Additional locations, therefore, are beneficial primarily because they provide more precise estimates of clone means.

Since there was essentially no genotype X environment interaction for specific gravity and the estimated genotypic response was similar at each location, it appears that little can be gained by measuring specific gravity at more than one location.

Summary

Among 32 cottonwood clones tested at three locations, the genotype X environment component of variance was as large as the genotypic component for age 1 height. At later ages, it was approximately half as large as the genotypic component for height and diameter. No such interaction was found for specific gravity. Only for age 1 height did the genotype X environment interaction cause the average of the three individual location estimates of expected genotypic gain to appreciably exceed the estimate from the combined analysis. Growth characters were closely correlated. Selecting the best 4 of 32 clones would give predicted genotypic gains of 9 percent in height, 21 percent in diameter, or 8 percent in specific gravity.

Key words: Populus deltoides, genotype X environment interaction, heritability.

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Effect of Annual Leader Pruning on Cone Production and Crown Uevelopment of Grafted Douglas-fir

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(Received August / revised September 1973)

Introduction

Grafted ramets of Douglas-fir (Pseudotsuga menziesii [MIRB.] FRANCO) in Oregon and Washington seed orchards commonly grow 2 to 4 feet in height each year. As a result, upper crowns of 14- to 16-year-old grafts are already difficult to reach and manage. Insect and disease control, controlled pollination, and operation of overhead irrigation systems are difficut. Climbing to collect cones of orchard trees which might have structurally weak graft unions is dangerous. Therefore, Douglas-fir seed orchardists would like to restrict tree leader growth even at the expense of some cone production.

Several methods for limiting or evading the tree height problem have been tried on Pinus species in the southern pine area of the United States. Tree shearing or pruning studies (VAN BUIJTENEN and BROWN, 1963) and tree shakers and mobile vacuum machines (NORTH CAROLINA STATE UNIVERSITY, 1970) have been tested under their orchard conditions. Tree shakers have not been used in Douglas-fir orchards because of the branch and leader damage which occurs during shaking. Also, there have been no adequate tests to prove that bole damage does not occur when the trees are reshaken each crop year. The vacuum machine technique of picking up seed from the ground has not been tested in the Douglas-fir region and would presently be unsuitable unless orchards had more thorough ground clean-up and maintenance programs. Chemical control of leader growth, as proposed by SACHS et al., 1970, is not favored for seed orchards because of potential mutagenetic effects on the reproductive buds and the developing seeds.

Reduction of tree height by leader pruning is an alternative, but Douglas-fir orchardists presently have little information concerning its use. Crown pruning was tested on Pinus taeda, and the resulting cone production from pruned trees was generally disappointing (VAN BUIJTENEN and BROWN, 1963). Crown shearing of a Christmas tree plantation shows that Douglas-fir is easily shaped (DOUGLASS, 1964). But trees of this size are generally too young to produce adequate numbers of cones and of no use in evaluating shearing effects on cone production. Personal observations of Douglas-fir trees growing under telephone and electric power lines in Oregon indicate that cones are produced on leader- and crown-sheared trees. But how the frequency of crops and number of cones produced by pruned trees compare with unpruned trees growing in similar areas is not known.

The following study was established in 1965 to determine the effect of leader pruning on cone production and crown shape.

Materials and Methods

Leaders were pruned annually to 1.0 or 1.5 feet above the top whorl of branches. From 1965 to 1970, succulent leaders (about 90—95% elongated) were pruned in July, and lignified leaders (fully elongated), in September. Single stem trees were desired, so lateral branches were trimmed

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whenever they became upright and threatened to make the trees multiple-topped. This trimming was limited to removal of 6 to 12 inches from the tips of the competing branches.

The study trees were grown in two Oregon and two Washington seed orchards. They had been grafted approximately 6 to 8 years earlier and averaged 7.5 to 15 feet tall in 1965. Study factors were orchards (four), clones within orchard (three), time of pruning (July or September), and leader lengths (1.0 foot, 1.5 feet, and no pruning). Each of the 18 treatment combinations was replicated three times in each orchard, thus the number of trees studied in each orchard was 54 (3 × 2 × 3 × 3).

