Zusammenfassung

Aus den laufenden Programmen zur züchterischen Bearbeitung der Baumart Pinus taeda L. wurde ein Zielmodell-Programm zur optimalen Selektion von Ausgangsbäumen für zukünftige Züchtungsprogramme entwickelt einschließlich der Erstellung von Samenplantagen der zweiten Generation. Das Modell wählt diejenigen Merkmalskombinationen aus, mit denen man den Zuchtzielen am nächsten kommt. Gleichzeitig wird der wirtschaftliche Gewinn mit kalkuliert. Das Zielmodell-Programm ist durchaus flexibel und eröffnet Möglichkeiten zur Information auch bei unterschiedlichen Komponenten eines Züchtungsprogramms.

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Competition Between Selected Black Cottonwood Genotypes

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Information on the nature of intergenotypic competition among plants comes primarily from work with agronomic species. Studies such as those reviewed by Sakai (1955), Donald (1963), Harper (1965), Brim (1969), Schutz (1969) and Sammeta and Levins (1970) have shown that the pure stand performance of a genotype can be significantly different than its performance in a mixture, and that the expression and magnitude of competitive interactions increase with the diversity of the genotypes involved. Competitive interactions have been demonstrated in forest tree species by Sakai et al. (1965, 1968) Snyder and Allen (1971) and Adams et *al.* (1973). However, the potential for increasing fiber yields by exploiting intergenotypic competition and the impact of such competition on testing by tree breeders has received little consideration.

This study was initiated to investigate intergenotypic competition in black cottonwood (Populus *trichocarpa* Torr. and Gray) grown under greenhouse conditions.

Competition and Its Measurement

In plants competitive ability is genotype dependent and a heritable character (Sakai, 1955; Donald, 1963). The competitive relationships expressed are due to direct genetic and environmental influences and complex interactions. Donald (1963) states that in general the effects of direct and interacting competitive factors are cumulative and, because they are integrated by plant growth, measurable.

Work by Hodgson and Blackman (1956), Hinson and Hanson (1962), and Shannon et al. (1971) suggests that density effects generally cause modifications of the same plant characters influenced by competition. However, competitive effects are a function of genotype while density effects are due to spacial distribution. Consequently, there is no genetic basis for differential competitive ability between propagules of the same genotype and with equal spacing density effects become constant.

Schutz and Brim (1967) presented a system for comparing a genotype's performance when grown with itself to its performance at various levels of competition with another genotype. Competition effects are quantified by the

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sign of the regression coefficient (r) of a trait with the number of competitors as the independent variable. The sign of the regression is considered zero unless significance at the .05 probability level is found using an "F" test. Their scheme assumes that the degree of competitive effect is linearly proportional to the relative frequency of the competitor genotype. Linear responses have been demonstrated with barley *(Hordeum sativum* L.) by Sakai (1957), and with soybeans *(Glycine max* (L.) Merr.) by Schutz and Brim (1967). *Table 1* lists all possible regression coefficient combinations and their classifications.

Table 1: Classification by the Sign of the Regression Coefficient (definitions modified from Brim, 1969)

Genotype A with B	Genotype B with A	Classification	Definition
0	0	neutral	The genotypes coexist with very little effect on each other
+	-	complementary	The effect of competition is balanced; what one genotype gains, the other loses.
+ + +	0 - +	overcompensatory	One or both genotypes gain in yield or one gains more than the other loses. The net effect is greater than zero.
- - -	0 + -	undercompensatory	One or both genotypes are depressed in yield relative to their pure stand performance. The net effect is less than zero.

Harper (1965) suggested that overcompensatory responses *(Table 1)* may provide potential for increasing yields. This class of interaction has been reported in a number of crop species including soybeans (Schutz and Brim, 1967, 1971), oats *(Avena sativa* L.; by Smith *et al.*, 1970), wheat *(Triticum aestivum L.;* by Jensen and Federer, 1964, 1965) and lima beans *(Phaseolus limensis* Mcfad.; by Allard, 1961). Adams *et al.* (1973) reported overcompensatory interactions between families of *Pinus elliottii* Engelm. seedlings and Hayashi and Sakai (1967) found that competitive effects were cumulative over years in *Cryptomeria japonica* D. Don, so competitive interactions may be of particular importance in perennials.

