THE TEA RESEARCH INSTITUTE

OF

SRI LANKA

CHEMICAL AND NON CHEMICAL DISINFESTATION OF TEA SOILS

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What are the objectives of this Monograph?

- **To introduce new soil disinfestants to control plant parasitic nematodes in tea**

- **To explain the different methods of soil disinfestation as applicable to tea nurseries, new clearings and mature tea in nematode active areas**

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1.0 Introduction

In many perennial crops, like tea (*Camellia sinensis* L.O.Kuntze), the crop is continuously grown on the same land, leading to build up of pest populations in the soil, particularly pathogens and root feeding pests like nematodes. This demands a need to develop effective soil disinfestation methods to ensure productivity.

Soil disinfestation is not the same as soil sterilization. There is complete destruction of soil biota when soil is sterilized, like what happens under steam treatment or heat treatment of soil. Soil disinfestation is the eradication of soil borne pests, existing in the soil uniformly to the desired depth before planting, with the minimal disturbance of the biological equilibrium, and without much affecting the chemical or physical properties of the soil (Katan, 2000). In this sense, soil disinfestation is target specific. The agents that are used for the purpose are mostly chemical.

Eradication of a specific pest can also, be achieved by crop rotation which is much more target specific than chemical disinfestation. This is particularly so in the case of tea nematodes.

⊘ Tea Nematodes

There are several species of phytophagous nematodes that live in tea lands. However, only three are of economic importance to tea. They are:

1. Meadow Nematode / the Root-lesion Nematode - *Pratylenchus loosi* Loof which is active in up-country, Uva and Deniyaya

2. Burrowing Nematode - *Radopholus similis* Cobb, found at elevations from 500-1000m amsl, and active in mid-country, Uva and Deniyaya, sometimes found together with P. loosi.

3. Root-knot nematode - *Meloidogyne brevicauda* (Chitwood)- now confined to one location, Kabaragala Estate at 2000m elevation. Since 1995, it has not been detected either at Oliphant or Mooloya Estate where this nematode was also found before.

These nematodes can cause heavy damage in tea nurseries, new clearings and young fields. A new clearing that has been affected by a heavy population of *P. loosi* is shown in Plate 01.

Plate 01- Typical site of new-clearing affected by heavy nematode population (Nayabedda Estate, 2000 N.C. in 2001)

⊘ Chemical Soil Disinfestation

In its present form, soil disinfestation was established at the end of the 19th century. In 1869, a French chemist, Thenard discovered that Carbon disulphide (CS_2) could eradicate the soil pest *Phylloxora* in vineyard soils (Wilhem, 1966). Within a few decades, thousands of acres of vineyards were fumigated with CS_2. Thereafter, many other chemicals have joined CS_2.

Soil disinfestation should be effective in controlling pests, safe, technologically feasible, economically justified and environmentally acceptable. It should ultimately lead to increase in both yield and income. Environmental consequences of disinfestation should be regarded in a broad sense, namely its effects on the biotic and abiotic soil components, surface and ground water, adjacent fields and crops, and the surrounding living and nonliving environment. An added advantage of chemical disinfestants is that they enhance plant growth.

⊘ Chemical Fumigants

Fumigant is a substance or mixture of substances which produce gas, vapour, fume or smoke intended to destroy insects, bacteria or rodents (AAPCO*). Fumigation is a technique that allows a fumigant to reach pests which are in soil, in durables, in perishables, and in structures and vehicles.

⊘ Methyl Bromide (Bromo methane)

Throughout the world, Methyl Bromide (MeBr) is mainly used as a fumigant type of disinfestant, helping to control a wide range of pests, including pathogens (fungi, bacteria and soil borne viruses) insects, mites, nematodes and rodents. Its insecticidal activity was first reported in 1932 by Goupil and it has been in use as a soil fumigant in agriculture from late 1940s (Anon, 1932).

At ambient temperature and pressure, MeBr is a colourless, odourless gas, but it is usually supplied and transported as a liquid in pressurized 0.6 to 200 kg capacity cans and steel cylinders.

* Association of American Pesticide Control Offcial

Methyl Bromide

Methyl bromide can alter the colour and smell of certain commodities. It is toxic to growing plants and produces bromide ion residue - a cause for concern in groundwater. It is also highly toxic to humans, thus requiring special training and equipment for operators. The broad spectrum of activity and easy use of MeBr have made it a useful substance for many applications. Its main assets are:

- ✦ It penetrates deep in the soil, commodities and structures, reaching the more inaccessible pests;
- ✦ It is effective against most pests at low concentrations;
- ✦ It works relatively quickly;

In 1996, global production of methyl bromide was about 71,425 tonnes, with an estimated 68,666 tonnes used for agricultural and related purposes and the remaining 2759 tonnes used as feedstock for chemical synthesis (UNEP, 1998).

