Creating New Broadleaved Woodland by Direct Seeding

PRACTICE GUIDE

Forest Research

Forestry Commission

Summary of establishment recommendations*

Timing	Operation	Vegetation management treatment stage
Year –1 (before sowing)		
September	Collect own dormant seed if carrying out own pretreatment.	
September–November	Place order for pretreated seed, and non-dormant seed, for delivery the following autumn (**recommended option**).	
December–May	Consider if the site requires drainage.	
Year 0 (sowing year)		
July	Start pretreatment of self-collected seed.	
August–September	Spray established vegetation (before end of August if grassland).	1
September	Collect own non-dormant seed if not purchasing.	
September	Drain site if necessary.	
September	Cultivate, and rip if necessary (at least one to two weeks after initial spray).	
September/October	Spray germinating weeds.	1
October–December	Create seedbed and germination niches. Take delivery of purchased seed. Drill larger seed first, then shallow harrow/rotavate and broadcast sow smaller seed. Roll, brush or rake to incorporate seed.	
Year 1 (after sowing)		
November–February	Fence against browsing mammals.	
February	Apply residual herbicide mix.	2
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	3
March–August	Monitor site for infestations of damaging pests.	
December–March	When trees are fully dormant, if necessary spray contact herbicides to control any established weeds.	4
Year 2 (after sowing)		
January–March	Apply residual herbicide mix (combined with contact herbicide if winter application did not take place due to lack of tree tolerance, or was unsuccessful).	5
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	6
July–August	Monitor the site closely and reapply residual herbicide mix if necessary to control germinating weeds.	7
	Subsequent weed control may not be necessary if trees have established.	
December–March	When trees are dormant, if necessary spray contact herbicides to control any established weeds.	8
Year 3 (after sowing)		
January–March	Apply residual herbicide mix (combined with contact herbicide if winter application did not take place due to lack of tree tolerance, or was unsuccessful).	5
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	6
July–August	Monitor the site closely and reapply residual herbicide mix if necessary to control germinating weeds.	7
December–March	When trees are dormant, if necessary spray contact herbicides to control any established weeds.	8
Year 4 (after sowing)		
January–March	Apply residual herbicide mix (combined with contact herbicide if winter application did not take place due to lack of tree tolerance, or was unsuccessful).	5
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	6
July–August	Monitor the site closely and reapply residual herbicide mix if necessary to control germinating weeds.	7
Year 5 (after sowing)	Trees should be established.	

*See Appendix 2 of this guide for modifications to the summary of establishment recommendations for heavy clay sites subject to winter waterlogging.

Practice Guide

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Contents

Disclaimer

This publication is not intended as an endorsement or approval of any product or service to the exclusion of others that may be available. The Forestry Commission accepts no responsibility for any loss or damage resulting from following any advice in this Practice Guide.

Research trials are by their nature carried out on a small scale compared with operational practice. Users are advised to test small areas to gain familiarity with new products and techniques, before engaging in large scale treatments.

Regardless of the guidance contained in this publication, the herbicide product label remains the primary source of information for the safe use of a herbicide.

Introduction

Direct seeding, also referred to as direct sowing, is the process of sowing tree seed by hand or machine directly onto a seedbed in the final growing position for the woodland. It is a historic technique, for which there are numerous references[1], some dating back to the 14th century[2]. Although rarely used compared with planting, the technique has been practised in North America[3] and Europe[4], and in recent years it has been used for both woodland creation[5–7] and amenity tree and woodland establishment[8–10] in the UK.

The Forestry Commission has carried out research on direct seeding since the 1920s[11]. The main conclusion, like that of early practitioners, was that the problems of depredation of seed by mice and birds, variable seed germination and weed competition were more easily managed in forest nurseries. The consensus was that the conventional silvicultural practice of planting trees raised in a forest nursery was preferable to direct seeding when restocking, but that the technique might have some potential in new planting situations.

It is a common misconception to assume that because trees can successfully regenerate themselves through natural seedfall, it is easy to replicate the process through direct sowing. However, a key difference between successful natural regeneration and direct seeding is the quantity of tree seed used in the system. One study estimated that 7.8 million seeds per hectare fell from a well-stocked beech (*Fagus sylvatica*) stand to give 110 000 seedlings per hectare after six years, a 99% loss after seedfall[12]. For ash, it is suggested that a final crop spacing of 120 stems per hectare is required for successful natural regeneration[13]. Since ash typically produces 100 000 seeds per tree every two years[14], this equates to 12 million seeds per hectare every two years. Clearly, sowing several million seeds per hectare over a large area is uneconomic and probably impractical. Fortunately measures such as site selection, species choice, seed pretreatment and vegetation management can increase seedling yields with the result that direct seeding is a practical option in certain circumstances.

