United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

Research Note
PNW-RN-487
March 1989

Bark Scoring Problem Grafts in Five Douglas-Fir Seed Orchards: A Case History

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Abstract

A bark-scoring trial was carried out on 379 of 1,234 grafts in five western Oregon seed orchards. Ages of grafted trees in 1983 ranged from 5 to 16 years. Scoring was done in April, June, or August of the first and third years of the 4-year test. Cuts across the defective interface of the union were made every 3.1 to 4.3 cm with a small, gas-powered chain saw. Many trees showed improved vegetative vigor after treatment. Annual mortality in the five orchards averaged just 1.6 percent when all defective grafts were treated. Diameter growth of rootstocks was least in incompatible grafts and greatest in compatible grafts. Form class (scion diameter divided by stock diameter) increased slightly during the study. The greatest improvement in average compatibility occurred in trees treated in April. Among the three orchards treated in April, the orchard with the youngest grafts responded to scoring treatments most favorably. Two different types of graft incompatibility were found: the inherent type with brownline around the entire circumference of the union, and induced type with brownline around only part of the circumference. The induced type usually began in grafts with one-sided compatible unions. Wound tissue that formed in bark scores of the induced incompatible grafts was usually free of brownline, but brownline appeared in all wound tissue of bark scores of inherently incompatible grafts. All the inherently incompatible grafts and some of the induced incompatible grafts will require additional treatments every 2 or 3 years to maintain a live cambium at the union.

Keywords: Grafting, vegetative propagation, seed orchards, incompatibility, compatibility.

Introduction

Grafted seed orchards of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) are often subject to tree losses caused by delayed graft incompatibility. Cells of incompatible stock and scion combinations react to cell-to-cell contact with the other graft partner by walling off the foreign cells with a separation zone of dead, suberized tissue (Copes 1970). The separation zone of dead cells is termed "brownline." This woundlike response occurs along the entire union interface in bark cells of both the stock and scion. This type of graft failure is the product of the inherent defense mechanism of each tree. Cells of unlike genotype react by cell lysis (death) at or near the point of contact (Copes 1970). It is the same process that enables trees to wall off invading insects and disease organisms or cover physical wounds with an impervious or protective covering (Biggs and others 1983).

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If losses from graft incompatibility occur several years after grafting, the economic impact is large in lost seed production and decreased genetic variability, and in the number of years required to replace the incompatible grafts. Trees grafted before the mid-1970's are especially troublesome because the unimproved rootstocks used at that time averaged only 65-percent compatibility (Copes 1982). Since the mid-1970's, the breeding and use of highly graft-compatible rootstocks in Douglas-fir seed orchards of the Pacific Northwest have reduced the number of graft unions becoming incompatible. Rootstocks now average 90- to 95-percent compatibility, but the other 5-10 percent are or will become problems in the future (Copes 1981).

Improving long-term survival and performance of established grafts is difficult, but bark scoring is one cultural technique that has potential for reducing graft losses and improving tree vigor. This type of scoring is done by making numerous vertical cuts across the defective union. The primary objective of bark scoring incompatible grafts is to improve translocation across the graft union. Bark scoring of problem Douglas-fir grafts temporarily overcomes the incompatibility by physically removing a portion of the impervious barrier of dead tissue separating the living stock and scion cambial cells. New cambia then differentiate across the saw cuts in the newly formed callus tissue. Only one report of bark scoring to correct translocation and structural problems in graft unions of conifers has been published (Karlsson 1970). Karlsson's treatment consists of cutting one to three vertical strips of bark from each Douglas-fir graft union. The width of individual bark strips removed ranges from 1.3 to 7.6 cm; the width and number of cuts differ with stem diameter.