In Sri Lanka, MeBr is currently used in pre-shipment and quarantine pest control and for soil fumigation at controlling nematodes, particularly in the tea plantations. Usage of MeBr on tea plantations is 13% of the total consumption (imports) in Sri Lanka (Ono, 2002). Import of MeBr is permitted only subject to an import license brought through Import and Export Control Act, as per Gazette extraordinary No.1007/14 of 1997/12/24 (Annexure 09) (Weeratunga, 2002).

⊘ Methyl Bromide Fumigation

Plate 0 2- MeBr can is fitted into the grove in the Jiffy Applicator
When the lever held by the right hand is turned inwards it pierces the can releasing the liquefied gas which flows out through the tube

Plate 03 - MeBr fumigation set up

The tube (a) originating from the MeBr can (b) is led into a vessel (c) kept on a shallow tray (d) to catch the drip.

A few soil filled bags (e) are kept on the nursery bags to create space between the polythene(f) and the bags(g).

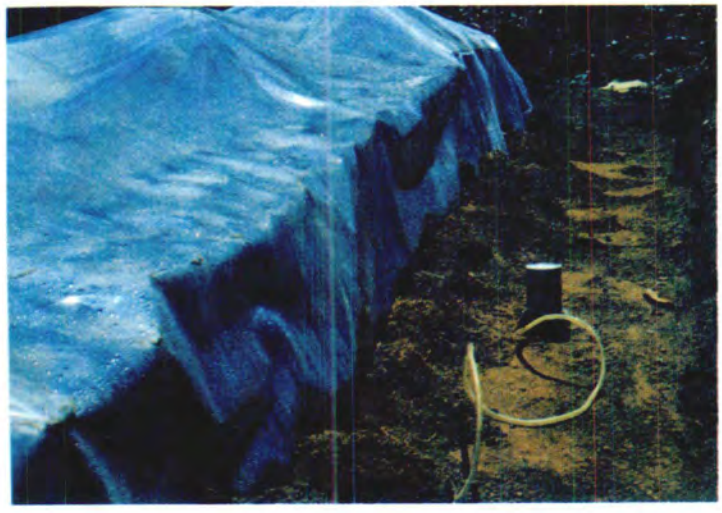

Plate 04 - **Fumigation with MeBr is underway**
Note the edges of the polythene sheet buried under the soil to make the fumigation chamber leakproof.

Plate 05- **Improvised method of using Methyl Bromide for soil fumigation**
Note the MeBr can (a) kept inside a wood frame (b) placed on the soil heap (c) and the tarpaulin (d) behind. The can rests on an iron nail which pierce- open the can when the can underneath the tarpaulin is hit.

Ozone Depletion and Phase out of ODSs

In 1997, methyl bromide was classified as an Ozone Depleting Substance (ODS). The Montreal Protocol, an international treaty under the United Nations Development Programme (UNDP) has scheduled a worldwide phase out of its use. However, still the quarantine and pre-shipment uses of MeBr are exempt from phase out controls under the Montreal Protocol, partly in recognition of the economic significance of international trade and of the relatively small amount of the substance believed to be used that time. United Nations Environment Programme (UNEP) reported that these uses have increased sharply in mid 1990s in some countries making it counterproductive to ozone protection efforts (UNEP, 1998). Some others have already taken restriction measures in response to concerns over air and surface water pollution related to methyl bromide.

Having ratified the Montreal Protocol and its amendments, Sri Lanka is bound to freeze her annual consumption of MeBr at its average 1995-97 level in 2002. A total phase out should be achieved by 2015.

The project, "Phase out of Methyl Bromide from eradication of tea nematodes in Sri Lanka", was funded by UNDP to evaluate and put in place alternatives to MeBr for the phase out of its use in Sri Lanka. Another objective of this project is to recommend regulatory and other measures that the government of Sri Lanka will formulate to ensure the phase out of use of MeBr.

2.0 Soil Fumigation in Tea

⊘ Soil Disinfestation with Chemical Fumigants

Among the chemical nematicides that the Tea Research Institute of Sri Lanka (TRI) has tested in the past are DBCP (Nemagon), dichloropropane-dichloropropene mixture (D-D), ethylene dibromide, thionazine (Cynem and Nemafos), phorate (Thimet), phosdrin, dimethoate (Rogor), dithiometon (Ekatin), phosphamidon (Dimecron), fenitrothion (Sumithion), methyl demeton sulphoxide, dazomet and methyl bromide.

TRI made it compulsory for all tea and green manure nurseries to be routinely fumigated (Hutchison, 1960). It was also stated that nurseries below this elevation could probably benefit from fumigation. Soil fumigation was primarily directed against plant parasitic nematodes. Of these, the Root-lesion nematode was the most important.

