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TERMITE CONTROL IN EUCALYPT PLANTATIONS

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ABSTRACT

Termites cause considerable damage to young plantations of eucalypts. Though a number of control methods are currently in practice, there has been no attempt so far to systematically evaluate them under Indian conditions. The purpose of this study was to evaluate various insecticides and their methods of application to evolve suitable control measures.

The evaluation was done in field trials conducted in Kerala over a period of 4 years from 1976 to 1980, using *Eucalyptus tereticornis.* Combinations of various dosages, formulations and methods of application of selected insecticides were tested in several experiments. Usually, three replicates of 50 seedlings were ussd per treatment in each experiment. In addition to these small-plot trials, treatments which showed the greatest promise were put to large-scale field trials, each treatment covering about 5 ha of plantation. Information was also gathered on ecological aspects of the termite problem in eucalypt plantations.

In general, one to three quarters of untreated experimental seedlings were killed by termites In the first year of planting. The mortality varied from p!ace to place and year to year and was not correlated with rainfall. General observations showed that *Eucalyptus grandis* planted in high ranges is equally susceptible to termite attack. All specias *of* termites were not injurious to eucalypt seedlings ; only 4 out *of* 17 species present in experimental plots were found to cause lethal damage. Most species that cause damage live in small subterranean colonies and do not build conspicuous mounds (nests).

Of four selected insecticides tested, aldrin and heptachlor were the *best* ; BHC did not provide satisfactory protect'on and chlordane, although effective, gave indications of phytotoxicity when used as emulsified concentrate (EC) formulation. Aldrin, heptachlor and chlordane were effective when applied in ths planting pit or container soil as dust or liquid formulation. Container treatment with liquid formulation was found to be the simplest procedure. This treatment gave sufficent protection to outplanted seedlings without additional pit treatment. Dosages as low as 0.03 g a i. (active ingredient) insecticide per container (12 cm by 18 cm) gave

satisfactory protection in experimental trsatments. However, a dosage of 0.12 g a.i. per container is suggested for routine plantations, in order to ensure an effective minimum dosage to individual seedlings in large-scale group-drenching.

Remedial application of insecticide after the attack has been noticed in a plantation was cumbersome and proved to be only partially effective.

The present study has made it possible to recommend a simple, standardised procedure for control of term'tes in eucalypt plantations. Details of procedure such as dilution of insecticide, method of drenching, etc. are described. The cost of treatment works *out* to about Rs. *50/-* per ha of plantation.

Key words : termite ecology, termite control, *Eucalyptus tereticornis*, insecticide evaluation, organochlorine insectsides, man-made forests.

1. INTRODUCTION

Termite damage is a major problem in the establishment of *Eucalyptus* Plantations in Kerala, as elsewhere in the country. Unnoticed because of their subterranean habitat, termites cause large-scale mortality of out-planted seedlings by feeding on and thereby girdling or severing the tap root. Although the incidence of attack may vary from place to place and year to year, the loss is recognized to be heavy throughout the State. The problem is serious in both *Eucalyptus tereticornis* and *E. grandis,* the two fast-growing pulpwood species commonly raised in Kerala, the former in the plains and the latter in the high ranges.

A preliminary survey in 1975 showed that in spite of routine insecticidal treatment, substantial losses continued to occur in many plantations. The survey also revealed that in the absence of a standard procedure, different methods of control were used in differant plantations, with consequent variation in the results. Although a large number of recommendations were found in the literature involving different combinations of insecticides, formulations, dosages and application techniques, it was evident that no systematic evaluation of control methods has so far been carried out on plantations of eucalypts in India. Most recommendations were based on 'field experience', and some, apparently on results of Field trials conducted in the dry woodlands and savannah areas of Africa. The present study was therefore undertaken to standardise the methods of control based on field trials under local conditions. A critical review of earlier literature is given in Section 2.

Evaluation *of* selected insecticides and their methods of application and dosage was made by repeated field trials carried out over a period 4 years from 1976 to '1980. In addition to small-plot trials of various treatment combinations, usualiy within 1 ha area, treatments which showed the greatest promise were put to large-scale field trials, each treatment covering about 5 ha of plantation. The results are presented and discussed in Section 3.

The ecological aspects of the termite problem in eucalypt plantations are discussed in Section 4 in the light of information gathered during the course of insecticide trials and observations in other plantations in Kcrala. The termite fauna of the experimental area has been studied and the species injurious to eucalypts determined. The conditions under which they attack the seedlings are discusssd and the differences in the nature of problems between Africa and India which have a bearing on techniques of control are brought out. It is shown that termites injurious to eucalypts constitute only a small fraction of the temite fauna of a given area. Although in the context of loss caused to agriculture, Peswani and Katiyar (1972) have asserted "it is time that control squads s'miiar *to* those for mosquito control be organised to destroy all termite mound; in the country", it must be recognized that termites are an important component of the tropical ecosystem and that it is neither feasible nor desirable to exterminate them.

The last Section gives an integrated summary of conclusions on the ecology and control of termites in eucalypt plantations in Kerala and outlines a simple, effective and economical method for preventing

2. REVIEW OF LITERATURE ON TERMITE CONTROL IN EUCALYPT PLANTATIONS IN INDIA

Indian forestry literature contains a large number of recommendations for control of termites in eucalypt plantations, but almost all are based on 'field experience' rather than planned tield trials. Most of these recommendations appear in proceedings of conferences and other 'reports'. Apparently, field trials in eucalypt plantations in some of the African countries (Parry 1959; Lowe 1961 ; Sands 1962 ; Wilkinson 1954 ; Brown 1965) provided the theoretical basis for some of the recommendations, but systematic studies under Indian conditions are conspicuously lacking.

The recent compilation of termite control recommendations and practices in India given in the Handbook of Afforesation Techniques (Ghosh 1977) shows the multipiicity of methods under current use in the different States. Many recommendations simply advocate use of a given quantity of an insecticlde formulation without specifying the concentration of the actual insecticide (active ingredient, a. i.) in the formulation, e.g., "30 g of aldrex powder", "one teaspoonful of aldrex powder", *"30-60* g of dieldrex of aldrex in 4.5 litres of water per bed", "dipping in aldrex solution", etc. (Ghosh 1974-175, 93-94, 199, 219-220). Such information is not useful because commercial formulations of insecticides may come in many different concentrations. Some recornmendations are impracticable and of doubtful validity, e.g., "placing a half-baked, narrow-necked pitcher in the soil along the *root* to provide moisture near the roots by slow seepage of water to discourage white ants" (Singh 1957) or providing a layer of quartz sand around the root collar (Kaul 1967).

Apart from the above, termite control methods described in Indian forestry literature may be classed into three main categories.

(1) *Application of an insecticide, as dust or liquid, to the planting pit, at the time of planting out* (Venkataramany 1956: Chatterjee *et al*. 1967 ; Nair 1968; Tewari 1972; Ghosh 1977 ; Singh 1977; Bakshi 1978; Seth *et al*. 1978). The recommended rates of application vary from as low as 0-01 g a.i. of aldrin (as 1% dust) per pit (Bakshi 1978) to as high as 250 g a,i. of endrin (as 10% emulsion) per pit (Ghosh 1977:175) — the highest dosage being 25,000) times the lowest. Recommended insecticides include aldrin, dieldrin, heptachlor, chlordane, endrin and BHC ; of these dieldrin and endrin have now been banned in India.

Application of an insecticide, as dust or liquid, to the container *(basket) soil before the seedlings are planted out* (Chatterjee *et al.* 1967 ; Das 1932; Ghosh 1977). This treatment may be effected in one of three ways– by dry mixing an insecticide dust with soil before filling the containers, by drenching container seedlings with an insecticide solution' or by dipping individual container seedlings in an insecticide solutions just prior to planting out. Recommendations include mixing "a pinch of gammexane" (Das 1972) or a "teaspoonful of aldrex powder" (Ghosh 1977 : 199) per container, saturating the container soil with 5 to 10% of an insecticide in the liquid form (with repetition of the treatment after planting out, upto 5 years) (Ghosh 1977 : 175), etc. More specific direction to use *0.5* g a.i. of the insecticide per container (although container size was not specified) has also been given (Chatterjee *et al.* 1967). Recommended insecticides include gammexane (BHC) and DBT in addition to those listed under (1) above.

(3) *Dipping the root portion of naked seedlings in an insecticide solution before the seedlings are planted out* (Hussain 1956; Chatterjee *et al.* 1967; Umarjee 1967; Ghosh 1977). Solutions ranging in concentration from 0.047% aldrin (Ghosh 1977 : 190-191) to "concentrated solution of aldrex'" (presumably 30%) (Umarjee 1967) have been employed. Recommended insecticides are the same as above.

Another insecticide recommended (treatment method no? specified) is folidol (Kaul 1967).

Reducing the chances of termite incidence by destruction of termite colonies in the planting area by inseticide treatment of termite mounds (nests) is another method that has been advocated, often as complementary to other methods (Beeson 1941 : 720; Roonwal and Chatterjee 1962; Rajagopal and Veeresh 1978). Since many species of termites destructive to eucalypts do not build conspicuous mounds *(vide* Section 4), this method alone cannot ensure sufficient protection. Overall treatment of the planting area with an insecticide (at the rate of 1.68 kg a.i./ha of dieldrin) as in the case of agricultural crops has also been practised in Uganda (Brown 1965).

The treatments described above are applied *as* a safeguard against potential termite attack, before the seedlings are planted out in the field. They may be called preventive, precautionary or prophylactic measures, in contrast to remedial measures that may be applied after termite attack has been noticed in a plantation. Remedial measures recommended in the literature

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[1] Many insecticides which are insoluble in water are formulated as emulsified concentrates (EC) and are diluted with water before use. Although the diluted insecticide still remains in an emulsified form, for convenience, it will be referred to as insecticide 'solution'.

consist of drenching the soil around individual seedlings with an insecticide solution. As in the prophylactic measures a variety of insecticides, formulations, concentrations, drenching volumes and frequency of applications have been suggested (Chatterjee *et al.* 1976; Ghosh 1977, etc.). Remedial measures are cumbersome and less effective because of difficulty in ensuring proper timing of treatment.

In practice, while some of the recommended prophylactic treatments have been found effective, others have failed. It appears that most failures have been due, not to the selection of ineffective insecticides, but to the use of inappropriate methods of application. For example, Umarjee (1967) states "In spite of using aldrex in the concentrated form in which the roots of *Eucalyptus* hybrid[sic] were immersed, and also as powder sprinkled around each plant, there were casualties also [sic] amongst the seedlings. The seedlings around which aldrex powder was sprinkled and which were artificially watered could not be saved". In this instance, although aldrin, an effective insecticide, was used, roots dipped in it may not have retained an effective dose of the insecticide or this treatment may have led to phytotoxicity because of the high concentration of insecticide used. Again, sprinkling the insecticide powder around the seedling without mixing it with the soil would have left only a superficial layer of the insecticide in the soil, giving enough chances for termites to approach and feed on the roots through untreated sub-surface layers of soil. Thus an effective insecticide could be rendered ineffective by inappropriate treatment methods.

It is obvious that from among a multitude of recommendations in the literature involving different combinations of insecticides, formulations, application techniques and dosages, with little supporting experimental data, it is difficult to choose an appropriate method. It is also clear that some of the recommended treatments, although effective, entail enormous wastage of insecticides. Our investigations were aimed at evaluation of the potentially effective insecticides with respect to the formulation, method of application and dosage in order to determine the most effective and economical usage.

3. EVALUATION OF INSECTICIDES AND TREATMENT TECHNIQUES

Prophylactic insecticidal treatment is the most promising method for control of termites in eucalypt plantations as already noted. Most experiments were therefore designed for standardization of this treatment. Four insecticides, viz., aldrin, chlordane, heptachlor and BHC (HCH) were tested. The first three were chosen as they are the most well established soil insecticides currently available in the market, known to be effective against termites. BHC was included because it has been recommended by some authors (Chatterjee *et al.* 1967 ; Das 1972 ; Singh 1977 ; Ghosh 1577 : 390) and is one of the cheapest and easily available insecticides in India, although there were indications (Das 1958 ; Parry 1559 ; Brown 1565) that it is comparatively less effective against termite;. Both dust and EC formulations of the insecticides (for those available) were included for evaluation. Treatment techniques included application of dust or EC to planting pit or container, container application followed by post-planting surface soil treatment and roof. dip treatment. Depending upon leads obtained during the course of study, selected combinations of insecticides, formulations, application techniques and dosages were evaluated by field trials over a period of four years from 1976 to 1980 to arrive at effective and economical treatments.

