Age-Age Correlation for Early Selection of Clones of *Populus* in India

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Abstract

In a field trial involving 56 clones of *Populus deltoides* and 4 clones of *P.* x *euramericana*, calculation of simple correlation coefficients revealed significant phenotypic age-age correlation from age 1 to age 6 (the rotation age adopted by Indian poplar growers) for D (dbh), H (tree height) and D^2H. Rank correlation coefficients between age 6 and younger ages were significant for the three traits; the coefficients increased with increasing age. Selection of the sets of best 30, 15, 10 and 5 clones from the available 60 clones at a given age was generally accompanied by a descending order of percentage success. It was suggested that (a) to have the best 30 clones of age 6, select the set of best 36 clones at age 2, (b) to have the best 15 clones of age 6, select the set of best 20 clones at age 3, (c) to have the best 5 clones of age 6, select the set of best 8 clones at age 4, and (d) to have the best 3 clones of age 6, select the set of best 3 clones at age 5. More than 80% of the targeted clones on D^2H or dbh basis and more than 76.7% clones on height basis were found to get selected at steps (a) through (d). For achieving early multiplication of the most productive clones for deployment, multiplication should be started with the best 36 (i.e. 60%) clones selected at age 2. Considering field growth and nursery performance (e.g. rooting ability, survival, etc.) in the successive years, culling can be done to reduce the number of clones under multiplication in nursery to 33%, 13% and 5% after age 3, 4, and 5, respectively. The requirement of nursery resources for progressively propagating the select clones would be in the order of age 2 < age 3 < age 4 < age 5.

Key words: Populus deltoides, early selection, early clonal multiplication, vegetative propagation, age-age correlation, simple correlation, rank correlation, evaluation of clones.

Introduction

Populus (cottonwood or poplar) is a popular tree species in the agroforestry system of north India. Agroforestry plantations in the fertile plains of western Uttar Pradesh, Punjab and Haryana states consist chiefly of *P. deltoides*. Agroforestry plantations in this region occupy an area equivalent to 60,000 ha pure plantation of this species (CHANDRA, 2001). Tree growers harvest it at an age of 6 years for selling to plywood and match industries. It is planted either at 3 m to 4 m spacing in linear rows on one or more borders of agricultural fields or at 5 m x 4 m spacing throughout the agricultural fields. Field crops such as wheat, sugarcane, sunflower, mustard, oat, lucerne, maize, vegetables, etc. are grown in the fields in various temporal sequences in the above spatial arrangements with poplar (KUMAR *et al.*, 1999).

Commercial planting of *P. deltoides* in India has so far relied on the use of very few clones of poplar viz. G3, G48, D121, ST-67, S7C4 and S7C8 (CHATURVEDI, 1992). Some openpollinated selections (e.g. clones of L-series, WSL-series, etc.) made in India from the progenies of G48 and D121 mother clones are expected to become popular for planting over the next few years. In order to increase productivity of *P. deltoides* and to widen the genetic base of plantations, Forest Research Institute (FRI) Dehradun has initiated a tree improvement programme under which (a) about 40 promising clones selected from amongst hundreds of clones in fields trials in the *'terai'* region will be tested at multiple sites, (b) control-pollinated progeny of promising clones will be produced, tested, and cloned and (c) new introductions from the natural stands of *P. deltoides*, located in the USA, will be tested and cloned, followed by field evaluation at multiple sites in the poplar-growing region of India (SINGH *et al.*, 1999). Evaluation of such trials at an early age, if possible, would pave the way for early supply of superior clones to the potential users. It is, therefore, essential to determine the optimum age at which early selection can be made. Studies conducted in temperate areas have shown that early selection of better clones of poplar can be done at age 4 years for indirectly selecting for age 7 years (FOSTER, 1986) or at 4 to 5 years for selecting for age 12 years (TSAREV, 1977). Indications about optimum age for early selection in near-tropical areas, such as the plains of north India where poplar is harvested at age 6 years, are not available.