'D-D' also known as Shell DD, and ethylene dibromide have been used in tea plantations since mid 1940s to eradicate nematodes in fields as well as in nurseries (Loos,1953 &1954). Ethylene dibromide was given up for reasons of phytoxicity (Loos, 1953). MeBr substituted for "DD" at fumigation, as the most cost effective method of nematode control. Later it was restricted to the nurseries (TRI, 1971). Rehabilitation under grass took over nematode control in the field prior to replanting of old tea

⊘ Soil Disinfestation With Naturally Occurring Nematicides

Like many other pests, tea nematodes have restricted host range and their survival in the absence of a susceptible live host is limited. This is the overriding principle behind disinfestation of infested tea soils by growing Mana (*Cymbopogan confertiflorus* C.Steud. Stapf.) and Guatemala (*Tripsacum laxum* Nash). Tolhurst (1958) addressing a Planters' meeting, stated that: "The overriding consideration regarding rehabilitation is still, as it always has been, the pathological one. Both the length of the period and the nature of the crop are dependent on the presence of pests or disease organisms, and it is not possible for me to be any more precise on either point".

There had been doubts about the susceptibility of Guatemala to *P. loosi* in the early days. Hutchinson (1962) conducted controlled pot trials to test its susceptibility to *P. loosi* and confirmed that Guatemala, Marigold and Mana did not support any nematode populations. However, this work was carried out in Talawakelle (up country). Much later, it has been shown that even though Guatemala was not host to *P. loosi* the plant did support the development of *R. similis* which is predominant in the mid elevation areas. Thus, it may have been due to the misidentification of the species that the doubts may have arisen. On the other hand, neither pest was shown to attack Mana making it the more suitable grass species for the purpose of land rehabilitation, at any elevation.

On the other hand volatile compounds from plants, essential oils, are known to have antimicrobial and insecticidal activities (Thompson, 1989; Shaaya *et al,* 1991). A few essential oils and their components have been evaluated for nematicidal effect (Sangwan *et al,* 1990). Marigold is one such plant well known for its nematicidal properties. Planting of Marigold within established clonal tea infested with nematodes had been recommended in 1960s. Roots of Marigold in all stages of vigorous vegetative growth are known to be effective in this way (Hutchinson, 1964).

3.0 Prospective Alternatives to Methyl Bromide

The chemical soil fumigants currently available in the world are: Chloropicrin, 1,3-Dichloropropene (1,3-D 97), Dazomet, Metham sodium, Metham potassium, Ethyl formate, Fenamiphos, Propylene oxide, Aldicarb, Iodomethane and Cadusafos. In studies conducted in Italy 1,3-D 97, Metham sodium and Metham potassium have given yields of cantaloupe as good as methyl bromide while fenamiphos as granules or microcapsules in liquid formulation had been slightly less effective (Tacconi *et al.*, 1998; Caroppo *et al.*, 1998; Di Vito *et al.*, 1998). Many others have used dazomet and metham sodium with promising results (Lamberti *et al* 2001a,b, Rodriguez *et al* 2001, McKenry *et al* 2001).

In the current study, metham sodium, fenamiphos and cadusafos have been tested and compared with dazomet for use against tea nematodes in the field and/or nursery, as chemical fumigants.

⊘ Dazomet

In 1980, dazomet, a granular fumigant was introduced as an alternative to MeBr at 0.5 kg per cube (2.83 m^3) of soil (TRI, 1980). Dazomet was shown to encourage better plant growth, compared to methyl bromide (Gnanapragasam, 1982a and 1982b). This is moderately stable, but is sensitive to temperatures above 35°C and to moisture. In moist soil, dazomet breaks down into Methyl isothiocyanate which is the fumigant.

However, methyl bromide was not completely displaced by dazomet. Comparatively, there was more plantations in upcountry using dazomet while the usage of Methyl bromide was more in the mid elevation areas. There was no explanation for this difference at that time. The reasons are explained in this volume, elsewhere.

⊘ Metam / Metham Sodium

Metham sodium (Sodium N-methyldithiocarbamate) (50%, by weight), first marketed in 1950s, is a dithiocarbomate soil disinfestant with broad spectrum action. It has been used to control plant parasitic nematodes, weeds and soil-borne plant pathogenic fungi affecting a variety of economically important fruit and vegetable crops. (Oka, *et al.*, 2000; Reuven *et al.*, 2000. Because, Metham sodium is water soluble and has low volatility. It is the only soil fumigant that is being applied through irrigation systems.

Metham Sodium
Cadusafos, Neem
Nematicidal Plants

⊘ Cadusafos

This has broad spectrum control of plant parasitic nematodes and soil insects by contact action. It is formulated in granular form (Rugby 10G), due to its high toxicity.

⊘ Formulations of Plant Extracts of Neem

There are several neem formulations claimed to be having nematicidal properties. In a preliminary study conducted earlier, raw neem leaf was shown to have both nematicidal and growth enhancing effect on the tea plant (TRI, 1998). Therefore, to neem formulations of reputed manufactures ,"Neemazal 1% TS" and "Multineem" were tested in the current study.

⊘ Intercropping and Thatching with Nematicidal Plants

Marigold, Vetiver (*Vetiveria zizanoides*, Fam. Graminae), Wild sunflower (*Tithonia diversifolia*: Fam.Compositae) have been recorded as having nematicidal properties.

Plate 06 - **Fumigation with Dazomet on-going**
(Diyagama East Estate, 2001)

Plate 07 - Covering the soil heap with grass mulch, after mixing soil with Dazomet.