Designs

Interactions between pairs of black cottonwood clones were evaluated by two methods; 127-tree hexagon flats and paired trees in pots.

Flat Study

The flat design was based on a 7-position hexagon plot with the center position the measurement position. All trees are equidistant. By placing clone A in the center position and from zero to six individuals of clone B in the surrounding positions definable competitive dosages were established. The surrounding positions not filled by clone B were planted to clone A to provide constant density. Competitive dosage was defined as the number of surrounding positions which were filled by the competitor clone, Clone B.

Basic 7-tree hexagons were systematically incorporated into a single large hexagon form shown in *Figure 1,* as suggested by Martin (1973). By using two large hexagons per clone pair and reversing the clone positions in the second hexagon the number of observations for each clone of a pair was 12, 12, 12, 18, 18, 12 and 7 at dosage levels 0, 1, 2, 3, 4, 5, and 6, respectively.

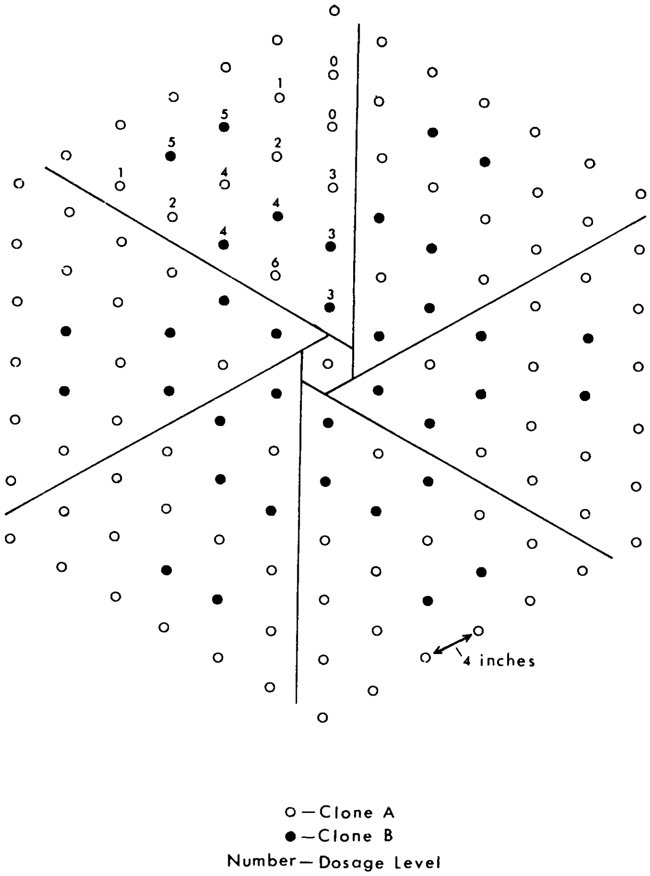

Figure 1. — The Hexagon Flat Design.

Pot Study

The pot experiments were designed to investigate the competitive interaction of paired clones when competition for light was minimal. Each clone pair test consisted of three types of pots; 1) two trees of clone A, 2) one tree of clone A and one tree of clone B, and 3) two trees of clone B. The 3-pot group represented 2 treatments for each clone of the pair; 1) clone A grown with itself, and 2) clone A in competition with clone B, with the same two treatments for clone B. The 3-pot group for each clone pair studied was replicated twelve times, with tree, and pot position randomized.

Materials and Methods

Ten clones were selected from a seven-year-old plantation of 69 clones of black cottonwood. A description of the plantation and its early development is given by Mohn (1969). The selected clones were paired for testing on the basis of their growth rates and genetic relationships. The ten clones were:

1) 118; a male clone from a wild population growing near Missoula, Montana (46^0 50' N).
2—4) 1600, 1603 and 1680; three progeny of 183-A, a female clone from a wild population near Juneau, Alaska (58^0 30' N), and 118
5—10) 342, 346, 348, 3316, 3424 and 3429; F2's, i.e., offspring of two of the progeny of 183-A and 118.

