

A DESTRUCTIVE ROOT DISEASE OF TEA
CAUSED BY THE NEMATODE
ANGUILLULINA PRATENSIS.

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The object of this paper is to draw attention to a destructive root disease occurring on a few estates in Ceylon. The cause has recently been ascertained to be the eelworm *Anguillulina pratensis* (de Man) Goffart, for which the common name 'Meadow nematode' appears to have been adopted in temperate countries. That name perhaps will not appear very appropriate to tea planters in Ceylon, nor to coffee planters in the Dutch East Indies and South India. It seems preferable, however, to maintain the same common name here than to adopt another which might be equally inappropriate in the U.S.A., England, or elsewhere.

The leaves of affected tea bushes are lighter in colour than is normal, so diseased areas appear somewhat 'yellow.' The bushes are generally unthrifty, deficient in foliage and have a 'thin' appearance (Fig. 1). Below ground, there is a marked absence of feeding roots and the main woody roots are usually dead for some distance from the tip. The main roots are not distorted in any way, nor are such feeding roots as remain swollen or knotted as when attacked by the root-knot nematode, *Heterodera marioni*.

There is no external symptom by which the presence of eelworms in the tea bush can definitely be recognised. It must not be assumed that all bushes with yellowish leaf are attacked by this eelworm, even if the bushes are partially defoliated. Similar above ground symptoms occur from other causes, e.g., when bushes are infested with red spider or mites. When, however, there is a marked deficiency of feeding roots accompanying these above-ground symptoms, the presence of eelworms should be suspected. Nematologists are somewhat sceptical that plant diseases caused by nematodes can be recognised with much accuracy by pathological symptoms alone, and consider an examination with the microscope to be the only safe way to determine the presence of eelworms ⁽¹⁹⁾.

