A NEMATODE ROOT DISEASE OF DADAPS.

By

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A nematode or eelworm has recently been found in association with a disease of dadaps (*Erythrina lithosperma* Bl.) in the Maskeliya and Dimbula districts, at an elevation above 4000 ft. The infected trees were being grown for shade and green manure for the tea through which they were interplanted. Difficulty has been experienced in establishing the dadaps in these fields, though in neighbouring fields and at higher elevations dadaps grow well.

Symptoms.—The diseased trees have a general sickly appearance. Numerous dead and dying branches are to be seen in the crown; the foliage is 'thin' and of a pale colour. (See plate 3, figs. 1 and 3). The 'thin' appearance of the crown is due to a premature fall of the lower leaves, the presence of dead branches, and the small size of the remaining leaves.

The leaves, before they fall, frequently become flecked with brown, particularly along the finer veins; this gives them a somewhat rusty appearance. The same discoloration may often be seen on old leaves of healthy trees just before they fall. This colour change appears to be part of the normal process which precedes defoliation, and should not be regarded as symptomatic of any particular disease.

A more characteristic symptom is the crowded state of the leaf-scars along the shoots of affected trees. Fig. 2 (Plate 3), is of a typical shoot. It will be observed that there are but few leaves at the apex, and that the scars left by fallen leaves occur at very short intervals along its length. The crowding of the leaf-scars is the result of imperfect elongation of the stem, and is a symptom of stunted growth.

At this stage, neither the leaves nor the shoot bear any lesions or spots indicative of a parasitic attack. The defoliation is from the base of the stem upwards, which is the opposite of what occurs in a true "die-back." Ultimately, the shoots are entirely defoliated; then they die. In severe cases, the trees may die.

The most characteristic symptom of this disease is to be found on the roots. Swellings or galls occur at various points on both large and small roots. These enlargements may be widely separated, or they may be so close together that the infected root appears to be abnormally thickened. They vary in size from scarcely noticeable swellings on the fine roots, to great knobs with irregular surfaces, two or more inches in diameter, on the older roots. (See figs. 1 and 2 plate 4).

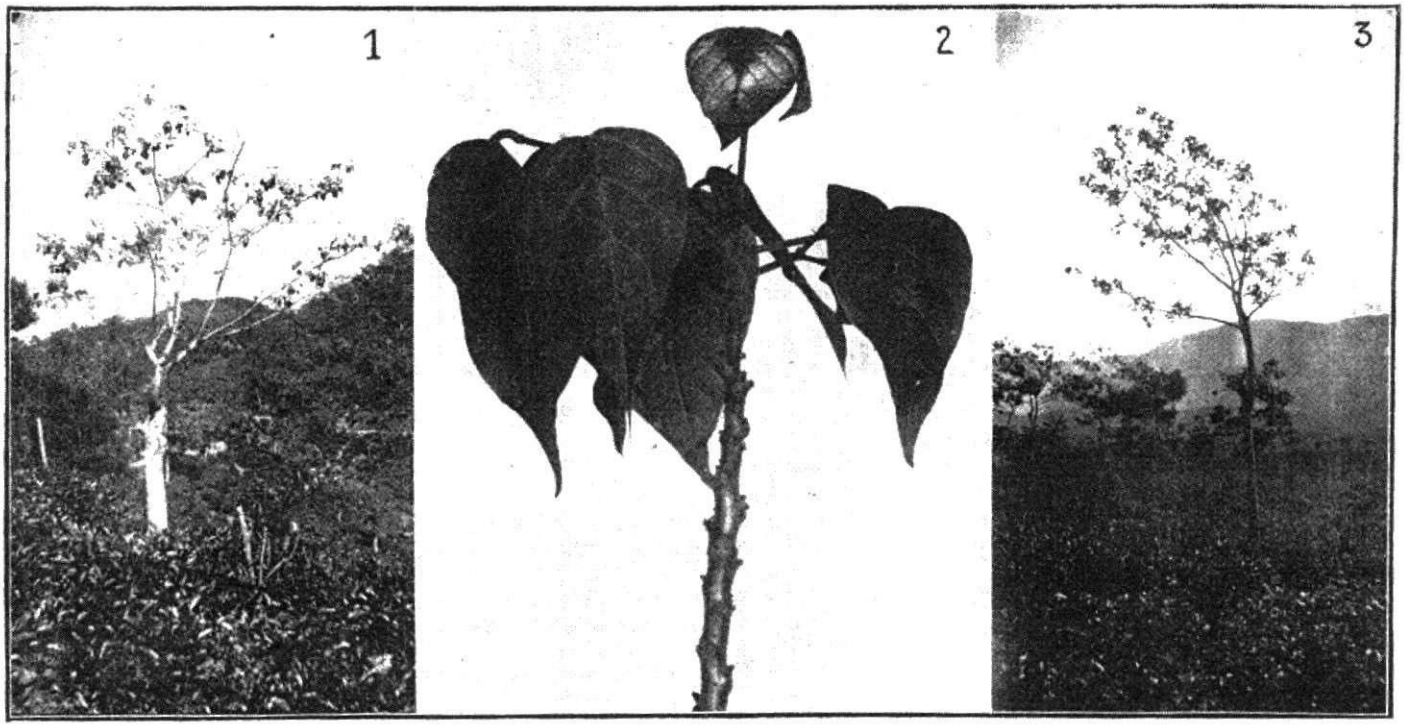
The parasites which cause these swellings are small nematodes or eelworms, and they live within the root tissues. A root gall, if carefully dissected or broken open, may show the female nematodes as glistening white sacs, or pearly white, rounded, pear-shaped bodies about half the size of a pin's head, just large enough to be seen with the naked eye.

