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COVER PICTURE

A view of the natural forests of the Montane Zone from World's end.

Photo — M. P. A. JAYATILLEKE

THE SRI LANKA FORESTER
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VOLUME XII — No. 2 (NEW SERIES) JULY — DEC. 1975

"The forest is a peculiar organism of unlimited kindness and benevolence that makes no demand for its sustenance and extends generously the products of its life activity: it affords protection to all beings, offering shade even to the axeman who destroys it."—GAUTAMA BUDDHA.

News in Brief

Retirement

Mr. A. E. K. Tisseverasinghe (Senior Assistant Conservator of Forests, Research and Education) and Mr. K. Arulchelvam, (Assistant Conservator of Forests) left the Department to accept assignments abroad. Both of them have been regular contributors to this journal and we hope that they will continue to lend their support in the future. We wish both of them success in their new assignments.

Training

Mr. D. L. Jayanetti (Timber Utilisation Research Officer) returned to the island after completing a course of training in U.K.

Appointment

Mr. S. M. S. Subasinghe was appointed as Assistant Conservator of Forests and is now serving as Assistant Divisional Forest Officer in Kurunegala.

Seminars

Mr. L. C. A. de S. Wijesinghe (Senior Assistant Conservator of Forests, Reforestation and Silviculture) and Mr. K. P. Shri Bharathie (Senior Assistant Conservator of Forests, Working Plans), attended a meeting on 'Integrated ecological research and training needs in deciduous forest Ecosystems of S. E. Asia' held at Benares Hindu University in October, 1975. The meeting was held under the auspices of UNESCO in co-operation with National MAB Committee of India and BHU.

Mr. K. Rajapakse attended a seminar on 'Site Diagnosis' held in Hungary in August, 1975. The seminar was organised by the FAO.

The Transport of Preservatives Through Green Wood

A. E. K. TISSEVERASINGHE *

(Senior Assistant Conservator of Forests, Research and Education)

INTRODUCTION

THE preservative treatment of green wood by dipping in concentrated solutions of Boron salts and block—stacking it under covered conditions that impede air movement within and around the stack, is well established. The method was used successfully to treat Rubber (*Hevea brasiliensis*) wood in an attempt to render it usable. This wood could not be used for other than temporary purposes due to its extreme susceptibility to borer attack (Tisseverasinghe, 1969 ; 1970).

Treatment of rubber wood required 3 weeks of diffusion storage for 1" thick wood and 5 weeks for 2" wood. These periods were sufficient for the growth of sap stain fungi —in the case of 1" timber the growth was mostly confined to the surfaces but in the 2" thick pieces, which had been stored for 5 weeks under conditions of restricted circulation, the sap-stain fungi generally penetrated the whole cross section of the pieces thus rendering them virtually unusable. This growth of sap-stain occured despite the use of a fungicide—Sodium pentachlorophenate—in the preservative liquid. This fungicide was selected because it has elsewhere been found to be one of the most effective in sap-stain control (Cserjesi and Roff, 1964; Arenas, 1967).

Specimens of stained wood were sent to the Western Forest Products Laboratory, Vancouver, British Columbia, Canada, for examination by Mr. A. J. Cserjesi who reported that the fungi were species of *Penicillium* and *Aspergillus*, both of which were able to convert Pentachlorophenol to other, less toxic substances—*Penicillium* at a much faster rate than *Aspergillus*. Toxicity tests were carried out at the Vancouver Laboratory with other fungicides but none had sufficient toxicity to suggest its use (Cserjesi, 1971).

It was apparent therefore that attempts to control these fungi by the use of fungicides were not likely to be very fruitful.

If the growth of fungi could not be controlled by the use of fungicides the only other way would be to shorten the treatment period leaving no time for the growth of fungi.

EXPERIMENTAL WORK

On the assumption that diffusion was the process at work in conveying the preservative salts into the wood, and since the rate of diffusion is dependent, among other

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things, on the concentration gradient between the preservative layer on the outside of the wood and the inside, it would be evident that diffusion would be speeded up if a consistently high diffusion gradient could be maintained.

A few pieces of green wood were left to soak in a bath of preservative fluid. The diffusion period was somewhat shortened and the timber was fungus free, but larger quantities of timber obviously could not be treated by this method.

Another possible way of maintaining a consistently high concentration gradient would perhaps be to spray preservative solution over a stack of timber built in such a way that all the pieces in the stack would be wetted by the liquid.

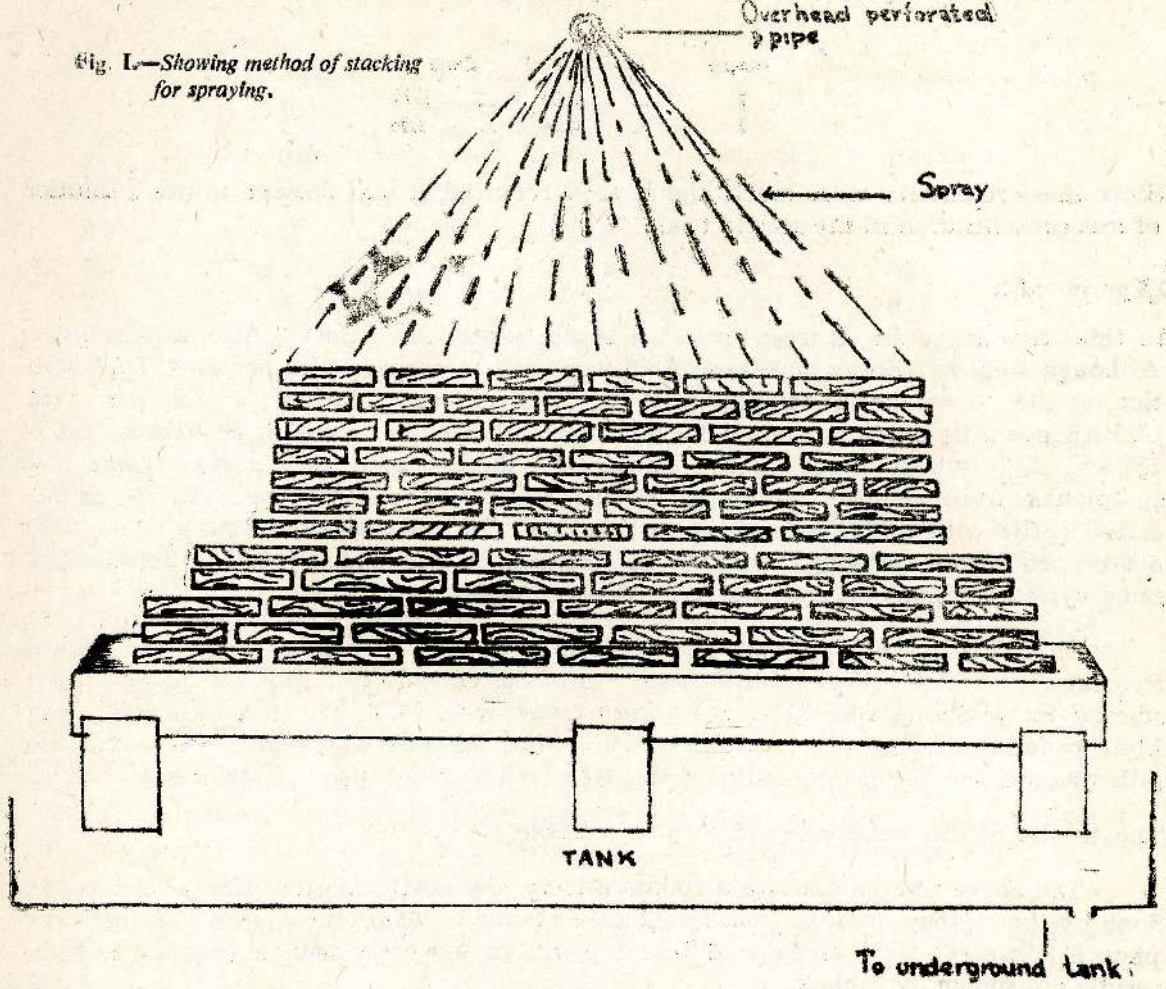
Experiment 1

THE first experiment was started on 17.8.1972. Eleven freshly felled rubber logs were obtained and sawn into 1" planks in the laboratory. 53.0 cubic feet of planks were obtained. These planks were treated by first dipping in a 25 per cent. Boric Acid equivalent (BAE) solution made by dissolving Borax and Boric Acid in water to which was added 0.2 per cent. of sodium pentachlorophenate. These planks were stacked over a tank in a 'staggered' manner so that any gaps in one layer did not coincide with gaps in the adjacent layers. This was to ensure that the preservative spray seeped through the stack instead of dripping through gaps (Fig. 1). A solution was made by dissolving the crystalline residue left from previous diffusion treatments and, at saturation, this resulted in a 20.6 per cent. BAE solution at 27°C (tested by hydrometer and read against Chart in "Plant Operator's Manual of recommended practice 1967). This solution was prepared in a tank placed below ground level. The solution was pumped through a perforated overhead pipe in such a manner that the stack of wood was subjected to a continuous spray spray of preservative solution. The preservative solution which seeped through the wood was collected in the tank over which the stack had been built and from this transferred by gravity to the below—ground tank. Thus the preservative solution was continuously recycled. The spray was turned on for half an hour and off for half an hour continuously. After two days a considerable drop in the level of the below—ground tank was observed—this drop roughly corresponded to 60 gallons. Part of this drop could be attributed to evaporation and part to losses by splashing, but a part of this drop was clearly due to absorption by the wood.

On 21.8.1972 i.e., after four days of the spray treatment slices were cut from two planks on top of the stack and spot tested for penetration by the Turmeric test. This showed complete penetration except for small patches in the centre. On 22.8.1972 i.e., after five days of spraying., the stack was broken and slices were obtained from planks in the centre of the stack. On testing with Turmeric, these also showed complete penetration. The spray was stopped on the next day and the planks were stacked for seasoning.

When the stack was broken and planks, examined, it was found that despite careful stacking of the planks, some parts of some of the planks were dry and untouched by the preservative. However, testing with turmeric showed that these areas were also penetrated by the preservative.

Fig. I.—*Showing method of stacking for spraying.*



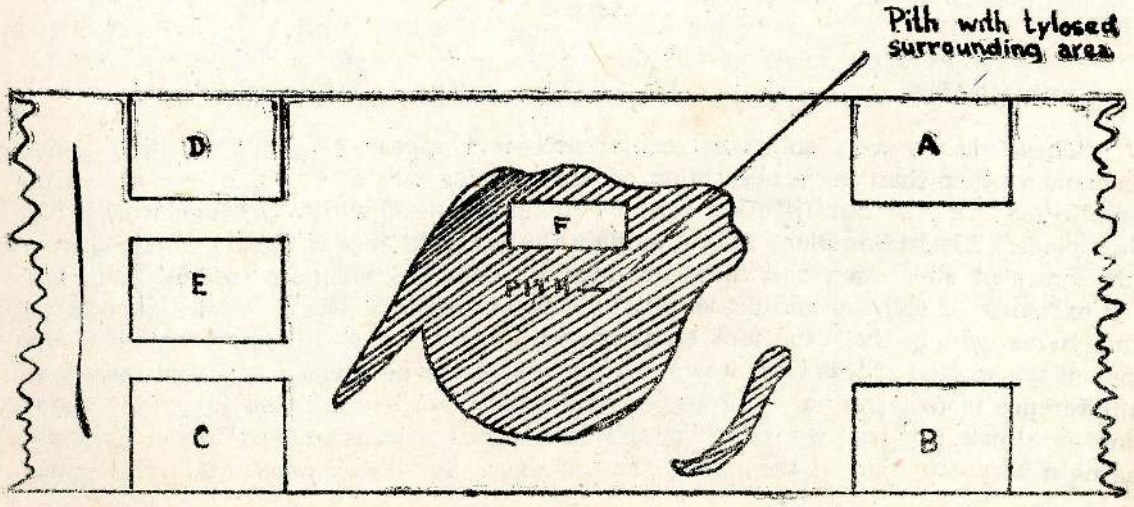


Fig. II.—*Cross-section of 2½" plank (to scale) showing untreated zone (hatched) and location of samples for chemical analyses.*

Chemical analyses done on two samples indicated the following loadings:

Sample	*Core % BAE*	*Shell % BAE*
1	0.80	1.75
2	0.94	1.76

Since these retentions were much higher than required, it was decided to use a solution of less concentration in the second trial.

Experiment 2

In this trial therefore, a fresh solution using Borax and Boric Acid was prepared Although sufficient Borax and Boric Acid was used to prepare a 10 per cent. BAE solution, at the atmospheric temperature of 77°C only a solution of 8.6 per cent. of BAE could be obtained (tested by hydrometer). On this occasion 48.9 cubic feet of 1⅛" and 2½" rubber wood were sawn. Of these, three 2½" planks and six 1⅛" planks were weighed before and after treatment. The stack was prepared as described earlir with the 2½" planks at the bottom. On this occasion the planks were not dipped before spraying. Spraying commenced at 2.30 p.m. on 6.12.1972, using the same cycle—1/2 hour on and 1/2 hour off—as before.

On 8.12.1972 i.e. after two days, samples of the 1⅛" planks were tested with Pyrocatechol violet and penetration was complete. On 9.12.1972 the 1⅛" planks were stacked for seasoning and 2½" planks were tested with PCV. The test indicated complete penetration except in samples which contained pith where an area round the pith was not penetrated. Accordingly the 2½" planks were also stacked for seasoning.

The results of the weighings are shown in Table 1.

The above figures indicate a comparatively low BAE retention. Chemical analyses done by the method described earlier (Tisseverasinghe, 1969) presented a very different picture. Samples were taken at different points in the cross section (Fig. II) and the results are shown in Table 2.

