to pests, and acceptable wood properties, *E. viminalis* has definite potential for use in the Coastal Plain of the southeastern United States.

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Studies in Populus ciliata Wall. ex Royle. II Phenotypic variation in natural stands[1])

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Summary

Natural variation studies were conducted in *Populus ciliata* Wall. ex Royle to determine the range of phenotypic variation in Simla, Kulu and Chamba regions of Himachal Pradesh. The characters studied were height, diameter (D. B. H.), taper, specific gravity and fiber length. These were subjected to analysis of co-variance to eliminate the effect of age on phenotypic variants. Diameter was found to be strongly affected by age. Correlation studies carried out between height and diameter, diameter and specific gravity, height and fibre length, specific gravity and fibre length and hight and taper showed variable values in different provenances. Strong correlations were observed between height and diameter. Under closer spacing the ratio of clear bole to total height was found to be higher and showed positive correlations with height. The species in general revealed a low magnitude of genetic variation among the natural stands.

Key words: Populus ciliata, phenotypic variation, taper, specific gravity, co-variance, correlations.

Zusammenfassung

Bei *Populus ciliata* Wall. ex Royle wurden Studien zur natürlichen Variation durchgeführt, um den Rang der phänotypischen Variation in den Simla, Kulu und Chamba Regionen von Himachal Pradesh zu bestimmen. Die untersuchten Merkmale waren Höhe, Durchmesser in Brusthöhe, Stammform, spezifisches Gewicht des Holzes und Faserlänge. Um den Effekt des Alters zu eliminieren, wurden diese Merkmale einer Kovarianzanalyse unterworfen. Es wurde gefunden, daß Alter und Durchmesser in enger Beziehung stehen. Durchgeführte Korrelationsrechnungen zwischen Höhe und Durchmesser, Durchmesser und Holzdichte, Höhe und Faserlänge, Holzdichte und Faserlänge sowie Höhe und Stammform zeigten variable Werte bei verschiedenen Herkünften. Enge Korrelationen wurden zwischen Höhe und Durchmesser beobachtet. Bei geringerem Abstand der Bäume war die astfreie Stammlänge im Verhältnis zur Gesamthöhe größer und mit der Höhe positiv korreliert. Allgemein zeigte die Art eine geringe genetische Variation zwischen natürlichen Beständen.

Introduction

The phenotypic variation in any natural stand may be due to genetic/environmental factors and/or interactions between them. The knowledge of relative influence of these factors is, therefore, a pre-requisite in planning any improvement programme of a species and also to copy nature by replicating superior clones under intensive cultural techniques. In an earlier communication Khosla *et al.* (1979) studied the phenotypic variation in male and female trees of *Populus ciliata*. Here, in the present investigations it is contemplated to determine the range of phenotypic variability in the natural stands of the species as met in mixed deciduous forest, Western mixed coniferous forest and West Himalayan Oak/fir forest types.

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Material and Methods

Provenance sampling and traits studied

Natural stands from various edaphic sites from Simla (31°1' to 31°25'N, 77°10' to 77°30'E), Kulu (31°23' to 32°26'N, 76°59' to 77°50'E) and Chamba (32°40' to 33°30'N, 75°20' to 76°30'E) formed three physiographic provenances for analysing phenotypic variation. Fifteen localities selected for the present studies are enumerated in *table 4*. In each locality ten trees (21-55 years) were randomly selected for studying height, diameter (D.B.H.), taper, specific gravity and fiber length.

Taper of a tree was calculated after ASSMANN (1970);

$$\frac{\text{Tree height (in m)}}{\text{D.B.H. (in cm)}} \times 100.$$

Specific gravity was determined by the maximum moisture method (SMITH, 1954) from 2 cm^3 samples taken from the three regions of the core sample *i.e.* adjacent to the pith, middle region and one adjacent to the cambium. The fibre length studies were made by maceration in SCHULTZ's fluid (PANDEY *et al., 1968*). Wood samples used for fibre length analysis belonged to the same three regions as taken for specific gravity. Twenty-five measurements were taken in each case.

