Viability of thinning sessile oak stands by girdling

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ABSTRACT

The effects of girdling were analysed in a sessile oak (*Quercus petraea* Matts. Leibl.) forest with an 80-year-old coppice with standard structure in northern Spain. The study evaluated the viability of girdling as an alternative to felling trees during crown thinning. Eighty-four direct competitors of selected future crop trees were girdled by double notching and peeling. Three years after girdling, 100% of the treated trees had died. Approximately half of the girdled trees did not resprout. The occurrence of basal sprouting was very low, and more than 35% of the sprouts had very low vigour. No correlation was found between sprouting and the diameter of the girdled trees or the distance to their nearest neighbour. A negative relationship between the diameter of the girdled tree and the stage of decline was recognized. Girdling is an economic alternative to non-commercial thinning in oak stands and can be seen as an effective structural enrichment treatment.

Key words: Girdling/ Snag/ Crown thinning/ Sprouting/ Stage of decline/ Silviculture/ Spain.

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INTRODUCTION

Girdling has been traditionally used in silviculture in temperate areas as a means to control non-valuable broadleaved trees in conifer stands. Girdling, as a thinning treatment is frequently described in North American silviculture treatises (Hawley and Smith, 1982; Zobel and Talbert, 1984; Smith et al., 1997) and in forest enhancement handbooks (Hart and Comeau, 1992; NRCS-IOWA, 2002; UNH, 2004). In contrast, girdling is scarcely mentioned in European literature (Hubert, 1983; Axelson et al., 2002). None of the classic European silviculture textbooks devotes more than a few sentences to this treatment (Schädelin, 1942; González-Vázquez, 1948; Evans, 1984; Leibundgut, 1984; Lanier, 1986; Burschel and Huss, 1987; Cappelli, 1988; Kramer, 1988; Boudru, 1989; Röhring and Gussone, 1990; Schütz, 1990; Mayer, 1992) showing that girdling is not usual in European forestry and there is even contrary advice against this treatment for forest aesthetic and safety reasons related to the risk of girdled trees falling down.

Since the last decade of the 20th century, girdling began to be considered as an effective structural enrichment treatment to enhance the abundance of snags in the forest as important structural features (Franklin et al., 1997; McComb and Lindenmayer, 1999). Although the management of dying and dead trees is recognized as an important silvicultural strategy for sustainable forestry, the phytosanitary risk of retaining declining trees and snags must be assessed (Fujimori, 2001). Girdling has also been considered an advantageous thinning technique in comparison to felling trees in very dense stands as it reduces the risk of windthrow due to a more gradual canopy opening (Peri et al., 2002).

However, one of the disadvantages of girdling is that it may produce basal sprouting. Thus, Smith et al. (1997) only recommended this treatment on species that do not produce epicormic sprouts. In this work we have evaluated the suitability of girdling as a thinning technique in natural *Quercus petraea* stands in the Cantabric Range (northern Spain). We focus on: (a) effectiveness of girdling for killing the main stem, (b) determination of the incidence of basal sprouting in the efficacy of the treatment, and (c) detection of changes in basal sprouting and decline due to tree size or competitive position.

METHODS

Study site

The study site was a natural oak forest located in the southern Cantabric Mountain Range (Spain) (42º59´7´´N; 4º30´17´´W), at an altitude of 1220 m, where climatic conditions are intermediate between Mediterranean and Oceanic regions (average annual rainfall of 1150 mm and mean annual temperature of 7ºC). The stand, representative of many oak forests in the area, is an 80-year-old coppice forest with standards, characterized by an average height (H_m) of 16.5 m, a basal area (G) of 36 $m \times ha^{-1}$, a quadratic mean diameter at breast height (D_{mg}) of 14 cm, and a density (N_{ha}) of 2200 trees$\times ha^{-1}$.

