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Effect of cleaning and thinning on height growth and girth increment in holm oak coppices (*Quercus ilex* L.)

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Abstract

This article studies the influence of cleaning or thinning intensity and of coppice age at the time of silvicultural treatment, on the growth of shoots remaining on the stool, in *Quercus ilex* coppices.

Two experimental designs were used to answer these questions. The first studied the effect of two cleaning intensities on 4, 8, 15, 20, and 25 year old coppices. The second studied the effect of 4 thinning intensities (26%, 42%, 58%, or 78% removal of the initial basal area) on 43 and 57 year old coppices. In both cases, control plots undergoing no silvicultural treatment were maintained for each age class.

The results, 4 and 5 years after silvicultural treatment, concerned girth increment and height growth of coppice shoots.

Cleaning or thinning consistently had a positive influence on girth increment. In young coppices, less than 25 years old, mean annual girth increment was approximately 6 mm in the controls and double that under heavy cleaning. In older coppices, girth increment was lower in controls (3 mm per year) but the effect of thinning was very positive and, under very heavy thinning, growth was more than 11 mm per year.

Cleaning and thinning often modify height growth. This effect was found to be either positive or negative and no general trend could be defined which was valid for all the age classes.

Silvicultural treatments also had a positive effect on the appearance and growth of epicormic shoots on the holm oak trunks.

The results were also analysed at the stool level. The number or percentage of shoots removed had a positive effect on the individual growth of selected shoots.

Introduction

The simple coppice method, where standing trees are clearcut every 20 or 30 years, is particularly suited to the production of holm oak firewood, which is currently its prime economic value.

Another types of management are now being envisioned in holm oak stands in order to augment their value (Ducrey 1988). This can take the form of cleaning or thinning to raise the forest canopy for better protection against forest fires, or to begin a conversion towards a stored coppice (i.e. a coppice in which only one or exceptionally two shoots per stump remain). Selection cuttings can also be used (i.e. selecting a limited number of shoots theoretically from seeds, but generally the best shoot on the stool) to create firebreaks along roadsides or near urban areas, or for forest grazing.

These are all new uses for holm oak forest which are different from the normal coppice method. Current knowledge is not sufficient to evaluate the consequences of these new techniques.

In fact, while in the coppice method no interventions occur between clearcuttings, the new techniques demand either the elimination or selection of shoots. Both are commonly used in high forests and their outcome has been well studied. In a high forest, one individual is removed which subsequently modifies the competitive relationships existing among the remaining trees. In coppices, elimination of a shoot only removes a part of the individual making up the stool (Jolyet 1916; Mathey 1929; Perrin 1964). Any thinning in a coppice results in a change in the competitive relationships both between the remaining shoots on the stool and between stools.

Thinning in a coppice would thus seem to be a biologically complex technique. In this article, the influence of cleaning and thinning intensities and of coppice age at the time of silvicultural treatment will be studied in relation to growth of shoots in the remaining coppice.

The experiments used were geared to respond to the following questions: what is the best age for coppice to be converted into a stored coppice and what is the optimum cleaning or thinning intensity?

Material and methods

Two experimental designs were set up to answer these questions: one focusing on young coppices less than 25 years old and the other on coppices over 40 years old.

The cleaning study in coppices from 4 to 25 years old was performed in the LA BRUGUIERE communal forest located in the Gard (Toth *et al.* 1986) in Southern France. This is a holm oak coppice with a 25 year rotation which has been regularly harvested up to the present time. All age classes of the coppice are thus represented.

Three silvicultural treatments were used: heavy intensity cleaning, light intensity cleaning and uncut controls. Each treatment was repeated twice for each age class. The selected age classes were: 4, 8, 15, 20, and 25 years old at the time of the experiment (end of 1984). The dendrometric characteristics of the studied coppices are given in Table 1.

The experimental standards for cleaning (see Fig. 1) were calculated from a curve describing the natural evolution of the number of shoots in coppice related to coppice age. Heavy cleaning began at 10000 shoots per hectare for 4 year old stands and ended at 1000 shoots per hectare for 30 to 35 year old stands. Light cleaning was respectively 20000 and 2000 shoots per hectare. The final values of 1000 and 2000 shoots includes the empiric values of 1500 shoots per hectare tested by the Office National des Forêts and the Centre Régional de la Propriété Forestière in the Languedoc-Roussillon region on coppices of the

Table 1. Dendrometric characteristics of the coppices studied.

Site	Age	Shoots per ha	Mean girth at 0.5 m (cm)	Basal area at 0.5 m (m^2/ha)	Mean height (m)
La Bruguière	4	29900	4.4	4.68	1.66
	8	30300	6.6	10.37	2.10
	15	31000	8.3	16.84	2.56
	20	17800	14.2	28.63	3.72
	25	12200	16.7	27.20	3.75
Puéchabon	43	8700	21.3	31.5	4.73
	57	6300	28.2	41.6	6.14

same age. The experimental network consisted of 30 individual 9-are plots. In each plot, 45 sample shoots were selected and observed in or near the central 1-are area. It covered a total surface area of 3.5 hectares and was set up during the 1984–85 winter.