Statistics

The data for height, diameter, taper, specific gravity and fiber length were subjected to analysis of variance as described by PANSE and SUKHATAME (1967). The data for these characters were analysed by 'Randomised Block Design' separately for three provenances, considering 10 trees within a locality as 10 different treatments and localities within a provenance as replications. The analysis of variance used for determination of variance components is given in *table 1*. As the trees within a provenance were not of the same age, analysis of co-variance was done separately for each provenance in order to eliminate the effect of age on these parameters (CHANDEL, 1972). Co-variance analysis was calculated only when the regression co-efficient of main character 'Y' on the concomitant variate 'X' was found to be significant. The variance components of analysis of co-variance are summarized in *tables 2* and *3* (a, b). The correlation studies were also conducted for height and diameter, diameter and specific gravity, height and fiber length, specific gravity and fiber length and height and taper.

Table 1. — Analysis of variance for a randomised block design.

Source of variation SV	Degree of freedom (df)	Mean sum of squares (MSS)	Variance Rate (VR)
Replications	(r-1)		
Treatments	(t-1)	Mt	Mt/Me
Error	(r-1)(t-1)	Me	
Total	(r-1)+(t-1)+ (r-1) (t-1) or rt-1		

Table 2. — Analysis of co-variance for sum of squares and sum of products.

SV	df	SS(X)	SS(Y)	SP(XY)
Replications (R)	(r-1)	R_X	R_Y	R_{XY}
Treatments (T)	(t-1)	T_X	E_X	T_{XY}
Error (E)	(r-1)(t-1)	E_X	E_Y	E_{XY}
Total	(r-1)+(t-1) +(r-1) (t-1) or (rt-1)			
T+E	(t-1)+(r-1) (t-1)	T_X+E_X $=G_X$	T_Y+E_Y $=G_Y$	$T_{XY}+E_{XY}$ $=G_{XY}$

X = concomitant or ancillary variate *i.e.* age.

Y = main variate *i.e.* height, D.B.H. *etc.*

R_X, T_X & E_X = sum of squares due to replications, treatments and error respectively for X variate.

R_Y, T_Y & E_T = sum of squares due to replications, treatments and error respectively for Y variate.

R_{XY}, T_{XY} & E_{XY} = sum of products due to replications, treatments and errors respectively for X and Y variates.

G_X = sum of squares due to treatments + error (T+E) for X variate..

G_Y = sum of squares due to treatments + error (T+E), for Y variate.

G_{XY} = sum of products due to treatments + error (T+E) for X and Y variates.

Table 3a. — Analysis of co-variance for test of significance of the regression in the error line.

SV	df	SS	MSS	F.cal.
Regression coefficient	1	SS(b)	SS(b)	$SS(b)/V'_E$
Adjusted error	(r-1)(t-1) -1	E'_Y	V'_E	

Regression coefficient (b) $= \frac{E_{XY}}{E_X}$

Sum of squares due to regression coefficient (SS) $= \frac{(E_{XY})^2}{E_X}$

Adjusted sum of squares ($E'_{Y'}$) $= E_Y - \frac{(E_{XY})^2}{E_X}$

Table 3b. — Analysis of covariance for adjustment of sum of squares for treatments.

SV	df	Adjusted SS for Y	MSS	F.cal.
Treatments	(t-1)	$G_Y'-E_Y'$	V_T'	V_T'/V_E'
Adjusted error	(r-1)(t-1) -1	E_Y'	V_E'	
T+E	(t-1)+ (r-1) (t-1) -1	$G_Y-\frac{(G_{XY})2}{G_X}=G_Y'$		

Adjustment of treatment means $\overline{Y}_i = \overline{Y'}_i - b(\overline{X}_i - \bar{x})$

Y'_i = adjusted treatment mean of the ith treatment

$\overline{Y}_i$ = unadjusted treatment mean of the ith treatment

b = regression coefficient

$\overline{X}_i$ = mean of the ith treatment in the X variate

$\overline{X}$ = general mean of the X variate

Results and Discussion

The phenotypic mean of various traits studied is summarized in *table 4*. The regression values of different characters with age are given in *table 5*, and the correlations between various characters are tabulated in *table 6*. In the succeeding paragraphs results are discussed with respect to phenotypic variability as influenced by age, site types, biotic factors and the correlations of various characters.