For convenience in presentation of results and discussion, the data given in this section will be restricted to primary results of inseticidal trials, that is, effect of various treatments on incidence of termite attack, although additional information on conditions under which termite attack occurred, the species of termites involved, etc. were gathered during the course of these trials. The latter information which is more of biological interest will be presented and discussed in the next section.

Materials and Methods

Evaluation of various treatments was rnade by field trials in plots laid out within routine plantations of *Eucalyptus* raised by the Forest Department or the Forest Development Corporation. Except for appropriate treatments, the planting operations were done in the same manner as for the rest *of* the plantation, using the same planting stock. Treatments which showed the greatest promise in small-plot trials were put to large-scale field trials in which each treatment was applied to about 5 ha of plantation. All trials were conducted in the Wadakkancherry Range of Trichur Forest Division, except one of the large-scale trials which was repeated in the Nilambur

Forest Division. *Eucalyptus tereticornis* Smith was used for all trials reported here. Experiments laid out with *E. grandis* Hill ex Maiden at Sultan's Battery (Kozhikode Forest Division) in 1978 had to be abandoned because of inadvertent additional insecticidal treatment carried out by local field staff. General methods and procedure are described below ; additional details of each year's experiments will be given under appropriate heads.

Nursery and planting methods

Seediings were first raised in nursery beds. For details of nursery technique see Nair (1968). Three to four-months-o!d seedlings were pricked out and transptanted into polythene bags, 12 cm by 18 cm, filled with sieved loamy *soil.* These soil-filled polythene containers, also called 'pots' or 'baskets' in the literature, will be referred to hereafter simply as 'containers", and the seedlings established in it as 'container seedlings'. The container seedlings were arranged on platforms (container beds), 12m by 1.2 m (40' by 4'). After one to two months of transplanting into containers, in June-July-August, the seedlings were planted out in field pits, 30 cm X 30 cm X 30 cm, at an espacement of 2 m by 2 m. At the time of planting, the container was slit open and discarded, with minimum disturbance to the soil column. The pits were filled upto ground level and the soil lightly packed.

No fertiliser was applied and no watering was done after planting out. The planting was done after the onset of south-west monsoon. Generaiiy, as in the surrounding area of the plantation, one or two crops of tapioca were grown (taungya cultivation) on mounds raised amidst the seedlings

Design of experiments

The experiments were laid out in a randomised compiete block design, usually with three replicates. Unless otherwise stated, in each blcck, each treatment was applied to 50 seedlings located in two adjacent rows of 25 seedlings each, which constituted a plot. Usually, two addit onal planting sites were included per plot to compensate for possible rocky sites which could not be planted up. As the rows were 2m apart, no buffer rows were left between plots. Each block was separated by atleast three unplanted rows.

For the large-scale trials,each treatment was applied to a 5 ha block. At Potta (Trichur Forest Division) where three treatments were tested, wiih in each of the 5 ha blocks, two twin rows of untreated seedlings, arranged Iike a cross along the length and breadth of the block (Fig. 1) were planted up first and marked out with stakes to serve as control (untreated). Treated container seedlings were pianted in the remaining area. Within each of the

Fig. 1. Distant view of a large-scale experimental block at Potta showing the central untreated rows of seedlings across the block. Selective weeding was carried out along the rows to demarcate untreated rows :the rest of rhe block was weeded subsequently. Eucalypt seedlings are hardly visible because of dense growth of the weed. **Eupatorium odoratum.**

four segments of the block separated out by the control rows, a plot covering 15 seedlings by 15 seedlings was marked out at random, to serve as observation plots for treated seedlings. For treated seedlings, the area represented for observation covered about 8 per cent of the total area of the block and for control (untreated) seedlings, about 4 per cent (all seedlings in the control rows). At Nellikkara (Nilambur Forest Division) where only on a treatment was tested, the control seedlings were planted in a half-hectors area adjacent to the 5 ha block and for both treated and control seedlings, observations were made on rows of seedlings marked out at random soon after planting.

Insecticides

EC formulation of aldrin (aldrex 30 EC) was obtained from National Organic Chemical Industries Ltd. (NOCIL) and of heptachlor (20%) from Bharat Pulverising Mills Pvt. Ltd. (BPM). Chlordane EC (20%) was obtained from Rallis India Ltd. for trials in 1976 and from BPM for trials in 1979.

Dust formulations (5%) of aldrin, chlordane and heptachlor were obtained from Pesticides India Pvt. Ltd. for trials in 1976 and from BPM for trials in' 1977 and 1979. BHC (5% dust) was obtained from Premier Pesticides Pvt. Ltd. for trials in 1976 and from BPM for trials in 1977 and 1979.

Insecticide application procedures

1. *Planting pit application*

(a) *Dust formulation* : Required quantity of the insecticide dust, weighed out into small packets, was sprinkled in the pit and the soil replaced and turned over with a spade to ensure proper mixing.

(b) *EC formulation* : Required quantity of the formulation was dispensed in about 300 mll water per pit using a rose can and mixed with the soil as above.

2. Container application

(a) *Dust formulation* : The treatment was carried out before the soil was placed in containers. To each quantity of soil measured out with an empty kerosene tin (18.5 *l*) two moderately heaped teaspoonfuls of the insecticide dust (about 18 g) were added. The soil was turned over several times with a spade to mix the insecticide. In order to ensure proper mixing, not more than five kerosene tin-fuls of soil were used at a time for treatment. This rate of incorporation was equivalent to approximately 50g a.i. insecticide per m^3 soil (lkg. 5% dust der m^3) and gave a dosage of roughly 0.04 ga.i. insecticide per container (12 cm by 18 cm).

(b) *EC formulation:* Required quantity of the insecticide was diluted in an appropriate volume of water (which was experimentally varied in different sets of trials) and poured over a group of container seedlings using a rose can. In this method, an unknown, but small quantity of the insecticide was lost due to spillage between the containers. To facilitate quick penetration of the insecticide solution into the container soil, routine watering cf seedlings was withheld for a day prior to application of insecticide. The timing of application was also experimentally varied as will be specified later. As an additional experimental treatment, in one set of trials, prior to application of the insecticide, each container was provided with four holes extending"about half the depth of the soil column. The holes were made by inserting a pencil-thick stick. Such containers will be referred to as 'pitted', containers.

3. *Container application,* with *post-planting surface-soil treatment*

In this method, in addition to container treatment, either 2 g of a 5% insecticide dust was placed around each outpianted seedling and raked with the surface soil or each seedling drenched with about 100 ml of an appropriately diluted insecticide solution so as to give an additional 0.1 g a.i. insecticide per seedling.

4. *Roof dip treatment*

This treatment was given at the time *of* transplanting the seedlings into containers. Groups *of* freshly pricked out seedlings were kept immersed upto the collet (root collar region) in insecticide solutlon *of* specified strength, for specified periods. In one *of* the root dip treatments, fresh cow-dung was mixed with the insecticide solution to form a slurry which left a visible coating on the root surface.

Recording of observations

For each plot, a separate observation sheetwas prepared in which each seedling was identified by its location in the plot and numbered. Observations were made at monthly intervals, andmore frequentiy during periods of high incidence of termite attack. Notes on the status of each seedling, such as mechanical damage during soil working (for tapioca) and damage by other insects were recorded. Thus the history *of* each seedling in each plot was available in the respective observatlon sheets which facilitated accurate determination of mortality due to termite attack. Wilting or dead plants were carefully dug out and examined to establish the cause of mortality.

For collection of root-feeding termites, the roots of freshly dead or wiiting seedlings were carefuily exposed by removing the soil from a side, Tetmites found on damaged roots or in tunnels leading to the roots were cdllected and identified. In addition to root-feeding termites, all species of termites found in the experimental plots and vicinity were collected and identified to estabiish the termite fauna of the locality.

Statistical analysis

For each plot, the number of seedlings lost due to causes other than termite attack was deducted from the initial number to get 'effective initial number' *of* seedlings. Mortality caused by termites was expressed as a percentage of the effective initial number. The percentsges were transformed t@ their arcsine values and the significance of differences tested by analysis *of* variance, followed by Duncan's multiple range test)Little and Hills 1978). All tests were carried out at 5% ievel *of* significance.

In one set of experiments (in 1977) height growth of untreated seedlings and seedlings treated with selected doses of aldrin EC was measured to investigate the effect of insecticide on growth *per* se. Measurementswere made after plantingout, at monthly intervals, for a period of *6* months. The significance of fhe differences in height increment on the last observtion dale was tested by analysis of covariance using the initial height as auxiliary variate (Snedecor and Cochran 1967). Only those seedlings which survived throughout the observation period were used for the analysis.

Results

The results of each year's experiments are presented below separately, together with a brief introduction on treatments selected for trial each year and other specific experimental details.

Experiments in 1976

Seventeen treatment combinations involving all the four insecticides, two dosages, two formulations and two methods of application (Table I) were evaluated in 1976. The trials were conducted at Arasseri in the Wadakkanchery Range of Trichur Forest Division. The seedlings were planted out in the third week of July. For container treatment with EC formulation, the required quantity of insecticide was dispensed in about 100 ml water per container two days prior to planting out.

The results are summsrised in Table 1. In the control (untreated), 80 per cent of the seedlings were killed by termites in the first year. Typically, the tap root of attacked seedlings was tapered out by termite feeding and because of this, the seedlings could be easily pulled out from the ground. (See next section for more details of the nature of attack). The number of seedlings dead due to causes other than termite attack ranged from 5 to 14 out of 150 per treatment. Such death occurred mostly within a month of planting out and was mainly due to cutting or ring-barking of stem just above ground level by unknown insects (possibly cutworms). In addition, in some plots, a few seedlings were lost due to gully erosion. Termites did not cause any mortality of plants in the second and third year, although they nibbled, particularly during the dry months, on dead as well as live bark of the lower portions of the stem under cover of mud plaster (flat tunnel). Damage to live stem often resulted in exudation of gum, but not death of the seedlings.

Except for BHC, all insecticides reduced the incidence of termite attack to negligible level (Table 1). Specific comparisons of treatment types are given below.

Planting-pit treatment versus container treatment : There was no significant difference in effectiveness between the two methods of treatment using EC formulations of aldrin or chlordane at either dosage. However, based on visual observation, seedlings given container treatment (with either insecticide at either dosage) appeared to grow slower than others initially, although no difference was recognizable about two months after planting out.

Comparative efficacy of the insecticides : At both dossges tested, there was no significant difference among aldrin, chlordane and heptachlor ; all the three reduced the incidence of attack to negligible level. BHC was significantly less effective, with about a quarter of the seedlings suffering mortality.

Dosage effect : There was no significant difference in effectiveness between the higher and lower dosages for any of the insectic'de.

Dust versus emulsified concentrate : With both aldrin and chlordane, use of either formulation gave the same degree of protection at both dosages.

Table 1

incidence of termite attack in **Eucalyptus tereticornis** *in* the *first year of planting, under various insecticide treatments — 1976 experiments, Arasseri*

Insecticide	Treatment: Formu-ation	Treatment: Dosage, a. i. in g/seeding	Treatment: Applied to	Effective initial No. of seedlings*	Mortality due lo termite attack
Nil	—	—		137	80[a"]
Aldrin	dust, 5%	0.50	pit	133	1[e]
Chlordane	dust, 5%	0.50	pit	I 40	2[e]
Heptachlor	dust, 5%	0.50	pit	144	0[e]
BHC	dust, 5%	0 58	pit	141	28[b]
Aldrin	dust, 5%	0.25	pit	143	1[c]
Chlordane	dust, 5%	0.25	pit	142	4[e]
Heptachlor	dust, 5%	0.25	pit	141	4[e]
BHC	dust, 5%	0.25	pit	123	23[b]
Aldrin	EC	0 50	pit	1%0	1[c]
Chlordane	EC	0.50	Pit	135	
Aldrin	EC	0 25	pit	140	I[e]
Chlordane	EC	0.25	pit	145	2[e]
Aldrin	EC	a 50	Conta:ner	743	1[e]
Chlordane	EC	0 50	Container	120	1[e]
Aldrtn	EC	0 25	Container	145	0[e]
Chlordane	EC	0.25	Conta,ner	144	1[e]

"Totai of 3 replicates; seedlings lost due to causes other than termite attack are excluded.