The thinning study on 43 and 57 year old coppices was performed in the PUECHABON state forest in the Herault (Ducrey *et al.*, 1987) in Southern France. In this forest, coppice management had basically come to a halt after World War II. This explains why old coppices can be found there and the oldest stands currently being managed are approximately 60 years old. The two experimental factors studied were coppice age and thinning intensity. To obtain a high variation in forest canopy structure, a wide range of thinning intensities was chosen, removing from 20 to 80% of the stand basal area. After thinning, we obtained the following treatment types:

Control:	0% of basal area removed,
Light thinning:	24–27% of basal area removed,
Moderate thinning:	40–45% of basal area removed,
Heavy thinning:	56–60% of basal area removed,
Very heavy thinning:	77–79% of basal area removed,

which corresponds to the following for shoots with a girth over 3 cm:

Control:	0% shoots removed,
Light thinning:	53–58% shoots removed,
Moderate thinning:	63–68% shoots removed,
Heavy thinning:	76–80% shoots removed,
Very heavy thinning:	89–91% shoots removed.

These five treatments were repeated twice in a 43-year old stand consisting of two blocks (block 1 and block 2) of five plots with a unit surface area of approximately 10 ares. These five treatments were used only once in a 57-year old stand consisting of a block (block 3) of 5 plots with a unit surface area of approximately 12 ares. In each plot, a sample of 45 shoots was studied in detail. Samples were chosen for each girth class in proportion to their relative number in the stand.

The experiment was set up during the 1985–86 winter. The dendrometric characteristics of the different coppices studied are shown in Table 1. Although thinning was defined using basal area, the standards actually used were consistent with those used for cleaning as shown in Figure 1. In fact, both cleaning intensities correspond to the two heaviest thinning intensities while the light and moderate thinnings represent slight thinning operations which only slightly open the forest canopy. Girth increment of the sample shoots was measured every year. Height growth was measured every year for the 4 and 8-year old coppices but only at the beginning of the experiment and at the end of 1989 for the oldest coppices.

All the stools in PUECHABON bearing a sample shoot were measured at the end of 1986

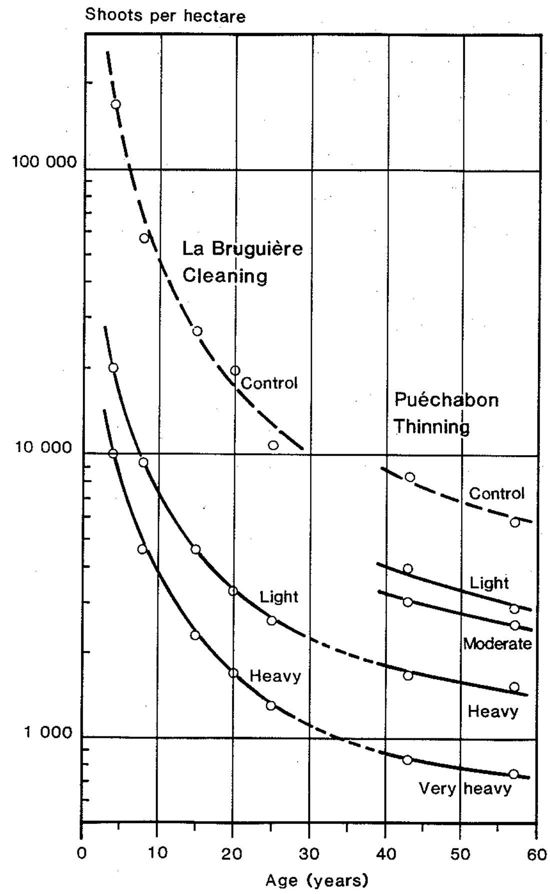


Fig. 1. Experimental standards used for cleaning and thinning of holm oak coppices in LA BRUGUIERE (Gard) and PUECHABON (Herault).

to characterize the initial stool and the degree of cut in the stool.

The following variables were quantified for each stool:
- number of cut shoots (S-CUT),
- total number of shoots in initial stool (S-TOTAL),
- percentage of cut shoots (PC-S-CUT),
- average girth of remaining shoots (CM-S),
- average girth of cut shoots (CM-S-CUT),
- average girth of all shoots (CM-S-TOT),
- basal area of remaining shoots (G-S),
- basal area of cut shoots (G-S-CUT),
- basal area of all shoots (G-TOT),
- percentage of cut basal area (PC-G-CUT).