The application and scope of this guide

Compared to planting, direct seeding has a number of advantages and disadvantages that must be carefully considered on a case by case basis before reaching a decision on the applicability of the technique. These are described in detail in the following sections. Once the decision has been made to use direct seeding, it is important to recognise that it can be more technically challenging than planting, and hence detailed practical guidance for practitioners forms the major part of this publication. The recommendations are based upon interim experimental results from a limited range of species[15–17], which indicate that direct seeding can be successful in certain limited situations if appropriate silvicultural techniques are applied. However, the outcome is less predictable and more variable compared with planting trees. The detailed prescriptions in this publication replace those given in earlier guidance[18,19].

Advantages of woodland establishment by direct seeding

Creating new broadleaved woodland on lowland sites by direct seeding has several potential advantages compared with the conventional planting of more widely spaced (2 m x 2 m) transplants.

Establishment time

High seedling densities, combined with the absence of transplant shock, can result in much earlier canopy closure (3–5 years after sowing) for direct-seeded stands compared with traditional transplanting at a wider spacing (which may take 10 or more years, depending on spacing). Thus a woodland environment is created far more quickly, which with further management (e.g. early selective respacing) can facilitate the early fulfilment of other objectives, such as the creation of a woodland ground flora[20] or the provision of a community woodland for recreation.

Adjacent plots of direct-sown and planted sycamore, during the third growing season. Transplants were planted in rows at 2 m spacing (2500 trees ha^{-1}); 200 000 viable seeds were sown per hectare. Average seedling density after three years was 44 000 ha^{-1}.

The same plot of direct-sown sycamore taken towards the end of the third summer after sowing, 2 m pole in foreground. Height increments of direct-sown seedlings were around 30% higher than transplants.

Timber quality

High stem density encourages the development of more trees with better form, and creates a large population from which the best quality final timber trees can be selected[13]. Denser spaced woodlands are also less vulnerable to neglect and more tolerant of minor damage from other factors such as pests and diseases[21].

Herbicide inputs

Early canopy closure reduces the length of time herbicides may need to be used, hence direct seeding provides scope to reduce the total amount of herbicide used for tree establishment. Potential savings are even greater if the chemicals used in nursery production are included in any comparison with conventional planting.

Appearance

Local variation in tree spacings and size, including small areas of randomly occurring open space, creates a more natural appearance to the developing woodland, similar to that recommended for the establishment of new native woodlands[20]. This suggests that with the development of the technique to include a wider range of species, direct seeding may offer great potential for linking up existing fragmented areas of ancient semi-natural woodland. In urban areas direct sown seedlings may also be less of a target for vandalism than more obviously managed straight lines of planted trees.

Direct seeded partial 'W8' shrub mix – field maple, hawthorn, dogwood, blackthorn, guelder rose, spindle, wayfaring tree – sown on the edge of a new woodland, after four growing seasons, 2 m pole in foreground.

Farm-scale techniques

Direct seeding uses techniques that are more akin in many ways to the production of arable crops than to conventional forestry. All ground preparation, sowing and subsequent weeding operations could potentially be carried out using modified agricultural machinery. This may be more attractive to a farmer, skilled in establishing agricultural crops but less skilled and perhaps unwilling to engage in the largely labour-intensive planting and establishment of trees using conventional forestry techniques. Farmers may bring their own innovative solutions to problems of seedbed preparation, sowing and seed depredation. Direct seeding may be particularly suited to new, large-scale woodlands where mechanised access is easy.

Cost

Appendix 1, Tables A1.1–A1.4, provides models for the cost of establishing pure ash and mixed native broadleaves by direct seeding and planting. Table 1 summarises total and variable costs over the first 10 years with and without discounting. The models suggest that the variable cost element of direct seeding is around 20% less than conventional planting of 2500 stems per hectare, depending on species and prevailing seed prices.

Table 1 **Summary of cost models for planting (2500 stems ha^{-1}) and direct seeding.**

	Ash (£ ha^{-1})		Mixed native broadleaves (£ ha^{-1})	
	Direct seeding	Planting	Direct seeding	Planting
Total cost	3035	3735	3278	3760
Total discounted cost (@ 6%)	2616	3332	2845	3355
Variable cost	2215	2915	2458	2940
Variable discounted cost (@ 6%)	1835	2551	2065	2575

Disadvantages of woodland establishment by direct seeding

Direct seeding may have the following disadvantages when compared with conventional establishment.

Unpredictability

The successful establishment of direct-sown seedlings is less predictable than planting transplants. Crucially, to have a reasonable chance of success, direct seeding requires careful adoption of good silvicultural techniques (for example, as recommended in the next section, pages 5–22). However, even with good silvicultural practice, complete re-seeding may still be necessary if there is germination failure, for example, as a result of a very wet winter causing seed rotting, or due to high populations of seed-eating predators.

Appearance

In the early phases of establishment, direct seeded sites can appear abandoned and unmanaged compared to neatly planted, well-maintained rows of trees.

Species suitability

Primarily due to the cost of seed and unpredictability of germination, direct seeding is limited to a small range of species. Only oak, ash and sycamore have been extensively tested so far.