The nematode belongs to the species *Heterodera radicicola*. Owing to the characteristic galls produced by this parasite, the disease on other plants is known by such common names as " root knot," " root gall," "eelworm disease," etc. Similar names might be applied to this disease of the dadap.

The root galls should not be confused with the nodules caused by nitrogen-fixing bacteria. The nitrogenous nodules of the dadap are almost spherical in shape, and vary in size up to half-inch or more in diameter. They are attached to the sides of the rootlets from which they may easily be broken off. The characteristic galls of this disease are enlargements of the roots themselves; consequently they cannot easily be detached. The difference in appearance between the injurious root galls and the beneficial bacterial nodules may be seen by comparing figs. 1 and 3 of plate 4.

Godfrey (3) gives the following description of the general effect of *Heterodera radicicola* on attacked plants. " As a rule, root-knot produces no malformations or enlargements on the parts of the plant above ground and consequently is frequently overlooked. However, plants badly infested are dwarfed, wilt readily in hot, dry weather, and are usually a paler green than healthy ones. Where this attack is most severe, plants may be entirely killed. In the case of a mild attack, only a small amount of dwarfing, together with a reduction in yield below the normal, is noticeable. Sometimes even the dwarfing is absent and the reduction of yield is not noticed. Since the disease is widely prevalent in some districts, the reduced yield is supposed by growers to be a normal one." The poor growth of the infected dadaps, the dwarfing and pale colour of the leaves, the imperfect elongation of the stem as shown by the crowding of the leaf scars, and the presence of root galls are symptoms which conform with those known to occur on other plants seriously attacked by this parasite.

Attacks by this parasite result directly in an interference with the normal functions of the root system arising from the malformation and the premature death of infected roots. The debility, so induced, renders the plants more liable to attack by other parasites, especially root fungi, which may assist in causing the death of the attacked plants. No other parasite or root disease fungus was found on the dadap trees examined; so it must be concluded that the parasite, *Heterodera radicicola*, is the primary cause of the diseased condition described here.



Figs. 1 and 3. Dadap trees infected by *Heterodera radicicola*. Fig. 2, Shoot of infected tree, × ¾.

