IV. EELWORMS

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The occasion of a general address provides me with an opportunity of surveying one of my particular interests in the wide field of plant pathology. My paper, therefore, deals with that branch of plant pathology known as nematology which is the study of nematodes or eelworms.

Eelworms are a self-contained class of the animal kingdom and are in a group apart, zoologically, from the well known earth worm, which is an annelid, or the wireworm which is a beetle larva. Eelworms are also known as roundworms and threadworms.

The group, as a whole, is of great medical and economic importance. On the medical side we have hookworm and filarial diseases, to name but two of the many diseases man and beast are subject to. Large numbers of workers are actively engaged in the study of these parasitic forms.

The study of free-living and plant-parasitic eelworms has not advanced to the same extent as the study of human and veterinary parasites though, in the last two decades, our knowledge of eelworms associated with agricultural crops has made some considerable advance.

Eelworms are one of the most abundant forms of animal life of soils in which organic matter undergoes decay. Most of these species are free-living or bacterial feeders, the other forms include parasites of plants and fungi and also predatory species which feed on other eelworms and small organisms found in the soil. The plant-parasitic species are fortunately few in number, there being between 50 and 100 species recognised as plant parasites. Of these, only relatively few, about a dozen species only, may be considered serious pests of agricultural crops.

The mouth and head structures of eelworms are adapted to the form of existence which the species leads. The bacterial and free-living species have simple oral ducts through which the small, soft-bodied bacteria are imbibed. The lip region of some

of these species carry curious ornamentations or structures. Predatory forms are either armed with teeth or denticles, as an aid to devouring their prey, or with a hollow protrusible spear which pierces the body wall of the prey and through which the body contents of the prey are imbibed. The plant-parasitic species are also armed with protrusible spears which are often basally knobbed and resemble a pin. The spear is inserted into the plant tissues and the eelworm feeds either from outside the root as an ectoparasite or the spear is used to aid entry of the worm into the plant tissues where it feeds as an endoparasite on the elaborated plant foods.

Eelworm Pests

The most important and harmful pests of agricultural crops are the sugar beet eelworm (*Heterodera schachtii*) ; the potato or golden nematode (*Heterodera rostochiensis*) ; the stem and bulb eelworm (*Ditylenchus dipsaci*) a pest of oats, clover, alfalfa and a number of other plants ; the root-lesion or meadow nematodes of the genus *Pratylenchus*, one of which is known to us as a destructive pest of tea and also the root-knot nematodes of the genus *Meloidogyne*.

The root knot eelworm

Infestation by the root-knot eelworm is easily recognised in the field from the characteristic galls or knots on roots of infested plants. The two green manure plants *Tephrosia vogelii* and dadap are highly susceptible to root-knot damage and so is seedling tea in nurseries. Until recently all members of the family *Heteroderidae* carried the generic name *Heterodera*. The root-knot forming species was known as *Heterodera marionii*, a name most of you are familiar with. In 1949, Chitwood (1) an American Nematologist, split up the genus into two genera. The cyst forming species, of which the potato eelworm and the golden eelworm are two members, retains the generic name *Heterodera* while the root-knot forming species revert to the fairly unpronounceable name of *Meloidogyne*. Our friend *Heterodera marionii* ceases to exist and we have a number of new species erected in its place. I have recently added to it with a new species from mature tea (2).

In my last Conference address (3) I sounded a note of warning on the continued use of root-knot susceptible green manures in mature tea areas. I had inferred, from the presence of root-knot damage in certain areas of mature tea, that a specialised race may evolve capable of attacking the major crop. I have now been able to prove that the mature tea eelworm is a distinct species, and not a specialised race evolved from the species which attacks *Tephrosia vogelii* and dadap. You may grow your Tephrosias and dadaps, if you can induce those plants to grow in the presence of the eelworm, without fear of setting up infestation in your mature tea.

The two known species of root knot eelworms of Ceylon tea plantations are *Meloidogyne javanica* (Treub, 1885) Chitwood 1949 of tea seedlings and certain other green manure plants (this specific name is subject to confirmation after more material can be examined), and *Meloidogyne brevicauda* Loos 1953, the pest capable of attacking mature tea.

In the case of the species which attacks tea seedlings we have the unusual feature of a plant which is highly susceptible to damage in the seedling stage but acquiring total immunity as the plant ages. No other crop is known to have a similar reaction. This unusual feature gives us the opportunity of using fairly clean material, for supplying fields, if the nurseries are disinfected by chemical means prior to the sowing of seed. I shall refer to this later in my address.

Meadow eelworm.