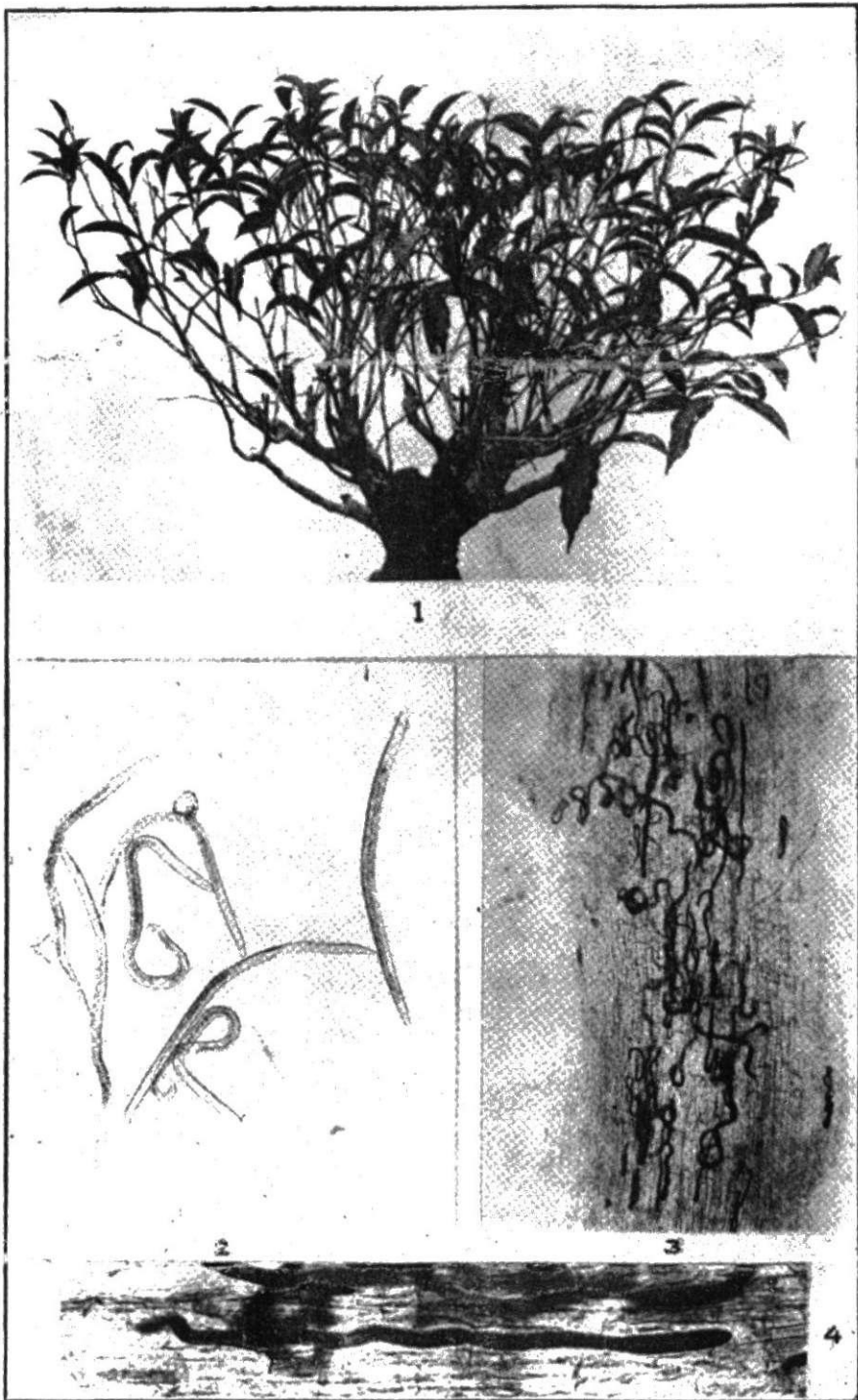


Fig. 1. A typical bush infected by *A. pratensis*.

Fig. 2. Eelworms isolated from the tissue ($\times 80$).

Fig. 3. Eelworms within a root of *Tephrosia vogelii* ($\times 52$).

Fig. 4. An eelworm lying within the tissue of *T. vogelii*. Note the constriction near the middle of the body where it passes through a cell wall ($\times 180$).

The eelworms may be found in lesions in the small feeding roots, but a better place to find them is at the junction of healthy and dead cortical tissue of the main roots. These junctions are not usually easily determined by superficial examination, but if the bark is lightly scraped away with a knife, living tissue will be seen to be white or pink whereas dead tissue is brown. The dead tissues are usually at the extremities of the main roots, though sometimes islands of dead tissue are found in the thicker parts of roots. The junction between the living and dead tissue is usually sharply marked, the boundary being quite distinct.

When excavating suspected bushes, care should be taken to dig out the main roots to their extremities. It is unnecessary to send the whole bush to the Institute's laboratories for examination; a few roots are sufficient if the specimens bear living and dead tissues. The specimens should be wrapped in hessian and the parcel secured firmly. They should arrive at the laboratory in as fresh condition as possible to facilitate examination.

Longitudinal sections, when stained in cotton blue in Amman's mounting fluid show the eelworms in abundance at the junction of the living and dead tissues of the root cortex. Few can be found in the dead tissues away from the junction, and none in the live tissues beyond. Evidently the eelworms move slowly but continually through the tissues, killing the cells as they go. The damage they do undoubtedly aids the entry of fungi which hasten decay.

Sometimes the worms may be seen coiled within individual cells but more frequently they lie parallel to the woody axis with their heads directed towards the living tissue. The bodies are often seen to be constricted where they pass through cell walls (Fig. 4). No distinct cavities or passages have been seen, such as are illustrated by Bally and Reydon⁽¹⁾ for Coffee. Movement is through the cells and not between them. Entry is achieved by the worm boring a hole through the cell wall by means of a small but powerful stylet or spear like organ situated in the mouth. More than one eelworm often moves along the same track.

The eelworms also tend to move inwards towards the woody cylinder but they never enter the wood. For this reason they are most easily found by stripping off the cortex at the junction of the living and dead tissues when they may be seen with a low power microscope as short hyaline threads lying on the inner side of the cortex which adjoins the wood. Examined thus, the worms exhibit very little movement and they might well be mistaken as dead. From this position they are easily washed off with a small quantity of water when they can be more closely examined, free from root

tissue (Fig. 2). In such a collection adults, larvae and eggs will be found. Even in water the worms remain very sluggish, all movement being very slow when compared with that of many species found in the soil.

Although the eelworms appear sluggish when examined as above, the following experiments show that they can move when advantage is to be obtained thereby. A piece of cortex from the root of an infected bush bearing numerous eelworms was placed in a damp chamber with the inner side of the cortex upwards. A recently germinated tea seed with a root about 2 inches long was placed so that the tip of the root rested on the cortex near the location of the eelworms. Forty-eight hours afterwards the root was killed, stained and cleared in the manner described by Godfrey ⁽⁴⁾ and examined. Numerous eelworms were to be seen in the root cortex a short distance behind the tip. They lay curled within the cells or extended parallel with the axis.