PLATE III.

The parasite.—Nematodes are worms of relatively simple structure. Typically they are transparent, slender, eel-like organisms which move about by a peculiar whipping process. Owing to their narrow cylindrical shape they have received the popular names of "eelworm" and "threadworm."

In the earlier stages of its development, *Heterodera radicicola* has the typical eelworm shape, but, later, the females become much swollen and pear-shaped. The females may usually be found in abundance within the root-knots or galls. When mature, she is pearly white in colour and measures from 400 to 1000 microns (1/60 to 1/25 inch) in length. As the development of the ovaries proceeds, the female is reduced to a lifeless bag of eggs.

The female produces as many as 500 eggs, which measure about 90 microns (i.e., less than 1/250 inch) in length. The eggs are laid within the root galls and hatch *in situ*, or in the soil if they are liberated by the death or decay of the galls. The larvae which emerge are colourless, very minute, too small to be visible to the naked eye, slender and eel-like. They may migrate within the root tissues or may escape into the soil, where they may survive for months without parasitic relations (4). They move actively through suitable soils, and on reaching a favourable root, preferably a young feeding root, they force their way in, usually near the tip. The entry of larvae into the root stimulates the root tissues to abnormal activities, which result in the formation of the characteristic galls.

The larvae develop and become sexually mature while in the root. The male is similar to the larva in form and appearance but is much larger. He measures about 1·4 mm. in length (rather less than 1/16 inch), but is not over one-fortieth as thick as he is long. After fertilizing the female, he bores his way out of the root into the soil and soon dies. Consequently, he is rarely seen except when searched for just at the right time.

The entire life cycle is completed in about 30 days. In warm climates the nematodes may pass through 10 to 12 generations in a year, but in cooler climates the number is less.

Duruz (1) has determined that the optimum temperature for Heterodera is between 65° and 85°F. Generally speaking, temperatures above 65°F. increase its activity, and temperatures below 65°F. and above 85°F. decrease its activity. The nematodes may be killed by freezing and by heating to 101°F.; by the latter treatment the larvae and eggs are also killed. In parts of Florida certain susceptible garden crops can be grown in infested soils during the autumn, winter and spring, owing to the greatly reduced activity of the nematodes at temperatures below 55°F. In the tropics, however, the soil temperature is such as will favour the activity of the parasite.

Heterodera appears to prefer light and sandy soils. Root-knot is seldom found in heavy soils, possibly because the nematode finds it difficult to make its way from one root to another through such soils, and possibly because clay soils readily retain sufficient moisture to interfere with the proper aeration of the parasite.

Fawcett (2) has recorded that although *Heterodera radicicola* is often found on coffee in Porto Rico, there is no real evidence that the trees are really injured by this disease. He suggests that the heavy nature of most Porto Rican coffee soils prevents it from becoming the pest which it sometimes is elsewhere.

Occurrence.—*Heterodera radicicola* is already known as a parasite of over 500 species of wild and cultivated plants in different parts of the world. On some of these, the nematodes appear to inflict no visible injury except the formation of small knots on a few of their smaller roots. Other plants, though more seriously infested as shown by the abundance of galls on the roots, exhibit no apparent injuries or reduction of crop. There is a third class, however, in which the nematode injury is very severe, and which cannot be grown profitably in infected soil.

In Ceylon, Heterodera is well known as a destructive parasite of tea seedlings. Nurseries have been partially or wholly destroyed by its ravages. A photograph illustrating the damage caused by this parasite in a tea nursery was reproduced in the first number of this Journal (Feb., 1928). The same nematode has also been recorded in isolated cases as a parasite of mature tea bushes. As yet, its occurrence on mature tea is relatively rare, but the fact that this eelworm has been known to attack well-grown bushes and cause injuries sufficiently great to be noticed by the practical planter suggests that the propagation of this parasite on the roots of plants intergrown with tea may ultimately prove to be a menace to the tea itself. This possibility requires consideration.

