Production of epicormic shoots on oak (*Quercus robur*): effects of frequency and time of pruning

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Summary

The effect of frequency and time of pruning on the population of epicormic shoots was investigated for two stands of oak (*Quercus robur* L.). Pruning frequencies consisted of eight permutations of pruning or not pruning in three successive years, comparisons were also made between pruning in four different months. The final pruning was in January 1994 and the last assessment was in early 1998. Pruning had a short-term effect on total number of epicormic shoots but this had mostly disappeared within the 7-year period. In addition pruning was shown to have little influence on the production of new epicormic shoots. No evidence was found to support varying the time of pruning to help control epicormic shoots. Different frequencies of pruning had inconsistent effects and none offered any guaranteed improvement over annual pruning, which must remain current advice for the long-term control of epicormic shoots.

Introduction

The problem of epicormic shoots and their control is a common theme of oak silviculture in North America and Europe. The earliest reports are from Europe, where Pontey (1810), for example, described epicormic shoots and the knots they cause as 'an evil of immense magnitude'. Foresters in North America began to realize the significance of epicormic shoots when virgin forests had been cleared and second growth stands were being brought under management (Kormanik and Brown, 1964). The presence of epicormic shoots on oak is regarded as undesirable because they can reduce the quality and value of timber: Hedlund (1964) described how they reduced the quality of 23 per cent of logs by two or more grades and Courraud (1987) showed how their presence affects value using French log grading rules. Even superficial epicormic shoots will suggest to timber buyers that individual knots, or clusters of them, may be present deeper in the log, resulting in lower prices being paid.

The population of epicormic shoots on an oak tree is determined by three main factors: (1) the initiation of buds, (2) the release of buds from dormancy and (3) survival of epicormic shoots. Whilst it is generally accepted that most epicormic branches develop from suppressed buds which become embedded in the bark, the reasons for their release from dormancy are not well understood (Bowersox and Ward, 1968; Roussel, 1978; Wignall *et al.*, 1987; Harmer, 1988; Wignall and Browning, 1988; Spiecker, 1996; Fontaine *et al.,* 1997). The survival of epicormic shoots on *Quercus mongolica* var. *grosseserrata* has been studied by Yokoi and Yamaguchi (1996) who confirm that light is important; other likely factors are oak leaf roller moth (*Tortrix viridana* L.) and mildew (*Microsphaera alphitoides* Grif.

& Maubl.). Foresters have most control over the survival of epicormic shoots using silvicultural operations such as intensity of thinning, underplanting and pruning.

There is widespread evidence that thinning, which exposes stems to more light, worsens the problem of epicormic shoots (Fabricius, 1932; Ward, 1966; Dale and Sonderman, 1984; Sonderman, 1984; McDonald and Ritchie, 1994). It is generally thought that frequent light thinning which maintains high canopy cover is an appropriate method of stand management. This is one reason why light crown thinning on rotations of 150–200 years is advocated in France (Evans, 1982a). Contrary to this Wignall and Browning (1988) did not detect any statistically significant increase in epicormic shoots or growth for up to 3 years after thinning at three different sites; similar results have also been reported by Jensen (1993). Underplanting of shade-tolerant species such as beech (*Fagus sylvatica* L.), to reduce light levels in the stand, is also widely reported as a means of controlling epicormic shoots (Fricke *et al*., 1980). This benefit has been quantified by Henriksen and Sanojca (1983) who reported that an understorey of beech reduced the number of epicormic shoots by 95 per cent on the lower 3 m of oak trees. There is general agreement (Büsgen *et al*., 1929; Courraud, 1987) that the use of understoreys does not affect release of buds from dormancy but is effective at reducing the number of epicormic shoots because the low light levels under the canopy reduces their survival and growth.

Another method of controlling the number of epicormic shoots is by pruning, but there are some suggestions in the literature that it may have the opposite effect (Evans, 1982b, 1985) and that when it is done may be important in determining its effect (Workman, 1989). The use of pruning to control epicormic shoots has recently received an added impetus caused by interest in 'free growth' regimes (Kerr, 1996; Severin, 1997). These involve heavy thinning to promote rapid stem growth and removal of epicormic shoots by pruning.

The experiment described here investigated whether either frequency of pruning (i.e. the number of years it was carried out) or the time of pruning (i.e. time of year) had any effect on the total number of epicormic shoots or the production of new shoots present on the stem.

