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Epicormic Branching of California Black Oak: Effect of Stand and Tree Characteristics

Abstract

Young California black oak (*Quercus kelloggii* Newb.) stands usually require thinning to increase production of acorns and wood products, but epicormic branches, which yield no acorns and constitute a serious lumber degrade, often result. A crown thinning in 60-year-old hardwood stands on a south exposure at the Challenge Experimental Forest in the northern Sierra Nevada of California created basal areas that ranged from 20 to 35 m^2 per ha. Trees in a control and bordering small openings expanded the basal area range. In 1976 or 6 to 9 years after thinning, 2069 living and dead epicormic branches on 189 California black oak trees were observed. Statistically significant (α = 0.05) predictors of epicormic branching were position in stand, cardinal direction of bole face, and bole segment—variables that generally affected epicormic branching on eastern species of deciduous oaks. Number of epicormic branches increased with decreasing stand density, proximity to openings, on south and east bole faces, and with increasing distance above the stump. These findings, together with silvicultural recommendations for enhancing crown development and lessening epicormic branching of California black oak, are discussed.

Introduction

Although native California hardwoods are virtually unmanaged and underutilized, the growing emphasis on ecosystem management and concern for a broad range of resource values is expected to bring about major changes. In California, black oak (*Quercus kelloggii* Newb.) exceeds all other native oak species in volume, distribution, and elevational range (McDonald 1969). Acorns are probably the most valuable current "yield" from California black oak (McDonald *et al.* 1983) with quality wood products a distant second.

To increase crown size and acorn production for wildlife management and to increase diameter and volume growth, managers need to thin oak stands (Tappeiner and McDonald 1980). But thinning usually results in excessive epicormic branching that in turn leads to serious lumber degrade. Epicormic branches are short (1 cm to 0.7 m long) branches that develop mostly below the live crown and produce few, if any, acorns. Such branches are responsible for more degrade in hardwood lumber than any other single agent (Kormanik and Brown 1967).

Because epicormic branches reduce wood quality, are visually unattractive, and produce no acorns, resource managers need information on how best to manage California black oak to lessen their presence. Our goal was to quantify a number of tree and stand characteristics and identify those that caused epicormic branching. Such knowledge should help managers decide on an appropriate strategy for increasing stand growth, growing quality trees, and using conifer/hardwood mixtures to enhance both stand growth and bole quality.

Methods

Site and Stand

The study site, located about 42 km east of Oroville in the northern Sierra Nevada of California, is characterized by high site quality (black oak site index 18 m at 50 years [Powers 1972]), abundant annual precipitation (1727 mm), a warm climate (mean annual temperature 13°C), and a generally southern exposure.

The species composition and structure of the hardwood forest at Challenge is typical of that in the region and elsewhere in California and southwestern Oregon. In addition to California black oak, other species included tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.) and Pacific madrone (*Arbutus menziesii* Pursh), both of which seldom produce epicormic branches. The forest originated from a wildfire that killed most of the conifers, and the hardwoods to groundline. The hardwoods promptly sprouted. Hence the forest consisted of three hardwood species, was even-aged (about 60 years old when initially measured), and in general had a large number of trees per hectare. Within this general description, however, tree density was by no means uniform; rather it was high in places, less high in others, and even low occasionally. Small openings were scattered throughout.

Based on 0.1-ha plots located in relatively homogeneous stands, stocking of trees averaged 1628 per ha in the range of 5 to 41 cm d.b.h. (diameter at breast height) before thinning. Overall basal area was 47.7 m^2 per ha. Height of dominant and codominant trees averaged about 17 m. Average diameter growth rate of trees in unthinned stands was low—about 0.15 cm per year.

The epicormic branching investigation, part of a large stand- and tree-growth study, was conducted in eight stands. Seven of the eight stands, with an average basal area of 46.7 m^2 per ha, were randomly assigned a residual basal area in the range of 20 to 35 m^2 per ha. Residual basal area differed for each plot and was not replicated. The basal area of the eighth stand, the control, amounted to 48.0 m^2 per ha. "Crown" thinning was used to create open spaces into which crowns of retained trees could expand. Trees adjacent to small openings were designated "border" trees.

Sampling and Analysis

The development of epicormic branches was observed annually in the course of measuring trees and quantifying stand growth. In 1976 or 6 to 9 years after thinning, we counted epicormic branches on 189 black oaks: 93 in thinned plots (hereafter called "interior" trees), 71 in a control plot, and 25 on borders. These trees comprised all of the California black oaks 9.0 cm d.b.h. or larger in each plot.