Cuttings of one-year-old wood of 0.30 to 0.55 mm diameter (small end), six inches in length, collected from the upper half of the crowns were used. In preliminary tests rooting of such cuttings exceeded 95 percent and immersion of the cuttings in water for 90 hours resulted in total saturation. Saturated cutting weight (nearest 0.1 grams) was obtained for each cutting to allow for statistical control of differences in initial cutting sizes.

Planting and Replacement

Flat experiments were conducted in two sets. Set I, planted January 5-6, 1972, included clones 118, 1680, 348 and 3316 paired in all six possible combinations. Set II included three clone pairs; 1600 with 342, 1603 and 3429 and 346 with 3424, and was planted March 27-29, 1972. Tree spacing was four inches.

Replacement materials were planted in conjunction with each set. The first forty days after planting were considered the establishment stage during which dead trees were replaced. The planting technique used for Set I was faulty and 51 percent mortality resulted, so only 6 of the original 12 flats were retained. Of these, only 2 complete flat pairs, 3316 with 1680 and 1680 with 348, remained and were used. Approximately half of the trees in these flats were transplants and it was assumed that essentially every tree was disturbed sufficiently to nullify any differential effects of transplanting. Planting techniques were improved for Set II, mortality was only four percent and all flats were retained. Replacement of trees was not considered in the analysis.

The remnant replacement cuttings for Set II provided the material for the pot study. The same clone combinations were used. These trees were transplanted into 6 quart pots when 30 days old.

The trees of all experiments were planted in a sandy loam soil, watered daily, and maintained under a simulated 20 hour daylight period.

Measurement

Visual observation of Set I clones indicated a possible influence of time from planting to growth initiation on subsequent growth. Therefore, the number of days between planting date and flushing date of Set II and the pot cuttings was tabulated to allow for statistical control. Flushing date was defined as that day on which the first leaf unfolded.

For both sets height growth was measured to the nearest 0.5 cm. starting on the 43rd day after planting. This starting date was chosen as a matter of convenience, and measurements were initiated early so that competitive interactions could be observed over time. Height was then measured at 12 day intervals up to and including the 103rd day after planting, at which time the flat experiments were terminated. Pot growth was measured in the same manner starting 43 days after transplanting. After the initial 103 day growth period the trees were cut back to 10 cm. for a second growth period of 91 days. Height was again measured every 12 days starting with the 31st day after cutting. The pot experiment was terminated 194 days after transplanting.

On the termination date of the studies stem diameter, 2.5 cm above the sprouting point, was measured. The stems, with leaves removed, and the roots, washed from the soil, were collected, oven dried and weighted to the nearest 0.01 gram.

Analysis

Flat mortality after the first 40 days posed an analysis problem. Since missing trees caused a change in density as well as dosage it was decided to use only those observations for which the 7-tree plots were complete. A Chi-square test was run for each clone to test for independence of mortality and dosage level.

The relationship of cutting wet weight and flushing date (Set II only) to the height, diameter and dry weight variables was examined using correlation analysis. All correlations were by clone.

Height, diameter and dry weight parameters were evaluated using a standard analysis of covariance, with cutting wet weight and flushing date (Set II only) as independent variables and dosage levels as treatments. Flat data for each clone pair were considered a separate and independent experiment and were analyzed on a clone basis. The analysis provided the adjusted treatment means and a "F" test for differences among treatment means.

The pot study data were first examined by correlation analysis, as described for the flats data, and then by covariance analysis, with cutting wet weight and flushing date as covariates. All pots which incurred mortality after the initial 40-day establishment period were dropped from the analysis.

Results and Discussion

Computed Chi-square values of the flat study data for the growth period of 40 to 91 days indicated that mortality and dosage levels were independent for all clones. Mortality was non-random for one clone in one flat at 103 days; however, all 17 of the dead trees involved had been killed by a localized insect attack.

