THE TEA RESEARCH INSTITUTE OF SRI LANKA

Soil Substitutes for Tea nurseries in nematode active areas

Sushila I. Vitarana,
D.D. Liyanage, U.B. Herath, G.P. Udamulla,
A.K. Prematunge, U.P. Jayaratne, N. Navaratne and
P.K. Jayawickrama

Editorial Assistance :

Shyamantha Bandara

Design and Layout :

S.A. Naleen Nisshantha Ratnapala

Secretarial Assistance :

Chapa Munasighe

Refeence only

3

Substitutes for Nematode-infested Soil in Tea Nurseries

Sushila I. Vitarana,
D.D. Liyanage, U.B. Herath, G.P. Udamulla,
A.K. Prematunge, U.P. Jayaratne, N. Navaratne and
P.K. Jayawickrama

The Tea Research Institute of Sri Lanka
Talawakelle
Sri Lanka

March 2002

Acknowledgements

This document was produced by the Tea Research Institute of Sri Lanka as part of its activities conducted under the Project SRL/99/G61 - Phase Out of Methyl Bromide use from Eradication of Tea Nematodes in Sri Lanka. The project was funded by the United Nations Development Programme (UNDP) under the Multilateral Fund.

The Institute wishes to place on record its appreciation of the services rendered by the following UNDP staff who managed the Project:

Mr. Maarten Poolman / OIC, Division for Environmental Programmes

Mr. Jacques Van Engel / Regional Programme Coordinator / MPU

Mr. Dionyssia Geka / Portfolio Manager

Mr. Olof Brystrom / Associate Portfolio Manager

Mr. Hicham Nahro / Portfolio Manager

Ms. Rekha Thapa / Resident Representative, UNDP, Colombo

Mrs. Manel Jayamanne / Programme Officer of UNDP, Colombo

Ms. Dorthe Jorgensen / Programme Officer of UNDP, Colombo

The Tea Research Institute of Sri Lanka would also, like to thank the following who contributed towards successful completion of the project:

Dr. Sheila Forsyth, Consultant Nematologist.

Dr. Gaminie Manuweera and Dr. Rohinie Ekanayake for their assistance at preparation of the Project Proposal.

The Chief Executive Officers of the Plantation Management Companies of the estates which accommodated experimental sites

The Collaborative Superintendents:

Mr. Kumar Bharathie,
Mr. Anura Madawala,
Mr. M. Pathiraja,
Mr. Chula Weerakoon,
Mr. A.S. Ratwatte,
Mr. Chaminda Gunaratne,
Mr. M.S.A. Akbar,
Mr. Lucas Bogtstra,
Mr. Manzur Mustaq,
Mr. Ronnie Gunaratne,
Mr. Sudath Ekanayake &
Mr. Ranjan Gunasekera,
Mr. Wasantha Wijesinghe,
Mr. A. Tissera,
Mr. H.A.P. Jayathilake,
Mr. Anil Bowange,
Mr. A.D Samarasekera,
Mr. M.I. Goudian,
Mr. C.S. Ekanayake,
Mr. Mohan Rajendran,
Mr. L. Fonseka,
Mr. Manil Perera.

Project Team

Dr. Wester W.D. Modder - Project Coordinator / Local Manager

Mrs. Sushila I. Vitarana - Project Leader

Mr. D.D. Liyanage - Experimental Officer

Mr. U.P. Jayaratne - Research Assistant (Contractual)

Mr. N. Navaratne - Experimental Officer

Mr. U.B. Herath - Experimental Officer

Mr. P. Udamulla - Experimental Officer

Mr. A.K. Prematunge - Experimental Officer

Mr. P.K. Jayawickrama - Experimental Officer

Mr. U.S. Mudalige - Technical Assistant (Part Contractual)

Mr. S.A.N.N. Ratnapala - Technical Assistant (Part Contractual)

Mrs. M.W.C. Munasinghe - Project Clerk (Contractual)

Contents

Substitutes for Nematode-infested Soil in Tea Nurseries

Sushila I. Vitarana, D.D. Liyanage, U.B. Herath, G.P. Udamulla, A.K. Prematunge, U.P. Jayaratne, N. Navaratne and P.K. Jayawickrama
The Tea Research Institute of Sri Lanka, Talawakelle, Sri Lanka

01 Introduction

When tea was first introduced as a plantation crop to Sri Lanka in 1867, seeds were used as the propagation material. Planting holes in the field were marked with a stake and a seed was dropped into the hole, hence it is termed as *seed-at-stake planting*. Casualties were in-filled or the passengers were replaced, sometimes repeatedly, the same way until a good stand of sturdy bushes were established in the field. This method was continued at large scale planting for reasons of convenience even after the bamboo-supply-baskets and then later, the polythene bags were introduced. That was well into the nineteen fifties. Vegetative propagation of tea ushered in the clones in mid nineteen forties. Plantation scale use of clones since 1952, necessitated the use of nursery propagated planting material which totally substituted for *seed-at-stake planting* thereafter. Even though, interest in seed as planting material has been revived with the introduction of biclonal and polyclonal seed, nursery propagation of the planting material has come to stay.

Soil has remained as the rooting as well as the growing-medium in tea nurseries, to date. Much research has been conducted on various aspects of the medium in order to define the soil most suitable for tea propagation (Lamb, 1955; Gadd, 1928a; Gadd, 1928b; Elias, 1961). The necessity for a suitable degree of acidity (hydrogen-ion concentration) of the medium surrounding the roots of the plant was amply demonstrated as early as 1928 (Gadd, 1928a; Gadd, 1928b). Physical properties of the soil such as the texture suitable for tea nursery have been determined. Specifications of material requirements and methods of establishment and management of the nurseries have been detailed by Anandappa and Kathiravetpillai (1995). The rooting medium should be either a sandy loam or clay loam with pH ranging from 4.5 - 5.0. A pH value up to 5.5 is said to be harmless. However, pH around 5.5 is known to promote excessive callusing at the expense of rooting. At values of pH beyond 5.5, roots tend to die back (this condition is known as *bitten-off disease*.) In spite of having ideal physical and chemical soil properties, a nursery can be a failure on account of a pest infestation. Nematodes are such pests that affect nursery plants seriously and their eradication has become essential.

Tea Nematodes ; Methyl Bromide

Tea Nematodes

There are several species of nematodes (phylum : Nematoda) that live in tea soils. Some of them depend on live plants inclusive of tea, feeding on the roots (phytoparasitic). Some feed on organic debris in the soil (saprophytic). Some others live as parasites or predators of living animal organisms inclusive of other nematodes. Only about ten of soil nematodes are parasitic on tea. However, only three of those species are of economic importance to tea at present. They are:

1. The Meadow Nematode / the Root-lesion Nematode - *Pratylenchus loosi* (Loof) which is the most serious pest and is active in up-country, mid country, Uva and Deniyaya and Morawak Korale districts of the low country.

2. The Burrowing Nematode - *Radopholus similis*, (Cobb), found at elevations from 500- 1000m amsl, and active in mid-country, Uva and Deniyaya and Morawak Korale districts and sometimes found in association with *P. loosi* Loof.