The same parasite has been found within galls on the roots of otherwise apparently healthy dadaps. At present, very little is known concerning the distribution of this nematode in tea soils in Ceylon, and the discovery of it in roots of what appear to be normal healthy dadaps is disconcerting. The extent to which tea soils are infected, and the frequency of occurrence of nematode galls on the roots of vigorously growing dadaps have yet to be ascertained.

Treatment.—Satisfactory control of Heterodera is obtainable only where the soil can be sterilized by heat. Steam sterilization has been proved to be most efficient, but such treatment can be applied economically only on small plots and seed beds. The sterilization of large areas of tea soils by steam or hot water is impracticable. Moreover, such treatment can, of course, only be applied to soils which do not bear any living plants.

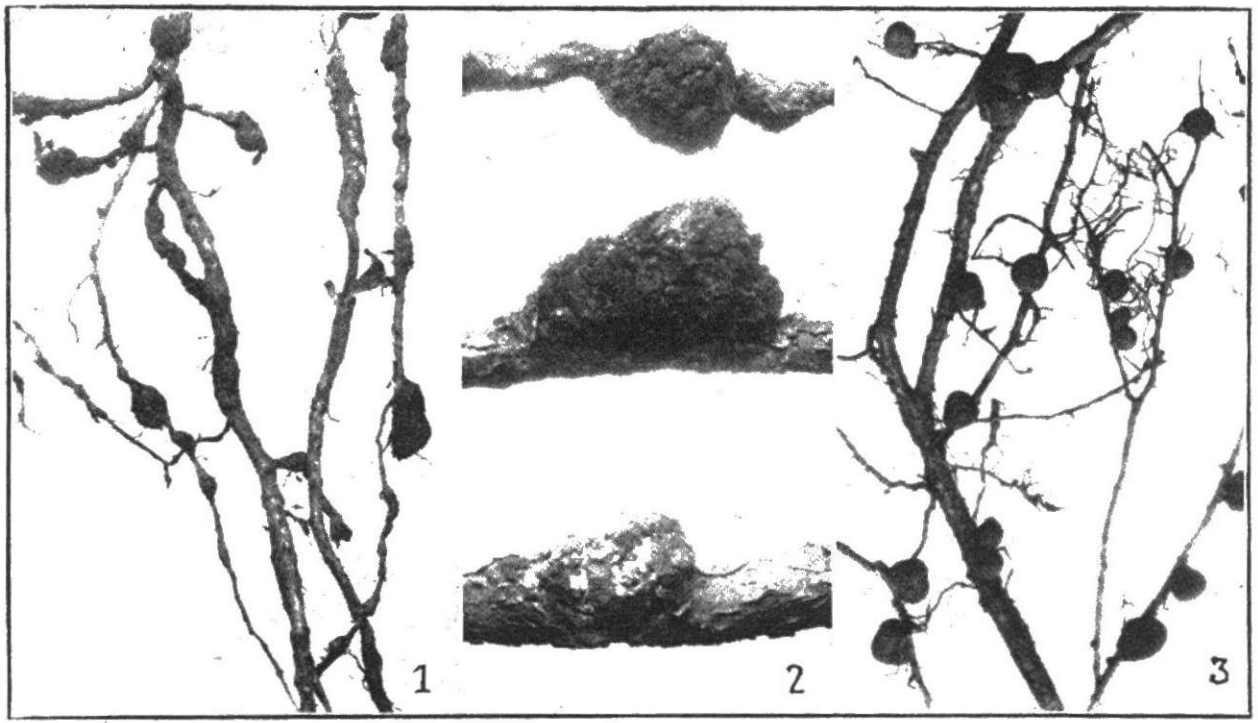


Fig. 1, Nematode galls on small dadap roots, x ½. Fig. 2, Old galls caused by *Heterodera radicicola*, x ¾. Fig. 3, Nodules on dadap roots caused by nitrogen-fixing bacteria, x ½.

