The potential for using a free-growth system in the rehabilitation of poorly performing pole-stage broadleaf stands

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Abstract

This paper is a literature review of the free-growth system, which may have potential for the rehabilitation of some poorly-performing pole-stage broadleaf stands. It involves releasing of a selected number of good quality stems from crown competition as a basis for the final crop. Generally, only stems with crowns adjacent to the potential final crop trees are removed. The aim is to increase diameter growth of the selected stems and thereby shorten the rotation length needed to achieve a given diameter. The treatment may result in a greater incidence of epicormic shoots, particularly in oak (*Quercus* spp.). To maintain stem quality, epicormics may need to be removed, which may make the free-growth system uneconomic. There is, however, some evidence to believe that this may not be the case. In addition, the free-growth system may also be applicable in species less prone to epicormics, such as ash (*Fraxinus excelsior* L.) and sycamore (*Acer pseudoplatanus* L.). The free-growth system may prove to be a useful system for the rehabilitation of poorly performing pole-stage broadleaf stands and, with the advent of Chalara ash dieback (caused by *Hymenoscyphus pseudoalbidus* V. Queloz et al.) in Ireland, may gain greater use for its ability to reduce rotation lengths.

Keywords: *Broadleaf silviculture, management, rehabilitation, free-growth, crown release.*

Introduction

As part of a Teagasc 5-year COFORD-funded research programme on the silviculture of broadleaf plantations (the B-SilvRD project), being conducted in cooperation with University College Dublin (UCD), silvicultural systems suitable for the rehabilitation of poorly performing pole-stage (10 to 20-year-old) stands are being investigated. Hawe and Short (2012) reviewed possible causes of poor performance in broadleaf stands and referred to systems that may have potential to bring some poorly performing pole-stage stands into production. Short and Hawe (2012) reviewed one such system: coppice-with-standards. This paper considers another system – a modified free-growth system – and its potential for converting poorly performing pole-stage broadleaf stands into productive crops. The free-growth system has been suggested as a possibly suitable silvicultural system by a number of authors (Hawe and Short 2012, Evans 1984, Kerr and Evans 1993) for stands that are marginally poor; that is, stands which have sufficient relatively good quality and relatively vigorous stems to make up a final crop (Figure 1).

In some broadleaf stands that are performing poorly due to malformed stems, a free-growth (or similar) system may be applicable to bring the stand into more

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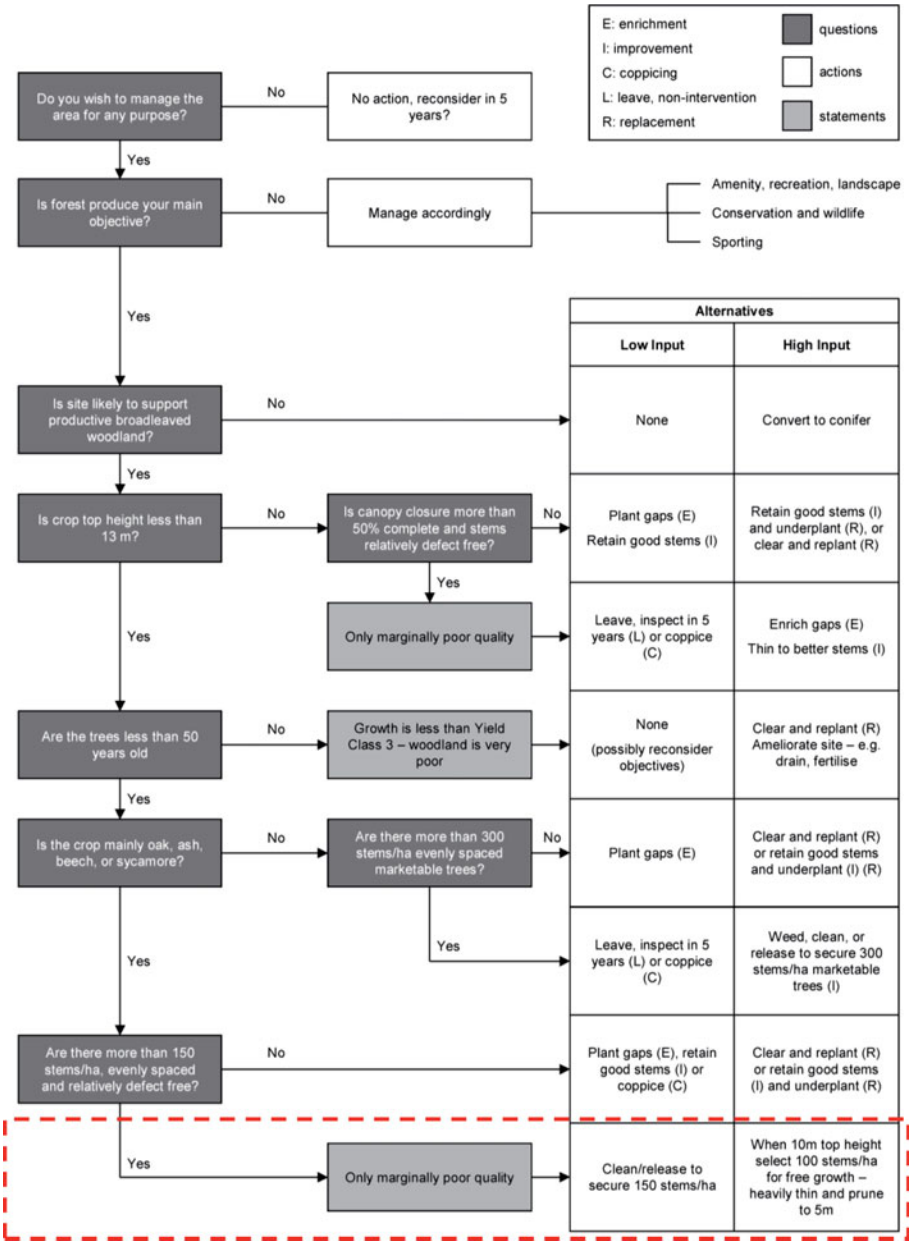