The bud selection method used in pruning closely approximated that described by Douglass (1963) for a Christmas tree plantation. One bud on the current year's leader, about 12 or 18 inches above the top whorl of branches, was selected as the new terminal bud. Next, the leader was severed about ½ inch above the selected bud. All buds on the leader within 1 inch of the new terminal bud were removed in order to reduce the possibility of multiple leaders developing. Single-stemmed trees were desired, so multiple leaders, if they developed, were cut back to a single leader the following year. Each tree received the same pruning treatment for 6 consecutive years. Exceptions were made only when yearly leader growth was less than the desired 1.0 or 1.5 feet. Trees with insufficient leader height were not pruned until the following year when their annual growth exceeded the minimum.

Good cone production occurred only in 1971, and cone data are presented only for that year. Cones were counted on each tree. Other measurements taken each year through 1970 were length of annual leader elongation, number of buds on the leader both before and after the leader was pruned, number of branches in the top whorl, number of internodal branches between the top two whorls.

Pruning was terminated after the 1970 growing season. At that time, the following additional measurements were recorded: (1) average length of whorled branches at 4.5 feet above the ground, at the base of the pruned crown (1965 whorl), halfway up the pruned crown (1968 whorl); (2) total tree height; (3) length of the pruned crown; and (4) crown shape and crown density. Crown shape refers to the overall outline of the pruned top. A numerical value representing the following upper crown shapes was given each tree: 0 = Δ, 1 = △, 2 = ⌂, 3 = ┌┐. Crown density refers only to the pruned area of the crown. A rating system was used to evaluate treatment differences *(Figure 1)*: 1, very dense; 2, dense; 3, moderately dense; 4, low density.

Trees showing symptoms of graft incompatibility were dropped from the study. By 1971, 11, 13, 22, and 31% of trees in the four orchards were excluded from further study.

All data were analyzed for each orchard separately and for all four orchards together. Analysis of variance and covariance were used. Height growth in 1964 and 1965 and branch characteristics prior to the start of the pruning treatments were used as covariates to control error and increase precision.

Results

All four orchards produced cones in 1971. Three of the four orchards had abundant cones, but the fourth orchard had only a light crop. Unpruned (control) trees averaged 313 cones per tree; 1.0- and 1.5-foot pruned trees averaged 191 and 207 cones per tree, respectively *(Table 1)*. Crown and branch measurements are recorded in *Table 2*. Differences in cone production between clones within orchards were significant in two of the four orchards *(Table 3)*. The time of year of pruning had little or no effect on cone production *(Tables 3, 4)*. Cone numbers were not significantly different on trees pruned at 1.0 foot from those pruned at 1.5 feet (191 vs. 207, respectively, *Tables 1, 3, 4)*.