Site suitability

Direct seeding techniques should only be attempted on new planting sites where seed predation pressure tends to be lower. Current experience in the UK and abroad suggests that direct seeding is generally unsuccessful in established woodland habitats due to excessive seed predation by small mammals such as field mouse (*Apodemus sylvaticus*), yellow-necked mouse (*A. flavicollis*), bank vole (*Clethrionomys glareolus*), grey squirrel (*Sciurus carolinensis*) and, to a lesser extent, birds. For example, within one experimental series with the same treatments, seedling emergence of ash sown on a windblown beech site was zero, compared with 68% emergence on an ex-pasture site, and 32% on an ex-arable site[15]. **Direct seeding is not currently recommended for broadleaved or conifer restocking where high numbers of seed-eating small mammals are present.**

Direct seeding onto heavy textured soils (clays) subject to winter waterlogging tends to lead to poor results due to seed rotting. For example, in one unpublished research experiment, seedling density in a series of 7 m x 5 m monitoring plots varied between zero in areas where the soil was saturated for long periods during the winter, to the equivalent of 110 000 per hectare in better drained areas only a few metres away.

Recommendations

For successful tree establishment using direct seeding, it is essential that all of the subsequent recommendations are followed.

Selecting suitable sites

Direct seeding should only be used for creating new broadleaved woodland on good quality, well-drained lowland sites, for example, improved grassland or arable sites, or possibly well-restored brownfield sites where mechanised access is easy. Sites with heavy textured soils subject to winter waterlogging should be avoided. As previously mentioned, direct seeding is not recommended for broadleaved or conifer restocking where high numbers of seed-eating mammals are present.

Species and design

The proportion of viable seed that survives, germinates and grows to a height where the trees are established varies greatly. Evidence from field experiments suggests that even under favourable conditions, the percentage of seed surviving to form seedlings at the end of the first year can range from 0 to 50%. It is recommended therefore that a minimum of 200 000 viable seeds (of all species combined) should be sown per hectare, with the intention of establishing 10 000 reasonably evenly-spaced and vigorous trees per hectare by year 10. This sowing rate aims to allow for potential losses from germination failure (the difference between laboratory-determined seed viability and actual field germination percentage) and environmental factors such as winter water-logging, seed depredation, spring drought, pest damage, herbicide damage and weed competition.

Field sowing rates can be calculated as follows:

$$\text{Field sowing rate} = \frac{\text{Target sowing rate (viable seeds per hectare)}}{\text{Proportion viable (from seed viability test)}}$$

For example, if 80% of seeds are estimated to be viable from a standard laboratory test:

$$\text{Field sowing rate} = \frac{200\,000}{0.8\ (80\%\ \text{viable})}$$

= 250 000 seeds per hectare (to give 200 000 viable seeds per hectare).

Seed merchants should provide seed viability test information. Alternatively, Forest Research can provide a testing service for seed that has been collected rather than purchased (see References and useful sources of information).

Species choice

Sowing at such high densities restricts the choice of species suitable for single species sowing to those with cheap, readily available seed (see Table 2). Forest Research have successfully established several stands of ash, sycamore and oak using direct seeding. In one experiment, using a high quality pretreated lowland native woodland 'W8' seed mix, successful establishment of field maple (*Acer campestre*), cherry (*Prunus avium*), hawthorn (*Crataegus monogyna*), blackthorn (*Prunus spinosa*), dogwood (*Cornus sanguinea*), hazel (*Corylus avellana*), wayfaring tree (*Viburnum lantana*) and spindle (*Euonymus europaeus*) has been achieved. However, such species require

further testing, and are likely to show more variable establishment success, depending on variations in seed dormancy and site conditions. Silver birch (*Betula pendula*) and downy birch (*B. pubescens*) are also cheap and readily available but, as yet, are untested by Forest Research for lowland woodland creation by direct sowing.

Good stand of pure oak five years after sowing.

Table 2 **Comparison of the costs of establishing single species by direct sowing of viable seed and planting.**

Species	Recommended sowing rate (seeds ha^{-1})	Typical viability (seeds kg^{-1})	Seed cost: pre-treated (£ kg^{-1})	Seed cost per '000 (£)	Cost (£ ha^{-1})		Planting density (ha^{-1})	Price per plant (£)	Cost (£ ha^{-1})	
					Seed only	Seed & sowing			Plants only	Plants & planting
Ash	200 000	4 000	18.00	4.50	900.00	915.00	2500	0.25	625.00	875.00
Oak	100 000	200	6.00	30.00	3000.00	3020.00	2500	0.30	750.00	1000.00
Silver birch	200 000	150 000	58.00	0.34	77.33	92.33	2500	0.15	375.00	625.00
Sycamore	200 000	3 500	10.00	2.85	571.43	586.43	2500	0.25	625.00	875.00
Wild cherry	200 000	2 000	28.00	14.00	2800.00	2815.00	2500	0.20	500.00	750.00

Where appropriate, seed costs and viability figures are estimated for pretreated seed. Actual prices and viabilities will vary between different seedlots of the same species.