Figure 1: *Silvicultural options for managing neglected woodland. Redrawn from Evans (1984) and Kerr and Evans (1993).*

profitable production and to shorten the rotation to enable replacement with a more productive species and/or system. This paper reviews the free-growth system, focussing predominantly on broadleaf species. It includes comparisons of stem radial growth under conventional thinning systems and also describes a site that is being used as a pilot trial.

Free-growth is "a system which stimulates vigorous crown development of selected trees, in order to achieve maximum radial stem increment" (Jobling and Pearce 1977). It has also been called "free-thinning" and is associated with "crown release" thinning. It has been described previously (see Anon., 1955) as a heavy crown thinning in which "a limited number of the best dominants, usually about 100 per acre (250 ha^{-1}), are freed from all crown competition from the first thinning onward by cutting out any tree that touches the crown of a selected tree." Free-growth could be viewed as an intense form of selective crown thinning. In conventional thinning, competition is reduced within the remaining crop, either systematically or selectively, which facilitates the continued growth of the remaining stems. The intensity of thinning is correlated with the proportion of competition removed; high intensity thinning removes the majority of crown competition. A free-growth system includes thinning to the point that there is virtually no stem competing with a selected stem at any time after first thinning.

Conventional thinning and free-growth

Thinning is carried out for a number of reasons (Savill and Evans 2004):

- To reduce stand density and hence to reduce competition, leaving remaining trees more space for crown and root development. This promotes stem diameter growth and usable sizes are reached more quickly.
- To remove dead, dying, and diseased trees, or others that may cause damage to the remaining healthy ones.
- To remove trees of poor form: crooked, forked, or coarse trees, so that future growth is concentrated only on the best trees.
- To provide the owner with some revenue, though if this is not possible, as in some early thinnings, in the expectation of greater returns later in the rotation.
- More occasional reasons include maintaining light beneath the canopy to encourage grass growth for grazing, or for amenity, recreational, or ecological reasons.

A given thinning intensity can be achieved in different ways with respect to the size and crown of trees that are removed. A useful indicator of the size of tree removed, and for describing the thinning type, is the ratio of the mean volume per stem of thinnings removed (v) to the mean volume per stem of the stand *before* thinning (V). The type of thinning can be classified as in Table 1 (Savill et al. 1997). It follows that free-growth thinning will have a v/V ratio in the region of 1–1.2, depending on whether lower canopy trees are also cut or left within the stand.

Selecting crop trees

Among many variations of selective thinning methods is the early selection of final

Table 1: *The variation of the v/V ratio (ratio of the mean volume per stem of thinnings removed to the stand mean volume per stem prior to thinning) with thinning approach used.*

Thinning method		***v/V* ratio**
Systematic methods	Line and strip thinnings	1.0
Selective methods	Low thinning	≈ 0.6
	Intermediate thinning	≈ 0.8
	Crown, or high thinning	≈ 1.2
Combinations of systematic and selective	e.g. Queensland selection thinning (Forestry Department, Brisbane, 1963)	Variable

