KFRI Research Report No. 215

ISSN 0970-8103

TERMITE CONTROL IN CLONALLY PROPAGATED ROOT TRAINER RAISED PLANTING STOCK

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September 2001

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(Report of the project KFRI 288/98, sponsored by Kerala Forest Department, Jan.1998-June 2001)

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ABSTRACT OF THE PROJECT PROPOSAL

1. Project No.	:	KFRI 288/98
2. Title:	:	Termite control in clonally propagated root trainer raised planting stock
3. Objectives	:	1. To study the nature and severity of termite damage in clonally propagated eucalypt plantations. 2. To standardise an effective method of treatment against termites attacking clonally propagated root trainer raised eucalypts.
4. Date of commencement	:	January 1998
5. Scheduled date of completion	:	June 2001
6. Funding agency	:	Kerala Forest Department
7. Principal Investigator	:	R.V. Varma
Project Fellow	:	P.R.Swaran
8. Study area	:	Selected clonal plantations raised by KFDC/KFD, and Kottappara for field trials.

CONTENTS

ABSTRACT

In recent times, Eucalyptus *and many other forest tree species are being raised in root trainers using clonal material. Most of these planting stock, especially eucalypts, are liable to be attacked by termites during the establishment phase, if prophylactic measures are not adopted. The method standardised by KFRI in the past was to drench the basketed seedlings at the nursery site with an organophosphate insecticide such as chlorpyriphos. This method may not prove effective for root trainer raised clonal material. Therefore, the present study was carried out to standardise an effective and safe method to protect root trainer raised planting stock from attack by subterranean termites. Attempt was also made to assess the nature and intensity of termite attack in clonal plantations of eucalypts.*

Information gathered from selected clonal plantations of eucalypts showed that the intensity of termite attack varied from 0 –20 %. Root trainer raised Acacias and teak was also found attacked by termites. Damage to transplanted teak seedlings by termites is reported for the first time. A comparison of the various potting media indicated that clones/seedlings raised in vermiculite is the least susceptible to termite attack.

Among the various treatment methods evaluated under field conditions, dipping the root trainer contained clonal planting stock in a 0.5% a.i. solution of chlorpyriphos before planting out gave adequate protection against termites during the establishment phase. This treatment methodology was field tested at Kottappara in Malayattur Forest Division and also in 10 ha eucalypts clonal plantation raised by Kerala Forest Development Corporation at Mannamangalam in Trichur Forest Division and proved effective. Though the treatment was standardised for eucalypts, other species of planting stock can also be treated in the same manner to contain damage by subterranean termites.

Remedial treatment in the field like application of insecticide solution around the base of the plant once termite infestation is noticed will be costly, labour intensive and can only be partially effective when carried out in a large scale.

The termite fauna in the experimental area showed that majority of the termites collected belong to the family Termitidae.

1. INTRODUCTION

Several forest tree crops are prone to attack by termites during different stages of their establishment (Thakur and Sen-Sarma, 1980). Among the forest plantations, eucalypts suffer the most damage due to subterranean termites during the initial stages of establishment in India and in many other tropical countries (Nair and Varma, 1981; Sen Sarma 1986; Nair *et al.*, 1986; Cowie *et al.*, 1989; Varma, 1990). In general, exotics are more liable to be attacked than indigenous tree crops. The nature and severity of damage can vary depending on the climate, edaphic factors and the population density of termites in a given area (Wardell, 1987).

Root feeding subterranean termites cause the maximum mortality in forest nurseries and out planted young plantations. Damage is usually severe during the dry season than in the wet season. It is generally held that temporal distribution of rain is more important than the annual precipitation as far as the termite attack is concerned, but Nair and Varma (1981) did not find any positive correlation between drought and termite incidence. In certain regions, moisture related foraging patterns of some termite species have been reported (Roonwal, 1979).

Several species of termites belonging to the genus, *Odontotermes* are the major culprits that damage eucalypts in India (Roonwal, 1979; Nair and Varma,1981, 1985; Varma, 1990). *O. obesus* also attacks transplants of Poplar and Sisso, in addition to eucalypts. It may also be mentioned that of the 280 and odd termite species known from India only 40 are considered as pests (Varma, 1990).

The intensity of damage due to termites can vary from locality to locality. The management strategy will also differ depending on the termite species involved. It is also possible that the termite attack can increase on account of faulty cultural management practices such as transplanting shock, use of unhealthy seedlings, removal of woody debris from the planting site etc. In general, the management of termites is aimed mainly:- i) to prevent termites gaining entry to the transplants, ii) to reduce the termite population in the vicinity of the out-planted seedlings and iii) to provide barriers to prevent termite attack.

Control of termites in forest plantations in the past had been relied mostly on cyclodiene insecticides *viz.* Aldrin, Heptachlor and Chlordane as a soil treatment. Based on field trials conducted from 1976-1980 (Nair and Varma, 1981), a treatment methodology to control subterranean termites attacking eucalypts was standardised using cyclodiene insecticides. The method standardised was to drench the polythene container seedlings at the nursery site, before planting out in the field. No post planting treatment was recommended. This method was effective and practised by the Forest Department. However, consequent to the increasing concern over the health hazards and long persistence in the environment, the cyclodiene insecticides were phased out or banned by 1994. Thus efforts were made to look for alternatives. Based on another field trial from 1993-1996, Varma and Nair (1997) recommended the use of a less persistent organophosphate insecticide, *viz.* chlorpyriphos to control termites attacking eucalypts. Others have also made similar recommendations (Mauldin *et al.*, 1987; Yoshioka *et al.*, 1991). Currently a number of insecticides such as Chlorpyriphos, Insofenphos, Permethrin etc., are in use as termiticides.

Though non-chemical control of termites is attracting renewed interest on account of the possible ill effects of chemical pesticides on the environment, there is little promise to date. The lack of critical evaluation of some of the laboratory results under forestry conditions makes it unreliable (Logan *et al.*, 1990).

Clonal plantations, especially of eucalypts, are of recent origin and are being raised in many states of India and elsewhere. The benefits of clonal plantations in terms of increased productivity and crop homogeneity are well established. In Kerala also, raising clonal plantations are on the increase and has been recommended as a strategy to improve productivity of eucalypts under World Bank aided Kerala Forestry Project. But information on the nature and intensity of termite attack in such plantations is not available. There is also wide variation in the potting medium being used. Another development along with this is the use of root-trainers in place of the conventional polythene bags. Because of the small quantity of potting medium in the root trainers (150 cc), the treatment methodology standardised earlier for polythene bag raised seedlings may not be effective. Recommendation to treat the planting stock raised in root trainers, against attack by subterranean termites, is not available.

Preliminary observations showed that the termites attack the out-planted clonal eucalypt plants at the stem portion from the sides, ring-bark and cause death of the seedlings, in addition to the typical root feeding damage. Hence, there was a need to look at this problem afresh and methods developed to protect the root trainer-raised planting stock from termite attack. The main objectives in the present project were – to study the nature and severity of termite damage in clonally propagated eucalypt plantations and to standardise an effective method of treatment against termites attacking clonally propagated root trainer-raised planting stock.

