Topworking Coastal Douglas-fir

Randy Johnson and Don Copes

Research Geneticist and Forest Genetics Team Leader (retired), USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR

Abstract

Topworking, the grafting of young scion material into tops of older, reproductively mature trees, was attempted with coastal Douglas-fir. Compared with grafting onto juvenile rootstock, grafts in the older trees had a larger percentage of scions with female flowers (27 percent vs. 5 percent, $p<0.01$) and more female flowers per scion (0.82 vs. 0.13, $p=0.16$); however, the increases were very small from a practical point of view.

Introduction

The rate of gain that can be achieved in a tree breeding program is limited by a number of factors, one being the number of years needed to breed control-pollinated families for the next cycle. Completing crosses has been more of a problem for Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] than for some other conifers. Douglas-fir seedlings rarely produce flowers as early as 2 yr following germination and produce only small quantities of seed before age 10 (Silen 1978). During the course of breeding, coastal Douglas-fir selections are typically grafted into breeding orchards where control pollination can take place starting as early as 3 yr after grafting, although crossing success at this time is sporadic. Delays in generating full-sib families increase the generation interval and reduce rate of gain.

A common method to stimulate flowering on young southern pine grafts is to graft the young scion into the tops of older trees or grafts (Bramlett and Burris 1995; Bramlett 1997). This procedure is commonly referred to as topworking. This is presently being used to reduce the breeding interval in pine tree improvement programs (e.g., Gooding and others 1999). No results from topworking Douglas-fir have been reported in the literature to date. This could be because breeders have simply not reported their attempts, or because the high levels of graft incompatibility inherent in this species have discouraged practitioners from attempting grafts onto older trees or grafts, most of which are not highly graft-compatible. The objective of this study was to examine the effectiveness of topworking in coastal Douglas-fir.

Methods and Materials

On March 7, 2001, dormant scions were collected from 11 "juvenile" 6-yr-old trees (~2 m (6.5 ft) tall) and stored at 2 °C for 2 wk. These same 11 trees were used as juvenile rootstock. Six 20-yr-old grafted trees were selected for the mature comparison (the physiological age of the trees was 50+ yr). These six trees had been used to produce graft-compatible rootstock seed and, in the past, had produced good cone crops in response to stimulation.

On March 21, 2001, scions from each of the 11 juvenile trees were grafted into the top of each of the 6 mature trees using top cleft grafts. In addition, 5 grafts were made into each of the juvenile trees, one being an autoplastic graft, i.e., grafted on to itself; the other four grafts were with scion from the other juvenile trees (table 1). One autoplastic graft was also made in each of the older grafted trees.

In April 2002, all 17 trees were bark girdled to promote flowering (see Ebel 1971 and Wheeler and others 1985 for discussions of stem girdling in Douglas-fir). A pruning saw was used to make one girdle at breast height three-quarters around the circumference of the tree. A second girdle was made on the opposite side of the stem at a distance below the first girdle approximating the tree's DBH. Procone® (gibberellic acid) was injected into the rootstock at the prescribed rate of 0.036 ml cm-2 (0.232 ml in-2) of basal area. Basal area at breast height was used for the mature rootstocks, and basal area at 0.6 m (2 ft) was used for the juvenile rootstocks. In May 2003, flower counts were made on each of the surviving grafts.

Two statistical analyses were performed. A chi-square test was used to examine whether there was difference in the number of grafts that had flowered (at least one flower).

The contingency table examined grafts on juvenile vs. mature trees and grafts with or without flowers. The second analysis examined the differences in flower counts per graft. Counts were square-root-transformed because counts are a Poisson distribution. The SAS mixed procedure was used to analyze the model:

$$\sqrt{(\text{flowers}+1)} = \text{rootstock}_i + \text{clone(rootstock)}_{ij} + \text{scion}_k + \text{rootstock} \times \text{scion}_{ik} + \text{error}_{ijk},$$

where rootstocki is the fixed effect of rootstock, i.e., tree age (contrast between juvenile and mature trees); $\text{clone(rootstock)}_{ij}$ is the random effect of *j*th rootstock or grafted interstock clone within a rootstock age category; scion_k is the random effect of the *k*th scion clone; and $\text{rootstock}\times\text{scion}_{ik}$ is the random effect of rootstock age category by *k*th scion interaction.

Results

Only two juvenile trees had female flowers on any of their grafts, and one had only one flower (table 1). None of the grafts produced pollen catkins. Five of the six mature trees had flowers on their juvenile grafts, although tree E had only one flower. Eighteen of the 66 grafts on the mature trees (27 percent) had at least one flower; only 3 of 55 grafts (5 percent) flowered on the juvenile rootstock. The chi-square value of 9.956 was statistically significant (p=0.0016).

The average number of flowers per graft was 0.26 for the juvenile rootstock (13 flowers on 49 grafts) and 0.82 for the mature rootstocks (46 flowers on 56 grafts). The probability level for this difference from the mixed model analysis was 0.1597, suggesting that this was perhaps marginally statistically significant.

All six of the older rootstock had prolific female and male flowers throughout their crowns. A branch would be covered with flowers until it reached the graft union; then flowering decreased dramatically (figure 1). Of the three autoplastic grafts found in the older trees (three were missing), all had female flowers and two had male inflorescences.