Design

Tree seed from more expensive species such as cherry and oak can be sown as a minor component in an intimate mixture of ash or sycamore to produce a mixed woodland. Given that the cheaper seeded species will form the bulk of the total 200 000 seeds per hectare sowing, it is possible that species comprising the minor component may be suppressed or eliminated. However, it is quite likely, particularly given suitable subsequent respacing operations, that at least a few individuals per hectare from the minor component will survive to maturity, and this may well be sufficient in many situations. See Table 3 for suggested minimum sowing rates. Table 4 gives some examples of possible seeding mixtures.

Where the planting design calls for tree species to be established in specific areas of the woodland rather than in an intimate, random mixture throughout the stand, they should be sown in small

Table 3 Seed costs and estimated minimum sowing rates for trees and shrubs that can be combined in mixtures.

Species	Estimated minimum sowing rate (viable seeds ha^{-1})	Typical viability (viable seeds kg^{-1})	Seed cost: pretreated seed (£ kg^{-1})	Seed cost per '000 viable (£)	Seed cost ha^{-1} seed only (£ ha^{-1})
Ash	30 000	4 000	18.00	4.50	93.90
Oak	10 000	200	6.00	30.00	200.00
Sycamore	30 000	3 500	10.00	2.86	68.70
Provisional recommendations					
Silver birch	60 000	150 000	58.00	0.34	23.20
Cherry	10 000	2 000	28.00	14.00	140.00
Blackthorn	10 000	1 500	18.00	12.00	120.00
Dogwood	10 000	8 000	35.00	4.38	43.75
Field maple	20 000	4 000	10.00	2.50	50.00
Hawthorn*	5 000	3 000	25.00	8.33	41.67
Hazel	2 000	200	6.50	32.50	65.00

* Similar sowing rates could be applied to other minor shrub species such as spindle, guelder rose and wayfaring tree.

Recommended sowing rates are the minimum for use in mixtures. Actual sowing rates should be varied depending on the number of species included in a mix and site conditions. Actual prices and viabilities can vary widely between different seedlots of the same species particularly if native origins are purchased.

Birch is relatively susceptible to residual herbicides, but also relatively cheap, therefore a minimum sowing rate of 60 000 viable seeds per hectare is recommended. Seed may need to be mixed with dry sand (in a 1:1 volume to volume ratio) to aid sowing.

Table 4 Examples of possible seeding mixtures.

Species mixture	Seed cost (£)	Total sowing rate ha^{-1} (viable seed)
200 000 ash	900	200 000
200 000 sycamore	572	200 000
100 000 ash + 100 000 sycamore	736	200 000
Partial 'lowland (W8) new native woodland mix'* 140 000 ash + 10 000 oak + 10 000 cherry + 60 000 birch + 20 000 field maple	1143	240 000
Partial 'native shrub mix'* on selected areas within W8 woodland design left unsown with main tree seed: 50 000 dogwood + 30 000 hawthorn + 15 000 blackthorn + 5000 hazel	811	100 000

* Mixture not fully tested.

Precise mixtures will depend on owner's objectives but a high proportion of oak, ash or sycamore is recommended as these species are subject to more extensive successful testing. In addition, these species are more tolerant of herbicide applications. Use of other species requires herbicide rates to be reduced, and hence levels of weed control are poorer in the first year, so reducing likelihood of success.

clumps separate from the main sowing. Sowing in pure species groups is more likely to guarantee the presence of that species in the established woodland. Such groups may require hand rather than machine sowing. For example, if it is intended that oak is to be the final timber crop species, it could be sown in regular groups of 10 m x 10 m using 20 viable seeds per m^2, throughout the main matrix. FC Bulletin 112 *Creating new native woodlands*[20] provides further guidance on the choice between establishing trees in single species clumps or as intimate mixtures.

Similarly, shrub species should be sown separately where they are specifically required. For example, shrubs could be sown on the edges of open space to create a graduated edge. Cost of seed dictates that shrub species should be sown at no more than 100 000 viable seed per hectare.

However, given that closer spacing is probably less critical than within the main tree species, these rates will probably be sufficient. If direct seeding fails or is inappropriate and certain tree or shrub species form an important component of the design, they can be planted at the end of the first growing season.

Usually, a woodland resulting from direct sowing will have a mixture of heights and spacings of trees, with some randomly occurring open space. However, open space that is required in specific areas of the woodland should be incorporated in the design at the outset. Areas could be left unsown, or if necessary, cleared by year 10, once trees are well established.

Direct seeded predominantly 'W8' native woodland mix – oak, ash, cherry, hazel, hawthorn, field maple, plus sweet chestnut and sycamore – after four growing seasons, 2 m pole in foreground. Shows variation in structure and naturally occurring open space, as advocated for new native woodlands.