Height

The height of the tree was found to be variable in all the three provenances (see *table 4)*. In the Simla provenance the mean values for height varied from 16.16 to 23.16 m, with an overall mean height of 19.58 ± 0.59 m. The maximum and minimum mean heights of 23.16 and 16.16 m were observed in Ghorna and Madhon localities respectively. In the Kulu provenance the mean values for height varied from 23.25 to 27.28 m, with an overall mean height of 25.54 ± 0.31 m. The maximum and minimum mean heights of 27.28 and 23.25 m were found in Kharuthatch and Diyar localities respectively. Whereas in the Chamba provenance the maximum and minimum values of mean height were observed to be 26.94 and 21.61 m in Chhatri and Kalatop localities respectively, with an overall mean height of 22.93 ± 0.47 m. The higher range of variability of height of the tree in all the three provenances may be attributed to the diverse edaphic sites that this species inhabits and the age of the crop studied.

The regression coefficient of height on age was found to be significant for the Simla and Kulu provenances but was non-significant for Chamba provenance (*Table 5*). The studies also revealed that, in general, the species ceases to add in height after a specific age. The trees usually

Table 4. — Shows the various characters studied for phenotypic variation in natural stands. (Mean of 10 trees each).

Provenance	Locality	Height (m)	DBH (cm)	Sp. Gr.	Taper (%)	Fiber length (mm)	Clear bole to total height ratio
Simla	1. Simla	19.34	40.30	0.39	48.71	1.14	0.26
	2. Theog	21.56	25.26	0.36	86.77	1.11	0.19
	3. Matiyana	17.68	33.41	0.42	53.62	1.06	0.17
	4. Madhon	16.16	24.05	0.41	67.58	1.15	0.34
	5. Ghorna	23.16	29.76	0.38	78.19	1.15	0.18
Kulu	6. Gahar	26.23	44.30	0.38	60.63	1.14	0.15
	7. Kharu-thatch	27.28	44.45	0.33	62.05	1.17	0.50
	8. Diyar	23.25	38.18	0.36	61.28	1.17	0.39
	9. Karain Bihal	25.98	43.81	0.37	59.80	1.20	0.17
	10. Kangni	23.91	38.60	0.33	62.83	1.15	0.17
	11. Kalath	26.59	41.99	0.39	65.32	1.16	0.16
Chamba	12. Kalatop	21.61	24.21	0.32	89.44	1.20	0.26
	13. Dalhousie	23.02	41.71	0.36	55.94	1.16	0.22
	14. Chhutri	26.94	47.82	0.42	56.25	1.14	0.51
	15. Kundi	24.15	40.17	0.39	61.89	1.17	0.29

**Significant at 1% level.
* Significant at 5% level.

Table 5. — Shows the regression of different characters with age

Character studied	Provenance	Regression coefficient	Adjusted sum of squares	Coefficient of variation (%)	Variance	$S.E._{diff.}$	C.D.
Height	Simla	42.20**	0.54	14.40	-	-	-
	Kulu	12.79**	1.00	8.38	-	-	-
	Chamba	0.35	-	12.20	-	-	-
Diameter	Simla	82.99**	0.33	13.40	-	-	-
	Kulu	53.14**	2.26*	-	6.599	2.568	5.179
	Chamba	18.94**	0.96	10.50	-	-	-
Specific gravity	Simla	0.14	-	7.80	-	-	-
	Kulu	1.34	-	10.81	-	-	-
	Chamba	6.28*	0.62	11.98	-	-	-
Fiber length	Simla	0.44	-	8.49	-	-	-
	Kulu	28.00**	5.50*	-	0.0006	0.0245	0.049
	Chamba	0.28	-	6.77	-	-	-
Taper	Simla	0.02	-	13.95	-	-	-
	Kulu	47.56**	2.91**	-	9.215	3.036	6.120
	Chamba	5.05*	0.93	10.45	-	-	-

**Significant at 1 % level.
*Significant at 5 % level.

Table 6. — Shows the correlation coefficients between different variables.

