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Title: Genetic Variation in Growth Potential of Black Cottonwood in the Willamette Valley

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Black cottonwood (Populus trichocarpa Torr. and Gray) cuttings were collected from five Oregon provenances along a partial north-south distribution of the species. Cuttings from each provenance were grown at two locations, one on the Willamette Valley floor, and the other on the Valley margin, for one year. Survival at both locations was very 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 provenances than among provenances, suggesting that single-tree-selection would be more profitable than provenance-selection. Leaf length and width measurements were found to be highly correlated with stem weight, and chosen as the best method for selecting superior individuals. Practical applications for cottonwood culture based on results of this and other studies are discussed.

GENETIC VARIATION IN GROWTH POTENTIAL OF BLACK COTTONWOOD IN THE WILLAMETTE VALLEY

by

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I. INTRODUCTION

Black cottonwood (Populus trichocarpa Torr. and Gray) is one of the major hardwood species of the Pacific Northwest, with an estimated volume of 58 million cubic feet (Metcalf 1965). It is presently found along streams and rivers, and in small patches in low-lying areas (Roe 1958), but is rarely managed as a commercial species.

Technology now exists to use poplars as a short-fiber source in paper products (DeBell 1975), as a protein source for livestock fodder (Anderson and Zsuffa 1977), as a source of pulp for fiberboard or corrugating medium (Heilman et al. 1972) as well as in a wide range of other products (McKnight 1970). With present black cottonwood silvicultural practices though, none of these uses appear to be economically feasible (Smith and DeBell 1973). However, they may become more feasible as conventional raw material for these products becomes more scarce, and more expensive. This may be particularly true for paper production (Josephson 1973).

Black cottonwood may be particularly well suited for supplementing conventional supplies of raw material used in wood fiber products. Its fast growth rate and ability to resprout makes it much more attractive than conifers for short rotation culture (Smith and DeBell 1973). Also, many areas which are currently supporting alder are capable of growing a more valuable crop of cottonwood under intensive management (Smith 1957; Smith and DeBell 1973).

To make plantation culture of black cottonwood more feasible, production costs must be lowered and yields must be improved (DeBell 1975). Production costs can be minimized by finding the best combinations of spacing, rotation length, and planting and harvesting systems. One of the ways to obtain yield improvement is through selection and use of genetically superior clones (Schreiner 1971). An initial step in the use of genetically improved black cottonwood is to determine the amount of variation in stem production within and among collection sites, or provenances, of potential planting stock. Knowing the relative amounts of variation allows a decision to be made concerning provenance versus individual tree selection.

Much work has been reported for other cottonwood species, especially P. deltoides (Panetsos 1969; Ying and Bagley 1976; Fasehun and Gordon 1977; Gordon and Promnitz 1976a). The work has shown there to be great variation in morphological characteristics between clones, and in general, more among-provenance than within-provenance variation for these characteristics (Ying and Bagley 1976).

Although single-year data must be interpreted with caution, and juvenile growth rates may not accurately predict later ones, estimates of survival and variability made on young material of clonal origin are helpful in the absence of long-term trials.

Ledig (1972) suggests that even if there is only a slight correlation between juvenile and mature traits (r=0.1-0.2), there might be greater gain from juvenile selection than mature selection. The selection intensity can be much higher under juvenile selection, due mainly to the large number of individuals which can be tested. More cycles of selection can also be accomplished in a given time period with juvenile selection as compared to mature selection. Because gains from each cycle of selection are additive, total gain in a single 20 year period of mature selection, for example, would have to be four times as effective as selection at four, five year intervals to justify the extra delay (Ledig 1972; Nanson 1976).

This study was designed to: 1) determine the within- and among-provenance variation in stem weight, after one year, of black cottonwood propagated from cuttings; 2) determine the differences in survival and growth between cuttings grown on the Willamette Valley floor and cuttings grown on the margin of the Valley; and 3) develop a non-destructive sampling method for selecting superior individuals, in terms of stem production, after one growing season.

II. MATERIALS AND METHODS

Clonal material of black cottonwood was collected in January and February of 1978 from selected populations in Roseburg, Eugene, Corvallis, Salem, and Portland, Oregon, thus sampling a partial north-south distribution of the species. At each collection location (provenance), ten individuals were collected. Cuttings, 30 cm long, from each clone were labled by provenance, clone number, and original position in the whip. The most basal cutting was labeled A, the next most basal B, and so forth through F. A total of 50 clones and 300 cuttings were collected.

Hybrid poplars of known parentage were also obtained from the North Central Forest Experiment Station (U.S.F.S., Rheinlander, WI) for evaluation. Each of these clones was selected earlier for rapid growth and/or other desirable characteristics (Gordon and Promnitz 1976b). (See Appendix I.)

After collection, the black cottonwood cuttings were stored in plastic bags at 2^{o}C. In late March, 1978, all cuttings were rooted in the following manner: Cuttings were given a three-second basal dip in 4000 ppm indolebutyric acid (IBA) in 50% ethanol, placed in a 1:1 mix of peat moss and vermiculite in one quart cardboard milk containers, and put under mist in a greenhouse with natural photoperiod. The mist cycle was a 10 second spray every 13 minutes, and the ambient air temperature ranged from 15^{o}C at night to 23^{o}C during the day.

On April 10, all cuttings were moved outside to a shade frame and watered as needed. Captan was applied (in powder form) to help control fungus growth.

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

The AC plantation is on soil in the Dayton series, which is very deep, and poorly drained (slope=0-2%). The surface layer, approximately 20cm thick, is dark, grayish-brown silt loam, and the subsurface layer is gray silty clay loam about 18cm thick (Knezevich 1975). The area was farmed for grass through the summer of 1977, and then was plowed in the fall of 1977. Grass grew profusely the next spring, so the area was sprayed with 4.68 l/ha (2 qt/ac) Roundup,[1] and 5.60 kg/ha (5 lbs/ac) simazine before planting.