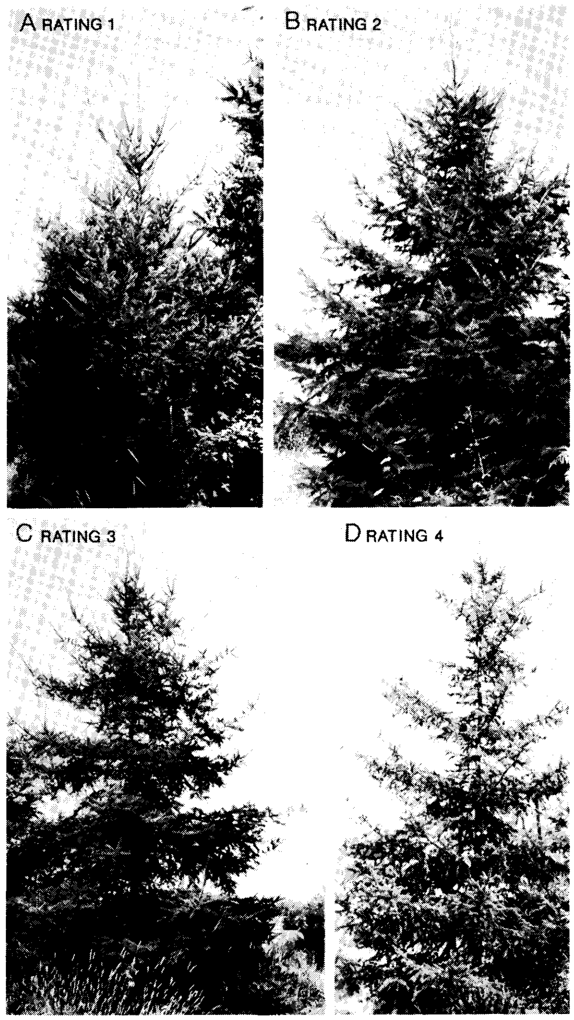

Figure 1. — Crown density values employed in rating pruned and unpruned trees are illustrated: A, very dense; B, dense; C, moderately dense; D, low density.

The difference in cone numbers between pruned and unpruned trees was large. Only one of the four orchards had more cones on pruned trees (90 on 1.5-foot trees vs. 66 on control trees), but it had the poorest crop of the four orchards and thus is not regarded as representative of the true treatment response *(Table 1)*. In the other three orchards, the controls averaged many more cones per tree than did the pruned trees, but the differences were not significant *(Tables 3, 4)*. For example, numbers of cones per tree on unpruned trees in the Orting, Wash., orchard ranged from 0 to 1,250.

Number of cones was closely correlated with tree height. In general, tall trees produced more cones than did short trees. Cone production, expressed as the number of cones per foot of tree height, showed that pruned trees had approximately the same number of cones per foot as did the unpruned trees (1.0-foot, 11.8 cones; 1.5-foot, 10.7 cones; control, 11.6 cones). Lower production per tree apparently occurred because of a reduction in the vegetative base

Table 1. — Average number of cones per tree in four seed orchards in 1971.

Factors	Oregon		Washington		Mean
	Cottage Grove	Sweet Home	Shelton	Orting	
Height of pruning:					
1.0 foot	16	173	297	275	191
1.5 feet	90	159	319	275	207
No pruning (control)	66	414	408	399	313
Time of pruning					
July	47	377	369	284	255
September	76	164	308	342	221
Clones:[1])					
A	71	230	388	71	
B	46	335	131	530	
C	63	214	431	192	

[1]) A different group of three clones was used in each of the four orchards.

upon which flower buds were laid down, not because pruning induced the trees to become more vegetative.

Pruning influenced the amount of leader growth which occurred the following year. Shorter leaders grew less: 1.0-foot, 21.1 inches; 1.5-foot, 25.3 inches; control, 33.0 inches *(Table 2)*. Growth differences between 1.0-foot and 1.5-foot trees and between pruned and unpruned trees were highly significant, both within and between orchards *(Tables 3, 4)*.

Leader succulence or stage of bud maturity when pruned also had a strong influence on leader growth the following year. July pruning resulted in greater height growth than did September pruning. The July leader data in *Table 2* do not indicate full growth because elongation each year was not completed at the time of measurement. This is illustrated by the difference in leader length of July and September control trees (31.9 vs. 34.2 inches, respectively) *(Table 2)*. If this 2.3 inches were added to the growth of 1.0- and 1.5-foot July-pruned trees, the leader length difference between July and September pruning would have been greater.

Cutting off part of the leader each year resulted in loss of the buds on the severed piece. Leaders pruned to 1.0 and 1.5 feet and unpruned leaders averaged 23.1, 24.9, and 30.3 buds per leader, respectively, after pruning *(Table 2)*. Differences were highly significant *(Tables 3, 4)*. Reduction in bud numbers after pruning reduced number of branches at the node (1.0 foot, 3.2; 1.5 feet, 3.4; control, 4.5), and between nodes (1.0 foot, 8.6; 1.5 feet, 11.5; and control, 24.1), which grew following pruning *(Table 2)*. The differences between 1.0- and 1.5-foot pruning heights and between pruned and control were significant *(Tables 3, 4)*.

