

Gastrodia and Mycorrhiza

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WE have learned from a report that has often been quoted that the mycorrhizal fungus of the saprophytic orchids, *Gastrodia* and *Galeola*, is the widely distributed tree parasite, the honey agaric, *Armillaria mellea*. Botanists who have not had access to the literature have sometimes wondered what the evidence for this amounted to. Now that I have been able to see the original papers I have found the story so interesting that I offer the following note for the benefit of those who cannot easily read about it for themselves.

The two well-known monographs on mycorrhiza are Rayner's, published by Wheldon and Wesley in 1927, and 'Mycotrophy in Plants' by Kelly, 1950, both readily available and both including extensive bibliographies. One paper concerning this special orchid saprophytism titled '*Gastrodia elata* and its symbiotic association with *Armillaria mellea*' by S. Kusano, 1911, *Journ. Coll. Agr. Imp. Univ. Tokio* 4, 1-66, is available in the library of the Natural History Museum, South Kensington, where I have read it. Kusano examined a large number of *G. elata* tubers, finding some with no mycorrhiza and some with well developed mycorrhiza, before he lighted on some specimens which gave a clue to the infection. These had a few black rhizomorphs running over the surface of the tuberous rhizome, with branches penetrating into the rhizome tissue. Carefully prepared sections, illustrated in the publication by drawings and photographs, showed hyphae from the rhizomorphs penetrating the rhizome tissue and forming characteristic mycorrhiza. Rhizomorph branches penetrate cortical tissue like haustoria but within the orchid tissue hyphae grow out singly and infect cortical cells. These become filled with coils of thick-walled, non-septate or very seldom septate hyphae, though outside the host the hyphae of the rhizomorph are dark-coloured and septate. In the inner cortical layers of the *Gastrodia* rhizome the hyphae, which are thin-walled, slender and rich in protoplasm, produce small vesicles and then break down leaving oil globules in the cells. Nevertheless, the main food reserve material in *Gastrodia* is starch.

The plant consists only of flowering stalk and rhizome, being without roots. The rhizome reproduces itself vegetatively by forming a number of long branches on the tips of which small uninfected rhizomes develop. When rhizomes were dug up carefully in the flowering season a large number of young tubercles were found near the old rhizome. Tubercles as small as 2mm in diameter were unearthed showing early stages in infection by brown rhizomorphs. Tubers were not found to flower till they had become infected and reached 10-11 cm in length; then after flowering they usually pro-

liferated and the old rhizome died leaving a number of smaller tubers.

Rhizomorphs such as infect the orchid occur widely in Japanese oak woods and in no case has *Gastrodia* been found in a place where there were not rhizomorphs in the soil or on nearby roots of *Quercus serrata* or *Q. glandulifera*. *A. mellea* grows saprophytically on dead bark or dead roots, even parasitically on living trees. As it is an edible fungus it is widely recognised. In a garden where an oak tree had been cut down and *A. mellea* toadstools were seen round the stump there later rose a crop of *Gastrodia* where none had been seen before.

The fungal rhizomorphs traversing the humus soil may meet living roots of trees on which they often develop parasitically. When they meet *Gastrodia* tubers, however, they usually form a beneficial mycorrhiza. Exceptionally they may become parasitic on *Gastrodia* tubers and destroy them. Exactly similar rhizomorphs were examined attacking potato tubers.

Experiments to induce the mycorrhizal condition largely failed. Uninfected rhizomes up to 6 cm long, planted in suitable places, were found either to have decayed, to be parasitized by rhizomorphs or to have proliferated and produced very small uninfected tubers. It is obvious from the nature of the plant that true symbiosis is not conceivable in *Gastrodia*. The orchid which is quite comparable to the holo-parasites of the Balanophoraceae or Rafflesiaceae is, Kusano believes, parasitic on the fungus.

The second Japanese paper on this topic which I have consulted is 'Studien über die Mykorrhiza von *Galeola septentrionalis* Reich. f.—Ein neuer Fall der Mykorrhiza—Bildung durch intraradicale Rhizomorpha' by M. Hamada, 1939, *Jap. Journ. Bot. Trans. and Abs.* 10, 151-211, which volume I was able to borrow from the Science Library. *G. septentrionalis* is also a completely saprophytic brown orchid which consists of a long thin rhizome carrying numerous long roots, and in season, a flowering stalk up to 1 m tall. Mycorrhizal development occurs in parts of both long roots and in short branches from them and is in two forms called by the author, temporary and permanent. The first is caused by individual hyphae penetrating the epidermal cells of the short branch roots and infecting the outer cortical cells in the same manner in which fungus develops in the roots of green orchids. The permanent infection on the other hand is different and occupies much of the length of the older roots. Here entire rhizomorphs penetrate the epidermis of the root and run up and down its length in the cortex causing an irregular thickening. From the rhizomorphs hyphae grow out into the surrounding cortical cells forming sporangioles or coils of hyphae. It proved easy to culture the rhizomorphs from the roots and although no fungal cultures fruited they showed the same characters as cultures of known *A. mellea* and therefore were so described.