TABLE 2

Sample	*A*	*B*	*C*	*D*	*E*	*F*
B AE %	1.9	3,8	3,6	1.9	3,7	0.09

These results were somewhat remarkable and appeared to indicate that some mechanism other than mere absorption of preservative was at work. No doubt diffusion also plays a part, but diffusion cannot explain the speed with which penetration had taken place. Absorption alone cannot explain the big difference in figures obtained from a measuure of absorption and those obtained by chemical analyses (unless there had been exchange of cell sap and preservative).. At one stage it was suspected that living parenchyma cells in the wood took an active part in the transfer of preservative to the inside of the wood, but this view was quickly abandoned whe it was found that there was no difference in penetration in pieces of wood which had been dipped in boiling water before treatment and that the rate of penetration of cell poisons such as Copper Sulphate was no different to that of the Boron preservatives. It was observed that the areas

TABLE 1

Thickness of Planks	Cubical content	Weight		Solution uptake	BAE uptake	BAE %
		Before Treatment	After Treatment			
	(ft.3)	(lb.—oz.)	(lb.—oz.)	(lb./ft.3)	(lb./ft.3)	
1 1/8"	0.625	40—8	41—11	1.9	0.16	0.40
1 1/8"	0.630	38—8	39—13	2.1	0.18	0.45
1 1/8"	0.596	35—8	36—6	1.5	0.13	0.33
1 1/8"	0.821	55—12	57—3	1.8	0.15	0.38
1 1/8"	1,025	67—8	69—4	1.7	0.15	0.38
1 /18"	0.825	51—8	53—3	2.0	0.18	0.45
2 1/2"	0.867	63—8	65—4	2.0	0.17	0.43
2 1/2"	0.985	65—12	67—12	2.0	0.17	0.45
2 1/2"	1.471	93—8	96—4	2.0	0.18	0.45

which were unpenetrated by preservative invariably had tylosed vessels. Sometimes untylosed vessels appeared in the midst of a generally tylosed area and preservative had penetrated into these vessels. It was apparent therefore that the open vessels in the wood played an important part in this transport. What mechanism was at work was not clear. Further experimental work was done in an effort to elucidate this point.

Experiment 3

First of all a preliminary experiment was done in order to determine the minimum time required for complete penetration of the cross section of pieces of different thicknesses. In all the previuus trials, by the time testing was done, penetration was found to be complete.

A small-scale spray apparatus was set up with a spray cycle of 15 mts. on and 15 mts. off and various cross sections of freshly sawn rubber wood were obtained from the Boron treatment plant run by the Sri Lanka Industrial Development Board. The pieces were brought to the laboratory wrapped in polythene. It was found that 1" x 1" battens were fully penetrated in 12-15 hours of spraying while 4" × 3" pieces required 24 hours of spraying. In the 4" × 4" pieces, penetration was complete after 24 hours —tylosed areas remianing unpenetrated.

Experiment 4

An experiment was then set up to find out what effect spraying had on the movement of preservative through the vessels. Two pieces of freshly cut rubber wood of 2" thickness were selected. Polythene bags filled with the preservative solution were tied on and sealed in such a manner that about half the length of the pieces were fully immersed in the preservative (see Figure III).

The exposed portion of one of the pieces was then subjected to a spray of water (15 minutes ' on ' and 15 minutes ' off ') while the other piece was left unsprayed. When these pieces were subsequently spot tested it was found that the penetration in the unsprayed piece was significantly better than in the sprayed piece. Also that in the un-

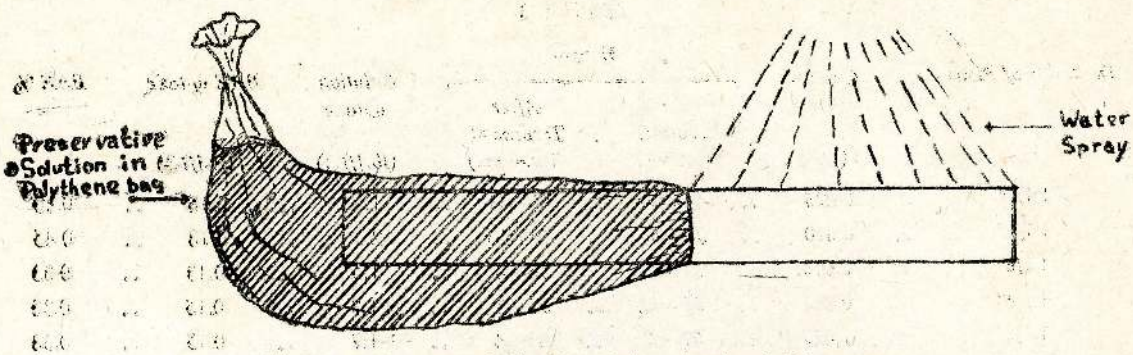


Fig. III—*Side view of 2" thick timber showing half immersed in preservative while the other half is subjected to a water spray.*

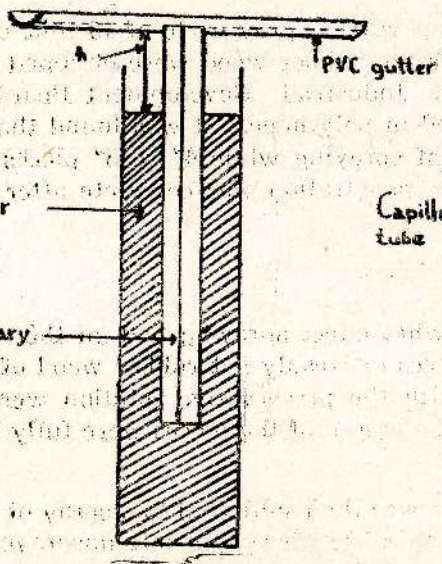


Fig. IV.—*Apparatus to test effect of flowing water over the end of a capillary.*

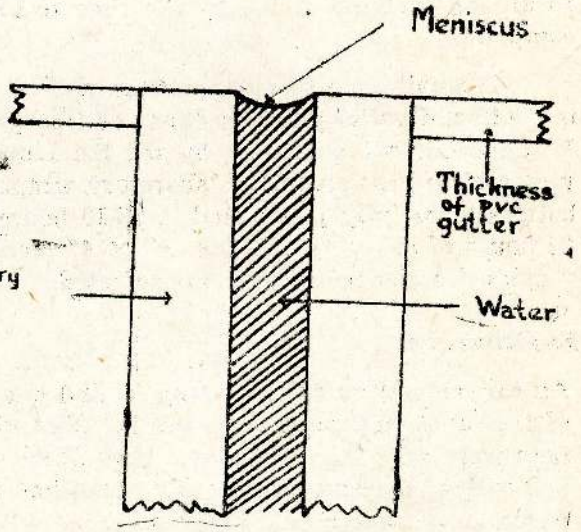


Fig. V.—*Enlarged diagrammatic view of top of capillary.*

sprayed piece the penetration was better close to the bag of preservative and the distribution was uniform while in the sprayed piece penetration was better in the core of the piece as compared with the shell. The penetration in the unsprayed piece was no doubt due to hydrostatic pressure but it was difficult to explain why the same result was not obtained in the sprayed piece. Spraying appeared to cause a pressure in the sprayed area in a direction opposed to that of the hydrostatic pressure. It might be thought that this could be a result of the pressure exerted by the water dropping from a height but this cannot explain why there was no penetration along the edges where the water merely flowed over the piece.

Experiment 5

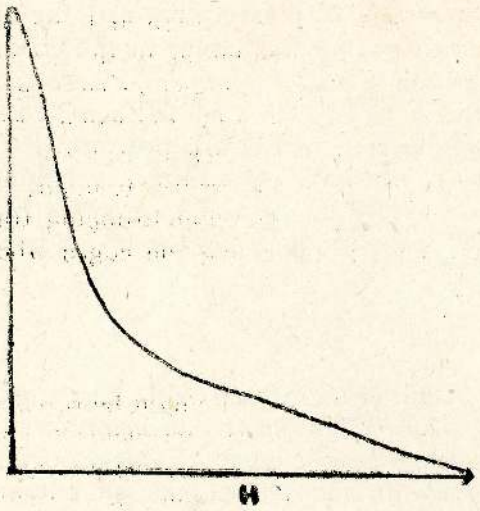
It was possible that the forces exerted by capillary action in the vessels might be responsible. Working with a simplified model might have thrown light on the mechanism; however, since it would be impossible to make a model to simulate wood, it was decided to work with a single capillary tube. A fine capillary tube of diameter 0.2 mm. was obtained from a broken thermometer. A suitable length of this was cut and fixed in a drilled hole in a half section of 1/2" PVC pipe (to a form a gutter) so that the surface of the capillary was flush with a inner surface of the pipe. (See Figures IV and V).

The capillary was then dipped in a cylinder of water till the water minescus in the capillary just reached the top. When water is allowed to flow along the PVC gutter it begins to flow through the capillary, the rate of flow depending on the height (h) of the top of the capillary above the level of water in the cylinder for a given capillary diameter. By mixing the water flowing over the capillary with a dye it was possible to measure rate of flow fairly accurately. The rate of flow was measured between two graduations on the thermometer stem at different heights of the meniscus. When values of time (t) were plotted against height, the graph in Figure VI resulted. The graph corresponds to the formula $t = \frac{k}{h}$ where k is a constant for the capillary andd liquid. When the cylinder was lowered so that the meniscus did not reach the top of the capillary, water flowed over the tube without entering the capillary.

The reason for this flow through the capillary tube is that when the meniscus is at the surface and water passes over it, the water becomes continuous with the water in the capillary and thus the meniscus is broken. Surface tension then no longer operates and the water in the capillary begins to flow down by gravity drawing with it the water flowing over the capillary. If the meniscus does not reach the top of the capillary, water flows over the capillary and not through it—the air bubble between the meniscus and the top of the capillary preventing the breaking of the meniscus by the flowing water—and surface tension is not released.

Experiment 6

The question arises as to whether this observed effect plays any part in the penetration of sprayed wood. An experiment was then set up in a manner opposite to that of Experiment 4. Two pieces of 2" thick and 17" long fresh rubber wood were selected and half of each piece was tied in a polythene bag to prevent drying and to prevent the preservative liquid from direct contact with it. The mouth of each bag was provided with a leak-proof seal. The free half of the pieces were then sprayed with pre-



g. VI.—*Graph of time* (t) *against heig.t* (h).

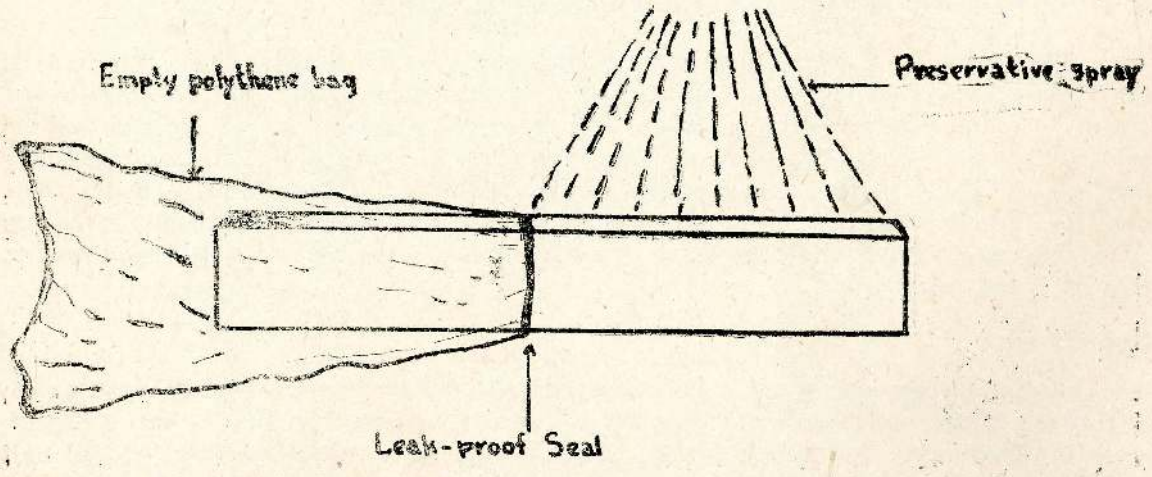


Fig. VII—*Side view of 2" thick timber showing half enclosed in polythene bag while the other half is subjected to a preservative spray.*

servative of 13 per cent. BAE concentration accodding to a 15 minutes on and 15 minutes off cycle. After 12 hours of spraying one of the pieces was removed and 5 slices were cut in the part enclosed in the polythene bag at intervals beginning from the end near the seal (No. 1) and ending with the slice near the end (No. 5). These were tested for penetration with turmeric and showed almost complete penetration in slice No. 1 grading with less uniform penetration to slice No. 2 islands of penetration in slice No. 5. There was no difference in the pattern of penetration to indicate which part of the wood was at the top (and thus received the spray directly) and which at the bottom.

After 20 hours of spraying the other piece was removed and similarly tested. The pattern was very similar except that the penetrated areas were larger.

The sprayed portion of the wood which had received the spray for 12 hours was also tested and the penetration was found to be complete.

In both these pieces it was noticed after a few hours of spraying that the portions within the bag had got extremely damp. In one of the bags there had been sufficient exudation of liquid to collect in the bag. This liquid was removed and analysed and was found to have a concentration of 4.9 per cent. BAE. Preservative from the sprayed portion had thus moved to the unsprayed portion and the exudation consisted of preservative mixed with cell sap. This could only have taken place through the vessels.

DISCUSSION

The very first experiment showed that it was possible to treat green wood with preservatives and to obtain complete penetration in a very short period of time using preservatives of comparatively low concentration. The other experiments were done only to attempt to elucidate the mechanism involved. Many more stacks of wood were treated in this manner but are not mentioned in this paper since the conclusions were the same. These other treatments however established the fact that the preservative concentration required to attain a retention of approximately one-third pound per cubic foot was only 5 per cent. BAE.

It may be considered as established therefore that spraying of preservative solution on fresh wood causes a movement of preservative in the vessels which is of sufficient force to exude out in other parts of the wood. What mechanism is at work in this transport is not very clear. In a vertical glass capillary, movement of liquid through the capillary is by gravity. Perhaps gravity plays some part in the movement of liquid through sprayed wood but this cannot explain the horizontal and sometimes upward movement which must occur if the wood is to be completely penetrated. It is suggested that this is due to differential release of capillary tension in the vessel system of wood. The assumption is made that the sap in the vessels of green wood is in tension and that the meniscus of each vessel is at the surface. When preservative solution flows over a particular vessel it breaks the meniscus thereby releasing the capillary tension within it. This causes the preservative solution to be sucked into the vessel. Since the vessel system in wood is continuous and ramifying, it will be open to the surface at several different points. If the release of tension at one opening is not opposed by the release of tension at all the other openings, the preservative solution will be able to

penetrate deep into the wood. If on the other hand, the pressure is equal everywhere (as would happen if the wood is soaked in a bath of preservative) there would be little penetration because the release of tension at various points in the system of capillaries would be balanced. When the wood is sprayed with the preservative solution however, the pressures at all points are not equal and the preservative thus has a chance of penetrating deep into the wood. When the spray is shut off, the menisci are re-established in the vessels, tension is set up in the l quid within the vessels and the system is ready to absorb preservative solution when the spray is restarted. Thus the on/off spray cycle acts as a pump. From this it will be evident, (and experimental work bears this out) that penetration occurs even in areas which are not touched by the preservative.