Cutting wet weight and/or flushing date significantly influenced subsequent growth of most clones. In general, heights, diameter and dry weights were positively correlated with cutting wet weight and negatively correlated with flushing date. These correlations are in agreement with earlier reports for *Populus* by Negisi *et al.* (1958) and Browersox (1970).

Differential responses for both factors among clones were observed. In some cases growth was significantly correlated with both cutting wet weight and flushing date. In other cases growth was correlated with only one of the variables or with neither. These differential responses may be due to clonal differences in vigor and rooting ability.

There was no apparent relation between the relative influence of cutting wet weight or flushing date on growth and the competitive abilities of the clones.

Pot Experiment Interactions

The design of this study only allows testing for interactions. The 0.10 probability level was used because of the exploratory nature of the study. The 103 and 194 day growth measurements, with significant treatment differences, are presented in *Table 2*.

Clones of the pair 346 with 3424 performed similarly across treatments and no interaction was apparent. Clone 1603 of the pair 3429 with 1603 grew significantly better alone than when competing after 103 days, as did clone 342 of the pair 342 with 1600 after 194 days. For these two clone pairs some type of competitive interaction occured.

Flat Experiment Interactions

Tabe 3 lists all significant differences, after covariance adjustments, that were found for each clone and all growth measurements. Clone pairs 342 with 1600 and 1603 with 3429 showed no consistent significant treatment differences. Clone pairs 3316 with 1680, 1680 with 348 and 346 with 3424 had significant and relatively consistent treatment dif-

Table 2. The 103 and 194 Day Adjusted Treatment Means with Standard Errors for Pot Experiment Clones

Clones as Paired in Test	Average Height (cm) at 103 days		Average Height (cm) at 194 days^a	
	Clone Grown with Itself	Clone in Competition	Clone Grown with Itself	Clone in Competition
3429	35.9 ± 2.1	34.3 ± 2.9	35.7 ± 2.3	32.4 ± 3.2
1603	43.0 ± 1.9	36.5 ± 2.5*	46.0 ± 3.1	40.1 ± 4.0
346	39.5 ± 1.9	41.3 ± 2.7	36.3 ± 1.8	33.1 ± 2.6
3424	47.3 ± 3.1	47.3 ± 4.3	37.2 ± 2.6	39.0 ± 3.7
342	32.3 ± 2.5	34.5 ± 3.7	33.5 ± 2.2	26.6 ± 2.9*
1600	52.0 ± 2.4	55.3 ± 3.5	49.5 ± 1.4	52.4 ± 2.1
	Average Stem Dry Weight (g) at 103 days		Average Stem Dry Weight (g) at 194 days^a	
3429	0.32 ± 0.5	0.32 ± .06	0.40 ± .04	0.32 ± .06
1603	0.50 ± .05	0.37 ± .06*	0.61 ± .08	0.44 ± .10
346	0.40 ± .04	0.45 ± .06	0.78 ± .07	0.70 ± .09
3424	0.67 ± .09	0.63 ± .12	0.48 ± .05	0.42 ± .07
342	0.40 ± .05	0.37 ± .07	0.41 ± .05	0.27 ± .06*
1600	0.61 ± .08	0.79 ± .12	0.58 ± .04	0.65 ± .06

*F-test shows significant differences between treatment means at .10 level.

^{a}Cut back to 10cm at 103 days

Table 3: Significant Differences, By Probability Level, Between Treatment Means for Each Clone by Growth Measurements; Based on the Covariance Analysis F Values, Flat Study

Clones	Height at --- Days							Root Dry	Stem Dry
By Pairs	43	55	67	79	91	103	Diameter	Weight	Weight
1680	NS	NS	NS	NS	NS	NS	NS	NS	NS
348	.10	.10	NS	NS	NS	NS	NS	NS	NS
3316	NS	NS	NS	.05	.05	.05	.01	.05	.05
1680	.05	.10	NS	.10	.10	.10	.10	NS	NS
342	.10	NS	NS	NS	NS	.10	NS	NS	NS
1600	NS	NS	NS	NS	NS	NS	NS	NS	NS
1603	NS	.10	NS	NS	NS	NS	NS	NS	NS
3429	NS	NS	NS	NS	NS	NS	NS	NS	NS
346	NS	NS	NS	NS	NS	NS	NS	NS	NS
3424	.10	.10	.01	.05	NS	NS	NS	NS	NS

NS = Not Significant

ferences. The fact that mortality from one measurement date to the next caused the loss of up to seven observations per dead tree may account for some of the inconsistencies in significance of treatment differences shown in *Table 3*.

