Variation in Rooting Capability of Populus deltoides 1)

By CH. CH. YING and W. T. BAGLEY 2)

(Received April/October 1977)

Introduction
Vegetative propagation is a valuable tool which facilitates basic genetic research and practical tree improvement programs (Libby 1974 a). Since cottonwood plantations can be established by planting stem cuttings, good rooting ability is a very important criterion in selecting clones for commercial culture (Schreiner 1970). Rooting ability is genetically controlled, responsive to selection (Wilcox and Farmer 1968), and transmitted to progeny (Heimburger 1940). Zuffa (1976) recently reviewed the factors affecting rooting of cottonwood cuttings.

Variation in rooting ability associated with geographic origins (provenances), parent trees (family), and individual clones within families were evaluated in this experiment.

Materials and Methods
Cottonwood cuttings used in this study were part of the cooperative tree improvement project of the North Central Agricultural Experiment Stations (NC-99). Four clones each of 48 open-pollinated families from seven provenances were included in a greenhouse test, and 188 clones from 47 families were represented in a field evaluation. Experimental design was a split-split-plot with four replications of a single cutting plot with family as main plot, clone as sub-plot and cutting position as the sub-sub-plot.

Eight wands of similar size, 2 m. long, were harvested from each clone in the stool bed in late January. They were stored at 50°C. Cuttings 25 cm long which were free from defect and disease were selected from tip, middle and base of the wands. Positions of the cutting, except for the apical one, were relative rather than absolute, and varied somewhat from clone to clone. Diameter of each cutting was measured at mid-point. They ranged from 3-8 mm, 6-20 mm, and 9-31 mm, respectively, for apical, middle and basal cuttings.

The greenhouse test was planted soon after collection of cuttings in a conventional rooting bench with moist sand as a medium. Air temperature in the greenhouse averaged 21°C. Cuttings were lifted and roots counted in late February after 4 weeks in the bench. The field test was planted May 1 at Lincoln, Nebraska in a silt-loam soil. The cuttings were lifted and rooting evaluated during the first week of June. Soil was moist at planting and during the test due to ample rainfall.

Analyses of variation follow the format for split-split plot design (Table 1). Satterthwaite's approximate F-test was used to determine the effect of families (σ²f) and families within geographic origins (σ²g) (Snedecor and Cochran 1967, p. 369).

Heritabilities of clonal means in both narrow sense (h²n) and broad sense (h²b) were estimated by adopting the model suggested by Burdon and Sheldon (1974).

\[
h_n^2 = \frac{\sigma_g^2 + \sigma_c^2}{\sigma_g^2 + \sigma_c^2 + 2\sigma_{gc}^2 + \sigma_{pc}^2 + \sigma_{pf}^2 + \sigma_{pcf}^2 + \sigma_{pcf}^2}
\]

\[
h_b^2 = \frac{\sigma_g^2 + \sigma_c^2}{\sigma_g^2 + \sigma_c^2 + 2\sigma_{gc}^2 + \sigma_{pc}^2 + \sigma_{pf}^2 + \sigma_{pcf}^2 + \sigma_{pcf}^2 + \sigma_{pcf}^2 + \sigma_{pcf}^2 + \sigma_{pcf}^2}
\]

Variance components of various sources are explained in Table 1.

Results
Number of roots initiated varied widely among clones. Root systems ranged from barely initiated to well developed. Cuttings with more roots had the best developed root systems. The correlation between number and length of roots was highly significant, r = 0.85 in the greenhouse test. The effects of geographic origin, family, clone, and position on the wand were all statistically significant (Table 2). Variance components of position-family and position-clone interactions were relatively smaller than those of the main effects. There is appreciable genetic variation at all three levels — among clones, among family, and among regions of geographic origin (Table 2). Both narrow and broad-sense heritability of clonal means was high.