The species of *Galeola* are all brown saprophytes of similar habit to the species of *Gastrodia*, but apart from floral differences and the development of roots many of them reach a larger size. Some Himalayan species reach enormous dimensions for such plants and may produce a robust flowering stem 12 ft high which must be the result of a very efficient food supply from the fungus to the orchid. It is of interest that the two orchids examined, *Gastrodia elata* and *Galeola septentrionalis*, both accumulate starch, although the food material which appears first in the root or rhizome cells after the breakdown of the fungal hyphae is globules of oil.

There is a beautiful modern (1953) Flora of Japan printed in Japanese with Latin names separately indexed, from which I gleaned the names of the currently accepted Japanese species of *Gastrodia* and *Galeola* but from which I could elicit no information about them. I looked through the specimens in the Natural History Museum Herbarium but found rhizomes with only two collections of *Gastrodia*, one from New Zealand and one from Tasmania, neither with any sign of rhizomorphs. Similarly specimens of these two genera in the herbarium at Kew were without rhizomes except for a couple which showed no fungus. Some specimens collected by J. D. Hooker in the Himalaya were models of botanical information with expertly intricate floral drawings attached to the herbarium sheet, but of course, no details about mycorrhiza which word was not even coined at the time. A Malayan Flora which I consulted gave floristic information about several *Galeola* species, one of which, *G. hydra*, a climber, reaches a very large size, but whether it is an annual or perennial I did not learn, not even from the widely informed Keeper of Orchids.

The relationship between the saprophytic orchids and the fungus is of special interest as the higher plant is leafless, without chlorophyll, and, for the *Gastrodia* species, even without roots. *A. mellea* is a very widely distributed fungus which is of considerable economic importance because it is a vigorous parasite. In New Zealand *A. mellea* has been found destroying trees in exotic plantations but whether it is the fungus of the N.Z. *Gastrodia* species is unknown. It would be interesting to know if *Gastrodia* really acts as a parasite on *A. mellea* and thus is capable of destroying pockets of fungal infection in the soil; or if, on the other hand, it forms in any degree a symbiosis with the fungus and so might help to support and distribute it. These problems present an interesting subject for further investigation.

A similar problem appears to exist in the growth of *Orobanche* which is a common plant about Nelson and elsewhere in New Zealand. Casual investigation of a number of these plants associated with broom and lupin on the sand dunes, and with *Senecio greyii* in the Cawthron grounds, has failed to reveal any direct connection

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down, or when a larger tree than usual falls, the gap in the canopy remains open for a very long time. A natural clearing is formed which for many years is occupied by native grasses (or by introduced herbs, grasses or vines if not too remote from occupied land). Regrowth of a forest cover is by means of a slow advance from the forested periphery of the clearing—none of the adjacent species seem able to jump out into the high light and nutrient poor condition in the centre but can advance centripetally only from the shade of the surrounding trees and with the help of the small nutrient return provided by their litter. If there were present in the plant assemblage of Samoa species better adapted to these poor soils the present day vegetation pattern of Western Samoa would surely be very different. In Fiji, where there have always been small areas of quartz-rich but nutrient-poor sands, chance arrivals adapted to poor soil conditions have been able to survive and these have, in the course of time, spread and now occupy most of the poor soils that developed on land of easy relief. The present day vegetation pattern of Fiji is much more elaborate than that of the islands of Western Samoa.

Another Pacific Island of great ecological interest is Chatham or Rekohu Island off the New Zealand coast. Here, under a cool, damp and windy climate like that of Invercargill (although not so wet), many common plants of the Southland assemblage, those of the podocarp forest, manuka scrub and tussock grassland for instance, are missing and their various ecological niches have been taken over by *Dracophyllum* forest. *Dracophyllum*, in this type of climate, is an exceedingly active agent of peat formation. The grass-like foliage, so rich in complex organic compounds of a resinous nature, are very slow to break down and deep layers of forest peat (mor) quickly build up and add greatly to the rate of soil leaching. Under *Dracophyllum* forest, recently stabilized dune sands rapidly develop podzol characteristics, including humus, silica and iron pans. These impede drainage to such an extent that, on landscapes of gentle relief, bog conditions soon develop. It is interesting to speculate on how much of the blanket peat covering the landscape of the Chathams is due to the absence of podocarp species, manuka and tussock, and to the peat-forming propensities of *Dracophyllum*.

Continued from page 5: Gastrodia and Mycorrhiza—between the *Orobanche* tuberosus, and apparently mycorrhizic, rhizome and the roots of the other plant. Possibly a connection exists through a fungus common to both. Again, further investigation would be interesting.

Many years ago G. M. Thomson examined the rhizomes of *Gastrodia* (*Proc. N.Z. Inst.* 40, 579) of which he gave an account that is still interesting to read. He remarks that 'It is desirable that the parasitic habit of these orchids should be more closely investigated. I have no record of the roots on which they grow, nor can I find that any careful investigation of these has been made'.