

EFFECT OF ROOTSTOCK VIGOR ON LEADER ELONGATION, BRANCH GROWTH, AND PLAGIOTROPISM IN 4- AND 8-YEAR-OLD DOUGLAS-FIR GRAFTS

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Douglas-fir field grafts on 4-year-old rootstocks exhibited vigorous leader and branch growth and upright tree form. Grafts on container rootstocks planted in the field grew significantly shorter leaders and branches and often developed a branchlike growth habit.

Vigorous leader growth and orthotropic tree form are two highly desirable traits in newly grafted or rooted ramets because such trees are able to quickly form a large cone-bearing surface. Such trees also are not as prone to windbreakage and snowbreakage as are plagiotropic trees. Unfortunately, vegetatively propagated conifers often pass through a lengthy period of plagiotropic growth following propagation. This period may persist for only a few months or may continue for over a decade.

Many factors, such as ortet age, crown position, types of graft, and rootstock, can influence leader growth and growth habit of grafts and cuttings. Ortet age is important; scions collected from physiologically young ortets have a shorter plagiotropic growth period and grow longer leaders than do ramets started from physiologically old ortets (1,6). Position in the crown, where scions are collected, affects *Pinus radiata* grafts for up to 8 years after grafting (5). Type or origin of rootstock significantly influences scion growth. Graft tests of *Picea*

abies (2) and *Pinus patula* (3) show more significant rootstock influence on scion shoot growth than do grafts established directly from ortets.

Height of the graft union above the ground was said to influence leader growth and tree form of Douglas-fir grafts (4). Grafts placed close to ground level on small rootstocks grew slowly and were usually plagiotropic, but grafts placed high on large rootstocks grew longer leaders and were orthotropic. A grafting-versus-budding study indicated that grafted Douglas-fir grew plagiotropically, whereas budded trees grew orthotropically (7).

In this study, the effects of grafting Douglas-fir scions on rootstocks that were well established and vigorously growing in the field were compared with grafts made on rootstocks recently placed in containers. Ramet growth habit and leader elongation for grafts made on the two types of rootstocks were compared when the grafts were 4 and 8 years old.

Methods

Two-year-old seedling rootstocks from a Willamette Valley seed source were either planted in 3.85-liter containers in November 1969 and then grown in a 50-percent shadehouse or batoroot planted in November 1969 in a field location near

Monmouth, Oreg. The bareroot trees were planted in a rototilled area at 3.7- by 3.7-meter spacing.

Rootstocks growing in the 3.85-liter containers were cleft grafted on the tips of the 1969 leaders in April 1970 (5 months after they were potted). Unions were made approximately 30 to 50 centimeters above the tops of the containers. Ungrafted rootstocks grew only 20- to 30-centimeter leaders in 1970. In November 1970, the grafts were removed from the shadehouse, the containers removed, and the trees planted at 0.6 by 1.2-meter spacing in a rototilled transplant bed. The trees were not potbound or characterized by any root deformities when transplanted. They remained in the transplant bed through the 1971 growing season, were lifted in December 1971 with a small rootball of soil around each tree, and field planted in permanent positions at the Monmouth, Oreg., outplanting site. The grafted trees were located at 7.3-meter intervals within the rows of ungrafted rootstocks that had been field planted in 1970. The final result was 3.7- by 3.7-meter spacing, with field-planted rootstocks alternating with the container-grafted ramets.

In April 1974, the rootstocks that had been field planted in November 1970 were cleft grafted 1.0 to 1.5 meters above ground level. Grafts were made on the

tips of the 1973 leaders. Leader growth of rootstocks varied from 50 to 80 centimeters the year before grafting. The same type of cleft graft used in 1970 on the container-planted trees was used on the field-grafted trees in 1974.

Scions for both field and container grafting came from 50 trees in several Oregon and Washington plantations. Orset age was 65 and 69 years in 1970 and 1974. The same clones were grafted on both types of rootstocks. Total graft height (excluding the distance from the ground to the graft union), orthotropic and plagiotropic growth, and length of the longest branch in the 1976 whorl were all measured in May 1978. At that time the container-grafted and field-grafted trees were 8 and 4 years old, respectively. Measurements excluded the yet-to-be-completed 1978 growth increment.

Weeds and grass at the field site were controlled by rototilling and mowing in early summer of each year. No fertilization or irrigation was used. Rootstock branches were gradually removed until none remained in 1977.

Results

By 1978, the 4-year-old grafts made on field-planted rootstocks had grown into normal, orthotropic trees with good leader and branch growth. Annual leader growth averaged 64 centimeters

for the 4 years after grafting (table 1). At that time, the 8-year-old, container-grafted ramets looked very different from the 4-year-old, field-grown ramets. The older container-grafted ramets were smaller, and their annual leader growth increments averaged only 27 centimeters (table 1). The difference of 37 centimeters in annual leader growth between container-grafted and field-grafted trees was highly significant ($p < 0.001$).

