RESISTANCE AND TOLERANCE OF TEA TO NEMATODES

M. T. Hutchinson

The name *eelworm* is probably more descriptive of the small animals that feed on tea roots than is the name *nematode*, which means *threadworm*. However, as long as specialists working in this field are called *nematologists*, it may be less confusing to have the animals called *nematodes*.

The problem is how to prevent damage by these nematodes to tea plants. Tea, to one just arrived on the island, is an unusual crop. Chemical treatments which are often relied upon for control of nematodes attacking annual or short-term perennial crops growing on flat lands, are not as well suited to tea. On the other hand, the rather large quantities of organic matter that are available to tea planters from loppings of shade trees and Guatemala grass, as well as composted manures, which probably assist in nematode control, are not to be had in most parts of the world. Resistant and tolerant varieties of plants are, however, one measure commonly used in all areas of the world. In the case of tea, this approach is by far the most important for nematode control.

At this point, a brief history of the discovery of the Meadow Nematode in Ceylon, and of the selection of tea bushes for resistance to this pest may be of interest.

The Meadow Nematode was undoubtedly present in Ceylon before the wide-spread planting of tea after the destruction of the coffee industry by the rust fungus, *Hemileia vastatrix*, about 1870. In a report on a visit to Mooloya Estate made in 1935, Dr Gadd was informed by the Superintendent that three fields had been affected with Witches Broom from the time of opening in tea, and that it had always been difficult to establish tea there (Gadd, 1935). These fields had previously been in coffee (Sparling, 1939).

This Witches Broom condition of tea, which later proved to be caused mainly by the Meadow Nematode, can be traced back at least to 1925, when a Mr Park described a complex of symptoms under this name in the Year Book of the Ceylon Department of Agriculture (Gadd, 1927). Yellowing of the leaves, spurs with tufts of leaves at the terminals, and small shoots with short internodes and dwarfed leaves, were among the symptoms mentioned. Ten years of experience with this baffling condition led Dr Gadd to discard temporary Witches Broom symptoms associated with a need for pruning, drought, and the presence of the root disease caused by the fungus *Poria hypolateritia*. He stated "There remains, however, a type of bush which exhibits what may be termed the Witches Broom symptoms persistently. They do not respond to cultivation or manuring, and when they are uprooted the roots are seen to be healthy except that there is a deficiency of feeding roots—(the bushes) appear to die very slowly but they are unproductive." (Gadd, 1935).

It was in January, 1939, while examining roots of Witches Broom bushes from Field 1A at Drayton Estate that Dr Gadd first saw the Meadow Nematodes (Gadd, 1939). Mistaking them for the larvae of the Root-knot Nematode, and surprised that there was no swelling of the roots typical of the injury produced by this nematode, he sent specimens to Dr T. Goodey, then the leading British authority on plant parasitic nematodes. But even before receiving a positive diagnosis of *Anguillulina pratensis* (now *Pratylenchus coffeae*) from Dr Goodey (Gadd, 1939b), Dr Gadd had noted that "odd dark-leafed bushes in this field appeared normally healthy." (Gadd, 1939a).

During the following months, various suggestions were made concerning the propagation of such possibly resistant bushes for supplying infested areas. By January, 1940, selection had apparently begun at Drayton and, after further testing for resistance, yield, and quality, in co-operation with the T.R.I., extensive propagation of a few clones was carried out for use on that estate (Crofts-Bolster, 1947).

In 1950, the Institute began selecting bushes from a large number of estates for testing against the Meadow Nematode (Visser, 1959a). Since that time, cuttings of 78 of these clones have been rooted and from 7 to 10 of each are growing in an infested area at St Coombs. In 1955, 39 of these clones and an additional 30 clones were planted in cement pots (Loos, 1955), and in 1956, were inoculated with Meadow Nematodes. Another complete series was grown in the pots, but not inoculated with nematodes, so as to compare the growth of infested and uninfested plants. Careful evaluation of both field and pot tests has shown that at least 17 of these clones are apparently resistant or tolerant to the Meadow Nematode, and are also good yielders (Visser, 1959a). Eight of them (DK 8, DK 16, DT 1, DT 95, GL 48, K 150, TRI 2142, TRI 2145)[1], also have above average quality (Keegel, 1959). Thus, the selection programme has so far produced about 7 per cent of high quality clones, and has laid an excellent basis upon which work can continue

Resistance and tolerance

It may be appropriate at this point to define these often-used words: by *resistant* we mean plants that are unsuitable for the normal development or reproduction of the nematodes; by *tolerant* we mean plants in which the nematodes multiply actively, but which are not noticeably harmed by this. *Immunity*, where the plant is in no way a host for a particular pest, is rarely encountered in selection programmes. More work will be needed before we can say whether or not certain tea clones are actually immune to Meadow Nematodes.