Thousands of problem Douglas-fir grafts currently exist in seed orchards, clone banks, and breeding archives of the Pacific Northwest that might benefit greatly if subjected to proper bark-scoring treatments. Some Douglas-fir seed orchardists have already begun using modified bark-scoring techniques similar to those of Karlsson (1970), but the scoring is often not begun until the grafts are in very poor condition, or the scoring treatment is not done often enough or intensively enough to restore the trees to full vigor. Uncertainty over the optimum time of treatment, size and number of cuts, method of applying the scores, age of trees to begin treatment, and possibility of inducing severe insect problems have caused many orchardists to take a "wait and see" attitude. This paper addresses their concerns by reporting the results of bark-scoring investigation carried out in five orchards from 1983 to 1986.

Methods

Common incompatibility symptoms that identify trees in need of bark scoring are scion-stock overgrowth, stem fluting at or close to the union, excessive resin flow from the union, chlorotic needles, extremely poor shoot growth, or unions with well-defined separation zones (bark discontinuities) between scion and stock (fig. 1, A-C). Symptoms of early incompatibility in older grafts were indicated by the presence of small pits or holes in the bark that occurred sporadically along the circumference of the union and the beginning of a separation zone or line along part of the union (fig. 2B). Unions of questionable compatibility status were tested by making one or more exploratory cuts in suspect areas to see if internal brownline was present in the exposed inner bark tissues. The compatibility status of many unions in orchards 1, 2, and 4 was also known from previous anatomical testing when the grafts were 2 years old.

Figure 1—External appearance of compatible and incompatible graft unions. **(A)** Incipient bark decline in an incompatible union is evidenced by a slight bark discontinuity along the union. **(B)** A clearly defined bark separation at the incompatible union. **(C)** In 1985, brownline from an inherent incompatible graft is shown in 1983 wound tissue. **(D)** A compatible graft union where the bole of the stock is slightly larger than that of the scion. No external symptom of bark decline is evident. **(E)** A compatible graft union where the bole of the scion is slightly larger than that of the stock. No evidence of bark degeneration was found.

Figure 2—Method of bark scoring Douglas-fir graft unions with a small, gas-powered chain saw. **(A)** The defective graft union area. **(B)** Incipient bark decline is indicated by the presence of a line of pits or fissures along the union. **(C)** Newly cut bark scores in August 1983. **(D)** Healing of the 1983 cuts in August 1985. **(E)** Newly made bark scores of the second treatment in August 1985. The 1985 cuts were centered between the scars of the 1983 treatment. **(F)** Cuts were made only where brownline was found; the healthy areas of indeterminate unions (induced incompatibles) were not treated.

Table 1—Orchard statistics for graft age, number of trees, month of bark scoring, percentage of trees with 1-sided unions, cuts with coneworm frass, stock, and scion diameter, and the space between vertical cuts

Orchard number	Graft age	Month scored	Number of grafts	Trees with 1-sided unions	Cuts with coneworm frass	1983 scion per stock stem diameter by compatibility class[a]			Spaces between vertical cuts
						C	Q	IC	(1983/1985)
	Years			*Percent*		*Centimeters*			
1	13-16	April	189	19.6	19	24.3/22.7	23.6/20.5	24.7/19.4	3.6/4.3
2	5	April	134	24.1	3	—[b]/—	—/—	—/—	—/4.7
3	10-12	April	316	15.2	15	12.5/12.6	12.9/12.4	12.1/11.2	3.0/4.3
4	10-15	June	298	18.5	16	15.3/15.3	13.5/13.7	13.0/13.3	2.8/4.3
5	12	August	297	8.1	42	22.1/21.3	17.9/16.8	21.5/19.1	2.8/4.1
Means					19	18.5/18.1	17.0/15.9	17.8/15.8	3.1/4.4

[a] Compatibility class: compatible (C), indeterminate (Q), and incompatible (IC).
[b] No diameter measurements were taken in 1983 for orchard 2.