Throughout the experiments, girth measurements were made 50 cm above soil level at La Bruguière and 1.30 m above soil level at Puéchabon. At the end of 1989, girth measurements were performed simultaneously at 1.30 m and 0.50 m in the 20 and 25 year old coppices at LA BRUGUIERE. This made it possible to calculate girth at 1.30 m (in cm) in relation to girth at 0.50 m (in cm).

$$C_{1.30} = 0.9101C_{0.50} - 1.3182 \ (r^2 = 0.932)$$

This formula was used to unify data.

Additional observations were performed on epicormic shoots growing along the trunk of holm oak shoots after silvicultural interventions. The number of epicormics was noted along with the length of the longest epicormic. It should also be noted that coppice age was always considered to be age at the time the experiment was set up.

Results

Height growth and girth increment varied considerably from year to year due to wide variations in climatic conditions, particularly temperature and rainfall (Zhang 1987). The mean annual growth or increment, calculated over a 5 year period for LA BRUGUIERE and over a 4 year period for PUECHABON, was therefore used.

Girth increment

The experiment designs made it possible to analyze the effect of the intensity of silvicultural treatment and the effect of coppice age at the time the experiment began.

Figure 2 shows the effect of thinning intensity on girth increment in the 3 blocks at PUECHABON as well as the average effect for the whole experimental site. Growth was not statistically different between the control (3.3 mm/year) and the light thinning (3.7 mm/year) treatments. However, moderate (4.7 mm/year), heavy (6.7 mm/year) and very heavy (11.3 mm/year) thinnings were statistically different from the first two treatments and also among themselves. It should be noted that girth increment in very heavy thinning was 3.4 times greater than that for controls. Figure 2 shows that the results are nearly identical for the two 43 year old blocks (blocks 1 and 2) and for the 57 year old block (block 3).

Figure 3 shows the mean annual girth increment in relation to the percentage of removed

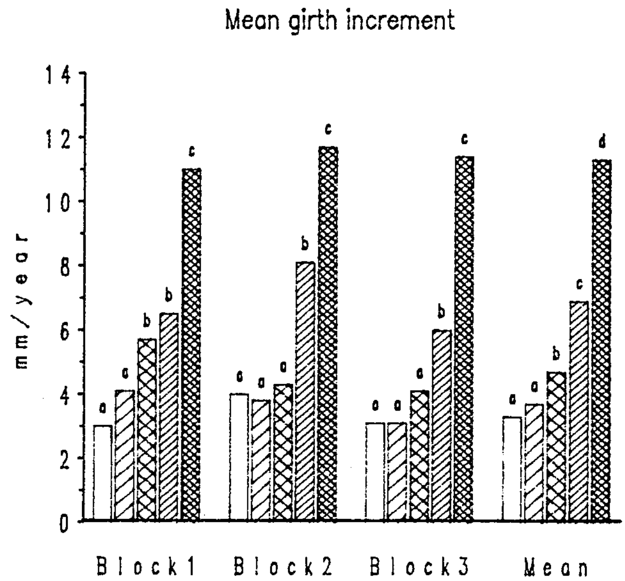


Fig. 2. Changes in girth increment as related to thinning intensity in each of the 3 blocks and for the whole PUECHABON experimental site. (For each block, from left to right: control, light thinning, moderate thinning, heavy thinning and very heavy thinning. In each block, identical letters indicate mean values not statistically different at a 5% significance level).

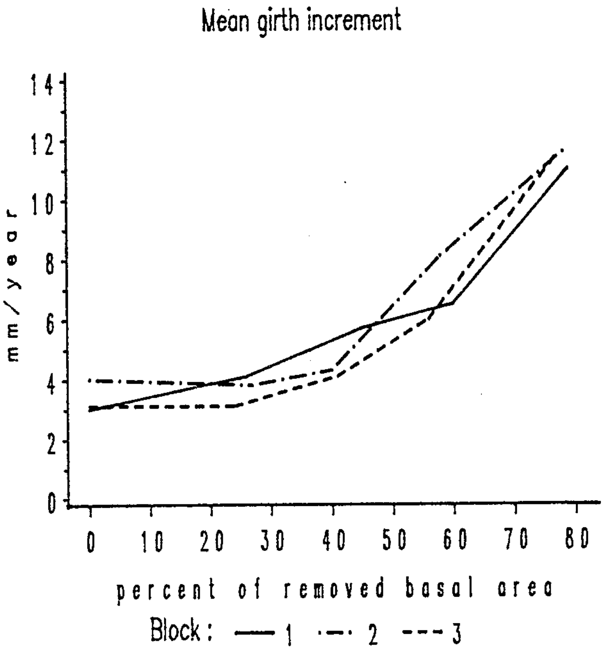


Fig. 3. Changes in girth increment related to the percentage of basal area removed through thinning in each of the PUECHABON experimental blocks.

