because gall makers and their galls are apparent and predictable resources for their natural enemies (PRICE et al. 1980, FERNANDES et al. 1987), insect galls support a diverse community of parasitoids (e.g. ASKEW 1975, PRICE et al. 1987), inquilines (e.g. SHORTHOUSE 1973), predators (e.g. MANI 1964, FERNANDES et al. 1987), and successori organisms (e.g. FERNANDES et al. 1989). In addition, predation or competition with other herbivores (sensu FERNANDES et al. 1987) to feed on the nutrient-rich and allelochemical-free nutritive gall tissue results in death of the galling insect by habitat modification and/or direct killing by the competitor herbivore (FERNANDES et al. 1987). Thus, it is not surprising that many gall defenses have been described including glandular trichomes, high levels of phenolics, resins, and fast lignification of some tissue layers on the outer gall tissues (see MANI 1964, MEYER & MARESQUELLE 1983, MEYER 1987). Crystals are also important as deterrent and anti-feeding structures against herbivores (FRANCESCHI & HORNER 1980, McNAUGHTON & TARRANTS 1983). For example, KIMMERER & PATTER (1987) argued that the major constraints which limit the success of a leafminer on shade leaves of Ilex opaca are the presence of crystal-containing cells. However, crystals are also involved in a multitude of functions within plants. Various functions have been attributed to plant crystals, for instance ionic balance, storage, or structural support (see FRANCESCHI & HORNER 1980 for a review). Thus, the significance of A. caprone gall crystals can only be understood after detailed studies on their chemical composition, physiological function, and ecological role have been carried out.

Acknowledgments

We would like to thank H. L. Mogensen, and J. States, and two anonymous reviewers for their encouragement and help. We also would like to thank H. Arnott for his analysis of the crystals and H. V. Cornell for the cynipid identification. In addition, we would like to thank Angela Fernandes for helping in the field and laboratory work, R. Helt for help with the translation of the abstract into German, and T. Theimer for helping with Figure 5. Research funds were provided by the Conselho Nacional de Pesquisas (CNPq-200.274/84-3-ZO) and Northern Arizona University.
References


Cynipid gall crystals


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