The experiment was repeated using the roots of recently germinated seed of *Tephrosia vogelii* and *Crotalaria anagyroides* instead of tea. The roots of both plants were invaded by numerous eelworms, adults as well as larvae. The *Tephrosia* root was more heavily invaded and a photograph of part of it is reproduced in Figure 3. As in tea, entry was made a short distance behind the root tip, in the piliferous layer. These observations agree with those of Linford ⁽⁷⁾ who observed *A. pratensis* to group round the roots of plants avoiding the elongating zone and collecting chiefly in the piliferous layer.

Specimens were sent to Dr. T. Goodey of the Institute of Agricultural Parasitology who kindly identified the eelworms as *Anguillulina pratensis* (de Man) Goffart.

Anguillulina pratensis was first described by de Man in 1884 as a rare species living free in the soil under the name *Tylenchus pratensis*, and by Kühn in 1889 as *T. gulosus*. *T. coffeae* was described by Zimmerman ⁽¹⁶⁾ as a parasite of coffee roots in the Dutch East Indies in 1898; *T. penetrans*, by Cobb ⁽²⁾ from potatoes, etc., from U.S.A. in 1917; *Aphelenchus neglectus*, by Rensch from wheat, etc. in Germany in 1924; and *T. brachyurus* by Godfrey ⁽⁴⁾ from pineapple in Hawaii. Goodey ⁽⁵⁾ gives the above names as synonyms of *Anguillulina pratensis*.

A. pratensis has been fully and accurately described by Cobb ⁽²⁾, Goodey ⁽⁵⁾ and others; it will be sufficient here to state that the adult eelworms measure from 0.45 mm. to 0.7 mm. long by 0.02 mm. to 0.03 mm. wide; the eggs are about 0.06 mm. long by 0.02 mm. wide; and the first stage larvae are about 0.22 mm. long by 0.01 mm. wide.

Very little is known of the details of its life-history. Hastings⁽⁶⁾ estimates that the life-cycle is completed in 54 to 65 days. In agreement with other observers the writer has seen only one egg at a time in the uterus, and solitary eggs only have been observed in tea cortex. Steiner⁽¹⁰⁾ reports that as many as five eggs have been seen deposited tandem, separated by only a few plant cells. Although eggs are usually laid within the plant tissues, parasitism within roots is not essential for reproduction since gravid females and larvae may be found in soil around roots.⁽¹¹⁾ Mayne's⁽¹²⁾ studies on the hatching of the eggs of this worm showed that they do not hatch when kept in a moist chamber without the presence of liquid water. On the addition of water they were found to hatch quite rapidly.

Goodey⁽⁵⁾ gives a list of over 50 known host plants which include *Calopogonium mucunoides*, *Centrosema pubescens*, *Cinnamomum camphora* (camphor), *Coffea arabica*, *C. excelsa* and *C. robusta*, *Dendrocalamus asper* (Bamboo), *Dioscorea* sp. (Yams), *Emilia sonchifolia* (a weed), *Gigantochloa apus* (Bamboo), *Saccharum officinarum* (Sugar cane), *Vigna sinensis* (Cow pea), *Zea mays* (Maize) and various unspecified grasses.

Since the above mentioned list was published, *A. pratensis* has been recorded on several other plants. It is evident that *A. pratensis* infests a large number of widely different plants, and it should not occasion surprise to find it on many others, including almost any of our crop plants, not yet recorded. This eelworm does not cause severe injury to all plants on which it has been recorded. Cobb⁽²⁾ states that when this eelworm was found in cotton roots the plants were not suspected of being infested, and that no definite evidence exists that it seriously injures the camphor tree. In general, the effects of attack by *A. pratensis* are to restrict growth and to cause yellowing of the leaves — features which, as Steiner⁽¹³⁾ comments, are most often attributed to causes other than nematode infestations.

As yet this eelworm has not been found in Ceylon on any other plant but tea, but it seems highly improbable that it has confined its attention solely to that plant. A careful search will probably reveal its presence on other plants.* No explanation can be offered as to how it got into our tea fields and from where it came.

