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Forest tree improvement in India

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Abstract. Forest tree breeding is relatively a young science. Even so, there is good evidence of its potentiality for increasing forest productivity and quality of the forest produce. The basic scheme for forest tree improvement involves selection of superior parent trees, assembling them as clones in seed orchards in special designs to promote maximum cross pollination among the different clones and reduce inbreeding. Interprovenance and interspecific hybridisation are also resorted to in special situations. Forest tree improvement work through selection and breeding has been in progress in India for the last nearly two decades. Some of the achievements and strategies used are briefly reviewed.

Keywords. Forest tree breeding; seed orchards; teak; eucalypts; pines; red sanders; semul; breeding strategies; interprovenance; inter-specific hybridisation

1. Introduction

Forest tree breeding *per se* is comparatively a young science which had its recognizable start about five decades back. Sweden was the pioneer in this venture and others followed suit slowly. Today every country, big or small, developed or developing, has active programmes on forest tree breeding. In some of the developed countries wood-based industries have invested money in such programmes with great expectations. Fortunately, there is sufficient good evidence today which indicates that such investments are sound and can pay rich dividends. In fact in recent years the research on the economics of tree improvement programmes has shifted its emphasis from programme justification to programme optimization.

Intensive management through artificial regeneration and establishment of plantations or what may be termed as 'man-made forests' are increasingly being resorted to in many countries. This naturally offers a good opportunity for not only better management of the conditions under which the trees are to grow but also of choosing appropriate genotypes which will not only have the capacity to exploit to the best advantage the environment provided but which can often be tailored to meet the specific needs. Since the area of potential production is often large even small improvements in productivity may be very significant at the national level both in terms of social benefits and production of raw material.

In this paper the general strategy that is followed in forest tree improvement and the work currently in progress in India in this fascinating field are briefly reviewed.

2. Tree improvement strategy

2.1 *Population improvement*

Exploitation of available natural genetic variability within the species is the first step in all selection and breeding work.

A characteristic feature of all living organisms is the immense natural variability they exhibit for various characters in most populations. Broadly three types of variation may be recognised (i) random variation from tree-to-tree on the same site, (ii) variations in the average of certain characters of all the trees in one locality or site when compared to the average of all trees in another locality (sometimes called local variation) and (iii) average variations in trees from widely different parts of the species range (often referred to as geographical variation or racial variation). In a regeneration programme it is essential first to identify the best adapted and productive seed origin or provenance for the species concerned. The thumb rule in forestry is "use seed from the local source until some other source or provenance has been proven superior to the local one". Superiority of new seed sources should be assessed by well laid out provenance trials.

Having identified the right provenance one can then exploit the tree-to-tree variation in economic traits for selection of superior individual trees. This is known as 'plus tree' selection. Plus trees may be defined as outstanding individuals occurring in natural stands or in even aged plantations combining in themselves a number of desirable features. As is to be expected such trees occur in low frequency and so may appear hard to find. But they do exist. These trees form the foundation for tree improvement by selection. Kedharnath (1982) has briefly reviewed the different methods employed in plus tree selection. Plus trees which are progeny tested and approved as good are called 'elite trees'. The number and type of characters used as selection criteria vary with the species but some of the most common characters used for selection are good growth vigour, superior height growth, superior diameter growth, good pruning ability, straight cylindrical bole, narrow compact crown, resistance to important diseases and insect pests.

The selected plus trees are then assembled as clones in special planting sites and they are called seed orchards. This is meant for mass producing quickly regular crops of genetically improved seeds for use in raising new plantations. These orchards require special management practices to enhance flower and seed production. Also, in the orchard the ramets of the different clones are so planted that there is very little inbreeding and maximum cross breeding between ramets of different clones in various combinations are favoured. Special planting designs are used for this. Usually grafting is resorted to using scions collected from the top one third of the flowering crown of the plus trees. This increases the probability of early flowering in the grafted plants. In some cases rooted cuttings can also be employed if graft incompatibility is a constraint. Seed orchard approach of mass producing genetically improved seeds in forest trees is so far the best publicised and most widely practised method in all the countries. This is most suitable for tree species that are normally cross pollinated. Also, to keep the genetic base sufficiently broad at least 20 clones should be used in an orchard. Theoretically there is no upper limit to the number of clones that can be used in an orchard. But the orchard should be large enough in area so that various possible cross combinations among the clones used could be realised.

