OBSERVATIONS ON THE PREVALENCE AND CONTROL OF PARASITIC EELWORMS IN TEA

T. Visser

1. Introduction

The problem of eelworms in tea nurseries and tea plantations of Ceylon is not a new one, as its discovery dates back to the inception of the Institute. In 1928 Stuart Light (24) drew attention to the destructive powers of the root-knot eelworm in tea nurseries. This eelworm, then called *Heterodera radicicola*, later named *H. marioni* and now known under the name *Meloidogyne javanica*, was also found responsible (7) for the poor growth and dying of dadaps, *Erythrina leucosperma*. In 1937 (8) it was discovered that the degeneration of *Tephrosia vogelii* was also due to attack by this eelworm. With respect to its spread it can be said that it can be found in many tea soils.

Mature tea was not found to be very attractive to this particular species, but Loos (17) ascertained in 1951 that a member of the same family, *viz. M. brevicauda*, was able to do severe damage to tea. So far, however, this eelworm is known to be present in an acute form on a few estates only.

The position is different with regard to the meadow eelworm which was discovered by Gadd in 1939 (10, 11) and found to attack both young and mature tea. This eelworm was at that time known under the name *Anguillulina pratensis* and is now called *Pratylenchus coffea*[1]. Its spread in tea appears to be much more extensive than that of *M. brevicauda*[2], for Loos reported in 1951 (17) that the presence of meadow eelworm had been ascertained on 50 estates, mostly at up-country elevations. At present meadow eelworm is known to be prevalent on many more estates.

It is usually noted in fields planted before 1900; the build up of the parasitic eelworm population to harmful levels in a monoculture of such long standing can be no matter for surprise. Its effect may have been aggravated by the gradual weakening of the bush with increasing age as well as unsatisfactory bush and soil management in the past. The preponderance of eelworm infestation at up-country elevations may also be partly explained by the fact that the tea in many estates was preceded by coffee. The latter crop is known to be susceptible to the same eelworm as tea (*P. coffea*).

Our information as regards its occurrence in the low- and mid-country is limited to a few estates only. A comprehensive survey may reveal a different situation, though possibly the infestation may be really less due to different conditions of soil and climate and because the tea is on the whole considerably younger.

---

[1] *Identification by*: LOOS, C.A.; *Proc. Helm. Soc. Washington* 20/2, 1953-83-91.

[2] *Identification by*: SHER, S.A. *and* M. W. ALLEN; *Un. Cal. Zool.* 57, 1953:441-470.

2. Effect on yield

As stated above, meadow eelworm has been found to be present on a large number of estates, though this does not mean that it can be labelled a pest on all these estates. According to present day information meadow eelworm occurs as a pest in an acute form in certain fields on a dozen estates or so only, while other estates where meadow eelworm is also present do not seem to suffer (as yet).

The general pattern of meadow eelworm infestation in mature tea is similar to that observed in other crops. It starts off in a certain field or fields as small patches of bushes or single infected bushes here and there. The patches gradually expand resulting in the general infestation of large areas.

The visual symptoms of infestation are not specific. Severe infestation initially results in the tea bush, often the weaker ones, becoming dormant, usually during drought periods and/or in the latter part of the pruning cycle. This is often followed or accompanied by yellowing of the leaves and defoliation in part or whole in the later stages. Subsequent pruning of such a bush leads usually to its death or to such poor recovery that the bush can be considered useless from an economical point of view. This process, though slow where the whole field is concerned, may be fairly rapid with respect to the individual bush. The low yield of a heavily infested field at a given time is largely due to the large number of vacancies which have occurred over the years, the majority of the remaining bushes appearing to yield normally.

In 1939 Gadd (11) gave an example demonstrating the severity of this pest in terms of loss of crop. In table 1 we have presented some additional yield data of fields known to be infested in comparison with those of fields lightly or not infested, from estates situated in different districts.

The general picture presented by the data given in this table is that the annual yields of comparable fields started to diverge at some time in the past and progressively more so with the years. That is to say, at some stage the yield of the eelworm infested field commenced to decrease as compared with a non-infested field, which was otherwise comparable in treatment, age, site, etc.

On estate I, infestation in an acute form dates back from 194?, on estate II from 1931, while on estates III, IV and V the pest became acute only fairly recently. It is also worthy of note that in some infested fields the downward trend appears to have been checked, undoubtedly due to improved soil and bush management. Nevertheless, the loss in crop is still real, as the yield of the non-infested fields increased in the meanwhile. The loss amounted to about 250 lb. tea/acre/year in all instances.