Moreover, the earlier studies (FOSTER, 1986; TSAREV, 1977; BISOFFI, 1995) do not state anything about the optimum age for starting early multiplication of the most promising clones, thereby obviously implying that it should be started after the recommended age of early selection of clones. Starting vegetative propagation of a set of judiciously chosen clones before the recommended age of early selection can hasten the deployment of the best clones by a few years. However, the success of such an approach will depend upon the reliability of the selection strategy. The logistics involved in this approach also need to be considered. This paper reports the results of a study on *Populus* clones with the aim of finding answers to these issues.

Materials and Methods

Cuttings of sixty clones of *Populus* (comprising 56 clones of *P. deltoides* and 4 clones of *P.* x *euramericana*) were provided by Forest Research Institute, Dehradun to Silviculturist, Sal Region, Haldwani for planting at Lalkuan nursery (29°10' N latitude, 79°40' E longitude). After sufficient number of one-year rooted plants were produced by vegetative multiplication through stem cuttings, a trial of the sixty clones was laid out at Gangapur Patia (29°07' N latitude, 79°27' E longitude) during February 1985 at 5 m x 3 m spacing in plots of 7 x 7 plants. The experiment was laid out in randomised complete block design with three replicates.

Tree height (H) and dbh (D) of various clones were recorded at age 1, 2, 3, 4, 5 and 6 years (JHA *et al.*, 1993). D^2H (dbh x dbh x height) was computed as a relative index for stem volume at each age. The data of above three traits were used for computation of phenotypic age-age correlation using software

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SPSS Version 6.1.3. Values of simple correlation coefficient *(r)* were computed among all trait and age combinations. Values of SPEARMAN rank correlation coefficient (r_s) were computed for each trait between age 6 and younger ages. Rank 1 was assigned to the lowest value and rank 60 to the highest value within each age for a given trait. Per cent success in correctly selecting the best 5, 10, 15 or 30 clones at age 2 and above, was calculated using the ranks of clones. Scatter plots between ranks at age 6 and at younger ages were plotted for each trait. Scatter plots of ranks for D^2H between age 2 and 3, age 3 and 4, and age 4 and 5 were also produced showing the identification numbers (viz. 1 through 60 in the order those clones were listed by JHA *et al.*, 1993) of respective clones against the plotted points.

Results

Significant and positive coefficients of simple correlation *(r)* were observed among all the combinations of traits and ages (*Table 1*). The values of *r* were greater when the data of different traits, which were being correlated, belonged to the same age. As the age difference increased, usually *r* decreased. The values of *r* within a trait varied from 0.634 to 0.985 for dbh, 0.651 to 0.995 for height and 0.646 to 0.989 for D^2H. The values of *r* between different traits were slightly low. However, all the values of *r* exceeded the corresponding values of probable error (PALANICHAMY and MANOHARAN, 1991) by a factor of more than 6. Thus, the existence of significant correlation among these data seems a practical certainty.

Similarly, significant values of rank correlation coefficient (r_s) were observed between age 6 and younger ages for dbh, height and D^2H (*Table 2*). The values of r_s with reference to age 6 ranged from 0.583 (for age 1) to 0.970 (for age 5) for dbh, from 0.654 (for age 1) to 0.990 (for age 5) for height, and from 0.650 (for age 1) to 0.986 (for age 5) for D^2H. Since r_s proved significant for all age combinations, it shows that there were no drastic changes in the ranks of different clones between age 1 and 6.

Table 3 shows that the best 70% clones on dbh basis, or 76.7% clones on height or D^2H basis, would get correctly picked up for age 6 years while selecting the best 30 clones at age 2. The proportion increased to 83.3% to 90% by selecting at age 3, and to 90% to 96.7% at age 4. The success in correctly selecting the set of best 15 clones for age 6 at selection age of 3 was 66.7% on dbh basis and 80% on height or D^2H basis; the success was much lower at younger selection age. The success in correct selection of the set of best 5 clones at age 4 was 80% on dbh or height basis and only 60% on D^2H basis.

