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VARIATION IN EARLY GROWTH OF BLACK COTTONWOOD CLONES IN THE WILLAMETTE VALLEY

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ABSTRACT

Black cottonwood (*Populus trichocarpa* Torr. & Gray) cuttings were collected from five Oregon provenances along a north-south gradient. Cuttings from each provenance were grown for 1 year at two locations, one on the Willamette Valley floor and the other on the Valley margin. Survival at both locations was poor. Stem production was greater on the floor site than the margin site because of differences in edaphic conditions and deer browsing at the margin site. Variation in stem production was greater within than among provenances, suggesting that single-tree selection would be more profitable than provenance selection. Leaf length and width measurements were highly correlated with stem weight and were chosen as the best method for nondestructive selection of superior juvenile individuals; however, as trees grow older, stem volume may be a better indicator. Suggestions for cottonwood culture in western Oregon are discussed.

INTRODUCTION

Black cottonwood (*Populus trichocarpa* Torr. & Gray) is one of the major hardwood species of the Pacific Northwest (Roe 1958), with an estimated total volume of 58 million ft^3 (Metcalf 1965). Though still rarely managed as a commercial species, poplars (*Populus* spp.) today can be used as a short-fiber source in paper products (DeBell 1975), as a pulp source for fiberboard or corrugating medium (Heilman et al. 1972), as a protein source for livestock fodder (Anderson and Zsuffa 1977), and in a wide range of other products (McKnight 1970). Black cottonwood's fast growth rate and ability to resprout make it much more appealing than conifers for short rotation culture, although related silvicultural practices are not yet as economically attractive as those for conifers (Smith and DeBell

1973). Additionally, some flood plain areas currently supporting alder (*Alnus* spp.) could grow a more valuable cottonwood crop under intensive management (Smith 1957, Smith and DeBell 1973). As conventional raw materials become scarcer and more expensive, particularly for paper production (Josephson 1973), black cottonwood could have substantial commercial impact in the Pacific Northwest.

To enhance plantation culture of black cottonwood, production costs must be lowered and yields improved (DeBell 1975). Production costs could be minimized by finding the best combinations of spacing, rotation length, and planting and harvesting systems. Yields could be increased through selection and use of genetically superior clones (Schreiner 1971). Work reported for other cottonwood species and hybrids, especially *P. deltoides* (Panetsos 1969, Ying and Bagley 1976, Gordon and Promnitz 1976a, Fasehun and Gordon 1977), has shown great variation between clones and, in general, more variation among than within provenances for morphological and physiological characteristics (Ying and Bagley 1976). Thus, knowing how stem production varies both within and among provenances for genetically improved black cottonwood will help researchers develop an optimal tree-selection system.

This study was designed to: (1) determine the differences in survival and growth between cuttings grown on both the Willamette Valley floor and Valley margin; (2) determine the within- and among-provenance variation in stem weight, after 1 year, of black cottonwood propagated from cuttings; and (3) develop a nondestructive sampling method for selecting superior individuals, in terms of stem production, after one growing season. Although single-year data must be interpreted with caution and juvenile growth rates may not accurately predict later ones, estimates of survival and variability for young clones are important in the absence of long-term trials.

SELECTING CLONAL STOCK

In January and February of 1978, black cottonwood stems were collected for cloning from selected native populations in five Oregon provenances (Roseburg, Eugene, Corvallis, Salem, and Portland) along a north-south gradient. Ten individual young stems were removed from each provenance and cuttings 30 cm long taken from each stem and labeled by provenance, clone number, and original stem position (the most basal cutting, A; the next most basal, B; and so forth through F). In total, 50 clones were collected and 300 cuttings made.

Cuttings were then stored in plastic bags at 2°C and, in late March 1978, were rooted in the following manner: they were given a 3-second basal dip in 4,000 ppm indolebutyric acid in 50-percent ethanol, placed in a 1:1 mix of peat and vermiculite in 1-qt cardboard containers, and put under mist (10-second spray every 13 minutes) in a greenhouse with natural photoperiod. Ambient air temperature ranged from 15°C at night to 23°C during the day. On April 10, cuttings were moved outside to a shade frame and watered as needed. Captan was applied (in powder form) to help control fungal growth.

Unrooted hybrid poplar cuttings of known parentage also were obtained for evaluation from the North Central Forest Experiment Station (USDA Forest Service, Rheinlander, Wis.). Each of these six clones had previously been selected for rapid growth or other desirable characteristics (Gordon and Promnitz 1976b).