Materials and methods

The experiment was replicated in two stands of pole-stage oak (*Quercus robur* L.) in Alice Holt Forest, Hampshire (0° 53′ W, 51° 10′ N) and Birchwood, Staffordshire (1° 50′ W, 52° 48′ N). The Alice Holt site is a gently sloping hillside with south-westerly aspect lying between 107 m and 122 m a.s.l. The Birchwood site is flat and lies at 125 m a.s.l. At both sites the soils were surface water gleys overlying heavy clay with average annual rainfall of 700 mm. Crop characteristics were similar for both sites (Table 1) and no thinning took place either during or for 3 years before the experiment started. The presence or absence of epicormic shoots up to 6 m on the main trunk was recorded for each tree.

The experiment had a split-plot design with eight main plots (frequency of pruning), four subplots (time of pruning) and three blocks, with a total of 96 plots. The eight frequency of pruning treatments consisted of permutations of pruning or not pruning in three successive years (Table 2). The times of pruning were April, July, October and January. Within each sub-plot there were five

Table 1: Stand characteristics for Alice Holt and Birchwood, measurements taken in 1997

	Alice Holt	Birchwood
Age	53	50
Mean height (m)	16.2	17.9
Mean d.b.h. (cm)	21.0	22.4
General Yield Class *	6	6
Stocking (stems ha^{-1})	710	700

* As defined by Edwards and Christie (1981).

Table 2: Summary of pruning regimes

Regime	Year 1 Apr. '91–Jan. '92	Year 2 Apr. '92–Jan. '93	Year 3 Apr. '93–Jan. '94
Prune 0 (control)	–	–	–
Prune 1	+	–	–
Prune 2	–	+	–
Prune 3	–	–	+
Prune 12	+	+	–
Prune 23	–	+	+
Prune 123	+	+	+
Prune 13	+	–	+

+, Prune; –, no prune.
For each treatment there were four sub-plots pruned in April, July, October and January.

trees at Alice Holt and eight trees at Birchwood. Treatments were applied to a height of 2 m but assessments were made between painted bands at 0.8 m and 1.8 m above ground level.

Pruning commenced in April 1991 and continued according to the frequency and timing scheduled for each plot until the last treatment in January 1994. Epicormic shoots were removed by cutting with sharp secateurs close to the tree. In March 1991, before pruning commenced, all epicormic shoots were painted with a thin band of white paint and counted. In subsequent years, usually at the end of the dormant season in March or April, new shoots were painted a different colour: red in 1992; yellow in 1993; blue in 1994; green in 1995; and at Birchwood only, orange in 1996. The number of shoots in each colour were then counted. Further assessments took place in January 1997 and January 1998 at Alice Holt and in February 1998 at Birchwood but only total numbers were recorded. There was no differentiation between epicormic shoots of different sizes. The final assessment at each site recorded the number of epicormic shoots on individual trees.

Results were investigated by analysis of variance using an appropriate square root transformation; mean numbers per plot are presented for clarity. In the presentation of data, the year is when the assessment took place, i.e. '1993' refers to the March 1993 assessment which includes any new epicormic shoots, most of which will be from the previous year, 1992.

Results

At both sites more than 98 per cent of trees produced epicormic shoots up to 6 m on the stem, and these were evenly spread throughout the treatments. The distribution of epicormic shoots was skewed, with relatively few trees having large numbers. Initially Birchwood had greater numbers of epicormic shoots with a mean of 132 per plot (16 per tree) compared with 58 (11) at Alice Holt. There was also a greater range at Birchwood (maximum 430, minimum 40) compared with Alice Holt (maximum 150, minimum 9). Analysis of variance confirmed that there were no significant differences between treatments in the initial number of epicormic shoots at each site.

Changes in the total number of epicormic shoots and production of new ones for the control trees – Prune 0 – at both sites are shown in Figure 1. At Alice Holt there was a large increase in the production of new epicormic shoots between 1992 and 1993 which was sustained until the 1994 assessment; this resulted in a fivefold increase in the total number of shoots in the same period. There was then a decline in total numbers between 1995 and 1997, and a subsequent increase to return numbers to the 1993/94 level in 1998. The pattern of production of new epicormic shoots was similar at Birchwood but smaller in magnitude, showing an increase to 1994 and then a decline. However, total numbers of epicormic shoots showed few