**figures superscribed by the same letter are not significantly different at 5% level of significance. Percentages are rounded off to the nearest integer.

Experiments in 1977

As seen above, in the 1976 trials, three of the insecticides were found to be effective at the lowest dosage tested, i.e., 0.25 g a.i. per seedling. Being equally effective, container treatment is preferable to pit treatment because of the simplicity of procedure. To determine the optimum dosage under this method, a graded series of dosages (Table 2) was tested in 1977 using EC formulation of one of the effective insecticides, viz. aldrin. Since effective movement of smaller dosages of the insecticide to the bottotn portion of the container soil was uncertain, in one set of treatments, the insecticide was applied after providing holes extending about half the depth of the soil column as described earlier. For selected dosages, seedling height was measured periodically to investigate suspected effect on growth. Unlike in the 1976 experiments, the insecticide drench was given prior to transplanting the seedling-, into containers and was effected in two consecutive instalments (using about 100 ml of diluted insecticide in total per container) to facilitate better absorption. At the dosage of 0.25 g a.i. / container (the highest dosage tested), an additional method of application which may be called split application, was included, in which half the insecticide was applied as usual, with the remaining half applied just prior to planting out. This was included to test whether the suspected growth inhibitory effect of a comparatively high dose could be offset by this method, but inadvertently, growth measurernents were not made as planned.

Dust forrnulation of all the four insecticides included in the 1976 experiments were evaluated again by container application. For this, the insecticide dust was incorporated into the soil as described earlier, to give a dosage of about 0.04- g a.i. per container.

When treated container seedlings are planted out, the layer of soil covering the surface of the ground remain untreated. This layer is usually thin but may vary with the depth of planting. To ascertain whether termites may gain access to seediings through this layar, some treatments were included in which a post-planting surface soil treatment was given in addition to container treatment.

Adjacent to the dust treated plots, but not forming part of that experimental set of plots, a few rows of seedlings were planted without any insecticidal treatment, to gather preliminary information on the effect of remedial treatments. two months after plant'ng out when about 10 per cent of the seedlings were killed by termites, So seedlings each were treated with an EC formulation of aldrin or lindane (YBHC). Half a litre of the diluted solution containing 0 25 g a.i. insecticide was poured (slowly, to aid penetration into soil)close to the base of each seedling.

The trials were conducted at Kondazhi in the Wadakkanchery Range of Trichur Forest Division. EC and dust formulation were evaluated separately in two sets of experiments laid out in plots located about 1 Km apart within a large plantation. There were two replicates of each treatment, with 42 seedlings per plot. The seedlings were smaller (about 10 cm in height) compared to those used in the other years and were planted out between late July and early August.

Results of trials using **EC** formulation of aldrin is summarised in Table 2. In this set of plots, a sizeable number of seedlings (7 to 35 out of 84) was lost due to causes other than termite attack, some due to damage sustained during weeding, but most due to interference by grazing goats. In the first year, 76 per cent of the effective initial number of control (untreated) seedlings were killed by termites. In contrast, only 0 to 6 per cent of the treated seedlings were killed and there was no significant difference among treatments. In the second and third year no further mortality occurred.

Table 2

Effect of container treatment with graded doses of aldrin EC on incidence of termite attack in **Eucalyptus tereticornis** *in the first year of planting — 7977 experiments, Kondazhi*

Insecticide dosage (g a. i. / container)	Other particutars	Effective initial No. of seedlings *	% mortality caused by termites
Nil	—	62	76[a]**
0.25	—	58	0[b]
0.12	—	51	2[b]
0.06	—	53	6[b]
0.03	—	65	6[b]
0.25	pitted soil, split application	58	2[b]
0.25	pitted soil	51	0[b]
0.12	pitted soil	45	0[b]
0.06	pitted soil	65	3[b]
0.03	pitted soil	73	3[b]

*-Total of two replicates; seedlings lost due to causes other than termite attack are e;:cluded.

**Figures superscribed by the same letter are not significantly different at 5% level of significance. Percentages are rounded off to the nearest integer.

Seedlings given the lowest dosage (0.03 g a.i. / Container) attained a greater height increment than untreated seedlings as well as seedlings given higher dosages (< 0.01) (Fig. 2). The enhanced height growth, already noticeable at: the time of planting out persisted throughout the 6 months' observation period. There was no significant difference in the height increments of untreated seedlings and seedlings treated with higher doses, although a growth promotion trend was noticeable at the dosage of 0.12 g.

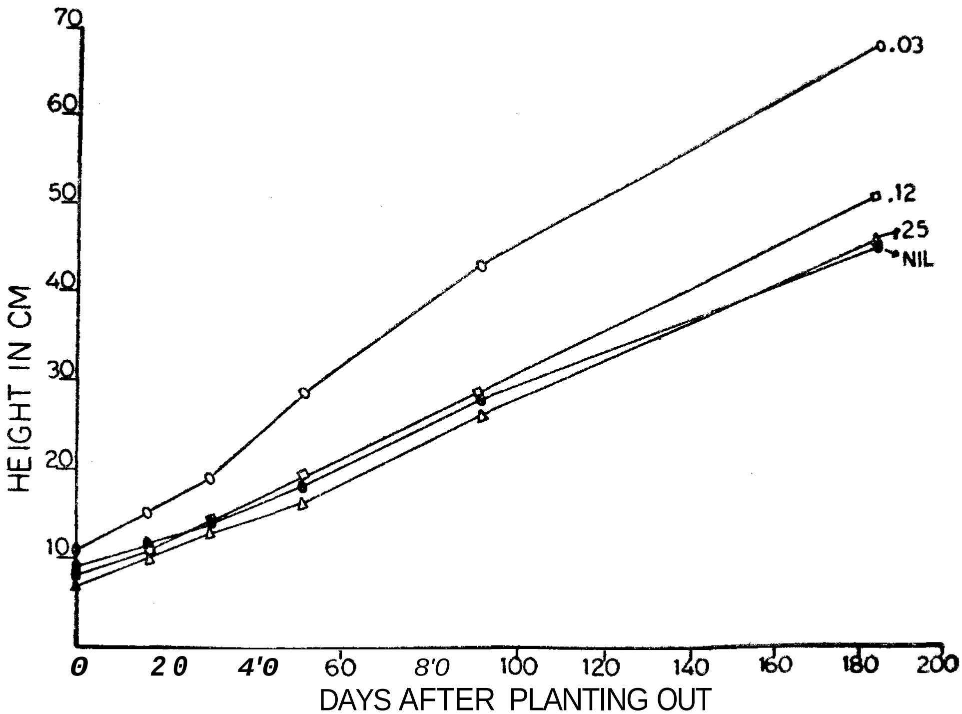

Fig. 2. Effect of graded doses of aldrin EC on height growth of **Eucalyptus tereticornis.** *The dosages indicated are in q a.i. per container.*

Table 3 shows the effect of container treatment with dust formulation of aldrin, chlordane, heptachlor and BHC at 0.04 g a.i. per container. In this set of trials, only a small number of seedlings (2 to 9 out of 84) was lost due to causes other than termite attack. In the first year, 28 per cent of the effective initial number of seedlings were killed by termites in the control (untreared) compared to 0 to 5 per cent in the others. There were no significant differences in mortality among the various insecticide treatments. No further mortality occurred in the second and third year.

Table 3

Effect of container treatment with dust formulations of insecticides on incidence of termite attack in **Eucalyptus tereticorinis** *in the first year of planting — 7977 Experiments, Kondazhi*

Treatment			Effective	% mortality
Insecticide	Dosage (g a. i. / container)	Post-planting treatment	initiai no. of seedlings"	due to termite attack
Nil	—	—	76	28a**
Aidrin	0.04	—	82	1[b]
Aldrin	0.04	0.1 g a.i. of aldrin dust	78	7[b]
Aldrin	0.04	0.1 g a.i. of aldrin EC	83	0[b]
Heptachloi	0.54	—	75	4[b]
Chlordane	0.04	—	38	
BHC	0.04	—	78	5[b]

* Total of two replicates ; seedlings *lost* due *to* causes *other* than termite attack are excluded.

** Figures superscribed by the same letter are not significantly different at 5% level of significance. Percentages arc rounded off the nearest integer.

In plots given remedial treatment, termite-caused mortality prior *to* treatment was similar — 8 to 11 per cent. After treatmcnt, 6 per cent of the remaining seedlings succumbed *to* termite attack in each of the treatment (aldrin and lindane). In the control (untreated) of the dust treated set, 9 per cent of the seedlings were killed by termites in the corresponding period prior to application of remedial treatment and 19 per cent of the remaining seedlings were killed subsequently. Although a strict comparison with the untreated control ,of the dust treatment set *is not* permissible, *the results* clearly indicate that remedial treatment gave only partia1 protection against termites.

Experiments in 1979

The objectives of the 1979 experiments were (1) to confirm the effectiveness of container treatment in additional small-plot trials (as in the previous years) and in iarge-scale trials and (2) to test some new treatment techniques. Treatments tested in small-plot trials werc the following.

(a) Container treatment with EC formulation of aldrin, chlordane and heptachlor. Although a dosage as low as 0.03 g a.i. ,'contained was found effective in *the* 1977 trials, dossges of *0.06* and 0.12 *g* a.i./container were used in the present trials because group drenching results in some loss of the insecticide due to spillage and may also lead to non-uniform distribution of the insecticide among containers. The resulting variation in dosage can be kept minimal in experimental treatments, but in routine forestry operations with large number of container beds and unskilled labour, it is more practicable to keep the dosage well above the minimum.

(b) Container treatment with dust formulations of the same inscctides. A dosage of 0.04 g a.i./container was used as in the 1977 trials ; it was not considered necessary to increase the dosage because the method of application ensured uniform distribution and did not entail spillage. BHC was tested, however, at double the dosage because it: was found less effective in the 1976 trials.

New treatment techniques tested were as follows .

(a) Container treatment using smaller containers. In an attempt to reduce the cost of planting operations, the suitability of smaller containers is being tested by the Eucalyptus Fungus Investigation Unit, Alwaye (Hindusran Paper Corporation *Ltd.)* (C. S. Nair, Pers. Comm.). Trials were therefore carried outto test whether smaller containers (9 cm by 15 cm and 7.5 cm by 11.5 cm) can be effectively treated by container application of the insecticide. For this test, dust formulation of aldrin was mixed with the soil at the same rate as for containers, i.e., *50* g a.i. per m^3 of soil, but the total quantity of insecticide per conta'ner was smaller because of the smaller container size.

(b) Root dip treatment. Since very low concentration of insectictiicide was found effective by container treatment, the adequacy of root dip treatment was tested.

The small-plot trials were conducted at Potta in the Wadakkancherry Range of Trichur Forest Division. In the large-scale trials, three treatments were tested at Potta, with ona of these treatments repeated at Nellikkara in the Kaiikavu Range of Nilambur Forest Division. Seedlings were planted out in the last week of June. Container treatment with EC formulation was done in the same manner as in 1977, except thatthe drenching volume was reduced to about 50 ml per container and the drenching carried out one week prior to planting out in the small-plot trials and about 3 weeks prior to planting out in the large-scale trials.