In late spring of 2001, three 1000 m^2 plots were established and direct competitors of selected future crop trees were girdled using power saws by notching two rings around the tree within a distance of 20 cm and 1 cm into the wood and peeling off the bark between them (Smith et al., 1997). Due to ergonomic reasons, the notches were made at breast height. The three plots ended up with 41, 19 and 25 girdled trees (Table 1). According to Smith et al. (1997) thinning type was established as crown thinning favouring the most promising trees by eliminating the most competitive tree. The leading competitors of the crop trees were selected among the upper crown class and the bulk of the intermediate and suppressed classes were left to restrict epicormic branching on the residual stems (Leibundgut, 1984; Schütz, 1990). Diameter of the girdled trees varied from 9.25 to 30 cm (average of 15 cm) and the distance between selected trees and their direct competitors ranged from 30 to 240 cm (average of 105 cm).

Table 1. Plot characteristics in the 80-year-old experimental stand before girdling and mean variables of the girdled trees. Data referred to the hectare.

Plot	Stand before girdling						Trees girdled		
	N	G	HO	Hm	Dm	Dg	N	G	Dm
1	2240	34.5	16.1	16.1	13.1	14.0	190	7.8	15.1
2	2200	36.0	15.9	16.0	13.4	14.4	240	4.2	14.7
3	3030	40.9	16.5	16.6	12.5	13.1	410	7.9	15.1

N: stem number per hectare; G: basal area per hectare ($m^2 \times ha^{-1}$); H_0: dominant height (m); H_m: average height (m); D_m: quadratic mean diameter at breast height (cm); D_g: mean diameter at breast height (cm)

Assessment of the natural dynamic of girdled trees

Basal sprouting expressed as number of sprouts per tree (BRT_i), length of the most vigorous shoot ($LONG_{i,}$), and vigour of the shoots (VIG_i) was qualitatively classified three years after girdling; all categories are described in Table 2. Five vigour classes (VIG_i) were established based on conditions of foliage according to Cadahía et al. (1991). Stage of decline (ED_i) of girdled trees was evaluated according to Carmichel and Guynn (1983) and Moorman et al. (1999); four decline classes, based on physiologic condition of the bark and branches, were assessed. Tree diameter (DBH_i) and distance between girdled trees and their nearest neighbour ($DIST_i$) were classified in four categories.

Data analysis

Spearman rank order correlations between the categorical variables were examined to evaluate relationships between the mean values of quantitative basal sprouting variables (BRT_i, $LONG_i$, $VIG_{i,}$), stage of decline (ED_i), tree diameter (DBH_i) and competitive position ($DIST_i$). Because of the use of categorical variables the correspondence between variables was subjected to a multiple correspondence analysis (MCA) (Lebart *et al.,* 1977; Benzecri, 1979). MCA is a method for analysing categorical variables processes such as seed morphology, growth patterns or browsing effects and has been used previously in forest ecology and plant physiology (Relva and Veblen, 1997; Gil et al., 2002; Echeverría and Lara, 2004). The theoretical basis of this procedure is that the structure of categorical multivariate data-sets can be explored and made more accessible by displaying their main patterns and regularities in two-dimensional plots. Contrary to correspondence analysis (CA), the variance explained by each MCA axis has no significant interpretation and was, therefore, not taken into account. Thus, the percentage of inertia calculated, based on the transformed eigenvalues (Benzecri, 1979), was taken as indicator of the total variance. All the analyses were performed using the multivariate and nonparametric procedures of STATISTICA (Statsoft, 2006).

RESULTS

Out of the 85 treated trees, 84 had died three years after treatment. Only one tree survived due to incomplete notching and it was therefore excluded from analysis. Between plots, no statistical significant difference was found in any of the measured variables.

Therefore, all statistical analyses were focused on the total number of trees (84). No basal sprouting was observed in 55 % of the snags (class 0). In the 45% of girdled trees that did produce basal sprouts 37 % of the shoots showed medium to severe defoliations (VIG classes 3 and 4). None of the basal sprouts from the snags could be assigned to the vigour class 1 (Shoots without defoliation, VIG_1) (Table 2). All shoots presented symptoms of oak powdery mildew (*Microsphaera alphitoides* (Grif. & Maubl.)): young twigs and leaves were covered with a greyish white mycelium and had conidia (asexual spores), distorted foliage and shoots (IDF, 2001). In contrast, no signs of this fungus were found in non-treated trees.