TEST PROCEDURE

Two clonal test plantations were established, one (AC plantation) representing the Valley floor at the American Can Company paper mill in Halsey, Oregon, and the other (RN plantation) representing the Valley margin at Oregon State University's research nursery near Peavy Arboretum, Corvallis, Oregon.

The AC plantation is on soil in the Dayton series, which is very deep and poorly drained (slope = 0-2 percent). The surface layer is dark grayish-brown silt loam about 20 cm thick; the subsurface layer is gray silty clay loam about 18 cm thick (Knezevich 1975). The area had been farmed for grass through summer 1977 and then was plowed that fall. Because grass grew profusely the next spring, the site was sprayed with 4.68 L/ha Roundup® (glyphosate) and 5.60 kg/ha simazine before planting.

The RN plantation, on a slight, west-facing slope, is on soil classified as Jorey silty clay loam, which is normally deep and well drained with a reddish-brown silty clay loam surface layer 38 cm thick (Knezevich 1975). However, the area has been repeatedly tilled to about 20 cm, producing a hardpan at this depth. The site was cultivated in fall 1977 and sprayed with 2.34 L/ha Roundup® in the spring before planting.

Three cuttings from each black cottonwood clone were planted at each test site in three randomized complete blocks. All cuttings from a given stem position were placed in the same block (i.e., all A sections were put in one block, all B sections in a second block, and so forth). This arrangement maximized variation among blocks but confounded cutting-size variation with environmental variation. The A, B, and C blocks were located at the AC plantation and the D, E, and F blocks, at the RN plantation. Ten cuttings of each of the six hybrid poplar clones also were planted in a randomized block at each test site. The rooted cottonwood cuttings and unrooted hybrid poplar cuttings were planted in 4- x 4-m spacings on May 23 and 24 at the AC plantation and on May 30 at the RN site.

Survival and length of the longest shoot on each cutting were measured every 2 weeks for all cuttings, beginning 2 weeks after outplanting and continuing until harvest in September. Length and width of all leaves on surviving cuttings were measured in late August. Surface area of a random sample of leaves was determined with a LAMBDA Instruments LiCor Surface Area Meter, LI-3000, and regression relating leaf surface area to leaf length and width calculated to estimate total leaf surface area for each cutting.

Because of extensive deer browsing at the RN plantation, cuttings were harvested on September 13, 12 days before those at the AC plantation, where no deer damage had occurred. Before harvesting, a visual estimate of the amount of deer damage (no, moderate, or extensive damage) was recorded for each cutting.

After harvest, the length and basal diameter of each shoot were measured and recorded for each cutting. Stem and leaf weights were obtained after drying at 70°C for 48 hours in a forced-air oven.

Analysis of variance was used to identify statistically significant sources of variation in stem weight within each test plantation (Table 1). Differences in stem weight were determined with a t-test; correlation coefficients indicated those variables most closely related to stem weight.

TABLE 1. ANALYSIS OF VARIANCE TABLE WITH EXPECTED MEAN SQUARES FOR FIVE BLACK COTTONWOOD PROVENANCES.

Source of variation	d.f.	Expected mean square[a]
Block	2	
Provenance	4	$\sigma^2_w/k + \sigma^2_{BP} + 3\sigma^2_P$
Block x provenance	8	$\sigma^2_w/k + \sigma^2_{BP}$
Clone/provenance/ block (error)[b]	24	σ^2_w

[a]

σ^2_w = within-provenance variation.

σ^2_{BP} = variation due to block x provenance interaction

σ^2_P = among-provenance variation.

k = harmonic mean.

[b]Error term accounts for 23 d.f. at AC, 24 d.f. at RN.

RESULTS

SURVIVAL

At harvest, 25.3 percent of black cottonwood cuttings at the AC plantation and 26.0 percent at the RN site were alive. No hybrid poplars survived at the RN site, and only 8 of 60 (13.3 percent) survived at the AC plantation.

Cottonwood mortality occurred at about the same rate throughout the growing season at both plantations (Fig. 1). Mortality rate was highest during the first month after outplanting and then decreased during the rest of the summer. At the AC site, a fairly strong inverse relationship ($P < 0.05$) existed between mean maximum temperature and number of cuttings that died ($r = -0.807$); precipitation and mortality were not significantly correlated. At the RN plantation, no significant relationship existed between mortality and either mean maximum temperature or precipitation.