After mixing with dazomet the soil is heaped up to a height of 30 cm, watered to maintain moist conditions for dazomet to release the toxic gas, methyl iso- thiocyanate and then covered with dry mulch.Polythene mulch is not necessary as the gas is heavy.

4.0 Experimentation in Sri Lanka

Damage due to heavy infestation in new clearings can show up in the form of heavy casualties as seen in Plate 01. This can arise from infestation originating in the nursery or with the residual population in the inadequately rehabilitated new clearing. Therefore, both the nursery soil and the land has to be free of nematodes for new planting to be successful.

Where the Nematode Problems Occur

The different situations where nematode problem is encountered are:

1 - Nursery at preparation
2 - Infested nursery
3 - At planting of a new clearing
4 - Infested new clearing
5 - Infested mature tea

1- Nursery at preparation: New chemicals such as metham-sodium and neem formulations were compared with fumigation with dazomet at preparation of the nursery soil.

2- Infested nursery: Formulated nematicides, fenamiphos and neem formulations were tested for this situation.

3- At planting of a new clearing: planting hole application of cadusafos, fenamiphos and metham sodium, intercropping with Wild sunflower and Vetiver were tested at planting of new clearing with infested plants.

4- Infested New clearing - Cadusafos, neem formulations and metham sodium were tested at planting nematode free plants on infested land.

5- Infested Mature tea - Repeat application of fenamiphos, intercropping with Wild sunflower and Marigold were tested in this situation.

Treatment Methods Nursery Experiments

⊘ Treatment Application Methods

i. In the nursery, metham sodium was diluted with water and then mixed into the soil just the same way as dazomet is used

ii. At field application, the chemical was diluted with equal volume of water and injected into 25-30 cm deep holes made 30 cm away from the base of the plant. i.e. at mid point between two plants and only in the row.

iii. Granular nematicides ("Rugby" and "Nemacur") were worked into the soil after scraping the moss cover in the case of nursery, (Plates 08 & 09) and the granules were dibbled into a shallow circular furrow 15 cm from the base of the plant in the field.

iv. In the case of nursery trials diluted neem formulations ("Neemazal 1% TS" & 'Multineem") were applied using a 50ml syringe minus the needle after disturbing the moss growth on the surface of bag soil (Plate 10), whereas, in the field the dilution was poured in to a shallow circular furrow round the plant

⊘ Nursery Experiments

✦ Conventional Chemicals and Organic formulation for Nursery Fumigation

Experiment at Hauteville Estate, Agarapatana

The following treatme nts were applied in completely randomized block design:

T_1 = MeBr fumigation @ 500g per cube of bagged soil (900 bags)
T_2 = Basamid fumigation @ 500g per cube of soil (10ft x 10ft x 1ft / 2.83 m^3)
T_3 = Metam sodium fumigation @ 600 ml per cubic meter of soil (1m x 1m x 1m)
T_4 = "Neemazal 1%TS" diluted @ 3ml in 1 litre water and using 30ml of dilution per plant
T_5 = Untreated Control

Nematode infestation and growth of plants were assessed at 7 months and 12 months after treatment. Results are presented in Tables 01 & 02.

Table 01- Root Nematode Count at 07 months from planting cuttings in the Nursery (Avg. *P. loosi* count per 1g of root)
(Hauteville Estate, 2001)

T_1- MeBr	T_2- Basamid	T_3- Metam	T_4- Neemazal	T_5- Control
00	00	00	07	00
00	00	00	20	07
00	00	00	07	00
00	00	00	11.33	2.33

Metam sodium and Basamid were comparable to MeBr in nematicidal activity at the assessment at 7 months. On the other hand, inspite of still harbouring nematodes Neemazal was comparable to dazomet in terms of growth of the plants.

Table 02- Influence of chemical fumigants on plant height and nematode count at 12 months. (Hauteville Estate, 2001)

Treatments	Avg. plant height (cm)	Avg. Nematode count/g root (n+1)
T1- MeBr	40.83 *b*	01.00 *c*
T2- Basamid	63.67 *a*	01.00 *c*
T3- Metam	47.00 *b*	01.00 *c*
T4- Neemazal	62.13 *a*	12.33 *a*
T5- Control	43.93 *b*	03.33 *b*
LSD 5%	15.77	6.38

Basamid (T2) and Metham Sodium (T3) were shown to be comparable with MeBr (T1).

At this up-country location, Dazomet performed better than MeBr or Metam in relation to growth.

✦ Formulated Nematicides for Infested Nurseries

Experiment at Westhall Estate, Nawalapitiya.