In the small-plot trials, loss or mortality of seedlings due to causes other than termite attack was moderately high, ranging from 11 to 27 per cent in treatments other than root dip. Most loss was attributable to mechanical damage during weeding or cultivation for the taungya crop; some mortality (< 5 per cent) was caused by drought between December 1977 and March 1980. In the root dip treatments, non-termite mortality was very high,

Table 4

Incidence of termite attack in **Eucalyptus tereticornis** *under various insecticide treatments — 1979 experiments, Potta*

Insecticide	Treatment: Formulation / concentration	Treatment: Dosage (g a. i. / seedling)	Treatment: Other particulars*	Effective initial No. of seedlings**	% mortality due to termite attack
Nil	—	—	—	110	35[a]***
Aldrin	dust, 5%	0·04	—	111	0[d]
Aldrin	dust, 5%	—	Container size, 9 × 15 cm	128	3[c, d]
Aldrin	dust, 5%	—	Container size, 7·5 × 11·5 cm	114	6[c, d]
Chlordane	dust, 5%	0·04	—	120	5[c, d]
Heptachlor	dust, 5%	0·04	—	107	1[c, d]
BHC	dust, 5%	0·08	—	103	4[c, d]
Aldrin	EC	0·12	—	128	1[d]
Chlordane	EC	0·12	—	109	0[d]
Heptachlor	EC	0·12	—	123	2[c, d]
Aldrin	EC	0·06	—	126	0[d]
Chlordane	EC	0·06	—	119	3[c, d]
Heptachlor	EC	0·06	—	128	0[d]
Aldrin	EC, 10%	—	Root dip, 10 min	86	4[c, d]
Aldrin	EC, 2%	—	Root dip, 1 min	75	13[b, c]
Aldrin	EC, 2% with cow-dung	—	Root dip, 1 min	61	2[c, d]
Aldrin	EC, 0·1%	—	Root dip, 30 min	79	28[a, b]

* Where not specified, the container size was 12 cm × 18 cm.

** Total of three replicates

*** Figures superscribed by the same letter are not significantly different at 5% level of significance. Percentages are rounded off to the nearest integer.

ranging from 42 to 56 per cent ; possibly due to ioxicity of insecticide which requires further investigation.

Incidence of termite attack in the various treatments is shown in Table 4. In the control (untreated), 35 per cent of the effective initial number of seedlings were killed. In all treatments except one, the incidence of attack was generally low and differed significantly from control. The one exception was root dip in 0.1% aldrin for 30 min, in which 28 per cent of the seedlings were killed by termites. Root dip in 2% aldrin for 1 min resulted in 13 per cent loss which did no't differ significantly from the above or from many o.ther treatments although it was significantly lower than in control (untreated). In all other treatments less than 6 per cent of the seedlings were killed by termites.

In the large-scale trials at Pofta (Trichur Forest Division) 19 to 24 per cent of the control (untreated) seedlings were killed by termites; practically no mortality occurred in *any* of the three insecticide treatments (Table 5). At Neliikkara (Nilambur Forest Division) the incidence of attack was very low both in the control (3 per cent) and treated (0.5 per cent) seedlings.

Table 5

Effect of selecred insecticide treatments on incidence of termite attack in **Eucalyptus tcreticornis** *in large-scale trials*

insecticide formulation and dosage in g a. i. ' *container*	No. of seedlings under observation	No. of seedlings killed by termites	% mortality
Aldrin dust[1]	Controi : 475	92	'19.3
0·04	Treated : ,924.	2	0.2
Aldrin EC[1]	Conk01 : 326	79	24.2
0·03	Treated : 591	1	0.2
Aldrin EC[1]	Control : 278	67	24.1
0·12	Treated : 971	"l	0.1
Aldrin EC[2]	Control : 782	32	4.1
0·12	Trea-:ed : 1170	6	0.5

1, Trials in Trichur Forest Division

2, Trial in Nilambur Forest Division

Discussion

As noted earlier, a variety of insecticides, formulations, dosages ,snd methods of application have been suggested in the literature for control of termites in eucalypt plantations. The present investigations provide, for the first time, adequate experimental data base under Indian conditions to decide on the most suitable treatments.

Remedial measures, i.e.., insecticide drench applied after termitesattack has been noticed, cannot ensure satisfactory protection as shown by the preliminary results obtained in 1977. Perhaps the treatment could be made more effective by providing holes around the seedling to aid penetration of the insecticide into the soil. However, treating individual seedlings in a plantation this way is not practicable. Pre-planting, prophylactic treatment is simple and more effective. Remedial messures may be resorted to oniy when there is no alternative but to save valuable seedlings; when required, drenching with aldrin or lindane (EC formulation) at the rate oi *0.25* g a. i. insecticide per seedling may give moderate control. Chatterjee *et al.* (1967) recommended drenching the seedlings with a water emuision of aldrln, dieldrin or BHC (WP or EC) at the rate of 8.5 to 1.0 g *a.i.* insecticide per seedling; however, no experimental data on effectiveness was presented. Dieldrin is no longer in the market and BHC may not be effective as our other experiments have shown.

The merits and demerits of the various prophylactic treatments that were ewluated in this study are examined below

Methods of applications

The four methods of application tested were *(1)* planting pit application, (2) coritainer application, (3) container application followed by post-planting surface soil treatment and (4) root dip treatment. Let us first consider the root dip treatment. Root dip in 0.1% aldrin did not give protection, but dip in higher concentrations (2% and 10%) reduced the incidence of attack significantly over control (untreated) (Table 4). The data suggest that a concentration of about 10% would be more suitable and that mixing cow-dung with the insecticide solution may be advantageous. However, further experiments are necessary to critically evaluate the adequacy of root dip treatments, for the following reasons.. (1) The high unspecific (non-termite) mortality of seedlings suggests possible phytotoxicity. (2) The low overall incidence of attack in the 1979 trial, combined with low effective initial number of seedlings make it difficult to. draw definite conclusions on the efficacy of root dip treatments.

Chatterjee *et al.* (1967) recornmended dipping the roots in 0.1% to *0.5%* emulsion of weltable powder of aldrin, dieldrin oBWC as one oF the control measures. Similar recommendations have been made by other authors. Our data are insufficient to prove effsctiveness of root dip treatment, as discussed above. It appears unlikely that the dip will leave sufficient quantity of insecticide on thn rootsurface to be effective against termite attack. With the available evidence, root dip cannot therefore be safely recommended.

The other three application methods proved effective. Effectiveness of planting pit treatment was clearly shown in the first yaar trials. Dust or EC formulaton of an appropriate insecticide could be used by this method (Table 1). As availability and transportation of water for application of liquid insecticide may pose problems in hilly terrains, dust *is* more convenient for pit application. Irrespective of the formulation, efficacy of pit treatment will depend upon proper mixing of the insecticide with the soil. Observatlons have shown that adequate attention cannot be paid to this aspect in large-scale planting operations. If soil working is not carrled out properly, the insecticide will remain in discrete layers of soil, providing sufficient scope for termites to work their way to the roots through insecticide-free portions *of* soil. *Most* failures in routine plantations are probably attributable to this cause. Under practical conditions, it is difficult to ensure proper mixing since the planting is carried out by unskilled labour who have little understanding of the reasons for doing so. It is allthe more difficult when planting is carried out on labour contract, with a fixed remuneration per unit area planted, because more area could be planted up per unit time if no mixing is carried out.

The effectiveness of contsiner treatment was demonstrated repeatedly in trials carried out in 1976, 1977 and 1979 (Tables 1 — 5). Either dust or EC fomnulation could be used for this treatment. Although EC formulations of some insecticides tended to retard growth at hjgh doses and promote growth at low doses, this effect is only of academic interest as it does not occur within the dosage range normally necessary for control. Being equally effective, container treatment is preferable to pit treatment for several reasons. (1) It can be conveniently carried out at the nursery site where supervision is easier. (2) A large group of seedlings can be treated simultaneously. (3) If EC formulation is used, no soil working is necessary and if dust, mixing can be carried out more easily than in pit. These advantages result in substantial saving in labour cost.

Between dust and EC, EC is more convenient to use, for the following reasons. (1) It comes in concentrated form which can be transported easily and diluted at site. (2) Drenching is easier than mixing dust with soil. (3) It can be applied any time before the seedlings are planted out. With dust, treatment must be carried out at the time of filling the containers arid any unexpected delay in obtaining the insecticide will upset the time schedule of operations. (4) It is not necessary to handle freated soil. The disadvantages of EC are (1) wastage of some qauantity of insecticide due to spillage and (2) need to use a higher dosage than for dust to ensure adequate coverage. The advantages far outweigh the disadvantages.

Experiments in 1977 (Table 2) have demonstrated that pitting the conlainer soil before the application of insecticide solution did not confer additional advantage. So also split application was not necessary. it is best to apply the treatment as soon as the transplants are well established in the containers ; this will prevent possible termite damage to seedlings maintained in the containers. Early application will also ensure more uniform distribution of the insecticide solution because of less dense foliage. In any case, the drenching must be carried out before the onset of monsoon so that the container soil is comparatively dry enough to absorb the insecticide solution.

That post-planting surface soil treatment did not confer additional advantage was shown by experiments (Table 3) although it could be expected to safeguard against termites that may work their way through shallow subsurface foraging galleries. it appears that most species destructive to eucalypts in Kerala forage through deeper galleries, aithough surface-active termites are considered to contribute substantially to mortality *of* eucalypts in Africa (Cooling 1962; Sands 1962; Wilkinson 1962). Bur results suggest that any damage inflicted by surface-active termites is negligible. Considering the cost !nvolved in field treatment of individual seedlings it is not economically worthwhile to prevent such damage, if any.

Experiments conducted in 1979 (Table 4) showed that the coritainer size could be reduced to 7.5 crn by 11.5 cm from the standard 12 cm by 18 cm, without any significant difference in the efficacy of container treatment. However, smaller containers were tj.ied only in one set of experiments where the overall incidence of termite attack was comparatively low. Since it is possible that critical differences between treatment; may not become cvident when the pest pressure *is* low, additional trials seem necessary to confirm the adequacy of smaller containers.

Thus our investigations clearly show that container treatment with EC formulation is the best method. With respect to the quantity of water required for dispensing the insecticide, 50 ml per container was found sufficient to give adequate coverage. It is best to dispense this volume in two consecutive instalments.

Choice of insecticides

Of the four insecticides tested, aldrin, chlordane and heptechlor gave consistent protection when appropriate application methods were used. There was no significant difference in effectiveness among these insecticides in any of the several experiments in which pit or container treatment was employed. The lowest dosage at which these insecticides were compared was approximately 0.04 g a.i. per container (dust formulation) (Tables 3 & 4). That chlordane is lest potent than the other two is suggested by the general recommendation for ant termite treatment of buildings where aldrin and heptachior are recommended lor use at a concentration of *0.5%,* but chlordane, at 1% (Hickin 1971 : 141.). Since no significant difference was found even at the lowest dosage tested in our experiments, it may be concluded that for control of termites in eucalypts, all the three are equally effective at the dosages used. It may be that critical differences, if any, will be shown up only at extremely low dosages or when a long period of protection is required.

BHC was significantly less effective than other; when used for pit treatment even a': the high dosage of 0.5 g a. i. / pit (Table I). In container treatment, however, no significant difference was found even at the lowest dosage tested, i. e., 0.04 g a.i. / container (Tables 3 & 4). Considering that each container holds roughly 875 m^3 of soil and each pit 2700 m^3, the concentration of BHC can be worked out to rougnly 50 g a. i. / m^3 soil in the container treatment at the lowest dosage tested (0.04 g a. i./container) and 20 g a. i. / m^3 soil in the pit treatment at the highest dosage tested *(0.5* g a. i. / pit). It appears that the higher concentration of BHC was responsible for its better performance in the container treatment. Better admixture of the insecticide dust with *soil* in the container treatment could be an additional factor. It is evident, however, that at critical dosages, BHC is less effective than the others. This finding is in agreement with other reports in the literature (Das 1953 ; Parry 1959 ; Brown 1965 ; Verma *et al.* 1979). Brown (1955) tried various dosages of BHC upto *3.68* g a. i. / pit in Uganda and reported that significant protection was rarely obtained. *It* msy be concluded that aldrin, chlordane and heptschlor are the most effective for control of termites in eucalypts. Preliminary results of ongoing experiments using container-grown seedlings have indicated that chlordane, even at low dosages (as EC), retards the growth of seedlings initially. The impact of this effect on field performance of seedlings may not be significant, but it is best not to use chlordane until we have further information.