crop trees in broadleaved stands. The best trees are marked when they are young and favoured in subsequent thinnings. Because some inevitably become damaged or do not grow as well as expected, at the outset it is necessary to mark two or three times the number that will actually form the final crop (Savill and Evans 2004). Garfitt (1995) describes a compromise employed in some Belgian forests that fulfils this objective where the crowns of 200 selected stems ha^{-1} are freed from immediate competition and the remainder are ignored. A suitable baseline is selected, for example a straight ride forming a boundary of the compartment. A stem is selected arbitrarily about five paces inside the crop at right-angles to this line, and is painted with a white band at eye-level, the "marker". The two best stems are then selected within a radius of five paces of this marker, and banded with yellow paint. They must be far enough apart to allow each to develop at least to pole-size without mutual interference. Each yellow-banded tree is then freed from immediate competition by felling surrounding stems to give 1.5 m clearance all-round the crown. The forester then walks ten paces from the marker, parallel to the base-line, and the nearest stem to this point is marked with a white band, as a second marker. Markers may be of any species and any shape; their function is simply to permit an even distribution of potential crop trees. The same procedure is then used again and the process continues, sighting back along the markers to ensure that the line is straight, until the boundary is reached. Then a right angle offset is taken and the process is repeated once more, parallel to and 10 m from the previous line. In this way two good stems are selected and given room to grow for every 10 m^2, thus providing two candidates from which to select the final-crop tree at a later date (Garfitt 1995). This process results in 200 candidate stems per hectare being selected and can be carried out in either a plantation or a stand resulting from natural regeneration. Short and Radford (2008) have outlined another approach – the "2-stick method" – that results in a specified density of trees being selected. Applying the Short and Radford method results in stocking between 350 and 500 stems ha^{-1}, but the method can be modified to result in any required number of selected trees, as long as the trees were planted in lines. It is not suitable for stands derived from natural regeneration.

Free-growth in conifers

Gehrhardt (1925), in his "rapid growth treatment" of spruce (*Picea* Mill. spp.), Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) and beech (*Fagus sylvatica* L.), wanted to achieve a rapid increase in the diameter of the individual stems by early heavy thinning interventions. The crowns of selected trees should not be allowed suffer but be assured of the crown-space necessary for them to grow free of competition. The stand matrix should disappear as quickly as possible as being superfluous or as troublesome competition. The crowns of the selected trees should remain free of competition through to the end of the rotation by continuous thinning and the lower portion of their stems should be pruned (Gehrhardt 1925; cited in Köstler 1956, p. 248). Gehrhardt envisaged that by following these procedures it would be possible to demonstrate: (i) a rise in volume production and (ii) a shortening of the rotation. However, it did not gain support because examples of the rapid growth treatment were not very attractive and yield projections were questioned. Köstler (Ibid.) was of the view that the lack of timber may in future perhaps compel the adoption of similar measures in pure stands of spruce and beech. The size of the stems produced by Gehrhardt's system is shown in Figure 2 in comparison to a moderate thinning system. It is clear that "rapid growth treatment" produces a larger stem and will reduce the time to felling at a target diameter.

The "Scottish Eclectic" thinning method (Macdonald 1961) went further than Gehrhardt's system. The eclectic method recommended the selection and pruning of approx. 150 stems ha^{-1} and to release them from seriously competing dominants. Additional smaller good quality trees (followers) were also selected and released from competition. Finally the better quality stems from within the matrix as yet unthinned are released from competition and pruned. This method was used in Northern Ireland from 1961 in Norway spruce (*Picea abies* (L.) H.Karst.), Sitka spruce (*P. sitchensis* (Bong.) Carr.) and Douglas fir which had already received one light low thinning and was likely to produce sawn timber (Fitzpatrick 1966, p. 105).

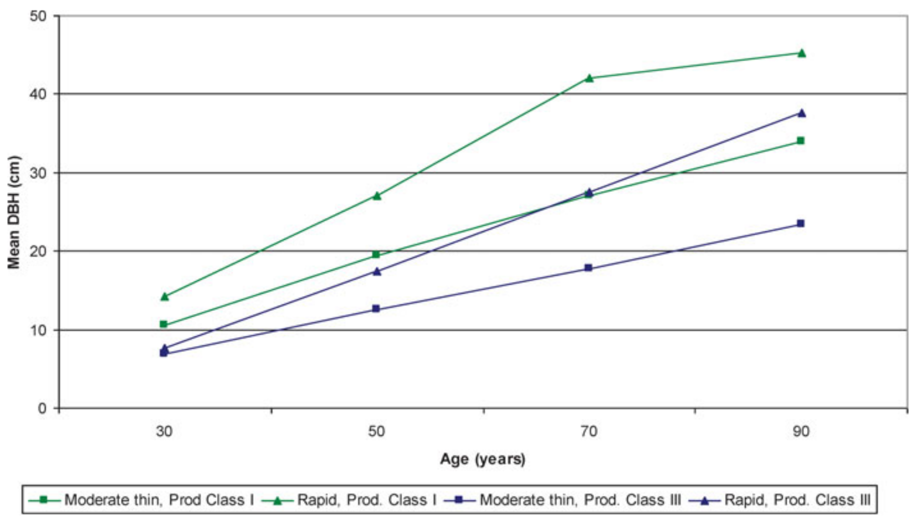

Figure 2: *Mean diameter at breast height (DBH) of Gehrhardt's "rapid growth treatment" in spruce stands of two productivity classes. Adapted from Köstler (1956); Table 60, p. 249.*

It commenced when the plantation was 7.5–9.0 m tall. Some 100–125 final crop trees ha^{-1} were selected and pruned progressively to 7.5 m height. The dominants were then isolated in a heavy thinning by removing competing dominants and sub-dominants, providing room for rapid growth. Smaller trees were retained as ground cover. Fitzpatrick does not explain whether additional, smaller, stems were identified, pruned, and released from competition as per Macdonald's (1961) description of the system.