The RN plantation is on soil classified as Jorey silty clay loam, with a slight west facing slope. This soil is normally deep and well drained with a 38cm thick dark, reddish-brown silty clay loam surface layer (Knezevick 1975). However, the site has been repeatedly tilled to about 20 cm, producing a hardpan at this depth. The site was cultivated in the fall of 1977, and sprayed with 2.34 l/ha (1qt/ac) Roundup in the spring before planting.

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1. Common name is glyphosate.

Three cuttings from each black cottonwood clone were planted at each test site in three randomized complete blocks. Cuttings from a given position were all put in the same block (e.g., all A sections were put in one block, all B sections were put in a second block, and so forth). This arrangement reduced variation within a block, and also simplified the mapping system. The A, B, and C blocks were located at the AC test site, while the D, E, and F blocks were located at the RN plantation. Ten cuttings of each of the six hybrid poplar clones were planted in a randomized block at each site. The rooted cottonwood cuttings and the unrooted hybrid poplars were planted at 4m x 4m spacing on May 23-24 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 two weeks for all cuttings, beginning two weeks after outplanting and continuing until harvest in September. Length and width of all leaves on all the surviving cuttings were measured in late August. Surface area of a random sample of leaves was determined using a LAMBDA Instruments LiCor Surface Area Meter, LI-3000. A regression line was fitted relating leaf surface area to length and width. Total leaf surface area for each cutting was thus calculated from leaf length and width measurements.

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

The length and basal diameter of each shoot were measured and recorded for each cutting. Weights of stems and leaves were obtained after drying at 70°C for 48 hrs.

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 using a t-test, and correlation coefficients were used to identify those variables which were most closely related to stem weight.

Table 1. Analysis of variance table with expected mean squares.

Source of Variation	df	EMS
Blocks	2	
Provenance	4	$\sigma_w^2/k + \sigma_{BP}^2 + 3\sigma_P^2$
Block x Provenance	8	$\sigma_w^2/k + \sigma_{BP}^2$
*Cuttings/Prov/Block (Error)	24	σ_w^2

*Error term accounts for 23 df at AC, 24 at RN

σ_w^2 = within proverance variation

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

σ_P^2 = among provenance variation

k = harmonic mean

III. RESULTS

A. Survival

At the time of harvest, 25.3% of the cuttings at the AC plantation and 26.0% of the cuttings at the RN site were alive. No hybrid poplars survived at the RN site, and only 8 of 60 survived at the AC plantation (13.3%). Mortality of the cottonwoods occurred at about the same rate throughout the growing season at both plantations (Figure 1).

Survival of the cuttings varied with their positions in the original clonal material (i.e., A, B, C, etc.) (Figure 2). In general, the more basal and more apical cuttings had poorer survival than those from the mid-portion of the original whip.

Source of origin, or provenance, also influenced survival of cuttings at both test sites. Cuttings from Roseburg survived the best (33.3% at AC and 46.7% at RN), and Portland cuttings had the worst survival (16.7% at AC and 15.0% at RN). Eugene, Corvallis, and Salem material had intermediate survival at both plantations (Figure 3).

The rate of mortality was highest during the first month after outplanting, and then decreased during the rest of the summer. At the AC site, there was a fairly good inverse relationship ($P \leq .05$) between the mean maximum temperature and the number of cuttings which died ($r=-.807$). There was no significant correlation between precipitation and mortality. At the other plantation, there was no significant relationship between morality and mean maximum temperature or precipitation.