As the experiments were allowed to progress until crowding became intense, the heights measured at 55, 67 and 79 days were selected for detailed analysis. These data were selected as those best expressing meaningful competitive relationships because; (1) increased mortality during the last 12 to 24 days of growth greatly reduced the number of remaining complete 7-tree plots, (2) in the final stages of the experiment crowding effects within genotypes began to greatly exaggerate small initial differences among trees, adding to dosage level variability, and (3) individual root systems began to extend beyond the original 7-tree plots. Data from all three of these measurement periods are simiar and only the 67 day height data are presented below.

Response Curves

The 67 day height treatment means plotted by dosage level for each clone by clone pair are presented in *Figure 2*. The two numbers following each curve in the figure, presented as a fraction (e.g. A/B), indicates that the data concern clone A's performance when competing with clone B.

For all clone pairs examined the root dry weight, stem dry weight and diameter data collected at growth termination generally reflect the same trends shown by the 67 day height curves. However, since growth over the last several weeks was confounded by several factors, as discussed previously, the trends were not as definitive as were the height trends.

To obtain a statistical test of the significance of these clonal interactions the SCHUTZ and BRIM (1967) regression technique, as previously described, was used. The results of this analysis *(Table 4)* show the overcompensatory interaction of clone pair 1680 with 348 and the undercompensatory interaction of clone pair 3316 with 1680 to be significant. On the basis of this test the interaction of the other three clone pairs must be considered neutral. There were no significant quadratic or cubic interactions.

Conclusions

Both the pots and the flats experiments demonstrate that measurable competitive interactions do occur between clone pairs of black cottonwood. Overcompensatory interaction, of the type described by SCHUTZ and BRIM (1967), was observed during the initial growth stages of the clones evaluated in the flat experiments.

The nature of the interactions of two of the clone pairs (3429 with 1603 and 342 with 1600) across the two studies appear to be different; neutral in the flat study and other than neutral in the pot study. This is not unexpected since DONALD (1963) reported in his review that different competitive responses may occur in different environments. The fact that competitive responses do vary with environment suggests that testing for utilization of overcompensatory responses should be conducted under conditions similar to those of actual planting.