Though the occurrence of *A. pratensis* may cause little or no damage to some plants, its effect on tea is of serious economic importance as can be ascertained from Table I, in which are given the annual and pruning cycle yields of two fields on different estates.

* Since the above was written specimens of ginger roots from the Department of Agriculture have been found to be infested by *A. pratensis*.

TABLE I

Yields of two fields infested with *Anguillulina pratensis*.

| Field A. 9 acres 3-year cycle | | Field B. 53 acres 2-year cycle | |
|-------------------------------------|-----------------------|--------------------------------------|-----------------------|
| Year | Yield lb. per acre | Season | Yield lb. per acre |
| 1929 | 838 | 1928/29 | 515 |
| 1930 | 462 | 1929/30 | 792 |
| 1931 | 778 | 1930/31 | 618 |
| 1932 | 807 | 1931/32 | 719 |
| 1933 | 278 | 1932/33 | 301 |
| 1934 | 947 | 1933/34 | 767 |
| 1935 | 378 | 1934/35 | 295 |
| 1936 | 195 | 1935/36 | 565 |
| 1937 | 412 | 1936/37 | 268 |
| 1938 | 380 | 1937/38 | 499 |

The yields of both fields show a marked and increasing fall in successive cycles beginning with that starting about 1933. That the effect of attack began to be reflected in the yields of both fields at about the same time is to be regarded as coincidence rather than an indication of when infection occurred. To affect the yield of a whole field markedly, the eelworm must be widely distributed through the field at that time, so infection must have occurred some years before 1933.

Reference has already been made to the invasion by eelworms of the main woody roots of the tea bush and the consequent death of the cortical tissue invaded. Such injuries alone would not materially affect a tea bush judging from what is known about other root disease of tea. *Poria hypolateritia*, for instance, attacks the woody

roots, and when treating *Poria* patches it is common to find tea bushes with the greater part of the root system dead and decayed, while the above-ground portion of the bush gives no indication that anything is amiss.

The main attack of *A. pratensis* is on the feeding roots of tea, and in that respect conforms with what is known concerning it on other plants. The eelworms invade the feeding roots, through the epidermal cells and force their way into and through the cortex. A discoloration of tissues follows shortly after invasion and the cells die. The nematodes then abandon the dead tissues by migrating into the soil or by moving further into the healthy tissues of thicker roots. Those that return to the soil seek other new, young roots which they similarly attack. Thus, there is a flow of nematodes from the killed roots, through the soil to young healthy feeding roots. With the passage of time that stream steadily increases and greater numbers of feeding roots are killed. The feeding efficiency of the root system is diminished and the attacked bush begins to show above-ground symptoms, fails to grow normally, and becomes unthrifty. The position ultimately arrives when the feeding roots are destroyed as fast as they are formed, and the bush becomes moribund.

Attacked coffee plants usually have a 'beard'⁽⁸⁾ or 'wig'⁽⁹⁾ of thick turgid adventitious roots at the collar occupying the top inch or two of soil. This suggests that the eelworms do not like the surface layer of coffee soils, possibly because that region is liable to dry out in the absence of rain. Similar tufts of roots at the collars of attacked tea bushes are not usual but they have occasionally been found on lateral roots partially exposed on the soil surface. An examination of such roots and adhering soil disclosed the presence of *A. pratensis* there.

Although the eelworm lives, feeds and breeds mainly in the roots it also occurs in the soil in large numbers wherever infected bushes occur. Soil examinations in S. India⁽¹⁰⁾ showed that the greatest concentration of eelworms occurred at a depth of about 9 inches, while below 12 inches the numbers decreased. There was also a great seasonal fluctuation of the population. With the onset of monsoon rains an extremely rapid increase of nematodes of both parasitic and saprophytic types occurred⁽¹¹⁾. In dry soil, few could usually be found unless the soil was moistened a short time before examination, when both larvae and adults were obtained.

Mayne⁽¹²⁾ suggests that there is an adult resting stage in which these parasitic eelworms survive desiccation in soil. Godfrey⁽¹³⁾ is of the opinion, based on his observations on pineapple soils, that *A. pratensis* is more resistant to desiccation than is *Heterodera marioni*.

Hastings ⁽⁶⁾, however, states that *A. pratensis* is very sensitive to desiccation as no living worms were obtained from infected oat roots which had become dry.