Table 2. Categorical variables and their acronyms, used in ordination.

Description	Code of the variable	Categories (Levels)
Stage of decline of the girdled tree	ED	0- Living tree 1- Dead tree with bark and limbs intact 2- Dead tree with loose and sloughing bark and most of the limbs broken 3- Snag with decayed and sloughing bark and a broken top.
Number of basal sprouts per tree	BRT	0- No sprouts 1- One basal sprout per tree. 2- Two basal sprouts per tree. 3- Three or more basal sprouts per tree.
Vigour of the shoots	VIG	0- No shoots 1- Shoots without defoliation. 2- Shoots with light defoliation. 3- Shoots with medium defoliation. Many leaves present microfila, deformations or pathological damages. 4- Shoots with severe defoliation. Most of the leaves present microfila, deformations or severe pathological damages.
Length of the most vigourous shoot	LONG	0- No shoots 1- The most vigorous shoots are more than 60 cm long. 2- The most vigorous shoots have a length between 30 and 59 cm. 3-The most vigorous shoots are less than 30 cm long.
Diameter at breast height of the girdled tree	DBH	1- DBH < 12.5 cm 2- DBH between 12.6 cm and 15 cm 3- DBH between 15.1 cm and 17.5 cm 4- DBH > 17.6 cm
Distance between the girdled tree and its nearest neighbour	DIST	1- Distance < 50 cm. 2- Distance between 50 and 100 cm. 3- Distance between 100 and 150 cm. 4- Distance > 150 cm.

The correlation between stage of decline (ED_i) and diameter (DHB_i) of the girdled trees was negative (Table 3). Basal sprouting dimensions (BRT_i, $LONG_i$, $VIG_{i,}$) were positively and highly significant correlated. No significant correlation could be found between competitive position ($DIST_i$) and any other variable (Table 3).

Table 3. Spearman Rank Order Correlation coefficients between the categorical variables assessed at the individual level to evaluate relationships between the mean values of quantitative basal sprouting variables (BRT_i, $LONG_i$, VIG_i,), stage of decline (ED_i), tree diameter (DBH_i) and competitive position ($DIST_i$). Where: BRT_i = Basal sprouts per tree; $LONG_i$ = Length of the most vigorous shoot; VIG_i = Vigour of the shoots; $DIST_i$ = Distance between the girdled tree and his nearest neighbour.

	ED	BRT	LONG	VIG	DIST	DBH
ED	1					
BRT	n.s.	1				
LONG	n.s.	0.89**	1			
VIG	n.s.	0.90**	0.96**	1		
DIST	n.s.	n.s.	n.s.	n.s.	1	
DBH	-0.23 *	n.s.	n.s.	n.s.	n.s.	1

* = $P < 0.05$; ** = $P < 0.01$; n.s. = non-significant

Two dimensions were selected in the multiple correspondence analyses according to the strong inflexion detected in the plot of successive eigenvalues (Figure 1). These two dimensions reproduced 29 % of the inertia. Dimension 1 accumulated 18 % of the inertia and included, in the negative axis, the three variables representing absence of sprouting (BRT 0, LONG 0, VIG 0). The positive axis was strongly saturated by the same variables but with classes other than zero. The first dimension can, therefore, be interpreted as an indicator of the existence of sprouting (Figure 2). In the second dimension, absorbing 11 % of the inertia, a decreasing order in sprouting vigour (VIG_i) was found in association with the shoot length. An obvious biological interpretation is that this dimension represents the vigour and intensity of sprouting.