2. MATERIALS AND METHODS

2.1. Termite damage intensity in root trainer raised planting stock

Intensity of termite damage of eucalypt was assessed in clonal plantations raised by the Kerala Forest Development Corporation (KFDC) at Mayannur, Arippa and Mannamangalam and also at Mekkappala, raised by the Kerala Forest Department (KFD). In the above plantations, either sample plots were taken and observed or general observations were made for over 1 year after planting out and data generated on termite attack. The clonal material supplied to the plantations raised by KFDC was from ITC Bhadrachalam, Andhra Pradesh and for KFD, Kerala Forest Research Institute (KFRI) supplied the planting stock.

2.2. Evaluation of different potting media to termite attack

A field trial was carried out to evaluate the susceptibility of termites to eucalypts grown in different potting media. For all the experiments root trainers of 150 cc were procured from Milton Plastics, Mumbai. The potting media evaluated were as follows:

1. Vermiculite
2. Soil
3. Compost
4. Compost and soil in the ratio 1:1
5. Vermiculite and soil in the ratio 1:1
6. Compost and vermiculite in the ratio 1:1
7. Compost, vermiculite and soil in the ratio 1:1:1

For the above field trial, *Eucalyptus tereticornis* seedlings were used. When the seedlings got established in the root trainers, they were planted out in the field in a randomised complete block design. There were three replicates with 30 seedlings for each treatment and the trial was laid out in July 1999. Different potting media were analysed to find out the pH, organic carbon, calcium, magnesium and water holding capacity.

Observations were taken periodically on the incidence of termite attack and also on other mortality factors, if any, for 2 years. Height measurements were also taken at 6- monthly interval.

2.3. Planting stock for field trials

Eucalyptus tereticornis used for the field trials were produced at Kottappara in the Malayattur Forest Division in the Central Circle. The area was planted earlier with *E. tereticornis* for more than one rotation.

The clonal material was prepared as per methods standardised by Balasundaran *et al.* (2000). Forty five to 60-day-old coppice shoots were harvested and brought to the mist chamber and processed as follows:- two-leaved, single node cuttings were prepared, leaves cut to about quarter to half length to reduce transpiration. The cuttings were sprayed with 0.1% Bavistin 50WP to prevent fungal infection. The lower portions of the cuttings were treated with rooting hormone mixed with talcum powder, and then planted in root trainers containing horticultural grade vermiculite (Keltech Energies Ltd. Bangalore). The root trainers were then kept on stands and placed in field mist chambers for rooting of cuttings. The cuttings were removed from the trenches after 3 weeks and kept outside for hardening.

2.4. Field trial I

Eight different treatment combinations were field-tested and the plots laid out in July 1999. The experimental design used was Randomised Complete Block Design with three replicates for each treatment. The various treatments tested were as follows: – two emulsified concentrate formulations,- Chlorpyriphos- DursbanTC 20EC (De NOCIL) and Lindane -Kanodane 20EC (Kanoria Chemicals & Industries Ltd.) and a granular formulation of Lindane - Kanodane 6G (Kanoria Chemicals & Industries Ltd.). Desired concentrations of the EC formulations were prepared and the root trainer blocks with clonal eucalypt were dipped for a minute, drained and kept on the stand for a day or a few days before planting (Figs.1-3). The granular insecticide was measured out (3g) in a plastic spoon and sprinkled around the seedlings within the root trainer containing the potting medium.

Two fungi, *viz. Metarhizium anisopliae* (Metschn.) Sorok and *Beauveria bassiana* (Bals.) Vuill., have been credited to offer some measure of control against termites, but not supported by field data. Under this trial the effectiveness of *M. anisopliae* was field-tested. The culture of *M. anisopliae* var. *major* for the trial was obtained from CPCRI, Kayamkulam and sub cultured at KFRI. The fungal spore suspension prepared in sterile water was applied at the rate of 5 ml per plant (10^7 spores/ml). The spore suspension was taken in a measuring jar and poured around the plant within the potting medium (Fig.4). The fungal culture was prepared in potato-dextrose-agar (PDA) medium and 14-day-old cultures were used for making the spore suspension.

Physical barriers have been suggested to prevent termite attack and hence a polyurethane strip (size 10 x 3 x 1 cm) was placed around the root portion, covering up to the stem and placed intact before transplanting into the root trainer and filled up with the potting medium. When the seedlings got established in the root trainer

(Fig.5), these were planted out in the field with the polyurethane barrier surrounding the plant.

In general, the effect of a cover crop on termite incidence in the case of field crops is not known. Thus a cover crop, *viz*, *Stylosanthes hamata,* an exotic legume of Australian origin was planted around the plants in the planting row just before the field plots were laid out.

During the first year of the project, field trials could not be laid out due to practical reasons. However, during this period small-scale pot trials were carried out in root trainer-raised eucalypt seedlings to arrive at suitable concentrations (dosages) of insecticides for dipping treatment as well as granular insecticide application. The dosages used for field trials i.e. 0.5% solution in the case of EC formulation and the granular insecticide 3 g /plant, were arrived at based on these pot trials.

2.5. Field trial II

This trial was also laid out at Kottappara during July 2000. The treatments, which were effective in the Field trial I, were included. Five treatments were field-tested which included EC formulations of both chlorpyriphos and lindane and the granular insecticide (lindane G). In the absence of Dursban TC in the market, the chlorpyriphos used in this trial was Durmet 20EC (Cyanamid India Ltd.). In the case of lindane EC, the 1st trial showed large-scale non-termite mortality and therefore a lesser dosage, 0.25%, was used. Also the scope of using the fungus *M. anisopliae* was further evaluated. Soil sample was collected from the field after six months to locate the presence of the fungus using dilution plate method.