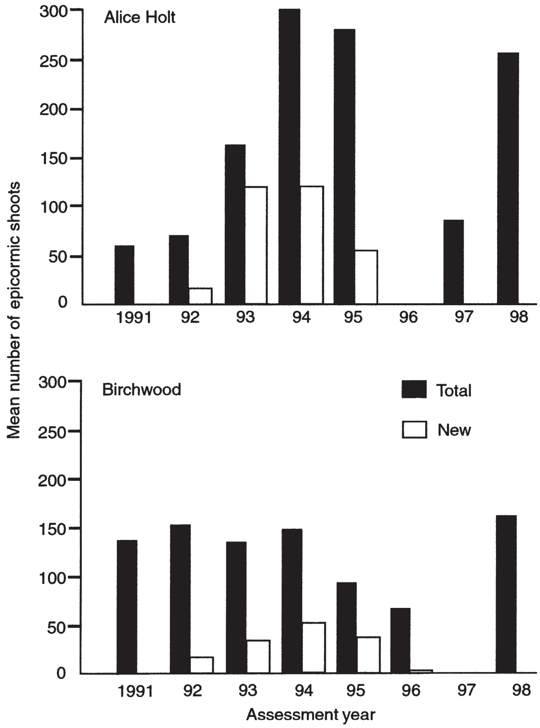

Figure 1. The mean total, and mean number of new epicormic shoots produced in different years at Birchwood and Alice Holt.

changes between 1991 and 1994, but after this they fell and rose again which reflected the changes at Alice Holt.

The short-term effects of pruning on epicormic numbers were obvious and data from some of the pruning regimes are shown in Table 3 to give an indication of the type of data collected. At Birchwood a single pruning treatment – Prune 1 – removed all white epicormic shoots before the 1992 assessment. A later single pruning – Prune 3 – removed all white, red and yellow epicormic shoots before the 1994 assessment. At Alice Holt the biennial pruning – Prune 13 – removed all white epicormic shoots before the 1992 assessment and then all red and yellow shoots before the 1994 assessment. Annual pruning – Prune 123 – removed white epicormic shoots before the 1992 assessment, red ones before 1993 and yellow shoots before the 1994 assessment. Figures along the diagonal show the production of new epicormic shoots, e.g. an average of 44 new shoots per plot were produced in 1993 at Birchwood in Prune 1; where this information is not shown only the total number of epicormic shoots was assessed, as shown along the top line.

Total number of epicormic shoots

The total number of epicormic shoots at the two sites varied greatly during the course of the experiment. Mean numbers per plot were in the range 3–161 at Birchwood and 9–384 at Alice Holt (Table 4). In most years there were significant differences between the means for the treatments at each site. The number of epicormic shoots at the assessment following pruning was usually less than the Prune 0 control (Table 4). For example, in 1993 at Birchwood the four regimes which had been pruned in the previous 12 months – Prune 2, Prune 12, Prune 23 and Prune 123 – had a mean of 20 epicormic shoots, compared with 133 in the control, Prune 0. However, treatment effects declined with time and by 1998 there were no significant differences between treatments at either site (Table 4); although at Birchwood results were nearly significant with Prune 1 and Prune 123 having relatively low numbers of shoots. Clear trends in the differences between treatments in the total number of branches present in the plots in the years following pruning were difficult to discern either between or within sites (Figure 2). For example, at Birchwood the final percentage of shoots (relative to controls) present on the stem was the same in Prune 1 treatments (single pruning) as that in Prune 123 (pruning in three consecutive years), but the single – Prune 2 or Prune 3 – treatments were much less effective in reducing the number of epicormic shoots.

Production of new epicormic shoots

Production of new epicormic shoots was very variable between sites and years for the period 1992–1996 (Table 5). At Birchwood annual production varied between 0 and 280 new shoots per plot (0–35 per tree), and at Alice Holt the range was 0–1075 (0–215 per tree). Generally there were no significant differences between pruning treatments in the number of new epicormic shoots produced in each year, but analyses

Table 3: The effects of a selection of pruning frequencies on the total number of epicormic shoots present