Summary of species and design recommendations

- Sow a total of at least 200 000 viable seeds per hectare.
- Recommended species for pure sowings, tested by Forest Research, are ash and sycamore.
- Oak has been successfully tested, and can be sown as pure woodland at rates of 50 000–100 000 viable seeds per hectare. However, if seed is purchased rather than self-collected, costs are only comparable to planting at rates of around 35 000 viable seeds per hectare.
- Seed from tree species that may be too expensive (compared to planting) to be sown in pure woodlands at rates of 200 000 seeds per hectare (e.g. oak) can be added as a minor component of the total.
- Minor components can be sown in clumps or in intimate mixture within the main species matrix. Sowing in clumps of at least 10 m x 10 m, at 20 viable seeds per m^2, is more likely to guarantee the presence of the intended species in the established woodland[1]. If seeding fails it may be possible to reseed, or plant in a defined location within the design. Intimate mixtures may be easier to sow, but survival or presence of a minor component in a particular location may be difficult to guarantee, and subsequent management may be more difficult.
- Whatever species mix is used, it is recommended that either ash, sycamore or oak form a minimum of 75% of the design, i.e. one or more of these species is included at a total sowing rate of no less than 150 000 viable seeds (excluding shrub mixes) per hectare.
- If open space is required in a specific location, it should be left unsown. However, some naturally occurring open space will occur at random throughout a direct-sown woodland.

Species and design: provisional recommendations

- Birch also has seed cheap enough to be sown as pure stands, and should offer good chances of success.
- Cherry seed is more expensive, but could be used as a small component of a cheaper seeded mix.
- Shrub and small tree species mixtures that could be used in clumps within a woodland design are field maple, hawthorn, hazel, dogwood, blackthorn, spindle, buckthorn and wayfaring tree. Guelder rose may have potential but is not yet screened for herbicide tolerance.

Seed: sources, pretreatment and handling

Seed for direct sowing can either be collected from a woodland or purchased from a reputable seed supplier. Self-collection has the advantage of being cheaper, and allows the use of local seed sources where this is an important objective – for example, when expanding or linking areas of existing ancient semi-natural woodland. However, there are several disadvantages to self-collection.

- Very few trees fruit annually – good crops of certain species can be erratic and unpredictable.
- The seeds of large-seeded species such as oak and sycamore are highly perishable and die if they dry out. These seeds are effectively non-storable and should be collected as close to the time of sowing as possible; see FC Practice Note 12 *Handling and storage of acorns & chestnuts and sycamore fruits*[22].
- Many species require complicated dormancy breakage pretreatment to achieve reliable germination[23].

Other than oak, most species currently suggested as potential options for direct seeding (ash, sycamore, cherry, field maple, birch, dogwood, hawthorn, hazel, blackthorn) have dormant seed. This means that the freshly collected or dry stored seed will either not germinate at all, or only germinate very slowly, until they have received a natural or artificial dormancy breakage pretreatment. Natural pretreatment generally takes one or more winters, and because it takes place in the field, seed is vulnerable to predation. Artificial pretreatment is therefore often required before direct seeding. Pretreatment may need to be started up to 48 weeks before sowing, depending on species and sowing date. Details of pretreatment durations are given in Table 5 but by far the best solution is to order pretreated seeds from a reputable seed merchant.

Species with dormant seed should be ordered at least a year in advance, with a stipulation that it must be suitably pretreated by the seed merchant to allow autumn sowing (unless spring sowing is necessary due to site conditions – see pages 11–12).

Species with short-lived, non-dormant seed should also be ordered a year in advance for autumn sowing to allow adequate time for planning collections. Exceptionally, if prolific free local sources of non-dormant seed of the more expensive species (i.e. oak in particular) are available, self-collection may be worth while. If dormant seed is self-collected, it could be sent to a seed merchant for pretreatment.

Although tree seeds are often treated as if they are inert matter, they are living organisms and must be handled with care. All pretreated and short-lived seed should be procured as close to sowing time as possible, kept moist and cool (1–4°C) but not frozen, and handled very carefully to avoid bruising. To reduce the risk of physical damage, seed should be handled with the same care that would be given to ripe, edible soft fruit such as tomatoes. If temporary (a few days or weeks)

storage is necessary, the risk of fungal infection and death can be reduced for modest quantities of seed by placing them at the bottom of a domestic refrigerator (not the freezer compartment), with seed bags left loosely tied to allow gas exchange. Seed should not be allowed to dry out.

The seed of 12 species that might be combined in varying proportions to create different native woodland types.