Where *e.g.* on estates I and II the yields of the so-called non-infested fields remained more or less constant over the last 10 to 15 years, it may be suspected that in these fields too the infestation has been building up, but that its effect has been masked by the introduction of better agricultural practices.

TABLE 1.—*The effect of spreading meadow eelworm (Pratylenchus coffeae) infestation over the course of years on the yield per acre (lb. made tea) on differently situated estates*

I. Mooloya. Elevation: 5,000–5,800 ft.

Yield of period	N. Inf. 24 ac.	Inf. 52 ac.	Loss of crop	N. Inf. 16½ ac. 1896*	Inf. 32 ac. 1899*	Loss of crop
1933—1942	650	630	3%	700	650	7%
1943—1947	840	570	32%	850	700	17%
1948—1952	800	560	30%	830	530	38%
1953—1957	780	390	50%	880	510	42%
Avg./acre since 1943	800	510	37% (290 lb.)	850	580	32% (270 lb.)

II. Rutland. Elevation: 3,300–3,600 ft.

Yield of period	N. Inf. 64 ac. 1888*	Inf. 38 ac. 1891*	Loss of crop
1924/25 — 1930/31	690	950	— 37%
1931/32 — 1937/38	750	490	+ 35%
1938/39 — 1944/45	680	160	+ 76%
1945/46 — 1951/52	660	250	+ 62%
1952/53 — 1957/58	760	410	+ 46%
Avg./acre since 1924	710	450	37% (260 lb.)

III. Ellamulle. Elevation: 4,000 ft.

Yield of period	N. Inf. 32 ac. 1900*	Inf. 27 ac. 1900*	Loss of crop
1945 — 1951	550	540	2%
1952 — 1954	750	560	28%
1955 — 1957	920	610	24%
Avg./acre since 1952	840	580	31% (260 lb.)

IV. Dambatenne. 4,600–5,800 ft. **V. Wootton.** 4,100–4,400 ft.

Yield of period	IV. N. Inf. 31 ac. 1894*	IV. Inf. 34 ac. 1894*	IV. Loss of crop	V. N. Inf. 15 ac. 1895*	V. Inf. 43 ac. 1890*	V. Loss of crop
1945—1951	760	740	3%	630	550	13%
1952—1954	1000	680	32%	830	720	13%
1955—1957	900	680	24%	1180	810	31%
Avg./acre since 1952	950	680	29% (270 lb.)	1000	770	23% (230 lb.)

N.B.—Loss of crop is expressed in percentages of yield from not infested fields; N. Inf. = not or lightly infested; Inf. = infested; ac. = acres; *approximate year of planting.

The figures given illustrate that it may take a long time before the infestation manifests itself as a pest, but once it does the yields drop very markedly mainly due to the loss of bushes.

3. The effect of organic matter on eelworms

With respect to the application of organic matter, it would seem that it may have a direct effect on the incidence of eelworms, apart from its beneficial effect on the soil and the plant.

Lindford *et al* (16) ascertained that the incorporation of large amounts of green material (of the order of 50 tons/acre) significantly reduced the number of *H. marioni* galls on roots of indicator cowpeas. Similarly Oostenbrink (20) found in field experiments that the application of stable manure (10 tons/acre) markedly reduced the *Pratylenchus* and *Meloidogyne* populations both in the soil and in the roots of agricultural crops grown on the treated soil. Likewise Van Der Laan (25) in pot experiments with potatoes ascertained that the addition of stable manure or compost suppressed the development of the potato eelworm in the roots.

With respect to the effect of manure on eelworm in tea soils a preliminary trial was laid out on an area fairly heavily infested with meadow eelworm. This area was divided into 2-acre blocks, respectively (*a*) kept fallow, (*b*) fallow, treated with a single application of pig manure (20 tons/acre) and (*c*) planted with Guatemala grass. From subsequent monthly sampling on the degree of infestation it appeared that the *Pratylenchus* population gradually decreased in all treatments. The number of eelworms per 100 g. soil (6 samples/time) had become almost nil after 8 months in the grass soil and after 13 and 14 months in the fallow and manured soil respectively.

