THE EFFECT OF MARIGOLDS AND SOME OTHER CROPS ON THE *PRATYLENCHUS* AND *MELOIDOGYNE* POPULATIONS IN TEA SOIL

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1. Introduction

Recent investigations carried out by OOSTENBRINK *et al* (6) and MEYNEKE *et al* (5) showed that several varieties of *Tagetes erecta* and *T. patula* reduced the population of certain root-infesting nematode species, such as *Pratylenchus*, *Tylenchorchynchus*, *Paratylenchus* and *Rotylenchus*, in the soil, while *Meloidogyne* species are probably also suppressed.

With regard to the effect of the cultivation of Tagetes on the population density of *Pratylenchus* species, a reduction of the order of 90% was normally obtained in comparison with other crops. The roots of the different marigold species and varieties were found to contain fewer *Pratylenchus* eelworms than any other crop tested. The number of eelworms found in the former was about 1% of the average of that for roots of a great number of agricultural crops.

It was also found in one of the experiments, that the eelworm population of a soil cultivated with marigolds was even less than that of a fallow soil fumigated with DD. The effect of marigolds on eelworm appears to be due to the nematocidal action of the growing plant roots, probably due to the exudation of *alpha*-terthienyl. This compound, which is known to be produced by marigolds, has been shown by UHLENBROEK and BYLOO,[1] to have a strong nematocidal action.

The experiments of OOSTENBRINK and his co-workers gave also abundant proof that the cultivation of marigolds, either as a "pre-crop" or as a cover has considerable value for the control of eelworm infestation in crops.

With a view to these promising results it was thought worthwhile to investigate whether *Tagetes* species would have a similar effect on eelworms when grown in Ceylon tea soils. In order to have some standard of comparison we included *Tephrosia vogelii*, *Crotalaria usaramoensis* and *Cr. anagyroides* in our trials, while also the influence of Guatemala grass (*Tripsacum laxum*) was also studied.

2. Experimental results

The effect of the cultivation of marigolds and other plants on meadow eelworm (*Pratylenchus coffeae*[2]) and root-knot eelworm (*Meloidogyne javanica*) was investigated in a number of small scale trials and field experiments carried out at St. Coombs and some other estates.

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[1] *Paper sect. VII, Int. Plant. Prot. Congr. Hamburg* (1957).

[2] *Identification after: Sher, S.A. and M. W. Allen Un. Cal. Publ. Zool.* 57, 1953: 441–470.

With regard to marigolds, we tried out a dwarf form, *T. patula nana flora* (I), which grows approximately to a height of 7–10" and two varieties obtained locally, which grew to a height of about 4–5', determined as *T. patula nana L.* cult. *Nana plena* "Harmony" (II) and *T. erecta L.* cult. *Plena* "Colorado Sunshine" (III). Variety II is characterised by orange flowers having a fringe of dark brown petals; variety III by its light yellow flowers. The former variety is more vigorous, branches more freely, seems to be less susceptible to environmental conditions (rain) and diseases, and has a somewhat darker foliage than the latter variety. It was also found that this variety withstood lopping better than the yellow flowered variety; both grow to a height of 4-5 ft.

Soil sampling was done as follows: from each treatment a number (2–6) of composite samples (each a mixture of 3–7 separate samples) was taken; 100 g of each was used for eelworm assessment according to the Baehrmann technique. The eelworm infestation of the roots was determined by subjecting 10 g samples to a fine spray of water for 7 days according to the method in use at the Nematology section of the Plant Protection Service (P.D.) at Wageningen, Netherlands.

2.1. Small scale trials

I. The first experiment was carried out in pots and consisted of the following treatments: (*a*) fallow, (*b*) *Tephrosia vogelii*, (*c*) *Tagetes patula*—I, (*d*) *T. erecta*—III.

Each treatment was replicated 6 times, the soil of the pots was moderately infested with meadow eelworm and heavily with root-knot eelworm.