This also explains why in the experiment depicted in Figure III, the unsprayed control had greater penetration than the sprayed piece. The release of capillary tension acts in a direction opposite to the hydrostatic pressure of he preservative solution.

Unlike the glass capillary the walls of the vessels are capable of absorbing water and thus even if the capillary menisci are not at the surface, the process of spraying will tend to fill the capillaries up to the surface.

Since there is transport of preservative solution through the vessels, even parts of the wood which might remain unwetted right through the whole spray regime, will still be treated. Experiment 6 bears this out

CONCLUSION

It is thus possible to achieve rapid and deep penetration of preservative solutions in green wood by an on/off cycle of spraying using a very simple apparatus. The method is simpler and more rapid than the hot and cold bath treatment followed by principle of differential release of capillary tension in vessels, in order to achieve diffusion at elevated temperatures described by Mc Quire and Goudie (1972). A new principle of differential release of capillary tension in vessels, in order to achieve rapid penetration of preservative, is used.

The advantages of rapid penetration are as follows:

(1) Lowered inventory costs at the treatment point.

(2) Lowered storage costs and elimination of cost of covers.

(3) Complete elimination of fungal attack and following from this, the elimination of toxic fungicides in the preservative formulation.

(4) Lowered heating costs as heat may be required only to dissolve the salts and heat to maintain high concentrations of salt in solution. Under ambient conditions prevailing in Sri Lanka, heat is not necessary.

(5) Poss'bility of treating finished wood thus doing away with the practice of removing the best-treated timber in planer shavings.

NOTE.—The method of treating green wood with preservatives described in this paper is the subject of Patent applications in Sri Lanka (No. 6951 of 2.9.1972) and Britain (No. 58515/73 of 18.12.1973).

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Design and Analysis of Progeny Tests

K. VIVEKANANDAN
(Research Officer, Silviculture)

INTRODUCTION

FOREST genetics when compared with agricultural and horticultural genetics is a young science and most advances in tree breeding have been made through the use of genetic principles derived from research on plants and animals.

Although the experience of the past twenty years has shown that these principles can be applied in forest genetics and tree breeding there are some important differences to be considered. Agronomists often have emphasised the development of pure lines, while the horticulturists aim to develop cultivars of fruit trees which can be propagated vegetatively. Thus agronomists and horticulturists place emphasis on the development of cultivars consisting of individuals having basically the same genotype.

By contrast the use of monocultures comprising single genotypes is not common in forestry and since in the great majority of forest trees the forester cannot satisfactorily use either pure lines or mass produce vegetative propagules he must resort to the task of producing high quality seed.

This high quality seed is commonly produced in seed orchards which are composed of clones or seedling progenies derived from selected individuals (plus trees) found in natural stands or plantations. Selection of these individuals is initially based on their phenotypic value. But the phenotypic expression of a tree is the result of genetical and environmental factors. To determine the breeding value of the selected trees these two components must be estimated and this is achieved by progeny testing.

THE OBJECTS OF PROGENY TESTS

The objects of progeny tests are two-fold:

(1) to determine such quantitative genetic parameters as heritability, combining ability and genetic correlation, and

(2) To identify the best progenies.

Estimates of heritability, combining ability and genetic correlation are essential to calculate genetic gain and construct selection indices, a knowledge of which is in turn necessary to identify the best progenies and advance the breeding programme.

The terms heritability, combining ability and genetic correlations are defined here :

(*a*) *Heritability.*—refers to that portion of the observed variance in a trait or traits which is due to inherent factors. Heritability may be expressed in the narrow or broad sense. Narrow-sense heritability refers to that part of the total variance due to additive genetic factors, while broad-sense heritability refers to the variance due to all the genetic factors, that is, the additive, dominant and epistatic effects of genes (Lush, 1956 : Kempthorne, 1957). Heritability is usually denoted by the symbol h^2 and can be expressed as a fraction or as a percentage of the total variance.

(*b*) *Combining Ability.*—the terms general and specific combining ability were originally defined by Sprague and Tatum (1942) who wrote the term 'general combining ability' is used to designate the average performance of a line in hybrid combination..... .....The term 'specific combining ability' is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of average performance of the lines involved.

The terms general and specific combining ability can be explained by an example. Matthews, Mitchell and Howell (1962) made a preliminary analysis of the height and diameter growth 1 + - transplants of larch progenies derived from a diallel test cross. A part of the data on height growth as given by Maththews *et al*, (1962) is presented in Table 1.

TABLE 1

Mean Height (in Centimeters) of Larch Progenies Derived from a Diallel Test Cross (*Matthews* et al, 1962)

Female Parent	*Male Parent*					*Mean*
	J 2	*J 10*	*J 40*	*E 6*	*E 141*	
J2	—	57	45	57	61	55
J10	54	—	45	64	46	52
J40	—	54	—	86	70	70
E6	62	64	75	—	—	67
E141	74	82	57	—	—	71
Mean	63	64	56	69	59	Overall mean 62

From Table 1 the following are evident :

(1) Trees J2, J10 and E6 are on average better than J40 and E141 when used as male parents and are said to have a high general combining ability when used as males. Conversely trees J40 and E141 are said to have low general combining ability when used as males.

(2) Trees J40, E6 and E141 are on the average better than J2 and J10 as female parents and hence they are said to hav high general combining ability when used as females.

(3) Among all the crosses the combinations of J10 × E6, J40 × E6, J40 × E141 E6 × J10, E6 × J40, E141 × J2 and E141 × J10 are superior to the rest and are said to have high specific combining ability.

The crosses J10 × E141 and E141 × J0 are interesting in that J10 as a mother produces poor progenies when crossed with E141, whereas if used as a father it produce good progenies—that is the specific combining ability is high in E141 × J10 and low in J10 × E141.

When high general combining ability is present selection of the best combiners will produce good genetic gain, whereas if specific combining ability is high, hybridization will pay best.

(c) *Genetic Correlation.*—Phenotypic correlation shows how one variable varies with another and is strictly an association analysis between two variables. Phenotypic correlation does not separate the variation due to environmental and genetic factors and so in breeding work has limited usefulness. It is essential to determine whether two traits are generally associated, that is to establish whether the traits are genetically correlated. If the primary object of a breeding programme is to produce more rapidly growing trees it is desirable for example, to establish whether rate of growth is genetically correlated to wood properties.

Progeny testing is often a slow and long-term process and because relatively little is known about the correlation between juvenile and adult traits, it frequently is not possible to predict the period of time required to provide reliable information on heritability, combining ability and genetic correlation for traits important at rotation age. There are, however, certain juvenile traits such as disease resistance (Squillace and Bingham 1954; Bingham *et al*, 1969), frost resistance (Ashton, 1958); Pryor, 1956b), specific gravity (Zobel and Rhodes, 1956) and others that can be determined in a relatively short period of time.

TYPES OF PROGENY TESTS

Progeny tests can be grouped into two classes : (1) One-parent progeny tests or half-sib progeny tests which compare progenies derived from open pollination and only the female parent is known.

(2) Two-parent progeny tests or full-sib progeny tests which compare progenies derived from controlled crosses. Here the identity of both parents is known.

MATING DESIGNS

The estimation of additive and non-additive genetic variance requires the use of appropriate mating and experimental designs. The term mating design refers to the system of mating used to produce progenies. Cockerham (1963) classifies mating designs as one, two, three or four-factor designs depending on the number of ancestors per progeny over which control is exercised. An account of the different mating designs now follows.

One—factor Mating Designs

A set of half-sib families derived from open pollination or polycross progenies constitute a one-factor mating design. Here only one component of variance for progenies or co-variance of relatives can be established. Among these designs the open-pollination test is the simplest and the progenies indicate the average value of the females when mated at random. The polycross test (Tysdal, Kisselbach and Westover, 1942) can be done either by artificially pollinating a number of females with a mixture of pollen collected from selected trees or clones used as males or allowing inter-pollination among the clones in a seed orchard and bulking the seed produced by each clone.

The open-pollination and polycross tests are relatively easy to do and allow the testing of a large number of parental phenotypes. But they give information only on general combining ability (gea) and do not permit estimates of specific combining ability (sca) or the effects of reciprocal matings. Furthermore one-factor mating designs assume that the male trees contributing to the natural cloud of pollen and the components of pollen mixtures contribute equally to all the families. This assumption is invalid when the males differ n periodicity of flowering. pollen production, pollen viability and genetic compatibility. In addition if there is considerable genetic variation among the males this may obscure real differences between the families.

The standard format for the analysis of variance and the expected values of mean squares of a one-factor mating design as given by Cockerham (1963) is set out in Table 2.

TABLE 2

Analysis of Variance for an Open Pollination or Polycross Test

Source of variation	*DF*	*Expectation of mean squares*
Replications	k-1	$\delta e + p\delta^2 k$
Progenies	p-1	$\delta^2 e + k\delta^2 p$
Residual	(r-1) (p-1)	$\delta^2 e$

The standard formats for the analysis of variance of an open-pollination or polycross test replicated in localities and time are well documented (see, for example, Burley, Burrows, Armitage and Barnes, 1966).

Two-factor Mating Designs

Such common mating designs as bi-parental progeny designs, complete and partial diallel test crosses and designs I, II and III of Comstock and Robinson (1948, 1952) are examples, of two-factor mating designs. In a two-factor mating design the identity of both the male and female parent is known and it therefore provides more genetic information than a one-factor mating design. An outline of these designs follow:—

(*a*) *Bi-parental Progeny Design.*—A total of parents are paired at random to yield ½n families. Genetic information is restricted to between and within family variances. Table 3 gives the standard format of the analysis of variance for a bi-parental progeny design.

TABLE 3

Analysis of Variance for a Bi-Parental Progeny Design

Source of variation	*DF*	*Expectation of mean squares*
Replications ..	k–1 ..	$\delta^2\omega + k\delta^2p + n\delta^2k$
Between families ..	p–1 ..	$\delta^2\omega + k\delta^2p$
Within families ..	n–p ..	$\delta^2\omega$

× n = total number of plants
× k = number of individuals within one mating.

(*b*) *Diallel Test Cross.*—Here n parents are crossed in all possible combinations, to yield n^2 families (Table 4). Jinks and Hayman (1953), Hayman (1954, 1958a, 1958b, and 1960) and Griffing (1956a and 1956b) have all dealt with the diallel test cross in detail and it suffices here to bring out the salient points.

TABLE 4

Format of a Complete Diallel Test Cross Involving Five Parents

Female parent	*Male parent* A	B	C	D	E
A	S	R	R	R	R
B	+	S	R	R	R
C	+	+	S	R	R
D	+	+	+	S	R
E	+	+	+	+	S

S = Selfs, = + Crosses, R = Reciprocals

In a complete diallel test cross involving five parents 25 families or progeny groups comprised of 5 self, 10 crosses and 10 reciprocals are produced (Table 4). The standard format of the analysis of variance and expectation of mean squares of a diallel test cross with no selfs based on the procedures outlined by Cockerham (1963) is presented in Tables 5 and 6.

TABLE 5

Analysis of Variance of a Diallel Test Cross with no Selfs

PRIMARY ANALYSIS

Source of variation	*DF*	*SS*	*Expectation of mean squares*
Replications	k–1 ..	S_5 ..	—
General combining ability (families)	p–1 ..	S_4 ..	$\delta^2e+k\delta^2r+2k\delta^2sca+k(p-2)\delta^2m+2k(p-2)\delta^2sca$
Specific combining ability ..	p(p–3)/2 ..	S_3 ..	$\delta^2e+k\delta^2r+2k\delta^2sca$
Maternal	(p–1) ..	S_2 ..	$\delta^2e+k\delta^2r+kp\delta^2m$
Reciprocal	$\frac{(p-1)(p-2)}{2}$ ..	S_1 ..	$\delta^2e+k\delta^2r$
Residual	(k–1) (p_1–p^2–1) ..	S_0 ..	δ^2e

TABLE 6

Analysis of Variance of a Diallel Test Cross with No Selfs

ALTERNATE ANALYSIS

Source of variation	*DF*	*SS*	*Expectation of mean square*
Replications	k–1	.. S_5 ..	—
General combining ability (families)	p–1	.. S_4 ..	$\delta^2e + 2k\delta^2sca + 2k\ (p—2)\ \delta^2gea$
Specific combining ability ..	p(p–3)/2	.. S_3 ..	$\delta^2e + 2k\delta^2sca$
Reciprocal	p(p–1)/2	.. S_2 S_1 ..	$\delta^2e + k\delta^2r$
Residual	(k–1) (pr–p–1)	.. S_0 ..	δ^2e

In the primary analysis the maternal and reciprocal sums of squares are calculated according to Yates (1947) and in the alternate analysis the general and specific combining ability sums of squares are those given by Griffing (1956b) and Kempthorne (1952).

Although a diallel test cross provides more genetic information it has two main disadvantages. First, the failure of crosses and production of insufficient seedlings of certain crosses, both of which are bound to occur in any breeding programme, can weaken the efficiency of a diallel test cross. Second, if a large number of trees is to be tested a diallel test cross is not practicable. It is demanding too much of the female flowering capacity of the parent trees to attempt a large number of crosses and the greater initial outlay in money, time and materials required to carry out diallel test crosses is not necessarily repaid by the results obtained. This has led to the development of several modified forms of the diallel test cross called "partial diallel crosses".

(c) *Partial Diallel Cross*—Griffing (1956b) gives models of three incomplete forms of diallel test cross : (1) a set of $\frac{1}{2}$n (n-1) crosses alone, (2) a set of $\frac{1}{2}$n (n-1) crosses and together with selfs and (3) a set of $\frac{1}{2}$n (n-1) crosses and their reciprocals without selfs. In all these cases n denotes the number of parents to be tested. Another modification of the diallel test cross is the " chain block incomplete mating design " of Cockerham (1963) in which each parent has the same number of progenies but all the possible matings among the parents are not made. There are many variations of the " chain block incomplete incomplete mating design " and the analysis of such designs is considered in detail by Matzinger and Kempthorne (1956), Kempthorne and Curnow (1961), and Fyfe and Gilbert (1963).