Survival of the cuttings varied according to position (i.e., A through F) in the original clonal stem (Fig. 2). In general, the more basal and apical cuttings had poorer survival than those from the midportion of the stem.

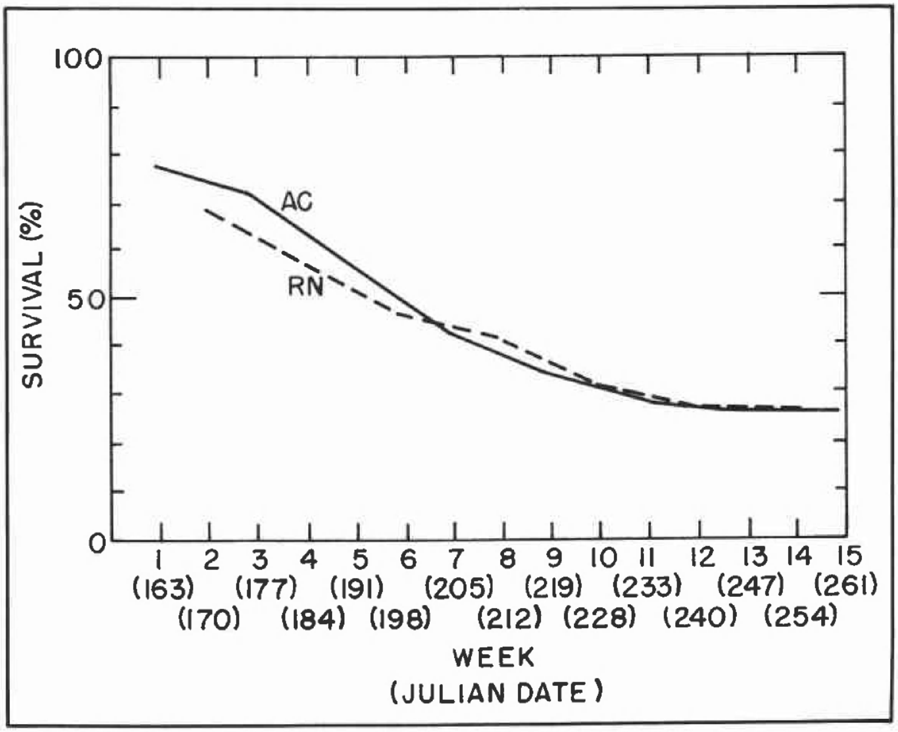

FIGURE 1. OVERALL SURVIVAL OF BLACK COTTONWOOD CUTTINGS AT THE AC AND RN TEST PLANTATIONS.

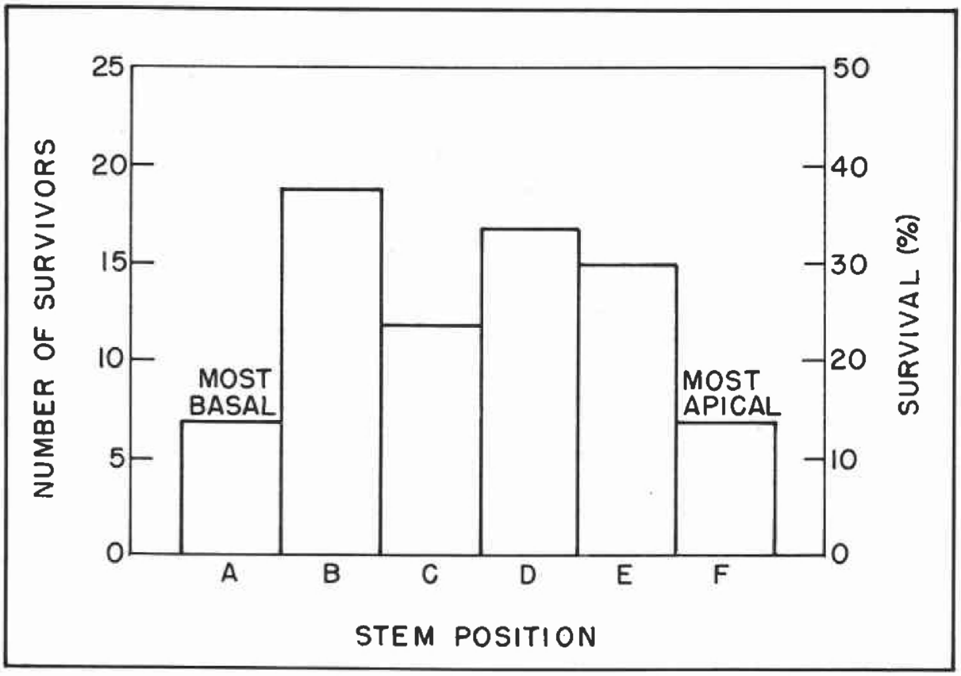

FIGURE 2. SURVIVAL OF BLACK COTTONWOOD CUTTINGS BASED ON POSITION IN THE ORIGINAL CLONAL STEM.