3. The Root-Knot Nematode - *Meloidogyne brevicauda* (Chitwood) - now (from about 1995) confined to one location, Kabaragala Estate at 2000m elevation, and ot detected elsewhere.

As far as root feeding nematode pests of tea are concerned, even a very low population level cannot be tolerated in tea lands. In the case of susceptible clones the population can build up quickly leading to bush debilitation and premature death. In the case of tolerant clones the build up of the population may be equally fast even though the bushes may not exhibit debilitation symptoms. Such a field would definitely become a source of infestation to other fields or to the nursery through runoff water and by other means. Thus, the tea nematodes necessarily have to be totally eradicated.

Methyl Bromide in Tea

Methyl Bromide (MeBr) has been used to eradicate the above nematodes from tea soils since 1965 (Kerr and Vithylingam, 1966). At present its application is confined to nurseries, even though fumigation is effective in the field as well as in the nursery. Rehabilitation prior to replanting of infested fields under a non host crop like Mana grass (*Cymbopogan confertiflorus*), has been substituted for fumigation of field soil and the operation has been made compulsory prior to replanting. At the same time chemical fumigation has been made compulsory for nurseries at elevations above 200m. (However, there are locations below 200m where nematodes have been a recurrent problem both in nurseries and in fields, such as in Deniyaya, Morawaka and Akuressa.).

Methyl Bromide

In 1980, The Tea Research Institute recommended dazomet @20g of 98% granular formulation per square meter, in addition to MeBr (Sivapalan *et al.*, 1980).

For years, soil fumigation has been the most common approach for the control of soil borne pests. Chemical soil disinfestation eradicates most microbial residents in the soil. While plants benefit from such conditions for a short time, the microbial vacuum that is created often leads to a rebounding of parasitic agents, resulting in plant diseases that cause more damage than those that were originally targeted for control. Soils, especially those with low microbial populations are often more vulnerable to pathogen reinvasion following fumigation. One way of increasing microbial population and diversity is the introduction of an adequate energy food source. Food sources can be soil amendments, such as plant residues, animal manure or organic waste (Gamliel, 2000).

The 3 major methods available for soil-disinfestation are: fumigation with highly toxic substances, physical means (with steam or dry heat) and soil solarization. Chemical fumigation still remains the least costly, most convenient and the most popular among some of the large scale farmers in the developed world.

Many workers have studied the combination of organic amendments with chemical fumigants and solarization as a different approach and an additional option for pest management in soil. This process involves physical, chemical and biological effects. (Di Vito *et al.*, 2000; Katan, 2000). Crop residues have been used by themselves and in combination for biofumigation.

Since phase out of methyl bromide is scheduled to begin in the year 2002 in Sri Lanka, studies have been conducted during the last 2-year period to find suitable substitutes for methyl bromide. Among the non-chemical methods tested, soil substitutes acquired an important place.

02 Materials that have the potential for soil substitution

Studies have shown that many different types of organic amendments such as crop residues and animal manures can be used for eradication of plant parasitic nematodes in the soil (D'Addabbo and Sasanelli, 1998; Manici, *et al*, 1998). In the ornamental plant industry, most plants are grown in containers using organic substrates such as peat, bark and coir dust combinations as growing media, in which soil is completely excluded. Such substitute media have also eliminated the need for the control of soil pests.

In the case of tea, the influence of organic matter on populations of Root-lesion Nematode and the Burrowing nematode had been studied as far back as in 1964. Raw cattle manure and composted cattle manure were tested and the study had yielded mixed results (Hutchinson, 1964). Agro-based waste materials have not been tested for their nematicidal activity until recently (Vitarana, *et al*., 2001).

Peatmoss

Peatmoss (100%) of medium grade had been used in Sri Lanka for single internode cuttings in the early days of tea propagation (Anon, 1939). The practice was later abandoned because of the additional cost involved in importing the material, and also because, soil of suitable pH and texture could be made available from rehabilitated lands and natural jungle. Today Peatmoss is still being used in countries where it is naturally occurring and many workers have tested it for soil substitution as an alternative to methyl bromide fumigation of nematode infested soils (UNEP, 2000b; Stamps and Evans, 1997 & 1999).

Coir dust

Coir dust is the spongy, peat like residue resulting from processing of coconut husks (mesocarp of the nut) for coir fibre. Also known as cocopeat, it consists of short fibres (<2cm) around 2% - 13% of the total fibre content and the cork like particles ranging in size from granules to fine dust (Evans *et al*., 1996). Unlike peat moss, coir dust is a renewable resource. The two materials vary in the water holding capacity, nitrogen holding nature, microbial activity and slumping over time. The coir dust is washed, heat treated, screened and graded before being processed into various coir peat products used in horticulture. Where the salinity is higher than desirable (> 1ds/m), the unwanted salt can be easily removed with a heavy irrigation. Several studies have been conducted to study the physical, chemical and microbiological properties of coir. Gardening coir is a multi-purpose conditioner and growing medium. It is a completely homogenous material that absorbs and holds water up to eight times its own weight. It has a natural pH of 5.1 - 6.8. (Cresswell, 2002, Vidhanaarachi and Somasiri, 1997).

Paddy Husk ; Saw Dust

At present good quality processed coir dust is being exported from India and Sri Lanka. However, the material is still an agricultural waste in many parts of Sri Lanka. The raw coir dust found in dumping heaps outside coir factories is exposed to the element and undergoing slow decomposition. Coir dust strongly absorbs liquids and gases. It is also hydrophilic (attracts water) which means that moisture spreads readily over the particle surfaces. When first produced, coir dust is of a light tan colour but darkens with age to a chocolate brown.

Coir dust is used as a medium for hydroponic production of flowers and vegetables replacing materials like rockwool, perlite and sawdust. It is also now used in soil mixes for golf courses. It has been trialed as a casing layer in mushroom production and as a biological filter for odour control. However, in most cases, coir makes up no more than 10% to 20% of the mix. . Based on studies conducted at the Tea Research Institute of Sri Lanka, Visser and Kehl (1968) reported that saw dust, coir dust and expanded mica were unsuitable as rooting media for tea. Different observations have been made in the current study.

The nitrogen and phosphorus content of coir as with most other organic media is too low to contribute greatly to plant nutrient needs. These and other nutrients must be added as part of a balanced fertilizer program to obtain maximum plant growth. All organic media have some capacity to immobilize (tie up) nitrogen so that it is not available to plants. The amount of immobilization is determined by the availability of carbon based materials that can act as a food source for micro organisms. Coir dust immobilizes more nitrogen and phosphorus than peat but less than composted bark or sawdust. (Cresswell 2002, Vidhanarachchi and Somasiri, 1997; Konduru, *et al*., (1999).