TABLE 1.—*Eelworm population per 100 g soil (avg. of 6 samples) and per 10 g roots (avg. of 2 samples) in pot experiment*

1	2		3		4			5		
	In soil							In roots		
Treatments	26-11-57*		8-3-58		19-5-58			19-5-58		
	Pr	Mel	Pr	Mel	Pr	Mel	Oth	Pr	Mel	Oth
Fallow	10	36	13	1	35	30	910	—	—	—
Tephrosia	28	157	14	56	10	60	1350	1630	5620	14630
T. patula (I)	15	115	15	2	5	0	580	0	0	120
T. erecta (III)	14	80	14	4	0	5	325	0	40	140

*Date experiment started. Pr = *Pratylenchus coffeae*; Mel = *Meloidogyne javanica*; Oth = other eelworms.

It can be deduced from the results presented in table 1 (columns 2, 3, 4) that both species of marigolds notably reduced the *Meloidogyne* and *Pratylenchus* populations when compared with *Tephrosia*. The marigolds were even more effective than keeping the soil fallow. This is also apparent in respect of other eelworms which numbered highest in the pots with *Tephrosia* and lowest in the pots with marigolds. The root tests (column 5) showed even more striking differences, *Tephrosia* roots containing a formidable number of both parasitic and other eelworms. The marigold roots, on the other hand, did not harbour any meadow eelworms, while only a small number of root-knot eelworms were isolated from roots of the *T. erecta* variety. The number of other eelworms was less than 1% of that found in *Tephrosia* roots.

II. The second experiment was done on small plots of 3 × 3 ft. and consisted of the following treatments (in duplicate): (*a*) fallow, (*b*) young tea plants, (*c*) *Tephrosia vogelii*, (*d*) *Crotalaria usaramoensis*, (*e*) *Tagetes patula* (II), *T. erecta* (III). The soil used for the experiment was moderately infested by meadow eelworm and contained only a few root-knot eelworms per sample.

TABLE 2.—*Average soil infestation (per 100 g) and root infestation (per 10g) of different plants*

1	2			3			4			5		
Treatments	In soil									In roots		
	2-6-58			20-9-58			9-12-58			9-12-58		
	Pr	Mel	Oth	Pr	Mel	Oth	Pr	Mel	Oth	Pr	Mel	Oth
Fallow	8	1	320	34	0	375	9	0	220	—	—	—
Tea	7	0	340	10	5	250	253	0	365	5280	0	1380
Tephrosia	15	3	500	35	8	500	45	4	725	480	38	570
Crotalaria	14	3	360	1	0	180	4	0	240	3	0	470
T. patula (II)	13	0	370	11	0	430	1	0	700	2	0	32
T. erecta (III)	9	0	460	7	0	275	3	0	240	3	2	44

N.B.—Experiments started 20th May, 1958; see for abbreviations table 1.

It appears from the data given in table 2 (columns 3, 4, 5) that the meadow eelworm population of the plots planted with young tea very considerably increased in about 6 months and to a lesser extent, in the plots sown with *Tephrosia*. Both *Crotalaria* and marigolds reduced the population. Only the *Tephrosia* plots contained a small number of root-knot eelworms. With regard to the roots (column 5) it can be seen that the tea was very heavily and *Tephrosia* moderately infested with meadow eelworm, the latter also harboured root-knot eelworms. The roots of *Crotalaria* and marigolds, however, contained only a negligible number of meadow eelworms and no root-knot eelworms. It is worthy of note that the number of other eelworms in the marigold roots is very small as compared with the number of those in the other plants.

The data of both trials indicate that the marigolds have to reach maturity—which takes 5 to 6 months—before they are fully effective (compare columns 3 and 4).

2.2. Field Experiments

I. Field experiments on mature tea were laid out on Mount Vernon and Eildon Hall estates in fields known to be infested by meadow eelworm, as was also noticeable from the considerable number of bushes in a drying or poor condition. The soils also had a fairly dense root-knot eelworm population. In both trials tea was retained in one area and uprooted in the other. Each of the respective areas was divided into 4 plots measuring 25 × 25 ft. The following treatments were carried out in both the fallow area and the area with tea (pruned at the start of the experiment):

Mount Vernon—1 plot sown with *T. erecta* (III), 1 plot with *T. patula* (I) and 2 plots with weeds and *Crotalaria usaramoensis*.

Eildon Hall—2 plots with *T. erecta* (II) and 2 plots with weeds.

On both estates the *T. erecta* variety grew exceedingly well in the fallow plots reaching a height of nearly 5 ft. (see Fig. 1) 6 months after sowing. *T. patula* did not grow well in the tea, while the cover given in the fallow plots compared unfavourably with that of *T. erecta*.