The bark-scoring treatments were done in 1983 and 1985 on 379 of 1,234 trees growing in five orchards within 50 miles of Corvallis, Oregon. The condition of all 1,234 trees was monitored through 1986. At the start of the study, graft age in orchards 1, 3, 4, and 5 ranged from 10 to 16 years. Orchard 2 contained 5-year-old grafts (table 1). All trees with defective unions were bark scored. Control trees with defective unions could not be maintained for this study because the orchard trees were too valuable for seed production to let them die without attempting to keep as many alive and as productive as possible.

Scoring was done on all unions with obvious external symptoms of incompatibility and on one-sided unions, which usually resulted from not matching both sides of the scion with both sides of the rootstock at the time of grafting. Bark scoring was done in April in orchards 1-3, in June in orchard 4, and in August in orchard 5. Study trees received standard seed orchard care.

Cuts in the bark for the scoring treatment were made with a small, gas-powered chain saw with a 12-inch bar. Defective graft unions were bark scored with evenly spaced vertical cuts (fig. 2, A-F) that included both scion and rootstock tissues. Scoring was begun in the poorest area of the union and progressed to the right and left around the stem until the entire circumference was treated (fig. 2C) or until areas free of brownline (internal zone of dead bark tissues at the union) were found (fig. 2F). Scoring of healthy areas (free of brownline) was avoided. Cuts (5 to 7.5 cm long) were made just deep enough to expose the outer xylem. In 1983, the cuts were located every 2.5 to 3.8 cm (table 1). Bark scores in 1985 were centered in the undisturbed areas between the healed-over cuts from 1983 (fig. 2E).

Measurements and observations to monitor changes in fitness or vigor of study trees were made from 1983 to 1986. All trees of low vigor having abnormally short leaders and chlorotic needles were noted in 1983, and any change in shoot growth or needle color was also noted. New tree mortality was recorded each year. Many unions were photographed immediately before and after bark cutting in 1983 and 1985 and again 1 year later in 1984 and 1986, respectively. Photographs were used to detect visual changes in union condition. In 1983 and 1986, the diameter of the scion was measured at the point of contact between the stock and scion. Rootstock diameter was measured immediately below any enlargement in the union. Diameters for orchard 2 were not measured in 1983 because the trees were too small (2.5 to 5.0 cm) for significant size differences to have developed.

Graft condition was classified as compatible (C), indeterminate (Q), or incompatible (IC) in 1983, and as C, IC, Q, or dead (D) in 1985. The external symptoms previously described, plus the presence or absence of brownline, and whether the brownline encompassed all or just a portion of the circumference were the criteria used to separate unions into different groups. Unions with questionable external appearance were scored with one or more exploratory cuts in suspect areas. The cambium, phloem, and cortex areas exposed by the cuts were examined for the presence of internal brownline. Grafts classified as Q-type had brownline, but the brownline did not initially form a continuous line around the entire circumference of the union. Q-type grafts were bark scored only in the areas of the union with obvious separation zones. The scoring treatment was stopped when healthy bark tissue was encountered. Grafts recorded as IC usually had obvious external symptoms of incompatibility. Bark scores in such grafts revealed internal brownline around the entire circumference, and scoring was done around the entire stem. Grafts classified as compatible were free of external symptoms of incompatibility, and no internal brownline was seen when exploratory cuts were made in unusual areas requiring examination.

Observations were made of insect activity in the unions and of low tree vigor. Orchardists were concerned that bark scores would create an insect problem or make an existing condition more severe. The presence of externally visible frass of *Dioryctria abietivorella* (Groté) in the graft union before bark scoring was noted from 1983 through 1985.

Quantitative growth data were subjected to analysis of variance by using the SAS procedure for general linear models (SAS Institute Inc. 1985). Diameters were transformed into logarithms to reduce the positive correlation between size of diameter and variance. Orchards were the units of treatment, so the reader is cautioned on the statistical limitations of interpreting treatment effects when within-orchard comparison of treatments was not possible. The effect of graft age on scoring was studied in contrasts of 5-year-old grafts (orchard 2) with 13- to 16-year-old grafts (orchard 1). Effect of time of year of bark scoring was examined in contrasts of three similar orchards: orchard 3 (April), orchard 4 (June), and orchard 5 (August). Compatibility data from the five orchards were analyzed with chi-square methods because each tree was recorded as belonging in one of three or four discrete classes (C, IC, and Q; or C, IC, Q, and D) in 1983 and 1985, respectively.