Paddy Husk (Rice Hull)

Fully composted rice hull holds more water than unprocessed hull and is less acidic (pH = 5.7 - 6.2). Decomposition of rice hull differs in relation to its physical nature, in terms of the brokenness. In Sri Lanka, there are two types of hullers. The machine with rubber rollers (Japanese type huller) and those with steel hullers (local rice sheller). The husk or hull released by the former remains mostly unbroken while the latter machine breaks the hull into pieces. When the hull is crushed/broken, decomposition is faster and the nature of the material can change physically as well as chemically. However, compared to a material like coir dust, the rate at which paddy husk changes is negligible.

Bark / Saw Dust

Bark, a byproduct of saw mills, is used extensively in many countries as a media additive in the nursery industry. It has a role in greenhouse media as well. It helps to improve aeration and reduce the cost of media. Variability of bark arises from the species and age of tree, method of bark removal and the degree of decomposition. Pine bark is the most widely used bark source. Bark must be aged or composted before using it as a media component to eliminate the presence of phytotoxic compounds. Raw Pine bark is screened and wood (tree cambium) is removed before the thin (<0.5 in) fraction is composted. In general, nutrient content and pH of unprocessed bark are low. Saw dust substrate with biological control agents have been used as alternative to Methyl Bromide in New Zealand (UNEP, 2000a; UNEP, 2000b). When using bark as a mulch component, it is advisable to monitor for pH and nutrient changes in the media and be aware of the low water holding capacity of the material. Another more important factor to consider is the danger stemming from the scavenging termites which inhabit most of tropical soils. Scavenging termites are very common in most of the tea lands in Sri Lanka. The current study left saw dust out partly for this reason.

Tea Waste (Refuse Tea)

This material has never been used in tea nurseries as a growing medium. The most it is used is as an organic soil amendment in the tea field. The raw refuse-tea is known to be toxic to tea plants. Therefore, it is used after denaturing by treating with lime or dolomite. Krishnapillai (1979) observed that addition of refuse tea in tea fields caused an inhibition of nitrification of NH_4+ derived from urea and ammonium sulphate. This has been corroborated by recent studies conducted by Zoyza *et al* (in print). The immobilization of nitrogen makes it non- available to plants. The amount of immobilization is determined by the availability of carbon based materials that can act as a food source for micro organisms. On the other hand the same study showed that the soils amended with organic matter had a higher microbial activity compared to normal soil and that refuse tea influenced the highest microbial activity. This was attributed to the higher C:N ratio of the organic materials compared to normal soil.

Nitrification of NH_4+ causes a reduction of soil pH. However, Zoyza *et al* concluded that tea waste did not significantly reduce soil pH when compared to three other organic materials tested (rubber seed meal, capock seed meal and neem seed meal).

03 Experimentation in Sri Lanka

Three different organic materials were tested as soil substitutes for use in the nursery with a view to eliminating tea nematodes from the nursery medium. Performances of the individual materials were compared with each other and also with standard chemical fumigants. Each experiment included an untreated control. An experiment was conducted over a period of about 18 months from establishment of the nursery to field planting of the nursery plants. After determining the efficacy of the organic materials, a set of 4 experiments were established to see the synergistic effect of other control methods on the performance of the soil substitutes in order to design Integrated Pest Management (IPM) programmes for the four agro-climatic areas. Only one of the IPM trials reached termination (Handford Estate, Deniyaya) while the other 3 (Rangala Estate, Nayabedda Estate and Diyagama East Estate) were ongoing at the time of compiling this monograph.

Materials and Methods

Locally available agricultural wastes were used in the current study, namely Tea waste, Coir dust and Paddy husk. Saw dust was left out of the current study for two reasons. Firstly, several species of subterranean termites are active in tea lands and saw dust is very attractive to all of these termites. Secondly, Sri Lanka has such a variety of timber species that the material available at saw mills locally, is a mixture of several different species of variable quality. Thus, the composition of the material may vary from mill to mill. This may be associated with a difference in the performance of saw dust originating at different mills.

Fundamental Studies

A study was carried out to determine the pH, moisture content and the density of the three materials in order to describe their physical nature.

The materials were collected from dumping sites and samples of known age were collected for each measurement. The change with time in density and moisture content of the different substances, are given in Figure 01 and Figure 02, respectively.

Paddy husk had undergone the least amount of changes over a period of 6 months. The material collected from the local rice-sheller had more broken hulls than the material from the Japanese type huller. The difference in their density as well as moisture content at 6 months is attributed to this difference in the content of broken husk. Coir dust had a high moisture content initially when compared to the other two materials, but, comparatively changed very little in density as well as moisture content, with time. Tea waste is the material that underwent the biggest change with time. Fresh Tea waste was as dry as paddy husk but imbibed moisture faster than the latter. Therefore it is important to allow tea waste to decompose before use.

Therefore, the following materials were used in the soil substitutes studies:

Tea Waste - decomposed over a period of about 6 months, with a moisture content of about 12% and density of 0.6 g/ml.

Coir dust - decomposed over a period of about 6 months, with a moisture content of about 12% and density of 0.6 g/ml.

Paddy husk - either fresh material or that what was decomposed up to 6- months. Time