(d) *Nested Mating Design.*—This is identical to the North Carolina Model I (NSM 1) mating design of Comstock and Robinson (1948, 1952) where each member of a group of parents used paternally is mated to a different group of parents used maternally and where no female occurs in more than one group. For example if 20 trees are to be tested 4 trees can be used as males and the balance of 16 trees split up into four groups of females, each female group consisting of 4 trees to produce 16 crosses. This is illustrated in Table 7.

TABLE 7

Illustration of a Nested Mating Design

M_1				M_2				M_3				M_4			
F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}
P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}

M = Male parent, F = Female parent and P = Progeny resulting from the cross.

Here, the variance among progenies may be partitioned into males, and females in males. Table 8 gives the standard format of the analysis of variance and the expectation of mean squares of a nested mating design.

TABLE 8

Analysis of Variance of a Nested Mating Design

Source of variation	*DF*	*Expectation of mean squares*
Replications	k—1 ..	—
Paternal	p—1 ..	$\delta^2e + k_1\delta^2m/_p + k_2m\delta^2p$
Maternal within paternal ..	p(m—1) ..	$\delta^2e + k_1\delta^2m/_p$
Residual	(k—1) (m—p—1)	δ^2e

[1] k_1 = number of plots per paternal parent

k_2 = number of plots per maternal parent

(e) *Factorial Mating Design*: This corresponds to the North Carolina Model II (NCM II) of Comstock and Robinson (1948, 1952). Here each of a group of parents used maternally is mated to each other of another group of parents used paternally. Of then parents, each of the males is crossed with every one of the f (= n-m) females to produce mf families. Considering the example given for the nested mating design (NCM I), out of the 20 trees to be tested four trees can be used as males and the rest as females, but unlike the nested mating design (NCM I) the females are not grouped.

An illustration of this mating design is given in Table 9.

TABLE 9

Illustration of a Factorial Mating Design

M_1	M_2	M_3	M_4
×	×	×	×
F_1—F_{16}	F_1—F_{16}	F_1—F_{16}	F_1—F_{16}
M_1 F_1—M_1 M_{16}	M_2 F_1—M_2 F_{16}	M_3 F_1—M_3 F_{16}	M_4 F_1—M_4 F_{16}

M = Male parent, F = Female parent and MF = Progeny resulting from the cross.

The standard format for the analysis of variance of a factorial mating design and he expectation of mean squares as outlined by Cockerham (1963) are given in Table 10.

TABLE 10

Analysis of Variance of a Factorial Mating Design

Source of voriation	*DF*	*Expectation of mean squares*
Replications	k—1	—
Paternal parents	p—1	.. $\delta^2e + k\delta^2mp + km\delta^2p$
Maternal parents	m—1	.. $\delta^2e + k\delta^2mp + kp\delta^2m$
Maternal × Paternal	.. (m—1) (p—1)	.. $\delta^2e + k\delta^2mp$
Residual ..	.. (k—1) (mp—1)	.. δ^2e

The factorial mating design is essentially a sampling method for testing a large number of selected trees in a relatively short time. Although the design provides a satisfactory method of progeny testing it is not so efficient as a diallel test cross because genetic information about reciprocals cannot be obtained.

The 4 tester plan of Zobel and Kellison (1963) used by the North Carolina State Industry Tree Improvement Programme is a form of factorial mating design employing four male parents. The 4 tester factorial mating design using four males is also being used in Idaho in the breeding of Western white pine (*Pinus monticola* Dougl.) for blister rust resistance (Bingham *et al.* 1967, 1969).

Three—factor Mating Designs

In a three factor mating design the identity of both the parents and at least one of the grand parents is known. Unlike the two factor mating designs which require only one generation to produce seed for progeny testing, the three factor mating designs require two generations to produce seeds. Cockerham (1963) describes several forms of the three factor mating designs and it suffices here to outline only the more important.

(*a*) *Three-factor Factorial Mating Design* : This is identical to the two factor factorial mating design except that an additional factor due to grandparents is introduced. The details of the methods of analysis are given by Cockerham (1963).

(*b*) *Three-factor Nested Mating Design*: The three factor nested mating design is an extention of the two factor nested mating design considered earlier and includes an additional factor due to grandparents. A detailed account is given by Cockerham (1963).

In some cases the three factor factorial mating design and the nested mating design are combined and referred to as a "mixed mating design". Details of analysis and interpretation of expectation of mean squares are given by Cockerham (1963). Other forms of three-factor mating design include the "triallel or three-way mating designs". An account of these designs is also given by Cockerham (1963).

Four-factor Mating Designs

In a four factor mating design control is exercised over both grandparents and one or more great grandparents. This gives rise to a number of relatives and to more components of variance. There are a number of different forms of the four factor mating design but all are essentially extensions of the two factor and three factor mating designs. Because of the complex nature of these designs a detailed discussion is not attempted here. Cockerham (1963) has outlined the salient features of the four factor mating designs and the statistical interpretations are provided by Rawlings and Cockerham (1962).

DISCUSSION

The breeding value of parent trees, selected either by random selection or plus tree selection is assessed from the performance of either half-sib or full-sib progenies or both under suitable test environments.

The progenies are produced by means of one or more of the mating designs discussed earlier and the choice of the mating design depends on the objects of the breeding programme. Generally the mating design preferred is that which is simple and yields the maximum of information for the smallest input of time and labour.

When a large number of phenotypes have to be tested it is most economical to use a simple one-factor mating design. But as pointed out earlier, a one factor mating design does not provide estimates of specific combining ability and reciprocal effects. To obtain estimates of these parameters it is necessary to use the more complex two factor and three factor mating designs. Among these the complete diallel test cross is the only mating design giving estimates of all the genetic parameters. But as noted earlier it has several drawbacks. These can be overcome by using nested and factorial designs, but the disadvantages of these designs it that they do not give any estimates of reciprocal effects; however even after sacrificing this the nested and factorial designs still emerge as superior to a complete diallel test cross. These designs are compared in Table 11 in terms of numbers of phenotypes and progenies tested.

TABLE 11

Comparison of Number of Parents Tested and Families Planted with Two-Factor Nested, Factorial and Complete Diallel Test Cross Designs

Number of parents	*Nested design (NCM I)*		*Factorial design (NCM II)*			*Complete diallel test cross*
	$m = 2f$	$m = 5f$	$f = m$	$f = 2m$	$f = 5m$	
6	4	5	9	8	5	36
12	8	10	36	32	20	144
18	12	15	81	72	45	324
24	16	20	144	128	80	576
30	20	25	225	200	125	900
54	35	—	729	648	—	—

If the number of progenies is fixed (eg. 36) and the total number of trees tested is used as a criterion of efficiency the nested design ranks first and the diallel test cross last (see Table 11). On the other hand if the number of trees is fixed (eg. 30) and the number of progenies tested is the criterion of efficiency the situation is reversed.

Although the nested mating design is the most efficient out of the three designs in terms of number of parent trees tested it can in some circumstances actually be rather less efficient because in this design a male is crossed to a group of females and if some females fail to produce adequate amount of flowers thus resulting in low seed production and fewer progenies these less successful crosses have to be discarded along with the more successful ones in the same group. This can be overcome by the factorial mating design because here even if there are insufficient number of seedlings of certain crosses only a limited number of males need be discarded because different males are mated to the same group of females. By careful selection of the males even this difficulty can be surmounted. Thus the factorial mating design is the most versatile of the two factor mating designs.

The complexities of three factor and four factor mating designs are obvious and it suffices here to mention that they provide more genetic information, especially the variance due to epistatic effects. But it is unprofitable to attempt such designs unless information on epistatic effects is essential.

So far the methods and merits and demerits of the different mating designs have been examined in terms of phenotypes tested, the progenies yielded by each design and the number and nature of the genetic parameters that can be estimated. The question now arising concerns which of the mating designs is the most helpful in tackling the problems that a tree breeder must solve. Is there one single design that will provide all the answers or is it more practicable to do the work in stages? The latter approach appears as the more logical and is examined here briefly.

The first stage in a breeding programme is phenotypic selection of trees for one or several traits and progeny testing the seedlings derived from open-pollinated to determine whether sufficient genetic variation exists to warrant further work. During this stage propagules of selected trees can be released for forest planting thus anticipating the existence of genetic variance. This is a calculated risk but has, for example, been found to pay good dividends in the Blister rust breeding programme (Bingham, 1966). Once the existence of substantial genetic variation is established the next stage is to determine the magnitude of general and specific combining ability, knowledge of which decides whether breeding by selection or hybridization will give the most rapid genetic gain. This is the crucial stage of a breeding programme because the breeder must now decide which test cross or mating system to use. Many would prefer the diallel test cross because it offers solutions to all the problems but the method has many pit falls and this has been recognised in the blister rust breeding programme of Bingham *et al* (1960) and the larch breeding programme begun in Britain by Matthews *et al* (1962). So the choice lies between the nested and factorial designs. For the reasons given in (*e*) the latter should be preferred. But this is also the point to assert that there is no one 'ideal' mating design applicable to all breeding programmes and the choice lies entirely with the tree breeder and his resources.

TABLE 12

Symbols and Notations of Genetic and Statistical Parameters

Symbol/Notation		*Meaning*
P	..	Phenotypic expression
G	..	Genotypic effect
E	..	Environmental deviation
$\delta^2 p$	..	Phenotypic variance
$\delta^2 g$	..	Genotypic variance
$\delta^2 e$ (VE)	..	Environmental or residual variance
$\delta^2 a$ (VA)	..	Variance due to additive genetic effects
$\delta^2 d$ (VD)	..	Variance due to dominance effects
$\delta^2 v$	..	Variance due to epistatic effects
$\delta^2 k$	..	Variance due to blocks or replications
$\delta^2 ges$	..	Variance due to general combining ability
$\delta^2 sca$	..	Variance due to specific combining ability
$\delta^2 r$	..	Variance due to reciprocal effects
Cov FS	..	Covariance of full-sibs
Cov HS	..	Covariance of half-sibs
rp	..	Phenotypic correlation
rg	..	Genotypic correlation
h^2 (NS)	..	Heritability in the narrow sense
h^2 (BS)	..	Heritability in the board sense
k	..	Number of blocks or replications
p	..	Number of progenies or families
f 1, 2	..	Covariance due to families for triats 1 and 2
Cov 1, 2	..	Mean cross products for between families between traits 1 and 2
v_1	..	Between family mean square for trait 1
v_1	..	Between family mean square for trait 2
Cov M	..	Covariance due to males
Cov F	..	Covariance due to females
$\delta^2 m$	..	Variance due to maternal paernt
$\delta^2 p$	..	Variance due to paternal parent
$\delta^2 m(1)$	..	Variance due to maternal parent for triat 1
$\delta^2 m(2)$	..	Variance due to maternal parent for trait 2
$\delta^2 p(1)$	..	Variance due to paternal parent for trait 1
$\delta^2 p(2)$	..	Variance due to paternal parent for triat 2
$\delta^2 mp$	..	Variance due to maternal parent within paternal parent
$\delta^2 mp$	..	Variance due interaction between maternal and paternal parents
$\delta^2 mp$	..	Variance due to progenies or families

GENETIC PARMETERS

SYMBOLS AND NOTATIONS

The symbols and notations used in this paper are given in Table 12 and 13.

TABLE 13

Covariance, Regression and Correlation Coefficients of Different Relatives
(Falconer, 1960)

Relatives	*Covariance*	*Regression coefficient (b)*	*Correlation coefficient (r)*
Off-spirng of one parent	$\frac{1}{2}VA$	$\frac{\frac{1}{2}VA}{VP}$	—
Off-spring and mid parent	$\frac{1}{2}VA$	$\frac{VA}{VP}$	—
Half sibs	$\frac{1}{4}VA$	—	$\frac{\frac{1}{4}VA}{VP}$
Full sibs	$\frac{1}{2}VA + \frac{1}{4}VD + VE$	—	$\frac{\frac{1}{2}VA + \frac{1}{4}VD + VE}{VP}$

ESTIMATION OF GENETIC PARAMETERS

(a) General : The phenotypic expression of a trait is the sum of a genetic effect and the deviation due to the environment (Falconer, 1960), Symbolically.

$$P = G + E \quad \ldots\ldots (1)$$

Where P .... Phenotypic expression

G — Genotypic effect

E — Environmental deviations

If genotypes are randomly distributed in relation to variations in the environment the phenotypic variance can be expressed as follows:—

$$\delta^2 p = \delta^2 g + \delta^2 e \quad \ldots\ldots (2)$$

Where $\delta^2 p$ — Phenotypic variance

$\delta^2 g$ — Genotypic variance

$\delta^2 e$ — Environmental variance

Wright (1935) defined three components of genotypic variance (i) additive genetic varience ($\delta^2 a$), (ii) variance due to dominance deviations from the additive genetic variance ($\delta^2 d$) and (iii) variance due to epistatic deviations from the additive genetic variance ($\delta^2 v$), so that

$$\delta^2 g = \delta^2 a + \delta^2 d + \delta^2 v \quad \ldots\ldots (3)$$

The variance due to the genetic and non-genetic components is determined by the use of an appropriate mating design.

(b) *General Assumptions* : Several general assumptions are made in intepreting the genetic information obtained from mating designs. These assumptions are :

(i) Regular diploid Mendelian inheritance ;
(ii) No maternal effects ;
(iii) No linkage or genes ;
(iv) No non-allelic interaction ;
(v) Uncorrelated distribution of genes.

(c) *Computation* : The different genetic parameters are computed using the genetic and environmental components of variance derived from the mating designs discussed earlier. The statistical aspects of the different mating designs have already been dealt with and only the 'expectation of mean squares' of the different sources of variation are extracted to show how they can be interpreted in genetic terms. Furthermore only the following five mating designs are considered to illustrate the methods of computation of the genetic parameters:

(i) Open-pollination test ;
(ii) Complete diallel test cross ;
(iii) Partial diallel cross ;
(iv) The nested mating design ;
(v) The factorial mating design.

The detailed discussions of the computation of genetic parameters using different mating designs have been provided by Cockerham (1963) Griffing (1956b), Kearsey (1965), Kempthorne and Curnow (1961) and others.