PLATE IV.

Control by chemical agents has not proved feasible on any adequate scale. McClintock (5) has shown that the nematode could not be combated satisfactorily by any of the following:—carbon bisulphide, corrosive sublimate, calcium carbide, ammonium sulphate, formalin, nicotine, benzine, or kerosene. Stone and Smith (7) demonstrated that manganese sulphate, common salt, potassium nitrate, magnesium sulphate, calcium sulphate, kainit, sodium nitrate, and lime are ineffective. Concerning the value of lime, Nowell (6) says " The usefulness of lime in this connection is disputed, but in any case only heavy applications can be expected to have any notable effect." Duruz (1) obtained almost perfect control by treating the soil with 200 lb. of sodium cyanide per acre, followed by a second similar treatment 5 days later. For this treatment, however, the soil must be free from growing plants.

The cure of plants that are already infected is practically impossible. It is difficult to conceive of more than palliative effects resulting from any chemical or other treatment of an organism so well protected, during much of its life history, by the tissues of its host.

A method sometimes applied with good results to permanent crops, like the peach, is that of forcing the trees to grow in spite of the presence of the parasite. Commercial peach growers cultivate thoroughly and apply an abundance of fertilizer, particularly stable manures and commercial nitrogenous fertilizers, rich also in potash, so that the roots are made to grow faster than the nematodes can produce knots. Some such method would be worth trial if dadaps were a main crop in Ceylon. But as the dadap is grown as a shade tree and to provide green manure, as mulch or loppings, for tea, the practice of such forcing methods does not appear justifiable.

The most satisfactory method of combating the root gall disease is that in which infested fields can be planted with non-susceptible crops for a period of years. If the ground could be kept absolutely free from vegetation of all kinds, which for obvious reasons is impracticable, the parasite could be starved out in a few years. Similar results may be obtained by growing non-susceptible plants for three or more years.

The problem of a satisfactory treatment of this disease on dadaps is complicated by the presence of the tea, which is the main crop. The health and the vitality of the tea are of more importance than the presence or absence of a particular variety of shade tree. For this reason, the question of immunity or susceptibility of tea to this parasite becomes of primary importance.

In the seedling stage, tea is known to be very susceptible to this disease, but so far, Heterodera has not shown itself to be a serious pest of old bushes. Its occasional occurrence on mature bushes indicates clearly that the roots are not completely immune from attack. Consequently it appears advisable to take every precaution against the

propagation of the parasite on the roots of other plants intergrown with the tea. It might be argued that the presence of plants more susceptible than tea is a safeguard for the tea, insomuch as the parasites will attack the more susceptible roots in preference to the tea roots. That would be true if the attacked roots were removed from the soil and destroyed. Otherwise they merely form breeding grounds for the parasite.

The only practicable way of dealing with the problem in areas where the dadaps are seriously infected, where they make poor growth and provide little foliage for shade or green manure, either as mulch or as loppings—in short, where the dadaps do not efficiently serve the purpose for which they are grown—is by the complete removal of the dadaps and the complete destruction of their roots. As already explained, the prospect of the discovery of an efficient cure is very remote. It may be possible to improve the condition of the dadaps by " forcing " methods, at considerable labour and expense. If such methods include the use of heavy doses of lime, as might be expected, the effect of the treatment on the adjoining tea will have to be considered. It would appear to be a more economical proposition to abandon the cultivation of dadaps on such areas, and to grow other shade trees in their stead.

Where, on examination of the roots, dadaps are found to be infected, though otherwise they appear normal and healthy, no action should be taken at present, other than close observation to ascertain whether the trees are deteriorating. Until more is known concerning the distribution of this parasite in tea soils and its occurrence on dadap roots, it is impossible to state whether the presence of root galls is to be interpreted as the beginning of an attack, or that dadaps, grown under more or less ideal conditions, are tolerant of the parasite and sustain little damage from its attacks.

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