Clones of Nebraska and Minnesota–Wisconsin origins produced significantly higher number of roots than other origins (Table 3) (Figure 1). Results of greenhouse and field

---

1) Published as Journal Paper No. 5254, Journal Series, Nebraska Agricultural Experiment Station. Research reported was conducted under project 80-28.

2) Authors are former research associate and associate Professor, Department of Forestry, University of Nebraska. Dr. Ying is now Research Scientist, Petawawa Forest Experiment Station, Chalk River, Ontario.
Table 2. — Estimates of variance components and heritabilities for rooting ability (number of roots) of cottonwood clones under both greenhouse and field conditions

<table>
<thead>
<tr>
<th>Variance component</th>
<th>Field</th>
<th>Greenhouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>g²</td>
<td>3.73 ± 2.44</td>
<td>4.02 ± 2.33</td>
</tr>
<tr>
<td>g</td>
<td>6.67</td>
<td>5.67</td>
</tr>
<tr>
<td>f(q)</td>
<td>2.47 ± 1.13</td>
<td>2.46 ± 0.82</td>
</tr>
<tr>
<td>s²_f</td>
<td>0.61 ± 0.31</td>
<td>0.24 ± 0.11</td>
</tr>
<tr>
<td>c²(v)</td>
<td>6.13 ± 4.23</td>
<td>6.75 ± 3.57</td>
</tr>
<tr>
<td>c²(v)</td>
<td>0.33 ± 0.31</td>
<td>0.37 ± 0.24</td>
</tr>
<tr>
<td>y²</td>
<td>0.33 ± 0.36</td>
<td>0.37 ± 0.37</td>
</tr>
<tr>
<td>y²</td>
<td>0.33 ± 0.36</td>
<td>0.37 ± 0.37</td>
</tr>
<tr>
<td>h²</td>
<td>0.80</td>
<td>0.86</td>
</tr>
<tr>
<td>h²</td>
<td>0.85</td>
<td>0.91</td>
</tr>
</tbody>
</table>

* All components are statistically significant at 0.01 percent level.

Standard error of variance component = \[ \sqrt{\frac{\sum_{i=1}^{n} \frac{V_i^2}{f_i}}{n-1}} \]

k = coefficient of the component of variance.

V_i^2 = mean square involved in the computation of the component of variance.

f_i = the degree of freedom for each mean square.

Table 3. — Comparison of average number of roots per cutting among cottonwood clones of different geographic origin

<table>
<thead>
<tr>
<th>Geographic sources</th>
<th>Field</th>
<th>Greenhouse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range of clone means</td>
<td>Range of clone means</td>
</tr>
<tr>
<td>Nebraska</td>
<td>7.6</td>
<td>0.2 – 20.0</td>
</tr>
<tr>
<td>Minnesota-Wisconsin</td>
<td>7.8</td>
<td>1.7 – 22.5</td>
</tr>
<tr>
<td>N. Illinois</td>
<td>3.8</td>
<td>0.6 – 10.8</td>
</tr>
<tr>
<td>Missouri</td>
<td>3.4</td>
<td>0.3 – 6.7</td>
</tr>
<tr>
<td>Indiana</td>
<td>3.4</td>
<td>1.0 – 6.7</td>
</tr>
<tr>
<td>Ohio-Pennsylvania</td>
<td>2.8</td>
<td>1.0 – 6.6</td>
</tr>
<tr>
<td>S. Ohio</td>
<td>1.7</td>
<td>0 – 6.7</td>
</tr>
<tr>
<td>mean</td>
<td>4.7</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Lines connect means that are not significantly different at the 5 percent level, on the basis of Dunn’s Multiple Range Test.

tests were highly correlated (r = 0.78 based on clone means and 0.89 on family means).

Cuttings from the base of the wands produced significantly more roots than those from upper portion (Table 4). No correlation between cutting diameter and number of roots within each position was found. Correlation coefficients were around 0.1 and negative in most cases. Root distribution within cuttings also differed. The cuttings from the tip of the wands developed roots almost exclusively in their lower portion while roots developed along the entire buried portion of the basal cuttings (Figure 2).