Clumping is apparent in the first two dimensions between the variables stage of decline (ED_i), diameter (DBH_i) and distance between trees ($DIST_i$) (Figure 2). These variables show very low values in both dimensions. The plot also displays marked clumping of the variables around the origin of coordinates. No trend in appearance can be detected. Distance between these variables and the indicators of sprouting (BRT_i, $LONG_i$, and VIG_i) shows a clear absence of correlation.

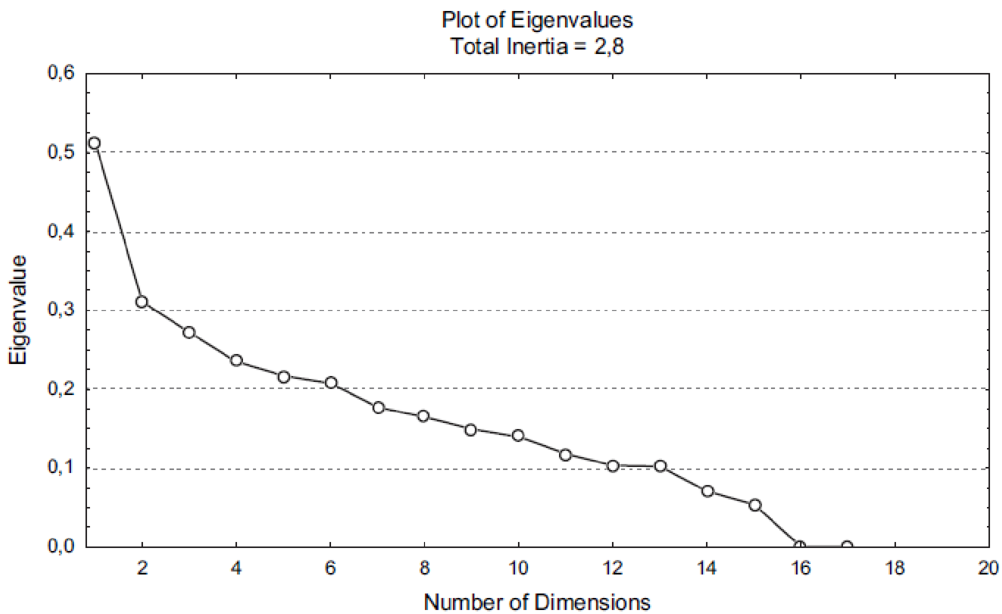

Figure 1. Multiple correspondence analysis. Successive eigenvalues plot.