(i) OPEN POLLINATION TEST

The expectation of the mean squares in an open-pollination test are as follows: —

Source of variation	*Expectation of mean squares*
Replications (k)	$\delta^2e + p\,\delta^2k$
Progenies (p)	$\delta^2e + k\,\delta^2f$
Residual (e)	δ^2e

δ^2f is the variance due the progenies and the groups of progenies are called families, which in this case are half-sibs. In genetic terms δ^2 f–is the covariance among half-sibs and estimates $\frac{1}{4}$VA (*see* Table 13) while δ^2e is equivalent to δ^2P—Cov HS. Thus δ^2f and δ^2e estimate the following parameters

Component	*Covariance*	*VA*	*VD*	*VE*	*VP*
δ^2f	Cov HS	$\frac{1}{4}$	—	—	$\frac{1}{4}$
δ^2e	δ^2p—Cov HS	—	—	—	$\frac{3}{4}$

Heritability based on the progeny means for a given trait is obtained by the formula :

$$h^2 (N.S.) = \frac{\delta^2 f}{\frac{\delta^2 e}{k}} \quad \ldots\ldots (4)$$

However, Wright (1962) used the following formula to estimate heritability in a narrow sense based on family means :

$$h^2 (N.S.) = \frac{2\delta^2 f}{2\delta^2 f + \frac{\delta^2 e}{k}} \quad \ldots\ldots (5)$$

The doubling of the numerator, (the variance due to female effects) is done on the assumption that the unknown male effects will equal the tested effects of females (Wright, 1962).

Genetic correlations between traits is obtained from :

$$rg = \frac{f\ 1, 2}{\text{Square root of } (\delta^2 f\ 1 \times \delta^2\ f\ 2)} \quad \ldots\ldots (6)$$

and phenotypic correlation is obtained from

$$rp = \frac{\text{Cov } 1, 2}{\text{Square root of } (V1 — V2)} \quad \ldots\ldots (7)$$

(ii) DIALLEL TEST CROSS

As noted in the analysis can be done by the method advocated by Yates 1947) or those of Griffing (1956b) and Kempthorne (1952). The method of Kempthorne is used here.

The expectation of mean squares are:—

Source of variation	*Expectation of mean squares*
Replications (k)	—
gca (p—1)	$\delta^2 e + 2k\ \delta^2$ sca $+ 2k\ (p-2)\ \delta^2$ gca
sca (p (p–3)/2)	$\delta^2 e + 2k\delta^2$ sca
Reciprocal (p (p–1)/2)	$\delta^2 e + k\delta^2$
Residual ((k–1)(p^2–p–1))	$\delta^2 e$

The genetic interpretations of δ^2 gca and δ^2 sca are

Component of variance	*Covariance*	*VA*	*VD*	*VE*	*VP*
δ^2 gca	Cov HS	½	—	—	—
δ^2 sca	Cov FS — 2Cov HS	—	¼	—	—

Heritability in the narrow sense is given by

$$h^2 (N.S.) = \frac{2\delta^2 \text{gca}}{\delta^2 p} \quad \ldots\ldots (8)$$

Genetic correlation is computed using the formula 6 given under 'open-pollination test'.

Thus as already noted the complete diallel test cross provides genetic information on general combining ability, specific combining ability, and reciprocal effects and permits estimates of heritability and genetic correlation.

(iii) PARTIAL DIALLEL CROSS

The analysis of the partial diallel cross given here is based on the method suggested by Griffing (1956b) for Model II of Eisenhart (1947). The expectation of mean squares are:

Source of variation	*Expectation of mean squares*
gca (p)	$\delta^2 e + \delta^2$ sca $+ (p + 2)\,\delta^2$ gca
sca (p (p−1)/2)	$\delta^2 e + \delta^2$ sca
Residual (m)	$\delta^2 e$

The genetical interpretations of these variance are :

Component of variance	*Covariance*	*VA*	*VD*	*VE*	*VP*
δ^2 gca	Cov HS	$\frac{1}{4}$	—	—	—
δ^2 sca	Cov FS — 2Cov HS	—	$\frac{1}{4}$	—	—

Heritability in the narrow sense is given by the formula :

$$h^2 (N.S.) = \frac{2\delta^2 \text{gca}}{VP} \qquad (9)$$

Genetypic and phenotypic correlations are calculated using formulas 6 and 7 respectively given under 'open-pollination test'.

Thus the partial diallel cross provides information on general combining ability, specific combining ability, heritability, and genetic correlation. Reciprocal effects cannot be estimated in a partial diallel cross.

(iv) NESTED MATING DESIGN (NORTH CAROLINA MODEL I)

The expectation of mean squares are :

Source of variation	*Expectation of mean squares*
Replicates (k)	—
Paternal (p)	$\delta^2 e + k_1 \delta^2 m/p + k_2 \delta^2 p$
Material within paternal (p(n—1))	$\delta^2 e + k_1 \delta^2 m/p$
Residual (pn—1) (k—1)	$\delta^2 e$

Where k_1 = number of plots per paternal parent

k_2 = number of plots per maternal parent

The genetic interpretation is :

Components of variance	*Covariance*	*VA*	*VD*	*VE*	*VP*
$\delta^2 p$	Cov HS	$\frac{1}{4}$	—	—	—
$\delta^2 m$	Cov FS — Cov HS	$\frac{1}{4}$	$\frac{1}{4}$	—	—
$\delta^2 p + \delta^2 m$	Cov FS	$\frac{1}{2}$	$\frac{1}{4}$	—	—

Heritability estimates are as follows :

$$h^2 p \text{ (N.S.)} = \frac{4\delta^2 p}{\delta^2 p} \quad \ldots\ldots (10)$$

$$h^2 m \text{ (N.S.)} = \frac{4\delta^2 m}{\delta^2 p} \quad \ldots\ldots (11)$$

Genetic correlations are calculated as follows :

(1) Using the paternal components of variance and covariance :

$$rg\,(p) = \frac{4 \text{ Cov M}}{\text{Square root of } (4\delta^2 \text{ p (1)}) (4\delta^2 \text{ P(2)})} \quad \ldots\ldots (12)$$

(2) Using the maternal components of variance and covariance :

$$rg\,(m) = \frac{4 \text{ Cov F}}{\text{Square root of } (4\delta^2 \text{ m(1)}) (4\delta^2 m(2))} \quad \ldots\ldots (13)$$

(3) Using both maternal and paternal componenets of variance and covariance :

$$rg\,(pm) = \frac{\text{Cov M} + \text{Cov F}}{\text{Square root of } (\delta^2 p_{(1)} + \delta^2 m_{(1)}) (\delta^2 p_{(2)} + \delta^2 m_{(2)})} \quad \ldots\ldots (14)$$

(v) FACTORIAL MATING DESIGN (NORTH CAROLINA MODEL II)

The expectation of mean squares in a factorial mating design are :

Source of variation	*Expectation of mean squares*
Replications (k)	
Paternal parent (p)	$\delta^2 e + k\delta^2 pm + km\delta^2 p$
Maternal parent (m)	$\delta^2 e + k\delta^2 pm + kp\delta^2 m$
Paternal × Maternal (pm)	$\delta^2 e + k\delta^2 pm$
Residual (pm—1) (k—1)	$\delta^2 e$

The genetic interpretations of the variance are :

Component of variance	*Covariance*	*VA*	*VD*	*VE*	*VP*
$\delta^2 p$	Cov HS(p)	$\frac{1}{2}$	—	—	—
$\delta^2 m$	Cov HS(m)	$\frac{1}{2}$	—	—	—
$\delta^2 pm$	Cov FS — Cov HS(p) Cov HS (m)	—	1	—	—

Heritability is calculated on the basis of paternal, maternal and the combined paternal and maternal parents as follows :

$$h^2(p) = \frac{4\delta^2 p}{\delta^2 p} \quad \ldots\ldots (15)$$

$$h^2(m) = \frac{4\delta^2 m}{\delta^2 p} \quad \ldots\ldots (16)$$

$$h^2(pm) = \frac{2(\delta^2 p + \delta^2 m)}{\delta^2 p} \quad \ldots\ldots (17)$$

Genetic correlations are calculated as follows :

(1) Using paternal components of variance and covariance :

$$rg(p) = \frac{\text{Cov M (1, 2)}}{\text{Square root of } (\delta^2 p(1))\,(\delta^2 p(2))} \quad \ldots\ldots (18)$$

(2) Using maternal components of variance and covariance :

$$rg(m) = \frac{\text{Cov F (1, 2)}}{\text{Square root of } (\delta^2 m(1))\,(\delta^2 m(2)} \quad \ldots\ldots (19)$$

(3) Using paternal and maternal components of variance and covariance :

$$rg(pm) = \frac{\text{Cov M (1, 2)} + \text{Cov F (1, 2)}}{\text{Square root of } (\delta^2 P(1) + \delta^2 m(1))\,(\delta^2 p(2) + \delta^2 m(2))} \quad \ldots\ldots (20)$$

The factorial mating design estimates both general and specific combining ability, heritability and genetic correlations. It does not provide an estimate of reciprocal effects.

CONCLUSIONS

The computations associated with the open-pollination test, complete diallel test cross, partial diallel cross, nested mating design and factorial mating design have been discussed. The statistical and genetical parameters each yield can be used as criteria to compare the five designs. The open-pollination test has the advantage of using a large

number of parents but has the disadvantage of only yielding two genetic parameters from which heritability and genetic correlation can be estimated. The nested and factorial mating designs are well suited to estimate all the genetic parameters except reciprocal effects. The partial diallel cross appears to have no advantage over the other designs and the analysis associated with it is arduous. Among all the designs the complete diallel test cross is the most satisfactory, but has several practical limitations.

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The Threshold Level of Boron Preservatives Against Attack by the Dry-Wood Termite-Cryptotermes Domesticus—Kalotermitidae

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INTRODUCTION

THE simplicity and success of the method of maintaining and observing groups of dry-wood termites in the laboratory (Tisseverasinghe & Jayatilleke, 1973) prompted this investigation. Rubber (*Hevea brasiliensis*) wood is now being treated on a commercial scale in Sri Lanka using borates. It will therefore be of interest to know what minimum level of Boric Acid Equivalent per cent. (BAE) in wood will be toxic to these termites. From preliminary observations and from the literature it is known that low levels of Boron in wood are toxic to the gut protoza of dry-wood termites even if they are not directly toxic to the termites themselves. Such termites deprived of their gut fauna starve to death as a result of their inability to digest wood. In practice, this means that a colony of these termites can never be established in wood containing more than the threshold level of Boron preservatives, since they cannot survive for more than about two months without starving to death.

Since termites of the family Rhinotermitidae also depend on gut fauna, these threshold values may be of use in regard to this group of termites as well. But the practical value of this is likely to be much less than in the case of the Kalotermitidae which are confined to the wood chosen by the mating pair to found a colony. Rhinotermitidae which have access to the ground would be able to survive through refaunation as a result of perhaps proctodeal feeding. Colonies of termites of the family. Rhinotermitidae are much more difficult to maintain under strict laboratory conditions *which should also simulate natural conditions*. Studies are now being initiated on this group of termites.

MATERIALS AND METHODS

Thin slices of Etamba (*Mangifera zeylanca*) or Rubber (*Hevea brasiliensis*) wood of 4" x 4" x 0.1" were prepared. These were divided into groups of six. Each individual slice was then oven dried and weighed. The selected groups of six were kept in the laboratory to reach equilibrim with the atmosphere and then impregnated under vacuum

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with different BAE concentrations of a Borax/Boric Acid mixture. Each individual slice was then weighed again after surface liquid had been removed using filter paper. They were then allowed to air-dry to constant weight. The BAE per cent. based on oven-dry wood was then calculated for each piece. Each group of 6 slices was divided into two sets of three and the mean BAE per cent. was calculated as the mean of the three individual values.

Each set of three was arranged in the form of a sandwich with 0.5" holes drilled in the top two slices—the bottom slice being left intact. In the first few trials ten fairly advanced nymphs of *Cryptotermes domesticus* were introduced into the chambers so created. Each chamber was covered with a cover glass the edges of which were sealed with Sellotape thus making the chambers air-tight. One or two sets were left unimpregnated to serve as controls. Observations were made at irregular intervals and survivals were counted.

RESULTS

In the first trial fairly high concentrations of the impregnating fluid were used (1%, 2%, 3% and 10% BAE) which gave mean BAE retentions, (for the three slices comprising the sandwich) on the basis of oven-dry wood, of 0.829%, 1.749% 2.818% and 8.544% respectively.

The termites were introduced into their chambers on 6.1.74. Till 15.1.74 all were surviving. After this deaths began till by 2.2.74 only 2 each survived in the sets impregnated with 1% solution. All the controls were surviving. Table I shows the position.

TABLE I

Number of Termites Surviving in First Feeding Trial

Species of timber used—*Mangifera zeylanica*
Number of termites introduced : Ten per set.
Date of introduction : 06.01.74

B.A.E. %	0.83		1.75		2,82		8.54		*Control*	
	Set No.									
Number of days after introduction	1	2	3	4	5	6	7	8	9	10
5	10	10	10	10	10	10	10	10	10	10
8	10	10	10	10	10	10	10	10	10	10
14	10	10	10	7	7	9	8	4	10	10
21	10	10	5	4	4	1	1	—	10	10
34	7	6	—	—	—	—	—	—	10	10
46	2	2	—	—	—	—	—	—	10	10

It is apparent from this table that at high B AE concentrations Boron is directly toxic to the termites. Even at the lowest level in this trial there appears to be evidence of direct toxicity. In fact, since B AE% of 0.83 in the wood permitted 4 termites out of 20 to survive for 46 days, it appears to show that threshold of *direct* toxicity is near this figure From a practical point of view however direct toxicity is not necessary and it would suffice if the treatment given to wood is sufficient to be toxic to the gut fauna. The next trial was designed to ascertain this level.

In this trial, 1% BAE solution was prepared and one part of this solution was diluted with two parts, three parts and four parts respectively of water. The experiment was repeated using these concentrations. The results are shown in Table II.

TABLE II

Number of Termites Surviving in Second Feeding Trial

Species of timber used : *Mangifera zeylanica*
Number of termites introduced : Ten per set
Date of introduction : 04.03.74

B. A. E. % in timber	0.300		0.227		0.189		*Control*
	Set No.						
Number of days after introduction	1	2	3	4	5	6	7
7	10	7	10	10	9	10	10
14	10	7	10	10	8	10	10
21	10	7	10	10	8	10	10
29	10	6	9	9	8	10	10
38	9	3	7	7	8	10	10
50	4	2	5	5	5	7	10
57	1	2	4	3	3	6	10
64	1	1	1	1	3	3	10
73	—	—	1	—	3	1	10
80	—	—	—	—	—	—	10

This trial was somewhat marred by some early casualties, probably due to handling. In set No. 2 two termites had died on the day after introduction. However, the result is unmistakable—after 80 days all the termites in treated wood were dead while all the termites in the control set survived. This indicated that the BAE percentages used in the trial, were above the threshold.