Figure 1 shows the scatter plot of ranks of clone means for D^2H by taking ranks at age 6 along X-axis and ranks at younger ages along Y-axis. With an increase in age along Y-axis, the plotted points tended to converge along the imaginary diagonal drawn from the origin. If the ranks on X-axis and Y-axis belong to the same age, the plotted points would axiomatically lie on the diagonal. As the difference in age on the two axes increased, the values of X and Y fell more and more out of step, resulting in increased scattering of the points and lesser r_s. Of the best 30 clones (ranking from 31 to 60) of age 6 on D^2H basis, 23 clones also figured among the best 30 clones at age 2 while 27 clones figured among the best 36 clones at this age. Thus, 76.7% or 90% of the best 30 clones of age 6 on D^2H basis could be picked up by selecting 30 clones or 36 clones, respectively, at selection age of 2. Similarly, 80% or 93.3.% of the best 15 clones of age 6 could be picked up by selecting best 15 clones or 20 clones, respectively, at selection age of 3. Selecting best 5 clones or 8 clones at age 4 would give 60% or 100%, respectively, success in picking up best 5 clones of age 6 for D^2H trait (*Fig. 1*). The scatter plots of dbh and height (not shown) also had similar trend. Selection of the set

Table 1. – Values of simple correlation coefficient (*r*) among dbh, height and D^2H recorded at age 1,2 3, 4, 5, and 6.

Trait	Dbh1	Dbh2	Dbh3	Dbh4	Dbh5	Dbh6	Height1	Height2	Height3	Height4	Height5	Height6	D^2H1	D^2H2	D^2H3	D^2H4	D^2H5
Dbh2	0.841																
Dbh3	0.739	0.813															
Dbh4	0.683	0.792	0.963														
Dbh5	0.653	0.746	0.934	0.976													
Dbh6	0.634	0.719	0.927	0.969	0.985												
Height1	0.876	0.815	0.641	0.603	0.559	0.532											
Height2	0.801	0.863	0.789	0.778	0.745	0.719	0.817										
Height3	0.768	0.839	0.862	0.865	0.854	0.832	0.762	0.898									
Height4	0.734	0.829	0.855	0.868	0.853	0.822	0.703	0.893	0.961								
Height5	0.712	0.805	0.896	0.909	0.908	0.882	0.651	0.874	0.930	0.967							
Height6	0.714	0.807	0.903	0.919	0.914	0.894	0.652	0.878	0.935	0.966	0.995						
D^2H1	0.954	0.825	0.674	0.621	0.595	0.569	0.883	0.795	0.761	0.724	0.689	0.684					
D^2H2	0.810	0.947	0.715	0.718	0.691	0.661	0.814	0.879	0.829	0.821	0.780	0.781	0.865				
D^2H3	0.776	0.838	0.951	0.920	0.908	0.889	0.726	0.842	0.917	0.893	0.916	0.917	0.778	0.818			
D^2H4	0.705	0.815	0.893	0.943	0.937	0.915	0.665	0.829	0.897	0.916	0.933	0.936	0.709	0.828	0.948		
D^2H5	0.664	0.763	0.876	0.929	0.956	0.928	0.615	0.790	0.867	0.887	0.929	0.927	0.664	0.776	0.929	0.984	
D^2H6	0.658	0.755	0.885	0.940	0.960	0.956	0.604	0.781	0.861	0.873	0.915	0.923	0.646	0.762	0.924	0.977	0.989

Dbh1, Dbh2 etc. refer to dbh at age 1, dbh at age 2, and so on. All values in the *table* are significant at $p < 0.01$.

Table 2. – Values of SPEARMAN's rank correlation (r_s) between age 6 and younger ages for dbh, height and D^2H traits.

Trait	Age combination (years)				
	1 and 6	2 and 6	3 and 6	4 and 6	5 and 6
Dbh	0.583	0.648	0.878	0.936	0.970
Height	0.654	0.848	0.920	0.949	0.990
D^2H	0.650	0.752	0.928	0.959	0.986

All values in *table* are significant at $p < 0.01$

Table 3. – Extent of success in correctly selecting a set of 5, 10, 15 or 30 best clones for age 6 by making selection at age 2, 3, 4 or 5.