Leader pruning to 1.0- and 1.5-foot annual increments caused many trees to develop multiple tops. Multiple tops resulted from either competition with branches growing from lower whorls or from branches growing on the leader close to the pruned tip. The latter type resulted from failure, at the time of pruning, to remove buds which were too close to the selected terminal bud or from failure of the selected terminal bud to grow the following year.

Pruning treatment indirectly influenced branch length. The 1.0-foot pruned trees required more severe branch trimming than did 1.5-foot pruned trees because shorter leaders were more readily suppressed by lower branches. The 1967 nodal branches in the whorl halfway up the pruned crown reflect this trimming: 1.0-foot trees, 30.5 inches; 1.5-foot trees, 40.3 inches; control trees, 51.9 inches *(Table 2)*. Branches growing at the base of the pruned crown showed a similar reduction *(Table 2)*.

Annual leader pruning for 6 years increased branch density in both upper pruned and lower unpruned areas of the crown *(Table 2)*. Some density increase in the upper crown areas resulted because of the reduced distance between branch whorls. Also, pruned trees produced additional foliage on nodal and internodal branches in both pruned and unpruned crown areas. Increased foliage density was much more prevalent in the Oregon orchards than in the Washington orchards, for both pruned and control trees *(Figs. 2, 3)*. Increased density from pruning was evident after only 3 years in Oregon, whereas it was just becoming noticeable in the two Washington orchards after 6 years of pruning. Density data indicate this phenomenon: 1.0-foot pruned trees, 2.0; 1.5-foot trees, 2.0; unpruned trees, 3.2 *(Table 2)*.

Crown shape or outline was drastically altered by pruning. Restricting annual height increase to 1 foot produced flat-topped or barrel-shaped trees *(Fig. 2)*. Trees pruned to 1.5 feet had rounded tops *(Fig. 4)*, whereas control trees had the usual pyramid-shaped tops *(Fig. 1D)* which characterize unpruned Douglas-fir.

Discussion

This initial pruning study was started in 1965 to develop recommendations that would help seed orchard managers select proper height reduction methods. Leader pruning was tested because it was least objectionable to the orchard managers who were afraid to subject their orchard trees to severe topping or shearing operations. The study is reported with the realization that other untested procedures, such as topping at a common height, may be better.

Extreme variability in cone production prevented statistical significance between pruned and unpruned trees even though the unpruned controls far exceeded either 1.0- or 1.5-foot pruning treatments. There were only 61 and 66% as many cones, respectively, on the 1.0- and 1.5-foot pruned trees as on unpruned trees. The differences tested nonsignificant, but common sense indicates otherwise. Sample size was too small for the variability found within treatments.

Looked at another way, cone production was reduced in proportion to the height reduction caused by pruning. Approximately the same numbers of cones per foot of tree height were produced on pruned and unpruned trees. Thus,

Table 2.--Crown and branch measurements made in 1970 on pruned and unpruned trees in two Oregon and two Washington seed orchards.