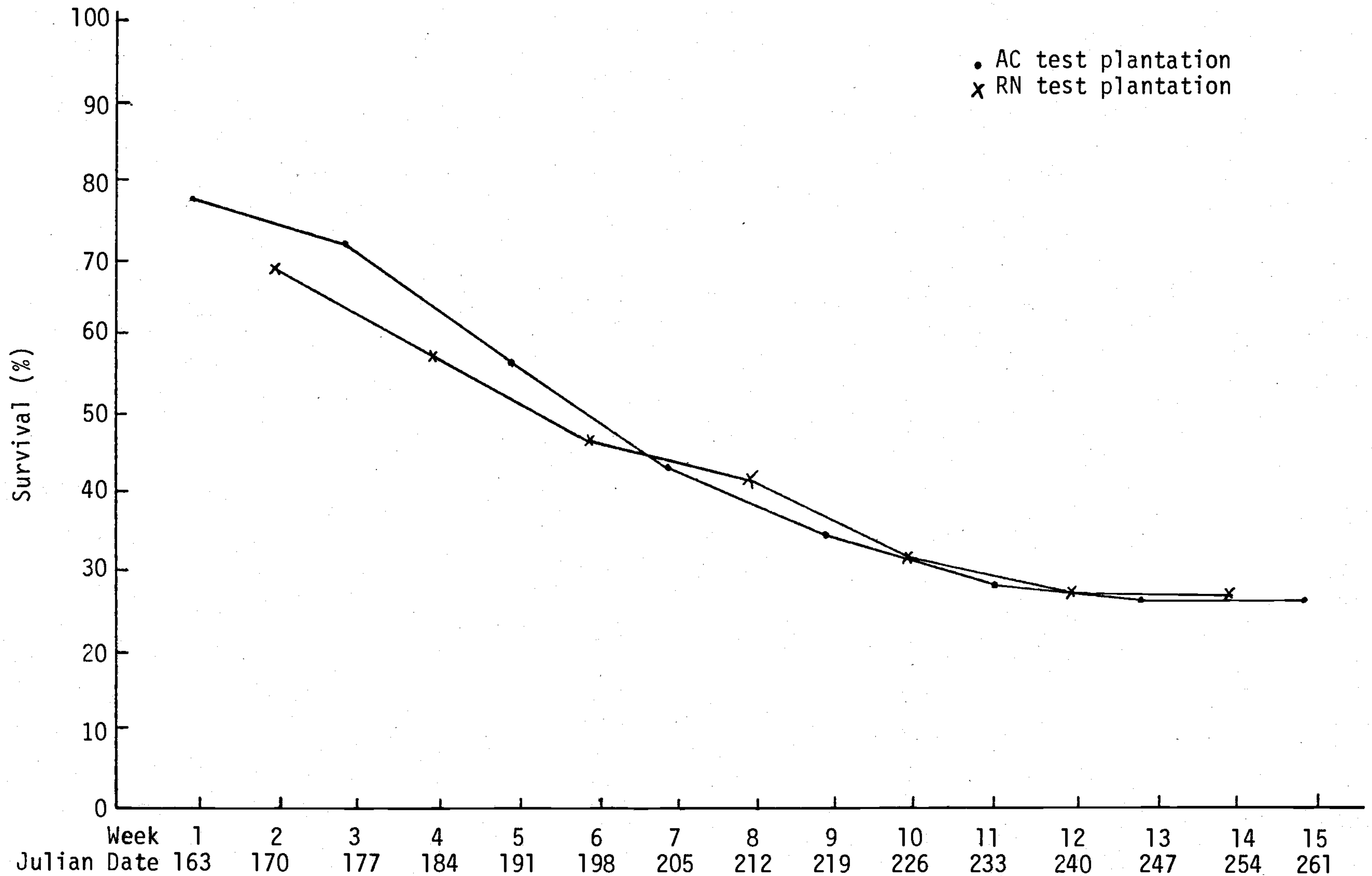

Figure 1. Overall survival of cottonwood cuttings at the AC and RN test plantations.

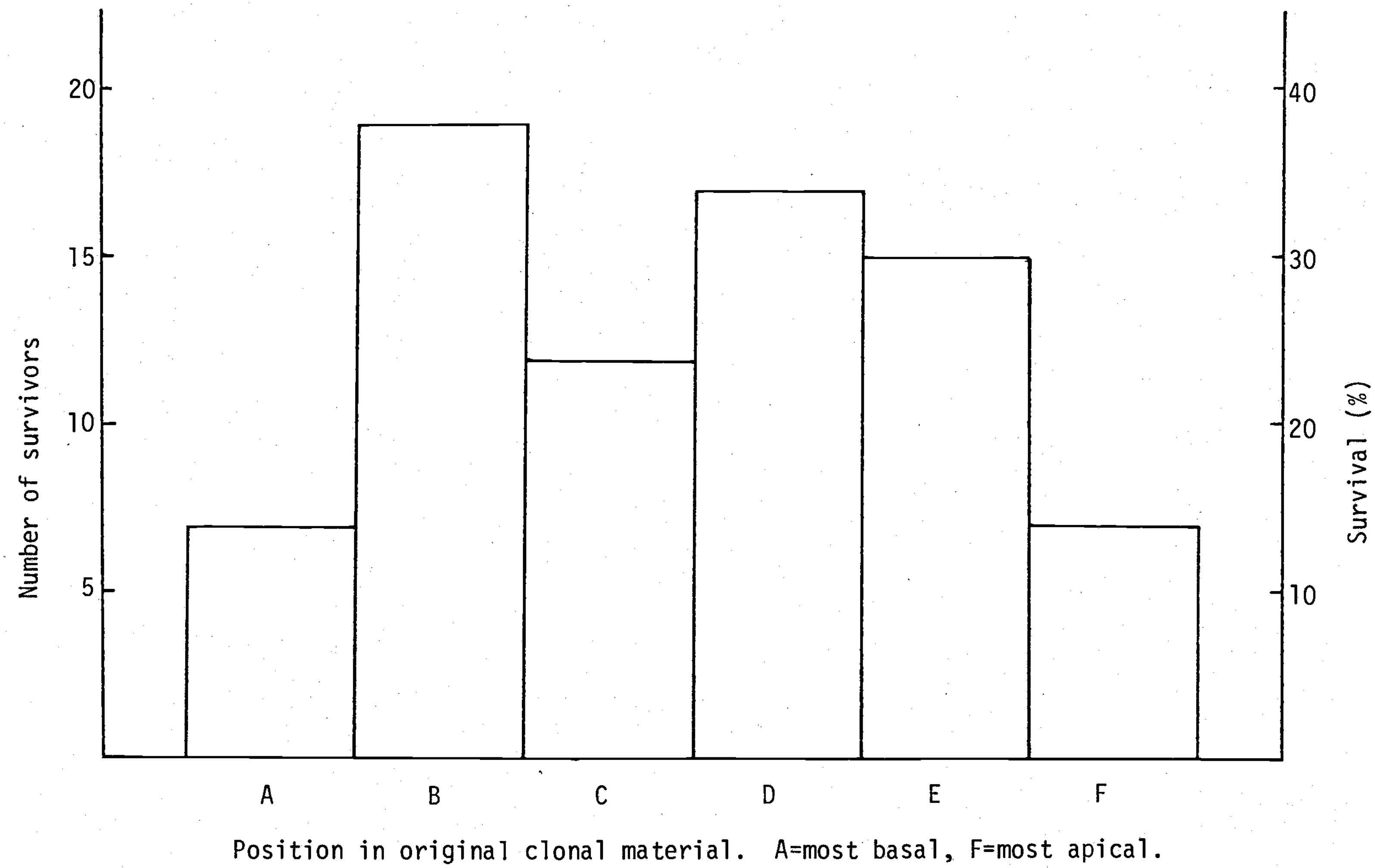

Figure 2. Survival of cuttings based on position in the original clonal material.