2.2 *Exploitation of hybrid vigour or heterosis*

Synthesising F_1 hybrids between selected provenances of a given species could be resorted to if some specific combination manifest hybrid vigour. Mass production of such F_1 seeds could be achieved through a seed orchard programme where selected clones of two provenances may be planted. The same approach can be followed for

obtaining F_1 hybrids between two selected species if there is *prima facie* evidence of hybrid vigour.

3. Work on tree improvement in India by selection and breeding

Organised work on breeding of forest trees was started in India in 1960 at the Forest Research Institute, Dehradun in some selected tree species of economic importance. The detailed programme of work to be initiated in forest genetics and tree breeding was presented at the Tenth Silvicultural Conference held at Dehradun by Kedharnath and Raizada (1961). The Forest Genetics Branch of Forest Research Institute, Dehradun in collaboration with the State Forest Departments have been active since 1960 in carrying out this programme of work and good progress has been registered in the case of teak (*Tectona grandis* L.f.) Chirpine (*Pinus roxburghii* Sarg.), Semul (*Bombax ceiba* L.) and in some species of eucalypts. The Kerala Forest Research Institute, Peechi (Kerala), the Department of Forestry, H P Krishi Vishwa Vidyalaya and the Faculty of Forestry of Tamil Nadu Agricultural University have been making very useful contributions in this field of work. Some of the important contributions in the area are briefly reviewed below.

3.1 *Teak (Tectona grandis L.f.)*

Teak is one of the most durable and valuable timber species and belongs to the family Verbenaceae. It has 36 as its somatic chromosome number (Kedharnath and Raizada 1961). It is native to the Indo-Malayan region and occurs naturally in some parts of India while in other parts it has been successfully introduced. Presently teak is being raised in plantations on a large scale. Approximately one lakh hectares are being planted annually. The objective of tree improvement programme in teak has been to produce by selection and breeding superior stem form, superior rate of growth in height and diameter, freedom from fluting, buttressing and epicormic branches, resistance to leaf skeletoniser (*Eutectona machaeralis* syn. *Pyrausta machaeralis*) and leaf defoliator (*Hyblaea purea*). There is general evidence of inherent variation in this species for all the characteristics stated above (Kedharnath and Matthews 1962).

Work on the selection of plus trees in the species was started in the year 1960 and todate about 700 plus trees are available for use in establishing clonal seed orchards. Simple budding and/or sometimes cleft grafting technique standardised for this species by Rawat and Kedharnath (1968) has been used for clonal seed orchards and germ plasm banks that have been established in a number of states. The first experimental clonal seed orchard in this species was established at New Forest, Dehradun. Studies carried out on early growth performance of 20 clones revealed considerable variation between clones (Kedharnath *et al* 1970). These differences have persisted in later years also. Similarly observations recorded over the years on the relative resistance/susceptibility of the different clones established in the germ plasm bank and in the clonal seed orchard at New Forest, Dehradun to two leaf infecting fungi—*Olivaea tectonae* and *Caldariomyces tectonae*—under natural conditions of infection showed consistent reaction. Some were absolutely resistant, some were very susceptible while some were moderately resistant. These two diseases are not economically important. In respect of studies on variation in fibre length carried out using trees from a replicated provenance

experiment revealed significant geographical and tree-to-tree variation in this trait (Kedharnath *et al* 1963). Testing of some of the clones of *T. grandis* and a related species *T. hamiltoniana* under controlled conditions for variation in resistance to *Eutectona machaeralis* showed that there is significant variation among the clones tested (Kedharnath and Pratap Singh 1975).