Discussion and Conclusions

Variation in rooting capability of cottonwood clones has been reported previously, but it has not been associated with race or geographic origins (Wilcox and Farmer 1968; Cunningham 1953). Association with geographic origin suggests the adaptive value of the character (Lobey 1974 b). Geographic variation seems to follow the north and west to south and east pattern which is prevalent in most character-

Figure 1. — Cuttings from a Nebraska origin (33) rooted more vigorously than those from Indiana (42).

itics investigated in cottonwood (Ying and Bagley 1976). March (1981) concluded that ability to form a new root system vegetatively was more crucial to the survival of cottonwood trees growing along the lower Mississippi River than to those on the upper part of the river because of the repeated flooding which deposits sedimentary materials around the existing trees. The tree’s ability to form new roots close to the surface is essential to its survival. We found that clones from Nebraska and Minnesota-Wisconsin
Both formulae should give equal estimates of \( \sigma^2_y \) if assumptions associated with the interpretation of the component of variances are valid. But average genetic correlation among open-pollinated offspring is very likely higher than 0.25 (Namkoong 1966; Soullace 1974). In this case the second formula is preferred because of the balancing effect of the two terms. Increasing genetic correlation among family members would decrease the within-family genetic variation and increase the between-family variance proportionally and vice versa.

In view of the high estimated heritabilities, improvement of clonal rooting ability can be realized through selection either by means of sexual or asexual propagation. Broad-sense heritability (\( h^2_s \)) on an individual cutting basis was 0.54 and 0.39 for the greenhouse and field tests respectively, which is very close to those reported by Stalker and Farnham (1968). Removal of ‘position effect’ (‘c’ effect or ‘topophysis’) (Burdon and Shibbun 1974) reduced considerably the phenotypic variance and thus increased the heritability ratio of clonal means.

Genetic potential of a cottonwood clone is usually evaluated by replicated clonal tests. Differences among clones in early root development could affect establishment and mask the genetic difference of early growth if the planting was established by unrooted cuttings (Ying and Bagley 1976). This problem could be alleviated by adjusting growth rate to rooting difference or by rooting cuttings before planting in the field plots.

**Summary**

Cuttings from clones of Nebraska and Minnesota-Wisconsin origins produced significantly higher number of roots than those of other geographic sources in greenhouse and field tests. Hertiability of clonal means was very high, over 0.8. Substantial gain can be achieved through selection. Cuttings from basal part of the parent shoot produced more roots than those from the upper part of the shoot.

**Key words**: Cottonwood, *Populus deltoides*, provenance test, vegetative propagation.

**Zusammenfassung**

In Versuchen zur Stecklingsbewurzelung von *Populus deltoides* zeigten Stecklingsklone aus Nebraska und Minnesota-Wisconsin eine stärkere Wurzelbildung als solche anderer Herkünfte. Die Unterschiede waren signifikant. Stecklinge aus der unteren Triebregion hatten mehr Wurzeln als Stecklinge aus der oberen Region der Trieb.

**Literature Cited**

Untersuchungen über die natürliche Selbstbefruchtung in Beständen der Fichte (Picea abies (L.) Karst.) und Kiefer (Pinus sylvestris L.)

Von G. Müller

(Eingegangen September 1977 / Januar 1978)


1. Bedeutung


Selbstbefruchtungsrate, die den für Zufalls- paarung maßgeblichen Wert überschreiten, bedingen somit einen Zuwachs der mittleren Abstammungs- und Inzuchtkoef- fizienten der Individuen der Nachkommenpopulation (Definitionen siehe z.B. CROW und KIMURA, 1970, Kap. 3) und bewirken konsequent eine Erhöhung des Anteils homozygoter Genotypen gegenüber den korrespondierenden Har-