Trait for selection of clones	Selection age	Clones targeted for selection at selection age		Clones successfully selected at selection age with the aim of selection for age 6		Per cent success of selection at selection age
	Years	Number	% of 60	Number	% of 60	%
(a)	(b)	(c)	(d) [1]	(e)	(f) [2]	(g) [3]
Dbh	2	5	8.3	3	5.0	60.0
Dbh	3	5	8.3	4	6.7	80.0
Dbh	4	5	8.3	4	6.7	80.0
Dbh	5	5	8.3	4	6.7	80.0
Dbh	2	10	16.7	5	8.3	50.0
Dbh	3	10	16.7	8	13.3	80.0
Dbh	4	10	16.7	8	13.3	80.0
Dbh	5	10	16.7	10	16.7	100.0
Dbh	2	15	25.0	7	11.7	46.7
Dbh	3	15	25.0	10	16.7	66.7
Dbh	4	15	25.0	12	20.0	80.0
Dbh	5	15	25.0	12	20.0	80.0
Dbh	2	30	50.0	21	35.0	70.0
Dbh	3	30	50.0	25	41.7	83.3
Dbh	4	30	50.0	27	45.0	90.0
Dbh	5	30	50.0	28	46.7	93.3
Height	2	5	8.3	3	5.0	60.0
Height	3	5	8.3	3	5.0	60.0
Height	4	5	8.3	4	6.7	80.0
Height	5	5	8.3	4	6.7	80.0
Height	2	10	16.7	7	11.7	70.0
Height	3	10	16.7	6	10.0	60.0
Height	4	10	16.7	7	11.7	70.0
Height	5	10	16.7	9	15.0	90.0
Height	2	15	25.0	10	16.7	66.7
Height	3	15	25.0	12	20.0	80.0
Height	4	15	25.0	12	20.0	80.0
Height	5	15	25.0	13	21.7	86.7
Height	2	30	50.0	23	38.3	76.7
Height	3	30	50.0	25	41.7	83.3
Height	4	30	50.0	29	48.3	96.7
Height	5	30	50.0	30	50.0	100.0
D^2H	2	5	8.3	3	5.0	60.0
D^2H	3	5	8.3	2	3.3	40.0
D^2H	4	5	8.3	3	5.0	60.0
D^2H	5	5	8.3	4	6.7	80.0
D^2H	2	10	16.7	5	8.3	50.0
D^2H	3	10	16.7	8	13.3	80.0
D^2H	4	10	16.7	8	13.3	80.0
D^2H	5	10	16.7	10	16.7	100.0
D^2H	2	15	25.0	7	11.7	46.7
D^2H	3	15	25.0	12	20.0	80.0
D^2H	4	15	25.0	12	20.0	80.0
D^2H	5	15	25.0	14	23.3	93.3
D^2H	2	30	50.0	23	38.3	76.7
D^2H	3	30	50.0	27	45.0	90.0
D^2H	4	30	50.0	27	45.0	90.0
D^2H	5	30	50.0	28	46.7	93.3

[1]) (d) = (c) x 100 / 60, [2]) (f) = (e) x 100 / 60, and [3]) (g) = (e) x 100 / (c)

of most productive 3 clones of age 6 could be made with certainty at age 5, although the ranks of the three clones changed among themselves during the sixth year.

Of the best 20 clones of age 3, the number of clones that simultaneously existed in the set of best 36 clones of age 2 was 20 on D^2H basis (*Fig. 2(i)*), and 19 each on basis of dbh or height. The best 8 clones of age 4 invariably figured in the set of best 20 clones of age 3 for D^2H (*Fig 2(ii)*), dbh or height. Each of the best 5 clones of age 5 and 6 figured among the best 8 clones of age 4 for D^2H (*Fig. 2(iii)* and *1*) or dbh, while only 4 clones out of the 5 top-ranking clones of age 6 could do so in respect of height.