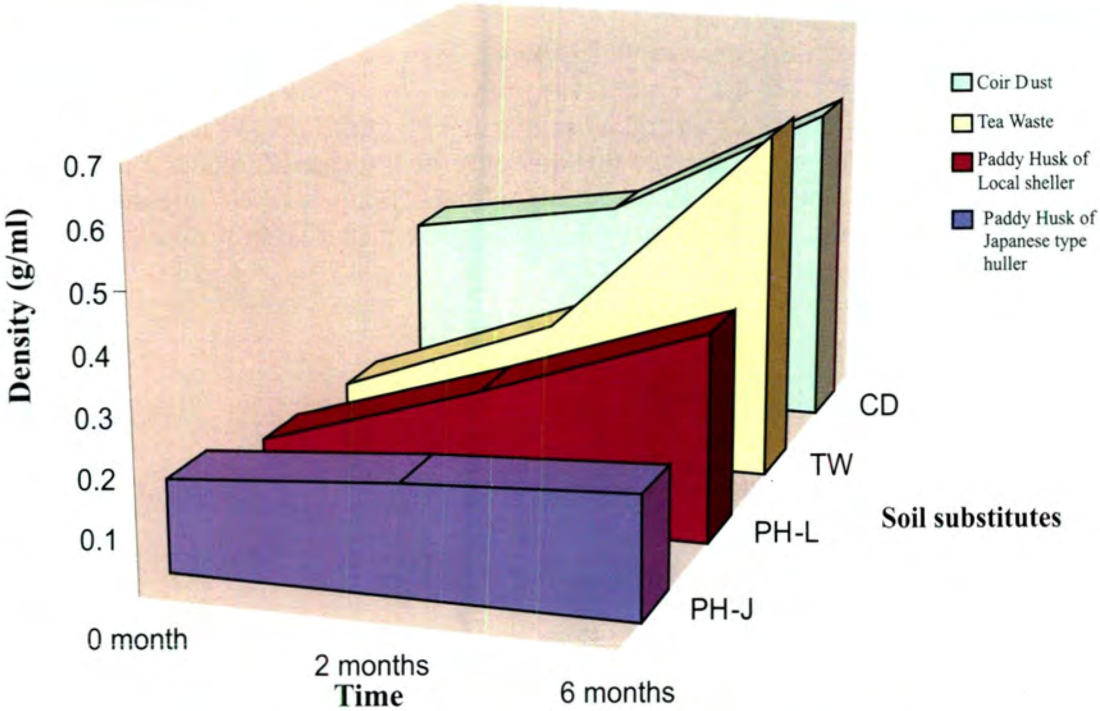

Figure 01-Changes in Density of Soil Substitutes with Time

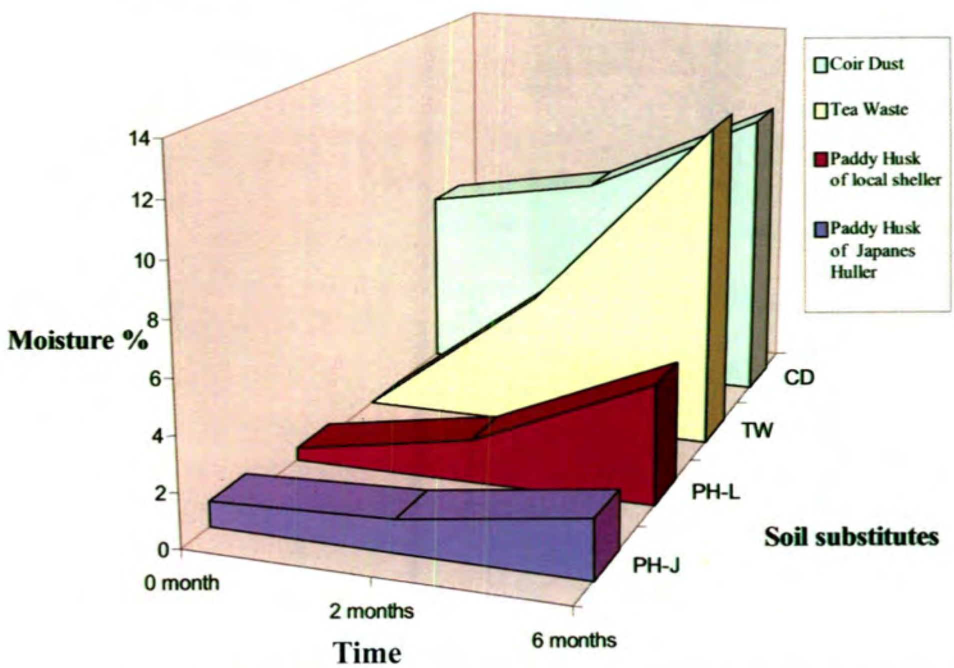

Figure 02-Changes in Moisture content of Soil Substitutes with Time

Tea waste (TW), Coir dust (CD) and Paddy husk (PH) were used in different ways:

(a) mixed with infested soil at a ratio of 1:1 by volume (eg. TW 1:1),

(b) in two layers with organic matter at the bottom (eg. TW 1/1),

(c) 100% organic matter - this was only in the case of coir dust, because in the case of paddy husk and tea waste the cuttings slumped when pressed into the medium.Figure 03 illustrates how pH values changed with partial substitution of organic material for soil.

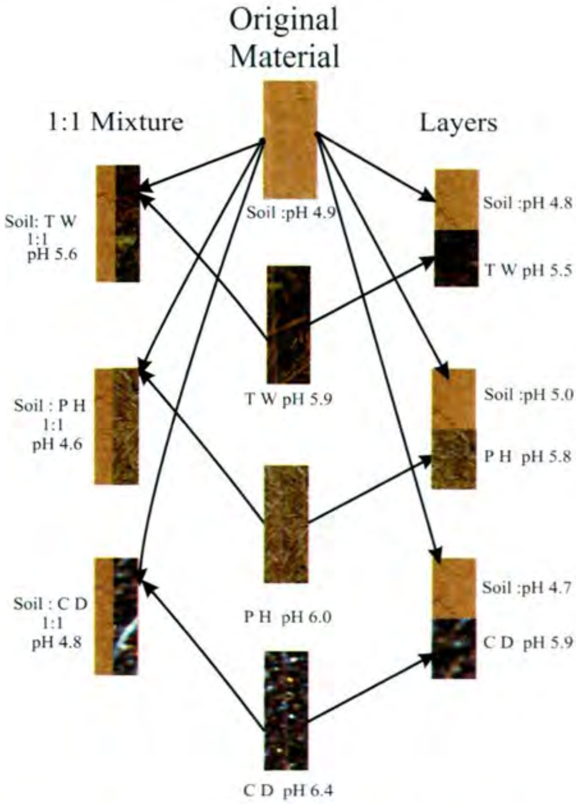

Figure 04-pH Changes observed at partial substitution of organic materials for soil.

All three organic materials recorded high pH values in their original form (Tea waste: 5.9; Paddy Husk: 6.0; Coir Dust: 6.4). After each material was brought in contact with soil (pH: 4.9), the medium turned more acidic than the original organic material, and only slightly less acidic than original soil. However, the root initiation took place in the area of the media having a pH ranging from 4.6 to 5.6; Tea waste in mixture had the highest pH (5.6) but, the growth of the plants was not unduly affected.

Nursery Trials ; Coir Dust & Paddy Husk

Nursery Trials

Bottom sealed nursery bags filled with soil substitutes were arranged on beds and allowed to settle over a period of 2 weeks. All other usual nursery practices were carried out. However, the plants were not subjected to any bringing into bearing operations in the nursery, so that the comparison of treatments could be based on free growth of the plants. Experiments were carried out at the following sites:

i. Diyagama East Estate, Diyagama (Up country)

ii. Kellebokka Estate, Kellebokka (Mid country)

iii Handford Estate, Deniyaya (Low country / Deniyaya district)

(a) Use of Coir Dust and Paddy Husk in the Nursery

Experiment at Diyagama Estate (up country)

At this location, coir dust was compared with paddy husk, while having fumigation with MeBr as the standard and Untreated Control for comparison. The experiment had the following treatments in randomized complete block design, accommodating 300 plants in each plot in two replicates:

T1 - 100% Coir Dust (100% CD)

T2 - Paddy Husk mixed with Soil at 1:1 (PH 1:1)

T3 - Soil and Coir Dust in 2 layers, with coir dust at the bottom (CD 1/1)

T4 - Dazomet (standard practice)

T5 - Untreated control

T6 - Soil + Coir dust mixed at 1:1 (CD 1:1)

Two assessments were carried out, one at 8 1/2 months and the other at 12 months from planting cuttings. The assessments included nematode counts in the roots and in the soil, growth parameters namely plant height, stem girth, lateral branching, number of leaves and root and shoot weight of plants at the time of destructive sampling for nematode assessment. Results are shown in Tables 01 and 02.