Fig.1. Dipping the root trainer block with clones in the insecticide solution

Fig.2. Draining out the excess insecticide solution

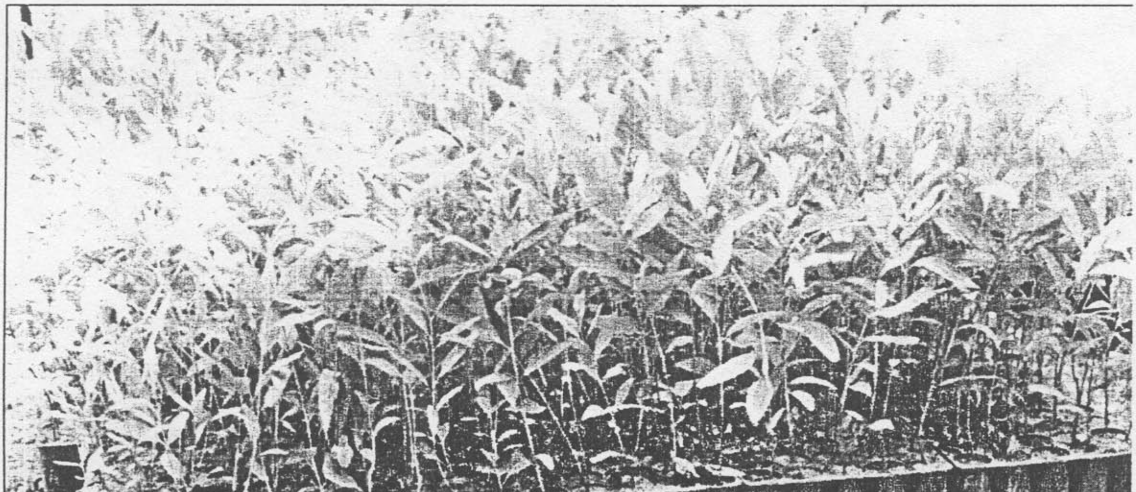

Fig.3. Four-month-old eucalypt clones after dip treatment

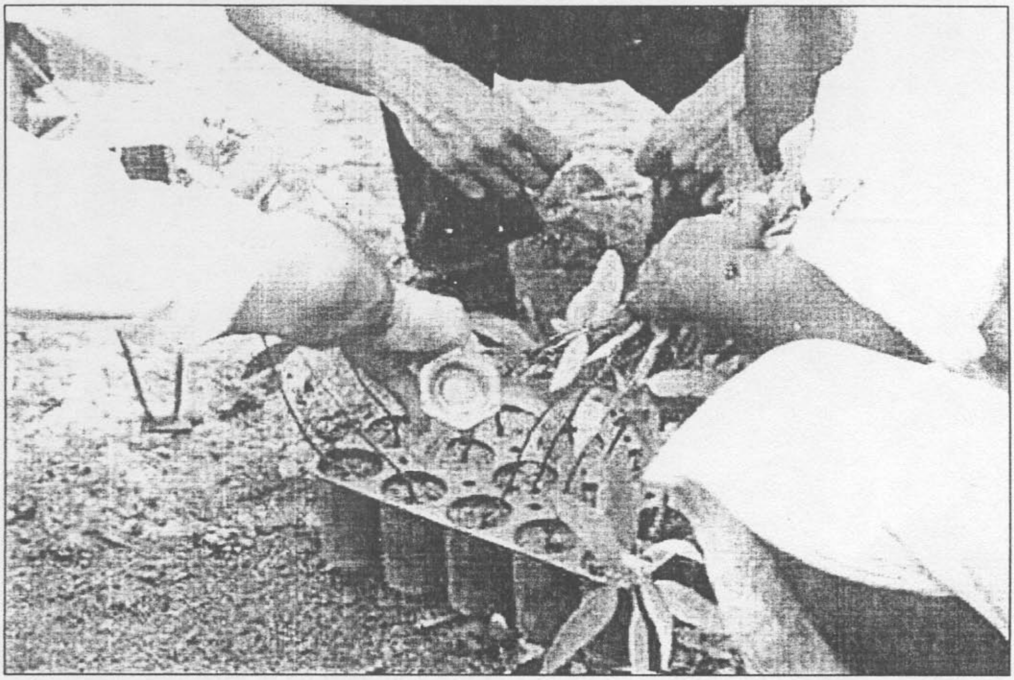

Fig.4. Application of fungal spore suspension

Fig.5. Polyurethane physical barrier fixed around the roots.

It is reported that wood ash has termite repellent properties, but without proper evaluation. Hence an additional treatment was tried with a mixture of vermiculite and wood ash at the ratio of 3:1 as potting medium to test the termite repellent properties of wood ash.

A large-scale trial was also laid out covering half a hectare and planted up with root trainer raised planting stock dipped in 0.5 % solution of chlorpyriphos, and planted with a spacing of 1m x 1m.

2.6. Recording of observations

Each seedling was identified by its location in the field with a number and recorded on observation sheets. Monthly observations and more frequent observations during the initial months after planting out were made. The cause of mortality was recorded and wherever termite attack occurred, the reason for primary causes of death confirmed by excavating the root system. The termites causing death of eucalypt were also got identified.

2.7. Data analysis

For each treatment, the number of seedlings lost due to causes other than termite attack was deducted from the initial number (i.e. total number of seedlings planted initially) to get the 'effective number' of seedlings. The saturated log-linear model was found to be appropriate and applied to the data sets to test the significance of the treatment effect on mortality due to termite.

The mathematical form of the model applied was:-

$$ln\ (Fijk) = \mu + \lambda_i^{M} + \lambda_j^{T} + \lambda_k^{R} + \lambda_{ij}^{MT} + \lambda_{ik}^{MR} + \lambda_{jk}^{TR} + \lambda_{ijk}^{MTR}$$

Where *Fijk* is the frequency in the cell, μ is the grand mean,

λ_i^{M} is the effect of the i th category of mortality due to termite attack (yes / no),

λ_j^{T} is the effect of the jth treatment category, λ_k^{R} is the effect of the kth replication,

λ_{ij}^{MT}, λ_{ik}^{MR}, and λ_{jk}^{TR} are two way interaction terms, and λ_{ijk}^{MTR} is the three way interaction term

This model was subjected to backward elimination procedure. The significant terms that emerged out of this procedure was interpreted.

The height measurements were subjected to ANOVA to test the significance of difference in height increment of plants raised in various potting media.

2.8. Diversity of termite fauna in the experimental area

In order to assess the abundance and diversity of termite fauna in the experimental area, termites were collected following a transect method (Jones and Paul, 2000). The procedure followed was as follows:

A 100m transect of 2m width was laid out along the experimental area. The transect was further divided into 20 plots of 5m x 2m area and one hour sampling effort was made per each plot to collect the termites.

3 RESULTS AND DISCUSSION

3.1. Termite damage in clonal plantations of eucalypts and other forestry species

Mayannur

At Mayannur, 5.2ha were raised as clonal plantations of eucalypts and the planting stock supplied by ITC Bhadrachalam. Basic information on anti-termite treatments either given prophylactically or after planting out was not available. Only the incidence of termite damage in this plantation was observed. The potting media used was vermiculite. Here, about 4% of clonal plantings were found attacked by termites. BCM-10 clones were more susceptible compared to BCM-3 and BCM-8.

Arippa

At Arippa, 9ha were planted up with clonal eucalypts supplied by ITC Bhadrachalam. The incidence of termite attack was about 5% initially after planting out in the field. However, post-planting treatment using chlorpyriphos was given later on and therefore observations were discontinued after six months.

Mannamangalam

At Mannamangalam, 10ha area was planted with the clonal material procured from ITC Bhadrachalam during July 1999. However, before planting out in the field, the root trainer blocks were dipped in a 0.5% solution of chlorpyriphos (DursbanTC 20EC) as per the recommendations of KFRI . Two hundred and fifty seedlings in a corner of the 10ha plot was left untreated. Continuous observations taken for more than 8 months showed that there was no termite attack, in the whole 10ha area, which was planted up with, treated plants. Field data obtained thereafter through the KFDC field staff for more than 1 year confirmed the effectiveness of the treatment in the treated area. About 3% of the seedlings were found attacked by termites in the untreated 250 plants and some of them were secondary in nature. The termite fauna in the area was rich as evidenced by the termites collected from the tree stumps and leaf litter. However, the intensity of attack, in the untreated group of plants was also very low.

Mekkappala

At Mekkappala, in Malayattur forest division, soon after planting in July 1999, there were lot of termite damage. *Odontotermes ceylonicus,* reported earlier as a eucalypt root-feeding termite (Nair and Varma, 1985) was found to attack the roots. The damage intensity was about 20%; seedlings were fully eaten up by termites. At Mekkappala, the eucalypt clonal planting stock was supplied by KFRI and at the time of distribution, no prophylactic treatment against termites was given. Hence the casualty was replaced with fresh planting stock and a post planting treatment using 0.5% chlorpyriphos was given. A few holes were made in the soil with a stick around the plants and about 200 ml of the insecticide solution was poured. Further observations did not show symptoms of termite attack. But post-planting treatment in a large scale may not be practicable.