Discussion

Existence of strong, positive simple correlation (*Table 1*) as well as rank correlation (*Table 2*) among dbh, height and D^2H suggests that selection of clones for superiority in respect of one of these traits would inevitably lead to selection of superior clones in respect of the other two traits as well. However, the decision about selection of clones should preferably be taken on the basis of D^2H trait because stem volume is more closely related with D^2H than with dbh or height only. BISOFFI (1995) suggested the use of dbh or volume in preference to height for early evaluations.

Figure 1 demonstrates that it is not possible to predict at a younger age, with a fair degree of success, as to which clone would occupy a particular rank at rotation age. At a younger age, a realistic attempt can be made to determine only the set of best n clones (n >1) of rotation age, without allocating the n ranks of rotation age to individual clones. Therefore, exchange of ranks among clones within the selected set of clones has not been viewed as failure in selection effort during this study.

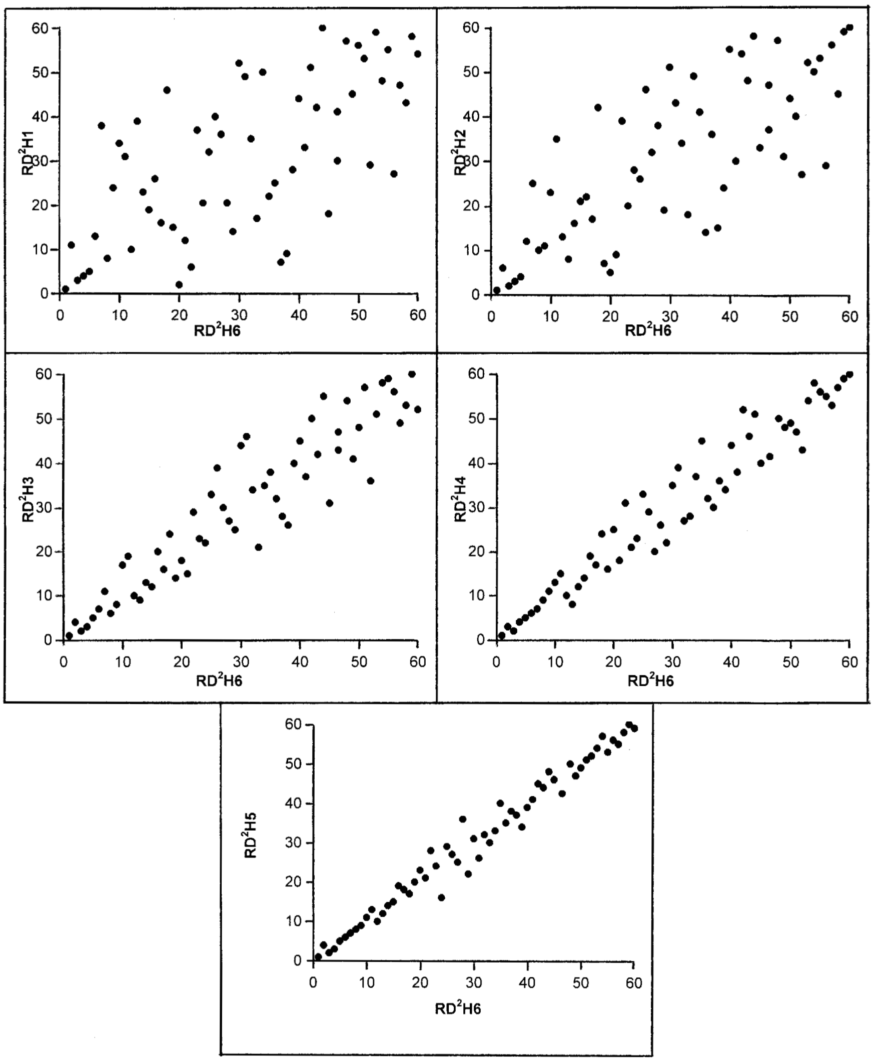

Fig. 1. – Scatter plot of ranks recorded at age 6 years vis-à-vis, (l) ranks at age one year, (ii) ranks at age 2 years, (iii) ranks at age 3 years, (iv) ranks at age 4 years, and (v) ranks at age 5 years for mean D^2H values of sixty clones. RD^2H1, RD^2H2, etc. stand for ranks of clones, on the basis of D^2H values, at age one year, age 2 years, and so on.