The meadow eelworm of tea has also changed part of its name. *Pratylenchus pratensis* is now known as *Pratylenchus coffeae*. We still have with us a relic of the old coffee days.

Meadow eelworm has, up to now, been reported from 48 estates situated in most of the Ceylon tea planting districts. I am confident that the distribution of the pest if far more widespread than records indicate. On a few estates the effects of the pest are causing anxiety.

The symptom of meadow eelworm attack is in the presence of fairly large patches of unthrifty tea which has a thin appearance due to a deficiency of maintenance foliage. Removal of such bushes often discloses an almost complete absence of the usual bunches of finer roots. The main root system is free of galling or malformation but if the bark is lightly scraped with a knife, from the root extremities upwards, dead brown areas or blotches may be observed. The presence of these dead areas together with the absence of finer roots on unthrifty tea is a suggestion of meadow eelworm attack. Peeling pieces of the bark or cortex from the junction between dying and healthy tissues and the examination of the undersurfaces of the peeled strips, under the low magnifications of a microscope, would reveal large numbers of the eelworm.

Control Measures

The problem of control of plant-parasitic eelworms and of our tea eelworm pests in particular divides itself into three general classifications :—

(1) Cultural practices. Crop rotation and the maintenance of high soil fertility.

(2) Chemical treatment.

(3) The selection and breeding of resistant or tolerant varieties of crop plants.

Cultural practices crop rotation.

This is not possible with our major crop which is a perennial plant but is possible with green manures, grown either as bush crops or low shade. If *Tephrosia* and dadap are so heavily infested as to cause death of the plants it is necessary to change to immune varieties such as *Crotalaria anagyroides* in place of *Tephrosia vogelii* and Albizzia or *Desmodium gyroides* in place of dadap. A period of a few years under the immune plants and Tephrosia and dadap may again be successfully planted.

The maintenance of high soil fertility.

Lindford *et al* (4) have shown that the decomposition of large amounts of organic matter in the soil was associated with reduction in numbers of root-knot galls on cowpeas grown as an indicator plant. Many years ago Dr. Eden (5) conducted a replicated experiment on St. Coombs in which plots had either no compost or compost added. The composted plots supported a fine stand of dadaps while the plots with no compost carried sickly plants, due to heavy root-knot eelworm damage. An estate in the Dimbula district used large amounts of compost, cattle bulk, etc., which were incorporated into a small area showing severe debilitation of tea due to meadow eelworm. That area, a year later, appeared healthy and in excellent condition in comparison with the untreated part of the field.

How does the maintenance of high soil fertility effect eelworm damage? Opinion on this subject is divided. Some workers consider that the incorporation of decaying matter into the soil increases conditions under which predatory forms of fungi, mites, insects and nematodes can thrive. Others consider that a healthy plant growing under fertile soil conditions can support large numbers of parasitic eelworms and still crop satisfactorily. There is much to be said for both opinions though the resulting benefit to the crop is the same in both cases. The crop yields satisfactorily.

I have often been asked, when I advocated the incorporation of large quantities of green matter to the soil, as a mulch or thatch, where the normal estate could find or grow the vast quantities needed. The answer is in your hands. The interplanting of green manures in tea will not alone supply the 15–20 tons of green stuff per acre required periodically to make thatching worthwhile. Is it preferable to expect 500 lbs. of tea per acre over say 500 acres, or 800–1000 lbs. per acre from three-fourths of that area ? The balance acreage may be used profitably to grow green material such as Guatemala grass etc., for thatching purposes. American farmers have answered the question themselves and many of them now grow sugar beets yielding higher crops over half the acreage of land they previously farmed.

Chemical control.

Almost without exception, for application over large areas chemicals toxic to eelworms have to be discarded due to high costs, injurious residues, toxicity to man and animals and toxicity to plants. Up to the present time two soil fumigants (Shell D–D and Dowfume N) and ethylene dibromide mixtures, are acceptable for large scale applications, though both are costly to apply, and toxic to living plants. They should only be applied in the absence of a crop and in soil which is of a suitable texture for effective fumigation. A single application over an acre, using 800 lbs. D–D gave a 50 per cent increase in yield and a 50 per cent kill of the potato eelworm as measured 4 weeks after injection of the fumigant. After a following potato crop, however, the eelworm population was as high, or higher, than on the untreated plots (6). 800 lbs. of D–D alone would cost over Rs. 900 and to that should be added the cost of application. Even then the 100 per cent kill we require for a permanent crop cannot be achieved.