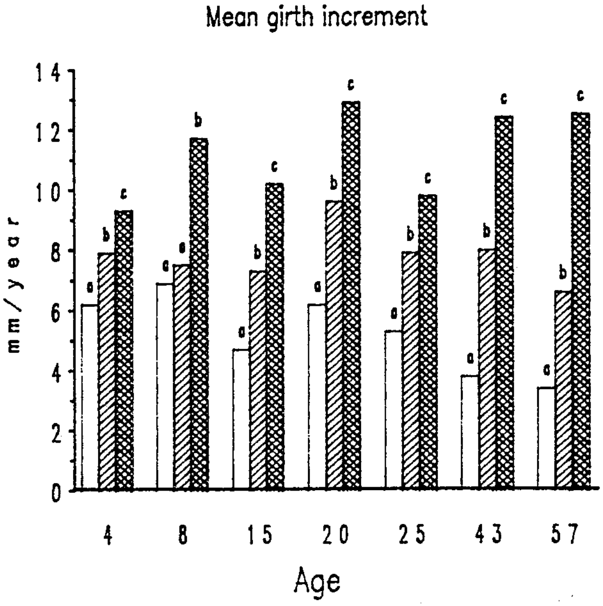


Fig. 4. Changes in girth increment for each coppice age class in relation to silvicultural treatment. (For each age, from left to right: control, light cleaning or heavy thinning and heavy cleaning or very heavy thinning. All girths were recorded at a height of 0.50 m. In each age class, identical letters indicate mean values not statistically different at a 5% significance level).

basal area, for each of the three experimental blocks at PUECHABON. In the light and moderate thinnings, which removed 25% and 42% of the basal area respectively, particularly subordinate shoots, the canopy is only slightly opened and little difference was found compared to controls. However, in heavy or very heavy thinning, where 58% and 78% of basal area is removed respectively, the canopy is greatly opened and girth increment is higher.

Figure 4 shows a comparison of girth increment, for the different coppice age categories, among 3 treatments: control, light cleaning or equivalent heavy thinning and heavy cleaning or equivalent very heavy thinning. This comparison was made possible by the analogy between, on the one hand, heavy and very heavy thinning intensities at PUECHABON and, on the other hand, light and heavy cleaning intensities at LA BRUGUIERE. To facilitate comparison, all increments were given for 0.50 m using the relationship of $C_{1.30}$ to $C_{0.50}$.

A slight natural tendency towards decreased growth was found in controls when related to coppice age. Scattering of data on both sides of the general trend may be due to differences in fertility between sites. The effect of the two thinning intensities was almost always statistically significant within each age category and this held true for all age categories. Girth increment after very heavy thinning increased 50% compared to controls for 4-year old coppices, 70% for 8 year olds, 117% for 15 year olds, 108% for 20 year olds, 85% for 25 year olds, 226% for 43 year olds and 268% for 57 year olds. In spite of slight differences in fertility, the increase in growth was greater for coppices with greater age, height, basal area or volume i.e. for coppices where competition between shoots was greatest.

To demonstrate the effect of silvicultural treatments over time, annual girth increment was expressed as a percentage of annual increment in the controls thus eliminating interannual growth variations. Figure 5 shows the relative evolution of girth increment at LA BRUGUIERE and

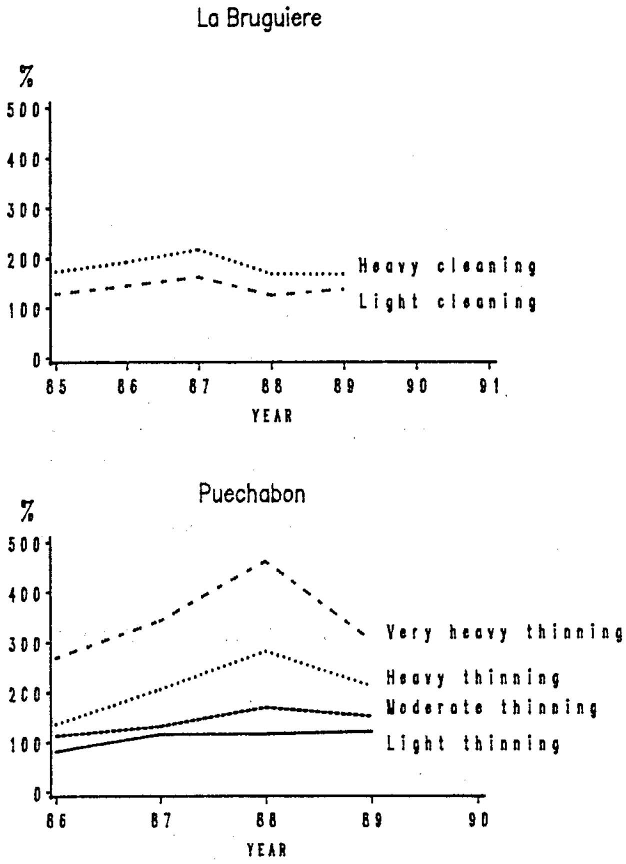


Fig. 5. Changes in annual girth increment expressed as a percentage of control annual girth increment over the 5 years following cleaning in LA BRUGUIERE and the 4 years following thinning in PUECHABON.