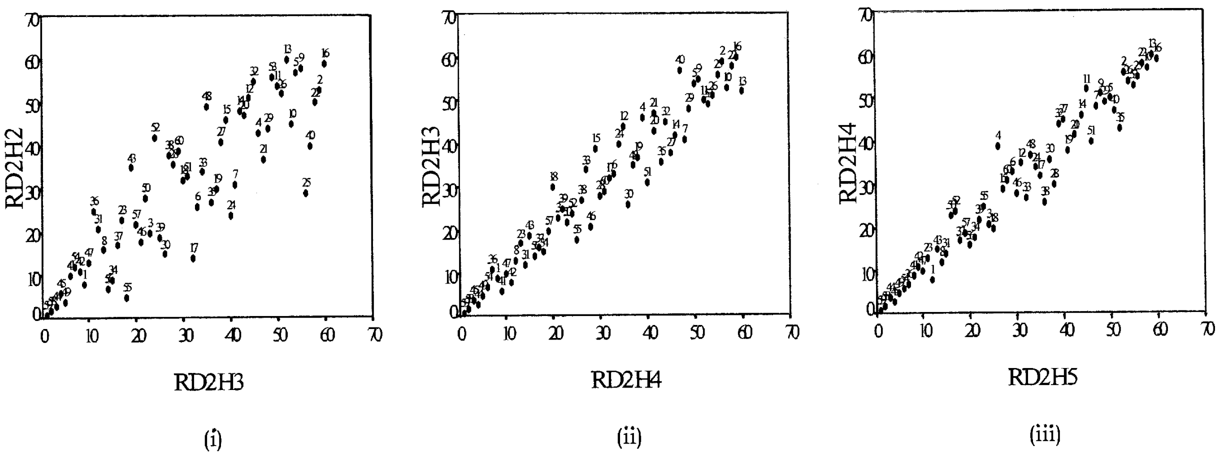

Fig. 2. – Scatter plot of ranks for D^2H recorded between (i) age 2 and 3, (ii) age 3 and 4, and (iii) age 4 and 5. The clone identification numbers are printed above the corresponding points in the plot.

YING and BAGLEY (1976) reported that the ranking in height among 11 provenances of *P. deltoides* did not vary much after 3 years up to 7 years of age. The mean data for each family and clone showed good correlation for height between age 7 and younger ages; the coefficient increased with increasing age suggesting that early selection was possible. RANDALL (1977) suggested that selection of fastest growing clones of *P. deltoides* on dbh basis could be done after age 1 to 3. FIGAJ (1978) observed that 'minus' trees of *P. maximowiczii* x *P. pyramidalis* could be identified after 3 growing seasons. Our study shows that it may not be judicious to select clones of *P. deltoides* in India at age 1. However, the growth data of age 2 to 4 can be differentially used in the selection process. Selection of the sets of best 30, 15, 10 and 5 clones from the available 60 clones at a given age was generally accompanied by a descending order of per cent success (*Table 3*). Thus, for a given level of per cent success in selection, the set of clones to be selected at a relatively young age needs to be big, while selection of a small set needs a higher selection age. Therefore, it is suggested that (a) to have the best 30 (i.e. 50% of the available germplasm) clones of age 6, select the set of best 36 (60%) clones at age 2, (b) to have the best 15 (25%) clones of age 6, select the set of best 20 (33%) clones at age 3, (c) to have the best 5 (8.3%) clones of age 6, select the set of best 8 (13.3%) clones at age 4, and (d) to have the best 3 (5%) clones of age 6, just select the set of best 3 (5%) clones at age 5. More than 80% of the targeted clones on D^2H or dbh basis, and more than 76.7% clones on height basis, were found to get correctly picked up at steps (a) through (d). Nevertheless, the 5 highest-ranking clones (viz. clones with identification number 10, 13, 16, 25 and 53) of age 6 on D^2H (*Fig. 1 and 2*) or dbh basis were found to be invariably present in the sets of clones selected at (a), (b) and (c). In order to determine the 2 to 3 most productive varieties of *Populus* species of age 12 in the erstwhile USSR, TSAREV (1977) suggested that 3 to 4 leading varieties should be selected at a minimum age of 4 to 5.