Provenance also influenced survival of cuttings similarly at both test sites. Cuttings from Roseburg survived the best (33.3 percent at AC and 46.7 percent at RN) and those from Portland, the worst (16.7 percent at AC and 15.0 percent at RN) (Fig. 3).

SHOOT PRODUCTION

At the AC plantation, shoot growth continued until harvest (Fig. 4). Roseburg cuttings produced the longest shoots (mean = 48.0 cm) and also the largest increase (mean = 36.8 cm) in shoot length. Cuttings from Salem produced the shortest shoots (31.1 cm) and also the least increase (17.6 cm) in shoot length. Overall mean shoot elongation from outplanting to harvest was 27.3 cm.

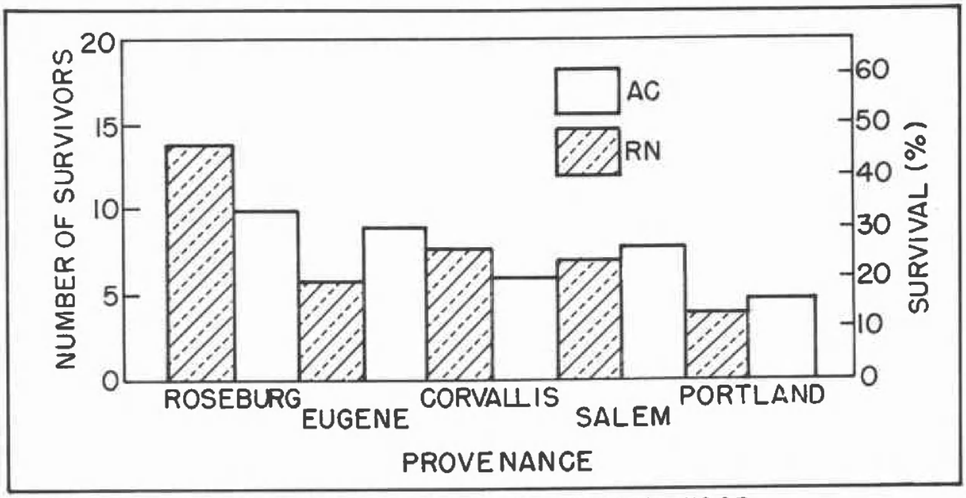

FIGURE 3. SURVIVAL OF BLACK COTTONWOOD CUTTINGS, BY PROVENANCE, AT THE AC AND RN TEST PLANTATIONS.

In contrast, at the RN site Salem cuttings had the longest shoots (mean = 25.1 cm) and the largest average increase in height (12.7 cm); Eugene and Portland cuttings had the shortest shoots at harvest (16.8 cm); and Portland cuttings had the smallest average increase in height (6.8 cm). At harvest, overall mean shoot length was 20.4 cm, and overall average elongation from outplanting was 9.4 cm (Fig. 4).

The rate of shoot growth at the RN site was slow during most of the summer and then stopped in mid-August (Fig. 4). Deer browse was the main cause of the cessation and, in some cases, the decline in shoot growth. First noticed at this plantation on July 3, deer browse became progressively worse until, by harvest time, 65 percent of the surviving cuttings had been browsed.