Some indication of the effectiveness of other insecticides (Thimmet, Dassnit, Furadan and Carbaryl) was obtained during the course of this study. Freshly planted out seedlings were treated with these less persistent insecticides with a view to protect the seedlings from termttes for limited periods in an attempt *to* study age-related susceptibility. The insecticides were raked into the surface soil as dust or granules, close to the seedling, except for Carbaryl which was incorporated into the container soil. These treatments were not laid out statistically and the results are only of indicative value.

Eight out of 34 seedlings (24%) were killed by termites when Thimmet 10 G was applied at *0.5* g a. i./seedling ; 2 out of *37(5%)* when Dasanit 5 G (Fensulfothion) was applied to pit at the same rate ; I1 out of 76 (15%) when Furadan 3 G was applied at 0.15 g a.i. *1* seedling and 16 out of 86 (19%) when Carbaryl was applied at 0.04 *g* a.i.,'seedling. The results suggest that all insecticides other than Dasanit are ineffective against termites when applied as described ; th? usefulness of Dasanit requires further investigation.

The dosage

As noted earlier, an unbelievably wide range of dosages have been suggested in the literature, most of them without any experimental support. It is obvious that the dosage will depend on the insecticide and the method of application. The following discussion will apply to aldrin, chlordane and heptachlor ; BHC is excluded as it was not effective at comparable dosages and is not recommended for use.

For pit treatment, a dosage of 0.25 *g* a.i./pit is sufficient as shown by the 1976 trials (Table 1) although higher dosages have been recommended in the literature (e.g., Chatterjee *et a/.* 1967). It may be possible to reduce the dosage further, but we did not test lower dosages. It must be pointed out that when the formulation used is a 5% dust (the most common dust formulation available) 5 *g* of the material is required per pit to give the above dosage ; further reduction of dosage will reduce the dust volume per pit which may impair the chances of proper admixture with soil. Dosage reduction should therefore be attempted only if less concentratsd insecticide dusts are available,

In the container treatment, trials with graded doses of aldrin showed that a dosage as low as 0.03 g a. i.jcontainer is sufficient *to* give satisfactory protection. As there was no significant difference in mortality among the various dosages tested, the critical effective dosage is likely to be still smaller. Sands (1962) reported that in laboratory studies with a test termite, extremely small concentrations of dieldrin (approximately 16 *X* 18-12 g/cm^2 of test filter paper) was sufficient to cause death. In the complex soil environment, however, insecticides may not retain their full potency. For reasons discussed earlier (see introduction to 'Experiments in 1979, under 'Results') a dosage OF 8.12 *g* a, i./seedling is considered suitable for routine plantations when container treatment is carried out with an EC formulation.

General conclusions on methods to be adopted for control of terinites in eucalypt plantations will be more appropriate after the ecological aspects the termite problem are considered in the next Section.

4. ECOLOGICAL ASPECTS OF THE TERMITE PROBLEM IN EUCALYPT PLANTATIONS

Experiments laid out to evaluate insecticides provided opportunities to gather information on ecological and biological aspects of the termite problem in eucalypt plantations. These observations, together with additional observations made in eucalypt nurseries and plantations in different parts of Kerala are recorded and discussed here.

Observations and Discussion

Nature of termite damage

Typical damage caused by termites to eucalypt seedlings is shown in Fig. 3. Because feeding occurs underground, early stages of attack are not easily recognised. Usually termite attack is recognizable only when the

Fig. 3. **Eucalyptus tereti-** *seedlings showing typical root damage caused by termite feeding* seedling is damaged beyond recovery, with the terminal leaves desiccated, but other leaves still green and apparently healthy (Fig. 4). At this time, the seedling can be easily pulled out from the ground because the tap root has been tapered out (by termite feeding) and severed a few centimeters below the collet. On careful exposure of the tap root by removing the soil in a vertical section (Figs. 5 & 6) active feeding of termites on the root could sometimes be observed. Mostly, feeding was observed in the early mornings, and rarely at other times of the day; observations were not made at night. It was not always possible to find termites *in situ* under an attacked seedling, possibly because of their quick retreat on disturbance or sporadic feeding habits. Termite tunnels leading to the root were usually noticed (Fig. 6). The earliest external system of attack is the flaccid, drooping appearance of tender terminal leaves. Examination at this stage suggested that typical

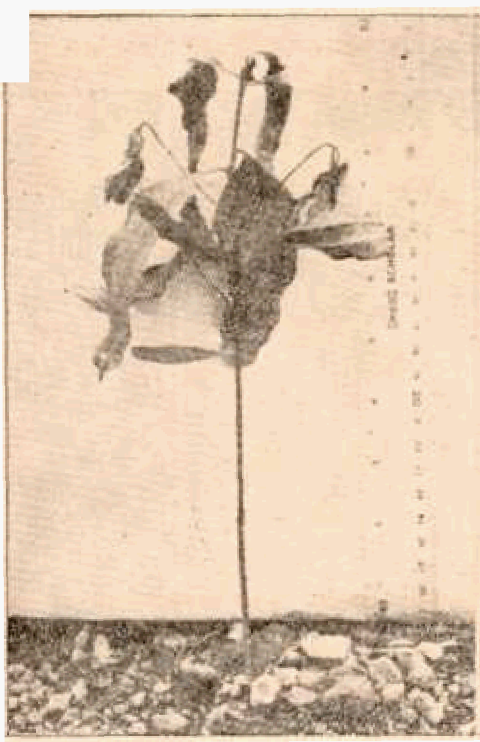

Fig. 4. **Eucalyptus tereticornis** *seedling wilting due to termite attack of root at Arasseri on* **10** *September 1976.*

Fig 5. Vertical section through soil showing the root portion of the same seedling shown in Fig. 4. on **11** *September 1976. Note the root stump:termites were present in the root zone, but the camera could not capture them.*

Fig. 6.

Vertical section through soil showing termite tunnels leading to the tap root of an attacked **Eucalyptus tereticornis** *seedling. about 8 months after planting out.*

progression of attack may occur as follows. The first point of attack is usually the basal part of stem or tap root a few centimeters below ground. Continued localised feeding occurs, resulting in the formation of a dumb-bell shaped region between the top and bottom portion below ground (Figs. 7 & 8). Further feeding leads to severance of the major portion of the root system from the upper region. Apparently, feeding is continued on the dead portions at either end. This peculiar method of attack appears to be an adaptation for causing quick death of the seedling so that dead plant tissues, the preferred food material, becomes available.

Another type of damage consisted of extensive browsing of the bark portion of roots, often combined with tapering off of smaller roots (Fig. 9a-d). This was less frequent and mostly noticed on somewhat older seedlings. In rare cases, rugged growth of callus tissue was noticed just above the ring-barked root portion, mostly, but not always, at the collet region (Fig. 9a). It appears that this occurs when the injury is caused slowly, e., mild bark feeding over a long period of time or when feeding is cut short abruptly.

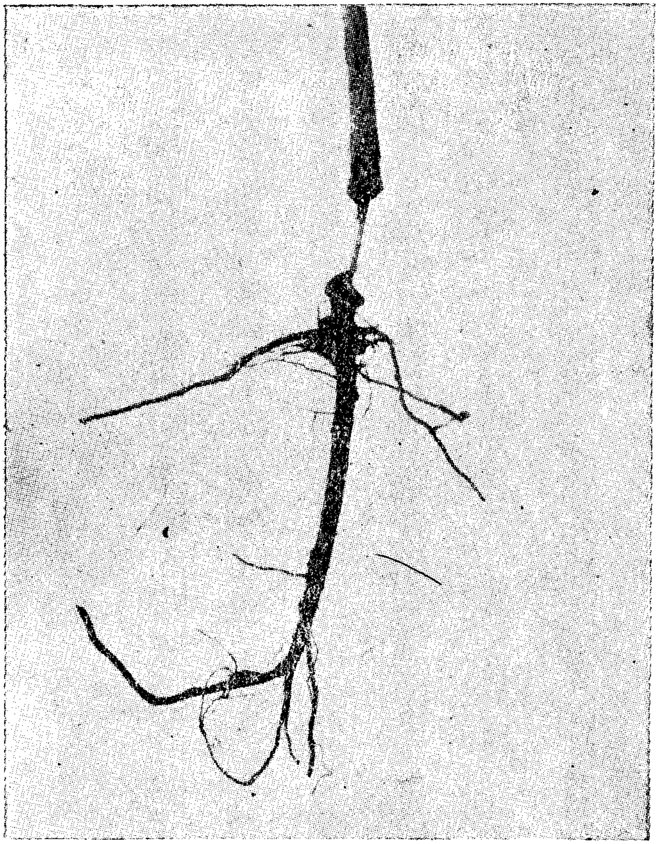

Fig. **7.**

Dumb - bell shaped region in the below-ground portion of **Eucalyptus tereticornis** *seedling* ***caus-*** *ed* ***by*** *termite feeding.*

in some dead seedlings with callus growth, root infection by the fungus, *Botryodiplodia theobromae* Pat. was found together with termite browsing, but callus growth was not observed in all cases of *Botryodiplodia* infection (Sharma arid Mohanan 1981).

In rare cases, especially with comparatively smaller seedlings, the attacked tap root had a more or less blunt end, with no distinct tapering. In all cases, the points of termite attack were not more than about 20 cm below ground level.

Another type of injury consisted of feeding on the bark above ground. Dead as well as live bark of lower portions of the stem of a small percentage of 2- to 5-year-old saplings were nibbled by termites under cover of mud plaster, particularly during the short, dry period. Injury to live bark often resulted in exudation of gum, but did not lead to death of the seedlings. Although some loss of vigour may have occurred, the damage is not considered serious.

Fig. 8a. **Eucalyptus tereticornis** *seedlings showing dumb-bell shaped region below the lionotuber caused by termite attack.*

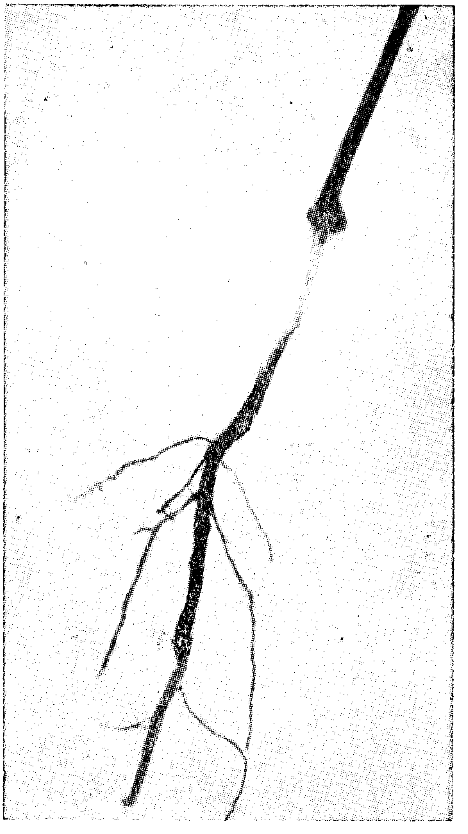

Fig. 8b. *Root portion of Fig 8a enlarged.*

Although termite feeding was common on dead stem of standing or fallen *Eucalyptus* seedlings and saplings, wood portion of live plants was not attacked. This is fortunate because some species of termites, e.g., *Coptotermes acinaciformis* in Australia and **C.** *truncatus* in Seychelles, are known to become established in living trees of eucalypts and feed on the heartwood, hollowing out the tree and causing serious loss of timber (Harris 1971 : 107, 109). The related species, *C. heimi* and **C.** *ceylonicus* occur in India, the former throughout India and the latter in southern India (Roonwal 1979 ; 80) and both are known to attack several tree species. They probably pose a potential threat to eucalypts in India. In Sri Lanka, *Postelectrotermes militaris* has been recorded from the heartwood of living trees of *Eucalyptus* sp. (Roonwal 1979 40).