Thus it would appear that the planting of Guatemala grass had been more effective than fallow, while the application of pig manure had no additional effect. The latter is more or less in accordance with findings of Oostenbrink (20), who observed that stable manure had no effect on the incidence of the potato root eelworm in the *absence* of the host plant. He assumes that the suppressing influence of manure on parasitic eelworms in the *presence* of host plants is rather due to a greater resistence of the plants than to an effect of the decomposition products, because the non-parasitic forms were less affected than the parasitic ones. Also Van Der Laan (25) concluded that plants treated with organic materials such as manure and compost develop some resistance to nematodes, perhaps due to physiological changes in the plant itself.

A further trial was carried out to determine the influence of the incorporation of organic matter on the eelworm population. In this case loppings of marigolds, *Tephrosia* and dadaps were mixed with soil infested with both meadow and root-knot eelworms (1 lb. loppings in 40 lb. soil). The mixture was put into cement pots, there being 6 pots for each treatment; 12 pots containing infested soil only, of which 6 were fumigated, serving as controls. All pots were regularly watered and kept free of weeds.

Three assessments on the eelworm population were made during the course of the experiment, the results of which have been presented in table 2.

TABLE 2.—*The effect of the incorporation of organic matter on the eelworm population of fallow soil; expressed in number of eelworms per 600g soil (6 samples of 100 g.)*

Treatments	26 Nov., 1957*		3 Feb., 1958		13 Sept., 1958		
	Pr.	Mel.	Pr.	Mel.	Pr.	Mel.	Oth.
Control: not fumigated ...	102	683	81	20	16	4	1541
Control: fumigated ...	107	669	1	2	1	1	2239
With marigold loppings ...	97	87	33	4	4	0	6739
With dadap loppings ...	73	71	17	7	2	0	13737
With *Tephrosia* loppings ...	66	95	20	7	3	3	14736

*Date experiment started; Pr. = Pratylenchus; Mel. = Meloidogyne; Oth. = Other nematodes.

The table shows that the *Pratylenchus* and *Meloidogyne* populations had notably decreased in all treatments about 2 months after the experiments started. The eelworm content of the fumigated soil was almost nil, while the non-fumigated control still contained a considerable number of meadow eelworms as compared with the pots with loppings. About 7 months later a similar trend existed, but the number of parasitic eelworms had further decreased.

It is worthy of note that the number of non-parasitic eelworms in the pots with the loppings was very much greater (statistically significant) than in the pots without. Lindford *et al* (16) suggest that the increased population of total nematodes, brought about by the decomposition of organic material, assists the building up of a micro flora and fauna destructive to nematodes. Soil organisms, *e.g.* certain fungi (6) have in fact been found to be predatory on eelworms.

It can be concluded that the incorporation of organic matter to some extent depresses the development of the parasitic eelworm population in the host plant whether directly or indirectly. It is therefore good agricultural practice to provide tea fields with organic matter in the form of loppings, thatch, compost or manure both from a point of view of soil improvement and on account of its adverse effect on harmful eelworms.

4. Cover crop and shade trees with respect to eelworm susceptibility.

The effect of cover crops, green manures and shade trees with respect to eelworm infestation may be twofold. On the one hand, they may assist in diminishing eelworm infestation, in so far as they are eelworm resistant and serve as providers of organic material. On the other hand, their influence may be unfavourable in cases where they are susceptible to attack by the same eelworms which are detrimental to the main crop. The relation between the susceptibility of the preceding crop and the degree of infestation of the crop grown thereafter has been amply demonstrated by Oostenbrink (21). He found that if the first crop had been severely attacked by eelworm, the crop grown in succession would be infested likewise, or *vice versa*. For instance, the subsequent growth of roses and apple seedlings, which plants are susceptible to *Pratylenchus*, greatly depended on the susceptibility of the crops which were grown in the two preceding years.

It is possible that likewise in tea, the population levels of *Pratylenchus* and *Meloidogyne* are to some extent affected by the degree of susceptibility of plants previously cultivated or intergrown with tea. Accordingly we have listed below a number of plant species the susceptibility of which to meadow and root-knot eelworms is approximately known.

Grasses and weeds.—Of the former, Guatemala grass (*Tripsacum laxum*) is the most important as it is widely used for soil-reconditioning. Following earlier observations (28) it was recently (26) confirmed that this grass is practically immune to both meadow and root-knot eelworm, thus explaining the depressing effect of its cultivation on these eelworms in the soil. From inoculation trials done by Gadd (15) it would appear that Mana grass (*Cymbopogon confertiflorus*), paspalum grass (*P. dilatatum*) and carpet grass (*Axonopus compressus*) are also resistant to meadow eelworm.