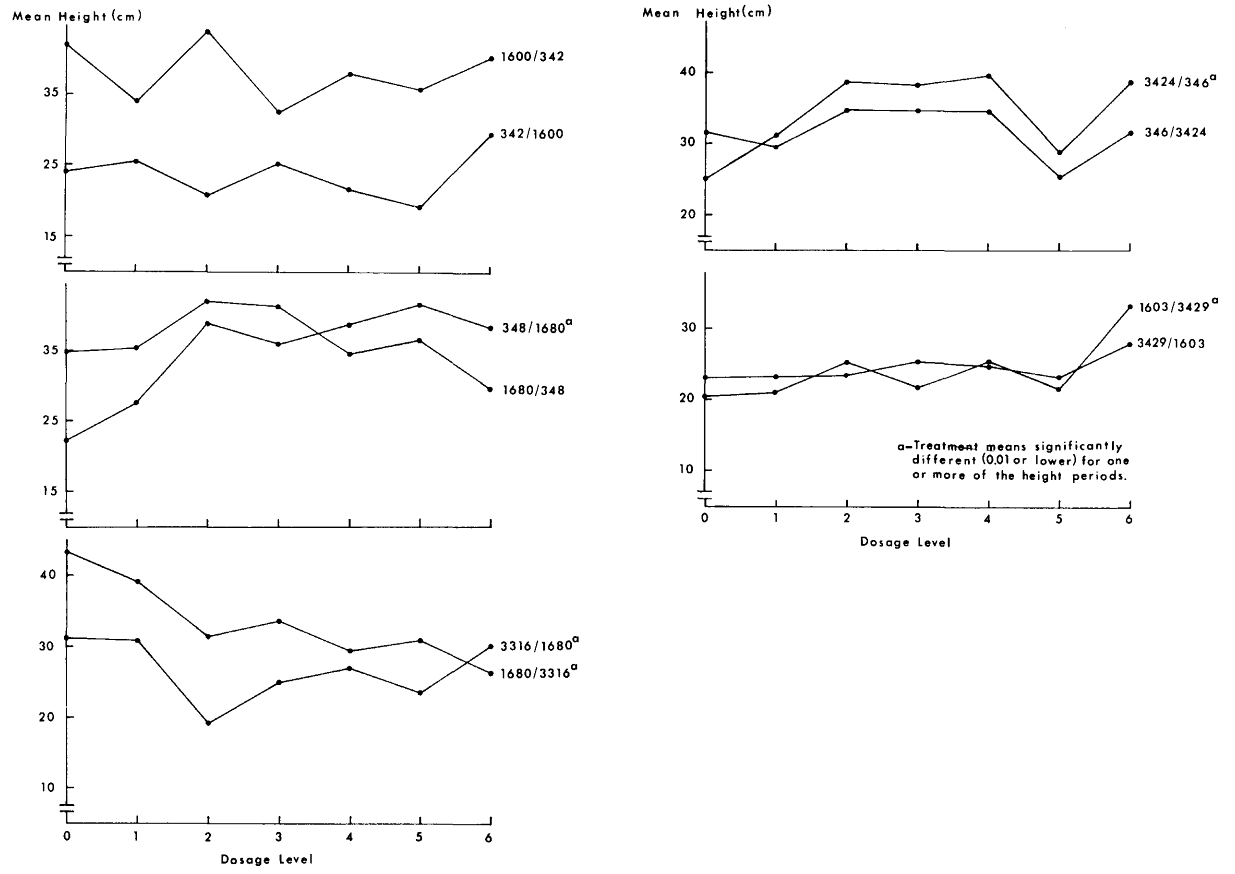

Figure 2. — Response Curves; Competing Clone Pair Height Growth at 67 Days.

Table 4: Clone Pair Competition Classification by Regression Analysis, at 67 Days' Growth

Clone Pair	Regression Coefficient		Competitive Classification
	Value	Sign*	
1680	-0.80	0	
348	2.62	+	Overcompensatory
3316	-0.36	0	
1680	-2.47	-	Undercompensatory
342	0.13	0	
1600	-0.27	0	Neutral
1603	1.37	0	
3429	0.55	0	Neutral
346	-0.31	0	
3424	0.97	0	Neutral

*Considered zero unless significant at the .05 or lower probability level

The change in ranking of the treatment means of clone pair 342 and 1600, pot study, indicates that trees, unlike annual crops, may require several to many years of growth before their final competitive relationships are concretely established.

The results of this study are tentative, and long-term field studies are needed to assess the importance of competitive interaction on productivity over a rotation.

Summary

Competitive interactions of paired black cottonwood clones were investigated in a greenhouse using the newly developed beehive design and single paired trees. Both studies demonstrated that competitive interactions are present in the early growth stages of the species. One clone pair exhibited an overcompensatory response, so further studies of this nature may lead to a technique of increasing productivity. Testing under field planting conditions over full rotation is recommended.

Key words: Competition, Black Cottonwood, Populus, Genotype Interactions, Productivity.