One is often faced with the task of making early selection of clones on the basis of a field test to give interim recommendation about choice of clone for further multi-location testing or deployment in production plantations. The age of early selection needs to be sufficiently long to effect a reasonable level of accuracy in selection. After making early selection, vegetative multiplication of the selected clones is started and it is continued for many years in order to build a stock of plants which is large enough to supply cuttings to all growers on a sustained basis. To shorten the time involved in this two-stage process of (i) selecting most promising clones, followed by (ii) multiplying their germplasm, an alternative approach involving concurrent shortlisting and multiplication of clones is suggested. According to this approach, early selection of the best 60% clones should be done at age 2 of the field trial and their vegetative multiplication should be immediately started in the nursery. Shortlisting of the best 33% (of the original number of clones under test) clones should be done from within the above set of select clones at age 3 on the basis of (a) growth data of age 3 in the field trial and (b) rooting and survival performance of cuttings during the previous year in nursery. Propagation of the rejected clones should be stopped. This process of simultaneous roguing of clones on the basis of current evaluation and vegetative propagation of select clones can be continued in the subsequent years till the desired intensity of selection and number of ramets are achieved. Best 5% clones can be shortlisted at age 5.

FOSTER (1986) found significant clonal difference in *P. deltoides* for first year survival but recorded low correlation of this trait with growth traits up to 7 years of age. COOPER (1982) observed that first year survival of poplar cuttings is strongly influenced by their rooting ability. Therefore, potential exists for selection of clones for superior rooting ability and survival. Our above-mentioned strategy enables testing of select clones for rooting and survival characteristics in nursery too during the course of their evaluation for growth in field. This would facilitate selection of clones for growth well as survival at no extra input of time. Besides, this strategy would allow commencement of multiplication of the best clones of age 6 at merely age 2, thereby virtually reducing the length of testing period by 67%.

Vegetative multiplication of a large number of clones selected at age 2 would require practically smaller area in nursery than what would be needed three years later for the multiplication of a much smaller number of clones (selected at age 5). This is because the number of ramets per clone would increase ten-fold every year (one stem cutting results in ten stem cuttings per year under the current propagation practice in India; stools are not used for cutting production) but the number of select clones would decrease less rapidly during the selection and vegetative multiplication process. The requirement of nursery space for propagating the age 2, 3, 4 and 5 selections would be in the ratio of 0.01 : 0.07 : 0.27 : 1. Use of stools which allows higher multiplication rate, will change the above ratio but the trend of smaller space requirement in multiplying younger selections, will not change. If required, the ratios can be altered by varying the number of ramets per clone from year to year. The point is that requirement of nursery resources will be quite small when the proportion of inferior clones in nursery will be relatively high. Thus, very little resources in nursery will be "wasted" on multiplication of clones that will be eventually discarded at a higher selection stage. It is, therefore, operationally feasible to simultaneously shortlist and multiply clones as suggested in the above strategy.

Early selection might result in some bias against clones which grow relatively slow in the initial stage but catch up with others at the later stages. However, *figure 1* and *table 3* suggest that such clones would be very few. Moreover, such clones would factually lag behind others if deployed in intimate mixture with other clones at high densities. The objective of a tree improvement programme is to maximise gains per unit time. Hence it would be undesirable to delay, just for fear of disfavouring such sporadic clones, making interim recommendation about choice of clones and starting their vegetative multiplication on the basis of early evaluation. The final recommendation about choice of clones for later deployment in plantations and for serving as parents for next generation of tree improvement can be done at rotation age because trees of poplar normally do not flower before the age of eight years in India.