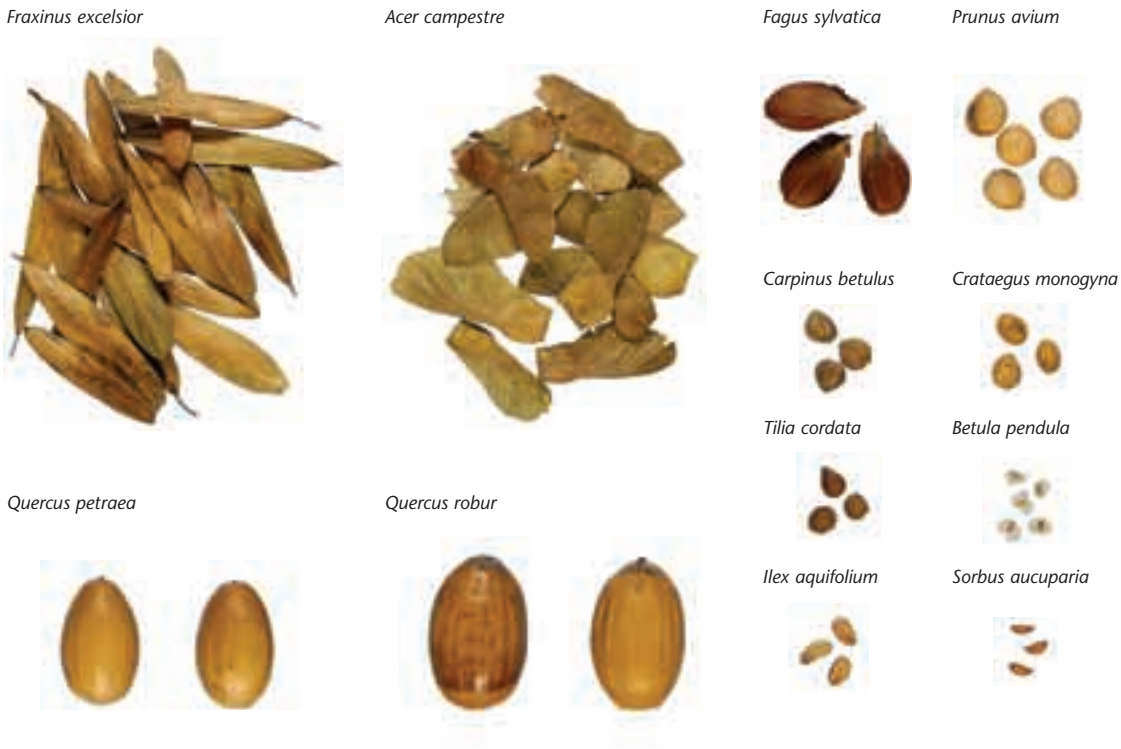

Table 5 Seed pretreatment durations for potential direct sowing species.

Common name	Scientific name	Pretreatment before spring sowing warm followed by cold		Pretreatment before Oct sowing	Efficacy of pretreatment/ remarks
		Weeks warm at around 15°C	Weeks cold at around 4°C	Weeks warm at around 15°C	
Ash	*Fraxinus excelsior*	**16** (8–16)	**20** (16–32)	**16**	B
Birch	*Betula pendula/pubescens*	not required	**3** (3–6)	not required	A
Cherry	*Prunus avium*	**2** (2–8)	**18** (16–24)	**2**	C
Oak	*Quercus petraea/robur*	not required	not required	not required	short-lived
Sycamore	*Acer pseudoplatanus*	not required	**12** (8–16)	not required	B
Dogwood	*Cornus sanguinea*	**8** (8–12)	**12** (12–20)	**8**	B
Guelder rose	*Viburnum opulus*	**4** (4–8)	**8** (8–12)	**4**	C
Hawthorn	*Crataegus monogyna*	**8** (4–12)	**26** (24–32)	**8**	C
Hazel	*Corylus avellana*	not required	**16** (16–20)	not required	C
Field maple	*Acer campestre*	**8** (4–8)	**24** (20–24)	**8**	C
Sloe/ blackthorn	*Prunus spinosa*	**2** (2–4)	**18** (16–20)	**2**	B
Spindle	*Euonymus europaeus*	**10** (8–12)	**16** (8–16)	**10**	C
Wayfaring tree	*Viburnum lantana*	not required	**10** (8–12)	not required	B

A Generally effective – a significant proportion of live seeds should germinate.
B Generally effective although effect of pretreatment durations and/or numbers of repeat cycles may vary significantly between seedlots.
C Only partially effective – even with the longest pretreatment durations and/or several pretreatment cycles.

Figures in bold indicate advisory pretreatment duration.
Figures in brackets indicate that different seedlots often require different pretreatment durations.

Summary of seed: sources, pretreatment and handling

- Order all seed from reputable seed merchants, at least a year in advance of a proposed autumn sowing.
- All dormant seed must be suitably pretreated to break dormancy for autumn sowing or for spring sowing if this is necessary due to site type. This should be specified to the seed merchant.
- In general, it is rarely worth attempting local collection or pretreatment yourself. Acorns may be worth collecting in good mast years, but it is essential to remember that they must be kept cool and moist and handled extremely carefully[22]. If seed from dormant species is collected, it should be sent to a seed merchant for pretreatment.
- Most commercially obtained, pretreated seed will be moist on delivery and must be handled extremely carefully.