STEM WEIGHT

Mean stem weight at the AC plantation (62.9 g) was significantly larger ($P < 0.05$) than that at the RN plantation (12.9 g); Roseburg cuttings had the greatest mean stem weight and Salem cuttings, the smallest. At

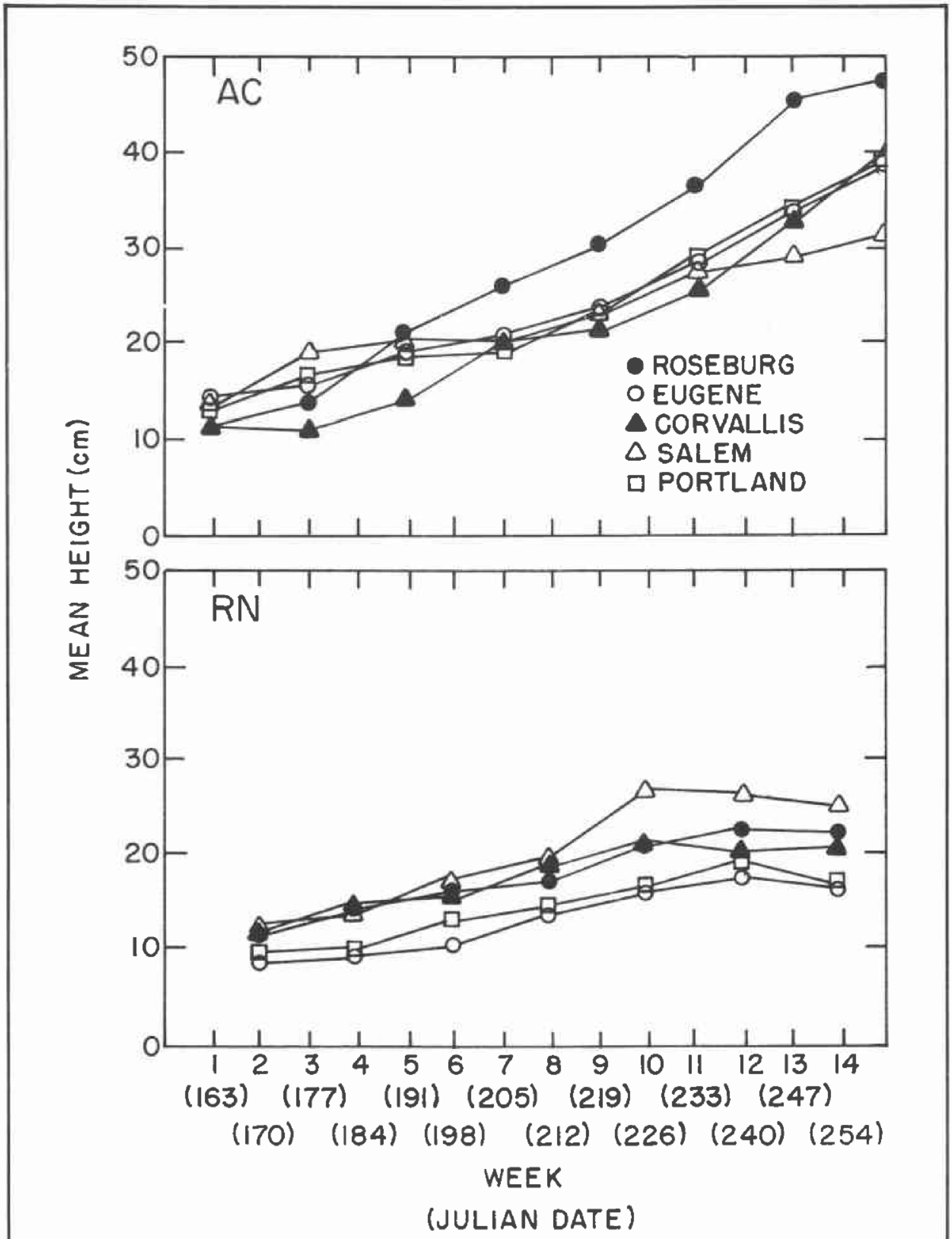

FIGURE 4. CUMULATIVE MEAN HEIGHT, BY PROVENANCE, AT THE AC AND RN TEST PLANTATIONS.

the RN site, Roseburg cuttings were again heaviest, Salem cuttings second heaviest, and Eugene cuttings lightest (Fig. 5).