Coir Dust & Paddy Husk

Plate 01 - Testing of Soil Substitutes - Rooting at 4 months (Diyagama East Estate, 2001)

1) Coir Dust only (100% CD)
2) Paddy Husk mixed with Soil at 1:1 (PH 1:1)
3) Soil & Coir Dust in layer (CD 1/1)
4) Dazomet (Standard Practice)
5) Untreated Control *
6) Coir Dust mixed with soil at 1: 1 (CD 1:1)

Plate 02 - Root Growth in 100% Coir Dust (T1) - at 6 months
(Diyagama East Estate) (2001)
(Note: ramification of the roots inside the material holding the particles firmly)

Plate 03- Growth in layer arrangement: with soil at the top and coir dust at the bottom (T3), at 6 months (Diyagama East Estate) (2001)

Table 01-Comparison of Treatments at 08 ½ Months (Average of 45 Plants) (Diyagama East Estate, Diyagama - Upcountry) - (2001)

Treatment	Plant Height (mm)	Plant Girth (mm)	No. of Leaves per Plant	No. of Lateral Branches	Occurrence of Banji %
T1- Coir Dust - 100%	214.00	3.47	10.08	2.51 a	42.22
T2- Coir dust: Soil (1:1)	228.33	3.93	9.26	1.89 b	53.33
T3- Soil / Coir dust in Layers	201.00	3.60	9.70	2.23 ab	42.22
T4- Paddy Husk: Soil (1:1)	255.67	4.00	10.38	2.24 ab	26.66
T5- Untreated Control	189.00	3.53	8.07	1.96 ab	35.55
T6- Basamid	169.00	3.50	7.04	1.73ab	40.00
$LSD_{5\%}$	NS	NS	NS.	0.60	NS

Coir Dust & Paddy Husk

Results were statistically significant only in relation to lateral branching, coir dust giving the best branching. However, considerable differences were seen between treatments in relation to other parameters. At 12 months nematodes were not detected in any of the treated plants whereas, the untreated control continued to have the infestation (Table 02).

Plate 04 - Difference in overall growth of tea in the different soil substitutes (after centering; prior to transplanting at 9m) (Diyagama East Estate) (2001)

1) Paddy Husk mixed with Soil at 1:1(PH 1:1)
2) Coir Dust mixed with Soil at 1: 1 (CD 1:1)
3) Soil & Coir Dust in layer (CD 1/1)
4) Coir Dust only (100% CD)
5) Dazomet (standard)
6) Untreated Control

Table 02 - Nematode Assessment at 12 months (*P. loosi* count per 1g root) (Diyagama East Estate, Diyagama, (up country) (January 2001)

Treatment	Nematode count per 1g root
T1- Coir Dust (CD 100%)	0.00
T2- Coir dust: Soil (CD 1:1)	0.00
T3- Soil / Coir dust in Layers (CD 1/1)	0.00
T4- Paddy Husk: Soil (PH 1:1)	0.00
T5- Untreated Control	4.33
T6- Basamid (500g / cube soil)	0.00

Profuse root growth was observed in almost all of the organic substitutes; the best at 4 months was in 100% coir dust (Plate 02). In the case of untreated control, root initiation was delayed and even at 4 months roots were few in number and comparatively small in size (Plate 01). The nematodes that survive in the bag will multiply and affect the plant, if not while still in the nursery, later after transplanting in the field.

In conclusion, it can be said that all organic substitutes in the manner in which they were used at the above location, and as described above can be used in nematode active areas in up country. They all proved to be equal to or better than the usual recommendation of dazomet.

(b) Use of Refuse Tea (Tea Waste) in the Nursery

Kellebokke Estate, Kellebokka (Mid country)

At this location, Refuse Tea (tea waste) was compared with paddy husk, while having fumigation with MeBr as the standard and Untreated Control for comparison. The experiment had the following treatments in randomized complete block design, accommodating 300 plants in each plot in two replicates:

T1- Fumigation with methyl bromide (MeBr)
T2- ½ Soil + ½ Tea waste in layers with tea waste at the bottom (TW 1/1)
T3- Soil + Tea waste mixed at 1:1 (TW 1:1)
T4- ½ Soil + ½ Paddy husk in layers with Paddy husk at the bottom (PH 1/1)
T5- Soil + Paddy husk mixed at 1:1 (PH 1:1)
T6- Untreated control

Final assessments on nematode infestation and growth parameters were carried out in 9 months from planting cuttings. However, plants were centered and retained in the nursery for a few weeks prior to transplanting. A count of plants with outstanding performance was recorded in relation to the vertical height of the plant. A plant with a height exceeding 45cm (disregarding the length of lateral branches) was considered as of outstanding performance. (The average plant of the estate nursery was 45 cm in height)

At nine months, nematodes survived in the nursery bags only in the case of Untreated Control (Table 2). Thus, all the test materials were shown to have the same nematicidal effect as methyl bromide. However, they exhibited differences in plant growth. Tea waste in 1/1 layer arrangement elicited the highest Increased Growth Response (IGR) in terms of plant height, total number of leaves and unaided lateral branching.

Results of assessments carried out at 09 months are presented in Table 03.

Table 03 -Results of Growth assessments (Average of 30 plants per plot) and Nematode Assessment (Average of 5 plants per plot) at the stage of transplanting (9 months) (Kellebokke Estate-2000)

Tr.No.	Treatment	Plant Height (cm)	Un-aided lateral branching (No. lateral branches per plant)	Amount of foliage (No. leaves per plant)	Stem girth (mm)	Nem. count (No. Per 1g root)
T1	MeBr fumigation	34.80abc	1.87 cd	13.930 bc	5.24 ab	0
T2	TW 1/1 layer	58.00 a	4.74 a	26.935 a	6.17 ab	0
T3	TW 1:1 Mixture	40.43ab	2.42 b	16.965 b	6.45 a	0
T4	PH 1/1 layer	25.93 c	1.00ad	10.400ac	4.22 b	0
T5	PH 1:1 Mixture	34.47 bc	2.19 bc	13.930 bc	5.32 ab	0
T6	Untreated Control	30.95 bc	1.39acd	12.750 bc	4.52 b	7
	$LSD_{5\%}$	10.96	1.05	5.43	1.72	

Increased Growth Response (IGR)

Plate 05 - Tea waste-in-layer treatment produced profuse growth; influenced unaided branching (no Thumb-nailing adopted) (Kellebokka Estate Nursery 2000)

In this treatment the tallest plant exceeded 100 cm in height.

Tea waste in 1:1 mixture came second in relation to growth boosting effect, though it is not significantly different from the untreated control. Paddy husk in 1/1 layer arrangement retarded the growth, though not significantly different from the untreated control. Paddy husk in 1:1 mixture imparted better growth though not significantly different from the untreated control.

Increased Growth Response (IGR)

All of the organic materials were nematicidal in nature, but they performed differently in relation to free growth of the plants. The performance of the plants was assessed in relation to the number of plants that had outstanding performance. The number reaching a height exceeding 45cm (the height of an average plant in the estate nursery), the number having at least one lateral branch and the number ready for field planting (based on estate standards), were recorded. The percentage of outstanding performance was calculated, based on the number of plants surviving up to the time of assessment and not the original number of 300. (see Table 04).