Free-growth in broadleaves

It was not until 1950 that research on free growth of broadleaves began in Britain, but little research of this kind has been undertaken in Ireland. The first study examined several hundred hedgerow and parkland oak (*Quercus* spp.) and showed that these free-grown trees had substantially greater radial increment than trees in forest stands (Hummel 1951). This led to the suggestion that selecting a relatively small number of well-formed trees early in the rotation and encouraging a clean bole by pruning could result in a complete stocking of valuable trees at maturity.

Kerr (1996) reported the findings of an experiment that included the free-growth of oak (*Quercus petraea* L. and *Q. robur* L.). After a free-growth treatment was applied to a 19-year-old plantation, DBH and stem volume increased compared with the control and light crown thinning treatments. However, pruning of epicormics was required to ensure stem quality was maintained. This led Kerr to the conclusion that this may have been the reason that free-growth of oak has not been widely used in Britain and that it may be a silvicultural system more applicable to ash (*Fraxinus excelsior* L.), sycamore (*Acer pseudoplatanus* L.), cherry (*Prunus avium* L.) and mixed stands of these species.

Free-growth primarily releases selected crop trees and

- favours only the crop trees, leaving the remainder of the stand unthinned;
- favours desired trees using a combination of thinning criteria;
- releases crop trees without strict regard to the position of the trees in the crown.

In an experiment outlined in Jobling and Pearce (1977), a free-growth treatment of oak consisted of 74 dominant trees ha^{-1} of equal dimensions in a 19-year-old plantation being selected, while preserving a space equal to approximately one half of the crown width around them at all times. The thinning cycle was three years. When the trees were 33 years-old, the free-growth treatment was thought unnecessarily severe and the prescription of space allowed around the crowns was altered from one half to one quarter of the crown width (Jobling and Pearce 1977). A comparison of the DBH of oak grown in a free-growth system with that in a conventional intermediate thinning system is shown in Figure 3. Note that, at 100 years of age, the selected free-growth oak have an annual diameter increment of 6.7 mm yr^{-1}, compared with approximately 4.5 mm yr^{-1} for the remaining stems. There is a slight discrepancy with the annual increments given by Evans (1982) for Yield Class 6 oak as averaging 8–9 mm yr^{-1} under free growth compared with about 5 mm yr^{-1} for conventionally thinned dominants, but the trend is similar.

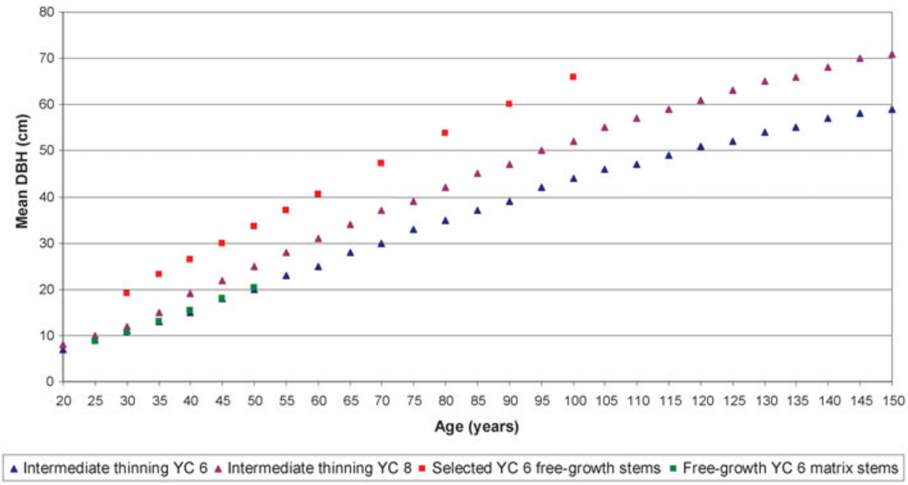

Figure 3: *Mean diameter at breast height (DBH) of maincrop oak. Data from Jobling and Pearce (1977; p. 9) and Edwards and Christie (1981).*

A similar trend of increased DBH in free-grown stems compared to conventional thinning can be seen for cherry (Figure 4). Similar to the previous example, the stems grown in free-growth systems show higher DBH increment, which if maintained, will result in a shorter rotation to a specified target diameter. Cherry is particularly intolerant of lateral crown competition. If a tree's crown growth is restricted, then the stem DBH increment will also be restricted. Even dominant stems can suffer crown dieback if their growth is severely restricted (Pryor 1985). Therefore thinning should be sufficiently heavy and regular to ensure that the crowns of selected trees remain unimpeded until the next thinning. The aim of the free-growth system is to facilitate this objective and may be useful for other similar species, such as ash.