There are several ways in which a tea plant could be resistant to the Meadow Nematode. These can best be shown by tracing the progressive steps by which such nematodes become established in plant roots. Before entry into roots, Meadow Nematodes explore the root surface for suitable entry sites. A chemical sense seems to be involved here. On locating a suitable site, the nematode proceeds to pierce the root epidermis with its hollow stylet, which very much resembles a hypodermic needle and which is directly connected with the nematode's throat or oesophagus. Because of slack in the oesophagus, the stylet can be extended or retracted from the mouth opening. The task of piercing the root surface is somewhat comparable to piercing a thick sheet of leather with an awl, and may explain why the Meadow Nematodes prefer to enter the less mature parts of the root just above the growing tip (Gadd and Loos, 1946).

Once the root is pierced, the nematode may feed on the liquid contents of the cells of the cortical layer, which it sucks up through the stylet by means of a pump located in the oesophagus. Then, by repeated thrusting of the stylet in the same area, the root epidermis is sufficiently weakened to enable the nematode to batter the root with its head, with some prospect of thrusting through into the opening produced. Once this is accomplished, the nematode moves easily into the cortex, where the cells offer virtually no resistance to further movement within the root. The fact that entry thus requires a considerable expenditure of energy may explain

[1] DK – Diyanilakele, DT – Drayton, GL – Glassaugh, K. – Kirkoswald.

why starved Meadow Nematodes cannot enter tea roots after 9 weeks, although they will live for more than 18 weeks (Gadd, 1942).

From this description, it is evident that resistance to entry could depend upon lack of chemical attractiveness or actual repellency or toxicity of the root surface to the nematode. The same could be true of the contents of the cells of the cortex. Or the root epidermis could be unusually tough and difficult to penetrate. Such resistance, it should be noted, implies only that *most* of the Meadow Nematodes will be prevented from entering, but that since individual nematodes differ from one another just as individual human beings do, a very few may be capable of entering. If none are capable of entering, then the plant is truly immune, at least until a type of nematode that can enter is produced.

Once having entered, the nematodes may encounter other types of resistance. The cell contents may not be such as to nourish the nematodes, and this may result in their leaving the root. The cell contents may be inhibitory or even toxic to them. This could result in young nematodes not completing the three moults required for maturity, or in the adult nematodes not being as fertile as usual. At this point, only a few of the twenty or so eggs normally produced may be deposited and these eggs may fail to hatch.

There are thus three major ways in which a tea plant can be resistant to the Meadow Nematode. It may resist entry of the nematodes. It may resist feeding and growth of the nematodes. It may resist the production and deposition of a normal number of fertile eggs. A single plant species, such as *Crotalaria anagyroides*, may show more than one type of resistance. According to Gadd and Loos (1941), although many female Meadow Nematodes entered the roots of this plant, most of them left again without depositing eggs. Very few of the eggs that were deposited actually hatched, and the larvae that did hatch matured much more slowly than normal.

As regards tolerance, there are also several possibilities, though not as many as for resistance. First, the roots may not be injured by the feeding of the nematodes. In the process of feeding, secretions from the glands that empty into the oesophagus of the nematode are pumped into the cells before the cell contents are sucked out. In the case of the meadow nematode, these secretions are usually toxic to the plant cells, the death of which produces the discoloured areas known as *lesions*; another name for the Meadow Nematode is the Root-lesion Nematode. Second, tolerance could depend on the rapid repair of mechanical damage to the plant. The Meadow Nematodes wander around inside the root and they pass through cell walls as well as around them. In its extreme form, this activity can result in a shredding of the insides of the root. Third, if the roots are definitely injured by the glandular secretions or movements of the nematodes, or both, the plant may be so vigorous as to put out roots faster than the nematodes can attack them. This sort of tolerance may cease to have a practical effect when the available soil volume is completely filled with roots, and when sufficient time has elapsed for the nematodes to become established in all parts of the root system.

It will thus be evident that tolerance is theoretically less desirable than resistance, since it does not check the nematode population, which can go on building up inside the roots, largely protected from natural enemies.

Further testing of resistant and tolerant clones

We have two major projects in mind for the further testing of clones.

The first is to determine what types of resistance are available in clones so far selected. This will be done in the laboratory, by growing rooted cuttings in soil in small glass dishes and inoculating them with Meadow Nematodes collected at St Coombs and other estates. The progress of the nematodes will be carefully observed and comparisons will be made with clone TRI 2024, which is very susceptible to nematode attack. This work can then serve as a basis for testing additional clones selected by estates or by T.R.I. staff as being apparently resistant. Such an initial test could result in the discarding of clones that were not worth further testing in the field, and thereby speed up the selection programme. Visser (1959) summarizes the results of research to determine the resistance to Meadow Nematode of the cover crops and shade trees used on tea estates.