Kellebokka

Table 04 - Plant performance at the time of transplanting.
Percentage of outstanding performers (based on the number surviving)
(Kellebokka Estate, Kellebokka) (2000)

Treatment No.	Treatment	* No. of Plants surviving up to transplanting		No. of Plants exceeding 45cm in height		% of outstanding performers Replicateaverage)
		R1	R2	R1	R2	
T1	MeBr fumigation	299	292	97	72	32.25 bc
T2	TW 1/1 layer	296	285	284	262	75.89 a
T3	TW 1:1 Mixture	284	283	73	130	36.56 b
T4	PH 1/1 layer	275	290	45	29	21.17 cd
T5	PH 1:1 Mixture	281	273	45	54	25.00 bcd
T6	Control 283	278	25	27		17.71 d
	LSD 5%					12.46

* Original No. of plants per treatment replicate = 300.
Outstanding performance is shown graphically in Figure 03.

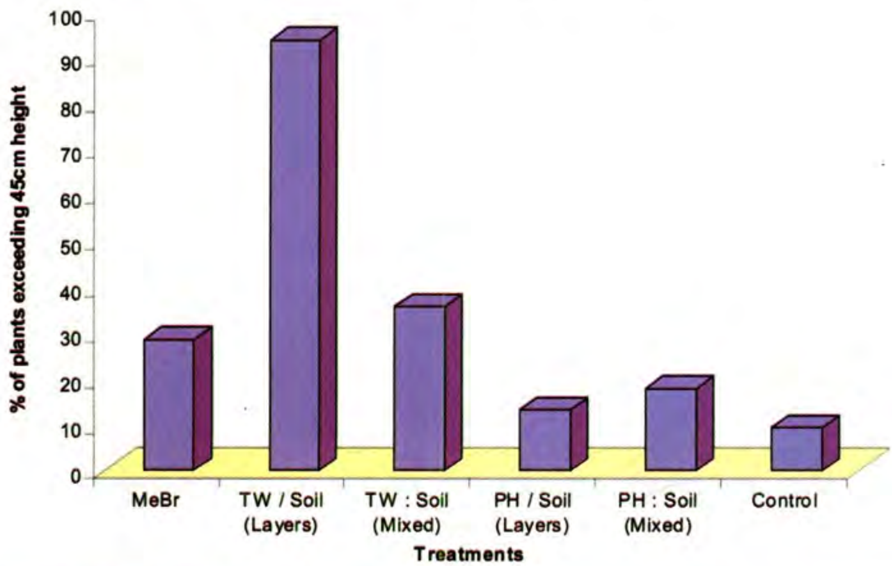

Figure 03-Performance of plants under different soil substitute combinations

Tea Waste in layer-arrangement is definitely the best of all combinations in this study at the mid country location.

Will the Organic matter cause "sinking" in the planting hole?

Shrinkage of the medium was evaluated at the end of the nursery period (Table 05).

Table 05 - Shrinkage of the Medium at 07 months (Kellebokke Estate, Kellebokke) (2001)

No.	Treatment	Avg. Column height of nursery medium (cm) (Original column height = 20cm)	% Shrinkage of the medium
T1	MeBr	19.37 a	03.15%
T2	TW1/1 layer	17.615 c	11.93%
T3	TW1:1Mixture	19.22 ab	03.90%
T4	PH1/1 Layer	18.72 abc	06.40%
T5	PH 1:1Mixture 5%	18.095 b	09.53%
T6	Control	19.785 a	01.08%
	LSD	1.124	

There was no significant difference in shrinkage between the untreated control and MeBr treatment. Tea-waste in layer treatment exhibited the highest amount of shrinkage of the nursery medium (11.93%) though it is not significantly different from Paddy Husk in similar layer arrangement. It was observed that in the case of Tea-waste in layer arrangement, shrinkage was caused by compaction of the material. However, it was also noted that the compacted block of tea waste was being held by a ramification of roots. (Plates 06 & 07).

Plate 06- Tea waste (Refuse tea) in layers with soil at the top and tea waste at the bottom. (Kellebokka Estate, Kellebokka) (2001)

Note the ramification of roots which hold the tea waste block.

The compacted structure resembled a non collapsing sponge. Therefore, there cannot be any sinking of the plant after transplanting; instead the porous material can act as a sponge to hold water from which the roots will benefit. Since the rootlets were binding onto the particles of the medium there was no possibility of further shrinkage in the planting hole. Thus, the possibility of sinking after transplanting can be ruled out.

Experimental plants were transplanted in field blocks in August 2000, in a rehabilitated land. The normal recommended field practices, were carried out.

Kellebokka

Plate 07- Use of Tea Waste (Refuse Tea) in the Nursery.
Growth at 9 months (Kellebokka Estate, Kellebokka) (September 2000)

The soil layer of one plant has been disturbed to show the root growth. See the long root that goes right down to the tea waste layer at the bottom. Heavily branched roots bind on to the particles or Refuse tea, holding the material in a non-collapsing lump. To the right is a lump of tea waste detached from another plant.

Casualty counts recorded at the end of the dry weather period (April 2001) at 8 months from field planting of the experimental plants confirmed that there is no danger of sinking of the plants of TW 1/1 treatment. There was no difference between the Tea waste-in-layer treatment and the others in terms of post-planting casualties. Casualties were well within the 5% that is allowed for natural causes in all treatments inclusive of TW 1/1 treatment. Field blocks will be checked for any residual populations of nematodes during the first cycle (up to 2005).

Soil Substitutes in IPM ; Results

Soil Substitutes in IPM Programme

Synergistic effect of chemical fumigation on partial soil substitutes

Four experiments were initiated in the four major agro climatic zones in the latter part of 2001 to evaluate the synergistic effects of other nematode control methods on soil substitutes. They were all on 3-factor split-split-plot design: Three chemical nematicides and an untreated control were split on three media which were at sub-plot level. All organic materials were used in 1:1 mixture with infested soil. The main plots were for two of solarization treatments.

1. At Handfort Estate, Deniyaya (low country)

The treatments included the following;

Main treatments (2M)

a) Tea waste

b) Paddy husk

Sub treatments (2SS)

a) Soil solarization of infested soil prior to mixing with organic matter

b) Soil solarization of the mixture of infested soil and organic matter

Sub-sub treatments (chemical nematicides) (3N)

a) Metam sodium (Metam) at 300ml per cubic meter soil (half of recommended dose)

b) Dazomet (98%G) at 250 g per cube of soil (half of recommended dose)

c) 'Neemazal 1% TS'30 ml per plant of diluted Neemazal (dilution: 3ml in 5 liter water / 1/5 of recommended dose)

The trial was initiated with soil solarization, in December 2000. Growth assessments and nematode analysis were carried out at 09 months from planting cuttings (February 2002).

04. Results

There were no adverse effects seen in any of the treatment combinations.

Nematode counts were zero in all treatments at 9 months. (However, monitoring for any build up of nematode population will continue after field planting up to 4 years). The differences between treatments were shown to be statistically significant only in relation to root-weight. The results are shown in Tables 06, 07, 08 & 09.