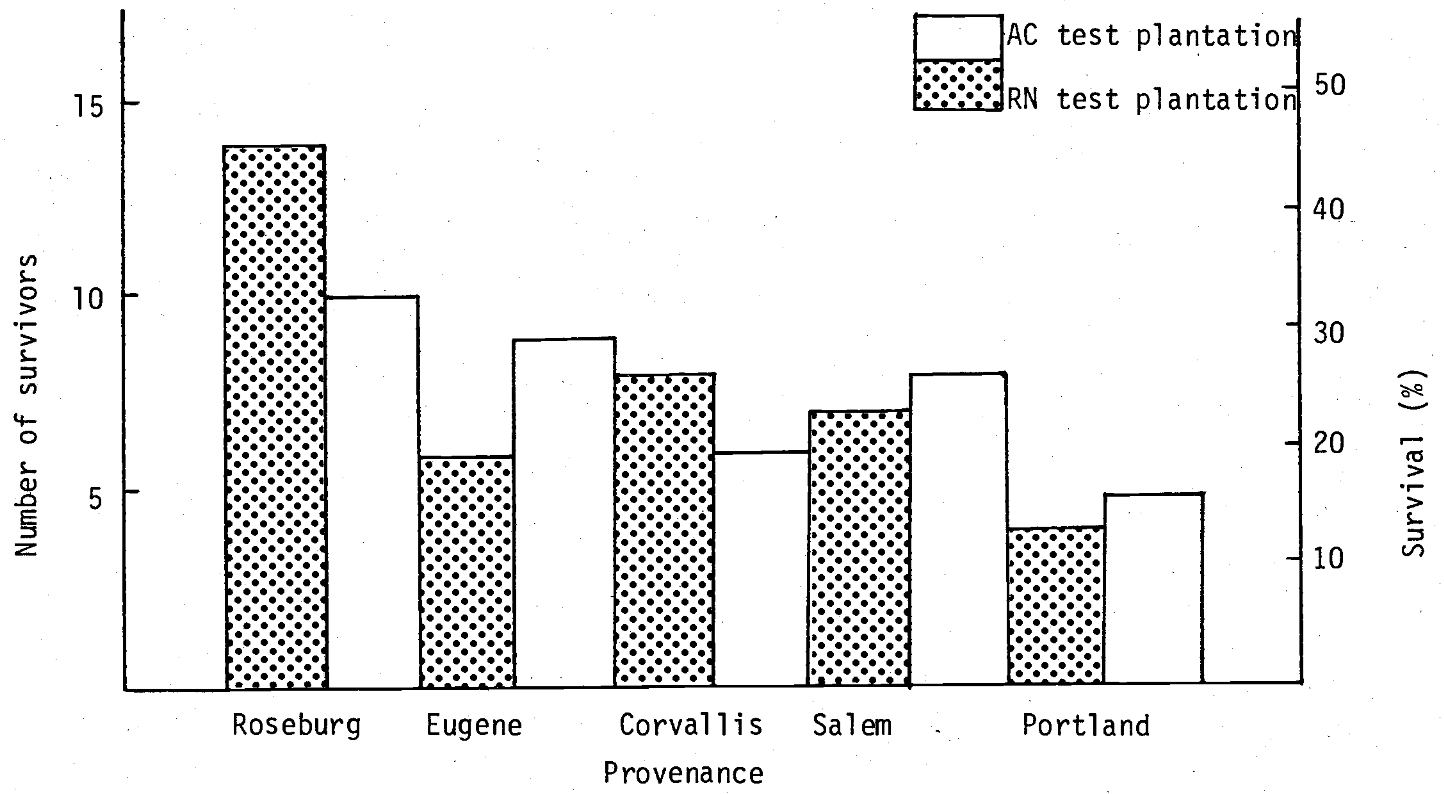

Figure 3. Survival of cuttings from each provenance at the AC and RN test plantations.

B. Shoot Production

At the AC plantation, shoot growth continued until the time of harvest (Figure 4). Roseburg cuttings produced the longest shoots (mean = 48.0cm), and also the largest increase in shoot length (mean increase = 36.8cm). Cuttings from Salem produced the shortest shoots (31.1cm), and also the least increase in shoot length (17.6cm). The overall mean height of the main shoots at the time of harvest was 40.0cm, and mean shoot elongation from outplanting to harvest was 27.3cm (Figure 4).

At the RN site, the rate of growth of the shoots was slow during most of the summer and then stopped in mid-August (Figure 5). Deer browse was the main cause of the cessation, and in some cases, decline of shoot growth. Deer browse was first noticed at this plantation on July 3, and became progressively worse. At the time of harvest, 65% of the surviving cuttings had been browsed.

In contrast to the AC plantation, Salem cuttings had the longest shoots at the RN site (mean = 25.1cm), and the largest average increase in height (12.7cm), Eugene and Portland had the shortest shoots at harvest (16.8cm), and Portland had the smallest average increase in height (6.8cm). At harvest, the overall mean shoot length was 20.4cm, and the overall average increase in length from the time of planting was 9.4cm (Figure 5).

C. Stem Weight

Overall stem weight at the AC plantation (62.9g) was significantly larger ($P \leq .05$) than the mean stem weight at the RN plantation (12.9g).