Container-grafted rootstocks were especially prone to develop plagiotropic growth habits (fig. 1); 8 years after grafting, 61 percent of the ramets had noticeable lean from the vertical because of the branchlike growth habit of their main boles (table 1). By 1976, 72 percent had formed orthotropically distributed buds or branches in at least one whorl (whorls in which the buds or branches were evenly distributed around the entire circumference of the stem



Figure 1.—An 8-year-old, container-grafted tree (6 years in place in the field) displays plagiotropic growth, which often occurred when grafts were made on small rootstocks incapable of promoting vigorous scion growth. Adjacent orthotropic trees are 4-year-old field grafts made on established rootstocks.

Table 1—Growth and form of Douglas-fir grafts made on container-grafted and field-grafted rootstocks

Rootstock treatment	Number of ramets	Graft age	Ramet height ¹	Leader growth per year	Longest branch in 1976 whorl	Trees with noticeable lean from vertical	Average number of years after grafting for orthotropic whorl formation
		Years	- - - Centimeters - - -			Percent	Years
Container-grafted ²	51	8	217	327	348	61	7.6
Field-grafted ⁴	41	4	255	364	386	0	.3

¹Ramet height excludes the distance from the ground to the graft union.

²Grafted April 1970 on rootstocks growing in 3.85-liter containers. Grafted trees were removed from the containers in November 1970, grown in a transplant bed until December 1971, and then permanently field planted.

³Differences between container- and field-planted grafts for annual leader length and for 1976 whorl branch length were both highly significant ($p < 0.001$).

⁴Grafted in April 1974 on rootstocks that had been field planted in November 1970.

rather than on just two or three sides). The percentage had increased to 92 by 1978. Average number of years after grafting for the change from plagiotropic to occur was 7.6 (table 1). The same change had occurred during the first growing season in grafts made on established field-planted rootstocks.

The longest branch in the 1976 whorl averaged 86 centimeters on field-grafted rootstocks; similar branches of container-grafted ramets averaged only 48 centimeters (table 1). This 38-centimeter difference was highly significant ($p < 0.001$). Reduced branch growth occurred in all plagiotropic trees, and the condition persisted for several years after the grafts had become orthotropic. Several of the container-grafted ramets may have established extensive root

systems sooner than most trees did after field planting. This is suggested since they overcame their plagiotropism and grew normal length branches much sooner than similar container-grafted trees did (fig. 2).

Discussion

Results indicate that rootstock vigor influenced both leader and branch growth and tree form of the grafted ramets. Normal, orthotropic trees grew when grafting was delayed until the rootstocks were capable of promoting vigorous leader growth. This was accomplished by planting the rootstocks in permanent seed orchard positions 4 years prior to grafting. This time allowed the trees to grow extensive root systems that were in

intimate contact with the soil. Field grafting could probably have been done 3 years after field planting and similar results still obtained. A good indicator of a rootstock's ability to support vigorous scion growth is length of rootstock leader growth the year prior to grafting. If growth exceeds 40 to 60 centimeters, the rootstock is ready to graft. If leader growth is less, a scion grafted on such a tree will probably grow slowly and plagiotropically. Any treatment that reduces the rootstock's contact with the surrounding soil will lower its ability to promote the desired scion growth.

When Douglas-fir grafts are made on small rootstocks growing in containers, on recently field-planted or transplanted trees, or on trees of noticeably low vigor,



Figure 2.—*The largest and most orthotropic 8-year-old, container-grafted tree (6 years in place in the field). The graft grew branches that were orthotropically distributed for the last three growing seasons. No growth inhibition was evident in leaders or branches of the orthotropic area of the tree.*

the ramets will always pass through a period of plagiotropic growth during which both leader and branch growth are reduced. Several seed orchards on the West Coast were established in the last 8 to 10 years with container-grafted rootstocks, which were transplanted 1 or 2 years later into permanent seed orchard positions. These orchards have all experienced lengthy periods of plagiotropic growth, but in most the ramets slowly became orthotropic. Unfortunately, the lean from the vertical, the asymmetrical lower crown, and the increased susceptibility to snowbreakage and windbreakage will persist for many years. In comparison, in the

orchards where grafting was done on larger, well-established, field-planted rootstocks the ramets have all grown well-formed, orthotropic trees with excellent leader and branch growth.

Slow growth which occurs after container grafting results in additional years being needed before the grafts form large crown areas for abundant seed production. Evidence from this study and from observations of ramets growing in other seed orchards indicates that reduced leader and branch growth continues for at least 8 years after grafting. This period may vary at different orchards according to the site and the cultural treatments applied to hasten root growth.

Rootstock vigor, or growth-promoting potential, is probably the most important factor influencing leader and branch growth and growth habit of Douglas-fir ramets. Naess-Schmidt and Søegaard (4) reported similar leader growth and plagiotropic results with Douglas-fir, but they concluded that the differences resulted because of the height that the union was placed above the ground. Their high-grafted trees grew longer leaders, which were less subject to branchlike growth than were their low-grafted trees. Differences in size and condition of the rootstocks prior to grafting were overlooked (Large trees were grafted high and small trees were grafted low.) and, consequently, the important role of rootstock

vigor or growth promotion was not detected. Other variables—such as position in the crown from which the scions were collected, ortet age, and physiological condition of the ortet—influence graft growth and form, but none have as much effect as the growth-promoting ability of the rootstock. Without a vigorous rootstock, the grafts will always grow slowly and plagiotropically for a number of years.

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