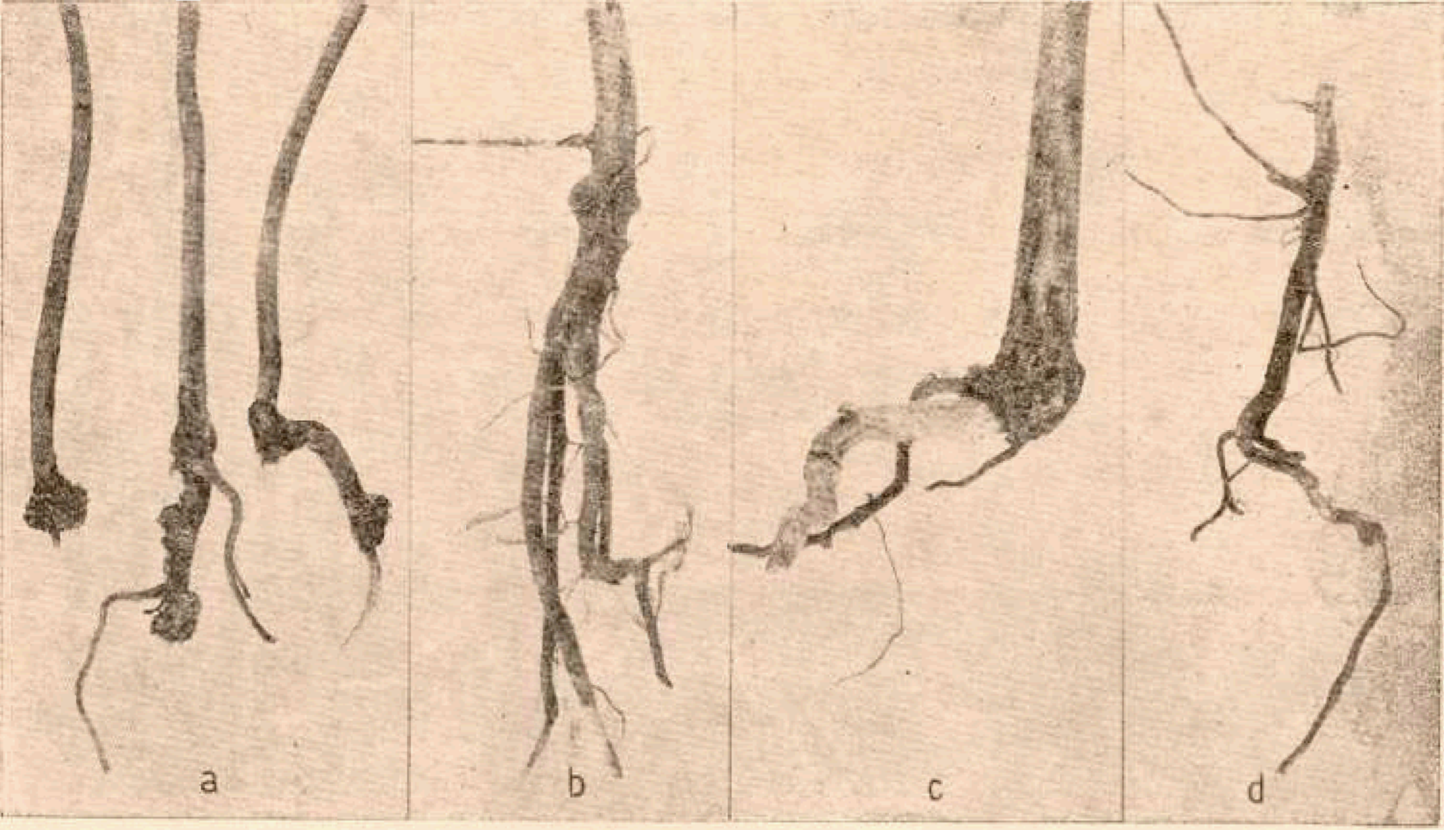

Fig. 9a—d. Some types of root damage of **Eucalyptus tereticornis** *seedlings caused by termites.*

Termite attack: primary or secondary ?

There has been some debate in the literature on whether termite attack of eucalypt seedlings is primary or secondary. Some authors (Chatterjee and Singh 1957; Sebastian and Subramanian 1963; Chatterjee 1972) have claimed that termites will attack *only* those seedlings which have been primarily weakened by other factors, while others (Cooling 1962; Sands 1962; Brown 1955) have suggested that increased plant vigour will lessen the liability to attack by termites. While the latter generalisation of a causal connection between plant vigour and susceptibility to insects (and diseases) is generally accepted as a principle, critical evaluation of the former claim reveals that there is hardly any experimental data to support it. Fungal infection of root as a condition for termite attack, first indicated by Sebastian and Subramanian (1963) and uncritically quoted by other authors, is based on feeble evidence. The idea that termite attack is secondary has probably stemmed from the fact that term'tes do attack seedlings killed or greatly weakened primarily by other causes and it is often difficult to distinguish between the primary and secondary causes. Based on our observations, we recognize three kinds of situations. (1) *Primary termite attack:* Common in eucalypt plantations upto 1-year old, particularly during the initial few months after planting out. The tap root is attacked and generally tapered out as described earlier ; in some cases, extensive feeding *of* the bark portion of roots occurs. In other instances (especially in Africa, *vide infra),* older seedlings may be attacked in which case death results from extensive ring-barking at the collet region. (2) *Secondary Termite attack:* Roots of seedlings killed primarily by other agencies and standing *in situ* are subsequently fed upon by termites. Upto l-year old or older plants may be attacked. Drought is one of the major factors which can cause death primarily. This was noticed at Potta in a small percentage of seedlings between December 1979 and March 1980. In experimental plots not treated with insecticides many of the drought-killed seedlings were not attached by termites initially, but in course of time feeding damage was noticed. In such cases, the roots were not severed and feeding mostly occurred, at least initially, on the dead bark ofroots. Death of seedlings due to drought was more prevalent in shallow soil near rocky outcrops in some of the large-scale experimental plots. Because of pre-planting insecticidal treatment, these dead seedlings were not attacked by termites, except for some feeding on portions of root outside the core of treated container soil. Root infection by the fungus *Botryodiplodia theobromae* was another primary cause of mortality in a small number of seedlings in the experimental plots at Potta. (3) *Complementary termite attack (combined action by termites and other causes)* : In some cases, in spite of frequent observations, it was difficult *to* determine whether termite attack preceded or succeeded death of the seedling. Such cases were noticed mainly at Potta during the dry spell in 1979—'80. it is assumed that seedlings which had lost their vigour due *to* water stress were attacked by termites and the combined action of drought and termite feeding resulted in death of seedlings. Similarly, root infection by fungus and termite attack could act jointly to cause death of seedlings, although both are capable of causing death independently. It is also possible that bark feeding by termites may provide a port of entry to fungal pathogens and may also reduce the ability of seedlings to withstand drought. Most deaths of seedlings in our experiments in 1976, '77 and '79 were due to primary termite attack ; other types of mortality contributed very little to the total loss.

Period of incidence of attack

Periods of incidence of termite attack in experiments conducted in the Years 1976, '77 and '79 are shown in Fig. 10. Untreated controls as well as treatments which permitted comparatively high incidence of attack are included in the graph. As already noted, all lethal attacks occurred within one year of planting out. It is generally held (Chatterjee 1972; Roonwal 1979) that eucalypt plantings under 5 years of age are liable to termite attack in India, although there is no observational record of significant damage except in the first year of planting. In *Eucalyptus grandis,* we have observed lethal damage of a few approximately 2-year-old seedlings in plantations at Begur and Sultan's Battery (Northern Forest Circle) but in *E. tereticornis* we have not come across lethal termite attack 1 year after planting out.

This situation differs markedly from West Africa where lethal damage can take place during the first 4 or 5 years of establishment (W. A. Sands, Centre for Overseas Pest Research, London, pers. comm., Feb. 1979). Cooling (1962) reported that *E. saligna* saplings upto 15 cm diam. at base may be ring-barked and killed bytermites in Northern Rhodhesia. Similarly 3 - 4 year-old saplings are known to be killed by termites in East Africa (Wilkinson 1962). Larger species of termites like *Macrotermes bellicosus, M. natalensis* and *Pseudacanthoterrnes militaris* are mainly responsible for lethal damage to eucalypts, especially older seedlings, in many parts of Africa (Sands 1962; Wilkinson 1962; Brown 1965). The age-related difference in susceptibility between Africa and India is the result of differences in the prevalent species of termites. Apparently, the indigenous species of termites in India are not attracted to roots of older eucalypts. The immunity of older seedlings does not appear to be due to tolerance, i.e., ability to withstand attack, for, if feeding occurs, the seedlings may be killed in view of the propensity of most termite species to build up enormously in numbers. Brown (1965), however, contends that the comparative "resistance" of some species of eucalypts to termites is more of an ability to continue growing despite attack.

It may be seen from Fig. 10 that most termite attacks occurred during July to November of the planting year, although scattered attacks were noticed almost every month. In one instance (one of the controls in 1977), there was a small second peak in April - May of the following year. The same data plotted in relation to time of planting (Fig. 11) indicate clearly that most termite attack usually occurs within 100-120 days of planting out.

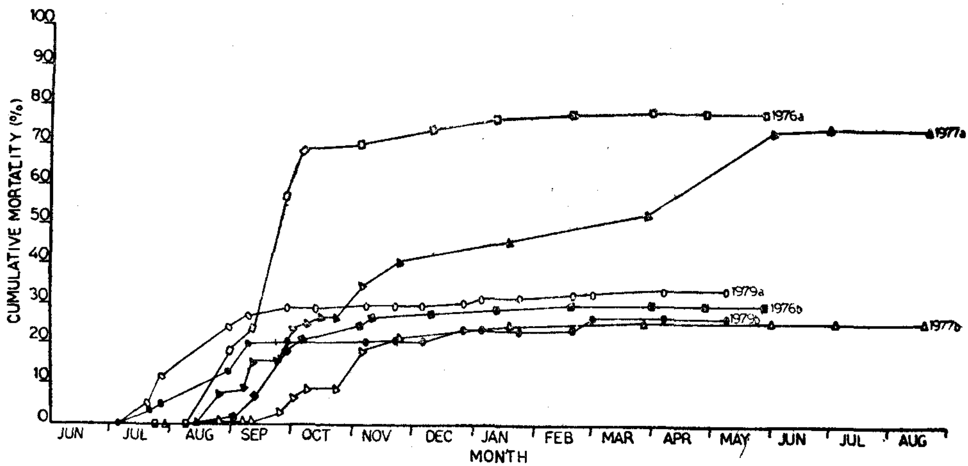

Fig. 10. *Graph showing the periods of incidence of termite attack of eucalypt seedlings in experimental plots in the years 1976, '77 and '79. Date of planting is indicated by the appropriate symbol on X-axis.*
1976a—Untreated control ; 1976 b—BHC (0·5 g a. i./pit) ;
1977a—Untreated control, EC trials ; 1977b—Untreated control, Dust trials ;
1979a—Untreated control ; 1979b—Root dip (0·1% aldrin, 30 min).