Sr.No.	Variables	Value of correlation co-efficient (r) in different provenances.		
		Simla	Kulu	Chamba
1.	Height (m) and D.B.H. (cm)	+0.493**	+0.620**	+0.634**
2.	Height (m) and specific gravity	+0.257	+0.089	+0.403**
3.	D.B.H. (cm) and specific gravity	-0.106	-0.125	+0.585**
4.	Height (m) and fiber length (mm)	+0.055	+0.146	-0.083
5.	Specific gravity and fiber length (mm)	-0.048	+0.608**	-0.335*
6.	Height (m) and Taper	+0.530**	+0.180	+0.550**

**Significant at 1% level.
*Significant at 5% level.

Table 7. — Shows the bar diagram of adjusted mean treatment values of D. B. H. in descending order.

Treatment	T_7	T_3	T_4	T_{10}	T_1	T_5	T_2	T_9	T_8	T_6
D.B.H. (cm)	45.84	44.21	43.99	43.35	42.72	42.71	39.99	39.59	38.90	37.59

A

B

C

D

attain a height of 30 to 40 m and after which they expand in diameter. This would suggest a short rotation specific to the diameter requirement, where optimum age for maximum productivity needs to be worked out.

Clear bole as a ratio to total height was also analysed to find out the natural pruning ability of the trees and the extent of merchantable logs available for match industry. The species tends to possess maximum clear bole in competition with other dominant species or within themselves, as was observed at Kharuthatch in Kulu provenance as well as at Chhutri in Chamba provenance (*Table 4*). This shows that this trait is more under the influence of environment as mechanical force available from closer spacing leads to forced pruning and thereby resulting in high percentage of clear bole. Thus this trait by closer spacing can successfully be exploited in future plantations, where artifical pruning is not feasible.

Diameter (D. B. H.)

The mean values of diameter in Simla provenance varied from 24.05 to 40.30 cm as representatives of Madhon and Simla respectively. The overall mean diameter for this provenance came to be 30.50 ± 1.04 cm, while it was 41.89 ± 0.83 cm in Kulu and 38.48 ± 0.82 cm in Chamba provenances. In Kulu provenance maximum and minimum range was 44.45 in Kharuthatch to 38.18 cm in Diyar and in Chamba provenance it was 47.82 at Chhutri to 24.21 cm at Kalatop (*Table 4*). Incidently, Madhon and Kalatop were the places where trees were comparatively younger and had minimum diameter. However, uniform diameter range in Kulu provenance may be due to better site conditions *i.e.* well aerated soils, with plenty of moisture. Such favourable edaphic factors are known to give best diameter in cottonwood (FARMER and WILCOX, 1964; BROADFOOT, 1970).

The regression coefficient of diameter on age was found to be highly significant in all the three provenances (*Table 5*), indicating that diameter is influenced by age factor. After accounting for age the treatments were significant only in Kulu provenance, so here, data were further subjected to the adjustment of treatment means and bar groups made thereof (*Table 7*). The grouping of these bar groups into four selective classes offers plasticity for selection purposes. In natural stands such variability is known to be under the environmental influences. FARMER and WILCOX (1964) attributed much of the variability especially on growth rate in natural stands of cottonwood to the environmental and site factors. According to STEPHENSON and SNYDER (1969) eighty per cent of the variation in growth rate, in general, perhaps stems from the soil differences and accidents such as disease, insect attack and competition from other vegetation. They also suggested that traits for height and diameter growth are not necessarily inherited in the same pattern.