Discussion

A statistically significant increase in female flowering appears to result from topworking young Douglas-fir scions. More grafts had flowers when grafted onto the older trees, compared with younger rootstocks, and more flowers per scion were found on the older trees. The practical significance of this small increase at the age tested is questionable, however. Results in loblolly pine (*Pinus taeda*) are much more practical; studies have found 2.5–5 or more flowers per graft 1 yr after grafting (Bramlett and Burris 1997, Gooding and others 1999). Two years after grafting, Bramlett and Burris (1997) found an average of nine female flowers per graft and also found pollen catkins on some grafts. The loblolly numbers are such that a breeding program could make great strides in accomplishing a crossing program.

Table 1. Untransformed female cone counts of grafts. X represents a dead graft; M is a missing graft arising either from mortality or loss of a tag.

	Juvenile rootstock clone												Mature rootstock clone						
Scion clone	1	2	3	4	5	6	7	8	9	10	11	Mean	A	B	C	D	E	F	Mean
1	0		0		0	0				0		0	0	X	0	3	0	0	0.60
2		0	9	1	0						X	2.5	0	0	X	X	0	0	0.00
3	X	0	0					0		0		0	0	0	0	0	M	0	0.00
4	0	0		0					0	0		0	0	0	3	4	0	0	1.17
5			0		0	X	0			0		0	0	0	X	X	X	0	0.00
6	0	0				0	0		0			0	2	0	8	M	0	2	2.40
7				0	0		0	0			0	0	0	0	4	4	0	0	1.33
8			3			0	X	0			0	.75	1	0	1	1	0	0	0.50
9		0		X			0		0		0	0	0	X	X	1	0	0	0.25
10				0		0		X	0	0		0	0	0	0	1	0	2	0.50
11	0				0			0	0		0	0	0	0	1	5	1	2	1.50
Mean	0	0	2.4	0.25	0	0	0	0	0	0	0	0.26	0.27	0.00	2.13	2.38	0.11	0.55	0.82

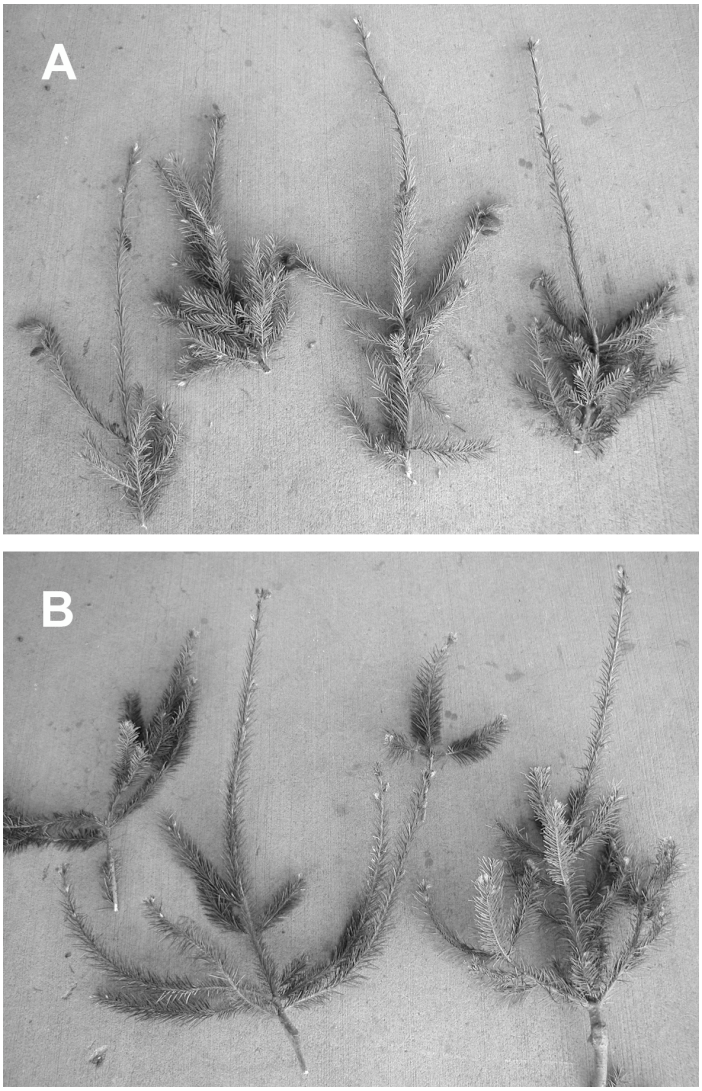

Figure 1. Grafted and ungrafted branches from the same main whorl of a mature tree: (A) ungrafted branches with flowers, (B) grafted branches without flowers

Our results with Douglas-fir suggest that very little time could be saved in completing a crossing program by topworking vs. normal breeding-orchard crossing because we did not find large numbers of female flowers and there were no pollen catkins in the topworked grafts. Better results may have been possible if we had waited an extra year before flower stimulation, since the grafts were twice as large and had considerable more branch tips where female flowers arise. Because of the cyclic nature of flowering in Douglas-fir, it was not feasible to stimulate the trees a second consecutive year; however, it should be noted that there were no flowers on any of the grafts the following year.

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