Studies carried out on vegetative propagation such as rooting of cuttings, grafting, budding etc have shown that it is a favourable material for cloning. There has not been any indication of graft incompatibility in *T. grandis*. Furthermore, budding on naked stumps (with about 15 cm length of root and about 3 cm of stem) just above the collar region gives very good take. Customarily such budded stumps are planted in polypots and the new sprout emerges in 15–20 days. The best time for such budding appears to be March–April. In June–July they are transplanted in the seed orchard site. More recently attempts have been made for clonal multiplication through *in vitro* tissue culture techniques and very good success has been obtained by Gupta *et al* (1980) at the National Chemical Laboratory, Pune. The important aspect of the above work is that mature excised terminal buds from field grown trees about 100 years old have been induced to form multiple shoots on a defined medium. Individual shoots were later made to develop roots on a low salt medium, containing three auxins. The plants so obtained have been later transplanted in pots and finally in the field. This technique offers a good method for cloning. But this is yet to become popular with foresters for large scale adoption in clonal seed orchard establishment.

All the teak-growing states are establishing clonal seed orchards for teak. It has been estimated that if one plants 156 grafts per hectare at 8 × 8 m espacement 1280 ha of seed orchards will be needed. Roughly 2 grafted plants will suffice to give enough seeds (3 kg each) to plant a hectare. About 800 ha of seed orchards have been established so far.

Progeny testing of the plus trees is an essential step to know the breeding value of the plus trees. Open-pollinated seeds from the plus trees have been collected and used in some states like Tamil Nadu, while some others have taken advantage of the early flowering of the different clones in the orchard and collected seeds under open pollination clone-wise and raised seedlings for establishing progeny trial. One interesting observation reported by Kedharnath (1973) regarding some of the seed orchards pertains to early flowering observed in many clones, non-synchronous flowering among some clones and production in general of good well-filled seeds with a very high percentage of germination. Intensive management of the orchards should be helpful in enhancing flower and seed production.

Some of the states like Andhra Pradesh, Gujarat, Kerala, Madhya Pradesh, Maharashtra and Tamil Nadu have made good progress in the selection of plus trees and in establishing clonal seed orchards. Now efforts are in progress to manage the orchards intensively so as to enhance flowering and fruit production.

Some of the teak plus trees of Tamil Nadu have been used as experimental material for gel electrophoresis studies to identify easterase bands (Kumaravelu 1979).

Two other species, *Tectona hamiltoniana* Wall. and *T. philippinensis* Benth. and Horn. f. ex. Merr. are known under the genus *Tectona*. They are not very valuable as timber species. *T. hamiltoniana* has 36 as its somatic chromosome number. This species has been introduced in Dehradun from Burma. Trees of this species appear to be comparatively free from attacks of leaf skeletoniser and defoliator. Exploratory crosses were therefore attempted between *T. grandis* and *T. hamiltoniana*. This cross, however, yielded only shrivelled seeds and failed to germinate. Embryological studies revealed

that fertilisation does take place in this cross but the hybrid embryo aborted very early. It should be possible to realise this hybrid by employing embryo-culture technique. Grafting work carried out with these two species *viz T. grandis* as stock and *T. hamiltoniana* as scion showed that the grafts are able to survive for about six years under Dehradun conditions and then graft incompatibility manifests itself. This is not surprising, considering the fact that *T. grandis* has ring porus wood while *T. hamiltoniana* has diffuse porus wood. The same graft combination has been carried out also at Kerala Forest Research Institute, Peechi which are 4 years old now and have grown well. It remains to be seen as to how soon late graft incompatibility will manifest itself in these. It is interesting in this connection to point out that studies carried by Gottwald and Parameswaran (1980) show that the general properties and anatomical features of the wood and bark, together with the leaf trichomes, are markedly different between *T. grandis* (of sect. *Tectona*) on the one hand and *T. hamiltoniana* and *T. philippinensis* (of sect. Leiocarpae) on the other. Perhaps a taxonomical revision of the genus may suggest retention of a single species under the genus *Tectona, viz T. grandis* and the other two taxa *T. philippinensis* and *T. hamiltoniana* be shifted to another new genus or put under some other already existing genus like for instance *Gmelina.*