Results

After 4 years, the greatest increase in compatibility occurred in the orchard with the youngest grafts. A 4.2-percent increase occurred in C-type grafts that had been 5 years old at first scoring, while a 2.6-percent increase occurred with 13- to 16-year-old grafts (table 2). The difference was not statistically significant at $P<0.05$. Scoring done early in the growing season appeared to be somewhat more compatible than later treatments. A 2.2-percent increase in C-grafts resulted when cutting was done in April, a 1.2-percent increase in June, and only a 0.3-percent increase in August. The differences among months were not significant at $P<0.05$. The increase in percentage of C-grafts came from improvement of unions originally classified as Q and from some unions that may have been improperly classified in 1983 as IC-unions.

Bark scoring trees twice during the 4-year study did not stop all mortality from occurring. About 6.6 percent of all 1,234 trees in the study were dead by 1986. This equaled an annual loss of about 1.6 percent (table 2). Most trees dying during the study had been classified as IC-grafts in 1983, and a majority of them had extreme scion overgrowths, chlorotic needles, and poor shoot growth in 1983. Many were probably too weak to form new vascular connections after scoring. More encouraging than the low annual mortality rate was that many low-vigor trees grew new, healthy green needles and had normal shoot and branch growth after scoring.

The relation between stem diameter and graft age was confounded by site differences among orchards. Beginning diameters (table 1) and annual diameter growth from 1983 through 1986 (table 2) suggest that orchard 3 was the poorest site. Rootstock diameters within orchards were progressively smaller in trees belonging to the Q- and IC-classes of compatibility than to the C-class (table 1). Scion diameters showed an opposite trend because of the effects of scion overgrowths in one-sided or incompatible unions. The 1983 difference among orchards in percentage of grafts in the C-, Q-, and IC-classes was highly significant ($X2= 47.8$, 8 df) because of past roguing and use of different compatibility screening techniques at establishment. Averages among orchards ranged from 50 to 80 percent for C-grafts, 7 to 23 percent for Q-grafts, and 13 to 26 percent for I-grafts (table 2).

Table 2—Orchard statistics for diameter growth of the scion and rootstock, union form, percentage of trees in each compatibility class,[a] and annual mortality rate

Orchard number	Annual diameter growth from 1983[b] to 1986 (scion)/(stock)			Union form[c] (1986)/(1983)				Trees within compatibility class in 1983				Change in compatibility class between 1983 and 1986				Annual mortality
	C	Q	IC	C	Q	IC	D	C	Q	IC	D	C	Q	IC	D	
	Centimeters											Percent				
1	1.85 / 1.75	2.39 / 2.06	1.70 / 1.07	1.08 / 1.08	1.16 / 1.16	1.36 / 1.31	1.44 / —	72.5	9.0	18.5	—	+2.6	-1.1	-9.0	+7.4	1.8
2	— / —	— / —	— / —	1.04 / —	1.20 / —	1.37 / —	1.52 / —	50.4	23.4	26.2	—	+4.2	-1.4	-9.9	+7.1	1.8
3	1.30 / 1.27	1.47 / 1.09	1.55 / .86	1.00 / .99	1.14 / 1.07	1.29 / 1.10	1.20 / —	65.8	13.6	20.6	—	+2.2	-2.5	-4.8	+5.1	1.3
4	1.83 / 1.85	1.75 / 1.73	1.25 / 1.14	1.00 / 1.00	1.00 / .99	1.00 / .99	1.06 / —	80.2	6.7	13.1	—	+1.2	-3.0	-4.0	+6.0	1.5
5	1.78 / 1.62	1.50 / 1.04	1.17 / 1.02	1.03 / 1.01	1.14 / 1.05	1.20 / 1.13	1.22 / —	68.4	11.8	19.8	—	+0.3	-4.1	-3.7	+7.4	1.8
Means	1.70 / 1.63	1.78 / 1.47	1.42 / 1.02	1.03 / 1.02	1.13 / 1.09	1.25 / 1.14	1.25 / —	69.1	11.9	18.9	—	+2.1	-2.4	-6.3	+6.6	1.6
Diff.	.07	.31	.40	.01	.04	.11	—									