The number of epicormic branches in all three categories totalled 2069: 83 percent living and 17 percent dead. Epicormic branches were counted on each California black oak bole, which was divided into cardinal directions. A bole "face," projected from the stem center, consisted of 45 degrees of bole circumference on each side of a cardinal direction. Sometimes a cluster of buds or short stubby branches were present. These were counted as one epicormic branch. Slender 5.4-m long aluminum rods, placed against the tree, defined each face. In addition, each bole face was divided into 2.5-m vertical segments. The bottom of the base segment began at 30 cm above mean ground line and extended to the base of the second segment. Concentrating on the two basal segments is appropriate because it is the basal portion that usually is the most valuable part of a hardwood tree (Trimble and Mendel 1969).

The total number of living and dead epicormic branches, relative to several tree and stand characteristics, was analyzed by analysis of variance of transformed (square-root) values and linear and nonlinear regression (SAS Institute Inc. 1988).

Results and Discussion

Number of epicormic branches on California black oaks were all significantly ($\alpha = 0.05$) related to bole segment (just above stump or next highest), bole face (cardinal direction), and position in stand (border versus interior) (Table 1). Stand basal area was represented by the blocking factor, which was not truly replicated. Therefore no P value is presented for this term.

TABLE 1. Analysis of variance of epicormic branching[1] on California black oak boles, northern California.

Source of variation	Degrees of freedom	Sum of squares	F	P
Block	7	116.53	–	–
Border vs interior	1	54.68	23.63	0.0001
Crown class	2	8.89	1.92	0.1994
Border x crown class	2	0.60	0.13	0.8791
Error (a)	176	407.29	–	–
Bole face	3	40.20	30.66	0.0001
Bole segment	1	16.11	36.87	0.0001
Face x log	3	1.36	1.04	0.3756
Error (b)	1316	575.24	–	–

[1]The dependent variable is the square-root of the number of epicormic branches. This transformation provided an analysis for which the residuals appear to be approximately normal.

For bole segment, the number of branches increased in general with distance from the stump to the base of the living crown. The mean number of epicormic branches (interior and border combined) was 4.4 branches for the base log and 6.7 for the second log, a highly significant difference ($P < 0.0001$) (Table 1).

Mean number of epicormic branches differed significantly by bole face (Table 1), which was analyzed further by Tukey tests ($\alpha = 0.05$). We found that (a) mean number of epicormic branches did not differ between south and east faces, (b) south and east faces had significantly more branches than north and west faces, and (c) mean number of epicormic branches was significantly greater on west than on north faces. The combination of south aspect and incident sunlight striking tree boles may account for these differences.

No relationship ($P = 0.15$) for epicormic branches among crown classes (59 dominant trees, 94 codominant trees, 36 intermediate trees) was found (Table 1). This was not surprising; number of epicormic branches apparently is a function of both crown configuration and bole surface area. We observed that smaller trees of the intermediate crown class do not have enough bole area to contain many dormant buds, which give rise to epicormic branches; medium-sized trees, most often of the codominant crown class, have enough bole area but narrow crowns and produce many epicormic branches; larger trees of the dominant crown class have adequate bole surface area and large crowns, but tend to have few epicormic branches.

Epicormic branching in California black oak also is related to decreased availability of site resources that results in an interesting postponement of mortality. While taking annual growth measurements, we noticed that overtopped, and hence smaller trees of the suppressed crown class, die from the top down and produce epicormic branches that also die from the top down. Although these trees usually succumb in 5 or 6 years after the top begins to die, epicormic branching prolongs life for an interval during which fire or logging could occur and kill the overstory. These trees then would sprout from the root crown. This form of epicormic branching took place on 10 trees in the control, but constituted 42 percent of the total number of epicormic branches produced there. Although unimportant silviculturally, this mortality postponement apparently constitutes an adaptive strategy to the fire environment in which this oak has evolved.

The amount of basal area that remains after thinning appears to influence the development of epicormic branches (Figure 1). However, because of the data collection techniques used in this study, it was not possible to statistically test the effect of basal area in the analysis of variance. Consequently, it was evaluated separately. To describe the relationship between number of epicormic branches and basal area, we applied a model using nonlinear regression and 189 trees:

$$Y = \exp[\beta_0 + \beta_1 I + \beta_2 ba] \qquad [1]$$

in which

I = 1 for border trees, 0 otherwise.
ba = breast height basal area (m^2/ha) of each stand, and
Y = number of epicormic branches per tree.

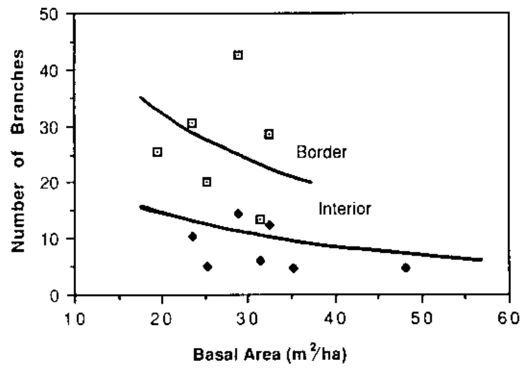

Figure 1. Number of epicormic branches for lower 4.9 m of tree bole relative to stand basal area for border and interior California black oak trees calculated by using equation [1].