The free-growth oak yield tables of Jobling and Pearce (1977) have been used to compare the financial performance of free-growth oak with traditionally managed oak. Beinhofer (2010) modelled the free-growth system, with and without pruning, and compared it with conventional management. Results from the model showed that oak that is grown under the free-growth system and is pruned, provides a better financial return than conventionally grown oak or unpruned free-growth oak. The free-growth oak approach was still more financially attractive even if the stand was not pruned.

As has been highlighted by Kerr (1996), the free-growth system can be labour intensive in oak due to the pruning and control of epicormic shoots. While this may be true, Beinhofer's economic model suggests that it is still more economic to grow oak under the free-growth system than in a conventional system, whether pruning is carried out or not.

Jobling and Pearce (1977) recommended the following silvicultural operations

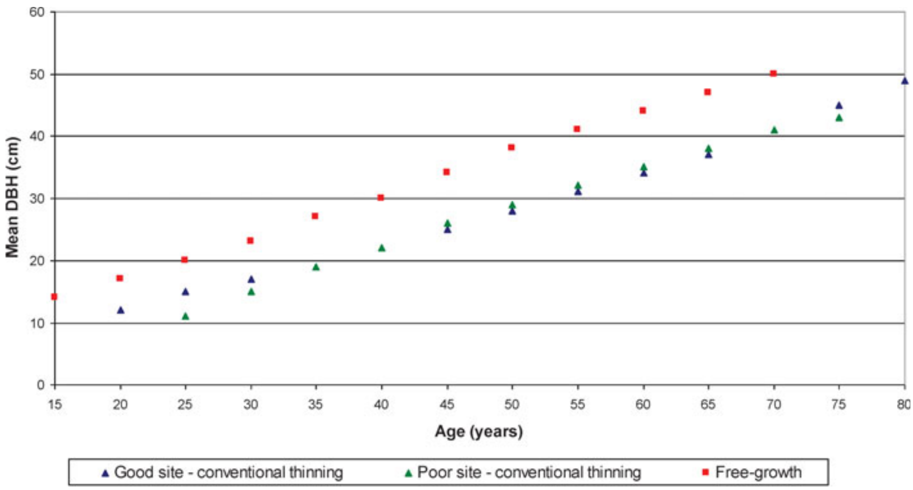

Figure 4: *Mean diameter at breast height (DBH) of cherry (Prunus avium L.) main crop under free-growth or conventional thinning systems. Data from Pryor (1988; p. 18–19).*

for the free growth of oak with the objective to produce veneer quality timber on a rotation of less than 100 years:

1. when mean height is >8 m select 60–80 well-formed dominant trees ha^{-1} evenly spread through the stand;
2. remove all trees whose crowns are within one quarter of the mean crown width of the crown of the chosen trees by thinning;
3. rigorously control epicormics and high prune to remove side branches, ultimately to a height of 6 m;
4. repeat thinning around selected trees every 3–5 years to maintain crown freedom.

There are few references to thinning regimes similar to free-growth in continental Europe. Lemaire (2010; p. 73) described a thinning regime for oak in France (Silviculture Dynamique) in which 70 stems ha^{-1} are selected as the final crop trees before the dominant tree height is 16 m. The selected stems must be free from disease, dominant in the canopy, of good stem form and spaced 6–18 m apart. All stems that are competing with the canopy of the selected stems and <2 m from the canopy of the selected stems are thinned. This regime leaves stems that are within the 2 m but are suppressed or not competing in the canopy. The selected stems are also high pruned as required. The whole procedure is then repeated again 6 years later. The objective of this "silviculture dynamique" system is to produce high quality oak in a rotation of less than 100 years. A target diameter of 65 cm can be attained within 80 years on highly fertile sites using this system. Hein and Spiecker (2009) modelled the growth of ash and sycamore with the objective of producing a target diameter within shorter rotations. Their model suggested that a target diameter of 60 cm could be attained within 60 years by ash and sycamore if the number of crop trees was 61 stems ha^{-1} and 69 stems ha^{-1} respectively. This would require that the mean canopy size is large and therefore would require heavy crown thinning or free-growth.

The expected crown diameter of ash for any mean stem diameter can be calculated as per Hemery et al. 2005. It therefore follows that mean DBH (cm) can be derived from crown diameter (m):

$$DBH = (\text{Crown diameter} - 0.75810) / 0.203565 \quad (1)$$

As crown diameter gets larger, stem diameter also increases. This is especially applicable to ash because it does not respond well to delayed thinning; all thinnings should be heavy with the aim of keeping crowns entirely free of competition. The crop should be at its final spacing by age 30 to 35 (Savill 1991).