Kariem Muriem

Root trainer raised clonal planting stock of *E. tereticornis* and *E. camaldulensis* planted in 1 ha area at Kariem Muriem at Nilambur during August 2000 suffered heavily due to termite attack up to six months, after planting out in the field. ITC Bhadrachalam supplied the clonal material and it was reported by the local staff that a post planting treatment was given when termite infestation was noticed initially. However, the treatment would not have been effective as evidenced by the onslaught of termites again in the plantation. In some cases, the bark of the plants was almost fully covered with mud-plaster and the damage extended even beyond the outer bark. In addition, root coiling and subsequent attack by termites was also observed.

Meenmutty

At Meenmutty of the Nagarampara Range of Kothamangalam Forest Division, *Acacia auriculiformis* was planted in 63.5 ha. The seedlings were raised in root trainers in the central nursery at Nilambur. About 2% of the seedlings were found damaged due to termite attack within two months after planting out in the field.

Kannimala

At Kannimala, in Erumeli Range of the Kottayam Forest Division, root trainer raised planting stock of teak from Nilambur/Kannur central nurseries was attacked and killed by termites within a week after planting in June 2000 (Figs. 6 & 7). About 20% of the teak saplings were lost. Since the damage was very much conspicuous, the planting was temporarily withheld and further continued only after dipping the root trainer blocks in a solution of 0.5% chlorpyriphos. The lost seedlings were replaced with treated ones. At the time of observation within three months after planting, around 10 plants were found attacked by termites. Further observations did not show termite incidence. The plants also picked up growth at a faster rate, which would have given some level of resistance to termite attack.

Based on the above data, the incidence of termite attack in clonal plantation of eucalypts is less compared to seedlings- raised plantations where the intensity of attack in untreated seedlings was over 80 % (Nair and Varma, 1981). The present data on clonal plantations of eucalypts cannot be generalised because we get lot of reports from various sources, including the forest department field staff, on extensive damages caused by termites in root trainer-raised clonal material/seedlings, if no prophylactic treatment is given. Among the observation areas, the termite incidence was almost nil in the treated 10 ha area at Mannamangalam, and was very low in the untreated area. One possibility could be the inherent resistance by some of the clones against termites. Another reason could be the potting medium; generally, attack of termites in vermiculite-raised seedlings is less. Yet another reason could be the planting at the correct time, adoption of good cultural practices in the plantation, which in turn would have increased the plant vigour. Earlier studies (Nair and Varma, 1985; Varma and Nair, 1997) have also shown that the incidence and severity of attack by termites vary from location to location and also over the years. Many other factors including edaphic, cultural practices and environment can influence the severity of attack. In spite of the fact that all the plantations surveyed had a good termite fauna, the incidence of attack varied from 0-20%. Unlike in the case of seedlings, where termite damage occurs during the first year (Fig.8), the observations in clonal plantations showed the incidence to be confined mostly to the initial 3-4 months (Fig.9). Afterwards the plants probably derive some inherent resistance due to increased growth.

Another noteworthy observation made was the attack by subterranean termites on root trainer raised seedlings of teak. This is for the first time that termites damaging the roots of young out-planted teak saplings has been noted. Earlier, Roonwal (1954) had reported severe attack on the bark of standing teak in Uttar Pradesh, but later considered to be of secondary in nature. Attack by *Neotermes tectonae* on living teak in Indonesia is also known (Kalshoven, 1954). Further detailed observations on the incidence of termite attack in clonal teak in different localities will be required to assess the damage intensity. The present observations also revealed that termite attack is possible in other root trainer raised planting stock such as *A. auriculiformis* and *A. mangium,* in addition to teak. All these observations indicate that irrespective of the tree species, all the root trainer raised planting stock may require a prophylactic treatment against attack by subterranean termites.

Fig. 6. Teak seedling damaged by termites

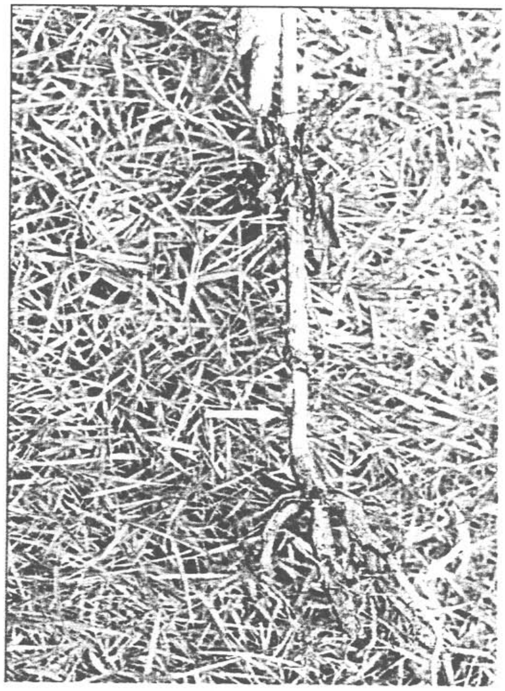

Fig.7. Nature of damage caused by termites to teak

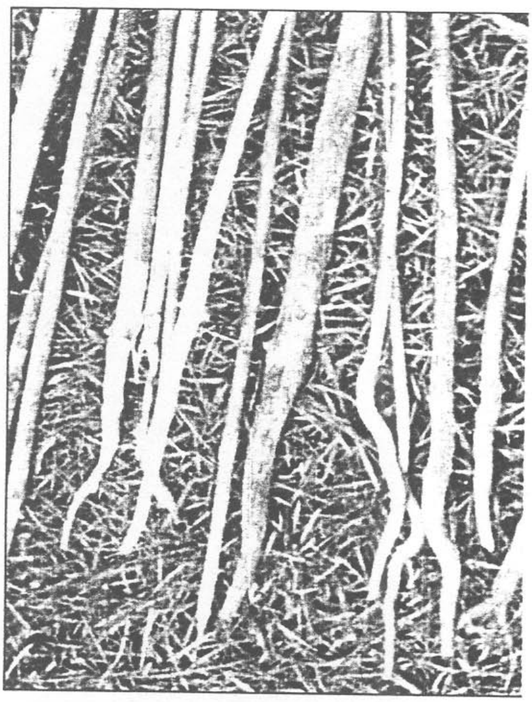

Fig.8.Termite attack in one-year-old eucalypt seedlings

Fig.9.Termite attack in young eucalypt clones

3.2. Effect of potting media on termite incidence

The various potting media either alone or in combination (Table 1) were prepared, filled in root trainers and planted up with *E. tereticornis* seedlings. The performance of the seedlings was observed in the root trainer itself for over two weeks; watering was done. Within 7-10 days, seedlings planted in compost showed symptoms of wilting in a number of cases. Some of the seedlings transplanted into vermiculite alone or in combinations with soil showed symptoms of wilting. A few seedlings also showed fungal attack which were treated with 0.05% Bavistin. Later on the seedlings were planted out in the field.

Based on the field data generated during one-year period, the least incidence of termite attack was observed on seedlings raised in vermiculite (Table 1). Seedlings raised in both soil and compost were highly prone to attack by termites. Analysis using log-linear model revealed that mortality due to termite attack varied significantly among different potting media (Chi-square value 16.39, $P>0.05$). However the model indicated that mortality due to termite attack was significant in the soil medium ($\lambda = -0.4409$, $Z = -2.99$)

In the case of media containing compost and soil, it is likely that termites may get attracted because of the presence of organic matter. Vermiculite is an inert material and it is possible that termites may avoid this compared to media containing soil and other organic materials such as compost.