The nursery at Westhall Estate was found to be heavily infested with both *Radopholus similis* and *Pratylenchus loosi* in mid 2000. It was selected for the above experiment in October 2000. Plants were arranged in 18 beds each with 200 plants. Sedimentation tanks were reconstructed to make nematode free water available. The six treatments replicated 3 times, included the following:

T_1 - "Neemazal 1%TS" diluted @ 3ml in 1 litre water and using 30 ml of dilution per plant

T_2 - "Multineem" diluted @ 3ml in 1 litre water and using 30ml of dilution per plant

T_3 - "Multineem" diluted @ 6ml in 1 litre water and using 30ml of dilution per Plant

T_4 - "Neemazal 1%TS" diluted @ 6ml in 1 litre water and using 30ml of dilution per plant

T_5 - "Nemacur 5G" @ 2g per plant

T_6 - Untreated control

The treatments T1 to T4 were repeated at 6 week intervals until nematodes were not detected. T5 was repeated at 12 week intervals until nematodes were not detected. (Methods of application are shown in the Plates 10 & 11).

Plate 08- Usage of Chemical Nematicides in Infested Nursery
(Westhall Estate, 2000-2001)
The moss growth on the soil surface is disturbed with a probe prior to application of either liquid or granular formulations.

Plate 09 - Usage of Chemical Nematicides in Infested Nursery
(Westhall Estate, 2000-2001)
Granular nematicides like "Nemacur" is measured out with a small measuring cup / spoon.

Plate 10 - Syringe Application of liquid formulations ("Neemazal"& "Multineem") with 50ml syringe. (Westhall Estate, 2000-2001)
Labour requirement - 1 man-day per 900 plants (Note; yellowing and stunted nature of plants -symptoms typical of nematode damage)

Plate 11 - Second repeat application of neem formulations
(Westhall Estate, 2000-2001)
(Note: plants have partially recovered; compare with Plate 10)

Plate 12 - Recovery after Six months of Treament
(Westhall Estate, 2000-2001)
Treated plants have considerably recovered after four applications of neem formulations and two of Nemacur. (Compare with Plate 10) Treated plants have vigor ours growth (a) as against the un treated (b).

Plate 13 - Recovery after 12 months of Treament
(Westhall Estate, 2000-2001)
Treated Plants have recovered from nematode damage, and are ready for field planting after 12 months of treatment (Compare with Plate 10).

Pre-treatment count of nematodes in the soil as well as roots were recorded in October 2000 prior to application of treatments. Two post-treatment counts have been recorded in early April and mid July 2001. The results are given in tables 03 & 04.

Table 03- Root Nematode Count
(Replicate average of nematodes per 1 g root matter)
(Westhall Estate, 2000-2001)

Treatments	Pre-count October 2000	At 6 months from Treatment April 2001	At 9 months fromTreatment July 2001
(Weather)	(Wet)	(Wet)	(Dry)
T_1- Neemazal (3ml usage)	13.6	0	0
T_2- Multineem (3ml usage)	9.0	0	0
T_3- Neemazal (6ml usage)	11.0	0	0
T_4- Multineem (3ml usage)	6.6	0	0
T_5- Nemacur (2g)	13.6	0	0
T_6- Untreated control	9.0	8.67	0.73

Untreated control plots recorded nematodes in all 3 replicates whereas, all treatments cleared the plants of all infestation of 06 months. The low counts recorded in the untreated beds in July 2001 is attributed to dry weather conditions..

Table 04 - Soil Nematode Count
(Replicate Average of Nematodes per 100 g soil)
(Westhall Estate, 2000-2001)

Treatments	Pre-count October 2000	At 6 months from reatment	At 9 months from treatment July 2000 April 2001
(Weather)	(Wet)	(Wet)	(Dry)
T_1- Neemazal (3ml usage)	8.3	3.83	0.2
T_2- Multineem (3ml usage)	7.6	0.0	0.0
T_3- Neemazal (6ml usage)	9.0	0.67	0.2
T_4- Multineem (6ml usage)	8.3	0.0	0.0
T_5- Nemacur (2g)	4.6	0.0	0.0
T_6- Untreated	4.0	5.33	1.93

Control plots recorded nematodes in all 3 replicates. Even though, T1 & T3 still had nematodes in one replicate at 9 months, only the untreated control had nematodes after 12 months.

Thus all five treatments have cleared the heavy infestation from the nursery bags.

Table 05- Growth Assessments
(Westhall Estate, 2000-2001)

Treatments	Root Weight		Shoot Weight	
	At 6 months	At 9 months	At 6 months	At 9 months
T_1- Neemazal (3ml usage)	6.73	14.53	11.46	28.70
T_2- Multineem (3ml usage)	9.02	11.46	13.10	19.63
T_3- Neemazal (6ml usage)	8.40	11.18	11.38	23.29
T_4- Multineem (6ml usage)	7.94	9.41	14.16	17.16
T_5- Nemacur (2g)	6.33	7.52	7.59	20.43
T_6- Untreated	3.32	10.49	7.76	20.55
LSD at 5%	NS	4.125	NS	NS

Treatments were significantly different from each other only at 9 months in relation to root weight. However, neem formulations exhibited generally better root and shoot growth.