[a] Compatibility classes: compatible (C), indeterminate (Q), incompatible (IC), and dead (D).
[b] No diameter measurements were made in 1983 for orchard 2.
[c] Union form was derived by dividing the diameter of the scion by the diameter of the rootstock.

Many 10- to 16-year-old trees had sizable overgrowths on the mismatched side of stems when first bark scored. The percentage of trees with one-sided unions in 1983 differed among orchards ($p<0.001$), probably because two orchards previously had been selectively rogued of many defective unions. A major change in the percentage of trees with one-sided unions was not noted after 4 years because insufficient radial growth had occurred to completely eliminate the size difference between the scion and rootstock that existed at the start of the study.

Annual diameter growth of rootstocks was less for IC-grafts (1.0 cm) than for Q- (1.5 cm) or C-grafts (1.6 cm) (table 2). Diameter growth of scions exceeded that of rootstocks for all compatibility classes, but this inequality was smallest for C-grafts (0.1 cm) and progressively larger for Q- and IC-grafts (0.3 and 0.4 cm, respectively). Month of bark scoring did not noticeably influence growth differences between stock and scion.

Form values for unions at the beginning of the study indicated C-class grafts to have scion and stock stem diameters of similar size, whereas the diameters of stock and scion of Q- and IC-grafts were more unequal (1.02, 1.09, and 1.14 for C, Q, and IC, respectively) (table 2). Differences among orchards were highly significant both in 1983 and 1986 ($p<0.001$). Changes in stem diameter after 4 years and two bark-scoring treatments were increases of 1 percent, 4 percent, and 11 percent by scions over rootstocks for the C-, Q-, and IC-grafts, respectively. Scion diameters of trees that died during the test averaged 25 percent greater than diameters of supporting rootstocks. Union form was not changed appreciably by month of scoring or graft age after two scoring treatments.

Centering the saw cuts of the 1985 bark scoring treatment in the uncut areas between the 1983 scores resulted in the 1985 cuts being more widely spaced than were the cuts in 1983. This occurred because the diameter growth after the 1983 scoring treatments increased the circumference of each union by about 18 to 23 cm (table 1). The differences among orchards in 1983 and 1985 were not significant ($p<0.05$).

Dioryctria (coneworm) frass was visible in many overgrown unions before bark scoring in 1983. The bark scores of older grafts showed more evidence of insect activity than did bark scores of younger trees. At the end of the growing season after treatment, 15 to 42 percent of the cuts of 10- to 16-year-old trees had visible frass, while only 3 percent of bark scores in 5-year-old grafts showed similar symptoms (table 1). Coneworms were also more prevalent in bark scores of overgrown IC-unions than in Q-unions. Coneworm activity was greatly reduced by the end of the second year after scoring. At that time, many of the more vigorous Q- and IC-grafts, which had insects in the bark scores the previous year, were almost free of insects, but *Dioryctria* remained in trees of low vigor that had large, overgrown IC-unions.

Discussion

The absence of untreated IC- and Q-grafts made it difficult to directly determine how much actual benefit was obtained from bark scoring, but the 1.6-percent tree mortality per year in this test seemed quite low. Average annual mortality was 6-8 percent during the 7-9 years after establishment of two untreated Douglas-fir orchards (Copes 1967). Most failures from 1983 through 1986 occurred in grafts that were weak when the study was started, and tree death was not a result of the scoring treatments. Karlsson (1970) reports losses of 2.5 percent annually in 3- to 8-year-old grafts after scoring, and he states that 2.5 percent was much less than during previous years when the trees were not bark scored.