Among the weeds, *Polygonum nepalense* (15) is probably resistant, while *Oxalis corymbosis* is slightly susceptible to meadow eelworm. The latter was found to be highly susceptible to *Meloidogyne arenaria* (26).

Cover crops.—*Stylosanthes gracillis* and *Drymaria cordata* appeared to be largely resistant to both meadow and root-knot eelworm; *Mimosa invisa* is moderately susceptible to the latter but not to the former (27). *Desmodium gyroides* is fairly resistant to *P. coffea* (12, 14), but not to *M. incognita* (5)

Marigold varieties of the species *Tagetes erecta* and *T. patula* deserve special mention. Both the investigations of Oostenbrink *et al* (22) and Meyneke *et al* (19) and experiments carried out at the Institute (26) proved the effectiveness of marigolds in suppressing the *Pratylenchus* and *Meloidogyne* populations in the soil. Their nematocidal action was found to equal that of fumigants; as such, marigold cultivation can be effectively adopted as a measure of eelworm control.

The large semi-wild varieties (probably varieties of *T. erecta*) found in Ceylon grow vigorously on fallow tea soil, but are less successful as a cover crop in mature tea (after pruning), growing only moderately under such conditions.

Bush crops.—Previous (10, 12, 13, 14) and recent findings (28, 29) indicated that *Crotalaria anagyroides* and *C. usuramoensis* are not attacked by either meadow or root-knot eelworm (*M. javanica*). The latter species as well as *C. juncea* have been found susceptible to *M. incognita* var. *acrita*; *C. striata* and *C. retusa* appear resistant (23), *C. spectabilis* used as a pre-crop has been shown to reduce the severity of root-knot eelworm in tobacco grown subsequently (18). Apparently, eelworm resistance is a feature of many species of this genus[1] and thus their cultivation is useful in infested areas.

Numerous investigations (8, 9, 26, 27) have confirmed that *Tephrosia vogellii* is susceptible to meadow eelworm and even more so to root-knot eelworm and is therefore not recommended to be planted in tea. It is possible that other species of *Tephrosia*, like *T. eriosemoides* and *T. toxicaria* could be used, for Gadd (15) ascertained from inoculation trials that these species were not invaded by meadow eelworm. *Sesbania cinerescens* shows some susceptibility to meadow and root-knot eelworm (27) though it does not appear to be adversely affected, as this species grew well in infested soil.

Shade trees.—*Gliricidia maculata*, *Tecoma stans* and *Grevillea robusta* when mature appear to be resistant to meadow and root-knot eelworm (27). The last mentioned was found to be susceptible to root-knot eelworm in the seedling stage only (10). *Albizzia moluccana*, *Acacia decurrens* and *Calpurnia aurea* showed a slight susceptibility to meadow eelworm but were not or only slightly infested by root-knot eelworms (27). *Erythrina leucosperma* (7, 9, 27) and *Albizzia sumatrana* (15, 27) must be listed as only slightly susceptible to meadow eelworm, but very susceptible to root-knot eelworm. However, whereas Albizzias appear to be tolerant to root-knot eelworm attack, dadap is often found to be adversely affected and to degenerate as a result.

The picture which emerges from the above—partly based on preliminary observations—is that a fair number of plants grown in tea are not or only negligibly susceptible to *Pratylenchus coffea*. Even those plants, which have been listed to be more or less susceptible to this eelworm have usually been found to harbour markedly less eelworms than tea. Whereas roots of the former category may contain 20–70 worms per 10g, roots of tea growing in similar soil may carry hundreds or even thousands of eelworms per sample. Apparently, the great majority of cover plants and shade trees are far less congenial hosts for *Pratylenchus* than tea.

With respect to *Meloidogyne* infestation, a number of plants appear to be highly susceptible to this genus. In most instances, but possibly not in all, as determination is fairly difficult, the species involved is, unless otherwise mentioned, *M. javanica*.

Mature tea has not been found to be susceptible to *Meloidogyne* species except in rare instances (*M. brevicauda*). It appears to be susceptible (to *M. javanica* and *M. incognita*) at a young stage only; it may be inferred from observations that a well grown tea plant of 6—7 months old is already immune. The same possibly holds true for a number of other plants (*e.g. Grevillea*). It is advisable, therefore, to take precautions against infestation in the nursery stage.