	Birchwood – mean number of epicormic shoots per plot							Alice Holt – mean number of epicormic shoots per plot						
	Initial	1992	1993	1994	1995	1996	1998	Initial	1992	1993	1994	1995	1997	1998
	Prune 1							Prune 13						
Total	129	3	46	73	59	30	100	76	11	142	227	169	53	240
White	129	0	0	0	0	0	–	76	0	0	0	0	–	–
Red		3	2	1	1	1	–		11	9	0	0	–	–
Yellow			44	43	23	12	–			133	0	0	–	–
Blue				30	18	9	–				227	118	–	–
Green					17	7	–					51	–	–
Orange						1	–							
	Prune 3							Prune 123						
Total	115	134	105	78	78	54	156	58	28	153	95	124	50	222
White	115	125	81	0	0	0	–	58	0	0	0	0	–	–
Red		9	4	0	0	0	–		28	0	0	0	–	–
Yellow			20	0	0	0	–			153	0	0	–	–
Blue				78	47	35	–				95	82	–	–
Green					31	14	–					42	–	–
Orange						5	–							

–, Only total number of epicormic shoots counted.

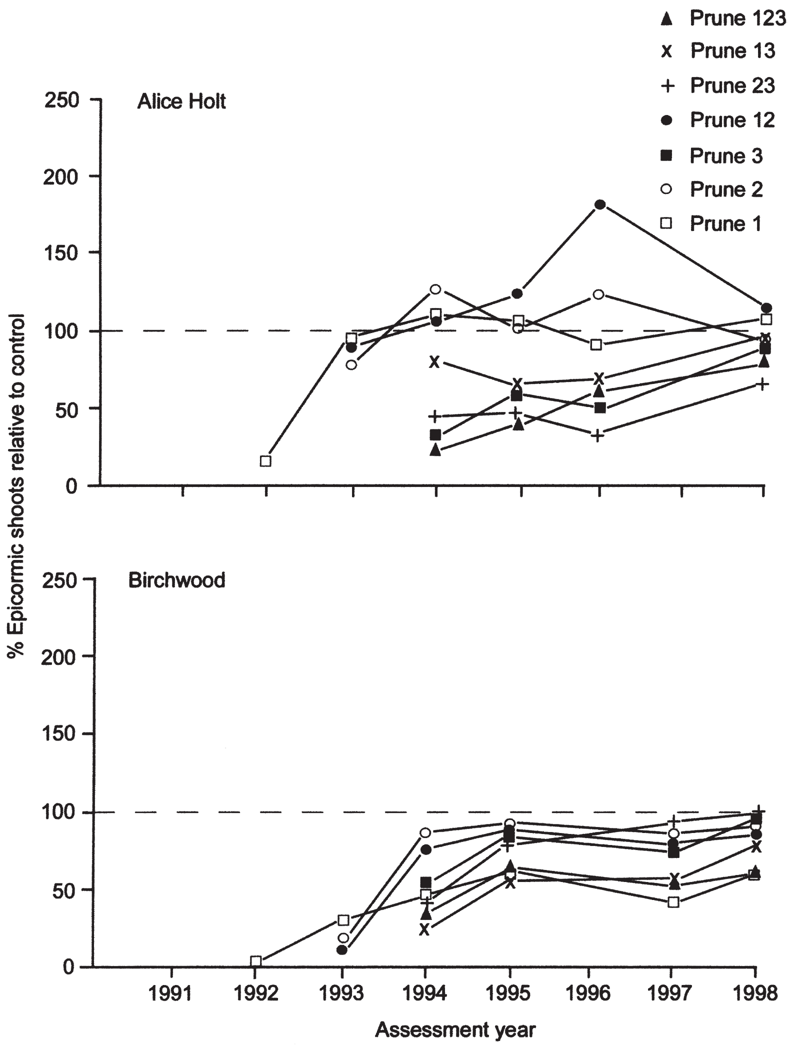

Figure 2. Mean total number of epicormic shoots relative to the control treatment (shown as a dotted line at 100 per cent) at Birchwood and Alice Holt.

indicated that there were differences in the numbers of new shoots in two of the years at Birchwood. Further investigation revealed that plots which had been pruned in the previous 12 months produced significantly fewer new epicormic shoots than those that had not been pruned in the same period. For example, plots pruned in the 12 months before the 1992 assessment produced only 4 new shoots whereas unpruned plots produced 14; similarly in 1993 pruned plots produced 19 new shoots and unpruned 34. The reduction in the number of new epicormic shoots was therefore caused by the pruning treatment.