Mortality difference between the Karlsson (1970) test and this study did not result from graft age because average annual mortality in this study was the same for 5-year-old grafts as for 13- to 16-year-old grafts. In addition, mortality rate was not related to month of treatment. Lower mortality in my study probably resulted from using slightly more effective bark-scoring techniques. Three bark-scoring factors enhance graft survival: width of cuts, number of cuts, and frequency of treatment. Treatments consisting of many narrow cuts heal faster than a few large, wide cuts, and repeating treatments every 2 or 3 years results in the continuation of more live-cell contact between the stock and scion.

Bark scoring done in early spring seemed to be slightly more beneficial than that done in June or August. The trees scored in April had a greater increase in percentage of compatible unions, whereas trees treated in August had the least increase. Exact interpretation of the effect of month of bark scoring is difficult because treatments were not replicated within orchards. The effect of this design compromise on actual results was probably small, but the limitation on statistical inference was great.

A small increase in percentage of C-class unions after two treatments occurred because of elimination of all brownline in some Q-grafts. Also, a few Q-grafts were incorrectly identified in 1983 as IC-grafts because they had brownline around the entire circumference of the union. In this study, Q-grafts were, by definition, unions with brownline that failed to extend completely around the circumference, yet all Q-grafts will ultimately develop a complete brownline zone around the stem if left untreated for several years. When that final stage of Q-grafts is reached, the grafts appear identical to those in the IC-class. The small increase in the proportion of C-unions is somewhat misleading because only two scoring treatments were completed. If a third treatment had been done, nearly all the original brownline would have been removed and many of the grafts classified as Q-type would have been reclassified as compatible.

Most Q-grafts showed evidence of having grown for many years with vascular connections on only one side of the union (fig. 1F). Comparisons of 1983 compatibility data, determined from external symptoms and inner bark observations, with anatomical graft test data of the same stock-scion combinations at age 2 (Copes 1970), revealed that about 20 percent of the grafts, which tested compatible at age 2, had never formed a union around the circumference of the bole. About one of every five compatible unions developed scion overgrowths above the mismatched areas during the 3 to 14 years after anatomical testing and had been classified during bark scoring as Q-grafts. In such trees, brownline in younger grafts was confined to the immediate areas near the mismatched surface, and in older grafts the brownline was found in union tissues farther away from the original mismatch area. Examination of Karlsson's (1970) photographs of five classes of compatibility suggested that many of his class 1 and 2 unions may also have been one-sided unions in various stages of degeneration.

The development of brownline in compatible unions may be linked to inadequate translocation or lack of growth factors in or near the defective areas of the union. The rootstock areas immediately below the mismatched areas typically have had little or no cambial activity after grafting. In one-sided grafts, factors from within or near the mismatched area of the rootstock appear to stimulate brownline formation in adjacent healthy tissues. Once the brownline mechanism is activated, it can, over several years, stimulate the formation of an impervious barrier of dead bark cells around the entire circumference of the union and utlimately cause graft failure. I have termed this type of graft rejection "induced incompatibility." The internal symptoms of induced incompatibility are anatomically identical to the internal symptoms of inherent incompatibility described by Copes (1970, 1974) but are not caused by the genotypic differences between contiguous stock and scion cells.

Scoring is effective in reducing and ultimately eliminating brownline-induced incompatibility in Q-grafts because brownline usually does not develop in new tissues of bark scores if adequate connecting vascular elements are formed between the stock and scion. A portion of the original brownline remained in the untreated areas between cuts after two scorings, so an additional treatment in the remaining brownline areas will be needed to remove the last of the brownline barrier.