Finally, it can be said that as far as mature tea is concerned, the use of root-knot eelworm-susceptible cover crops and/or trees is not likely to be harmful to tea. However, one may encounter difficulties, *e.g.* in the case of dadaps, in establishing such plants in infested soil. In such instances it may be wiser to plant resistant plant species.

5. The effect of soil fumigation.

1. **In mature tea.**—Soil fumigation is an obvious means of control of eelworms. Of a number of fumigants like Shell DD, Nematox 100 and Nemagon, tried out,

[1] A chemical compound responsible for this resistance has been identified by investigators in the Netherlands (oral information.)

only the last mentioned appeared to be suited for mature tea as the two former were found to be strongly phytotoxic. Nemagon applied in the field at the recommended rate per acre, of 10 gallons diluted to about 40 gallons by adding kerosene, was found to have no adverse effect on mature tea bushes (27). When applied at double this rate (20 gallons + 20 gallons kerosene) some of the older leaves became scorched, but otherwise no damage occurred.

With regard to its effectiveness on eelworms, it appeared from a preliminary trial with Nemagon on infested tea at St. Coombs, that following fumigation at rates of 5, 10, 20, 30 and 40 gallons per acre moderate re-infestation of the soil occurred about 2, 7, 9, 10 and 11 months later, respectively.

Larger scale field trials were carried out on blocks of ½ to 1 acre of infested tea in its 2nd or 3rd year after pruning on Eildon Hall, Wootton, Kirimetiya and Dambatenne estates, respectively. The Nemagon-kerosene mixture (1 : 3) was injected into the soil (6" deep) with an injector gun on 4 sides of the bush at 10 ml. per side. The fumigation was carried out in February-March, 1957. Its effect was assessed by monthly examination of 25 soil samples (100 g each) from each area respectively; the last sampling was taken in July, 1958.

It appeared that fumigation at Dambatenne estate had not been very effective, as the number of parasitic eelworms had been reduced to only about half, following fumigation. On the other 3 estates the meadow eelworm population was virtually nil for a limited time after fumigation. The general trend of re-infestation by meadow eelworm after fumigation on these estates is shown in figure 1. This figure presents "the degree of infestation with time" as expressed in the number of soil samples per 25 examined which were found to be free of meadow eelworm at different times.

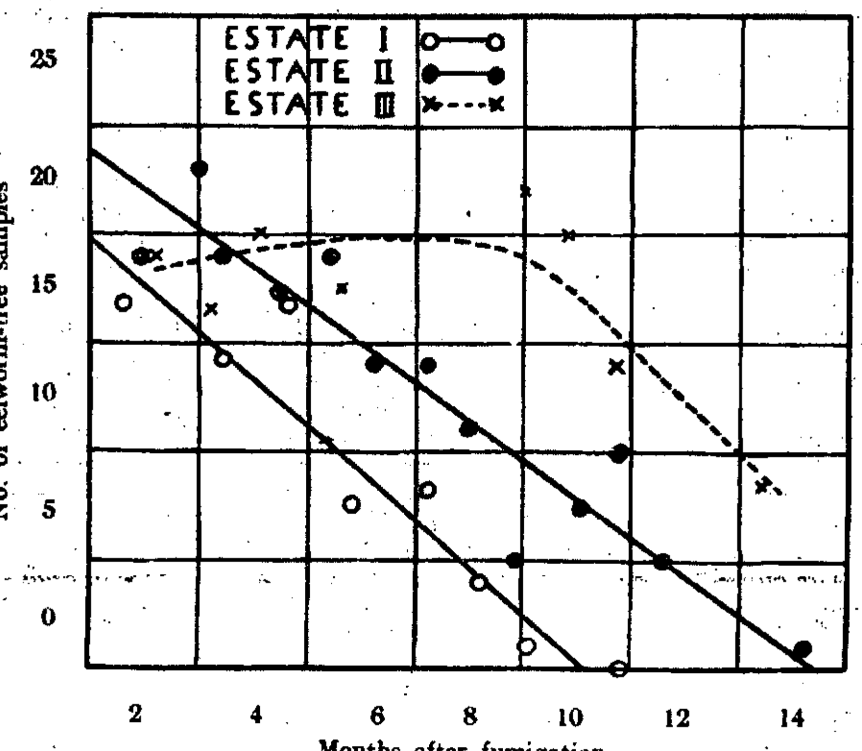

Figure 1. The re-occurrence of meadow eelworm infestation after fumigation with Nemagon as expressed in number of eelworm-free samples per 25 examined.