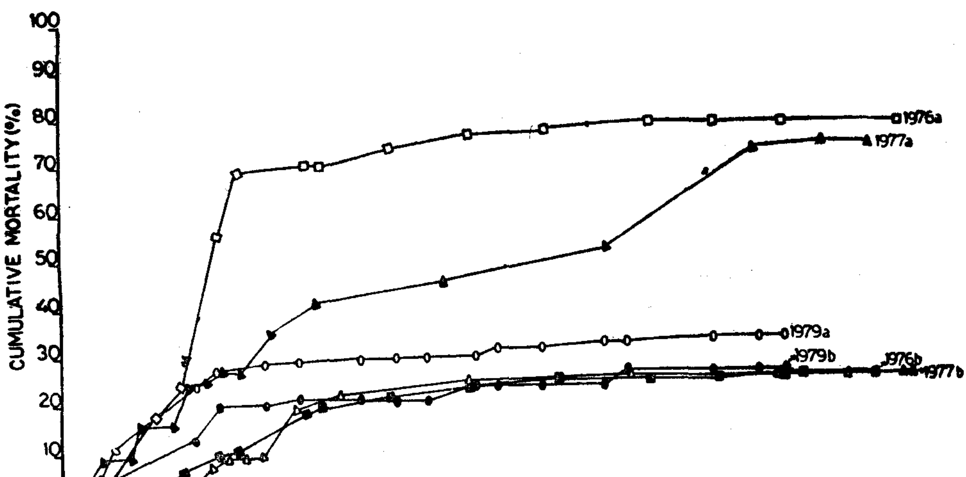

Fig. 11. *Graph showing the incidence of termite attack of eucalypt seedlings in the years 1976, '77 and '79 in relation to days after planting. The data used are the same as in Fig. 10.*

To examine possible correlation between the seasonal distributions of rainfall and incidence of termite attack, data coilected from a meteorological station located at Vazhani at a distance of between 20 and 40 Km from the different experimental sites were plotted along with mortality curves (Fig. 12), but no correlation was found. Nor was there any relationship between the annual rainfall and the annual loss due to termites. There is a general belief that termite attacks are more common during dry periods. Ourdata (Fig. 12) do not lend support to this. Indeed, above-ground activity of termites such as scavanging on woody debris and bark feeding, was more pronounced during the dry months. Primary root feeding, however, was not correlated with the dry period; active root feeding was observed even on rainy days. Apparently, secondary attack of drought-killed seedlings may give a false impression of increased termite attack during the dry season. Although some primary termite attacks did occur in the dry season, in our experiments, most damage occurred before the onset of the dry season (Fig. 12). The pattern of seasonal incidence of attack in dry zones outside Kerala needs to be investigated as the combined action of drought and termites may be more important in the dry zones.

The strong relationship between the time of planting and peak incidence of termite attack may be a function of seasonal activity rhythm *of* the termites or age-related susceptibility of the seedlings. Annually, following the onset of monsoon, alate reproductives are released from the subterranean nests of termites (swarming). Changes in activity rhythm of the colony are therefore possible during this period. Whether colonies newly established after swarming may contribute to attacks on seedlings is also not known. Trials with seedlings of different age groups could throw light on age-related susceptibility. Since good establishment of seedlings in the field is dependent on adequate rainfall, it may not be feasible to alter the planting time, but it is feasible to alter the age of the planting stock if it can bring about reduced incidence of attack, although the cost of maintaining the seedlings in the nursery for one year more would be prohibitive. Further research in this direction may prove fruitful since there is already indication that older seedlings of *Eucalyptus tereticornis* are less prone to attack. Our observations did not indicate, however, that more vigorous seedlings, i.e,, those of the same age which grow faster than others, are less prone to attack, but vigour and age are factors which may act differently.

Even in African countries where older seedlings are killed, it has been widely observed that most losses occur in the first year of planting, particularly during the initial few months (Brown 1965). Factors influencing termite attack of eucalypts in Africa have been discussed by Brown (1965), Cooling (1962), Harris (1962) and Wilkinson (1962). It has been suggested that transplanting shock, by lowering the vitality of seedlings, may enhance

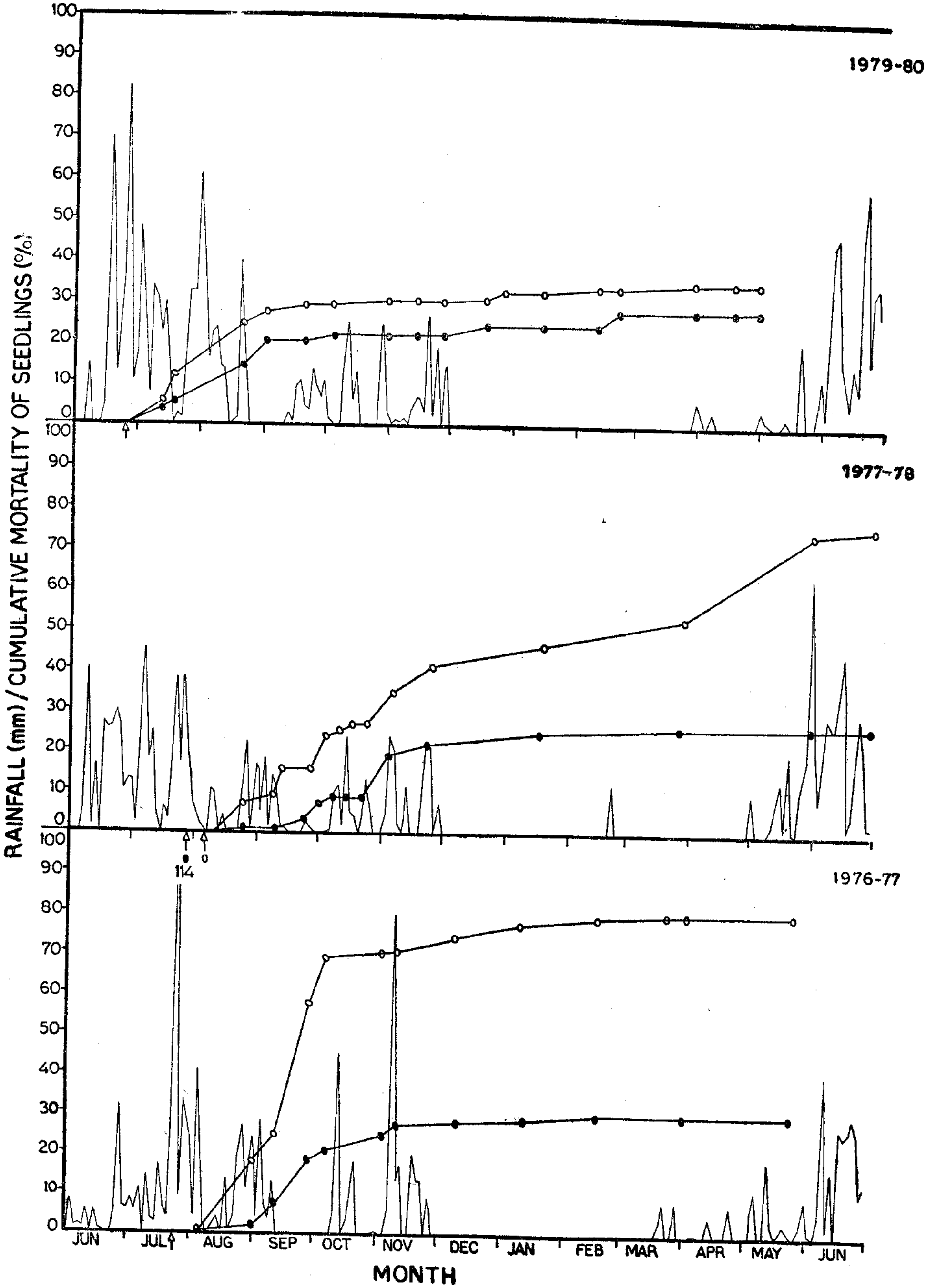

Fig. 12. Incidence of termite attack in eucalypt seedlings (untreated cotrols and ineffective treatments) during the years 1976–77, 1977–78 and 1979-80 at Arasseri, Kondazhi and Potta, respectively, in relation to distribution of rainfall (2-day averages). Dates of planting are indicated by arrows on the X-axis.

susceptibility to termites during the initial few months, but in our trials it was common to find well established, vigorously growing seedlings suddenly knocked down by termites.

Species of termites injurious to eucalypt seedlings

Table 6 presents a classified list of termite species collected from the experimental plots (small-scale insecticide trials) and immediate surroundings. All the plots were in the Wadakkanchery Range of Trichur Forest Division and lay within a radius of 9 Km at an altitude of about 180 m, at 10^{o} 42' N latitude and between 76^{o} 12' and 76^{o} 27' E longitude. *Odontotermes* was the dominant genus in the locality, with 11 of the 17 species belonging to this genus. Six species were found injurious to eucalypts, of which all except one *(Microtermes obesi)* belonged to the genus *Odontotermes.* Two of .these, *O. redemanni* and *O. vaishno,* attacked only the bark portion above ground and are not serious pests. Lethal damage was caused by *Microtermes obesi, Odontotermes ceylonicus, O. guptai* and *O. roonwali.* The same species were also found to attack eucalypt seedlings in other localities. (Table 6, see foot note). Table 6 does not indicate the root feeding termites recorded from Arasseri because the samples collected specifically from root were lost in transit. *O. guptaiand O. roonwali* found at this site on dry cow-dung and Grass are, however, root feeding species.

Although several authors have listed the species of termites attacking eucalypts in India (see Roonwal 1979 : 40), only a few of the records are based on original observations. Roonwal (1979 : 41) associated five species specifically with damage to seedlings. These are *Microcerotermes minor, Odontotermes feae, O. horni, O. parvidens* and *O. microdentatus,* the last one confined to northern India. None of these were represented in our collection of root feeding termites, although O. *feae* was present in other niches in the locality. Our list includes only those established beyond doubt as root feeding ; it is possible that some of the root feeding species escaped collection. On one occasion, *Coptotermes heimi* was obtained from the root region of an attacked seedling in a mixed collection with *O. guptai* (root feeding), but more evidence is necessary to include C. *heimi* in the root feeding category. Those included have been collected independently on several occasions. *O. heimi* is known to attack the tap root of apple tree and the wood of several other living trees (Roonwal 1970, 1979: 37). In addition to possible damage to root, this species has the potential to become a pest of living *Eucalyptus* trees, as mentioned earlier.

It is interesting to note that most root-feeding termites found in our study do not build conspicuous mounds. Located within or in the vicinity of our experimental'plots were mounds of O. *kushwahai* and *O. wallonesis*

Table 6

Termite fauna of experimental sites

Sl. No. of species	Species	Locality: Arasseri	Kondazhi	Potta
	Root Feeding			
1	*Microtermes obesi* Holmgrena		+	
2	*Odontotermes ceylanicus* (Wasmann)[b]		+	+
3	O. *guptai* Roonwal & Bose		+	+
4	O. *roonwali* Bose			
	Bark Feeding			
3	*Odontotermes guptai*	+	+	+
5	*O. redemanni* (Wasmann)		+	
6	*O. vaishno* Bose	+		
	Other Feeding Habits			
7	*Angulitermes keralai* Verma[e]		+	
8	*Coptotermes heimi* (Wasmann)			+
9	*Macrotermes* sp.	+		
10	*Nasutitermes brunneus* Snyder	+		
11	*Odontotermes anamallensis* Holmgren Holmgren	+		
12	*O. feae* (Wasmann)	+	+	
3	*O. guptai*		+	
13	*O. indicus* Thakur			+
14	*O. kushwahai* Roonwal & Bose		+	
15	O. *obesus* (Rambur)			+
5	*O. redemanni*		+	
4	*O. roonwali*	+	+	
16	***O.*** *wallonensis* (Wasmann)		+	
17	*Trinervitermes* sp.	+		

a, Root feeding at Nilambur and Begur also

b, Root feeding at Peechi and Thuva (Agali) also

c, Root feeding at Thatchamala (Agali) also

d, Root feeding at Peechi and Thuva (Agali); believed to be root feeding at Arasseri and Kondazhi from where it was recorded on dry cow-dung and grass

e, New species to be described by Dr. S.C. Verma, Zoological Survey of India.

(within plots, Kondazhi). O. *redemanni* (near plot, Kondazhi) and O. *obesus* (within plot, Potta), but none of these species were found to attack the seedlings. It is of interest to examine the habits of the root-feeding species.

Microtermes obesi is one the most injurious to economic crops in India, attacking cereal and vegetable crops, sugarcane, tea, fruit trees, etc. It lives in small subterranean communities, and often construct nests in the mounds of other termites (Roonwal 1970, 1979). In one of the collections, we found them in close association with O. *obesus* but on several occasions the species was found independently. It is known that frequently *M. obesi* is accompanied by O. *obesus* in foraging expeditions (Roonwal 1970). According to Sands (1973) *Microtermes* spp. enter the plants (woody or herbaceous) at the collet region and hollow it out from within and the excavation is characterised by presence of mud. In jute, *M. obesi* enters the tap root and then goes up the basal portion of the stem which is hollowed out and filled with earth (Roonwal 1979 : 35). In attacked *Eucalyptus* seedlings, however, no such hollowing out was found. Although, in rare instances the attacked tap root was found to end bluntly without the characteristic tapering, it was not possible to associate this type of damage with *M. obesi* definitely.