Thus, it has been shown that "Multineem" or "Neemazal 1%TS" (at 3 ml / litre dilution), when repeated at 6 week intervals, are comparable to "Nemacur 5G" at 2 g / plant repeated at 3 month intervals. Also, all treatments could clear heavy infestation of nematodes from roots as well as soil in the nursery bags. The neem formulations performed marginally better in terms of root & shoot growth when compared to "Nemacur 5G".

Thus, it can be concluded that application of 30 ml of either "Neemazal 1%TS" or "Multineem" diluted at 3 ml / litre and repeated at 6 week intervals, and Nemacur at 2 g / plant and repeated at 12 week intervals can control the nematodes in the nursery.

This also explains the reason why with single application, Neemazal (3 ml) did not clear the pest at Hauteville Estate, when used to fumigate soil for the nursery.

Field Experiments

Chemical nematicides, organic mulches and trap crops were tested in the same locations at field trials.

✦ Nematicides to Eradicate Nematodes in Infested Land at Re-planting

The chemical nematicides included cadusafos ("Rugby"), metham sodium,Nemamort, fenamiphos (Nemacur) and neem formulations such as "Neemazal 1% TS" & "Multineem".

In the preliminary trials carried out from 1997, cadusafos exhibited very good nematicidal activity at upper elevations (Kandapola, Maskeliya) but, was phytotoxic to a considerable extent at mid elevations such as at Nawalapitiya, Hali-Ela. At Queenstown Estate, Hali Ela, cadusafos caused heavy casualties while Neemazal treatment gave the best survival of plants and not statistically significantly different from the untreated control or Nemacur.

Table 06- Survival of plants after application of nematicides at planting of NC. (Queenstown Estate, Hali-Ella, 2000)

Treatments	Average % Live Plants		TreatmentAverage (%)
Clone	C1	C2	
T1= Rugby @ 7g / hole	46.37	17.72	32.04 *b*
T2= Neemazal 30ml / plant	92.89	69.40	81.14 *a*
T3= Nemacur @ 7g / hole	64.75	60.77	62.76 *a*
T4= Control	82.66	69.41	76.03 *a*
Clone Average	71.67	54.32	LSD5%=30.08

Therefore, it was decided to restrict cadusafos @ 7 g, to upper elevations and test lower dosages for lower elevations.

Experiment at St. Coombs Estate, Talawakelle

The following treatments were given on 2 clones TRI 3025 the susceptible clone & TRI 4052, the tolerant clone in a split-plot design, in an un-rehabilitated and infested land.

T_1- Untreated control
T_2- Rehabilitated under Mana
T_3- "Nemacur 5G" @ 7g / hole (thatching with Mana) (standard treatment)
T_4- "Neemazal 1%TS" @ 30ml of 0.021% dilution / plant + Thatching with Mana
T_5- Wild Sun flower thatching
T_6- *Adathoda vesica* thatching (renewed regularly)
T_7- Vetiver intercropped

Nematode assessments were carried out at 02 months, 07 months and 12 months. There was no significant difference between clones in relation to nematode counts.

Table 07- Nematode count in tea roots (per 1g root)
St. Coombs Estate, Talawakelle

Treatment	At 02 months	At 07 months	At 12 months
T_1- Untreated control	3.095	2.484 *bc*	2.019
T_2- Mana rehabilitation	-	-	-
T_3- Nemacur	4.077	1.122 *a* *	2.077
T_4- Neemazal	3.511	1.699 *ab*	2.595
T_5- Tithonia thatch	3.647	3.241 *c*	2.726
T_6- Adathoda thatch	4.127	2.418 *bc*	2.697
T_7- Vetiver inter cropped	2.399	1.831 *ab*	3.326
LSD at 5%		1.2935	

There was significant difference between treatments only at 07 months. Vetiver intercropping, "Nemacur 5G" and "Neemazal 1%TS" lowered the nematode population at 07 months considerably, compared to the other treatments. However, none of the treatments could eradicate nematodes in any of the plots.

Table 08- Growth Assessment
St. Coombs Estate, Talawakelle

Treatment	Plant Girth (cm)		Plant Height (cm)		Tipping Weight
	At 07 Months	At 12 Months	At 07 Months	At 12 Months	At 12 Months
T1- Untreated control	1.1400 *a*	1.3817 *ab*	62.200 *b*	100.183 *ab*	177.13 *ab*
T2- Mana rehabilitation	-	-	-	-	-
T3- Nemacur	1.2350 *a*	1.5017 *b*	70.600 *a* *	110.067 *a* *	220.58 *a* *
T4- Neemazal	1.1300 *a*	1.3767 *ab*	65.500 *ab*	101.800 *ab*	165.27 *b*
T5- Tithonia thatch	1.2567 *a*	1.4800 *ab*	71.583 *a*	107.933 *ab*	218.67 *a* *
T6- Adathoda thatch	1.1800 *a*	1.3217 *a*	62.333 *b*	95.300 *b*	130.92 *b*
T7- Vetiver intercropped	1.1200 *a*	1.3417 *ab*	65.300 *b*	95.900 *b*	166.42 *b*
LSD at 5%	0.1612	0.1681	7.0069	12.771	49.911

The treatments were repeated wherever applicable, regularly, except Adathoda thatch. *Adathoda vesica* did not re-grow fast enough for the purpose. This treatment had to be dropped from the trial. The plots that were under Mana grass were planted to tea in December 2000. The experiment was in progress.