Time of pruning

Recording the production of new epicormic shoots also allowed the effects of month of pruning to be examined. During any calendar

Table 4: Effect of pruning regime on total numbers of epicormic shoots at Birchwood and Alice Holt

Birchwood	Mean number of epicormic shoots per plot						
Treatment	1991	1992	1993	1994	1995	1996	1998
Prune 1	**129**	3	46	73	59	30	100
Prune 2	143	**160**	29	130	92	58	150
Prune 3	115	134	**105**	78	78	53	156
Prune 12	**138**	**9**	20	109	80	55	140
Prune 23	141	**120**	**9**	71	75	60	152
Prune 13	**120**	10	**42**	59	53	36	127
Prune 123	**135**	**3**	**20**	61	57	38	94
Prune 0	131	151	133	149	95	68	161
Significance	n.s.	***	***	***	*	*	$P = 0.065$

Alice Holt	Mean number of epicormic shoots per plot						
Treatment	1991	1992	1993	1994	1995	1997	1998
Prune 1	**53**	9	159	342	311	80	277
Prune 2	61	**88**	137	384	309	106	251
Prune 3	64	75	**141**	108	167	44	243
Prune 12	**47**	**27**	152	335	352	148	287
Prune 23	51	**70**	**162**	139	135	33	179
Prune 13	**76**	11	**143**	227	169	53	240
Prune 123	**58**	**28**	**153**	95	125	50	222
Prune 0	59	69	163	300	280	84	256
Significance	n.s.	***	n.s.	***	***	*	n.s.

Significant differences between means within each year at each site are shown: n.s., results not significant; *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$.
Values in bold indicate when pruning took place.

year trees pruned in April appeared to produce many more shoots than those pruned on the other three dates: for example, the 1993 assessment for Birchwood found that plots pruned in April produced 62 new shoots, whereas those pruned on the other three dates produced only 15 in total, most of which were in the July treatment. These results can be explained by the fact that if a tree is pruned in April and assessed in March of the following year then there is a full growing season during which new shoots can grow. However, if a tree is pruned mid-season (July) or in the dormant period (October or January) and assessed in the following March then there is little or no opportunity for new epicormic shoots to grow. To overcome this difficulty, only treatments which had had at least one full growing season after pruning were included in the analysis. For example, the 1994 assessment was analysed to include new shoots produced on any of the treatments pruned in July and October 1992 and January and April 1993. Results for these analyses for 1993 and 1994 from both sites (Table 6) show that there were no significant differences between month of pruning and subsequent production of new epicormic shoots during the next growing season.

Discussion

The two stands investigated had similar characteristics; they had the same soil type, they were both within the same warm dry climatic zone (Pyatt, 1995), and were undisturbed by thinning

Table 5: Production of new epicormic shoots at Alice Holt and Birchwood

Year	Number of new epicormic shoots per plot		
	Maximum	Minimum (no. of plots with 0)	Mean
Birchwood			
1992	101	0 (21)	9.1
1993	280	0 (15)	26.7
1994	205	0 (47)	57.7
1995	124	0 (1)	31.0
1996	22	0 (30)	3.2
Alice Holt			
1992	209	0 (9)	20.3
1993	712	6 (0)	138.6
1994	1075	0 (1)	146.7
1995	181	7 (0)	50.7

Table 6: Effect of time of pruning on production of new epicormic shoots

	Mean no. epicormic shoots per plot in year N			
	Alice Holt		Birchwood	
Month of pruning	1993	1994	1993	1994
July of year N – 2	35	90	15	32
October of year N – 2	43	79	7	30
January of year N – 1	36	91	15	31
April of year N – 1	58	49	22	18
{$\bar{X}$}	43	77	15	28
Significance	n.s.	n.s.	n.s.	n.s.

n.s. = results not significant.

for the duration of the experiment. In addition, both showed similar patterns of production of new epicormic shoots and had very high proportions of trees with epicormic shoots. However, the complexity of the factors influencing a population of epicormic shoots was illustrated by the fact that initial numbers were greater at Birchwood, whereas trees at Alice Holt subsequently produced more new shoots. This may be related to some historical difference between the sites or possibly that mortality of epicormic shoots prior to the start of the experiment was higher at Alice Holt. In addition, there were year-to-year fluctuations in both the production of new epicormic shoots and the total numbers present on the control trees; these were unrelated to the pruning treatments and cannot be explained with the information available. Similar patterns have been observed by Jensen (1993) for *Q. robur* in Denmark.

As anticipated, pruning generally reduced the number of epicormic shoots in the year following treatment. The only exception to this was for Alice Holt in 1993 where the total number of epicormic shoots present on the controls more than doubled and the number of new shoots produced on pruned trees was greater than the number initially present. The experiment also produced evidence that pruning has little influence on the production of new epicormic shoots, which contrasts with the increased production of epicormic shoots predicted by Evans (1985).