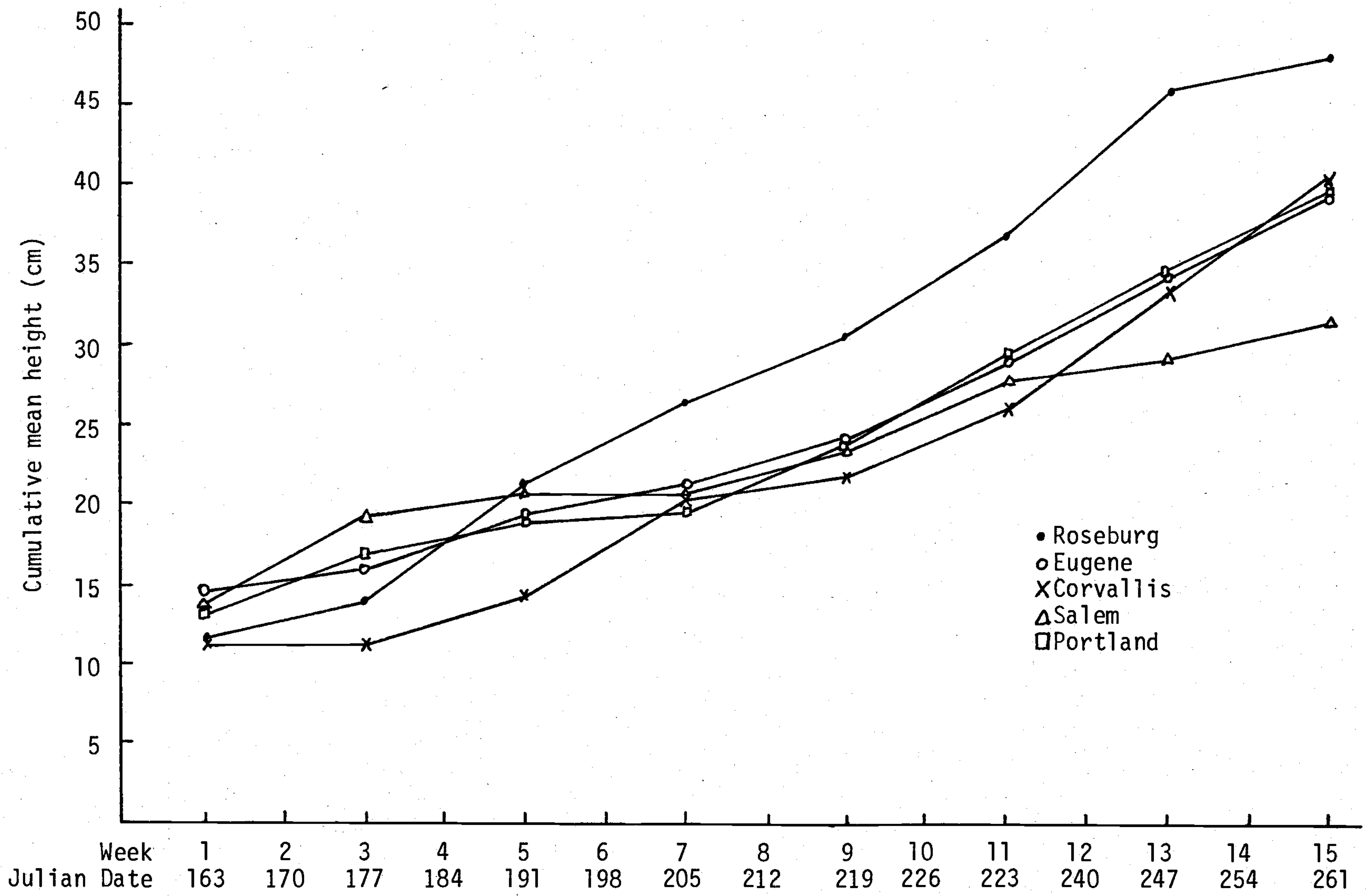

Figure 4. Cumulative mean height of each provenance at the AC test plantation.

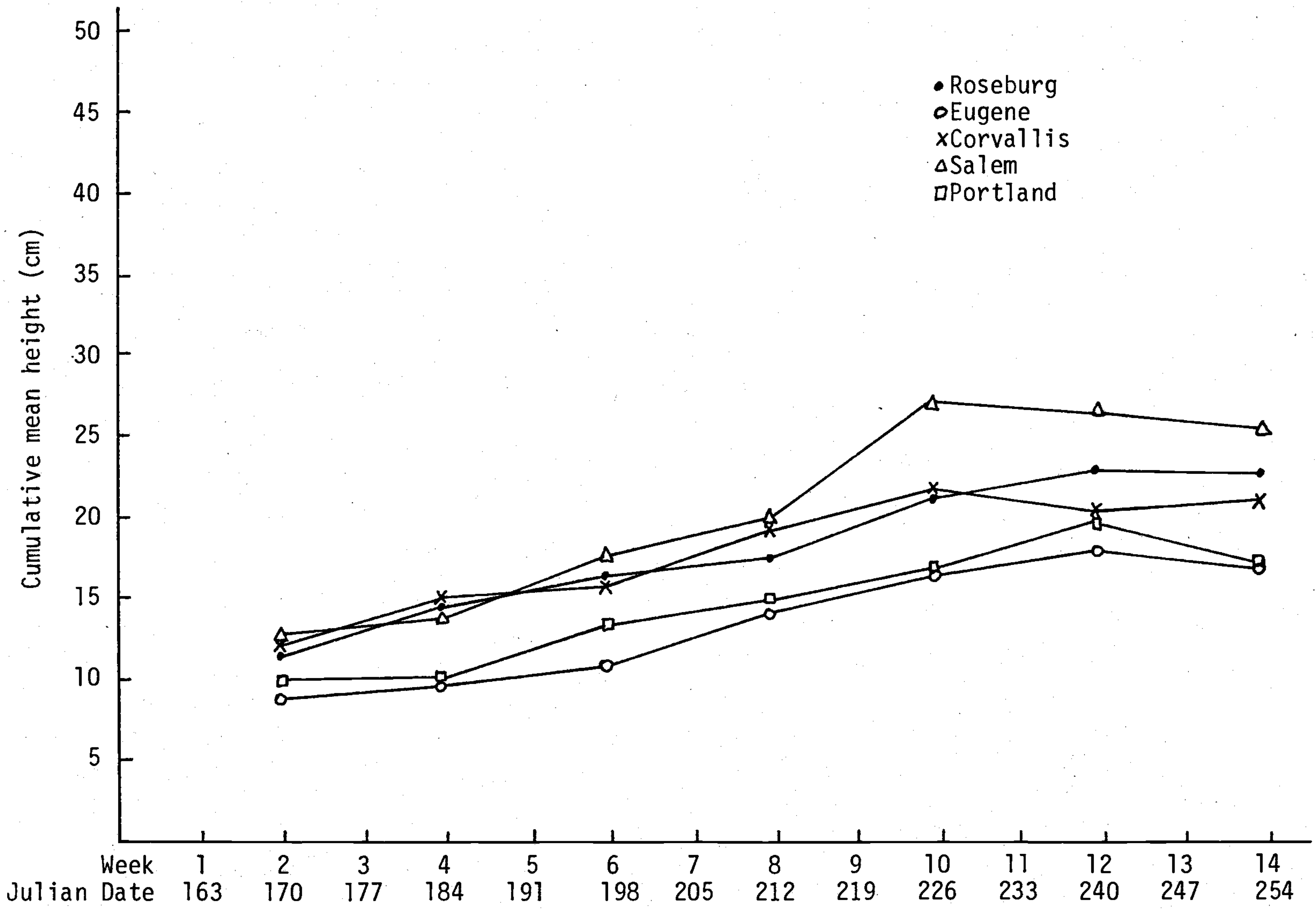

Figure 5. Cumulative mean height of each provenance at the RN test plantation.