Highly significant positive correlations between height and diameter were observed in all the three provenances (*Table 6*). Similar strong positive correlations in *P. deltoides* were reported by FARMER and WILCOX (1968), MOHN and RANDALL (1971) and WILCOX and FARMER (1967). In the absence of influence of age on height in any mature stand, the superior height growth may be taken as a positive indicator for selection criteria in *P. ciliata*. However, over reliance of growth potentials like height and diameter for selection in the natural stands is not without error as these traits are heavily influenced by environment.

Taper

Taper which is the percentage ratio of height and diameter (D. B. H.) was calculated for all the localities. The mean values of taper varied from 48.71 at Simla to 86.77 per cent at Theog with an overall mean of 66.97 ± 1.32 per cent in Simla provenance. While the mean values in Kulu provenance varied from 59.80 at Karain Bihal to 65.32 per cent at Kalath with overall mean of 61.98 ± 0.94 per cent and in Chamba provenance it varied from 55.94 at Dalhousie to 89.44 per cent at Kalatop with overall mean taper of 65.88 ± 1.17 per cent *(Table 4)*.

The regression coefficient of taper on age was found to be non-significant in Simla, but highly significant in Kulu and Chamba provenances *(Table 5)*. After accounting for age, the treatments showed highly significant differences in Kulu and non-significant differences in Chamba provenance. The data were further subjected to the adjustment of treatment means in Kulu provenance only and bar groups made thereof in the regular descending order *(Table 8)*. It was observed that the bar groups A, B and C differed from one another significantly, however, the treatments falling within a particular group were non-significant among themselves.

The significant effect of age on taper in Kulu and Chamba provenances may be attributed to the significant effect of age on diameter. The aberration in Simla provenance might have come owing to high range of height variation as seen in various localities *(Table 4)*. The positive correlation of taper with height in all the three provenances is understandable *(Table 6)*. However, in Kulu provenance the lesser magnitude of this correlation may be due to the occurrence of uniform crop at various sites. The increased diameter in such stands minimizes the extent of taper in the species. For maximum productive utilization of timber the effect of taper on sawing can be minimized by propagating clonal material from trees growing in competition and ranking superior in diameter.

Specific gravity

The overall range of specific gravity was found to be 0.32 to 0.42, which is in line with the earlier reports of 0.32 to 0.45 by Pearson and Brown (1932). The maximum range of specific gravity was observed in Chamba provenance where it varied from 0.32 to 0.42 (mean 0.37) followed by Simla provenance with a variation of 0.36 to 0.42 (mean 0.39). The Kulu provenance with lowest range of specific gravity (0.33 to 0.39) possessed lightest wood with a mean specific gravity of 0.36 *(Table 7)* where fast rate of growth may be responsible for lighter wood.

Within tree variation in specific gravity was also observed in all the trees, which showed an erratic pattern, i. e. in some trees specific gravity was more near the pith region, whereas in others higher value was seen near the cambial region. This variation seems to be either due to the expression of the environmental influences affecting the growth rate or might have resulted due to the differential deposition of tannins.

Specific gravity is an index of the amount of cell wall substance in the wood and is often used as an indicator or measure of wood quality. Its variation in the various provenances is, therefore, related to the environmental factors. This variation in specific gravity between trees and between localities has been reported by various workers (Farmer and Wilcox, 1966 a, b, 1968; Dawson *et al.*, 1976). Farmer (1970) had shown that even moisture stress can reduce specific gravity. The variable pattern of specific gravity in our observations also suggests that this character is more under the influence of edaphic conditions. Likewise, Einspahr *et al.* (1963) also postulated the specific gravity to be less under the genetic control.

Height and specific gravity showed highly significant positive correlations only in Chamba provenance whereas, in Kulu and Simla provenances the correlations between these variables were non-significant *(Table 6)*. Diameter and specific gravity like height and specific gravity showed highly significant positive correlations in Chamba provenance only, whereas, in Kulu and Simla provenances there was a non-significant negative correlation between these characters. The Chamba provenance seems to be potentially a better provenance for selecting suitable clones of genetic reliance as height, diameter and specific gravity could be combined in one genotype. All the three traits showed positive correlation between them in this provenance *(see table 6)*.