The frequency of pruning had inconsistent effects on the number of epicormic shoots present, as it varied both between and within sites. Intuitively it would be expected that the more pruning that occurred then the greater would be the reduction in the number of branches, but this did not always occur. Reasons for this are unclear but may be related to the origin of epicormic buds and their release from dormancy. Fontaine *et al.* (1997) observed that when an epicormic shoot dies, a number of secondary axillary buds are formed and these are the basis of clusters of epicormic shoots which can commonly be found on the boles of oak trees. As there are often large numbers of dormant buds on a stem, the potential number of branches exceeds the number present: when epicormic branches are pruned there are many buds which can produce new branches and it may take many pruning cycles to reduce the number of branches present. However, pruning may have had a similar effect to that of death, i.e. the secondary axillary buds were produced and accumulated in bud clusters during the course of the experiment. If this occurs, then repeated pruning may have a greater effect on reducing numbers if epicormic shoots are very young and small rather than old and large (Evans, 1982b). Information on buds and the site of origin of epicormic shoots was not recorded in the experiment and these questions would need to be answered by further experiments.

If an epicormic shoot is allowed to persist for more than 1 year it produces woody tissue which can form a small knot in the trunk of the tree (Wignall *et al.*, 1985). For this reason the standard British prescription for the removal of epicormic shoots has been to control them by annual pruning (Evans, 1984) which is the same as that for some Danish forests (Jensen, 1993). Any pruning costs must be balanced against the value of the end-product which may be greater if the final stem quality is improved. However, pruning is an expensive operation and results from this study suggest that epicormic shoot numbers may only be reliably reduced by annual pruning, which is likely to make the costs uneconomic in commercial forests. Although pruning had short-term effects on the number of epicormic branches on the stems, the effects had disappeared within the 7-year period of the assessments. This suggests that any beneficial effects are unlikely to be long-lived and that any short-term investment in pruning will be wasted.

The experiment produced no evidence to support the observation that varying the timing of pruning can help control epicormic shoots and thus support the results of Jensen (1993) on *Q. robur* and McQuilken (1975) on *Quercus palustris* Muenchh. The practice of summer pruning of epicormic shoots has been recommended by Evans (1984) with reference to little, if any, objective information, which is because the subject of time of pruning has been little researched. One of the few studies in this area was done by Lonsdale (1993) who investigated the pruning of larger branches in an arboricultural context. Whilst he theoretically supports summer pruning because the tree is active, wood moisture and food reserves are high and many decay fungi do not release spores until autumn, there is little support for this in his results for oak. He measured cambial dieback and wood discoloration in pruning wounds made in each month of the year and set arbitrary 'acceptable' limits for each. Using these as a basis he recommended pruning oak during the dormant season between November and April. However, to what extent this is applicable to small epicormic shoots is debatable. Claims of advantages for summer pruning of epicormic shoots have also been made by Workman (1989) who, whilst producing no data, stated that pruning in July or August was best because it would allow wounds to occlude before the winter. However, this is unlikely to influence the growth of epicormic shoots. Other evidence of the effect of season of operation on epicormic shoots comes from Wignall and Browning (1988) who observed that epicormic bud outgrowth was inhibited by summer thinning in the previous year. This experiment produced no evidence to support summer pruning but on the basis of other biological criteria, as discussed by Lonsdale (1993), this may still be the best time to prune.

There are many unanswered questions concerning the origin of epicormic buds on oak, their release from dormancy and subsequent survival. However, despite these uncertainties the fact remains that, to produce high value end-products, epicormic shoots must be controlled. The main methods of control are silvicultural and include thinning intensity and underplanting. Pruning is another element in any strategy of control and the results of this experiment have shown that it can achieve short-term control in the total numbers of epicormic shoots, even though it is unclear whether repeated pruning will achieve longer-term control. The variety of pruning regimes used did not offer any guaranteed improvement over annual pruning, which must remain the best current advice for the longer-term control of epicormic shoots. The available evidence suggests that the treatment can be applied at any time during the season. Whilst pruning may be necessary for trees grown under free growth conditions (Kerr, 1996; Severin, 1997) it may be inappropriate for conventionally managed forests where costs may be prohibitive unless it is targeted to a few selected trees.

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