At the AC site, Roseburg cuttings had the greatest mean stem weight, and Salem cuttings had the smallest stem weight. At the RN site, Salem cuttings had the second highest mean stem weight, finishing behind Roseburg cuttings. Eugene material had the smallest mean stem weight at this plantation (Figure 6).

D. Variation

There were large differences among provenances in the mean stem weight produced at the AC site, but the differences were not significant due to very large variation within each provenance (Table 2). At the RN site, the differences between the provenance means for stem weight were much smaller than at the AC site, and also not significant, except for the difference between the Eugene and Salem provenances. Here, the variation within provenances was much higher than the variation among provenances (Table 3).

E. Trait Correlations

At both plantations, provenances with the most survivors generally had the highest mean stem weight, but also had 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 weight, oven dry leaf weight, and leaf area[2]. The r and r^2 values are shown in Tables 4 and 5.

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2. Total leaf surface area (1 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.

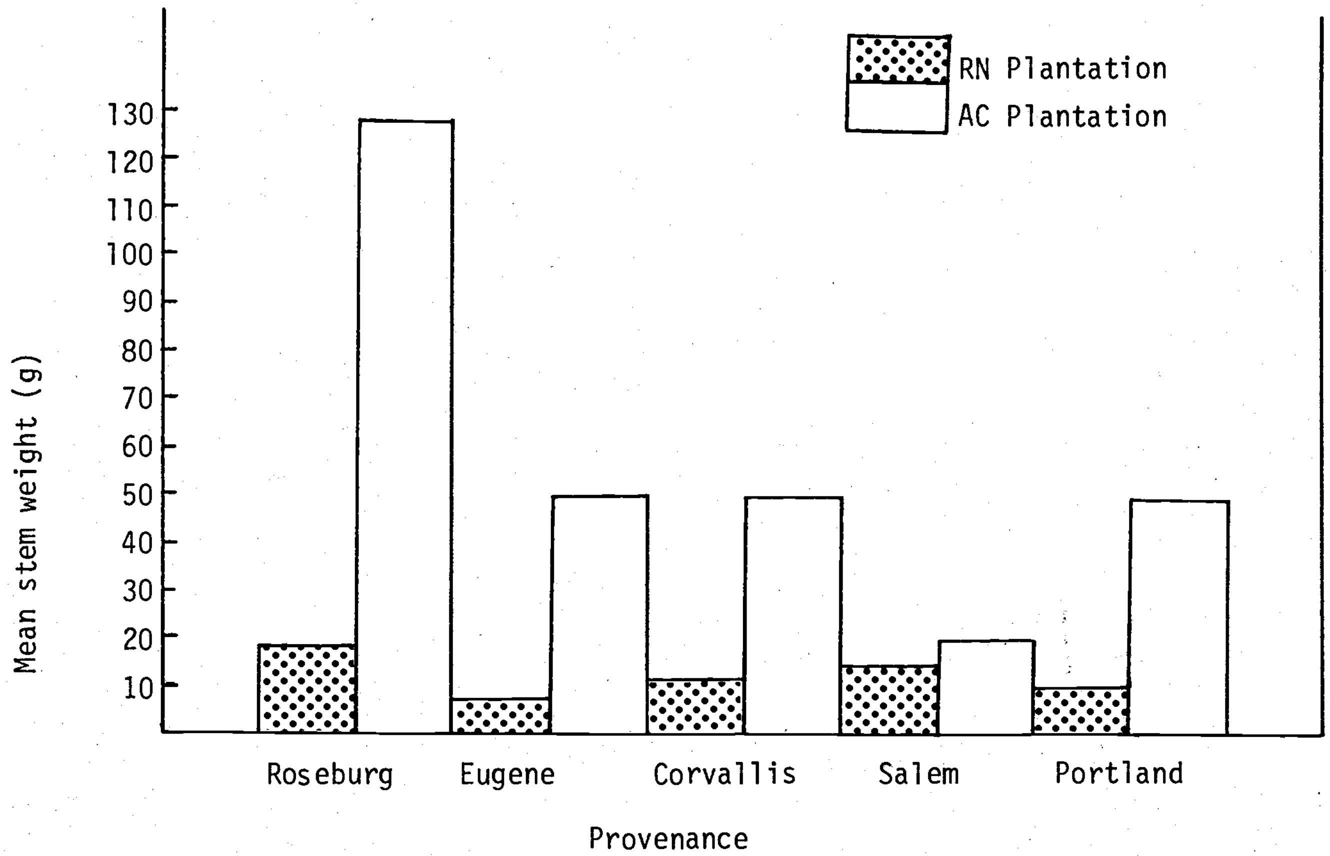

Figure 6. Mean stem weight of each provenance at the AC and RN test plantations.

Table 2. Analysis of variance table for stem weight at the AC test plantation. See Table 1 for definitions.

Source of Variation	df	Mean Square
Block	2	83.20
Provenance	4	214.80
Block x Provenance	8	125.24
Clone/Prov/Block (Error)	23	27.02

$\sigma_w^2 = 27.02$ $\sigma_p^2 = 29.85$

Table 3. Analysis of variance table for stem weight at the RN test plantation. See Table 1 for definitions.

Source of Variation	df	Mean Square
Block	2	.37
Provenance	4	.69
Block x Provenance	8	.33
Clone/Prov/Block (Error)	24	2.75

$\sigma_w^2 = 2.75$ $\sigma_p^2 = .12$

At the AC site, height at outplanting was very poorly correlated with all the other parameters, including final height. Final height was only moderately correlated with the remaining variables, with its highest r^2 value being .578 (with leaf area). Leaf weight and leaf area were highly correlated with each other (.933), and also with stem weight (r^2 = .972 and .941 respectively).