Experiment at Moray Estate, Maskeliya

T_1 = Metam sodium @ 500 l/ha injected into the soil round the plant

T_2 = Cadusafos "Rugby" @ 7g / plant

T_3 = Interrow planted, *Vetiveria zizanoides* lopped every 6 months and the loppings used to thatch the inter-row

T_4 = *Tithonia diversifolia* thatch in the inter-row

T_5 = Fenamiphos ("Nemacur") @ 7g / plant

T_6 = "Neemazal 1% TS" 30 ml / plant of 0.003% solution

T_7 = Untreated Control

Table 09- **No. of *P. loosi* in 100g soil at 04 months from treatment.**
(Moray Estate, Maskeliya, 2000/2001)

Treatments Replicates	T1- Metam	T2- Rugby	T3- Vetiver	T4- Tithonia	T5- Nemacur	T6- Neemazal	T7 Uuntreated
R1	0	7	0	13	3	5	3
R2	0	0	0	0	5	0	5
R3	0	2	0	2	3	2	3
Avg.	0	3	0	5	3.66	2.33	3.66

Table 10- **No. of *P. loosi* in 100g soil at 14 months from treatment.**
(Moray Estate, Maskeliya, 2000/2001)

Treatments Replicates	T1- Metam	T2- Rugby	T3- Vetiver	T4- Tithonia	T5- Nemacur	T6- Neemazal	T7- Untreated
R1	29	14	41	54	64	139	34
R2	13	4	89	1	51	64	51
R3	63	51	38	9	34	53	9
Avg.	35.00	23.00	56.00	21.33	49.67	85.33	31.33

Treatment with Metham Sodium and *Tithonia diversifolia* have reduced the nematode population to undetectable levels in 4 months. At 4 months the growth parameters such as plant height, plant girth, etc. did not show any significant difference between nematicidal treatments. However, after 14 months the assessments showed that the nematode population had built up to alarming proportions.

✦ Treatment of Infested Young Tea (young tea in the 2nd Cycle)

Experiment at Rothschild Estate, Pussellawa

Treatments:

Field infested with *R. similis* was selected for treatment with the following treatments.

T_1- *Tithonia diversifolia*- A row of Tithonia for every 02 rows of tea. Tithonia was lopped and the inter-rows thatched.

T_2- Marigold - Planted in the inter-rows and in vacant space

T_3- "Nemacur" 3g/bush - repeat in 6 month interval for 3 times

T_4- "Neemazal 1%TS" @ 1 lt of 1% Neemazal in 600l water / ha

Nematode assessments were carried out at 03 months, 09 months and 14 months from initiation of experiment.

Table 11 - Assessment at 03 months from treatment
Average nematode count in 100g soil
(Rothschild Estate, Pussellawa - 2001)

Treatment	*P. loosi*		*R. similis*		*R. reniformis*	
	R1	R2	R1	R2	R1	R2
T1- Wild Sun flower	0	0	0	0	23	2
T2- Marigold	2	0	0	0	08	8
T3- Nemacur 5G	0	0	0	0	07	0
T4- Neemazal 1%TS	0	0	2	2	00	0

Tithonia diversifolia and "Nemacur" treated plots showed zero counts of the tea nematodes at 03 months whereas, "Neemazal 1%TS" seem to have eradicated *R. reniformis* which is a pest on weeds, but not *R. similis*.

Table 12 - Assessment at 09 months from treatment
Average nematode count in 100g soil
(Rothschild Estate, Pussellawa - 2001)

Treatment	*P. loosi*		*R. similis*	
	R1	R2	R1	R2
T1- Wild Sun flower	03	-	-	-
T2- Marigold	-	-	-	-
T3- Nemacur 5G	-	-	-	02
T4- Neemazal 1%TS	-	-	-	03

Table 13- Average Nematode Count in 100g soil
Assesment at 12 months from treatment (Rothschild Estate ,Pussellawa)

Treatment	*P. loosi* (100g soil)		*R. similis* (100g soil)	
	R1	R2	R1	R2
T1	-	-	-	-
T2	-	-	-	-
T3	-	-	-	-
T4	-	-	-	-

At 12 months none of the plots recorded any nematodes. The symptoms caused by nematodes disappeared. Thus, it can be concluded that all the treatments can be adopted in infested young tea, to clear the nematodes. It is advisable to continue with the treatments so long as the odd bush exhibits any symptoms.

5.0 Discussion

1. The experiment at Hauteville Estate proved that Metham sodium @ 600 mlm^{-3} and Basamid 98% @ 500g per cube are comparable to Methyl Bromide in relation to nematicidal activity. However, Basamid performed better than MeBr or Metam in terms of growth enhancing activity, in this up country location.