Table 06 - Sub Plot Treatment effect on root weight

Treatment	Root weight per plant
SS1 = Solarization prior to mixing ½ load PH	7.23 b
SS2 = Solarization after mixing the soil and substitute material	8.98 a
$LSD_{5\%}$	1.61**

Results showed that soil solarization of the medium after mixing the organic material into the soil resulted in better root growth, than in the soil that was solarized prior to mixing with organic matter.

Interaction between Soil substitutes and chemical nematicides was statistically significant.

Treatment	Root weight per plant (g)		
	Metam	Dazomet	Neemazal
Paddy Husk	7.97 bc	11.47 a	8.52 b
Tea Waste	6.47 c	06.50 c	7.72 bc
$LSD_{5\%} = 1.84$			

Results clearly showed that Paddy Husk is superior to Tea waste when used in mixture, in relation to root weight. The difference is more pronounced in the presence of dazomet, than with Metam or Neemazal.

Table 08- Influence of Chemical Nematicides on root growth

Treatment	Root weight per plant (g)
Metam	7.22 b
Dazomet	8.98 a
Neemazal	8.12 ab

Results

The three treatments were significantly different from each, dazomet eliciting best root growth. Interaction between nematicide and solarization was statistically significant.

Table 09 - Nematicide X Solarization Interaction
Growth Assessment at 09 months from putout cuttings (Handford Estate, Deniyaya) (2002)

Main Plot	Sub sub plot	Tea Waste mixed with Soil	Paddy Husk mixed with Soil
SS Prior to mixing	Metam	6.03 d	06.57 d
	Dazomet	6.57 d	09.07 b
	Neemazal	6.97 d	08.17 b
SS after mixing	Metam	6.90 d	09.37 b
	Dazomet	6.43 d	13.87 a
	Neemazal	8.47 c	08.87 c
	$LSD_{5\%}$	1.31	1.31

The above analysis shows that tea waste X solarization or tea waste X chemical treatment interactions are not significant other than with Neemazal application under solarization after mixing. On the other hand, paddy husk influenced the effect of other treatments. Paddy husk gave higher root growth in the presence of dazomet under solarization of either type. However, the best root growth was produced in paddy husk in the presence of dazomet and solarization of mixed medium. In the presence of metam too, paddy husk gave good root growth under solarization of the medium after mixing.

At this early stage, the interactions between treatments did not have any influence over other growth parameters.

2. Nayabedda Estate, Bandarawela (Uva):

Main treatments (2SS)

a.) with 6-week Soil Solarization,

b.) Without Soil Solarization

Sub plot treatments (3M)

a.) coir dust

b.) paddy husk

c.) infested soil

Sub sub treatments (chemical nematicides) (4N)

a.) Metam sodium at 300ml per cubic meter soil (half of recommended dose)

b.) Dazomet at 250 g per cube of soil (half of recommended dose)

c.) 'Neemazal F'30 ml per plant of diluted Neemazal' (dilution: 3ml in 5 liter water / 1/5 of recommended dose)

d.) untreated control

The trial was initiated with soil solarization where, in September, 2001. Growth assessments were carried out at 03 months from planting cuttings (February 2002). There were no statistically significant differences between treatments, at this stage.

3. Rangala Estate, Rangala (mid country):

The experimental design and other details are the similar to those as at Nayabedda trial, but the experiment was initiated in 2002.

4. Diyagama East Estate, Diyagama (up country)

The trial was initiated with soil solarization in September 2001 and the cuttings were planted in November 2001. Growth assessments were carried out at 03 months from planting cuttings (February 2002). There was no statistically significant difference between treatments, at this stage.

5. Discussion

The test materials have been evaluated with reference to two aspects.

i. Nematicidal activity

ii. Increased Growth Response (IGR)

All three organic substances were found to have equal nematicidal activity. The different arrangements in which they were used (in layer; in mixture or 100%) had no influence over their nematicidal activity.

The organic materials were different in terms of their influence over the growth of the plants. The different arrangements too had different effect on the plant growth. Tea waste in layer (TW 1/1) gave the highest increase in growth. TW 1/1 was superior to tea waste in mixture with soil (TW 1:1) which was marginally better than paddy husk in either arrangement (PH 1:1 and PH 1/1). There was no significant difference between the Paddy husk treatments and Methyl Bromide treatment in terms of overall growth at the mid country location. However, Paddy husk in mixture (PH 1:1) induced higher growth at Deniyaya when compared to tea waste in mixture. In the IPM trial, the effect of paddy husk was further enhanced by the presence of chemical nematicides. Dazomet at half the recommended dosage gave the highest synergistic effect to paddy husk.

The fundamental studies showed that the age of Paddy husk is immaterial when it is used as a soil substitute. Paddy husk changes very little with time when unbroken material is used. The broken Paddy husk (PH-L) absorbed moisture and decomposed comparatively faster than the unbroken type (PH-J). The small difference between the two types is small enough to be ignored.

Coir dust had a high moisture content at all ages even though the change was more rapid after 2 months. Due to this high moisture content it undergoes changes faster than other media. For the same reason the medium is more compact from the initial stages and therefore can hold the single inter-node cutting even in 100% organic media.

Coir dust encouraged more root proliferation than Paddy husk. Vidanaarachchi and Somasiri (1997) showed that total N of the coir dust increased with time and attributed it to either accumulation of N though rainwater or release of N- compounds during the process of microlization during decomposition. They also reported that nutrient retention capacity of coir dust increased with ageing of coir dust. Thus the profuse root growth from the very initial stages in coir dust may be due to an increase in available N. However, the overall growth in the untreated control and dazomet treatment at the stage of transplanting was comparable to coir dust and paddy husk.

On the other hand, ageing of discarded tea waste decides the degree of decomposition and the moisture content of the material. Tea waste produced nitrogen deficiency in the form of yellowing of the foliage, at 4 month stage. This is in agreement with Krishnapillai's (1979) and Zoysa, *et al.*'s, (unpublished) findings. However this yellowing was corrected with the fertilizer application, and did not cause any set back in the growth.

Dazomet gave the best synergistic effect with Paddy husk, when the medium components were mixed prior to solarization.

Conclusions and Recommendations

6. Conclusions and Recommendations

Refuse tea (Tea waste), Coir dust and Paddy husk are all nematicidal in nature and suitable as soil substitutes in tea nurseries:

The following criteria should be adhered to at using soil substitutes.

1. Age of the Organic Material:

i. Paddy Husk -	Fresh material can be used in all tea areas.
ii. Tea Waste -	must be well decomposed prior to use; a period of 6 months of exposure to the element is adequate.
iii. Coir dust -	decomposed over a minimum period of 2 months.

2. Method of Incorporation:

i. Paddy Husk -	Mix with soil in equal proportions;, When fresh paddy husk is used wet the material prior to mixing.
ii. Tea Waste -	Preferably in two layers with soil at the top or mixed with soil in equal proportions;
iii. Coir Dust -	can be used in any one of the 3 combinations a. 100% Coir Dust b. in layer arrangement with soil at the top c. mixed with soil at 1:1 proportion

3. Synergists

Mix half the recommended dosage of dazomet with the soil and then mixed with paddy husk before solarization of the mixture, over 6 weeks.