Zusammenfassung

Die Konkurrenz zwischen Paaren von Pappelklonen (*Populus trichocarpa* Torr. et A. Gray ex Hook.) wurde unter Gewächshausbedingungen untersucht, wobei einmal das kürzlich entwickelte „Beehive Design" (hexagonale Anordnung) und zum anderen eine Einzelpaarung von Stecklingspflanzen zur Anwendung kam. Beide Untersuchungen zeigten, daß im Frühstadium des Wachstums Konkurrenz besteht. Außerdem wurde bei einem Klon-Paar Überkompensation festgestellt, so daß weitere Studien in dieser Richtung evtl. eine Produktionssteigerung versprechen könnten, wobei solche Untersuchungen jedoch unter normalen Standortsbedingungen durchgeführt werden sollten.

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Growth and flowering of 'primary' and 'secondary' grafts of Scotch pine

By E. Andersson and H. H. Hattemer[1])

(Received April 1975)

1. Introduction

In the establishment of seed orchards, the question arises which of two types of grafts gives better results: Primary grafts are made with scions taken from adult trees that are selected on the basis of field and/or progeny-test performance. Secondary grafts are made using scions collected from the primary grafts. In the latter case one does not need to again climb a tall tree if it were to be included in an orchard. Moreover, the ortets are sometimes very old and thus difficult to propagate. It is advisable in the beginning to produce only a few grafts so that sufficient quantities of reasonably vigorous scions can be collected later. The existence of such primary ramets also provides the possibility of making experiments where clonal effects are to be tested under scrutiny (Quijada *et al.* 1973).

The behavior of the resulting two types of grafts was originally to be compared in three field experiments. It was planned to simultaneously study the effect of increased distance between the origins of the ortets and the environment of the grafts. In all, three plantations in northern, central, and southern Sweden were to be studied. The plantation in northern Sweden had, however, to be culled since various adverse environmental conditions lead to the loss of most of the experimental material.

2. Material and Methods

The locations of the 10 indigenous ortet trees in northern Sweden are shown in *Figure 1*. This figure also shows the locations of the two remaining field trials that were established with graft material from these clones. The ortets represent plus trees (Andersson 1963) that entered various seed orchards in Sweden. The geographic positions of the

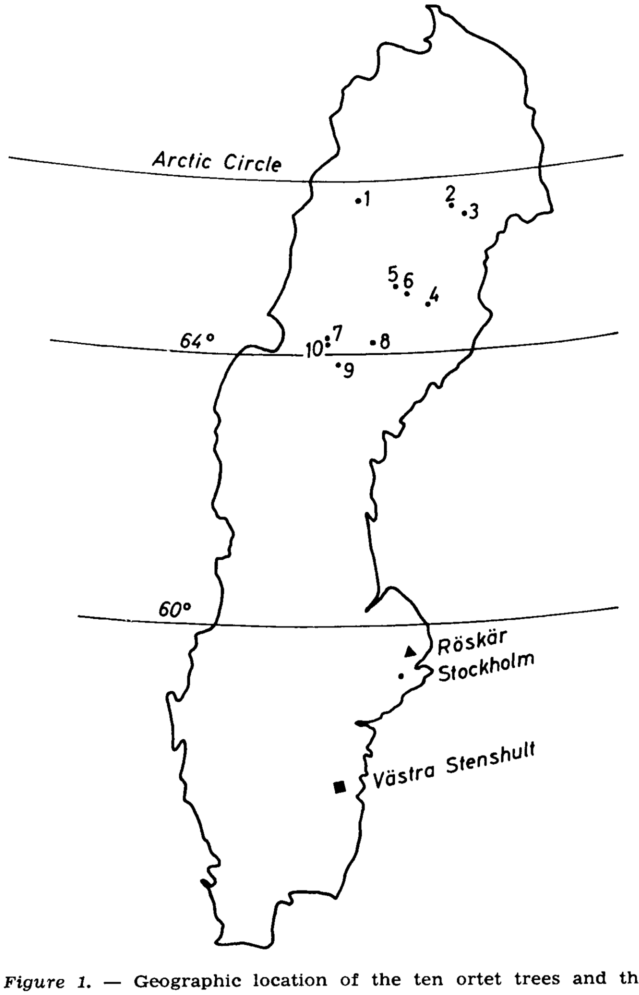

Figure 1. — Geographic location of the ten ortet trees and the two field experiments.

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