The relation between re-infestation and time on two estates (Eildon Hall-I and Wootton-II) is a linear one (the regression is highly significant). That is to say, the number of samples found to be free of eelworms decreases linearly with time. After about 9 months on estate I and 13 months on estate II *all* soil samples (25/time) contained a small number of meadow eelworms. On estate III (Kirimetiya) the picture was somewhat different as up to about 9 months after fumigation the majority of samples were still free of eelworms. Even after 13 months not all samples showed infestation and those which did, contained very few eelworms only.

The greater effectiveness of fumigation on the last estate as compared with the two other estates, is possibly due to differences in the organic matter content of the soil, fumigation being more effective if the organic matter content is lower. It is quite possible that this has been the case as the soil conditions at the one estate are poorer than those at the others.

On one estate separate yield records of the fumigated plot (¼ acre) and the rest of the field (24 acres) were kept by the Superintendent. These data are presented in table 3.

TABLE 3.—*Yield of a fumigated plot in comparison with that of an untreated area*

	Yield in lb. fresh leaf per acre	
	Not treated	Fumigated
March, July, August	218	200 (91.7)
September, October, November ...	238	300 (126.1)
December, 1957; January, 1958; February ...	366	516 (141.0)
March, April, May	393	486 (123.7)
June, July, August, September	323	430 (133.1)
Total for 1 year after pruning: September, 1957–August, 1958	1487	1886 (126.8)

N.B.—Figures within parenthesis denote the yields of the fumigated plot as percentages of those of the untreated area.

Table 3 shows that the yield over the first three months following fumigation (in early March; pruning in April) was somewhat less than that of the untreated area. Thereafter, the treated plot yielded considerably more per acre than the rest of the field. Notwithstanding that the areas compared are very different in acreage and that analysis of the figures is not possible, the observed yield trend indicates that fumigation favourably affected subsequent yield.

The field trials show that fumigation at the recommended rate keeps the eelworms in check for not much longer than one year, or even for a shorter interval, depending on the soil and weather conditions at the time of and immediately after fumigation. The favourable effect on yield would probably last for a longer period. It is clear, however, that fumigation would have to be repeated at least once every pruning cycle in order to prevent undue re-infestation. Under the circumstances, therefore, fumigation of mature tea cannot be envisaged as a means of control in practice, as the costs—in the order of Rs. 800/- per acre—are prohibitive.

II. In nurseries.—Extensive experiments on the effect of soil fumigation on *Meloidogyne* species (*M. incognita*) in seedling nurseries have been carried out by the Tocklai Experimental Station with methyl bromide (1, 2) and Shell DD (2, 3, 4, 5) at rates of 200 to 400 lb. per acre and with Nemagon (5) at 2 and 4 gallons per acre. The results appeared to be variable; in many instances the original population had been reduced to 10–15% of the original level but sometimes the reduction amounted to only 35–50% one month after fumigation. In general, fumigation did not prevent the majority of seedlings (sown 4–6 weeks following fumigation) becoming infested by root-knot eelworm. However, infestation was often less and growth better, though not markedly so, than that of the controls, when assessed 6–8 months after soil fumigation.

The results obtained with fumigation in Ceylon seem to be on the whole more favourable than those obtained at Tocklai. It appeared from one of the field trials (26), that young tea plants planted in a fumigated area (2 weeks after treatment with Shell DD at 10 gallons/acre) carried, 7 months later, about twice as many leaves as control plants growing in a non-fumigated plot (57 versus 29 leaves per plant); the meadow eelworm population of the former plot was only 7% of that of the former area. One year after fumigation the differences in growth were even more marked, but the soil of the fumigated area carried at the time as many meadow eelworms as that of the non-fumigated plot (71 versus 73/sample).

An experiment carried out with Nemagon at rates of 3, 4 and 5 gallons (made up to 40 gallons by adding kerosene) in an infested nursery carrying young tea plants gave the following results (average number of eelworms from 5 samples) presented in table 4.