The marigolds in the fallow area were sown in rows about 9" apart; in the pruned tea the seeds were sown between tea rows and in vacant spots. At Mount Vernon estate, *T. erecta* gave an excellent cover in the pruned tea and had become higher than the bushes 6 months after sowing. At Eildon Hall estate growth was satisfactory in the vacancies but not between the tea rows, probably because of the quick recovery of the bushes after pruning causing unfavourable light conditions for the flowers.

Figure 1.—Growth of *T. erecta* 5 months after sowing in fallow tea soil (mature tea in background)

TABLE 3.—*Influence of marigolds and weeds on the eelworm population of tea soil with or without mature tea* (*eelworms*/100 *g soil*)

A. Mount Vernon

Treatments	28-11-57*		26-6-58		3-9-58		
	Pr	Mel	Pr	Mel	Pr	Mel	Oth
Weeds	20	11	0	10	2	10	491
T. patula	14	2	0	13	1	3	296
T. erecta	13	14	1	11	2	3	291
Tea + weeds	23	20	10	76	33	3	361
Tea + *T. patula*	18	20	3	14	19	0	202
Tea + *T. erecta*	20	7	4	7	8	0	246

B. Eildon Hall

Treatments	21-1-58*		19-5-58		21-8-58		
	Pr	Mel	Pr	Mel	Pr	Mel	Oth
Weeds	63	54	3	7	4	17	315
T. erecta	94	62	2	8	1	6	245
Tea + weeds	61	33	7	25	26	21	304
Tea + *T. erecta*	248	15	3	30	10	6	111

*Date experiment started; see for abbreviations table 1.

The results presented in table 3 show that the marigolds in both trials had significantly reduced the *Pratylenchus* and *Meloidogyne* populations and that of other nematodes in the soil both when growing as a pure crop and when sown in tea. The marigolds had a greater repressing effect on eelworms than leaving the soil to weeds. The trial at Mount Vernon estate indicates that *T. erecta* was more effective than *T. patula* probably due to the more vigorous growth of the former.

TABLE 4.—*Root infestation of marigolds and other plants and the effect of these plants when intergrown with tea on the infestation of tea roots*

Location & sampling date	Roots from	Eelworms/10 g roots Pr	Mel	Oth
Eildon Hall 21-8-58	*T. erecta*	0	3	52
	Tea (+ weeds)	77	0	74
	Tea (+ *T. erecta*)	28	0	81
Mount Vernon 19-5-58	*T. erecta* III (2 plots)	10	170	290
	"	0	0	10
	T. patula	0	0	120
	Weeds:			
	Axonopus compressus	0	0	1177
	Crotalaria anagyroides	20	0	1450
	Sesbania cinarescens	50	50	5560
	Oxalis corymbosis	63	2510	2917
19-5-58	Tea (+ weeds)	620	0	390
	Tea (+ *T. patula*)	0	0	200
	Tea (+ *T. erecta*)	0	0	170
3-9-58	Tea (+ weeds)	210	0	441
	Tea (+ *T. patula*)	115	0	302
	Tea (+ *T. erecta*)	83	1	99

Table 4 presents the root infestation of marigolds, of four species of "weeds" (2 of which are leguminous bush crops) growing in plots without tea, and of tea with or without marigolds 6–10 months after the experiment started. It can be seen that the meadow eelworm infestation of marigolds was nil or negligible, while the roots were only in one instance found to harbour a number of root-knot eelworms. The number of other eelworms was very low when compared with that of the weeds.

and cover crops (*Crotalaria* and *Sesbania*). The grass (*A. compressus*) appeared to be free of parasitic eelworms; *Crotalaria* roots were only lightly infested with meadow eelworm, while *Sesbania* was moderately infested with both meadow and root-knot eelworm. *Oxalis* roots, besides harbouring some meadow eelworms, were heavily infested with a root-knot eelworm which was identified by Dr. Oostenbrink as *M. arenaria*.

With regard to the tea roots, the figures show that those obtained from the areas which had marigolds as a cover crop carried considerably less meadow and other eelworms than those from plots with weeds in all instances.