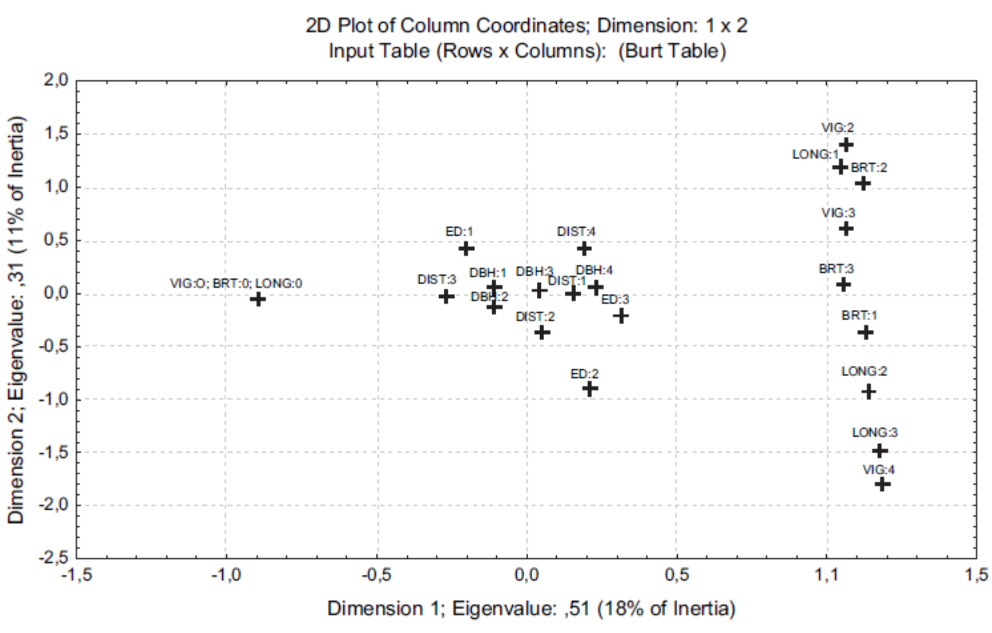

Figure 2. Multiple correspondence analysis. Ordination of categories. Only the two first ordination axes are retained. Where: ED_i = stage of Decline; BRT_i = basal sprouts per tree; $LONG_i$ = length of the most vigorous shoot; VIG_i = vigour of the shoots; $DIST_i$ = distance between the girdled tree and its nearest neighbour; DBH_i = diameter a breast height.

DISCUSSION

The type of girdling applied killed the trees completely, and the occurrence of basal sprouting was very low. Thus, the treatment produced a similar effect to felling the tree. No correlation was found between sprouting and tree size or competitive position with respect to adjacent trees. Probably the low sprouting and the absence of correlation can be explained by the relatively high density of the remaining density. The crown thinning applied which favoured crop trees directly and positively, avoided direct sunshine on the stem of either the selected tree or the girdled competitors. Therefore, conditions for the activation of epicormic buds or for root sprouting were not fulfilled. The negative correlation between stage of decay and tree diameter indicates a more gradual decay in trees of bigger size, probably related with the higher accumulation of reserve substances and the higher volume to be decomposed by fungi and insects.

The present study does not cover the health effects of girdling in *Quercus petraea.* The main oak disease observed in the study area is root rot caused by *Armillaria mellea* Vahl. Kummer. The scattered and selectively applied treatment presented here, together with the reduced basal sprouting make a major outbreak of this pathogen unlikely. In any case, the risk of pathological infection can be considered similar for girdling as for tree felling, since in both treatments the roots of the trees are left and infection is mainly related to the vigour of the stand and to the number of treated trees (Phillips and Burdekin, 1992; IDF, 2001). In relation to pest problems, the loose and decayed bark found in most of the snags and the condition of secondary pests of the bark boring beetles *Scolytus intricatus* (*Scolitidae), Agrilus biguttatus* and *A. viridis* (*Buprestidae*) in the Cantabrian Range suggest a low risk of damage due to these insects as result of girdling (Moraal and Hilszczanaski, 2000). Even more, girdling would maintain shady conditions in the stand, thus decreasing the susceptibility for infestation by these species (Evans et al., 2004).

The importance of snags in the forests as an element of structural diversity has been repeatedly described since the last decades of the twentieth century. Snags provide essential food resources, provide a store of nutrients that can be cycled through forest ecosystem, serve as nursery site, and provide habitat for various organisms (Kohm and Franklin, 1997; McComb and Lindemayer, 1999). However, in managed forests declining trees, snags and fallen trees are not frequently found because traditional forestry prescribes that the trees are harvested before they begin to die or decline. Their presence in the forests has long been seen as a waste of wood fiber, a fire hazard, or a phytosanitary risk. Girdling, applied as a crown thinning on sessile oak stands produces low economic losses and can be seen as a viable management option for the recruitment of dead and dying trees enriching forest stands with structural features. Thus, the girdling presented here can be included among the structural enrichment strategies of dispersed retention (Frankin el al., 1997) enabling the structural complexity of the stand to be increased (Fujimori, 2001).

Our results show that crown thinning by girdling may be particularly useful in three types of forests: those where a reduction of density is considered suitable but no investment return can be expected, stands where incorporation of snags to the ecosystem is desirable to achieve higher levels of structural diversity, and forests where negative effects derived from canopy opening must be prevented (i.e. epicormic sprouting on remaining trees or windthrow). On the other hand, caution is advised when applying the treatment in stands of reduced vigour in order to avoid damage due to the honey fungus *Armillaria mellea*.

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