Observation	Pruning treatment	Oregon		Washington		Combined orchards		
		Cottage Grove [1]	Sweet Home [1]	Shelton [1]	Orting [1]	July pruned	Sept. pruned	$\bar{X}$
Tree height (feet)	1.0 ft.	14.2	13.7	18.8	17.7	16.5	16.1	16.2
	1.5 ft.	16.5	17.7	22.4	21.3	19.5	19.3	19.4
	Control	22.9	27.8	27.3	26.8	26.0	26.3	26.1
Length of pruned crown	1.0 ft.	6.5	6.3	5.5	5.7	6.1	5.8	6.0
(feet)	1.5 ft.	8.3	9.1	8.0	8.4	8.3	8.4	8.4
	Control	14.5	20.3	12.3	16.0	15.5	16.2	15.9
Branch length:								
Whorl closest to 4.5	1.0 ft.	90.1	121.4	90.0	89.8	91.6	101.9	96.9
feet above ground	1.5 ft.	97.7	126.6	91.2	92.8	101.7	101.2	101.4
(inches)	Control	92.9	112.4	91.4	87.8	98.4	95.2	96.9
Whorl at base of pruned	1.0 ft.	71.9	94.5	59.8	65.4	71.7	72.1	71.9
crown (1965 whorl)	1.5 ft.	84.7	109.6	73.7	84.2	90.4	84.4	87.4
(inches)	Control	86.5	103.6	66.9	82.0	87.2	83.7	85.4
Whorl halfway up pruned	1.0 ft.	30.2	38.1	26.8	28.2	30.0	31.0	30.5
crown (1967 whorl)	1.5 ft.	39.9	46.1	36.2	39.9	40.3	40.2	40.3
(inches)	Control	51.5	63.9	39.3	51.8	51.7	52.1	51.9
Crown density code	1.0 ft.	1.1	1.0	2.7	2.9	2.1	1.8	2.0
(1 = very dense, 2 =	1.5 ft.	1.3	1.1	2.6	3.0	2.2	1.8	2.0
dense, 3 = moderately	Control	2.6	2.9	3.8	3.9	3.2	3.3	3.2
dense, 4 = low density)								
Crown shape code (0 = Δ,	1.0 ft.	2.4	2.9	1.6	2.2	2.1	2.3	2.2
1 = △, 2 = ⌂, 3 = ⊓)	1.5 ft.	2.0	2.4	1.1	1.5	1.8	1.7	1.7
	Control	0.6	0.1	0.5	0.3	0.3	0.5	0.4
Annual leader growth	1.0 ft.	21.5	29.2	16.2	18.9	22.0	20.2	21.1
before pruning (inches)	1.5 ft.	24.4	34.6	19.8	23.5	26.5	24.2	25.3
	Control	31.0	41.7	26.3	31.7	31.9	34.2	33.0
Number of buds on leaders:								
Before pruning	1.0 ft.	26.8	26.4	19.9	19.6	24.0	22.2	23.1
	1.5 ft.	29.6	26.3	21.9	20.6	26.2	23.6	24.9
	Control	33.3	34.7	26.1	25.3	30.4	30.2	30.3
After pruning	1.0 ft.	13.5	16.6	9.3	11.0	11.2	13.5	12.4
	1.5 ft.	18.1	12.9	12.3	13.1	14.1	14.4	14.3
	Control	33.3	34.2	26.1	25.3	30.4	30.2	30.3
Number of branches:								
Per node	1.0 ft.	3.5	3.0	3.6	2.8	3.5	3.0	3.2
	1.5 ft.	3.6	3.9	3.3	2.9	3.8	3.1	3.4
	Control	4.4	4.8	5.3	3.5	4.7	4.4	4.5
Per internode	1.0 ft.	11.6	8.6	6.1	8.3	9.5	7.8	8.6
	1.5 ft.	14.2	11.4	9.1	11.2	12.9	10.4	11.5
	Control	25.7	28.5	18.6	22.4	24.7	23.4	24.1

[1] Average of July and September pruning treatments.

initial tree height in 1965 strongly influenced the number of cones produced in 1971. Oregon trees averaged only 7.4 and 7.7 feet tall in the two orchards, but Washington trees averaged 12.5 and 13.9 feet tall. After 6 years of pruning, the pruned Oregon trees were only 13.7 and 14.2 feet tall and produced about 100 less cones per tree than did the taller pruned Washington trees. It is also not surprising that the taller, unpruned trees in both Oregon and Washington, some 36 feet tall in 1970, outproduced the smaller pruned trees in both States. The height-cone production

Table 3.--Individual orchard[1/] significance table for cone, leader, and branch observations made in two Oregon and two Washington seed orchards.