Odontotermes ceylonicus, known to attack dead wood, also nests in underground soil and do not build a moilnd, nest chambers being usually found in the mound of other termites.

O. guptai, the most versatile in feeding habits (found on root, bark and other micro-habitats) belongs to the obesus-group and was separated from O. *obesus* only in 1964 (Dr. S. *C.* Verma, Zoological Survey of India, pers. comm., Nov. 1980). We have no information on its nesting habits; no mounds of this species was found in the vicinity of our experimental area. It is interesting to note that O. *obesus* which ranks with *Microtermes obesi* as one of the two most destructive species to crops in India (Roonwal 1979:14), has not been found to attack *Eucalyptus* seedlings although it was found in other habitats within the locality.

O. roonwa/i is usually found in logs of rotten wood, in soil under dung and under mud plaster on tree trunks and is also a non-mound-builder (Roonwal 1978).

In many parts of Africa, most deaths in young eucalypt plantations are caused by three species of termites, viz. *Macrotermes bellicosus, M. natalensis* and *Pseudacanthotermes militaris* (Sands 1962; Brown 1965), all of them large species not occuring in India. Other termites implicated (Brown 1965) are species of *Amitermes, Ancistrotermes* and *Microtermes,* but specific information is lacking. In Uganda, according to Brown (1965), although

Odontotermes are widely distributed, they have not yet been definitely associated with damage to eucalypts. Possibly, this is only due to dearth of information. However, other species msntioned above are apparently more damaging. In India, 7 of the 9 harmful species (4 new records by us and 5 earlier records) belong to *Odontotermes,* the other genera being *Microtermes* and *Microcerotermes.* The reiative importance of the species involved explain the difference in age-related susceptibility of eucalypts between Africa and India, as noted earlier.

Variation in damage intensity

There was considerable variation in the incidence of termite attack in the various trials (Table 7). Generally, loss due to termites was high, ranging from about 20 to 80 per cent of the seedlings. The only exception occurred in the 1979 trial (large-scale) at Nilambur where only 4 per cent of the seedlings suffered mortality. The cause(s) of this extreme variability is not clear. It is not due to influence of weather conditions in the year of planting because in the same year marked variation occurred between two plots in the same locality (Kondazhi 1977) and between two localities (Potta and Nilambur 1979) (Table 7).

Table 7

Incidence of termite attack in the untreated controls of various experiments and soil properties of some sites

Experimental site and year of experiment	Top Soil*		% iossof seedlings due to termite attaclc
	Texture	pH in water	
Arasseri, 1976	Loam	5.8 2 0.3	80
Kondazhi, 1977a**	—	—	76
Kondazhi, 1977b	Loamy sand	5.4 ± 0.1	28
Potta, 1979	Loam	5.9 + 0.2	35
Potta, large-scale, 1979	—	—	19-24
Nilambur, large-scale, 1979	—	—	4

* Data provided by the Soil Science Division, KFRl

** No taungya crop ; in all other plots a taungya crop of tapioca was raised in the first year.

It appears that properties characteristic of the experimental sites were responsible for the variation. Limited data available on soil properties (Table 7) did not show any marked variation among plots which could be related to the intensity of damage. Obviously, the intensity of attack is a function of the endemic species of root-feeding termites and their population in the site, which in turn will be determined by the history of the site, i. e., previous vegetation, management, etc. Unfortunately, we do not have sufficient data on these aspects.

Termites in general are scavengers of woody debris on the forest floor and form an important component of the ecosystem of tropical soils. During preparation of land for planting, the existing vegetation is cleared and the debris burnt. No leaf litter accumulates on the ground, at least during the first year of planting. This is particularly so when the weed growth is also cleared and burnt for taungya cultivation. These operations deprive the termites of their normal food — woody debris and leaf litter, and the attack on seedlings may be a forced reaction in search of alternate sources of food. The influence of site clearance in aggravating the termite hazard has also been suggested by other authors (Cooling 1932; Sands 1973). However, absence of taungya cultivation (i.e., less intense site clesrance) did not reduce the incidence of termite attack in our experiments at Kondazhi in 1977 (Table 7). It is also common to find termite attacks on seedlings planted one year after site clearance (casualty replacements). Well planned, large-scale trials are necessary to throw light on the influence of land preparation on termite incidence.

Species of eucalypts susceptible to termites

Currently only two species of eucalypts are grown extensively in Kerala — *Eucalyptus tereticornis* and *E. grandis.* Although our trials were conducted with the former, general observations have shown that *E. grandis* is equally prone to termite attack. Other species known to be susceptible in India are *E. citriodora* and *E. robusta* (Chatterjee *etal.* 1967; Roonwal 1978). Seedlings of *E. citriodora* and *E. maculata* have been reported to show some resistance to termites in China (Harris 1971 : 109). There is no report of any *Eucalyptus* species being absolutely resistant to attack, although for many species, termites have not been specifically listed as pests. The available literature suggests that most species used for afforestation work in India and Africa are susceptible, although the degree of susceptibility may vary. The possible existence of resistance and the relative susceptibility of different species remains to be explored.

Some general considerations

It seems appropriate here to discuss briefly, how far the methods of protection standardised for *Eucalyptus tereticornis,* based on field trials conducted at some locations in Kerala, are applicable to other species of eucalypts and other geographical regions of India. Since the treatment is directed against termites, the host species of *Eucalyptus* is important only in as much as it influences the species composition of pest termites and the period of host susceptibility. There is some indication that the toxicity of a given insecticide to different species of termites may vary slightly (Sands 1962), but the general toxicological literature on insects suggests that the magnitude of such differences will be small within a given taxonomical group of species. All the destructive species of termites found in this study belong to the subfamily Macrotermitinae (family Termitidae). Since the insecticide dosage recommended for routine plantations (0.12 g a.i./seedling, Section 3) is several-times the minimum effective dosage, it should take care of any possible differences in susceptibility between species. As far as we are aware, larger species of termites similar to those attacking older saplings of eucalypts in Africa do not occur in India. Had they been present, additional surface-soil treatment would have become necessary in view of their different habits of attack.

Although there is no conclusive evidence, it seems likely that in India, the susceptibility (at least the greater part) of all species of eucalypts is limited to the first year of planting. As discussed earlier, the period of susceptibility is apparently a function of the prevalent species *of* termites and not of intrinsic differences between species of *Eucalyptus* in this respect. Even if the period of susceptibility is much longer, the recommended insecticides can take care of the situation, as cyclodiene insecticides such as aldrin and heptachlor are generally known to persist in soil for several years, even under tropical conditions. Stud'es in West Africa (Sands 1962) showed that 1/3 rd to 1/5 th concentration of aldrin applied to soil persisted for about 3 years. Approximate calculations indicated that when applied at the rate of 5.6 Kg/ha, termiticidal concentrations *of* aldrin may persist for about 9 years.

Because of the two monsoons (south-west and north-east), Kerala has a short dry season. In the comparatively drier zones outside Kerala, greater mortality of seedlings may result from the combined action of drought and termites, as pointed out earlier. The season of peak incidence of attack man also vary. Field studies in other parts of India are needed to throw light on the above aspects. However, irrespective of the period of peak incidence of attack, the method of treatment recommended here should protect the seedlings from termites. In the case of combined action of drought and termites, the treatment will eliminate one of the contributing causes of mortality so that the seedlings will not die unless drought is sufficiently intense to cause mortality *per* se. The relative importance *of* termites and other factors in other geographical regions must be established based on field experiments. It must be recognized that insecticidal treatment is not a panacea for all the mortality in eucalypt plantings ; it can prevent only losses caused by termites.

An important factor that may limit the applicability elsewhere of recommendations based on studies in Kerala, is soil pH. Most of the forest soils in Kerala are acidic (Koshy and Varghese 1971). Organochlorine insecticides like aldrin and heptachlor are less stable in soils of high pH. For example, in studies conducted at IARI, about 96% of aldrin and 86% of heptachlor were lost in 6 months, in soil of pH 8.2 (Agnihotri 1980). Although pH is not the only factor which influences the rate of degradation of insecticides in soil, it is safe to suggest that recommendations made here are applicable to most locations in India where the pH is not high. Differences in the termite fauna are not important for reasons d'scussed earlier.

5. CONCLUSIONS AND RECOMMENDATIONS

The present study has shown that termite damage is a serious problem in plantations of *Eucalyptus tereticornis* in the first year of establishment. When no protective treatment was given, 20 to 80 per cent of the seedlings were lost in trials conducted in the Trichur Forest Division, although the loss was only 4 per cent in one trial conducted at Nilambur. Most losses occurred in the initial 4 months after planting out. Although the incidence of attack was found to vary from place to place and year to year, the risk is considered to be serious for most localities in Kerala. General observations showed that *E. grandis* was also susceptible. The incidence of attack was not related to rainfall and possibly depended on site factors including species of termites present and their population density. It is not possible to predict the intensity of damage in a given area.

All termites are not harmful to eucalypts ; out of 17 species present in the experimental plots in the Trichur Forest Division, only 4 were found to cause lethal damage to seedlings. Most species that are injurious live in small subterranean colonies and do not build conspicuous mounds (nests). Absence of termite mounds in the planting area, therefore, does not suggest freedom from the risk of attack, and *vice versa.*

One year after planting out, *E. tereticornis* seedlings suffered no mortality, although the termites nibbled on the bark portion of stem. This is unlike the situation in most African countries where they are susceptible for the initial 4 to 5 years of establishment. The difference is attributable to presence of different species of termites.

Remedial measures applied after attack has been noticed in a plantation are cumbersome and cannot ensure complete protection. Prophylactic methods are therefore necessary and must be applied before the seedlings are planted out.

Good protection can be obtained by treating the soil with an appropriate insecticide. Of four selected insecticides tested in field, aldrin, chlordane and heptachlor gave good protection ; BHC was not satisfactory. Preliminary results of ongoing experiments indicated a slight growth retarding effect of chlordane on newly planted seedlings. Use of aldrin or heptachlor is therefore recommended.

The insecticide may be applied either in the planting pit or container soil, as dust or water emulsion. When used in the planting pit as dust or liquid spray, the soil should be turned over adequately to mix the insecticide with the soil. Most failures in routine plantations where pit treatment is employed appears to be due to improper mixing. In container treatment, if dust is used, it should be mixed with the container soil prior to placing the soil in containers. If an emulsified concentrate (EC) is used, it can be applied by drenching the container seedlings with the diluted insecticide solution. Container treatment with EC formulation is the simplest procedure. It can be carried out any time after the seedlings are established in containers. Since termite attack usually occurs within the upper 20 cm portion of the tap root, preplanting container treatment affords sufficient protection to seedlings planted out in the field : additional pit treatment is not necessary. Under Kerala conditions, the risk of attack by termites that may work their way to the seedlings through the thin layer of untreated soil above the treated container soil is minimal ; therefore no economic benefit can result from additional pit treatment or post-planting surface-soil treatment. Such treatments are necessary only in some of the African countries where larger species of surface-foraging termites pose threat to eucalypt seedlings.

Dosage as low as 0.03 g active ingredient (a. i.) per container gave sufficient protection in experimental treatments. For routine treatment, a osage rate of 0.12 g a.i./container is recommended to ensure an effectived minimum dosage to individual seedlings, in large-scale group drenching.

In brief, the procedure recommended is as follows. After the seedlings have become established in containers and before they are planted out, drench the seedlings with a water emulsion of aldrin or heptachlor. Use 1 litre of aldrin 30 EC or 1.25 litres of heptachlor 20 EC per lot of 2,500 seedlings to give a dosage of 0.12 g a.i./container. Dilute the insecticide in about 125 litres of water to give about 50 ml water per container. The drenching is best carried out using a rose can, applying the liquid in two or three consecutive instalments, covering the entire group of 2,500 seedlings each time as uniformly as possible.

The cost of insecticide works out to about Rs. 50/- per hectare of plantation (2,500 seedlings). Labour cost is negligible compared to pit treatment.

The present study provides for the first time a standardised procedure for termite control in eucalypt plantations, based on field trials in India. It is applicable to most species of eucalypts and most locations in India where the soil pH is not high.

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