Seedbed preparation and sowing

Site preparation must begin in the summer before sowing. Existing vegetation should be completely killed with an overall spray of a broad spectrum contact herbicide, such as glyphosate, no later than the end of September. Grass swards should be killed off before the end of August, when the soil is still dry to reduce the risk of damage from leatherjacket infestations the following year.

The soil should be investigated by digging a series of soil pits across the site. If a plough pan – a layer of compacted soil at the base of the ploughing zone – is present, the site **must** be ripped (subsoiled). All sites should be fully cultivated and rotavated when conditions are suitable (not too wet or dry) to achieve a firm, fine tilth. After cultivation, weeds should be allowed to germinate, then sprayed with a broad spectrum contact herbicide two to three weeks after cultivation.

Sites should be well drained – standing water over winter can kill seeds, and can encourage damaging infestations of slugs. If necessary, create new drainage. This may require inspection the winter before sowing.

Burying tree seed too deep, or allowing it to dry out on the surface, will result in very poor germination. Larger seeded species such as oak should be drilled to around 10 cm. Alternatively, a furrow can be ploughed, seed placed in the bottom, then covered by rolling, or if other smaller seeded species are to be used in addition, covered by shallow rotavating or harrowing. This has the potential to both incorporate the larger seeded species to the correct depth and provide a suitable seed bed with germination niches for smaller seeded species. Smaller seeded species should be sown after any large seeded species have been sown and covered. Small seeded species should be broadcast sown and incorporated to a depth of around 2 cm. Birch seed is best surface sown, and should be mixed with a carrier such as fine, dry sand, to make sowing easier. Sites should be prepared to a fine tilth with very shallow furrows and niches (prepared for example by a ridged roller or harrowing), seed broadcast sown, then rolled with a light, flat roller. If rolling is impossible, the site could be lightly brushed or raked.

Partially pretreated seed should be sown between late October and the end of December, into moist, frost-free sites. Generally, autumn sowings are likely to be preferable to spring as the seed germinates earlier and so is less likely to suffer from heat damage and spring drought. In addition, weed control using herbicides is easier. However, autumn sown seed may suffer more from depredation. The most successful sites established by Forest Research were sown in early December. Sowing can take place throughout the winter until the end of February – late winter

sowing may reduce depredation risk. However, it is often difficult to gain access to and prepare ground from December to late February, hence the recommendation for a late autumn sowing.

Heavy clay sites that are very wet or suffer from standing water in winter months are best avoided. However, if direct seeding is attempted, seed should not be sown in the autumn as the seed may rot over winter. Such sites should be prepared and sown with fully pretreated seed as early in the spring as possible, once conditions allow access.

Protection against mammals and invertebrates

Mammals

Despite high stocking levels, direct sown trees are still vulnerable to mammal damage. High pest population levels usually result in complete failure of tree establishment. Presence of a cover crop or weed cover has not been found to reduce tree damage to any useful extent.

If deer, e.g. roe (*Capreolus capreolus*), are present on or near the site for the new woodland, a combined deer and rabbit fence should be erected. Rabbits (*Oryctolagus cuniculus*) will usually be present: the entire site should always be fully fenced against rabbits and none left within the fenced area. Fences should be inspected regularly to ensure their integrity. FC Bulletin 102 *Forest fencing*[24] gives details of necessary fencing specifications for different mammal species.

Bank voles (*Clethrionomys glareolus*) and field voles (*Microtus agrestis*) may cause problems, particularly once trees are established. Damage can be reduced by maintaining good weed control. Given adequate seedling densities (>10 000 seedlings per hectare), losses from vole damage are unlikely to be catastrophic.

Invertebrates

In common with planted broadleaved woodlands, there are few invertebrate pest problems associated with direct sowing and the use of insecticides is seldom required. In addition, the presence of high numbers of seedlings means that occasional damage to trees is less serious than when establishing transplants at substantially lower stocking levels. The greatest problems in direct sown woodlands are likely to be caused by slugs (e.g. *Deroceras reticulatum*) or leatherjackets, the larvae of cranefly (*Tipula* spp.), during the first growing season after seeding.

In the first year after removal of grass swards, leatherjackets can cause problems, particularly on wet sites. High population levels result in browsing at or below ground level of the seedlings, sometimes leading to tree death. As noted earlier, removal of the grass sward before the end of August, while the soil remains dry, can help to reduce populations.

Other pests, such as wireworms (*Agriotes* spp.), cutworms (*Agrotis segetum*) or short snouted weevils (*Otiorrhynchus* spp., *Strophosomus* spp., *Phyllobius* spp.), as well as slugs, can cause problems to young first year tree seedlings, as they do in forest nursery production. Good weed control both before and after sowing, and site preparation when soil is dry to produce a well-drained, firm, fine tilth, will reduce their incidence. Pine weevils *(Hylobius abietis*) may cause problems where woodlands are established adjacent to conifer stands.