The correlation of specific gravity with growth rate, fibre length, height and diameter has also been studied by various workers (Einspahr *et al.*, 1968; Farmer and Wilcox, 1968; Namkoong *et al.*, 1967). However Einspahr *et al.* (1968) considered specific gravity to be negatively correlated with the zero tensile strength and not with growth rate. Farmer and Wilcox (1966 b) while studying the correlation of specific gravity with mean annual diameter increament found a slight negative correlation (r = −0.20) in cottonwood. However, one of our provenances i. e. Chamba with high positive correlation of specific gravity with diameter differed from the recorded observations in literature.

Table 8. — Shows the bar diagram of adjusted mean-treatment values of taper in regular descending order.

Treatment	T_6	T_8	T_{10}	T_2	T_9	T_4	T_5	T_3	T_1	T_7
Taper (%)	67.01	64.49	62.88	62.06	61.47	61.19	60.23	59.01	58.89	56.28

A: T_6 – T_4

B: T_8 – T_1

C: T_{10} – T_7

Table 9. — Shows the bar diagram of adjusted mean treatment values of fibre length in descending order.

Treatment	T 10	T 8	T 3	T 9	T 1	T 6	T 5	T 4	T 7	T 2
Fiber length (mm)	1.232	1.217	1.191	1.169	1.143	1.139	1.129	1.128	1.101	1.091

A

B

C

D

E

F

Fibre length

The mean values of fiber length did not show significant differences between different trees and localities while within tree variation was of high order. The mean fibre length within localities was found to vary from 1.06 to 1.20 mm (see *table 4*). The regression coefficient of age on fibre length was found to be significant only in Kulu provenance, indicating, thereby, the influence of age on fibre length. So, here, data were further subjected to statistical analysis and adjusted mean treatment values are represented as bar groups in a regular descending order in *table 9.*

The only significant differences as shown in treatments of Kulu provenance might have resulted from the diverse environmental conditions prevailing in the different localities of this provenance, such as, river basins and mixed forests. Anon. (1969) has reported the average length of pulp fibres to be 1.14 mm in the species. Ring width and growth rate are known to influence the fibre length in *Populus* species (Boyce and Kaeiser, 1961; Kennedy and Smith, 1959). However, Wilcox and Farmer (1968) did not report significant differences between ring width and fibre length.

Non-significant positive correlations between height and fibre length were observed in Simla and Kulu provenances, while in Chamba provenance the said correlation was negatively insignificant. Specific gravity and fibre length were negatively correlated in Simla and Chamba provenances but the correlation was only significant in the latter case. However, positive significant correlation was observed between these variables in the Kulu provenance. The variation in the fibre length and specific gravity has been observed by Boyce and Kaeiser (1961), Farmer and Wilcox (1966 b) and Wilcox and Farmer (1968). These authors suggested that individual trees with desirable wood properties should be selected because the intra-taxa variation in wood properties and stem form occurs due to interactions of specific genotypes to environment or genetic differences alone. The variable expression of correlations between fiber length and height and specific gravity in various provenances in the present studies may also have stemmed from variable genotypes in these provenances.

The overall analysis of the phenotypic variation of various traits in natural stands of *P. ciliata* at three distinct geographical areas indicates a very low magnitude of genetic origin. The species is more under the influence of environment and none of the characters studied in this case showed the possibility of getting high heritability from the standing trees in the natural stands. The genotype of this species is very plastic as natural cultural techniques influence highly the characteristics of growth rate. The pioneering nature of the species to invade new edaphic sites may also account for the strong environmental factors, determining the phenotypic expression of the species. The vegetative propagation in the species through natural root suckers might have also reduced the genetic base in the natural stands. The testing of clonal material from penotypically superior trees seems to be a pre-requisite before a clone can be released for large scale plantation programme.

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