Most incidence of termite attack was observed during the initial months after planting out in the field (Fig. 10).

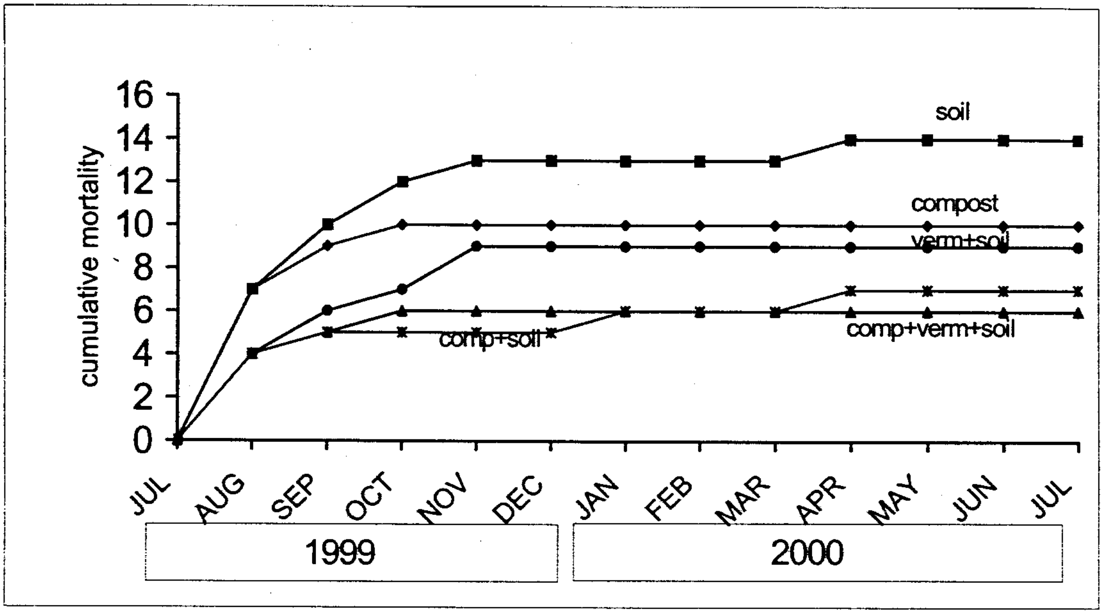

Fig. 10. Incidence of termite attack on eucalypts grown in different potting media during the first year, after planting out.

Table 1. Incidence of termite attack on seedlings raised in various Potting media

Potting medium	Total plants	Effective No.	Mortality due to termite attack (%)
Soil	90	63	22.2
Compost	77	60	16.7
Vermiculite + soil	88	75	12.0
Vermiculite + soil + compost	91	78	9.0
Compost + soil	85	79	8.9
Compost + vermiculite	79	63	7.9
Vermiculite	86	66	6.1

The height measurements taken at 6-monthly interval showed that seedlings raised in compost had maximum increment in height and those in soil had the minimum after six months. The growth of seedlings in vermiculite was in between (Table 2). However, the results of ANOVA showed that the increment in height over 6 months as well as over 2 years did not differ significantly among plants grown in various potting media (F-value=1.832, P>0.05 and F-value=1.571, P>0.05 respectively).

Table 3 shows some of the properties of the various potting media tested in this trial. Most of the available information such as pH, water-holding capacity, Ca, Mg etc are from the termite mound soil (Lee and Wood, 1971). The present data are not based on the termite activity in different potting media and therefore does not convey much in terms of preference to any particular potting medium. Usually the organic carbon content of termite mound soil is rich. Here, only the compost contained higher percentage of organic carbon. Increased water holding capacity is also reported to be correlated with organic matter content (Pathak and Lehri, 1959).

Table 2. Height of seedlings raised in various potting media at 6 and 24 months

Sl. No.	Sample	Height at 6 months (m)	Height at 24 months (m)
1	S	0.91	3.31
2	C	1.22	4.24
3	V	1.07	3.71
4	C+S	1.18	3.64
5	C+V	1.10	3.78
6	S+V	1.08	3.60
7	S+V+C	1.17	4.31

S= soil C= compost V= vermiculite

Table 3. Selected properties of the potting media

Sl. No.	Potting medium	pH	OC% (organic carbon)	WHC (water holding capacity)	Ca % (calcium)	Mg % (magnesium)
1	S	5	1.12	44	0.17	0.126
2	C	7.1	8.41	190	0.28	0.198
3	V	7	0.7	158	-	-
4	C+S	5.6	1.96	53	0.16	0.234
5	C+V	6.7	8.96	205	-	0.228
6	S+V	6.2	1.26	95	0.25	0.21
7	S+V+C	6.5	4.48	120	0.14	0.126

S= soil C= compost V= vermiculite

Because of specific termite problems reported from the root trainer raised eucalypts in compost as potting medium, it was suspected that compost already contained termites at the time of planting. Therefore samples were brought from the central nurseries at Kulathupuzha and Nilambur and were examined to identify the macro and microforms present. Samples were observed under the microscope to identify the microforms. Samples from both locations showed only presence of mites and collembolans. From Nilambur sample, one staphylinid beetle was observed, which usually occur in decaying matter. All the organisms mentioned above are known to feed on decaying animal and vegetable matter and can be classified as beneficial. Though none of the samples contained termites, it is likely that once planted, compost may attract termites from surrounding soil.

3.3. Field trial I

The various treatments and the results of the field trial I are summarised in Table 4. Analysis of the data using log-linear model showed that the mortality due to termite attack varied significantly across different treatments (Chi-square value = 31.77, P>0.05). The model showed significant termite mortality of plants in the control plot (λ= -1.0266, Z= -5.82) and in the treatment with physical barrier (λ= -1.0111, Z= -6.25) *i.e.* these two treatments differed from others with respect to termite attack.

In general, mortality due to reasons other than termite attack was a bit high and was unequally distributed in various treatments. The major cause for loss of seedlings was grazing by cattle. It is important to note that almost 100% mortality of seedlings was observed in the treatment with lindaneEC. Lindane is gamma hexachlorocyclohexane (gamma HCH) and belongs to the organochlorines. It is not as highly persistent as cyclodiene group such as aldrin, chlordane and heptachlor. Lindane has also been recommended against termites attacking buildings (Edwards and Mull, 1986; Agnihothrudu, 1993). The cause of seedling mortality in the LindaneEC treatment could not be confirmed. It was suspected to be phytotoxic effect, but controlled experiments in pot trials did not show phytotoxic symptoms with lindane EC, at various doses. The Central Insecticides Board and Registration Committee, Ministry of Agriculture approve lindane for protection of wood and buildings. The use of lindane EC specifically against crops in agriculture/forestry needs confirmation.

Between lindaneEC and lindaneG, lindaneG was effective and also at the same time did not show any symptoms of wilting / drying after planting out in the field. The literature on lindane indicates that it has contact, systemic and to some extent fumigant action. Laboratory trials using lindane EC and G at various concentrations ranging from 0.125 % to 1% in the case of EC and from 1g to 10g in the case G did not show immediate effects of phytotoxicity. However, in course of time in the case of higher concentrations of the EC formulations, some of the lower leaves wilted and shed off, but did not result in mortality. Watering the plants, with a rose can after the treatment was found to prevent wilting of leaves even at higher concentrations.