2. Based on studies conducted over a period of about 7 years, the Institute recommended dazomet (Basamid 98%) as an alternative to Methyl Bromide in 1980 (TRI, 1980). Gnanapragasam (1982) reported that Dazomet was superior to Methyl Bromide in relation to growth boosting effect which resulted in the plants becoming ready for transplanting in the field at least 2-3 months earlier. In the current studies too, tea exhibited increased growth response to these two nematicides. However, it was not always that Dazomet was superior to Methyl Bromide. It was definitely the case at locations situated at high elevations such as Diyagama East, Nayabedde, Hauteville and Moray Estates. (Some of these observations have been given in the other Monographs of this series). On the other hand the opposite was observed at locations of low elevations such as Kellebokka, Rangala and Deniyaya Estates. The above 1982 report had been based on work conducted at Talawakelle which is at an elevation very close to that of Hauteville or Diyagama East Estate. Thus, the difference in the observations can be explained as due to the difference in performance of the two chemicals at different elevations.

We conclude that both nematicidal and growth boosting activity of dazomet is best at high elevations whereas, Methyl Bromide performs better, at mid elevations. It is probable that the higher temperatures at lower elevations affected the plant growth response towards dazomet. It may be that the dissociation products of dazomet such as ammonia, which remain in the soil and promote plant growth are released faster into the air under warmer conditions but, retained in the soil for longer periods , under cooler conditions.

It would be advisable to combine dazomet with other agents which can have synergistic effect on dazomet when it is being used at lower elevations. Mixing paddy husk with infested soil and soil solarization showed promise in this respect in another study at Handford, Deniyaya (see other monographs of the same series : i.Soil Solarization in Tea Nurseries, March 2002; ii. Substitutes for Nematode-infested soil in Tea Nurseries. March 2002).

3. Both "Neemazal 1%TS" and "Multineem" at 3 ml per litre dilution were found to be comparable to "Nemacur 5G". @ 2g per plant, if repeated at 6 week intervals as against Nemacur application repeated at 12 week intervals.

4. In addition, neem formulations have been shown to promote enhanced growth. This can impart a certain degree of nematode tolerance to the plant. If application was repeated regularly, both formulations, Neemazal 1%TS and "Multineem" could reduce the pest population which reached zero levels in 12 months, as at Westhall Estate nursery.

5. The field trials at St. Coombs as well as at Moray Estate showed that non of the treatments ("Nemacur 5G", "Neemazal 1%TS", "Rugby 5G", "Tithonia thatch", "Vetiver intercropping") could eradicate nematodes in an infested land if direct planting is undertaken. Therefore, it can be concluded that there is no substitute for rehabilitation under grass for infested fields.

6. In the case of infested young tea, perhaps, because of early infestations, it is possible to adopt control measures to eradicate nematodes from the soil as seen at the experiment at Rothschild Estate. Repeat application of "Nemacur 5G" @ 3g per bush and "Neemazal 1%TS' @ 1 litre of "Neemazal 1%TS / ha, inter row planting of *Tithonia diversifolia* and planting of Marigold in vacant spaces have all been able to clean the soil of *R. similis* infestation in 12 months.

6.0 Recommendations

1. MeBr substitutes for tea nurseries at establishment

Metham sodium is mixed in to the soil at the rate of 600ml a cubic meter of soil. The soil is leveled to a height of about 30cm. A few soil filled bags are kept on the surface to create space in between the bed and the tarpaulin. The treated soil heap is then covered with a polythene sheet (2-5 mil thick). 14 days is allowed for the fumigation. After the polythene is removed, the soil is turned over to release any excess gas. The soil can be bagged the following day.

2. Nematode infestation in established nursery:
Treat the plants individually with one of the following treatments.

i. Nemacur 5G @ 2g per plant; repeated at 12 week intervals

ii. Multineem @ 30ml of a dilution made with 3 ml concentrate in 1 litre water per plant; repeat ed at 6 week intervals

iii. Neemazal 1%TS @ 30ml of dilution made with 3 ml concentrate in 1 litre per plant and repeated at 6 week intervals. The above treatments should be repeated up to about 12 months or until such time nematodes cannot be detected in the soil.

3. Direct planting of infested lands:

There is no alternative to the currently recommended method of soil rehabilitation under grass, for a period of two years. Direct planting cannot be recommended.

4. Infested young tea;

If the nematode infestation is detected early enough in either new clearing s or young tea in the 2nd cycle, the following treatments can be adopted:

i. "Nemacur 5G" applied at the rate of 2g per bush; application is repeated up to end of one year or until such time that nematode infestation cannot be detected.

ii. "Neemazal 1%TS" is applied on the ground at the rate of 1 litre of concentrate dissolved in 600 litre water per hectare. The application is repeated at six week intervals up to one year or until such time that the nematodes cannot be detected.

iii. Wild sun flower planted in the inter-row, one row for every two rows of tea; plants are regularly lopped and the material used as mulch in the same field.

iv. Marigold (*Tagetes patula*) is planted in all vacant spaces and maintain without allowing the plants to flower at least up to one year or until such time nematodes cannot be detected.

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