The third test was designed to find out the approximate threshold value. One part of % BAE solution was diluted with water to 2, 3, 4, 8, 16, 32, 64 and 128 part and these solutions were used to impregnate the slices wood. Table III shows the resuts.

TABLE III

Number of Termites Surviving in Third Feeding Trial

Species of timber used : *Hevea brasiliensis*
Number of termites introduced : Ten per set
Date of introduction : 18.11.74

B. A. E. % in timber	0.226		0.167		0.122		0.066		0.035		0.019		0.011		0.006	
	Set No.															
Days after introduction	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
14	7	6	5	10	7	9	9	8	8	5	7	8	7	8	10	10
18	6	6	5	9	7	8	8	8	8	5	7	8	7	8	10	9
21	5	5	4	8	6	8	8	7	7	5	7	8	7	7	9	8
24	5	3	3	7	6	8	6	7	6	5	7	8	7	7	9	8
32	2	2	2	2	5	8	6	7	6	3	7	8	7	7	9	8
43	0	0	0	0	4	6	4	7	6	3	6	8	7	7	9	8
58	—	—	—	—	1	1	2	3	5	3	6	8	7	6	9	7
63	—	—	—	—	1	0	2	2	4	3	6	8	7	6	9	7
83	—	—	—	—	0	6	0	1	3	0	6	8	7	6	9	7

From this it appeared that the threshold value lay somewhere between 0.03 and O.122% BAE. This trial was done with only twenty termites at each BAE value. Possible handling casualties thus caused great percentage errors. It was decided to test the relevant ranges of retention again using 100 termites at each BAE value. Table IV indicates the results.

TABLE IV

Number of Termites Surviving at Fourth Feeding Trial

Species of timber used : *Hevea brasiliensis*
Number of termites introduced : 50 per set
Dates of introduction : 15.09.75 for sets 1–6, 09.10.75 for sets 7 and 8 : 13.10.75 for sets 9 and 10

B. A. E. % in timber	0.226		0.167		0.122		0.066		0.035	
	Set No.									
Number of days after introduction	1	2	3	4	5	6	7	8	9	10
0	50	50	50	50	50	50	50	50	50	50
15	50	50	50	50	50	50	49	50	48	50
24	43	42	44	44	48	45	49	50	48	50
32	37	32	37	37	44	44	46	49	48	50
46	19	17	17	17	36	34	45	47	48	50
56	7	4	3	7	29	27	—	—	45	50
65	5	2	1	1	27	24	45	46	45	50
70	3	1	0	1	23	23	—	—	—	—
87	1	1	0	1	19	18	—	—	—	—

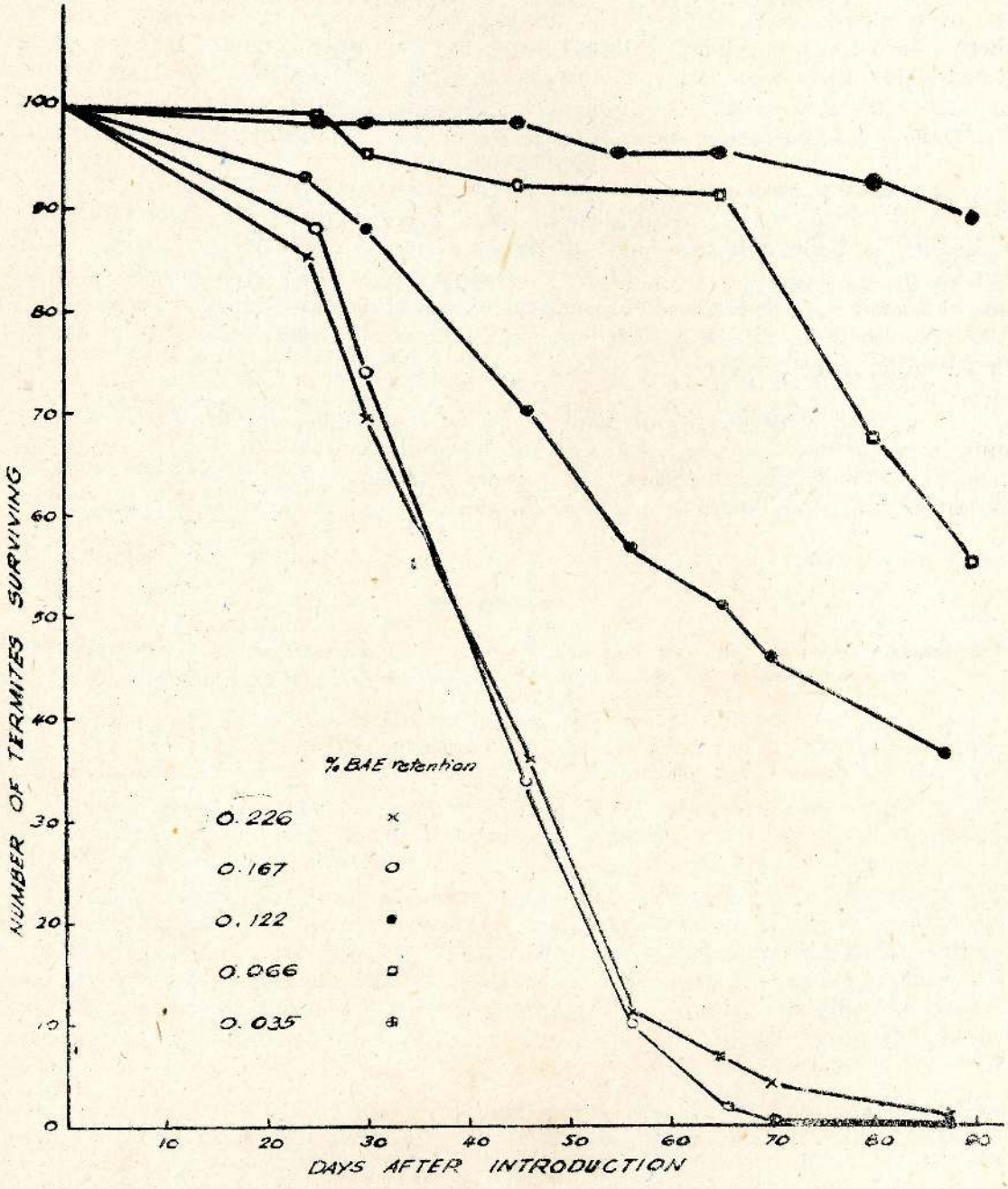

FIGURE 1

CONCLUSIONS

From the last Table it will be seen that a concentration of 0.122% BAE (based on oven dried wood) is toxic to the termite *Cryptotermes domesticus*. However, there were 18.5% survivors after 87 days. In the next higher BAE% retention tested—0.167, there were only 1% survivors after 65 days (although at a B AE retention of 0.226% there were 3.5% survivors after 65 days). Even at the retention of 0.122% B.A.E. there is a progressive increase in casualties as is graphically illustrated in Figure I.

The close correspondence between the curves for B AE of 0.167% and 0.226% is very striking, but is to be expected if a B AE of 0.167% is well above the threshold of toxicity to gut gauna. From this threshold, till the level of direct toxicity is reached, death is caused only by starvation. All deaths by starvation can be expected to run the same course and this explains the close correspondence of the curves for BAE values of 0.167 and 0.226 %. Both these values are above the threshold for gut faunal toxicity but below the threshold for direct toxicity.

The BAE threshold is thus likely to be near the figure of 0.122, hence it would be quite safe, for practical purposes to fix the threshold at 0.15% for *Cryptotermes domesticus*.. It is likely that this same value would also apply to other species of dry-wood termites since they share in common the need for gut fauna to digest cellulose.

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The Present Status of Tree Improvement work in Sri Lanka *

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INTRODUCTION

SRI Lanka (Ceylon) lies between 5°55' and 9°55' North latitude and 79°41' and 81°54 East longitude. The total land area of the island is 6.6 million hectares. The island could be demarcated into two clearly defined climatic zones, the dry zone and the wet zone with an intermediate zone in between. Nearly 66 per cent (2/3rd) of the island constitutes the dry zone which consists mainly of flat and undulating land. The wet zone is situated in the south and south-western region of the island and consists of the coastal plains and very rugged mountainous terrain rising up to an elevation of 2750 metres. The mean monthly temperature varies from 30°C in the lowlands to 20°C in the highlands over 2000 metres. The annual rainfall varies from 1250 mm to 1850 mm in the dry zone and 2500 mm to 5000 mm in parts of the wet zone. The total population is nearly 14 million people.

Of the 6.6 million hectares of land in Sri Lanka, 4.2 million hectares fall in the dry zone and 1.5 million hectares in the wet zone while about 0.9 million hectares fall in the intermediate zone.

According to an estimate made in 1970 the extents of natural forests in the three zones are :

Dry Zone : 2.1 million hectares
Wet Zone : 0.2 million hectares
Intermediate Zone : 0.1 million hectares

The natural forests of Sri Lanka contain more than 100 indigenous timber species. Majority of them are found in the wet zone while the dry zone and the drier parts of the montane zone contain fewer valuable species and the stocking is extremely poor.

At present, the total timber production from all the natural forests of Sri Lanka consists of about 200,000 cubic metres. Both the dry zone and wet zone contribute nearly equally to the total timber production.

Although the extent of natural forests in the dry zone is large (nearly 86%), the bulk of this is unproductive or low yielding. This together with expansion of agricultural activity in this region, is resulting in the decrease in forest area and the gradual diminishing of timber resources. Of the 0.2 million hectares in the west zone only 0.13 million hectares (9%) constitute forest reserves and this has been classified as protection forests and the timber output from this zone will gradually diminish in the future.

To compensate the loss in timber production from the natural forests of these two zones large extents of man-made forests are being established with proven species of exotics. During the past decade there has been substantial planting of exotics in the two zones and there are over 72,000 hectares up to the end of 1975.

In 1970, a long term Forestry Development Plan was drawn up with emphasis or large scale reforestation.

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* An estended version of the paper prepared for the XVIth IUFRO World Congress Norway, June 1976.

Annually 6500 hectares are being planted with the following species :

	hectares
Teak (*Tectona grandis*)	4,040
Eucalyptus	400
Dendrocalamus strictus	200
Pinus (*P. caribaea, P. patula*)	800
Albizzia moluccana	200
Swietenia macrophylla (enrichment planting)	800
Others	60

With large scale planting of exotics it is imperative that seeds of genetically improved quality and the right provenances be used, of the proven species, to raise plantations so that they would produce timber of the desired quality in the shortest possible time with the minimum input of money and man-power.

Realizing the importance and urgency of tree improvement work in Sri Lanka a tree improvement programme was drawn up in 1970 for the three important plantation species viz. Teak, Eucalypts and tropical species of *Pinus*.

In this paper the present status of improvement work done with respect of the three species is outlined.

GENETIC IMPROVEMENT OF TEAK

History of Introduction

The introduction of Teak into Sri Lanka date as far back as 1680 when a Dutchman, Van Rhede planted the first teak in the Matale region (wet zone). Subsequently more Teak was planted in the coastal area but most of these plantations were lost sight of. During the initial stage of Teak planting Teak was declared a crown tree and this regulation prevented large scale planting of Teak on private land.

There appears to be no record maintained of the earlier plantations, but a census taken in 1880 revealed the presence of 17 plantations totalling 50 acres in the wet zone.

The planting of Teak suffered a severe set back when in 1921 a Forestry adviser, in his report to the Government stated 'Ceylon is not suited to the growth of Teak as a large timber tree. Teak plantations if they are continued in Ceylon.....should be an exception and not the rule'. Subsequently, however the view held by the Forestry adviser was proved to be wrong and large scale planting of Teak was undertaken in the dry zone. Today Teak dominates the planting programme comprising about 75 per cent of the planted exotic acreage in Sri Lanka.

Objects of the Improvement Programme

The main objects of the programme is to develop by repeated selection and breeding a superior strain of Teak with the following traits :

(a) Late flowering types in which first flowering does not occur until the trees are 7 to 10 years old.

(b) Superiority in height and diameter growth.

(c) Branches flat or slightly ascending with small diameter and shedding easily off the merchantable bole.

(d) Narrow crown with a low ratio of crown diameter to stem diameter.

(e) Bole free of sweeps and kinks, with no fluting and little buttressing.

(f) Free from pest and diseases.

(g) Superior quality timber.

(h) Profuse production of large viable seed at regular intervals.

The programme of genetic improvement of Teak being undertaken in Sri Lanka is outlined below.

Seed Production Areas

Several seed production areas have been opened in predominantly Teak growing areas. Each area is 2 to 5 acres in extent and they have been thinned to the best 75 to 125 trees per acre. The age of the seed production areas range from 10 to 30 years.

Provenance Trial

In 1973 a trial with the following provenances was established at Puttalam.

(i) Vakaneri, E. D. (Sri Lanka)

(ii) Dehra Dun (India)

(iii) Papua New Guinea

(iv) Thailand

First year height growth after planting indicate that the local provenance is far superior to the rest.

In 1974, seeds of 10 provenances were obtained from the FAO/Danish Forest Tree Seed Centre, Denmark and the provenances were planted out in replicated trials at 2 locations in December, 1975.

Plus Tree Selection

A total of 80 plus trees have been selected by cruising several plantations in the island. The trees were selected on the basis of vigour, stem and crown form and flowering capacity. The age of trees varies from 10 to 50 years.

Clonal Garden

Two clonal gardens have been established using scion material from selected plus trees to provide budwood for future grafting work.

Seed Orchard

A total of 100 acres of seed orchard have been established using a total of 80 clones. The clones have been planted at an espacement of 40 feet in a random manner to permit crown spread and to maximize cross pollination.

The grafting was done using an improved method which was developed for the first time in Sri Lanka.

The orchards are completely isolated from existing Teak plantations to prevent the drift of foreign pollen.