At the RN plantation, the same trends were evident, but the r^2 values were in general less. Leaf weight was fairly highly correlated with leaf area (.895), and both were again highly correlated with stem weight (r^2 = .843 and .916 respectively).

Volume of the stems was calculated for the RN plantation cuttings, using the stem length and basal diameter data[3]. The r^2 value for the correlation of stem weight with volume was .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 times average leaf width times the number of leaves on the cutting. The r^2 values were .901 at AC and .917 at RN.

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3. Volume/cutting = $[1/2(\text{mean basal diameter})]^2$ x mean length x number of shoots.

Table 4. Correlation matrix for stem weight, leaf weight, initial height, final height, and leaf surface area at the AC test plantation. $r(r^2)$ values respectively. N = 38

	STWT	INHT	FIHT	LFWT
INHT	.197(.039)			
FIHT	.752(.566)	.493(.243)		
LFWT	.986(.972)	.146(.021)	.737(.543)	
LFAREA	.970(.941)	.194(.038)	.760(.578)	.966(.933)

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

Table 5. Correlation matrix for stem weight, leaf weight, initial height, final height and leaf surface area at the RN test plantation. $r(r^2)$ values respectively. N = 39. Abbreviations as in Table 4.

	STWT	INHT	FIHT	LFWT
INHT	.071(.005)			
FIHT	.649(.421)	.440(.194)		
LFWT	.918(.843)	-.147(.022)	.456(.208)	
LFAREA	.957(.916)	-.091(.008)	.550(.303)	.946(.895)

IV. DISCUSSION

A. Survival

Overall survival of the cuttings at both plantations was low due to late planting. Many of the cuttings were rapidly desiccated before they had a chance to begin root growth at the planting site. With earlier planting, survival can be better. In a species trial, unrooted cottonwood cuttings were planted in March of 1977 on an abandoned grass field adjacent to the current study. First year survival of these cottonwoods was 79.2% (Jim Martin, personal communication).

Field survival also varied depending on the position of the cutting in the original whip. Those cuttings from the middle portion of the whip survived better than cuttings from the bottom or top of the whip.

The topmost section may have had poor survival because the 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 uptake water. They also may have lacked suppressed buds, from which shoots arise (DeBell and Alford 1972), and perhaps never formed shoots.

Survival of the cuttings was also influenced by their source of origin. At both plantations, cuttings from Roseburg survived the best, while cuttings from Portland survived the worst. Roseburg is an area with a warm and dry climate, while Portland is cooler and wetter during the growing season. Thus, one would expect the Roseburg cuttings to survive the best under the hot and dry conditions at the test sites.

The hybrid poplars had extremely poor survival, as did the hybrid poplars in the species trial described above. This poor survival agrees with the results of a much earlier study reported by Silen (1947).

B. Stem Weight

Mean stem weight of all surviving cuttings differed significantly between the two test plantations. Deer tended to browse on the larger cuttings, and thus lowered the overall mean stem weight at the RN plantation. Microclimatic differences between the two sites may also have contributed to the difference 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 prior to establishment. Nutrients added to the grass field undoubtedly were still present, and may have aided in growth of the cuttings. No nutrients had been recently added to the RN site, and the hardpan that was present at about 20cm probably restricted root growth, and subsequently top growth.

Finally, ground cover prior to planting may have influenced growth. The RN site was virtually bare, while 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, while the AC site retained moisture for a much longer time.

Growth at the AC plantation was less than might be expected on this site. In another study originated at American Can (referred to as the "sludge study"), black cottonwood cuttings were grown under varying levels of a mixture of sludge and nitrogen (Martin, personal communication). After two growing seasons, the trees in the control plots averaged 85.4g/yr. oven dry stem weight (manuscript in preparation), as compared to 62.9g/yr. at the AC plantation.

Roseburg cuttings outproduced the sludge study control plots, averaging 127.4g/yr., although survival was not as good (33.3% versus 54.0%). The difference in survival and overall mean stem weight is probably due to the late outplanting of rooted cuttings in the current study, since 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 explainable. Roseburg had the largest mean weight in both cases, and Corvallis, Eugene, and Portland cuttings all had approximately the same mean weight at each plantation. However, Salem had the lowest mean weight at the AC site, but the second highest at the RN plantation. Since there were so few survivors from each provenance at both plantations, it is difficult to determine if this difference in Salem's ranking is a genotype-environment interaction, or just happenstance.

C. Variation

Of main interest in this study was the amount of variation in stem production that occurred within the provenances. This is important in deciding whether to do single-tree-selection or provenance-selection for superior trees.

At the AC plantation, there were large differences in the mean stem weight among provenances. Cuttings from Roseburg had a mean stem weight 2.5 times as large as Corvallis, Eugene, or Portland cuttings, and were more than six times as large as the Salem cuttings. However, even though there were large differences, the variation was so high in all five provenances that there were no significant differences ($P \leq .05$) in the mean stem weight between any of the provenances.

At the RN plantation, the differences between the mean stem weights were not so large, and there were no statistical differences, except between Salem and Eugene cuttings. This difference was mostly because Salem had a relatively small variance, and 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, so it was not statistically different from Eugene.

In simple terms, these data mean that some cuttings from the provenance with the smallest mean stem weight produce more stem weight than do some cuttings from the provenance with the largest mean stem weight. Therefore, the conclusion is that single tree selection will yield better results than provenance selection.

By performing provenance selection, many superior clones from other provenances would be discarded, while many inferior clones in the chosen provenance would be retained. Single tree selection allows all superior clones to be retained, and all inferior clones to be discarded.

D. Deer Damage

Deer damage reduced stem production at the RN plantation, but not necessarily in the manner one would expect. Cuttings with the most severe damage were generally those cuttings with the highest stem weight. Likewise, cuttings with no deer damage had the smallest mean stem weight.