Source of variation	d.f.	Number of cones per tree	Tree height *feet*	Length of pruned top *feet*	Branches: Length: at 4.5 feet *inches*	Branches: Length: at base of pruned crown *inches*	Branches: Length: halfway up pruned crown *inches*	Branches: Number: per node	Branches: Number: per internode	Leader: Annual growth *inches*	Leader: Number of buds: before pruning	Leader: Number of buds: after pruning
		orchards										
		1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4
Replications	2	No test										
Clones	2	ns ns * **	ns ** ns **	* ** * **	ns ns ns ns	** * ** **	** ns ns ns	ns ** ns ns	ns ** ns **	ns ns ** **	ns ns ** **	ns ns ** **
Time when pruned	1	ns ns ns ns	ns ns ns ns	ns ns ns ns	ns ns ns ns	* * ns ns	ns ns ns ns	ns ** * *	** ns ** *	ns ns ns ns	ns ns ns ns	ns ns ns ns
Pruning treatment	1	ns ns ns ns	** ** ** **	** ** ** **	ns ** ns ns	ns * * ns	ns ns ns **	** ** ** ns	** ** ** **	** ** ** **	** ** ** **	** ** ** **
Interactions	7	ns ns ns ns	** ns ** ns	** ns ** *	ns ns ns ns	ns ns ns ns	ns ns ns ns	* ** ns ns	ns ns ns ns	* ns ns *	* ns ns *	* ns ns *
Control vs. pruning treatment	1	ns ns ns ns	** ** ** **	** ** ** **	ns ns ns ns	** ** ** **	** ** ** **	* ** ** ns	** ** ** **	** ** ** **	** ns ** **	** ns ** **
Among clones/ control	2	No test										
Subsampling/ control	3	No test										
Error	28											

[1/] Orchards: 1--Cottage Grove, Ore.; 2--Sweet Home, Ore.; 3--Shelton, Wash.; 4--Orting, Wash.

* = P less than .05, 95% probability level.

** = P less than .01, 99% probability level.

n.s. = P greater than .05, less than 95% probability level.

Table 4.--Combined orchards significance table for cone, leader, and branch observations made in two Oregon and two Washington seed orchards.

Source of variation	d.f.	Number of cones per tree	Tree height	Length of pruned top	Branch length at 4.5 feet	Branch length at base of pruned crown	Branch length halfway up pruned crown	Number of branches per whorl	Number of branches per internode	Annual leader growth	Number of buds on leader before pruning	Number of buds on leader after pruning
Orchards	3	No test										
Replications/ orchards	8	No test										
Clones/orchards	8	No test										
Time when pruned (T)	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Pruning treatment (H)	1	ns	**	**	*	ns	ns	*	**	**	ns	**
T x H	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Control vs. pruning treatment	1	ns	**	**	ns	**	**	*	**	**	*	**
Error	12		1/					1/	1/	1/		

[1/] Analysis of covariance was used with 11 d.f. for error.

* = P less than .05, 95% probability level.

** = P less than .01, 99% probability level.

n.s. = P greater than .05, less than 95% probability level.

relationship suggests that leader pruning may best be delayed until the trees approach the desired orchard height or early cone production will be reduced *(Fig. 4)*.

Crown shape is a factor in the survival of pruned trees and in the relative efficiency with which the trees can be managed. It should be noted that when different growth rates are present, identical pruning treatments can result in very different crown shapes. For example, the lower branches of pruned Oregon trees grew faster than did those of Washington trees and formed flat tops, but similarly pruned Washington trees did not undergo nearly as drastic a change. Shape is of vital importance when the pruned trees are grown in heavy snow zones. Flat-topped trees, like the 1.0-foot pruned Oregon trees, retain a greater

Figure 2. — A 1.0-foot pruned Oregon tree in 1968 showing dense foliage and flat-top or barrel-crown shape.