The chief danger of spread of the eelworm lies in soil movement. Labourers working on infected areas, particularly during wet weather, are liable to carry the eelworm in soil, adhering to the foot or agricultural implements, beyond the existing limits of infection. A short cut through infected tea is a similar source of danger. During forking the soil tends to move downhill; for this reason and because the sub-soil drainage is in the same direction the general trend of movement of the eelworm is downhill. During heavy rains soil is washed into the drains and may be carried some distance before it sediments in a silt-pit or at the bottom of a bunded or reverse sloped drain. When the silt-pit or drain is cleaned out, the silt is thrown into the tea, and if parasitic worms are present in the silt, as they often are, that tea is liable to become infected. Even when the eelworm-containing drainage water reaches a stream all danger is not eliminated if the stream is liable to flood. Cases have been observed where tea bushes have become infected by silt deposited by a stream after flooding. The transport of roots from an infected area is another source of danger unless precautions are taken to prevent the loss of some of them and of soil adhering to them on the way.

The importance of preventing further spread cannot be too strongly emphasised. Bally and Reydon ⁽¹⁾ concerning the spread of this parasite in the coffee lands of the Dutch East Indies write: "In the earlier stages of the planting of Robusta coffee it was only a matter of smallish 'Nematode patches' on various estates. Now the position is different. Not only are there large areas infected by nematodes, but in some cases whole estates."

When once soil becomes infected, it is a very difficult matter to free it again from this eelworm. The most obvious way is to destroy the eelworms in the soil by means of chemicals or steam. Such methods have proved of great value in treating the soils of glass houses, but no satisfactory method has been found of sterilising large areas of field soils to a depth such as is necessary in tea fields. Nematodes as a class are very resistant to chemicals, and although it is possible to reduce materially the eelworm population of field soils by chemical methods, when the area is clear of all vegetation, it has not proved possible to eradicate completely all the eelworms. A reduction in the population of parasitic eelworms may be of great value to agriculturists cultivating a crop plant which will occupy the ground for a short period, as the harvest may be reaped before the parasitic eelworms again become sufficiently numerous to damage the plants seriously. With a permanent crop

like tea, nothing short of complete eradication of the parasitic eelworms can prove entirely satisfactory. If relatively few parasites remain after treatment, they will in the course of time increase in number to such an extent that serious damage will be done to the replanted tea.

Another way of killing the eelworms in the soil is by starvation. This necessitates keeping the soil free from all plants on whose roots the parasites can live. With annual crops this is achieved mainly by the practice of crop rotation. After a susceptible crop has been grown, non-susceptible crops are planted during the next 3 or 4 years. During this interval the parasitic eelworm population is reduced to such an extent that it becomes possible to grow the susceptible plant again with successful results. Rarely, however, are the parasites completely eradicated by rotation.

To starve *A. pratensis* out of infected tea soils the land must be kept clear of all susceptible plants for some years. Although it is possible to supply a list of plants known to be attacked by this eelworm, all plants whose names are not on that list are not necessarily immune or resistant. As already stated very little is known of the host plants of this parasite in Ceylon, so it will be necessary to examine periodically the roots of weeds and other plants which may grow on a starved area, to ensure that none is harbouring the pest. Bare fallow would increase the risk of soil movement by erosion and probably affect adversely the fertility of the soil. How long the areas must be kept clear of susceptible plants is unknown. Bally and Raydon ⁽¹¹⁾ report that ground from which coffee had been uprooted and planted with cocoa was not free from this eelworm after 4 years. Pfaltzer ⁽¹²⁾ reviewing the methods of control of *A. pratensis* in coffee soils in the Dutch East Indies, however, considers that starving the parasite out of the soils will give the best results.

Fluiter ⁽⁹⁾ reports that in coffee plantations infested with *A. pratensis* many of the plants are killed but a good percentage seem to remain healthy even though their roots are invaded by the parasite. By selecting these apparently resistant plants and growing them on, even in infested soil, they retain their resistance. No resistant tea plants have yet been found but the possibility of their occurrence must not be overlooked.

In the writer's opinion little can be achieved in infected tea areas by a more liberal manurial policy or by greater attention to cultural methods which promote root growth. Such treatment may mask the detrimental effect of the eelworm for a time, but it is highly improbable that infected bushes can be kept in an economic productive condition by such means.

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