There are a number of published studies from the US which have relevance. Erdmann et al. (1985) described the results of a number of thinning treatments on 54-year-old red maple (*Acer rubrum* L.) in Michigan. Some of the treatments were free-growth treatments (called crown release treatments). The crown-thinning treatments were applied to groups of six well-matched trees within each of three crown classes: dominant, co-dominant and intermediate. Six treatments were examined: 1) unreleased control; 2) single-tree release; 3) two-tree release; 4) 1.5 m release; 5) 3 m release, and 6) 4.6 m release. Only the most important crown competitors were cut in the single-tree and two-tree treatments. All surrounding trees, including intermediate and suppressed trees, whose crowns were within the specified distance of the study tree's crown perimeter were cut in the 1.5, 3, and 4.6 m crown-release treatments. These three treatments are forms of free-growth treatment. No thinning occurred in the matrix beyond the treatment areas. After seven years the diameter of crown-released trees had grown 90% faster than the controls, and 33% faster than when only one or two crown competitors were removed. The 1.5, 3.0, and 4.6 m crown release treatments were equally effective in stimulating diameter growth over the 7-year period (Figure 5), implying that canopy closure and resultant crown competition had not occurred within this timeframe.

The 5- and 10-year effects on growth of a free-growth thinning in four hardwood species in Maryland and West Virginia, USA, was reported by Miller (2000). The experiment was carried out in stands that were 12–16 years-old at the time of treatment. Black cherry (*Prunus serotina* Ehrh.), yellow poplar (*Liriodendron tulipifera* L.), northern red oak (*Quercus rubra* L.) and chestnut oak (*Quercus prunus* L.) crop trees were selected and, in the release treatment, all competing trees with canopy touching the crown of a selected crop tree were removed. At one site an additional, higher intensity release treatment was carried out in black cherry and yellow poplar only. All competing trees within 5 ft (1.5 m) of the crown of the selected crop trees were removed in this "release +5" treatment. In both the release treatments there were cases where adjacent crop trees were left touching each other and the treatments were applied around both crop tree crowns. The crown release treatments significantly enhanced the DBH (see Figure 6) and crown growth of the four species, with no adverse effect on survival or crown position for 10 years after treatment. However, too much growing space can be detrimental to height growth of

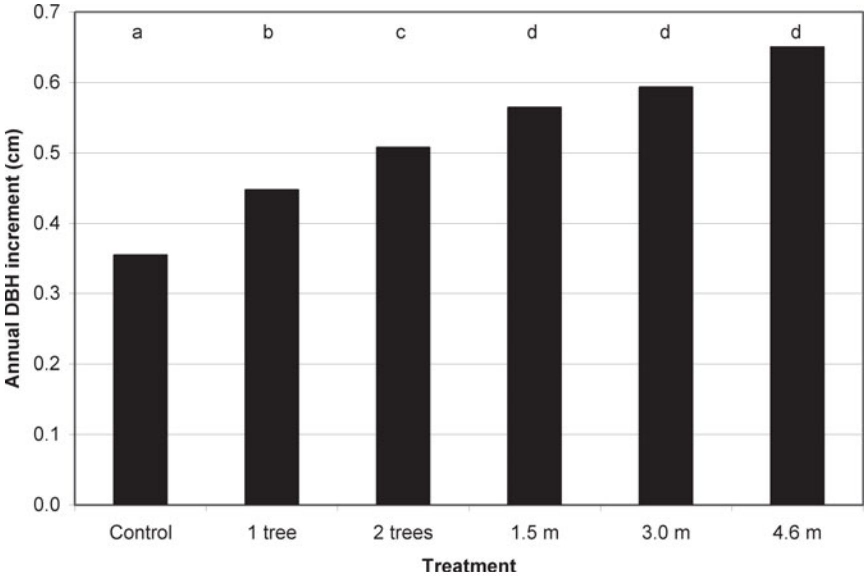

Figure 5: *Annual diameter at breast height (DBH) increment 7 years after crown thinning treatments in 54-year-old dominant red maple in Michigan. See text for treatment descriptions. Treatments with different letters are significantly different p ≤0.05. Source: Erdmann et al. 1985.*

black cherry and yellow poplar, as indicated by results of the release +5 treatment. Miller (2000) concluded that the release +5 treatment should not be prescribed because it could potentially lead to reduced height growth and possible crown class regression. The release +5 treatment was also found to reduce stem quality. It reduced clear stem development by an average of 10 ft (3 m) and the canopy was still open 10 years after treatment. The release treatment reduced clear stem development by an average of 4 ft (1.2 m) for black cherry and yellow poplar and the canopy was nearly closed 10 years after treatment, facilitating natural pruning. Miller's (2000) results suggest that a crown-touching release is an effective, low-risk cultural treatment for young hardwood stands and this treatment is being recommended for young hardwoods in the US (Miller et al., 2007).