3.2 *Eucalypts*

Three species of eucalypts in particular, *Eucalyptus tereticornis*, *E. grandis* and *E. globulus* are in use for raising large scale plantations. *E. globulus* is mostly used in the Nilgiris in South India and no work on the genetic improvement of this species has been initiated so far. In respect of the other two species a lot of research work has been done for the genetic upgrading of the species. The provenance of *E. tereticornis* usually referred to as, 'Mysore Gum' or sometimes as 'Mysore hybrid' is the one that is in use in most of the states for raising large scale industrial plantations. It is also in use in agroforestry. *E. grandis* is usually raised in higher ranges of western ghats particularly in Kerala and to a small extent in Tamil Nadu. These two species are worked on a short rotation of 8 yr. While in many areas it has given good yields, in some areas, however, the yields have been rather poor. Work on provenance testing is in progress in a number of states.

Differences in rate of growth and susceptibility to *Cylindrocladium* blight has been reported by Jayashree *et al* (1984) from a study of 39 provenances representing 15 species. A toxin bioassay method for assessing relative susceptibility of eucalypts to pink disease caused by *Corticium salmonicolor* has been reported by Sharma *et al* (1984). They screened 23 eucalypt entries and observed significant variation in their susceptibility.

Plus tree selection and establishment of progeny trial has been taken up in *E. grandis* and *E. tereticornis*. Vegetative propagation by rooting of stem cuttings has not been very encouraging for large scale use. Clonal propagation by grafting has also not been very encouraging because of late manifestation of graft incompatibility. Thus, there has not been much enthusiasm for establishing clonal seed orchards. However, it is hoped that with the recent reports on the success achieved in obtaining plantlets from meristem culture in *E. citriodora* by Gupta *et al* (1981) and in *E. grandis* by Lakshmi Sita *et al* (1984) there will be enthusiasm to use this approach for establishing clonal seed orchards.

Valuable information on various genetic parameters has been reported from

E. tereticornis and *E. grandis* by Kedharnath and Vakshasya (1977), Kedharnath (1982a) and Krishnaswamy *et al* (1984).

A number of spontaneously occurring interspecific hybrids have been identified and studied in India (Kedharnath 1980). These include *E. camaldulensis* × *E. tereticornis*, *E. citriodora* × *E. torreliana*, *E. grandis* × *E. tereticornis*. These hybrids manifest good hybrid vigour for growth and volume production. It would be very beneficial to multiply them clonally and establish plantations using the tissue culture approach. Also, experimentally synthesised hybrids have been evaluated by Venkatesh and Sharma (1977). F_1 hybrids from some of the cross combinations exhibit good hybrid vigour.

3.3 *Pines*

Till very recently only four species of pines were known in India—*Pinus roxburghii* Sarg., *P. wallichiana* Jack., *P. kesiya* Royle ex Gordon and *P. gerardiana* Wall. Now one more species *P. bhutanica* Grierson, Long and Page, has been recorded from Arunachal Pradesh. This species was collected from Arunachal Pradesh by Naithani and Sahni in 1977 (Naithani and Bahadur 1981). The same species has been collected from Bhutan by Grierson *et al* (1980) and given the name *P. bhutanica*. It is a five-needle pine.