TABLE 4.—*Effect of soil-fumigation with Nemagon at different rates on eelworm populations.* (*5 ml. every sq. ft.*)

Treatments	7 months after fumigation		9 months after fumigation	
	Pr.	Mel.	Pr.	Mel.
Control	20	0	67	0
Nemagon at 3 gall./acre ...	2	2	11	0
,, ,, 4 ,, ,, ...	4	2	10	10
,, ,, 5 ,, ,, ...	0	0	1	10

Pr. = *Pratylenchus*; *Mel.* = *Meloidogyne.*

The figures show that while fumigation with 5 gallons Nemagon per acre had kept both meadow (Pr.) and root-knot (Mel.) eelworm down for 7 months, the lower concentrations were less effective. After 9 months re-infestation became evident in all treatments, but the number of meadow eelworms was still much less than that of the control though more root-knot eelworms were present. These results more or less tally with those of the field experiments described in the previous paragraph—*viz.* that re-infestation of the soil at a moderate level may be found within 7 months after fumigation, if the soil *carries tea throughout.* Under such circumstances soil re-infestation is bound to occur as Nemagon is of doubtful effectiveness as regards the killing of eelworms *living in* the tea roots. Fumigation is not fully effective in the presence of host plants.

Indeed, fumigation never kills all eelworms, so that it is advisable to leave the soil fallow for some time, resulting in the weakening or death of the surviving eelworms by starvation.

With respect to the length of such a period, Gadd (14) ascertained from experiments, in which meadow eelworms were kept in humid sand, that only 20% had survived after 18 weeks. However, at the end of 9 weeks, although 45% of the eelworms had survived starvation, none of the survivors were able to enter the roots of *Tephrosia vogellii* seedlings.

In our fumigation trials the percentage of surviving eelworms in a fallow soil has been found to be only a fraction of the above survival figure, usually varying between 1 and 5% one to two months after fumigation. Accordingly if one allows a minimum of 10 to 14 weeks after fumigation before cuttings or young plants are planted, it is unlikely that after the lapse of such a period any virile parasitic eelworms would remain, especially if soils with a low initial eelworm population were used. The latter condition is actually an essential one which can be adhered to by using "virgin" soils only.

A better alternative to the fumigation of nurseries which appears to be promising, is the cultivation of marigolds, preferably together with that of Guatemala grass. By doing so, eelworm control and reconditioning are achieved simultaneously.

Summary and conclusions

From the information available it would seem that meadow eelworm infestation is fairly widespread, presumably more so at up-country than at lower elevations. However, the pest appears to be latent in many instances; in those cases where infestation has become acute, losses in crop can be estimated at 250 lb. tea/acre/year. The fact that tea is a monoculture of long standing and a number of other features, *e.g.* age, unsatisfactory bush and soil management, etc. are likely to have contributed to the aggravation of the eelworm problem.

There is reliable experimental evidence that the incorporation of organic matter, in the form of loppings, compost and manure will assist in reducing the effects of eelworm infestation. Presumably, the influence of organic matter is primarily indirect, *viz.* by increasing the resistance of the plant and improving soil conditions, while a direct depressing effect on the eelworm population must also not be ruled out.

A fair number of cover crops, green manures and shade trees associated with the cultivation of tea appeared to be more or less immune to meadow eelworm and not very susceptible to root-knot eelworm. The susceptibility of these plants to the latter is probably no danger to tea over one year old as by then the crop appears completely resistant. The planting of *Tephrosia vogellii* is not recommended because of its susceptibility to both eelworms. The cultivation of marigolds shows promise as an effective means of eelworm control in nurseries or in fallow tea soil.

Soil fumigation in mature tea can depress eelworm infestation considerably but for a limited time only. Its effect on yield was found to be favourable. The fumigation of tea fields is not practical on account of its prohibitive cost. Fumigation of nurseries is advisable in cases where no regular replacement of the worn-out soil by virgin and/or eelworm-free soil is possible. It is recommended that the soil be left fallow for a period of 10 to 14 weeks after fumigation in order to weaken any surviving eelworms.

Acknowledgments

My thanks are due to Mr. B. N. Webster, the former Pathologist, who initiated the fumigation experiments and Messrs. M. K. Vythilingam and P. A. John for their invaluable assistance in carrying out the experiments and assessment of the soil samples. I would also like to thank the Superintendents of those estates who assisted in carrying out fumigation trials and for sending information on yields of eelworm infested tea fields.