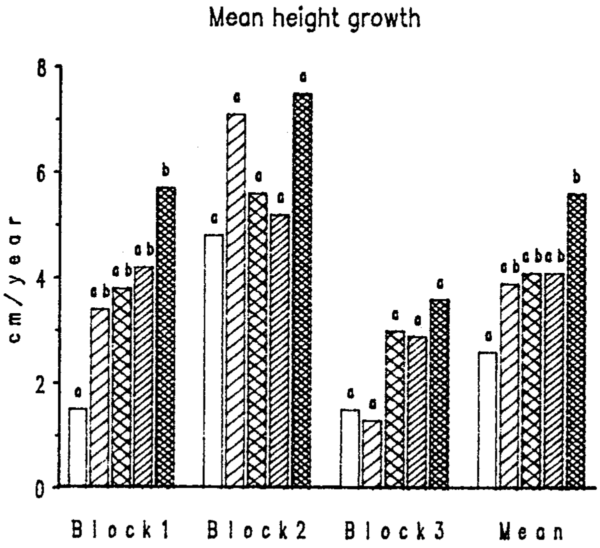


Fig. 6. Variation in height growth related to thinning intensity in each of the three blocks and for the whole PUECHABON experimental site. (For each block, from left to right: control, light thinning, moderate thinning, heavy thinning and very heavy thinning. In each block, identical letters indicate mean values not statistically different at a 5% significance level).

PUECHABON respectively during the 4 or 5 years following silvicultural treatment. The increase in growth due to thinning was regular and reached a maximum in the third year. A decrease was observed in the 2 experiments from the fourth year onwards. This tendency remains to be confirmed.

Height growth

Height growth was analyzed in the same way as girth increment by using mean annual height increment calculated over a 5 year period for LA BRUGUIERE and over a 4 year period for PUECHABON. Figure 6 shows the effect of thinning intensity on height growth in the 3 blocks at PUECHABON and the average effect for the whole experimental site. The increase was low: from 2 to 4 cm/year in control plots and from 3 to 8 cm/year in thinned plots. Thinning intensity had no significant effect on height growth, except in the first 43-year old block.

Figure 7 shows the effect to the highest degrees of treatment on height growth in age categories from 4 to 57 years old. First, height growth in controls is low: 12 to 15 cm/year for 4 to 20 year old coppices and is negligible in older coppices. The effect of silvicultural treatments varies from one age category to another and is rarely statistically significant.

As opposed to girth increment, the effect of silvicultural treatment on height growth varies according to coppice age. While cleaning in young coppices (4 to 8 years old) had little or no positive effect on height growth, the reverse was found in older coppices (15, 20 and 25 years old) at LA BRUGUIERE. At PUECHABON height growth was too low to interpret the results.

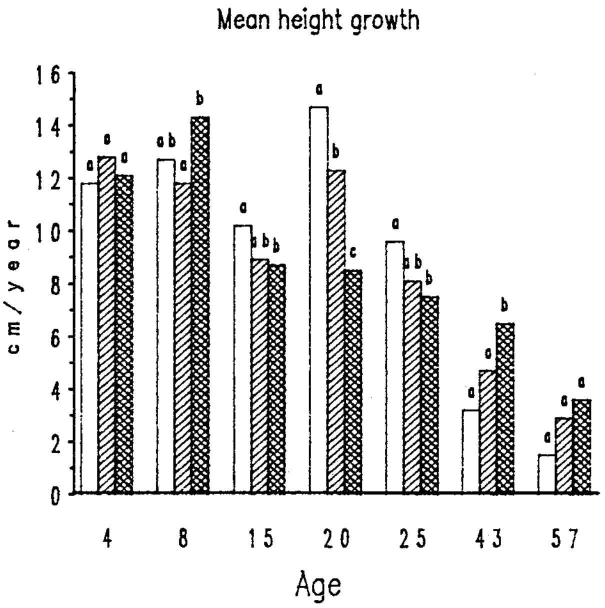


Fig. 7. Variation in height growth for each coppice age class in relation to silvicultural treatment. (For each age class, from left to right: control, light cleaning or heavy thinning and heavy cleaning or very heavy thinning. In each age class, identical letters indicate mean values not statistically different at a 5% significance level).

Shoot growth in relation to stool characteristics

To study the response of the stool to thinning, it was attempted to relate growth of sample shoots at PUECHABON to the initial stool characteristics and the degree of thinning in the stool.

To this end, a progressive multiple regression was made between mean girth increment and the 10 variables characterizing the stool and the degree of thinning in each stool. The regressions were calculated for each thinning level in each of the three blocks by using, in each plot, data from the 45-shoot sample.