Earlier studies by Varma and Nair (1997) showed that chlorpyriphos give effective protection when applied prophylactically to the soil in the container seedlings. The treatment was found effective for more than a year, which was sufficient to tide over the vulnerable period of attack by termites under normal conditions. In this trial, the treatment methodology was modified to dipping the root trainer blocks in a known concentrated solution of chlorpyriphos, which ensured the desired protection during the establishment phase. In addition, compared to the seedlings, the clonal planting stocks appear to have a faster growth, which retains the vigour of plants, and probably makes them less susceptible to attack by termites. Moreover, in the case of clonal plantings of eucalypts, unlike the seedlings, the vulnerable period of termite attack seems to be only the first 3-4 months period. By this time the clonal plantings attain better growth compared to seedlings.

The present field trial showed promise of the fungus, *Metarhizium anisopliae* as a potential biocontrol agent when applied in the potting medium before planting out in the field. Termites are natural hosts for at least 20 species of obligate ectoparasitic fungi (Blackwell and Rossi, 1986). The infectivity and pathogenicity of some of these have been demonstrated under the laboratory, but their ecological significance remains poorly known. Two fungi *viz. Metarhizium anisopliae* (Metschn.) Sorok and *Beauveria bassiana* (Bals.) Vuill. are reported to be useful as bio control agents against termites (Rosengaus and Traniello, 1997; Culliney and Grace 2000). Though there are biological limitations and logistical problems, the use of fungi is suggested as useful bait in termite control programmes (Jones *et. al.*, 1996).

Table.4. Field trial I. Relative performance of various treatments for termite control

Treatment	Dosage / method employed	Total plants	Effective No.	Mortality due to termite attack (%)
Nil (control)	-	90	60	40
Lindane 20EC	0.5% a.i. (dipping)	88	-*	-
Lindane 6G	3g /plant (sprinkling)	88	64	1.6
Chlorpyriphos 20EC	0.5% a.i. (dipping)	86	45	2.2
Cover crop (*Stylosanthes*)	Planted around the seedling	83	66	4.5
Physical barrier (Poly urethane)	Provided around the root system	86	46	43.5
Fungal spore suspension (*Metarhizium anisopliae)*	2×10^7 spores/ ml (@ 5 ml / plant)	90	79	0
Physical barrier + Lindane 6G.	3g of granules applied around the barrier	82	65	7.7

*all the seedlings lost due to external causes

Laboratory trials using the subterranean termites, *Odontotermes guptai* confirmed the pathogenicity of the fungal spore suspension to termites maintained in petriplates. The spore count of the suspension was kept constant for all the experiments; *i.e.* $2x10^7$ spores per ml, which was also the same dose used for field experiments. All the doses, which were tested, resulted in complete mortality of the test termites in 4 to 7 days (Fig.11).

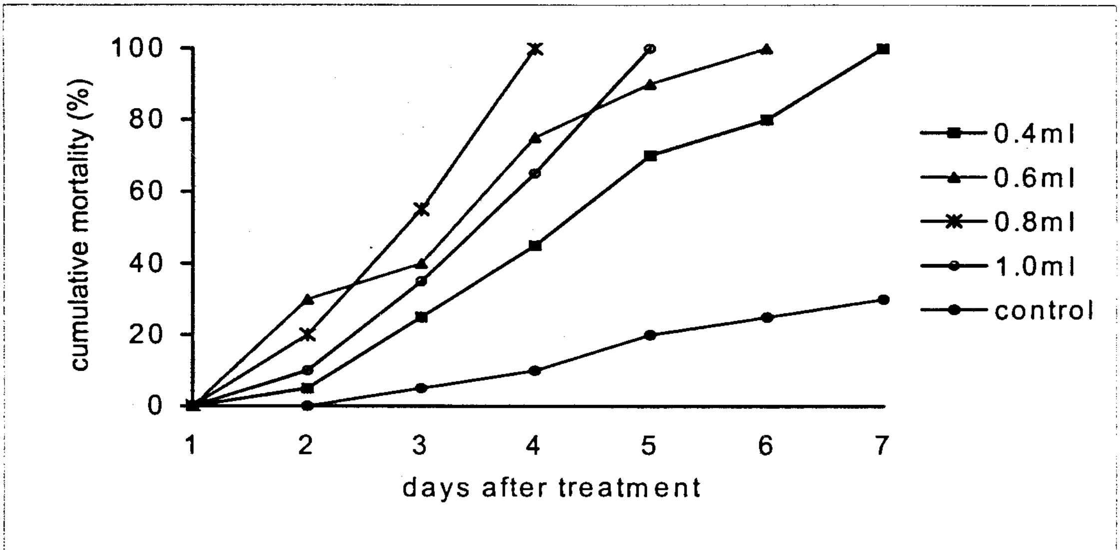

Fig.11. Cumulative mortality of lab-culture of termites on application with different doses of the fungal spore suspension.

The physical barrier, using polyurethane foam did not give effective protection. The foam was found eaten up in most cases (Fig.12) and resulted in large-scale termite attack. Wardell (1987) had suggested that retaining the plastic container in which the seedlings are maintained at the time of planting will serve as a barrier. But this was proved otherwise by Cowie *et.al.* (1989), who showed that termites can destroy much more durable plastic. It is reported that termites could destroy non-cellulose materials such as plastic, leather, lead covered cables etc. Mostly these materials act as barriers for termites to reach their food source and hence destroy them without using as a feeding material. *Coptotermes curvignathus* is reported to cause damage to polyethylene tubes and electro cables in Indonesia (Kalshoven, 1963). It is likely that plastic may also restrict root growth. However, in the present case, the polyurethane foam helped in the growth of root system including the lateral ones without any problem (Fig.13), but was destroyed by termites when out planted in the field.

Addition of lindane granules along with physical barrier also did not yield effective protection against termites. The use of physical barrier like fine mineral particles, as a preventive measure in the control of subterranean termites attacking buildings is a possibility but this method may not work effectively under forestry conditions.

Use of a cover crop to maintain moisture around the plant and subsequent effect of termites avoiding the target plants is often suggested. The use of the cover crop, in this trial with *Stylosanthes hanata* proved to be effective in reducing incidence of termite attack. However, assuring uniform growth of the cover crop around the eucalypt plants is often difficult. Though termite incidence was negligible under this treatment, the practical implications of this observation are difficult to explain. The benefits of the practice of growing nitrogen fixing cover crop in rubber plantations in terms of preventing pest attacks especially soil pests are also not fully understood. In Nigeria, the farmers plant certain specific grasses to keep termites away from farms and gardens (Malaka,1972). *S. hanata* may also have sometimes a deterrent action on termites. Any way, the effect of intercropping in eucalypt plantations in terms of termite damage requires further investigations.

3.4. Field trial II

In this trial, three treatments that were promising in the previous year's trial were further field-tested. In addition, a lower dose of lindane EC (0.25%) was also field-tested. The trials were carried out quite adjacent to the 1999 trial. The incidence of termite attack during the one-year period of observations showed a general decline compared to Field trial I (Table 5). In the control plot, only about 7% mortality was observed as against the 22% in the previous year's trial. The lindane EC, even at a lower dosage was not promising. The rate of non-termite mortality was quite high in this trial also with lindane EC. Though the actual cause of mortality could not be established in most cases, grazing accounted for death of several seedlings.