GENETIC IMPROVEMENT OF PINUS

History of Introduction

The first recorded trials of introduced Pines date back to 1952 when trial plots were laid out in the montane zone with *Pinus caribaea, Pinus elliottii, Pinus patula, Pinus kesiya* etc.

New systematic introductions were done in 1965 and repeated during the following years, when a number of species of Pinus were tried in the 3 different climate zones.

These trials indicated that the following species of *Pinus* were suitable for planting in the montane zone and wet zone (low country and uplands)—

(1) *Pinus patula*

(2) *Pinus kesiya*

(3) *Pinus caribaea*

(4) *Pinus oocarpa*

At present attention is being focussed on these 4 species of *Pinus* with a view to developing adequate acreages of these for supplying the future requirement of the local paper and pulp industry.

Species Trial

In addition to the four proven species of *Pinus* (*P. caribaea, P. patula, P. oocarpa* and *P. kesiya*. Several other species of *Pinus* (*P. elliottii, P. merkusii, P. strobus, P. pseudostrobus. P. montezumate, P. halapensis*) and also being tested in the montane zone.

Varietal Trial

Among the 4 proven species of *Pinus*, *Pinus caribaea* has been found to be the best adapted species to grow under a wide range of soil and climatic conditions in the island. With a view to finding out the suitability of the 3 varieties of *Pinus caribaea* for the 3 climatic zones a varietal trial was initiated in 1971.

The trial has been laid out as a randomized block design with 4 or 64—tree square plots (depending on the availability of plants) at 4 sites (montane zone, wet zone and intermediate zone).

Pinus oocarpa has also been included in the trial in addition to the following 3 varieties for comparison purposes :—

P. caribaea var. *bahamensis*

P. caribaea var. *caribaea*

P. caribaea var. *hondurensis*

Provenance Trial

Provenance trials have been established for *P.caribaea* and *P.oocarpa*. For *P.caribaea* 20 provanences are being tested in replicated trials at 4 sites and in the case of *P oocarpa* 4 provenances are being tested at 2 sites. The seeds for these trials were supplied by the Commonwealth Forestry Institute, Oxford.

In 1975 provenances trials for *P. kesiya* and *P.merkusii* were commenced and the nursery phase of the trial has been completed. The provenances will be planted out in replicated trials in 2 or 3 locations in 1976.

Plus Tree Selection and Propagation

A total of 10 plus trees of *Pinus caribaea* has been selected in plantations over 10 years of age.

The trees have been selected on the basis of superiority in growth rate, branch traits and crown form.

Work has commenced on the vegetative propagation and the results so far obtained indicate that reasonable success can be achieved by resorting to air-layering.

It is proposed to established clonal gardens of selected trees within the next 2 years.

GENETIC IMPROVEMENT OF EUCALYPTS

History of Introduction

Early introduction of Eucalpts into Sri Lanka has been a largely a matter of chance ; many planters having links with Australia introduced species of their own choice. Some of the species were amazingly successful.

In 1880 the Botanic garden made a more organised attempt with about 50 species. Some 20 of these species are still represented at Hakgala today.

In the 1930's the Forest Department initiated several arboretum plots in the Up-Country and over a dozen species of *Eucalyptus* were tried. These trials have indicated that species such as *E. saligna, E. grandis, E. microcorys, E. robusta, E. citriodora,, E. pilularis, E. camaldulensis* and *E. globulus* can be successfully raised in the montane zone.

In the early 1960's trials with Eucalypts were extended into the dry zone and low country wet zone. *E. camaldulensis* and *E. citriodora* have been found to be suitable for the dry zone and *E. deglupta* for the wet zone.

Species Trial

Species trial with *E. alba, E. tereticormis, E. bicostata, E. bosistoana, E. viminalis, E. nitens, E. cypellocarpa, E. microtheca, E. maculata* and *E. tetradonta* are in progress in in the dry, wet and montane zone.

Provenance Trial

In 1974 provenance trial was initiated with 4 known provenances of *E. camaldulensis* at Puttalam in the dry zone. At the end of the first year significant variation in form and leaf traits have been observed.

In 1975 provenance trials with the following species have been initiated :

(1) *E. camaldulensis*
(2) *E. tereticornis*
(3) *E. alba*
(4) *E. tetradonta*
(5) *E. microtheea*
(6) *E. maculata*
(7) *E. salinga*
(8) *E. grandis*

Plus Tree Selection & Progeny Tests

A total 60 plus trees of *E. grandis* and 30 plus trees of *E. microcorys* have been selected. Short term progeny tests were carried with half-sib progenies of *E. grandis* under glasshouse condition and significant variation in leaf traits, and production and distribution of dry matter have been observed.

Field trials have been established with selected number of half-sib progenies of *E. grandis* in the Up-Country.

Seed Production Areas.

Seed production areas have been opened for *E. grandis, E. microcorys* and *E. camaldulensis.*

In the case of *E. camaldulensis* the seeds collected from the local seed production area have produced seedlings which are more vigorous than the one raised from imported seeds.

Some methods of Preservative Treatment of Bamboo

D. L. JAYANETTI
(Timber Utilisation Research Officer)

INTRODUCTION

From ancient times bamboo has been used for construction purposes in this country. Now it is mostly used for scaffoldings and temporary structures.

Bamboo is liable to decay after some time due to fungal attack or is destroyed by insects and borers. Because of these reasons, bamboo used for scaffolding is discarded within a couple of months. The service life of bamboo can be extended by treating it with a wood preservative.

Bamboo is found in almost every part of the country. Generally it grows in the forests and river banks naturally. A variety of species of bamboo are found and the two varieties commonly used in this country are—

Bambusa arundinacea (Katu Una or Thorn Bamboo)
Bambusa vulgaris (Una or Yellow Bamboo)

TREATMENT OF BAMBOO

Bamboo for external use should be treated with a fixed preservative such as Copper Chrome—Arsenic (e.g. Ascu, Tanalith C). There are several methods of carrying out the treatment. Only the methods which layman could do are outlined here. For all these methods large containers (such as old oil drums) are required for the preparation of the preservative solution.

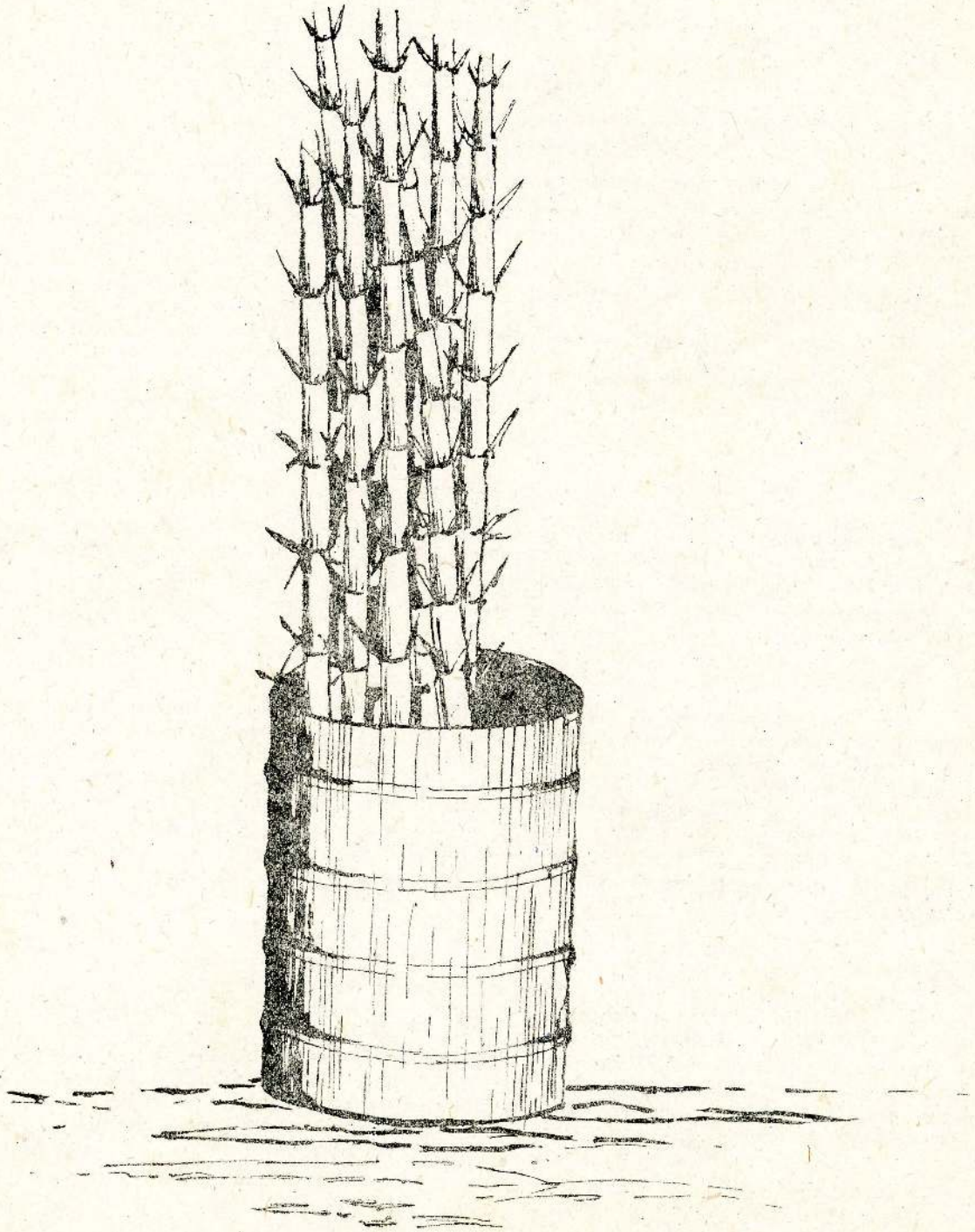
Dipping Method

The bamboos are cut to required length after removal of branches and leaves. These are then dipped in the solution for treatment. As this method takes a considerable time, freshly cut bamboos with leaves on could be dipped in the preservative solution (Fig. 1). The leaves should remain out of the solution in contact with air. Normally it takes 2 to 3 days for this type of treatment but the actual time depends on the length of the bamboo species and the climatic conditions. The progress of the treatment could be observed by the change of the colour of the leaves. With experience, it could be judged when to stop the treatment. The preservative to be used is 5 per cent. Ascu or Tanalith C.

Boucheric Process

Freshly cut bamboos are connected by means of old car or motor cycle tubes (depending on the diameter) to a drum containing the preservative solution (Fig. 2). The bamboos should be kept at a slight inclination and the drum at a higher level. It will be seen that after some time solution starts dripping from the lower end. It is advisable to allow this solution to flow out until preservative solution starts dripping. This could be observed by the colour of the preservative. This solution flowed out could be re-used for treatment bringing the concentration to required strength by adding more chemical. When the colour of the solution coming from the lower end is the same as that of the solution in the drum, the treatment is considered complete. A 5 per cent. solution of Ascu or Tanalith C is recommended for this as well as the modified Boucheric Process.

FIGURE 1



Modified Boucheric Process

Freshly cut bamboos with branches and leaves on are connected to a drum as in the earlier case. If this is done early morning on a sunny day, the time of treatment will be very much less. The preservative will be absorbed into the bamboo by transpiration of the leaves in addition to hydrostatic pressure.

The same process could be done using a polythene bag and tying with rubber bands (Fig. 3).

Expected service life of properly treated bamboos may be considered indefinite due to decay, but the actual serviceable life will solely depend on the purpose for which it is used. For instance the serviceable life of treated bamboo used in scaffolding will totally depend on how carefully the bamboos are dismantled, stored, transported and erected.

Precautions to be taken when handling C.C.A. (Copper, Chrome Arsenic) Salts—

(1) Before starting work, cuts, wounds and abrasions on hands and arms should be covered with a clean waterproof dressing.

(2) Protective rubber gloves must be worn for handling salts and it is very important that insides of these gloves are kept clean.

(3) Avoid inhaling the dust from salts and wear an industrial face mask if desired.

(4) Good agitation during mixing is essential.

(5) After handling rinse the hands and arms in clear running water and then wash with hot water and soap.

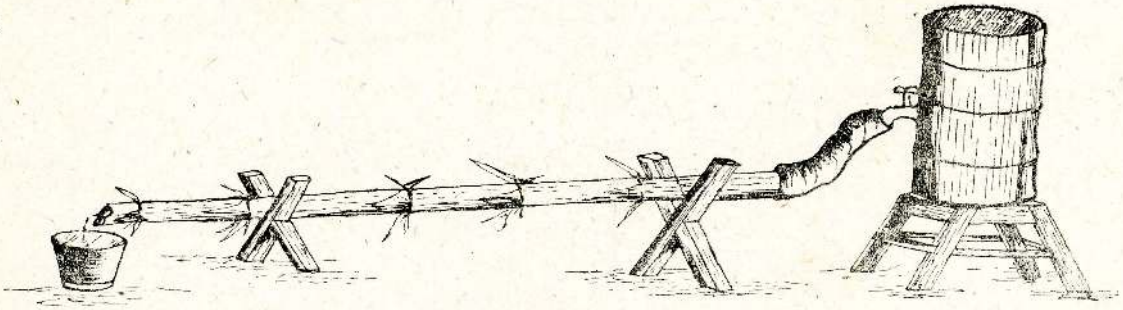


FIGURE 2

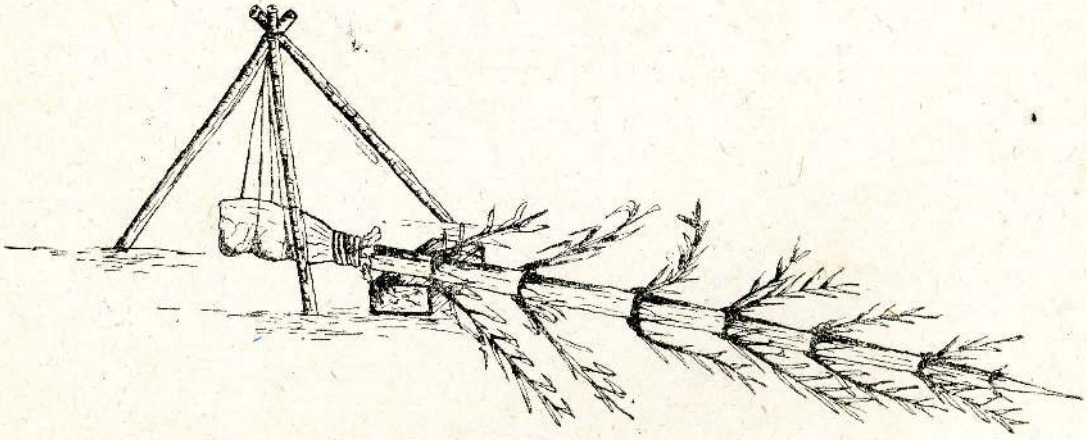


FIGURE 3

The Sri Lanka Forester, Vol. 12, No. 2, July-December, 1975

දැව පදම් කිරීමේ මූලධර්ම

දැව භාවිත පර්යේෂණ නිලධාරි—ඩී. ඇල්. ජයනෙත්ති.