Crop-tree release was found by Ward (1995) to increase 4-year stem diameter growth of northern red oak by 86%, black/scarlet oak (*Quercus velutina* Lamb., *Q. coccinea* Muenchh.) by 65%, red maple by 56%, and black birch (*Betula lenta* L.) by 52% in Connecticut compared to unreleased trees. Height growth of the upper canopy oaks was suppressed with increasing crown release during the first two-year period after the treatment but stabilised during the second two year period.

Ash dieback caused by *Hymenoscyphus pseudoalbidus* V. Queloz et al. (commonly called Chalara because it was first described as *Chalara fraxinea* T, Kowalski in 2006) has become more prevalent in Europe during the last decade, so silvicultural strategies have recently been published for the management of affected stands (Thomsen and Skovsgaard, 2012). The strategy recommended is dependent

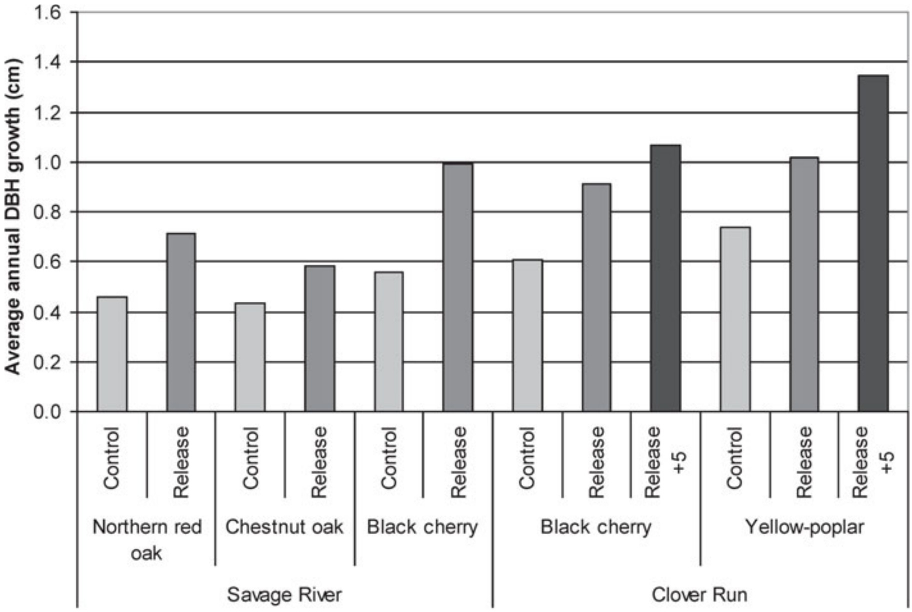

Figure 6: *Average annual diameter at breast height (DBH) growth 10 years after release treatments of four North American 10–16 year-old hardwoods (Miller 2000).*

on the age of the stand and the intensity of infection; severely infected young stands should either be clearcut and replanted, or surviving ash trees should be used as shelter and replanting carried out beneath their canopy. Young stands that have a high percentage of healthy trees should either be retained or more than 200 stems ha^{-1} should be marked and a thinning carried out among the unmarked trees. Older stands should be inspected and all trees with epicormic shoots should be felled as soon as possible to prevent stem wood discolouration through infection of such shoots. Where most of the primary crown is dead and survival is based on epicormic shoots in the crown, the tree should be harvested within the following year. Where >50% of the primary crown is dead the tree should be considered for harvesting. A tree may be considered healthy enough to keep for several years if >75% of the primary crown is intact, unless there are signs of honey fungus (*Armillaria* spp.) fructifications at the base of the tree. It appears that this two-pronged approach has two different objectives. The objective for the younger stands is to maintain productivity and health of the remaining stand, while the objective for the older stands is to harvest merchantable wood prior to any detrimental impact on quality caused by dieback. The free-growth system may have applicability to ash dieback affected stands. Similar to that recommended by Thomsen and Skovsgard (2012), 150 potential crop trees ha^{-1} could be selected and then a free-growth thinning carried out which, in addition, should also remove dieback-affected trees from within the matrix. However, this may open the canopy to such as extent that, on some sites, the stand could be at risk of wind damage.