When the data are analyzed by treatment (Table 2), it can be seen that the models used explain only a small part of the variability in girth increment ($R^2 < 0.30$) even though they are all significant at the 5% level. The variables showing a significant relationship were those related to number and percentage of cut shoots as well as to the initial characteristics of the stools.

Analyzing the data by blocks (Table 3) shows that growth is slightly better explained by regression models (R^2 between 0.4 and 0.5). The first variable included in the model is always average girth of remaining shoots, followed by percentage of cut basal area and basal area of remaining shoots.

Analysis of epicormic shoots

Observations of epicormic shoots made at the end of 1989 are summarized in Figure 8.

The percentage of shoots bearing epicormics increased with coppice age. It was less than 10% for 4 and 8 year old coppices, between 10 and 35% for 15, 20 and 25 year old coppices and between 35 and 70% in 43 and 57 year old coppices. A significant difference between the two treatment intensities was not always found. However, when a significant difference existed (older

Table 2. Results of progressive multiple regressions relating girth increment to the initial stool characteristics and to those of the cutting for each of the 4 silvicultural treatments (S-CUT: number of shoots cut, PC-S-CUT: percentage of cut shoots, CM-S: average girth of remaining shoots, G-S-CUT: basal area of cut shoots, G-TOT: basal area of all shoots, PC-G-CUT: percentage of basal area cut). Only variables whose slope is statistically different from 0 at a 5% level are included . Their sign is indicated in parentheses.

Treatment	Variables in the order they occur in the model	R^2
Light thinning	S-CUT (+) CM-S (+)	0,143
Moderate thinning	PC-S-CUT (+) CM-S (+) G-TOT (−)	0,168
Heavy thinning	G-TOT (+)	0,139
Very heavy thinning	G-TOT (+) G-S-CUT (−) PC-G-CUT (+)	0,287

Table 3. Results of progressive multiple regressions relating girth increment to initial stool characteristics and to those of the cutting for each of the three experimental blocks (S-TOTAL: total number of shoots in initial stool, PC-S-CUT: percentage of cut shoots, CM-S: average girth of remaining shoots, G-S: basal area of remaining shoots, PC-G-CUT: percentage of basal area cut). Only variables whose slopes is statistically different from 0 at a 5% level are included. Their sign is indicated in parentheses.

Block	Variables in the order they occur in the model	R^2
1	CM-S (+), PC-G-CUT (+), G-S (−)	0.408
2	CM-S (+), G-S (−), PC-G-CUT (+), PC-S-CUT (−)	0.477
3	CM-S (+), PC-G-CUT (+), S-TOTAL (−)	0.495

coppices), the greatest number of epicormics was always found for the highest degree of intervention.

No significant difference was observed between the two treatment intensities for the number of epicormics per coppice shoot. A regular increase in the number of epicormics was observed along with coppice age. It was between 4.3 and 12.4 for young coppices at LA BRUGUIERE and between 18 and 25 for older coppices at PUECHABON.

Epicormic shoot length was basically uninfluenced by treatment intensity. Differences between LA BRUGUIERE and PUECHABON were due to epicormics age, which was one year less at PUECHABON than at LA BRUGUIERE, as well as to ecological differences between the two sites.

Discussion and conclusion

The preceding results demonstrate the positive effect of either cleaning or thinning on girth increment in coppice shoots.