Application of lindane granules, dipping in chlorpyriphos solution and fungal spore application yielded cent percent protection against termite attack. The granular formulations are advantageous because the toxic effect will be released slowly and can remain effective for longer periods than liquid formulations. However, from a practical point of view dipping the container root trainer blocks will be easy and less cumbersome. The use of the fungus, *M. anisopliae* proved to be effective in this trial also. This fungus offers potential as a bio-control agent, but its mode of action under field conditions needs to be understood.

Table 5. Field trial II. Mortality of seedlings due to termite attack across various treatments

Treatment	Dosage / method employed	Total plants	Effective no.	Mortality due to termite attack (%)
Nil (control)	-	90	56	7.14
Lindane 20EC	0.25% a.i. (dipping)	90	11	0
Lindane 6 G.	3g/plant (sprinkling)	90	50	0
Chlorpyriphos 20EC	0.5% a.i. (dipping)	90	52	0
Fungal spore suspension (*Metarhizium anisopliae*)	2×10^7 spores/ ml (@ 5 ml / plant)	90	50	0

Though, enough quantities of infective conidia were present at the time of planting out in the field, there was no evidence of fungal induced death of termites. Soil samples collected after 6 months from around the fungus treated plants on dilution plate method did not show evidence of fungal spores. Whether termites have avoided the fungal treated plants due to some repellent action is also to be established. Moreover, termite incidence was very less during this trial, though the area was highly termite prone. The development of more stable formulations of fungus would be required to achieve long-term protection. Federici (1990) indicated that in the absence of cost-effective methods for mass production, commercial production of *B. bassiana* and *M. anisopliae* has not progressed well in the USA.

Use of wood ash is a common practice to control termites. In this trial also an attempt was made to evaluate the potential of this when mixed with the potting medium. However, all the seedlings raised in this medium i.e. vermiculite and wood ash (3:1) did not establish in the root trainers and therefore the field trial as planned could not be carried out.

Along with the field trial II, about 0.5 ha was planted up with *E. tereticornis* dipped in 0.5% solution of chlorpyriphos. Here, the incidence of termite attack was only 0.35% over the 1-year observation period. However, as indicated earlier, the intensity of termite attack was much less in general during the trial in the year 2001.

3.5. Termite fauna in the experimental area

In the present study an attempt was made to collect the termites from the experimental area mainly to generate data on the diversity of termites and also to understand their preferences in terms of attack on live out-planted eucalypts. The data are incomplete in the sense that about 100 vials of termites collected are yet to be identified up to species level which is pending with Zoological Survey of India. Majority of the termites collected belong to the family Termitidae. The preliminary data also suggest that most termites belong to the subfamily Macrotermitinae that are widespread and economically important (Table 6). The dominant genus was *Odontotermes*.

Generally all species belonging to Macrotermitinae are decomposers and species belonging to the genera *Speculitermes*, *Anopleotermes*, *Pericapritermes* etc. are soil and humus feeders (Sen-Sarma 1996). Some of these generalisations may not be true because Nair and Varma (1985) listed *Microtermes minor, Euritermes topslipensis*, *Pericapritermes assamensis*, and *P. vythiri* all belonging to the subfamily Termitinae as attacking eucalypts. Generally, many genera in this subfamily are regarded as economically unimportant. There could be exceptions depending on the termite fauna in a locality. However, Macrotermitinae are undoubtedly the major group causing damage to eucalypts and other forest crops in India.

No reliable estimate on the population and distribution of subterranean termites is available due to inherent difficulties involved in quantitative sampling procedures. It is true that the distribution is also determined by various factors, both biotic and abiotic and can vary widely from small groups to larger aggregations.

Table. 6. Partial list of termites collected from the experimental area

Sl. No	Termite species	Host
	SUBFAMILY MACROTERMITINAE	
1	*Odontotermes anamallensis* Holmg.&Holmg.	eucalypts
2	*O. bellahunisensis* Holmg.&Holmg.	eucalypts
3	*O. ceylonicus* (Wasman.)	eucalypts
4	*O. obesus* (Rambur)	other feeding habits
5	*O. roonwali* Bose	eucalypts
6	*O. distans* Holmg.&Holmg.	eucalypts
7	*O. malabaricus* Holmg.&Holmg.	dead wood
8	*Trinervitermes* sp.	dead wood
9	*Macrotermes* sp.	dead wood

The termites in the study area obtained food from the dead and decayed plant tissues. They are also found feeding on dung of cattle and play a scavenging role. Among the living plants, eucalypt was the target of attack. In field trial II, the experimental area was left with all wood debris and no cleaning up carried out before planting (Fig.14). It is possible that termites would have enough of other sources of food material and consequently the pressure on live eucalypts would have reduced. Even in the untreated control the incidence of termite attack was very low in the field trial II. In the absence of correct identity of termites it will be difficult to arrive at some conclusions on the termite fauna in relation to nature of feeding habits. Compared to eucalypt seedlings planted as done in the past, the currently used clonal plantings of eucalypts were less attacked by termites. Maintaining plant vigour through better growth in the initial establishment phase in the case of clonal plantings could be an additional factor in favour of less attack by termites.

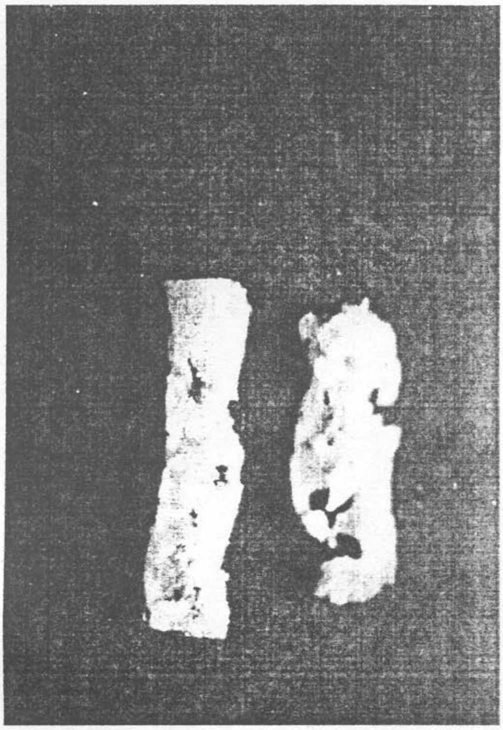

Fig.12. Polyurethane foam attacked by termites

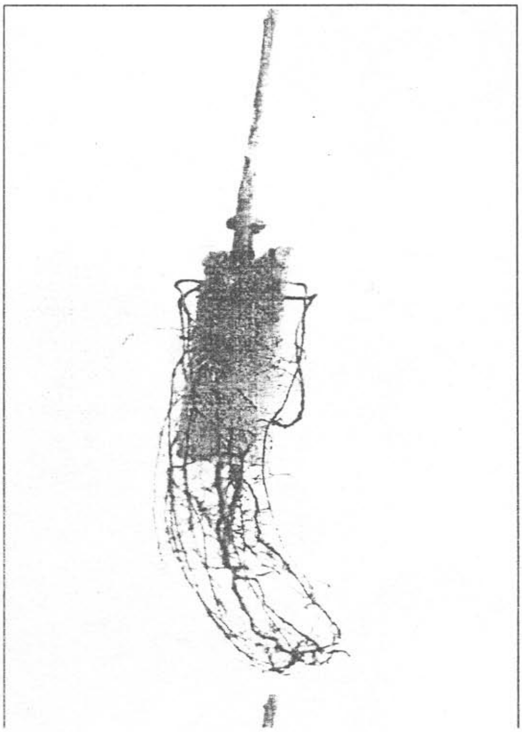

Fig.13. Intact polyurethane foam with complete root system.