Pinus roxburghii the low level pine confined to the monsoon belt of the outer Himalaya from Bhutan to North Eastern part of West Pakistan is a valuable pine for its oleoresin and also timber. It grows in lower elevations generally up to 1830 m. Troup (1921) recognised nine provenances on the basis of growth characteristics. Considerable variation in oleoresin yield was found among the trees in the different provenances growing at New Forest, Dehradun in a provenance trial. In some provenances there were high-yielders of 4 to 7 kg. A programme of breeding for improving oleoresin yield was suggested by Kedharnath (1971). A number of plus trees specifically for high resin yielding character were selected in the State of Uttar Pradesh. Clonal propagation techniques by Cleft grafting in the succulent region with 85–90% graft take was worked out for this species (Kedharnath *et al* 1979). Additionally, the grafted plants can be used for further clonal multiplication by air-layering. A very high percentage of rooting response was obtained in airlayering trials carried out by Kedharnath and Dhaundiyal (1963). Successful rooting of stem cuttings using hormones and mist tent has also been reported from Himachal Pradesh Forest Department by Gupta (1979) and from the Forest Research Institute, Dehradun, by Bhatnagar (1979). Plus trees in this species have been selected based on characters such as good growth, stem form, straight cylindrical bole etc. by Khosla *et al* (1979) and Uniyal and Thapliyal (1979). The stage is now set for establishing clonal seed orchards. Additionally, valuable genetic information in this species has been reported by Snehalata Chawla (1977). Using an open-pollinated progeny trial she assessed the natural variation in morphological, growth and wood characters. She has also obtained heritability estimates for the various traits and correlations both phenotypic and genetic amongst various wood characters.

Studies on sensitivity of seeds of different seed origins of this species to acute gamma radiation have been reported by Upadhaya and Kedharnath (1974). When air dry seeds were used as experimental material the LD 50 for germination ranged between 3·31 and 9·12 KR. Two provenances were studied at 10 and 30% moisture content of seeds. In

one case the LD 50 came down to 7·50 KR from 9·12 KR when the moisture per cent of seeds was increased to 30 %. In the second case, the increase in moisture content to 30 % did not alter the LD 50.

The karyotypes of some of the pine species of India have been examined in detail by Mehra and Khoshoo (1956), Kumar *et al* (1966) and Upadhaya and Kedharnath (1970).

Pinus kesiya, the pine which occurs in the Khasi hills of Assam has also been taken up for genetic improvement at the Forest Research Institute, Dehradun. A provenance experiment has been laid out at New Forest, Dehradun and is being assessed regularly. The same test had also been laid out in a number of states. Additionally, a cross between *P. kesiya* and *P. merkussi* was attempted over three years. All the seeds obtained were shrivelled and they failed to germinate. In one year three viable seeds were obtained. But soon after germination the seedlings died. Thus there was no opportunity to confirm the hybridity of the seedlings.

The blue pine of Himalaya, *Pinus wallichiana*, is a soft pine which is valued very much both for its timber and oleoresin. As a prelude to initiating genetic improvement work on this species variation has been studied by Dogra (1972). He has recognised seven altitudinal provenance types. Four of these are adapted to the outer moist and inner dry north-west Himalaya; and three to the outer wet, middle moist and inner dry eastern Himalaya. The major blue pine forests grow in Kashmir, Himachal Pradesh, Uttar Pradesh and Nepal. Bhutan is the major blue pine area of the east. According to Dogra (1972) a weak reproductive barrier exists between the blue pine populations growing at lower and higher altitudes of both moist and dry zones but a strong reproductive barrier is functional between the moist and the dry arid zone blue pine of Himachal Pradesh.

The additional importance of blue pine is its resistance to blister rust caused by *Cronartium ribicola* to which the two American pines *Pinus strobus* and *P. monticola* are highly susceptible. *P. wallichiana* has been used in crossing programme with the two American species cited above and resistant hybrids manifesting hybrid vigour have been realised in USA.

3.4 *Introduced tropical pines*

Pinus patula, has been successfully introduced in West Bengal and at Kodaikanal and Ootacamund in Tamil Nadu. It is a promising species. But no work on the genetic upgrading of the species has been initiated so far in India.

Pinus caribaea has been successfully introduced in a few States. The three varieties *P. caribaea* var. *caribaea*, *P. caribaea* var. *hondurensis* and *P. caribaea* var. *bahamensis* are included in the various trials. A number of provenances of these varieties are also under trial in a number of states.