The estimate for β_0 was 3.185 (asymptotic s.e. = 0.373); for β_1, 0.841 (asymptotic s.e. = 0.162); for β_2, -0.028 (asymptotic s.e. = 0.011). Because basal area is fixed for trees in any given stand, hypothesis testing of the basal area term in this regression is not recommended. The root mean square error was 11.7. This function indicates that a decrease in basal area of 10 m^2/ha, from 30 to 20 m^2/ha for example, would result in an expected increase of 7.8 epicormic branches per border tree and 3.4 branches per interior tree.

In this study, border trees averaged 19.2 more branches in the first two logs than interior trees. The reason for this can only be surmised, but it is logical that border trees have access to more site resources (soil moisture and light) than interior trees. After a disturbance that opens up a stand, these "extra" resources relative to the typical narrow crown of forest-grown trees, become manifest in epicormic branches. In a sense, these branches function as part of the crown for a short time and then die after the true crown develops.

Basal area is particularly important because the greater its value, the fewer the number of epicormic branches. This finding (Table 2), in conjunction with growth estimates reported earlier (McDonald 1980), allows the land manager to compare the thinning level with the expected growth and number of epicormic branches.

Study results show that the slightest reduction in the density of California black oak stands produces epicormic branches. Fully 94 percent of interior trees on thinned plots, but only 48 percent of trees in the control produced these branches. And the number of epicormic branches

TABLE 2. Relationship of basal area to predicted growth of stem volume and predicted number of epicormic branches on California black oak trees 10 years after thinning.

Basal area (m^2/ha)	Predicted volume growth per interior tree over 10-year period	Predicted number of epicormic branches for lower 4.9 m of tree bole	
	(m^3)	Interior	Border
19.5	0.113[1]	–	32.5
23.4	0.102	12.6	29.1
25.3	0.097	12.0	27.5
28.7	0.087	10.9	25.1
31.2	0.080	10.2	23.4
32.4	0.077	9.8	22.6
35.1	0.070	9.1	–
48.0	0.034	6.4	–

[1]Values smoothed by regression: volume growth = 0.167-0.0028 basal area, root mean square error = 0.0218

can be large—up to 86 per lower 4.9 m of bole on border trees. The paradox is that while thinning promotes fast-growing trees, it also causes large numbers of epicormic branches to develop. Thinning also is desirable for development of large crowns capable of producing large and frequent acorn crops, vital to many species of wildlife.

Of particular note is that the tree and stand characteristics that cause epicormic branching on black oaks in California are the same characteristics in general that lead to epicormic branching on oaks in the eastern United States (Ward 1966, Carl H. Tubbs, pers. comm.). This similarity is of ecological interest, given the large differences in environments (season of precipitation, frequency and intensity of fire) between California and the eastern United States.

Management Considerations

Study results suggest three possible silvicultural considerations to lessen epicormic branching in similar and mixed stands, and to increase acorn and wood product yields. The first two involve a thinning regime and the second deals with compartment size.

The interrelationship of stand density, tree vigor, and crown size denoted in this study suggests that a series of thinnings may enhance both acorn and wood production. The key is that vigorous trees have better developed crowns and produce fewer epicormic branches. After the first thinning, some degree of epicormic branching probably is inevitable. However, more site resources would be available to the remaining trees, and their vigor and crown size would increase. Fewer epicormic branches and more acorns should be produced in ensuing thinnings. Consequently, the manager might wish to thin lightly at first and follow with heavier thinnings.

In naturally-occuring mixed hardwood/conifer stands, which are common at mid-elevations in southern Oregon and California, California black oak most often originates as root-crown sprouts and the pines and firs as seedlings. With careful and innovative stand manipulation, each species can aid the other. Partial shade from the oaks can lessen environmental stress for the conifers, especially when seedlings, and their shade, when older, can shield black oak boles and lessen epicormic branching.

Because California black oaks on borders produce a disproportionately large number of epicormic branches relative to interior trees, the proportion of trees near the border should be minimized by managing the species in larger compartments, thereby reducing the amount of edge.

Sudden exposure of California black oak trees to increased amounts of site resources almost always leads to epicormic branching and a degrade in bole quality. However, the magnitude of branching and the environmental factors that cause it may vary with site quality, tree size, and the amount of sunlight striking the tree bole. This study presents results for trees of one age (but of various sizes) on one exposure, and provides initial knowledge for at least part of the epicormic branching phenomenon. A second study, soon to be reported, will examine epicormic branching relationships for older trees on a different exposure.

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