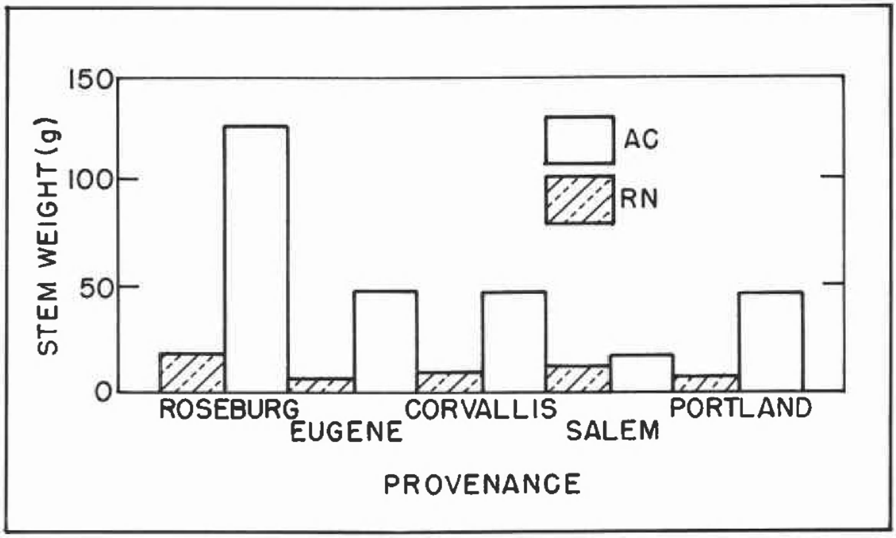

FIGURE 5. MEAN STEM WEIGHT, BY PROVENANCE, AT THE AC AND RN TEST PLANTATIONS.

At the AC site, large differences in mean stem weight occurred among provenances, but these differences were not significant due to very large within-provenance variation (Table 2). At the RN site, the differences for stem weight between provenance means were much smaller than at the AC site but again were not significant, except for that between Eugene and Salem. Thus, variation within provenances was much higher than that among provenances (Table 2).

CORRELATIONS

At both plantations, provenances with the most survivors generally had the highest stem weight but also the highest variance. A correlation matrix was developed for each plantation relating initial height (at time of outplanting), final height (at harvest), oven-dry stem

TABLE 2. ANALYSIS OF VARIANCE TABLE FOR STEM WEIGHT AT THE TWO TEST PLANTATIONS.[a]

Source of variation	d.f.	Mean square
	AC	
Block	2	83.20
Provenance	4	214.80
Block x provenance	8	125.24
Clone/provenance/block (error)	23	27.02
	RN	
Block	2	0.37
Provenance	4	0.69
Block x provenance	8	0.33
Clone/provenance/block (error)	24	2.75

[a] For AC: $\sigma^2_w = 27.02$, $\sigma^2_p = 29.85$.

$\sigma^2_w = 2.75$, $\sigma^2_p = 0.12$.

(See Table 1 for definitions.)

weight, oven-dry leaf weight, and leaf area.[1] At the AC site, initial height was very poorly correlated and final height only moderately correlated with all other parameters (Table 3). Leaf weight and area were highly correlated with each other ($r^2 = 0.933$) and also with stem weight ($r^2 = 0.972$ and 0.941, respectively). The same trends were evident at the RN plantation (Table 3), although r^2 values were generally lower. Leaf weight was highly correlated with leaf area ($r^2 = 0.895$), and both were again highly correlated with stem weight ($r^2 = 0.843$ and 0.916, respectively).

[1]Total leaf surface area (one side) was calculated by summing the estimated area of each leaf over the entire cutting. Individual leaf area is directly related to leaf length and width.

Stem volume was calculated for the RN cuttings on the basis of stem length and basal diameter data.[2] Stem weight was fairly well correlated with volume (r^2 = 0.810). No data for determining stem volume were available for the AC plantation.

Leaf surface area was highly correlated with stem weight at both plantations, but it is once removed (by a linear regression) from the actual leaf length and width measurements taken. Therefore, a regression was performed relating stem weight to average leaf length x average leaf width x number of leaves on the cutting. The r^2 values were 0.901 at AC and 0.917 at RN.

TABLE 3. CORRELATION MATRIX FOR STEM AND LEAF WEIGHT, INITIAL AND FINAL HEIGHT, AND LEAF SURFACE AREA AT THE TWO TEST PLANTATIONS; r(r^2) VALUES, RESPECTIVELY.

	STWT[a]	INHT	FIHT	LFWT
		AC (N = 38)		
INHT	0.197 (0.039)			
FIHT	0.752 (0.566)	0.493 (0.243)		
LFWT	0.986 (0.972)	0.146 (0.021)	0.737 (0.543)	
LFAREA	0.970 (0.941)	0.194 (0.038)	0.760 (0.578)	0.966 (0.933)
		RN (N = 39)		
INHT	0.071 (0.005)			
FIHT	0.649 (0.421)	0.440 (0.194)		
LFWT	0.918 (0.843)	-0.147 (0.022)	0.456 (0.208)	
LFAREA	0.957 (0.916)	-0.091 (0.008)	0.550 (0.303)	0.946 (0.895)

[a] STWT = oven-dry stem weight.
INHT = length of longest shoot at outplanting.
FIHT = length of longest shoot at harvest.
LFWT = oven-dry leaf weight.
LFAREA = surface area (one side) of all leaves on a cutting.