Field-grafting trials with *P. caribaea* has been carried out in India by Kapoor and Kedharnath (1976) and the time of the year best suited for field grafting has been ascertained. This should facilitate taking up work on the establishment of clonal seed orchard for this species.

3.5 *Semul (Bombex ceiba L.)*

Semul is one of the valuable indigenous soft wood species which is in great demand for use in the match industry. The annual requirement of this wood by the match industry is of the order of 2 lakh tonnes. This tree belongs to the family Bombacaceae and has a

somatic chromosome number of ca.72. Semul is widely distributed on the Indian main land while the related species *B. insigne* Wall. is confined in its distribution to the Andamans, Western Ghats and Assam. The objective of tree improvement work in this species is to evolve varieties which will be fast growing with good stem form, narrow crown and without buttresses. In nature, in some areas the trees are subject to heavy attacks by shoot borer (*Tonica niviverana* Walk). So, incorporating resistance to this pest also forms one of the breeding objectives. Also, it is known that Semul from some areas particularly that growing in Assam is valued more by the match industry because of the quality of wood. 'Plus trees' of Semul have been selected from those growing in Assam and in Uttar Pradesh and search for plus trees from other areas are in progress. A small clonal seed orchard has been established at Ranipur, 60 km from Dehra Dun using the simple grafting technique worked out for use with this species by Kedharnath and Venkatesh (1963). The grafts in the species flower the very next season after grafting if the scions had been carefully selected (Venkatesh and Arya 1967). Since each fruit contains 200–300 seeds and the percentage of germination of seed is very high, it has been estimated that half a hectare of seed orchard can yield enough seeds to plant up 500 hectares (Venkatesh 1970).

The detailed observations taken on the flowering and fruiting in the different clones in a half acre clonal seed orchard established at Ranipur, in Uttar Pradesh appear very promising from the point of view of good seed yield (Venkatesh and Arya 1967).

The chromosome number in semul has been reported from meiotic and/or somatic counts by Baker and Baker (1968), Mehra and Sareen (1973) and Sareen *et al* (1980). Somatic numbers of 72, 92, and 96 have been recorded. This would mean that both hexaploids and octoploids are present in the species if we assume that the basic chromosome number is 12. It would be interesting to raise a progeny trial as well as a clonal trial from these different chromosome number trees and assess their performance for growth and any other special attributes it may have such as resistance to drought, insect pests and also wood quality.

3.6 *Red Sanders (Pterocarpus santalinus L.f.)*

Red Sanders is a very slow growing species confined to a small region in South India. It belongs to the family *Papilionaceae* and has 24 as its somatic chromosome number. The heavy, dark claret red heartwood has been in use for centuries for carvings, doll making etc. In recent years, a variant in this species which has wavy grained wood has leapt into sudden prominence because it is highly valued in the export market. Trees with this variant character occur at very low frequency in nature and they seem to show no apparent morphological differences by which they could be easily recognised from the normal grained trees. However, such individuals can be recognised from surrounding normal trees by blazing the sap wood, because the sap wood also shows the characteristic wavy grain. Since both normal and wavy grained trees occur in the same general areas of dry sites with poor shallow soils, it is unlikely that this character is entirely controlled by environmental factors. If it is an inherited character, then the low frequency of its occurrence in nature would appear to indicate that the gene for this character is present in a low frequency in the population or the character is conditioned by multiple genes. As a first step to increase the frequency of occurrence of trees with this variant trait, such trees have been identified and assembled as grafts in a clone bank. These can then be asexually multiplied and a plantation established. Seeds have been

collected from individual trees showing the wavy grain trait in the wood to raise half-sib progenies and scoring variation among and within the progenies in growth and other characters such as internode number and average internode length. It is anticipated that there will be segregation for two kinds of seedlings in each progeny—one normal looking and the other showing stunted growth with shorter internodes. This second category of seedlings may have a high probability of yielding trees with wavy grained wood. From the work carried out in Sweden on wavy grained trait in Birch, there is evidence that this trait is genetically controlled and the frequency of recovery of such plants in the progenies of trees with this trait varies.