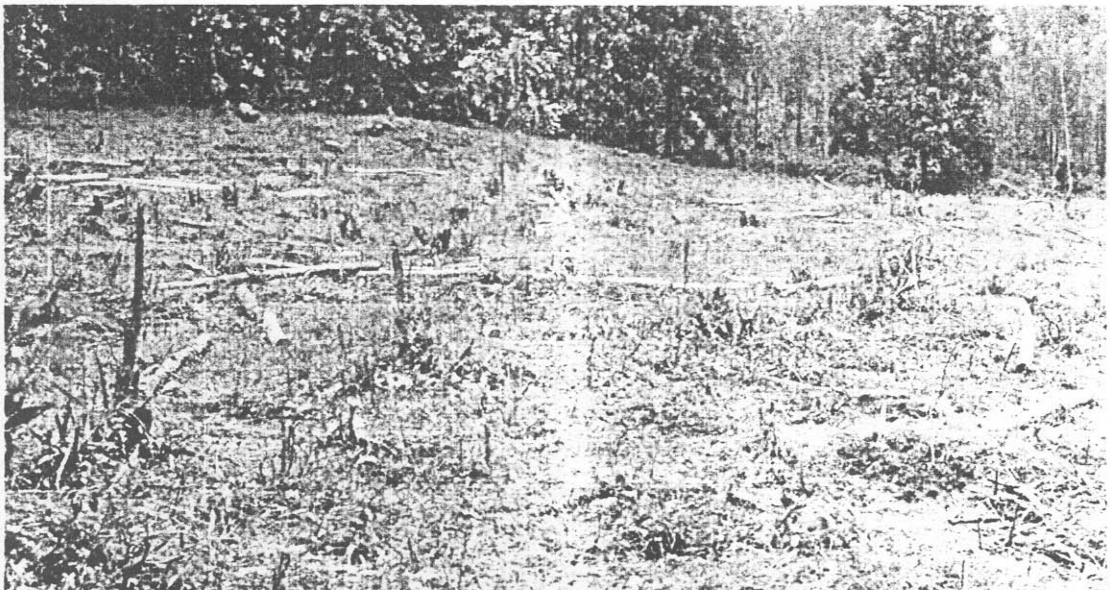

Fig.14. Study area for the Field trial II, before planting showing the wood debris

4. GENERAL CONCLUSIONS

Clonal plantations of eucalypts and other forest crops raised in root trainers are of recent origin. In the conventional polythene bag raised eucalypt seedlings, if prophylactic treatment is not given, over 80% of out planted seedlings were killed due to termites. However, in root trainer raised clonal plantations the damage varied from 2 to 40%. Clonal plantations generally pick up growth at faster rate and build up plant vigour, which make them probably resistant to termite attack.

There is a need to standardise the potting medium to raise the planting stock in root trainers. The present results show that clonal plantlings raised in vermiculite, as a potting medium is least susceptible to termite attack. But other factors are also to be considered while selecting a potting medium.

Several factors either singly or in combinations such as species and population abundance of termites in a given locality and their seasonal activity, land preparation, time of planting, soil factors including moisture level, plant vigour etc. can affect intensity of termite attack.

Even when a dip in chlorpyriphos solution is given, it is likely that sometimes attack of termites can occur depending on the locality and the termite species present in that area. After the dip treatment, before planting out, application of 3g of lindane granules per root trainer is being experimented. Whether this additional treatment would provide added protection is under watch. Lindane has contact and fumigant action with a limited systemic action as well. Application of lindane EC, however, was not very promising.

Remedial treatment like applying insecticide solution around the plant once termite infestations are noticed is costly, labour intensive and can only be partially effective when carried out in a large scale.

Though other treatments such as application of the fungal spores, *M. anisopliae* and Lindane granules were also effective against termite attack, dipping in a 0.5% a.i. solution of chlorpyriphos 20EC is recommended due to practical and logistic reasons.

5. RECOMMENDATIONS

As a practical method to prevent termite attack in root trainer-raised eucalypts, it is recommended to dip the root trainer blocks with the planting stock in a 0.5% solution of chlorpyriphos as detailed below.

Mix 25ml of Chlorpyriphos 20EC in one litre of water in a suitable container

↓

Dip the root trainer block with the seedlings, holding horizontally, for a minute

↓

Drain off excess insecticide solution

↓

Keep them on stands at the nursery site

This treatment may be given one or two days before planting. If slight wilting or drooping of leaves is noticed in some clones of eucalypts, give a water drench covering the foliage. Do not keep the treated planting stock for several days without proper watering. Care should also be taken while dipping, because if seedlings are not well established in root trainers, it is likely that the potting medium will drain out resulting in the exposure of the root system.

Chlorpyriphos marketed for agricultural purposes alone should be used. Some specific products of chlorpyriphos, for example chlorpyriphos 50EC, available in the market are meant for control of termites in buildings. Such products should not be used for treating plants. This may be confirmed from the label on the packet.

The present recommendation is based on dipping 4-month old clonal material of *E.tereticornis* raised in root trainers and dipped in 0.5% a.i. solution of chlorpyriphos 20EC. Specific field trials using crops like *Tectona grandis*, *Acacia auriculiformis, A. mangium* etc., have not been carried out.

Cost of treatment

Chlorpyriphos is marketed under different trade names such as Classic, Durmet, Dursban, Piramid, Thrisul, Tafabaan, Radar, Dhanvan etc., and all these products are available as 20EC. However, De NOCIL markets Dursban TC 50EC and is available in the market with wholesale dealers. The maximum retail price (MRP) of chlorpyriphos 20EC (eg. Durmet 20EC, Dhanvan20EC etc.) is Rs.258/- for one litre packing. However, there is wide variation in the selling price of chlorpyriphos.

One labourer can usually treat about 5000 seedlings (about 210 root trainer blocks of 24 cells each with a capacity of 150 ml) at a total cost of Rs.1100/- which includes the cost of insecticide and labour. This works out to be about Rs.0.25/- per seedling.

5. ACKNOWLEDGEMENTS

I thank Dr. K.S.S Nair, former Director and Dr. J.K. Sharma, Director, for their keen interest in the progress of this project. Thanks are also due to the Kerala Forest Department for the financial support and for facilities provided at Kottappara for the field trails. The local forest staff also rendered help at different places.

Shri P.R. Swaran, Project fellow did an excellent job in the execution of field trails and also in the collection and processing of field data. The services rendered by Shri Thankachan, field worker at Kottappara are duly acknowledged. The advice and input received from Dr. K. Jayaraman and Dr. M. Sivaram in the analysis of the data are gratefully acknowledged. My thanks are also due to Shri. Subhash Kuriakose for the help in photographic work and Shri. K.C.Joby for word-processing the draft report.

Finally I thank Shri.K.C.Chacko,Dr.M.Balasundaran and Dr.V.V.Sudheendrakumar for editorial comments and suggestions on the draft report.

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