[2]Volume per plant = [½(mean basal diameter)]^2 x mean length x number of shoots.

DISCUSSION

Overall survival of black cottonwood cuttings at both plantations was low due to late planting. Many were rapidly desiccated before they had a chance to begin root growth at the planting site. In a species trial, unrooted cottonwood cuttings were planted in March 1977 on an abandoned grass field adjacent to the current study; their first-year survival was 79.2 percent (J. Martin, personal communication). Thus, with earlier planting, survival should be better.

Field survival varied depending on the position of the cutting in the original stem. Cuttings from the middle portion of the whip survived better than those from the bottom or top. The topmost section may have had poor survival because cuttings were generally smaller and may have desiccated more easily. The bottom sections may have formed fewer roots than other sections and may have desiccated due to the inability to take up water. They also may have lacked suppressed buds from which shoots arise (DeBell and Alford 1972).

Survival of the cuttings also was influenced by their origin: at both plantations, cuttings from Roseburg survived best and those from Portland worst. Roseburg has a warm, dry climate, whereas Portland is cooler and wetter during the growing season. Thus, the Roseburg cuttings would be expected to fare best under the hot and dry conditions at the test sites, particularly in view of the late planting date. The unrooted hybrid poplar cuttings had extremely poor survival, as did the hybrid poplars in the species trial previously described. This poor survival supports the results of a much earlier study (Silen 1947).

Mean stem weight of all surviving cuttings differed significantly between the two test plantations. Deer tended to browse the larger cuttings at the RN plantation, thus lowering the overall mean stem weight. Microclimatic differences between the two sites also may have contributed to the differences observed in stem weight.

Edaphic conditions at the two sites may have caused differences in stem production. The AC plantation was an old grass field that had been farmed as recently as the year before establishment. Nutrients added to the grass field undoubtedly were still present and may have aided the growth of the cuttings. In contrast, no nutrients had been recently added to the RN site, and the hardpan present at about 20 cm probably restricted root growth and, subsequently, top growth.

Deer damage reduced stem production at the RN plantation but not necessarily as might be expected. Cuttings with the most severe damage were generally those that were heaviest, whereas undamaged cuttings had the smallest mean stem weight. However, this situation was not due to a subsequent increase in shoot growth; instead, browsing became more severe as the growing season progressed and was worst at harvest time.

The deer apparently preferred larger shoots and browsed them extensively, but not to the point that their stem weight fell below that of the unbrowsed cuttings. By this selective action, the deer reduced the differences in stem weight between the large and small RN cuttings and thus reduced the variability at this test site. They also increased the difference in overall mean stem weight between the two plantations. Unfortunately, the magnitude of the difference cannot be estimated.

Finally, ground cover before planting may have influenced stem growth. The RN site was virtually bare, whereas the AC site had a dense mat of dead grass on top of the soil. The RN site dried and cracked quickly after the onset of hot, dry weather, but the AC site retained moisture for a much longer time.

Growth at the AC plantation was less than might be expected on that site. In another study originated at American Can (unpublished data, R. Stine and J. Martin), black cottonwood cuttings were grown under varying levels of a mixture of sludge and nitrogen. After two growing seasons, the trees in the control plots averaged 85.4 g/yr oven-dry stem weight compared with 62.9 g/yr at the AC plantation in the current study. Roseburg cuttings outproduced local cuttings in the sludge study control plots, averaging 127.4 g/yr, although survival was not as good (33.3 versus 54.0 percent). The difference in survival and overall mean stem weight was probably due to the late outplanting of rooted cuttings in the current study because the sites are nearly identical.

The difference in the relative order of the provenances, in terms of stem weight, at the two test sites is not readily explainable. Roseburg cuttings had the largest mean weight in both cases; Corvallis, Eugene, and Portland cuttings all had approximately the same mean weights at each plantation. However, Salem had the lowest mean weight at the AC site but the second highest at the RN plantation. Because so few cuttings from each provenance survived at both, we could not determine if this difference in Salem's ranking was a genotype–environment interaction or just happenstance.