References

1. Ann. Rep. Tocklai Exp. Stat. Myc. Branch, 1953: 117–122.
2. „ „ „ „ „ Myc. Branch, 1954: 120–122.
3. „ „ „ „ „ Myc. Section, 1955: 101–104.
4. „ „ „ „ „ Ent. Section, 1956: 114–116.
5. „ „ „ „ „ Ent. Branch, 1957: 129–130.
6. Capstick, C. K., Twinn, D. C. and Waid, J. S.: Predation of natural populations of free-living nematodes by fungi. Nematologica **2**, (3), 1957: 193–201
7. Gadd, C. H.: A nematode root disease of dadaps. Tea Quart. **1**, 1928: 39–44
8. Gadd, C. H.: Root-knot of *Tephrosia*. Tea Quart. **10**, 1937: 183–187.
9. Gadd, C. H.: Rep. Mycol; Ann. Rep. Tea Res. Inst. Ceylon 1938: 30–32.
10. Gadd, C. H.: Rep. Mycol; Ann. Rep. Tea Res. Inst. Ceylon 1939: 33–35.
11. Gadd, C. H.: A destructive root disease of tea caused by the nematode *Anguillulina pratensis* (De Man) Goffart. Tea Quart. **12**, 1939: 131–139.
12. Gadd, C. H. and Loos, C. A.: Host specialization of *Anguillulina pratensis* (De Man). I. Attractiveness to roots. Ann. Appl. Biol. **28**, 1941: 372–381.
13. Gadd, C. H. and Loos, C. A.: Host specialization of *Anguillulina pratensis* (De Man). II. Behaviour of the parasite within the roots. Ann. Appl. Biol. **28**, 1941: 382–388.
14. Gadd, C. H.: Rep. Mycol; Ann. Rep. Tea Res. Inst. Ceylon, 1941: 27–33.
15. Gadd, C. H.: Rep. Mycol; Ann. Rep. Tea Res. Inst. Ceylon, 1944: 23–25.
16. Linford, M. B., Francis Jap, Fr. and Oliveria, J. M.: Reduction of soil population of the root-knot nematode during decomposition of organic matter. Soil Science, **45**, 1938: 127–140.
17. Loos, C. A.: Pathological problems. Tea Quart. **22**, 1951: 27–30.
18. Macbeth, C. A. and Taylor, A. L.: Immune and resistant cover crops valuable in root-knot infested peach orchards. Proc. Am. Soc. Hort. Sc. **45**, 1944: 15–16.
19. Meyneke, C. A. R. and Oostenbrink, M.: *Tagetes* for the control of nematode infestations (Dutch with English summary) Meded. Dir. Tuinb. **21**, 1958: 283–290.
20. Oostenbrink, M.: The significance of free-living root nematodes for Agriculture and Horticulture. (Dutch with English summary). Verslagen & Meded. Plantenz. Dienst. **124**, 1954: 196–233.
21. Oostenbrink, M.: The influence of different crops on the reproduction of and damage by *Pratylenchus pratensis* and *Pratylenchus penetrans* (Vermes, Nematoda), with a record of an unidentified sickness in woody perennials. (Dutch with English summary) Tijdsch. Plantenz. **62**, 1956: 189–203.
22. Oostenbrink, M., Kuiper, K. and S'Jacob, J. J.: *Tagetes* als Feind-pflanzen von *Pratylenchus* arten. Nematologica **II**, Suppl. 1957: 424–433.
23. Peacock, F. C.: Studies on root-knot nematodes of the genus *Meloidogyne* in the Gold Coast. I. Comparative development on susceptible and resistant host species. Nematologica **3**, 1957: 76–84.
24. Stuart Light, S.: Pests of tea nurseries; a warning. Tea Quart. **1**, 1928: 19–22.
25. Van Der Laan, P. A.: The influence of organic manuring on the development of the potato root eelworm, *Heterodera rostochiensis*. Nematologica **I**, 1956: 112–125.

26. VISSER, T. and VYTHILINGAM, M. K.: The effect of marigolds and some other crops on the *Pratylenchus* and *Meloidogyne* populations in tea soil. Tea Quart. **30,** 1959: 30–38.

27. VISSER, T.: Rep. Act. Nematologist; Ann. Rep. Tea Res. Inst. Ceylon, 1958: 67-73.

28. WEBSTER, B. N. and PORTSMOUTH, G. B.: Guatemala grass in relation to Poria and meadow eelworm. Tea Quart. **28,** 1957: 54–55.