Figure 3. — A 1.0-foot pruned Washington tree in 1968 showing less pruning response than the Oregon tree in *Figure 4.*

Figure 4. — A 1.5-foot pruned Oregon tree in 1972. Adjacent trees were not study trees but were topped for the first time in 1971 when the trees were 20—25 feet tall.

snow mass and are more susceptible to snow breakage. Round-topped or pyramid-shaped trees are more preferred in heavy snow zones. Crown shape also affects cone picking efficiency. The dense, barrel-shaped trees are easier to gather cones from because most cones are formed on the outer crown surface where they can be picked without moving the ladders in and out from the base of the tree.

Pruning results in a height reduction in two ways. First, part of each year's leader is cut off. Second, reduced leader growth occurs the following summer. Buds which grow into the new leader the year following pruning are smaller and are not as capable of elongating into full length leaders. Trees pruned in late summer or fall start leader growth the following spring with smaller selected terminal buds than do unpruned trees or trees pruned earlier in the summer. This second type of reduced leader growth makes annual pruning unnecessary since pruning every year at 1.0 foot would result in an average increase of only 16.5 inches per year. This is about half the 32.4-inch annual leader growth rate of unpruned trees. The smallest height increase from every-other-year prunings would occur if pruning were done in September rather than July. Several types of leader failure were observed during the study. Bird damage to pruned leaders was prevalent in two orchards. Damage resulted when birds perched on them and broke off the top buds or deformed the succulent leaders. Pruned trees appear to make more attractive perching spots than unpruned trees. Terminal buds produced by pruning also failed if pruning cuts were made closer than ½ inch above the selected bud.

Lammas growth was seldom observed in either the pruned or unpruned orchard trees. It is likely that the 40- to 100-year-old orchard trees were physiologically too old since lammas growth did occur on the juvenile rootstocks beneath the scions and was reported to commonly develop on July-sheared Douglas-fir in a Christmas tree plantation (Douglass 1963). Lack of lammas growth after pruning on orchard trees necessitated proper apical bud selection because the largest branches, and chief cone producers, developed from the whorl of buds immediately below the bud selected to be the new terminal. If there were few buds in that area, the cone-bearing surface for future years was reduced. Proper bud selection was easier in September than in July because September buds were larger.

The present study explored only the leader-pruning method; therefore, its results cannot be compared with other untested methods. It does not answer the question of whether it is economically practical to prune for height control. To answer that question, each orchard manager must weigh the need for the seed against the cost of obtaining it. But some pruning alternatives have been shown to be definitely better than others, so recommendations can be made which will help orchardists prune properly.

1. Do not start pruning until the trees are at least 15 to 20 feet tall.
2. Prune every other year. Nearly the same average annual height increase is obtained as with annual pruning.
3. Prune leaders of fast-growing trees to 1.0 or 1.5 feet.
4. Trim lateral branches in the top one or two whorls in order to reduce branch competition and the likelihood of multiple tops.
5. Prune in September. This results in less leader growth the following year and is the particularly recommended time if pruning is to be done every other year. Also, terminal bud selection is easier in September.
6. Leader should be severed at least ½ inch above the selected terminal bud.
7. Select the new terminal bud above a whorl of buds (four or more buds located within 1 inch of each other).

This is required in order to maintain an adequate number of large branches in the main whorls.

8. Prune with caution in orchards characterized by rapid growth when the orchards are located in heavy snow zones. Avoid providing flat-topped trees in such snow zones.

Summary

Douglas-fir grafts in two Oregon and two Washington seed orchards were leader-pruned for 6 successive years in July or September to yearly leader growth increments of 1.0 or 1.5 feet. In the 7th year, cone production in each pruning class was as follows: 1.0 foot, 191 cones; 1.5 foot, 207 cones; unpruned, 313 cones. But the number of cones produced per foot of tree height was nearly the same for both pruned and unpruned trees. Lower production per pruned tree apparently occurred because of a reduction in the vegetative base upon which flower buds were laid down, not because pruning induced the trees to become more vegetative. Pruning results in a height reduction in two ways. First, part of each year's leader is cut off. Second, reduced leader growth occurs. Because of this second type of growth reduction, pruning every other year would have been nearly as effective as annual prunings in controlling height growth. In order to provide a large crown surface for cone production, it is recommended that ramets be permitted to grow at least 15 to 20 feet tall before annual or every-other-year pruning is started.