At the AC plantation, large differences in mean stem weight occurred among provenances. Cuttings from Roseburg had a mean stem weight 2.5 times as large as those from Corvallis, Eugene, or Portland and were more than 6 times as large as those from Salem. However, even though differences were substantial, variation was so great within all five provenances that no significant differences ($P < 0.05$) in mean stem weight occurred among provenances.

At the RN plantation, differences between mean stem weights were not so great, and only that between Salem and Eugene was statistically significant. This difference occurred primarily because Salem had a relatively small variance, not because its mean was much larger than Eugene's. In fact, Roseburg had a larger mean stem weight than Salem but also a larger variance; thus, it was not statistically different from Eugene.

These data indicate that some cuttings from the provenance with the smallest mean stem weight produced heavier stems than did some cuttings from the provenance with the largest stem weight. Thus, on the basis of provenance selection, many superior clones from other provenances would be discarded, whereas many inferior clones in the chosen provenance would be retained. Therefore, we must conclude that single-tree selection would yield better results than provenance selection if one course were to be pursued. Although it would be tempting to use Roseburg provenance data as the basis for initiating a selection program for the Willamette Valley, moving *Populus* provenances north may result in greater risk of frost damage as well as greater growth.

APPLICATIONS

Use of native cottonwood is preferred over hybrid poplars in the Willamette Valley. Hybrids having a black cottonwood parent may be beneficial but are not now readily available.

Black cottonwood cuttings should be collected from mid-December to mid-February from young stems 2 to 3 m tall and should range from 1 to 2 cm in diameter and 35 to 45 cm in length. Cuttings from the most apical and basal portions should be discarded. Cold storage of cuttings (~2°C) is required until outplanting.

A basal dip in indolebutyric acid and an early spring planting of unrooted cuttings on plowed land is preferable to the use of rooted cuttings. Survival and growth of unrooted cuttings are as good or better than those of rooted cuttings. Time and cost are also reduced when unrooted cuttings are used. Planting must be done early in the spring (February-March) to allow sufficient root growth before hot, dry weather occurs.

Superior individuals can be selected by measuring leaf length and width (or surface area) or by calculating stem volume. Large leaf-surface area is directly related to large stem weight. Although leaf length and width more accurately estimate stem weight than does stem volume while trees are young, as trees grow older and bigger, stem volumes may become an easier and better indicator for selection. In the sludge study at American Can, stem volume of 2-year-old trees was highly related ($r^2 = 0.90$) to oven-dry stem weight (unpublished data, R. Stine and J. Martin).

Much work remains to be done concerning cottonwood culture in the Willamette Valley. Clones should be collected from more widespread provenances and grown in both Valley margin and floor test plantations. Shoot-growth correlations for juvenile and mature trees must be established, as must the most accurate juvenile selection system.

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Black cottonwood (*Populus trichocarpa* Torr. & Gray) cuttings were collected from five Oregon provenances along a north-south gradient. Cuttings from each provenance were grown for 1 year at two locations, one on the Willamette Valley floor and the other on the Valley margin. Survival at both locations was poor. Stem production was greater on the floor site than the margin site because of differences in edaphic conditions and deer browsing at the margin site. Variation in stem production was greater within than among provenances, suggesting that single-tree selection would be more profitable than provenance selection. Leaf length and width measurements were highly correlated with stem weight and were chosen as the best method for nondestructive selection of superior juvenile individuals; however, as trees grow older, stem volume may be a better indicator. Suggestions for cottonwood culture in western Oregon are discussed.

KEYWORDS: clone, cottonwood, *Populus*, provenance.

Stine, R., J. C. Gordon, and K. K. Ching. 1980. VARIATION IN EARLY GROWTH OF BLACK COTTONWOOD CLONES IN THE WILLAMETTE VALLEY. Forest Research Laboratory, Oregon State University, Corvallis. Research Paper 43. 23 p.

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British/Metric Conversions

1 inch (in.) = 2.54 centimeters (cm)
1 foot (ft) = 0.3048 meter (m)
1 cubic foot (ft^3) = 0.028 cubic meter (m^3)
1 acre = 0.4047 hectare (ha)
1 pound (lb) = 0.45359 kilogram (kg)
1 ounce (oz) = 28.35 grams (g)
1 quart (qt) (dry) = 1.101 liters (L)
(wet) = 0.946 liter (L)

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