The variation of this trait from pith to periphery in a tree and between trees has been studied from wood core samples taken from trees at breast height. This revealed significant variation in the intensity of waviness from pith to periphery in individuals and also between trees. This information is now being used to select the most desirable trees for use in a seed orchard programme. It is anticipated that this orchard will produce seeds which would in turn yield plants that have a high probability of showing wavy grained wood. Variation in fibre morphology and the growth of grafts from different clones have been studied (Kedharnath and Rawat 1976; Kedharnath *et al* 1976).

3.7 *Poplars: (Populus spp.)*

Poplars, particularly clones of *Populus deltoides*, have a good future as a plantation crop in certain regions of North India. The clones so far tried are those that have been tested and selected for site and climatic conditions obtaining abroad. Testing of some of these exotic clones in the hope of identifying some amongst them as suitable for us is certainly a useful short cut approach to get something without much investment. But a more logical and realistic approach would be to develop our own clones of the promising exotic species *P. deltoides*. An approach currently being taken up in Uttar Pradesh envisages (i) collection of seed resulting from open pollination on some of the good female clones, (ii) attempt at controlled hybridisation between selected female and male clones should they exhibit synchronised flowering. It is proposed to raise seedlings from the seeds resulting from the above two approaches and test them in the appropriate region and then the promising plants from amongst these will be cloned. Tests for resistance to important diseases and insect pests will also be carried out.

While this work with exotic clones of *P. deltoides* progresses, it has also been planned to work on the genetic upgrading of *P. ciliata* and *P. gamblei*, two of our native poplars. A programme of genetic improvement work has been proposed for the poplars in India by Kedharnath (1979). Khurana and Khosla (1982) have been active in the selection of desirable phenotypes in *P. ciliata* and studying their variation in provenance testing. Khosla *et al* (1979) have also assessed the sex ratio in natural population of this species and studied the correlation between the sex of the tree and its growth.

4. Strategies for the future

Problems of immediate importance and finding solutions to them certainly deserve high priority and in this context tree breeding programmes had set high priority for the selection of plus trees and assembling them in clonal seed orchards so that as soon as the

orchards started producing regular crops of seeds, genetically improved planting material become available for raising the new plantations. That would mean immediate gains. But it is also necessary to think of the longterm goal and plan for building material for advance generation or multigeneration breeding programmes. In developed countries where forest tree breeding programmes have been in operation for a long time tree breeders have given much thought in this direction. For example, Bourdon *et al* (1977) examined a wide range of alternative mating designs for various purposes including estimates of variances and combining abilities, development of breed populations and production of seed. They found that no single design was best for all purposes and no single purpose will be served by only one design. According to Lindgren (1977) reasonably good progeny tests can be made with a limited number of trees in any of the several designs including common testers, partial diallels, polycrossers and pollinations in seed orchards.

Strategies suggested for the development of long-term genetic improvement programmes by different experts in the field of tree breeding differ quite markedly. However, they all agree on the need to separate the short-term function of seed production from the long-term goal of developing and maintaining broad-based genetic populations for future advances in the tree improvement.

The commonest example of a production population is a seed orchard. In the orchard we generally tend to increase the genetic gain by increasing the selection differential. This may appear as a conflict to maintaining a broader genetic base for future breeding work. In the past there has been rigorous selection of plus trees so that only the best or more outstanding individuals were included in the seed orchard. However, the present tendency is to select a large number of good trees (rather than a few super trees) in the first round of selection of plus trees. Thus it is expected that it would not only ensure a broad genetic base than before but would also facilitate a reasonable level of improvement in the second and subsequent generations (Pederick and Griffin 1977). It is very satisfying to know that today amongst foresters there is an increasing appreciation of the role and potentiality of genetics and tree breeding in maximising production from the forest plantations.

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