The second project involves testing the clones already selected, against as many as possible of the Meadow Nematode populations that they are likely to encounter upon widespread distribution.

Considerable experience with plant resistance to nematodes has shown that a selection resistant to one nematode population can be quite susceptible to another of the same species. This problem can be important even with annuals such as potatoes (Jones, 1957), or short-term perennials such as alfalfa (Goplen *et al*, 1959). With a crop such as tea, that may not be replanted again for another fifty years or more, there are fewer opportunities for correcting mistakes.

This idea of testing clones against several populations of Meadow Nematodes is not a new one, since attempts were made at four estates (Dambatenne, Diyanilakele, Kirimetiya and Mooloya) beginning in 1955 to establish resistant and tolerant clones (Loos, 1956). By 1956, 167 clones were under test (Webster, 1957), but for various reasons these trials have not been fully successful. However, the clones remaining in these plantings will be evaluated as a first step in testing their resistance to various populations of Meadow Nematodes. Later, a few of the most resistant clones will be tested in pots against many different populations, and a long-range experiment to determine the value of tolerance under field conditions will be established at St Coombs.

That some tea clones may be resistant to one population of Meadow Nematode and susceptible to others is shown by the different results obtained with some clones when they were tested in the field plot at St Coombs, and in the cement pots. The nematode populations used for inoculating the pots came from Eildon Hall and Diyanilakele estates, since in 1956 sufficient nematodes could not easily be found at St Coombs. The field plots, on the other hand, had a population presumably native to St Coombs. Clone TRI 2135, selected at St Coombs, proved to be practically immune in the field plot. However, it eventually proved to be quite susceptible in the pot test (Visser, 1959a), and is therefore not known at present to be resistant except to the St Coombs population. By contrast, DT 95, selected for apparent resistance at Drayton Estate, has proved to be highly resistant in both the field plot and pot tests. Likewise, a preliminary survey indicates that it grows well in infested areas at Mooloya Estate and supports very few Meadow Nematodes. This clone is therefore probably resistant to at least five populations of Meadow Nematode.

After learning from the laboratory tests what types of resistance are available, crossing of plants having various types of resistance could make the progeny much more resistant to present and future nematode populations.

Resistance and tolerance to other nematodes

So far, I have dealt only with the Meadow Nematode, *Pratylenchus coffeae*, which is the principal nematode pest of Ceylon tea. As far as we know, there is only the one species here, but in the world as a whole, there are at least fifteen different species of Meadow Nematodes all of which can be damaging to crops. In Ceylon tea, there are also the Root-knot Nematodes of the genus *Meloidogyne* to contend with. One of these, *M. javanica*, attacks only young tea, while *M. brevicauda* also attacks mature tea (Loos, 1953). *M. javanica* is widely distributed throughout the tea-growing areas of the island, whereas *M. brevicauda* is known to be present on only three estates within nine miles of each other. Thus, neither nematode is at present a serious threat to the industry. However, times may change. *M. javanica* may adapt to mature tea, and *M. brevicauda* may spread to different parts of the island. It would therefore be desirable to test clones against both of these Root-knot Nematodes. Also, it is desirable to prevent spread not only of *M. brevicauda*, but likewise of *M. javanica* and *Pratylenchus coffeae* by not moving soil or plants from one estate to another.

At this point, we must prepare planters for what may prove to be other nematode pests of tea. There appear to be at least five additional nematodes that are found even more frequently associated with tea roots than either the Meadow or the Root-knot Nematodes. These belong to groups whose common names are *pin* and *spiral* nematodes. In contrast to the Meadow and Root knot Nematodes, they feed from the outside and rarely enter the roots. Three of these five were noted by Gadd (1946, 1947), but no work has been done to determine whether or not they will multiply on tea and, if so, whether or not they are harmful. If one or more should prove harmful to tea, it would be desirable to test clones for resistance or tolerance to them. Another need would then arise, namely, to determine whether or not Guatemala grass and marigolds are as resistant to these nematodes as they are to the Meadow and Root-knot Nematodes. In these plants, used for reconditioning tea soils, tolerance may not be enough, particularly if the nematode populations are built up to a point where the tea subsequently planted is injured.

The role of surveys

It has been supposed that the low-country of Ceylon is not particularly troubled with Meadow Nematode. According to our recent survey of a total of 14 estates in the Balangoda, Ratnapura, Rakwana, Morawak Korale, Kalutara, and Galle Districts, this supposition is correct. Should further survey of these and similar districts confirm the virtual absence of Meadow Nematodes, or rather their apparent inability to multiply in these areas, it will probably not be necessary to consider resistance or tolerance to this pest when selecting clones for these areas. On the other hand, *M. javanica* and the Pin and Spiral Nematodes appear to be just as widely distributed there as in the high country.

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