Key words: Douglas-fir, *Pseudotsuga menziesii*, pruning, seed orchards.

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Charakterisierung von Fichten-Klonen (Picea abies Karst.) mit Hilfe morphologischer, physiologischer und biochemischer Methoden

I. Variation der untersuchten Merkmale[1])

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(Eingegangen April / Revision Juli 1973)

1. Problemstellung

Die Entwicklung der Verfahren der Stecklingsvermehrung von Fichte zur Praxisreife wurde 1972 abgeschlossen (Kleinschmit *et al.*, 1973). Damit werden in Zukunft verstärkt in ihrem Genpool stark eingeengte Bestände begründet werden. Um den daraus erwachsenden, aus dem Pappelanbau, aus Gartenbau und Landwirtschaft bekannten Gefahren zu begegnen, ist bei Fichte geplant, nur einen Teil der Anbaufläche mit Stecklingen zu bepflanzen und diese nur in Klongemischen mit mindestens 50 geprüften Klonen anzubauen. Hierbei ist es zur Erzielung sicherer Erträge notwendig, daß die Klonmischungen den jeweiligen Anbaustandorten so angepaßt werden, daß sie sowohl gegen abiotische als auch gegen biotische Schadeinflüsse widerstandsfähig sind und hohe Massen- und Wertleistung erbringen. Um dieses Ziel zu erreichen und um für einen Sortenschutz Identifikationsmöglichkeiten zu haben, sollte als erster Schritt in dieser Untersuchung eine Inventur der Eigenschaften der verschiedenen Klone erfolgen und Merkmale herausgearbeitet werden, die ihre Unterscheidung ermöglichen. Generell können zur Identifikation von Klonen alle Merkmale herangezogen werden, die unter starker genetischer Kontrolle stehen und eine große Variation aufweisen.

Hier sollte geklärt werden, welche morphologischen, physiologischen und biochemischen Eigenschaften für eine Charakterisierung von Fichtenklonen geeignet sind. Dafür sollte die Merkmalsvariation zwischen verschiedenen Genotypen, die Variation beim gleichen Genotyp unter verschiedenen Umweltverhältnissen und die Variation beim gleichen Genotyp unterschiedlichen Alters untersucht werden. Die Untersuchung wurde in Zusammenarbeit zwischen der Abt. Forstpflanzenzüchtung der Nds. Forstlichen Versuchsanstalt in Escherode (Kleinschmit, Sauer) und dem Institut für Forstzoologie der Universität Göttingen (Lunderstädt) durchgeführt.

Bei einer Vielzahl von Klonen der Gattung *Populus* sind die Ansprüche an den Boden (Fröhlich 1966, Grosscurth 1971), das Klima sowie ihre Resistenz gegenüber Pilzkrankheiten und Schädlingsbefall (Fröhlich 1968) ermittelt worden. Zur Unterscheidung der einzelnen Klone konnten Blattform, Verzweigungstypen, Austriebstermine und andere physiologische Merkmale herangezogen werden (Fröhlich *et al.* 1964 a, b, Hattemer 1969, Melchior/Hattemer 1967).

Bei Fichte ist ebenfalls eine Reihe von Eigenschaften bekannt, die eine große Variation aufweisen. So konnten signifikante Unterschiede im Austriebsverhalten (Dormling *et al.* 1968, Kiellander 1966, Reck 1972), den Holzeigenschaften (Kleinschmit/Knigge 1967, Klem 1967), der Frostresistenz (Scheumann/Hoffmann 1967), verschiedenen Samenmerkmalen (Schmidt-Vogt 1972), dem Höhenwachstum

[1]) Die Untersuchung wurde aus Mitteln der Deutschen Forschungsgemeinschaft gefördert. Den Technischen Assistentinnen Frau Gils und Frau Postel wird für ihre Arbeit bei den biochemischen Analysen gedankt.

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