හැඳින්වීම

දැව පදම් කිරීම යන්නෙන් අදහස් කෙරෙනුයේ සිමාකර ගසුරු වන ලද පරිසරයක දැව වේලීමයි. අලුතින්ක් බිම හෙලනු ලබන සෑම ගසකම විශාල ජල ප්‍රමාණයක් ඇති බවත්, භාවිතයට පෙර ඒ වේලා ගතයුතු බවත් අප කවිරුත් දන්නා කරුණකි. සෑම ඒ කැබෙල්ලකම යම්කිසි ජල ප්‍රමාණයක් ඇත. එම ප්‍රමාණය වාතයේ ඇති සාපේක්ෂ අර්ද්‍රතාවය මත රඳා පවතී. පදම් කිරීමේදී තෙරෙනුයේ භාවිතයට ගැනීමට අවශ්‍ය ඒ වල තිබිය යුතු ජල ප්‍රමාණය වනතෙක් වේලා ගැනීමයි.

දැව පදම් කිරීමේදී දැනගත යුතු මූලික කරුණු දෙකක් ඇත. පළමුවැන්න නම් එක් ඒ වර්ග යක්වත් ඒකාකාරව සැදී නැත. අතික එක් වර්ගයක් අනික් වර්ගයෙන් සැදී ඇති අයුරිනුත්, භෞතික ගුණාංග වලිනුත් එකිනෙකට වෙනස්වන බවයි.

මේ හේතුකොට ගෙන දැව පදම් කිරීමට පෙර, එයට අදාළ මූලධර්ම දැන කටයුතු කරන්නේ නම්, ඉතා උසස් අන්දමින් වැඩි ප්‍රයෝජනයක් දැව කර්මාන්තයෙන් ලබා ගත හැක.

තෙතමනය

අලුතින් බිම හෙලන ලද ගසකින් කපාගත් ඒ කැබෙල්ලක ඇති තෙතමනය ක්‍රම දෙකකින් කෑන්පත්ව ඇත. ශෛල ඇතුලෙහි නිදහස්ව රඳා ඇති ජලය පළමුවැන්න වන අතර, ශෛල බිත්තිවල උරාගත් ජලය දෙවැන්න වේ. නිදහස්ව රඳා ඇති ජලය ඉවත් කළ විට, ඵලඹෙන්නේ කෙදි සංතෘප්ත ලක්ෂයටය. මෙම අවස්ථාව වේලන ලද ඒ මත බැලූ විට ලැබෙන තෙතමනය ප්‍රමාණය සියයට 25 ත් 30 ත් අතර පවතී.

ඒ කැබෙල්ලක තෙතමනය යනු:—

ඒ කැබෙල්ලේ පළමු බර—උදුනේ වියලාගත් ඒ කැබෙල්ලේ බර

උදුනේ වියලාගත් ඒ කැබෙල්ලේ බර

ඒ වල හැසිරීම, ශක්තිය, විදුලි ප්‍රතිරෝධ ආදී භෞතික ගුණාංගවල වෙනස්වීම පවත් ගැනෙන්නේ, ඉහත සඳහන් අවස්ථාවෙන් පහතට වේලීමේදී, ශෛල බිත්ති උරා ගත් ජලය ඉවත් වීම නිසාය.

දැව පදම් කිරීමේ ක්‍රම

ඒ වේලා ගත හැකි ක්‍රම බොහෝ ඇත. දැව අවස්ථාවේ ඇති ජලයෙන් එක්තරා කොටසක් යන්ත්‍රානුසාරයෙන් ඉවත් කළ හැකි නමුත්, මේ ප්‍රායෝගිකව කළ නොහැක්කක් වන අතර, නියම අන්දමට වේලා ගත හැකිද නොවේ. ඇසිටෝන් වැනි රසායනික ද්‍රව්‍යයක් භාවිතා කොට පදම් කිරීමේ ක්‍රමද ඇති නමුත්, ඒවා විශාල වශයෙන් යොදා ගත හැකි මිල පහසු ක්‍රම නොවේ.

ඇත්ත වශයෙන්ම ඒ පදම් කරනු ලබන ජනප්‍රිය ක්‍රම ඇත්තේ දෙකකි. පළමුවැන්න වාතයේ පදම් කිරීම සහ දෙවැන්න උදුනේ පදම් කිරීමයි. උදුනේ පදම් කිරීමේදී හෝ වේලීමේදී කරනුයේ වාතයේ උෂ්ණත්වයට වඩා උෂ්ණත්වයක් උදුන තුළ ඇති කිරීමයි. කෙසේ වෙතත් මෙය ජලයේ තාපාංකය වන සෙන්ටිග්‍රේඩ් 100 ට වඩා අඩුය. මෙම ක්‍රම දෙකම අදාළ වී ඇත්තේ එකම මූල ධර්මයක් මතය. එනම්,

ලී වල තෙතමනය වාෂ්ප කිරීමට උෂ්ණය ලබාදෙන මාධ්‍යයත්, එම වාෂ්පිය වූ තෙතමනය ලීයෙන් ඉවත් කරන මාධ්‍යයත් වාතය වීමයි. වෙනසකට ඇත්තේ උදුනේ වාෂ්පවීමේ සීඝ්‍රතාවය හසුරුවා ලීමට හැකි වීමත්, එහි උෂ්ණත්වය වාතයේ උෂ්ණත්වයට වඩා වැඩිවීමත්ය.

ජල වාෂ්ප පීඩනය සහ සාපේක්ෂ අර්ද්‍රතාවය

තෙත් ද්‍රව්‍ය වේලීමේදී වන්නේ, ඒ වාඩිනේ ජලය ඉවත් වීමයි. මෙසේ ජලය ඉවත්ව යාම ජලයේ වාෂ්පී භවනය ලෙස හැඳින්වේ. ජලයට නිශ්චිත තාපාංකයක් ඇතත්, කවර උෂ්ණත්වයකදී වුවද එය වාෂ්පවේ. වාෂ්පී භවනයේ සීඝ්‍රතාවය කෙරෙහි බලපාන සාධක කිහිපයක් ඇත. ඒවා නම්, උෂ්ණත්වය, වාතයේ වියළි බව, වාතයේ චලිතය හා පීඩනයයි.

මධ්‍යසාර, වයින් ස්ප්‍රීතු, පැට්රල් වැනි වාෂ්ප ශීලී ද්‍රව්‍ය තබා ඇති බෝතලවල මූඩි තරයේ වසා නැත්නම්, එම ද්‍රව්‍ය වාෂ්පී වී ගොස් බෝතල හිස්වන බවත්, සමහර අවස්ථාවලදී ඒවායේ මූඩි "පොප්" හඬින් විසිවී යන ආකාරයත් අප දැක ඇත. මීට හේතුව මෙම ද්‍රව වලින් හටගන්නා වාෂ්ප පීඩනයයි. එමෙන්ම ජලයටද සෙන්ටිග්‍රේඩ් අංශක 100 දක්වා ඉඩලිය හැකි උපරිම වාෂ්ප ප්‍රමාණයක් ඇත. ඒ උපරිම අවස්ථාවේදී, ජල වාෂ්පය නිසා හට ගන්නා පීඩනය, සන්තෘප්ත වාෂ්ප පීඩනය යන්නෙන් හැඳින්වේ. වාතය සහ ජල වාෂ්පී මිශ්‍රණයක පීඩනය, වාතයේ අර්ධ පීඩනයත්, ජල වාෂ්ප පීඩනයේත් ඓක්‍යය වේ. යම්කිසි වාත ප්‍රමාණයක ජල වාෂ්ප පීඩනය, සන්තෘප්ත වාෂ්ප පීඩනයට වඩා අඩුනම්, එම වාත ප්‍රමාණයට තවත් තෙතමනය ඇතුල්කර ගැනීමේ හැකියාවක් ඇත්තේය. ජල වාෂ්ප පීඩනය සන්තෘප්ත වනතෙක් මෙම හැකියාව සීමා වන්නේය. වාතයේ ජල වාෂ්ප පීඩනයේ සහ සන්තෘප්ත වාෂ්ප පීඩනයේ වෙනස වාතයේ "වේලීමේ හැකියාව" හෝ "වේලීමේ ධාරිතාව" ලෙස හැඳින්විය හැක.

වියළි වාතය නමින් හැඳින්වෙන ජල වාෂ්ප රහිත වාතයක තෙත දෙයක් වේලා ගැනීම ඉතා පහසුය. උපරිම වාෂ්ප ප්‍රමාණයෙන් ඉතා සුළු කෝටසක් ඇති වාතය වුවද, වියළි වාතය ලෙස සැලකිය හැක. ජල වාෂ්ප ඇති වාතයේ තෙතමනයක් ඇති අතර, වියළි වාතයේ තෙතමනය ඇත්තේ ස්වල්ප වශයෙනි. වාතයේ ඇති ජල වාෂ්ප සන්තෘප්ත වූ කල තෙතමනයට උපරිම අගයක් ඇත. අර්ද්‍රතාවය වාතයේ ඇති තෙතමනයේ මිණුමක් ලෙස සැලකේ. දෙන ලද වාතය පරිමාවක ඇති ජල වාෂ්පයේ ස්කන්ධය, එම උෂ්ණත්වයේදීම එම වාත පරිමාවේ තිබිය හැකි උපරිම ජල වාෂ්ප ස්කන්ධයට ඇති අනුපාතය, "සාපේක්ෂ අර්ද්‍රතාවය" ලෙස හැඳින්වේ. මෙය සියයට ගණනක් ලෙස පහත සඳහන් ආකාරයට හැඳින්විය හැක.

වාතයේ සාපේක්ෂ අර්ද්‍රතාවය :

$$= \frac{\text{සංතෘප්ත ජල වාෂ්ප පීඩනය}}{\text{ජල වාෂ්ප පීඩනය} \times 100}$$

තෙත් ලී කැබෙල්ලක් වාතයේ වේලීමට ඉඩ හැරියොත් එය මතුපිටින් වාෂ්පී භවනය සිදුවේගන ගොස්, එක්තරා අවස්ථාවකදී මෙම වාෂ්පී භවනය නවතී. මේ අවස්ථාවේදී එම ලී කැබෙල්ලේ දෙන ලද උෂ්ණත්වයේ "සම තුලිතා තෙතමනය" ලෙස හැඳින්වේ.

පරිසරයේ උෂ්ණත්වය

තාපාංකය තෙක් උෂ්ණත්වය නොනැංවුවද ව්‍යාත භාජනයක ඇති ජලය උණුසුම්ව තැබුවහොත්, සිසිල්ව ඇති විට වඩා ඉතා ඉක්මනින් වාෂ්පී භවනය සිදුවේ. මෙම ජලයට රත්කිරීමෙන් වාෂ්පීකරණයේ ගුප්ත තාපය ලබා දුන්නොත්, එය වහා වාෂ්ප වී පිටව යයි. සාමාන්‍ය අවස්ථාවන්හිදී වනුයේ අවට තාපය හේතුකොට ගෙන වාෂ්පී භවනය වීමයි. තෙත් ලීයක මතුපිටින් තෙතමනය වාෂ්ප වීමෙන්,

බාහිර තට්ටුවේ තෙතමනය අඩුවී වෙලෙන් නට පටන් ගන්නා නමුත්, අභ්‍යන්තරයේ තෙතමනය ටිකින් ටික වේලීගෙන යන පෙදෙසට සංක්‍රමණය වේ. මෙම සංක්‍රමණය සෑම ලීයකම ඇති නමුත් ඝණ තද ලී වල ඇති වන්නේ ඉතා අල්ප වශයෙනි. මෙකී සංක්‍රමණයට වඩා බාහිර තට්ටුවේ වාෂ්පවීම ඉතා සීඝ්‍ර යෙන් සිදුවන්නේ නම් ලීය තුල තෙතමන අනුක්‍රමණයක් ඇතිවේ. මේ වියළීම හේතුකොට ගෙන, තෙතමනය කෙදි සන්තෘප්ත ලක්ෂයට වඩා අඩු වුවහොත්, ලීය හැකිලී යාමට ඉඩ ඇත. තෙත් වූ අභ්‍යන්තරයත්, වියැලුන බාහිර තට්ටුවත් අතර පීඩනයක් ඇති වීමෙන්; අභ්‍යන්තරය සම්පීඩනය කටත් බාහිර තට්ටුව ආකෘතියකටත් භාජනයවේ. මෙම පීඩනයට වැඩිවීමට ඉඩ දුනහොත් බාහිර තට්ටුවේ ඉරි තැලීමට පටන් ගනී. ඉරි තැලීමක් නොමැතිව, බාහිර පෙදෙස ඇදී පැවතුනහොත් පිටුතල ඇඹිම යයි නම් කෙරේ. මෙකී දුෂ්කර තාවලට තුඩුදෙන තෙතමන අනුක්‍රමණය, වාතයේ වියැලීමේදී පමණක් නොව, උදුනකවියැලීමේදී පවා හට ගැනීම වලක්වා ලිය නොහැක. දෙන ලද උෂ්ණත්වයක, අභ්‍යන්තර යෙන් බාහිරයට ඇතිවන තෙතමන සංක්‍රමණයේ සීඝ්‍රතාවය උෂ්ණත්ව අනුක්‍රමණයේ වැඩිවීමට සමානුපාතිකවේ. ලීයට හානියක් නොවන සේ මෙම තෙතමන අනුක්‍රමණය වැඩිවීමට ඉඩ හැරීමෙන් බාහිර තට්ටුව දක්වා සංක්‍රමණය වන තෙතමණයේ සීඝ්‍රතාවයට සරිලන අන්දමින් වාෂ්පවීමේ සීඝ්‍රතාවය හසුරුවා ලීමක් මත ලී පදම් කිරීමේ සාර්ථකත්වය රඳා ඇත.