Conclusion

Early selection of *P. deltoides* clones for rotation age of 6 years can be done effectively at age 4. Selection at age 2 is relatively less accurate but it results in early propagation of selected clones for further testing or deployment. A differential selection strategy is suggested to combine advantages of both above ages of early selection. According to this strategy, best 60%, 33%, 13% and 5% clones of the original set should be selected at age 2, 3, 4, and 5, respectively. The sets of clones to be selected at age 3 and above should be contained in the sets selected in the preceding years. Multiplication of the selected clones should be started at the end of second year of field trial and continued in successive years. Selection at age 2 should be done on the basis of growth, preferably D^2H, in the field trial.

The rejection of clones at age 3 and above should be based upon their current nursery performance e.g. rooting, survival, etc., in addition to the last available data of growth in field trial. Propagation of a given clone should be stopped if it gets rejected at any stage in selection process. The requirement of nursery space for progressively multiplying the germplasm of the selected sets of clones will be practically of the order of second year < third year < fourth year < fifth year, although number of selected clones will be in the opposite order. The above strategy is, therefore, operationally feasible.

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Age Trends of Heritabilities and Genotype-by-Environment Interactions for Growth Traits and Wood Density from Clonal Trials of *Eucalyptus grandis* HILL ex MAIDEN

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Abstract

Obtaining accurate and precise genetic parameter estimates is fundamental to determining breeding strategies, and for choosing genotypes for commercial propagation. Results for survival and growth from seven clonal genetic tests of *Eucalyptus grandis* in Colombia supported the a priori contention of sub-dividing them into three different environments for deployment and possibly breeding purposes. The genotype-by-environment interactions (GxE) for growth traits were moderate at six years of age in the target environment (5 sites representative of 95% of the *E. grandis* planting area for the clonal program). Therefore, it is recommended to breed and select for clones that perform well across the range of sites within the target environment. The clonal rankings for growth traits at the two extreme sites differed markedly between these two distinct environments, and between each extreme environment and the five sites in the target environment. Thus, the extreme environments require separate clonal test locations and deployment populations. Broad sense heritabilities for survival, individual tree volume and mean annual increment (MAI) tended to increase over time for the three environments, but the trends for height were quite different among environments. The broad sense heritabilities for mean wood density declined with age, but GxE interaction for wood density was low indicating that clonal rankings were stable among the five sites within the target environment. The estimation of genetic gains by two methods, predicted clonal values and the classical formula, gave similar results and showed great potential for increasing productivity in the target environment through selection of the top clones.

Key words: Eucalyptus grandis, genetic parameters, clonal forestry, genetic gain.

Introduction

In the last twenty years, there has been increasing interest on the part of many *Eucalyptus* breeding programs around the world in developing clonal forestry to enhance both plantation productivity and product uniformity (LAMBETH *et al.,* 1989; DENISON and KIETZKA, 1993; BERTOLUCCI *et al.,* 1995; ARAUJO *et al.,* 1997). In this context, the estimation of basic genetic parameters is crucial in determining the best strategies for clonal breeding and testing and in predicting genetic gains from deploying the best clones (BURDON, 1992; WHITE, 1996).

In the case of *Eucalyptus grandis*, there are few reports in the literature regarding genetic parameters for growth and wood quality traits of clonal material (KAGEYAMA and KIKUTI, 1989; IKEMORI, 1990; LAMBETH *et al.,* 1994). In general, broad sense heritabilities have shown moderate genetic control for growth traits (H^2=0.22 to 0.41) and wood density (H^2=0.30). However, some of these heritability estimates are based on a single genetic test and therefore may be upwardly biased by the presence of genotype-by-environment interaction if the GxE interaction variance is larger than zero (COMSTOCK and MOLL, 1963; HODGE and WHITE, 1992). There are no estimates from multiple sites over many ages, and given the importance of *E. grandis* in world plantations, such estimates are needed.

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