However, this situation was not due to deer browsing early in the growing season, causing a subsequent increase in shoot growth. Instead, deer browsing became more severe throughout the growing season, and was worst at the time of harvest. Therefore, cuttings had little time to resprout following damage by the deer.

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 browsing, the deer reduced the difference in stem weight between the large and small cuttings at RN, and thus reduced the variability at this test site. They also increased the difference in overall mean stem weight between the two plantations. The magnitude of the difference cannot, unfortunately, be estimated.

PRACTICAL APPLICATIONS

Use of native cottonwood is preferred over hybrid poplars in the Willamette Valley. Hybrids using black cottonwood as one of the parents may be beneficial, but they are not now readily available. Cuttings should be collected from mid-December to mid-February, and should range from one to two cm in diameter and 35 to 45 cm in length. Cuttings from the most apical and most basal portions of the whip should not be used. Cold storage of the cuttings ($\sim 2^{o}C$) is required until outplanting.

A basal dip in indolebutyric acid and an early spring planting of unrooted cuttings on plowed land is preferrable to the use of rooted cuttings. Survival and growth of unrooted cuttings is as good, or better, than that 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 or stem volume is directly related to large stem weight.

Leaf length and width provide a more accurate estimate of stem weight than does the stem volume calculation while the trees are young. However, as the trees get older and bigger, stem volumes may become easier and more accurate to use in a selection system. In the sludge study at American Can, stem volume of two-year-old trees was related to oven dry stem weight with an r^2 value of .90 (manuscript in preparation).

Much work remains to be done concerning cottonwood culture in the Williamette Valley. Clones should be collected from more widespread provenances, and should be grown in more divergent test plantations. Juvenile-mature correlations in shoot growth must be established, as must the most accurate juvenile selection system. The effects of sludge application and irrigation also need to be studied.

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APPENDICES

Appendix I. Hybrid poplar acquisition numbers, common names, parentage, and sex.

5260	Tristis No. 1	*Populus tristis* Fish. x *P. balsamifera* L.	male
5321	Negritode Granada	*Populus* x *euramericana* Guiner (*deltoides* x *nigra*)	female
5323	Canada Blanc	*Populus* x *euramericana* Guiner	male
5326	Eugenii	" " "	male
5328	I45/51	" " "	male
5377	Wisconsin No. 5	" " "	male

Appendix II. Rooting Experiment.

Variation in early root development of cottonwood clones is under fairly strong genetic control (Wilcox and Farmer 1968). Also, coppice growth of cuttings in the field is strongly influenced by root production (Lee 1978). When rooted cuttings are used for outplanting, it is very important that the cuttings be rooted under identical and near optimal conditions. This helps to insure that any differences in rooting ability (number and size of roots formed) are due to genetic factors rather than environmental factors. These genetic differences in root growth may in turn cause growth differences in the field. Randall and Miller (1971) reported that misting should be used, as it keeps the cuttings from drying out. Farmer (1966) suggested that IBA (indolebutyric acid) increased rooting, and Shapiro (1958) postulated that darkness during the first few days of rooting would increase the number of roots formed.

An experiment was designed and performed in January, 1978,to determine the best greenhouse conditions for rooting the cuttings. A complete factorial experiment was performed, with 10 replications per treatment. The 16 treatments included all possible combinations of Provenance 1 (Corvallis) versus Provenance 2 (Eugene), apical versus basal portions of the whips, dark versus no dark (dark treatment lasted for the first 10 days of rooting), and IBA versus no hormone.

After five weeks, all roots from all the cuttings were removed, dried (48 hrs. at 70^{o}C), and weighed. The only factor which significanty increased root weight was the IBA application. There was also

Appendix II. (cont.)

no significant correlation between cutting diameter or age, and root weight.

It was therefore decided to use a container-type system similar to that developed by Shreve (1974) for black walnut. The cottonwood cuttings were rooted under mist after a basal dip in IBA, with a natural photoperiod.

Appendix III. Visual Selection System.

Black and white photos were taken of each cutting prior to harvest. The set of 38 photos from the AC plantation were given to various people with the instructions to rank them according to stem weight. In other words, the cutting they felt had the greatest stem weight was ranked first, the next greatest second, and so forth. Each person was also told that leaf area is highly correlated with stem weight.

The ranking proposed by each person based on the photos was compared with the actual rank, and a Spearman rank-order correlation coefficient (ρ) was calculated (Downie and Heath 1974). The ρ (or r) values ranged from .909 to .940.

These values are on the same order as the r values for leaf weight and leaf length and width discussed above. Sampling requires only a photograph of each cutting, and selection is much simpler and less time consuming than other methods described. Whether the accuracy of this method will decline as the trees get older is unknown.

Appendix IV. Growth data for black cottonwood cuttings at the AC test plantation.

Heading Code

CLON - clone number
- 1-10 - Corvallis
- 11-20 - Eugene
- 21-30 - Roseburg
- 31-40 - Portland
- 41-50 - Salem

POS - position of cuttings in original whip
- A - most basal
- B - second most basal
- C - third most basal

SURV - SURVIVAL OF THE CUTTING
- 0 - did not survive
- 1 - survived

DIAM - diameter of the cutting (mm)
SHOOT - number of shoots produced during the growing season
HT1 - length of longest shoot on June 12, 1978 (cm)
HT2 - " " " " " June 26, 1978
HT3 - " " " " " July 10, 1978
HT4 - " " " " " July 24, 1978
HT5 - " " " " " Aug. 7, 1978
HT6 - " " " " " Aug. 21, 1978
HT7 - " " " " " Sept. 4, 1978
HT8 - " " " " " Sept. 18, 1978
STWT - oven dry weight of the stems (g x 10)
LFWT - oven dry weight of the leaves (g x 10)
LFLEN - mean length of all leaves on the cutting (mm)
LFWID - mean width of all leaves on the cutting (mm)
LFNUM - total number of leaves on the cutting