II. The second experiment was done with a view to ascertaining the effect of marigolds on young tea. The experimental area concerned already carried young tea which badly suffered from meadow eelworm infestation before the experiment started. These plants were uprooted and replaced by one year old plants of clone 2024. The area was divided into 3 plots (7 × 15 yards) with the following treatments: (*a*) fumigation with Shell DD (2 weeks before planting), (*b*) sown with *T. patula* II in rows 9" apart, (*c*) left fallow. Each plot had 8 rows of 15 plants each; the "fallow" and fumigated plots were clean weeded throughout. Planting was done by the end of June; the marigolds were sown in the beginning of July, 1958 (in plot *b*). As they had fully covered the plot by the end of October and reached a height of about 4 ft., lopping around the tea plants at monthly intervals became necessary. The tea plants were manured twice at the rate of ½ and 1 oz. Sterameal respectively.

The relevant data concerning the eelworm population of the soil, infestation of the roots and average number of leaves and height of plants recorded 5 to 6 months from the start of the experiment, are given in table 5.

TABLE 5.—*Effect of fumigation and sowing of marigolds as a cover crop on the eelworm population of the soil, infestation of the roots and on growth of young tea plants*

1	2			3			4	
Treatments	Eelworms per 100 g soil 3-12-58			Eelworms per 10 g roots 3-12-58			Avg. per plant 19-1-59	
	Pr	Mel	Oth	Pr	Mel	Oth	No. of leaves	Height in ins.
Tea fallow	13	0	240	4385	2	1485	29.1 (100)	15.2 (100)
Tea + *T. erecta*	6	0	250	1315	0	475	34.0 (117)	18.1 (119)
Tea fumigated	1	0	195	780	1	480	57.1 (168)	19.5 (128)

N.B.—Figures within parentheses in column 4 express number of leaves and height in % of control (tea fallow); see for abbreviations table 1.

The above table again indicates that marigolds intergrown with tea both depressed the meadow eelworm population in the soil as well as decreased the degree of infestation of the tea roots. Fumigation had a greater effect, as is also illustrated by the enhanced growth of the plants. The tea plants with the marigold cover crop had also grown somewhat better than the control plants. Their growth was, however, less good than expected on account of the decreased infestation. This is probably partly due to competition and partly due to the fact that the marigolds become effective only after reaching maturity with the result that the tea plants become infested before that stage is reached. The infection of the tea plants in the fumigated soil is probably mainly on account of the too short interval lapsing between fumigation and planting (8).

An assessment carried out in July, 1959, showed a number (average of 6 samples) of 74, 23 and 71 meadow eelworms per soil sample for the fallow, marigold and fumigated plot respectively. Accordingly, one year after the experiment started marigolds appear to have been more effective than fumigation.

III. It appeared from a field experiment reported elsewhere (8), that a meadow eelworm infested area the tea of which had been uprooted and subsequently planted with Guatemala grass (*Tripsacum laxum*), had become practically free of eelworm 8 months later, the period required for an adjacent, but fallow area was 12 months. This finding was in accordance with previous observations (9) and suggested that Guatemala grass is not susceptible to meadow eelworm. However, since this grass is so widely used for soil reconditioning and also in eelworm infested areas, we sought further confirmation as to its resistance.

For this purpose soil and root samples were taken from meadow eelworm infested fields of two estates on which mature tea had been interplanted with Guatemala grass for 1–2 years. The controls were samples obtained from an area of tea without grass and of grass without tea (planted in the vacancies). The results from soil and root sampling (average of 6 composite samples) are recorded in table 6.

TABLE 6.—*Soil and root infestation of tea and Guatemala grass when intergrown and when growing separately*

1	2			3			4			5		
Soil or roots from	Eildon Hall Estate						St. Clair Estate					
	per 100 g soil			per 10 g roots			per 100 g soil			per 10 g roots		
	Pr	Mel	Oth	Pr	Mel	Oth	Pr	Mel	Oth	Pr	Mel	Oth
(*a*) Grass only	3	15	309	31	1	880	2	9	360	1	4	270
(*b*) Grass + tea	16	7	267	39	0	135	20	1	790	4	1	170
(*c*) Tea only	24	1	409	1874	2	1135	24	1	250	1120	3	540
(*d*) Tea + grass*	—	—	—	267	2	365	—	—	—	315	1	265

*The soil samples of (*d*) are the same as those of (*b*); see for abbreviations table 1.