Scoring was also effective in maintaining or increasing tree vigor of the many inherently incompatible grafts, but scoring of IC-grafts did not prevent brownline from developing in the new tissues filling the saw cuts (fig. 1E). Observations made of knife cuts 1 to 4 years after scoring revealed brownline in many healed saw cuts. Karlsson (1970) also noted that brownline reappears in the wounds of some unions. All inherently incompatible grafts will require additional scoring treatments at regular intervals as long as the grafts live if a functional cambial contact is to be kept across the union. Some stock-scion combinations are so highly incompatible that brownline develops rapidly in the scores, and no gain in tree vigor is achieved.

Seed orchardists are justly concerned about any cultural treatment creating open wounds on trees. The presence of coneworms at the end of the first growing season in new cuts made on 10-year-old (or older) grafts was not a long-term problem in vigorous trees. Most graft unions were free of signs of coneworm activity by the second year if the trees were reasonably vigorous. Extremely weak trees having coneworms in the unions before bark scoring often continued to show evidence of insect activity 2 years after scoring. Younger graft unions seemed to experience less damage from insects because the saw cuts completed healing sooner than did cuts in older trees with thick, platy bark. Also, there were fewer coneworms in incompatible unions of young trees before bark scoring. Little difference in insect damage to the union was seen among trees scored in April, June, or August. The coneworms' production of multiple, overlapping generations each year (Koerber and others 1976) may have allowed them to attack new wounds throughout the growing season.

The bark-scoring procedures used in this study may be beneficial when used on incompatible grafts of other species. Species that develop impervious barriers of dead tissue at the graft union would be good candidates for scoring. Incompatible grafts on ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) have responded favorably to bark scoring.[1] The scoring technique has also been effective in saving wire-girdled trees in evaluation plantations.

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[1] Personal communication, Bruce Boom, USDA Forest Service, Tree Improvement Center, Chico, CA 95928.

Bark scoring of seed orchard trees seems to be an effective treatment for extending survival and vigor of both inherent and induced incompatibility grafts of Douglas-fir. Early detection of physically defective unions and prompt corrective treatment to reduce or eliminate barriers to early union formation can help to eliminate conditions that become more serious as the grafts grow older. Bark tissues of unions that have failed to join properly several years after grafting should be scored in the defective areas to promote union formation. Personal field experience with Douglas-fir grafts indicates that such treatment should begin by the third or fourth growing season and that repeated treatments are usually required to maintain or increase tree vigor. The inherently incompatible graft will require treatment as long as the trees live, but most induced incompatible grafts will probably require only three treatments to restore most trees to their original compatible condition. A 2-year interval is adequate for the first two treatments, but later treatments might be done at 3- or 4-year intervals.

Literature Citations

Biggs, A.R.; Merrill, W.; Davis, D.D. 1983. Discussion: response of bark tissues to injury and infection. Canadian Journal of Forest Research. 14: 351-356.

Copes, Donald L. 1967. Graft incompatibility and union formation in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Moscow: University of Idaho. 186 p. Ph.D. thesis.

Copes, Donald L. 1970. Initiation and development of graft incompatibility symptoms in Douglas-fir. Silvae Genetica. 19: 101-107.

Copes, Donald L. 1974. Genetics of graft rejection in Douglas-fir. Canadian Journal of Forest Research. 4: 186-192.

Copes, Donald L. 1981. Selection and propagation of highly graft-compatible Douglas-fir rootstocks—a case history. Res. Note PNW-376. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 8 p.

Copes, Donald L. 1982. Field test of graft compatible Douglas-fir seedling root-stocks. Silvae Genetica. 31: 183-187.

Karlsson, I. 1970. Delayed incompatibility in grafted clones of Douglas-fir. Res. Note 52. [Location of publisher unknown]: British Columbia Forest Service. [Pages unknown].

Koerber, T.W.; Roettgering, B.; Parks, G. 1976. Preventing fir coneworm damage to newly grafted ponderosa pine. Tree Planters' Notes. 27: 18-19, 24.

SAS Institute, Inc. 1985. SAS procedures guide for personal computers, Version 6. Gary, NC: SAS Institute, Inc. 373 p.

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