On small areas such as nurseries fumigation can, however, be a worthwhile and routine practice. I have already mentioned that tea acquires immunity with age to the commoner species of root-knot eelworm which has often caused almost total failure of nurseries. Application rates of 400 lbs. D–D per acre on properly prepared beds which have been freed of stones and undecomposed organic matter should give almost total extermination of plant parasitic eelworms together with cutworm, wireworm, white grub and other injurious soil pests. The plants are able to establish themselves and pass the stage of root-knot susceptibility before the small proportion of eelworm larvae, which survive fumigation, can build up to numbers capable of injuring the crop.

For efficient fumigation the soil in the nursery should be moderately loose and free from clods, lumps and undecomposed organic matter such as the roots of the preceding crop. If cattle bulk or compost is to be incorporated into the soil it should be done before the fumigant is applied. The soil should be fairly moist and not too wet or dry. Mark the area lengthwise and crosswise with strings set 15 inches apart to form small squares like a chess board. Starting along one side make injections along the points where the strings intersect and on alternate lines midway between the intersection points. This method would stagger the injections in a manner giving the greatest amount of diffusion of the fumigant. The Shell Company of Ceylon loan injector guns for this purpose. The gun should be set to deliver, with 25 strokes of the plunger, one quarter of a pint of fumigant which is the application rate of 400 lbs. per acre.. The injector tube should be set to introduce the fumigant 6 inches below the ground level and the plunger actuated once only at each injection point. Immediately after application the nursery should be lightly wet and lightly rolled to compress the soil surface, and then covered with old jute hessian or sacking which has been previously wetted, in order to hold moisture and to avoid evaporation at the surface of the soil. The area should remain undisturbed for a week or ten days to allow the fumigant to diffuse completely through the soil after which the soil should be dug up to release the fumigant. Treated areas should not be planted for at least 3 weeks after fumigation. A half acre nursery which is about the size of average nurseries on estates should cost less than Rs. 250/- for fumigation.

Selection & Breeding of Resistant & Tolerant Varieties of Crop Plants

Considerable research has and is being directed throughout the world in the selection and breeding of resistant varieties of plants to eelworm injury. Plants considered to be resistant may either be totally immune to attack or eelworms may enter the root but are unable to complete their life cycle in the plant. Tolerance constitutes the presence of the eelworm in the plant without noticeable effects of deterioration or loss in crop.

Investigations into resistance have met with some success both in Ceylon and other countries and it seems probable that the use of resistant varieties of plants is the most productive and economical method for the control of eelworm pests in the

future. The problem does, however, bristle with difficulties as resistance or tolerance to one species of eelworm does not necessarily infer immunity to infestation to other closely related species.

American nematologists have developed as alfalfa variety known as Nemestan which is resistant to the bulb and stem nematode and the oat variety S.225, raised by Prof. E. T. Jones, has been grown free of the stem eelworm by Dr. T. Goodey of the Rothamsted Experimental Station on a farm in East Hertfordshire, where susceptible oats commonly fail. Two varieties of bean are known to be resistant to the root knot nematode. Shalil peach rootstock is resistant to the root-knot species *Meloidogyne incognita* but not to *M. javanica* while the peach variety S.37 is relatively resistant to both species of that eelworm. Paradox, a cross between the English and black walnuts is proving a good resistant rootstock against the rootlesion or meadow eelworm in America.

From 1939 onwards Dr. C. H. Gadd made a large number of selections of tea bushes, apparently resistant to the meadow eelworm, in areas of heavy infestation on a Dimbula estate. Clones were established by vegetative propagation in nurseries and then in multiplication plots. The progeny from those mother bushes are now well established and in production. Unfortunately the mother or clonal bushes no longer exist as with a change of management valuable records and the means of location of those plants have been lost. We are now unable to work back to those original selections, made 12–13 years ago, to find out how those clonal bushes have continued to react with time and in the presence of continuous heavy eelworm populations. Progeny from a few of the selections show obvious signs of deterioration while others grown in close proximity to them continue to flourish and crop satisfactorily. Those plants will supply valuable material for future investigation.

Other estates, too, are co-operating in the selection of high yielders growing in the midst of severely debilitated tea. I hope that the pooling of such material will eventually supply the needs of those eelworm infested areas which eventually become due for replanting. The policy is a long term one as much work has still to be done before material can safely be passed as suitable for large scale replanting. We have still to ascertain if resistance or tolerance is of short term duration and whether growing wholesale one type of material can be negatived by the evolution of a specialized race of the pest capable of breaking down that resistance or tolerance. Up to recent years we had heard a lot on specilization but it is now becoming increasingly apparent that what was considered a specialized race may in reality be a closely related but distinct species. If that is the case our chance of success is very encouraging.

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