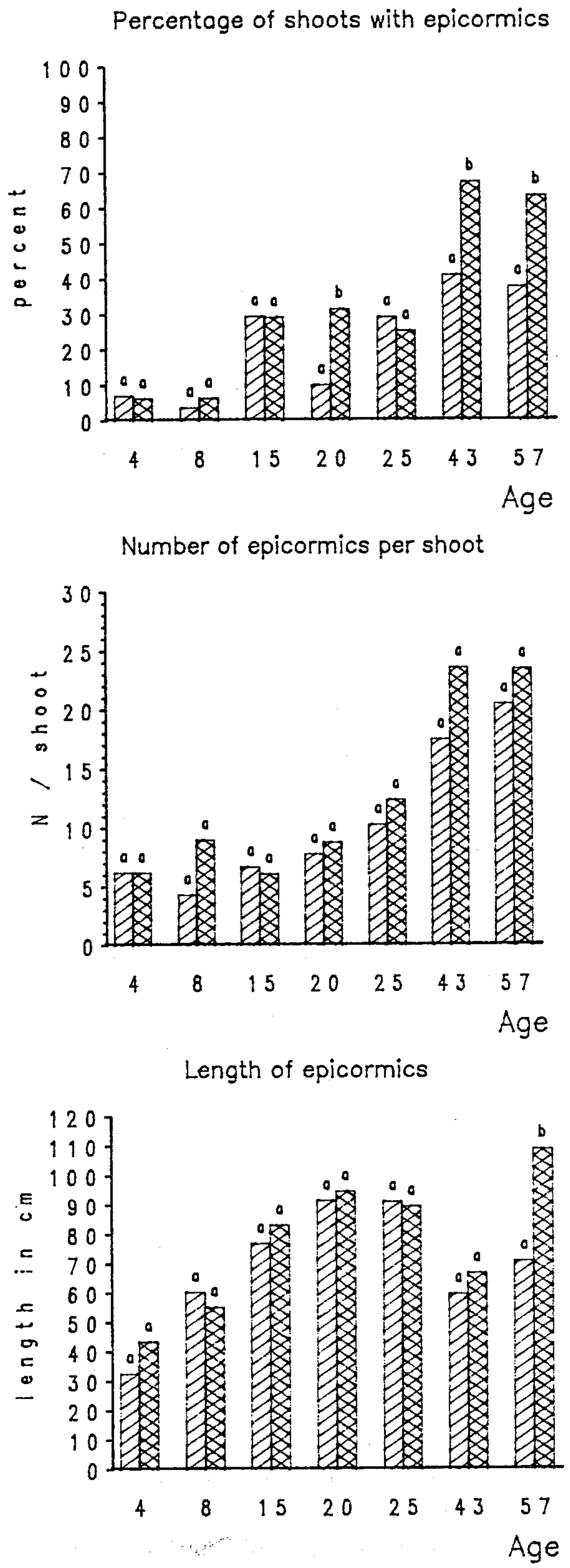
Variations in girth increment as related to thinning intensity fairly accurately reflect the importance of canopy opening in both of these techniques. Figure 3 showed the evolution of girth increment as related to the percentage of basal area removed for each of the three experimental blocks at PUECHABON. In light and moderate thinning, the canopy is only slightly opened and little difference was found compared to controls. However, in heavy or very heavy thinning, the canopy is greatly opened and girth increment is higher, due to better light conditions. These results have frequently been found for coppices. Mer (1909) showed the positive effect of cleaning on girth increment of selected shoots in oak, lime and hornbeam. More recently, Dreuillaux *et al.* (1985) and Aufort (1985) reached the same conclusions for chestnut.

These results are similar to those obtained after cleaning or thinning young broadleaf or conifer high forests, although competition is not the same. In terms of individual shoot reaction, the present results indicate that girth increment was greater for thicker shoots, i.e. thinning appears to benefit the most vigorous shoots. Mer (1909) made the same observation for the 3 species he studied.

Height growth was not noticeably affected by cleaning or thinning. From the general pattern of results, it appears that cleaning in coppices less than 10 years old does not affect height growth. In older coppices, cleaning generally has a negative effect. In very old coppices height growth is absent and no effect of thinning is observed.

This can be explained by visual observations made during periodic measurements. Observations have shown that the shape of the holm oak crown, which is usually in a ball, fluctuates considerably over time. Summer drought, especially when severe, as was the case during the summer of 1989, leads to a high degree of die back in small-sized twigs and can decrease total shoot height. In addition, the holm oak is frequently infested by a *Buprestidae*, *Coroebus bifasciatus*, which can kill several centimetre thick branches by forming rings and thus damage large parts of the crown. Fortunately, the crown develops again during wet years, although total shoot height does not significantly increase.

In young coppices, similar results have been



reported in the literature. Aufort (1985) has shown that height growth for 1-year old chestnut shoots in cleaned coppices and that of control shoots were not significantly different. Piskoric (1963) came to the same conclusion for the holm oak: reducing the number of shoots in coppices less than 10 years old had no effect on height growth.

In older coppices, Mer's results (1909) conflict with our findings. He observed a positive effect of thinning on shoot height growth. This may be due to climate as the coppices Mer studied were located in a temperate climate while the holm oak coppices we studied were situated in a Mediterranean climate. Opening the canopy in a Mediterranean climate causes greater stress than in temperate climates and leads to greater crown die back.

Up to here, we discussed shoot response to cleaning and thinning at the stand level. However, for a given thinning intensity, all the stools are not thinned in the same way and all the different degrees of intervention can be observed, from those stools which have been clearcut to those left intact. It was found that girth increment in shoots was positively related to the percentage of shoots or basal area removed. Similar results were also obtained by Aufort (1985), who showed that diameter growth in chestnut shoots increased with the cleaning rate (percentage of shoots removed in the stool). Johnson and Rogers (1984), who cleaned red oak and left only one shoot per stool, found that diameter increment was primarily controlled by the ratio between basal area of the shoot and total basal area of the initial stool.

In order to understand these results, competition between coppice shoots must be taken into account. First, competition between stools and competition within a given stool must be sepa-

Fig. 8. Percentage of shoots bearing epicormics (above), number of epicormics per shoot (middle) and maximum length of epicormics (below) for each age class in 1989 related to silvicultural treatment. (For each age class, the left represent light cleaning or heavy thinning and the right, heavy cleaning or very heavy thinning. In each age class, identical letters indicate mean values not statistically different at a 5% significance level).

rated. Competition between stools is similar to competition between trees in a high forest: competition between roots for water and nutrients, competition between branches for light and carbon uptake. Competition within stools is complicated by the fact that relations between the underground and above-ground parts of the stool occurs through the stump. Even at this level, the results of competition differ depending on whether the shoots come from the same bud group (group of buds resulting from the division of the same proventitious bud), from different bud groups located on the same butt (piece remaining on the stump after removal of a shoot) or from different butts.