Pilot trial work

A modified free-growth system is being investigated by the B-SilvRD project as a pilot trial in a privately-owned ash stand in Co. Mayo, planted in 1992. The site is 50 m above sea level. A single 20 × 20 m plot was established in the winter of 2010/11. A similar management approach has been used for the surrounding stand. The area was planted at an original target stocking density of 2,500 stems ha^{-1}. However, the actual stocking rate is 2,850 stems ha^{-1}. The mean DBH of the plot is 9.8 cm (11.7 cm when only stems with DBH >7 cm are considered), a basal area of 30.2 m^2 ha^{-1} (27.4 m^2 ha^{-1} with DBH >7 cm) and 12.6 m top height. The stand had been rated as General Yield Class 8. The stand was of relatively poor quality but there was sufficient quality stems to identify and mark 200 potential crop trees (PCTs) ha^{-1}. Extraction racks were marked at 1:10 lines (approx. 20 m apart). Four crown competitors of each PCT were then marked; some identified competitors were in the racks. Due to the exposure of the site, it was considered too risky to remove more than four crown competitors per PCT. In the majority of cases any remaining trees adjacent to the PCTs were either suppressed or sub-dominants so would have had relatively little competitive impact on the PCTs. The free-growth operation reduced the basal area to 18.3 m^2 ha^{-1} (17.0 m^2 ha^{-1} with DBH >7 cm). The racks, which included some competitors, had a basal area of 1.5 m^2 ha^{-1} (0.7 m^2 ha^{-1} with DBH >7 cm). The DBH of all remaining stems and height of the PCTs is being monitored each year and it is intended that the trial will continue to be monitored and managed after the conclusion of the B-SilvRD project. The objective of the trial is to demonstrate the system and to attain a PCT target diameter within the shortest time period possible. However, the trial is not a replicated experiment so

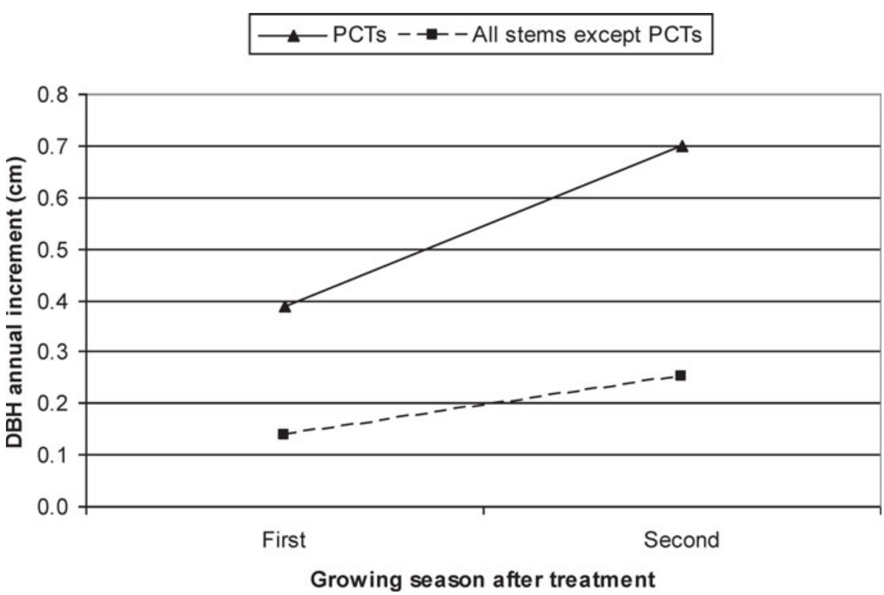

Figure 7: *Annual diameter at breast height (DBH) increment of Potential Crop Trees (PCTs) and matrix trees of a modified free-growth system in 19-year-old ash, Co. Mayo.*

the data must be interpreted cautiously. It is hoped that other similar trials will be laid down in the future, thus allowing a more robust evaluation of treatment effects.

Erdmann et al. (1985) estimated that red maple in America managed with regularly scheduled crop tree release thinnings could result in a stand with mean DBH of 45.7 cm within 85 years. Without release, an additional 42 years would be required to produce similarly sized trees. It is hoped that a similar effect will result in the current trial. The mean annual DBH increment of the first two growing seasons subsequent to the free-growth treatment being applied to the current trial, is illustrated in Figure 7. With a regular continued free-growth management practice being applied it is hoped that the PCTs will continue to exhibit increased DBH growth and attain the target diameter as quickly as possible.

Conclusion

A number of studies have concluded that the free-growth system has the potential to reduce the rotation length of broadleaf stands. The established view of the system seems to be that it is not suitable for oak because of the additional labour required to control epicormic shoots. However, an economic model that used a British free-grown oak yield model casts doubt on the validity of this widely held belief. A free-growth system is being recommended for oak in France. In pole-stage broadleaf stands where there are only a limited number of evenly-distributed stems suitable for selection as potential crop trees, the free-growth system may be the best option that is likely to result in a productive stand. The B-SilvRD pilot trial will, given time, provide useful information for the management of such poorly performing stands and will inform the design of any future fully replicated trial for a robust reappraisal of the free-growth system.

Recommendations

A reappraisal of the free-growth silvicultural system is warranted as it may have potential to improve the productivity and economic viability of poorly performing pole-stage broadleaf stands and the free-growth system should be considered for a number of broadleaf species, including oak.

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