It can be deduced from table 6 (columns 2 and 4) that the Guatemala grass planted in formerly infested plots (*a*) had notably reduced the meadow eelworm populations, while it had little effect on the population when interplanted with tea (*b*) as compared with tea only (*c*). However, it appeared from the root tests (columns 3 and 5) that roots from tea bushes intergrown with the grass (*d*) were very much less infested than tea roots from bushes growing on their own (*c*). The meadow eelworm infestation of the grass roots was low as compared with that of tea roots and virtually the same whether the roots were obtained from grass growing together with or separately from the tea.

3. Conclusions and summary

The experiments leave no doubt that the marigold species tried out, *Tagetes erecta* and *T. patula*, can considerably decrease the *Pratylenchus coffeae* (meadow) and *Meloidogyne javanica* (root-knot) eelworm populations in tea soil. In fact the cultivation of marigolds reduced the populations more quickly and more effectively than keeping the soil fallow. Their roots usually carried no meadow or root-knot

eelworms or relatively small numbers where the soil was heavily infested. Apparently eelworms are able to invade the roots to some extent. This probably occurs before the plants have reached full maturity, as only then the repressing effect on eelworms becomes noticeable. However, it is unlikely that the invading eelworms survive because even the number of non-parasitic eelworms found in the roots was only a fraction of that found in other plants. It also appeared that marigolds as a cover crop both in young and in mature tea notably decreased the infestation of tea roots by meadow eelworm. Our observations on the effect of marigolds on eelworm are in complete accordance with those of OOSTENBRINK *et al* (6).

Accordingly, marigolds show considerable promise for the control of eelworms in tea soils. Marigold varieties of the "bush type" are preferable to the dwarf forms in respect of height, vigour, production of organic matter, extensiveness and depth of root system and ability to withstand lopping. It is not expected that marigolds can be generally grown as a cover crop in mature tea after pruning unless there are many vacancies, because the period between pruning and recovery is normally not long enough for their establishment. The cultivation of marigolds as a pre-crop or cover crop in young tea is feasible. However, our agricultural experience with this crop is limited and more information is needed.

With respect to *Tephrosia vogelii*, it was observed that this plant is susceptible to both meadow and root-knot eelworm, thereby sustaining or increasing the original populations in the soil. This confirms previous findings of GADD (1, 2) and GADD *et al* (3). This bush crop should, therefore, not be planted in any area which is suspected to be infested with meadow or root-knot eelworm.

Crotalaria usaramoensis and *Cr. anagyroides* appear to be largely resistant to meadow and root-knot eelworm attack and depressed the population in the soil. In this connection it is worthy of note that inoculation experiments carried out by GADD (2) in the past indicated that both species are unsuitable hosts for meadow eelworms. These observations are also substantiated by recent field sampling (VISSER—8) which showed that both *Cr. usaramoensis* and *Cr. anagyroides*, though growing in infested soil, were virtually free from parasitic eelworms. Further, PEACOCK (7) found from inoculation trials that *Cr. striata* and *Cr. retusa* were resistant to *M. incognita var. acrita*, though *Cr. usaramoensis* and *Cr. juncea* appeared to be susceptible to some extent. MACBETH *et al* (4) noted that *Cr. spectabilis* reduced the severity of root-knot eelworm attack on tobacco grown subsequently. The above suggests that non-susceptibility to *Pratylenchus* and *Meloidogyne* infestation may be a general feature of the genus *Crotalaria*. Hence, *Crotalaria* species would seem to be suitable bush crops in eelworm infested areas.

With regard to *Tripsacum laxum* (Guatemala grass), it would appear that this grass is also non-susceptible to meadow and root-knot eelworm attack. It depressed particularly the meadow eelworm population of the soil, while its roots harboured only few parasitic eelworms. When intergrown with tea, it considerably reduced the meadow eelworm infestation of the tea roots. The above corroborates field observations made previously (8, 9). Accordingly, soil reconditioning with this grass, is also recommended on account of its adverse effect on eelworms parasitic to tea. Though reducing the infestation of tea, interplanting is not advisable, because of severe competition for nutrients and water.

The experiments showed that both mature and young tea is very susceptible to *Pratylenchus coffeae*, judging from the very large number of eelworms which may be found in the roots. Mature tea is apparently not susceptible to *Meloidogyne javanica* as was already observed in the past, though root-knot eelworm is dangerous to young plants.

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