Trophic relationships, i.e. sap flow between shoots and roots, occur preferentially according to the distance between them. This leads to an unequal distribution of nutrients from the roots to the shoots. In birch, some zones receive a high flow, while others receive nothing at all (Bedeneau & Pages 1984). This division of the stump into more or less independent sectors can also be found in the chestnut (Carlier 1987; Aymard & Fredon 1986). Destremeau and Roderbourg (1968–69) have estimated that shoots in the cork oak lead an independent life, the stump only providing mechanical support.

The age of the shoots studied may be one of the reasons for the difference observed between the cork oak and the birch and chestnut. Destremeau and Roderbourg studied older shoots (10 years old) and it is possible that, as here, each shoot had acquired a certain degree of independence (Aymard & Fredon 1986). In eucalyptus, Riedacker (1973) showed that shoots located in the sector corresponding to a root supplied with ^{32}P received 90% of all radioactive sap. He also noted that migration of sap is greater in younger stumps. Age and physiological state of the vascular system thus appear to be controlling factors in stump activity.

In holm oak coppices containing old stumps, sprouts appear in higher number after complete coppicing. However, competition rapidly leads to high mortality by eliminating sprouts and initially maintaining only one sprout per bud group, followed by one or two sprouts per butt. Each butt does not necessarily lead to an adult sprout (i.e. a shoot). Under these conditions, it may be assumed that an almost total independence exists between shoots from the same stool. This would mean that elimination of shoots in one stool would not favour trophic and hydric resources for the remaining shoots. Each shoot in the stool would have its own root system and the shoots would act independently in much the same way as trees in a high forest, except that the contact zone between the shoot and the stump hinders hydric exchanges. A slight positive effect of treatment intensity within the stool on girth increment of the remaining shoots was nonetheless found in this study. This demonstrates that the independence between the different stump sectors is imperfect and that the same roots at least partially supply nutrients to several shoots. However, this positive effect is also linked to a decrease in above-ground competition around the remaining shoots, which is greater when the intensity of thinning within the stool is high.

Cleaning and thinning of holm oak coppices leads to the appearance of epicormic shoots along the trunks. This phenomenon has been observed in most oak species and corresponds to the development of epicormic buds on the trunk.

The results obtained showed that coppices behave differently depending on their age. The reaction of 4 and 8 year old coppices is almost unnoticeable. The percentage of trees bearing epicormics, as well as the number and length of epicormics are low and change little during the first season after cleaning. This is due to the fact that, at this age, few epicormic buds have yet been formed. The appearance of epicormics is higher in coppices 15 or more years old, particularly at the end of the first year, after which the number of epicormics tends to decrease. In addition, in the PUECHABON coppices, more shoots bore epicormics than in the oldest coppices at LA BRUGUIERE and the epicormics were longer and more numerous. It would therefore seem that in holm oak coppices managed using the same thinning intensity, the appearance and development of epicormics is higher in older coppices.

The number of epicormics appears to be independent of thinning intensity, although this does not seem to be true for epicormic shoot length (particularly in older coppices). The explanation of this, provided by several authors (Ward 1966; Dale & Sonderman 1984) is that thinning causes those buds already present to develop. This led Wignall and Browning (1988) to consider that buds have a minimum light requirement necessary for development to begin.

This requirement varies from one shoot to another, a fact which may explain the increase in percentage of shoots bearing epicormics with thinning intensity. In fact, when the canopy has been notably decreased, the number of shoots reaching this 'threshold' also increases. Breaking the dormancy of epicormic buds can be explained (Roussel 1978) by the photodestruction of an auxine (indol acetic acid). However, according to the findings of Wignall and Browning (1988) and of Harmer (1988), temperature and hormonal factors also influence bud physiology.

From a silvicultural point of view, the effect of cleaning and thinning can be summarized as follows: a positive effect on girth increment, a zero or slightly negative effect on height growth and the appearance of undesirable epicormic shoots on the trunk. We should also add the appearance of new stump sprouts, although they were not included in the present study. The conversion into a stored coppice would thus lead more or less rapidly to larger shoots which could be used for purposes other than simply firewood: small calibre boards, wood floors, panelling, etc. At the present time, it is impossible to predict whether the shoots would be longer: the goal of raising the canopy as a protection against forest fires is difficult to achieve. However, it is possible that height growth may increase once the canopy closes again and the crowns are reformed. It is also necessary to control sprout and epicormic shoot growth when a coppice is converted into a stored coppice.

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