Either "Neemazal TS" at the recommended dosage or Metam sodium at half the recommended dosage can be used in place of dazomet, together with solarization of the mixed medium to enhance the effect of organic soil substitutes.

07. References

Anandappa, T.I. and Kathiravetpillai, A. (1995)., VP Tea Nursery Management *Field Guidebook*, The Tea Research Institute of Sri Lanka, (1995) p. 10-17.

Anon, (1939). Propagation of tea by single internode cuttings in Peat moss. Tea Quarterly, Vol 12, P. 50-51. Proceedings of the 6th Conference of the TRI.

Coelho L., Chellemi, D.O., and Mitchell, D.J. (1999). Effects of solarization and cabbage amendments for the control of Phythophthora spp. in north Florida. *Plant Disease* 83: 293-299.

Cresswell,G. (2002). Coir dust a proven alternative to peat. *www.cocopeat.com.au.*

D'Addabbo,T.and Sasanelli,N.(1998). The suppression of *Meloidogyne incognita* on tomato by grape pomace soil amendments. *Nematol. medit.*, 26: 145-149

Di Vito, M., Zaccheo, G., Catalano, F. and Campanelli, R. (2000). Effect of soil solarization and low doses of fumigants on control of th root know nematode *Meloidogyne incognita.* Proc. IS Chemical and Non-Chemical Soil and Substrate Disinfestation Eds. M.I. Gullino, J. Katan, A. Matta. Acta. Hort. 532, ISHS 171-173.

Elias., A.L.(1961), Nursery Management. Tea Quarterly, 32 : 42-50

Evans, M.R., Sreenivas, K. and R.H. Stamps. (1996). Source variation in physical and chemical properties of coconut coir dust. *Hort Science,* 31 (6): 965-967.

Gadd, C.H. (1928a). Water Culture Experiment (I) Tea and Soil Acidity. *Tea Quarterly,* 1, p 2-6.

Gadd, C.H. (1928b). Water Culture Experiment (II) Tea and Soil Acidity. *Tea Quarterly,* 1, p 31-35.

Gamliel, A. (2000). Soil Amendments: A Non Chemical Approach to the Management of Soilborne Pest. *Proceedings of Fifth Internationa Symposium on Chemical and Non-Chemical Soil and Substrate Disinfestation* Eds. M.L. Gullino, J. Katan, A. Matta, Acta Hort. 532, p. 39-47.

Katan, J. (2000). Soil and substrate Disinfestation as influenced by new technologies and constraints. *Proceedings of Fifth Internationa Symposium on Chemical and Non-Chemical Soil and Substrate Disinfestation*. Eds. M.L. Gullino, J. Katan, A. Matta, Acta Hort. p 29-35.

Kerr, A and Vithylingam, M.K (1966). Fumigation of nursery soils with Methyl bromide, *Tea Quarterly,* 37,p. 162.

Konduru, S. and M. Evans and R. Stamps. (1999). Coconut husk and processing effects on chemical and physical properties of coconut coir dust. *Hort Science* 34(1): p 88-90.

References

Krishnapillai, S. (1979). Inhibition of nitrification by waste tea ("Tea fluff"). *Plant and Soil* 51, p 563-569.

Lamb, J.1955. The condition of tea soils. *Tea Quarterly*. 26, p. 16.

Manici, L.M. Lazzeri, L., Baruzzi, G., Leoni, O., and Palmieri, S. (1998). Brassicaceae with High Content of Thiofunctionalized Glucosinolates as Green Manure to Control Soil-Borne Pathogens. *Proceedings of 7th International Congress of Plant Pathology,* Edinburgh, 9-16 August 1998.

Mateeva, A. and Ivanova, M. (2000). Alternative Methods for Control of Root-Knot Nematodes, *Meloidogyne spp. Proceedings of Fifth Internationa Symposium on Chemical and Non-Chemical Soil and Substrate Disinfestation* Eds. M.L. Gullino, J. Katan, A. Matta. Acta Hort. 532, ISHS 2000. p. 109-111.

Sivapalan, P., Gnanapragasam, N.C. & Jebamalai, A.S. (1980). Treatment of nursery soils with Dazoment 98% granular (Basamid) as an alternate method of control of the root lesion nematode *Pratylenchus loosi* of tea. Tea Q. 49: 134-136.

Stamps, R. and M. Evans. 1997. Growth of *Dieffenbachia maculata* 'Camille in growing media containing Sphagnum peat or coconut coir dust. *Hort Science,* 32(5): p 844-847.

Stamps, R. and M. Evans.1999. Growth of *Draceana marginata* and *Spathiphyllum* "Petite" in Sphagnum peat and coir dust-based growing media. *Journal of Environmental Horticulture* 17(1): p 49-52.

UNEP (2000a). Case Study 3: Tomatoes in New Zealand : Substrates and *Trichoderma* (contact:Hunt,John,S). Case Studies on Alternatives to Methyl Bromide Technologies with Environmental Impact. UNEP.

UNEP (2000b). Case Study 9: Strawberry in Scotland: Natural substrates (contact Mr. Henk Nuyten, Netherlands).

Vavrina, C.S., Armbrester, K., Arenas M. and Pe, M. (1996). Coconut Coir as an alternative to Peat media for Vegetable transplant production. *SWFREC Station Report* - VEG 96.7.

Vidhanaarachchi, L.P. and Somasiri, L.L.W. (1997). Use of Coir Dust on the productivity of coconut on sandy soils. *COCOS*, 12, p 54-71.

Visser, T. and Kehl, F.H. (1958). Selection & Vegetative Propagation of Tea. *Tea Quarterly,* 29, p. 76-86.

Vitarana, Sushila.I., Liyanage, D.D., Herath, U.B., Navaratne, N., Prematunge, A.K., Udamulla, P. and Jayawickrama, P.K. (2001). Methyl Bromide Substitute for usage on Tea Plantations with Special Reference to Eradication of Phytophagous Nematodes, Proceedings of the 2001 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, California, 136-1 to 136-5.

This volume is one in a set of monographs prepared to introduce new techniques to control phytoparasitic nematodes of tea (*Camellia sinensis,* Kuntze). The information contained in this monograph is based on research conducted over a period of two years on nematicidal agents alternative to methyl bromide. Research was sponsored: by United Nations Development Programme (UNDP).

For more information contact:

The Director

The Tea Research Institute of Sri Lanka
Talawakelle
Sri Lanka.

Tel. : 00-94-5258230, 00-94-5122601
Fax : 00-94-5258229
e.mail : <tri@slstinet.ac.lk>, <postmaster@tri.ac.lk>
<triratn@lanka.ccom.lk>, <vitaranasi@hotmail.com>

Kalyani Graphics Tel: 531628, 572647

Editorial Assistance :

Shyamantha Bandara

Design and Layout :

S.A. Naleen Nisshantha Ratnapala

Secretarial Assistance :

Chapa Munasighe