Specialist advice should be sought if any suspicious damage occurs, e.g. cut stems for cutworms; root damage and girdling for larvae of short snouted weevils or foliage feeding from the adults; girdling for all other pests. Different strains of nematodes are commercially available to control both slugs and root feeding insects. A pheromone monitoring scheme exists for cutworms, providing information on the need for and timing of control treatments – contact ADAS for more information.

If the cultural or biological controls described above fail, slugs can also be controlled by applications of metaldehyde, while infestations of leatherjackets, cutworms, wireworms or weevils can be controlled effectively with applications of synthetic pyrethroid insecticides such as alpha-cypermethrin. Specialist advice should be sought before carrying out any insecticide spraying operation (for example from ADAS, or the Tree Health Division of Forest Research).

Vegetation management

The need to weed

Effective weed control is essential, especially in the first year after germination, to ensure seedling survival and reduce the need for weeding in subsequent years. In some Forestry Commission experiments on very fertile weedy sites, weed control was only required for the first two years after sowing because of early canopy closure. By comparison, planted transplants required weeding for a further 1–2 years and several years more of inter-row mowing. Generally, trees should be weeded until they are established and dominating the site – early experiments have shown this will usually occur within 2–3 years when direct seeding at the recommended seed densities is successful.

Recent research experiments suggest the use of arable cover crops offer little benefit. For example, in one experiment, direct sowing with a wheat cover crop produced 625 ash seedlings per hectare, but with no cover crop and full weed control, densities of 6563 seedlings per hectare were obtained[17]. Cover crops provide increased initial income, but are usually detrimental to woodland establishment and long-term revenue, **and as such are not recommended.**

Direct seeding is currently only recommended on fertile, lowland, ex-agricultural sites, or well restored brownfield sites. Once agricultural cropping ceases, or after brownfield site restoration, such sites usually suffer from a prolific growth of highly competitive weeds, which can kill and suppress young tree seedlings. However, the complete eradication of all potentially competing vegetation is seldom practical and not always desirable. A more sensible aim is to maintain the site as weed free as is possible, while accepting some weed invasion is inevitable (around 80–90% weed free is a good practical level of weed control) for the first 2–4 years after sowing, or until trees have become established and access to the site for weeding is no longer possible.

On a very small scale, hand weeding (hoeing) or the use of organic mulches may be an option for weed control. However, in most cases, amongst dense and irregularly spaced small trees, overall sprays of herbicides using farm-based spraying technology is currently the cheapest, most practical option. There is a risk of some herbicide damage to seedlings, particularly in the first year after emergence, but sowing rates should be sufficiently high to allow for this possibility. Given that complete failure is very likely without weed control, the potential benefits outweigh the risk of damage to some seedlings. Although overall sprays are required as opposed to the usual practice of band sprays of planted trees, more rapid woodland establishment may still result in a reduction in the total amounts of herbicide used, when compared with conventional planting.

Where recommended in this guide, herbicides can be used as overall sprays with little danger of damage to, or suppression of, crop trees. However, although no **significant** damage to tree seedlings occurred in any research trials when using herbicides at the rates recommended here, it is possible that some damage may occur in field conditions. Nevertheless, the benefits of removing weed competition should still outweigh any possible disadvantages from using herbicides. The large numbers of tree seedlings present following direct seeding and successful germination (over 10 000 per hectare initially) means that occasional damage or death to a small proportion of the trees from applications of herbicide is not as critical as in low density plantations.

Tree species vary considerably in their relative tolerance to herbicides, particularly in the first year after sowing. Guidance in this publication is for weed control within the main species recommended for direct seeding – ash, sycamore, oak, cherry, field maple and birch. Some information is also given for other, possibly less suitable, species which are not yet fully tested. Recommendations on herbicide tolerance in the first year of establishment are based upon limited evidence, except for those relating to ash, sycamore and oak.

Weeding information is limited to the establishment of new farm woodlands on better quality land – former improved grassland or arable sites – defined as 'farm forestry' for the purposes of herbicide approvals by the Pesticides Safety Directorate.

Vegetation management recommendations

Table 6 gives a typical sowing and weeding regime while Appendix 2 contains recommended modifications if attempting to sow on heavy clay soils that might be waterlogged in winter. Table 7 summarises the herbicide options for each of the weed 'treatment stages' highlighted in Table 6. Given timely pre-emergence weed control (treatment stages 1, 2 and 5), subsequent treatment stages (3, 4, 6, 7 and 8) may not be necessary. However, adopting a purely reactive approach to vegetation management, and failing to carry out effective site preparation and post-sowing pre-emergence weed control, will lead to poor establishment.

In general, herbicides used for the control of agricultural weeds in farm woodlands can be divided into three broad categories.

- Those that are applied directly to established weeds (via roots or foliage) – contact herbicides.
- Those that are applied to bare soil to kill weeds as they germinate – residual soil acting herbicides.
- Those with both contact and residual activity.

The nature of herbicide activity and the species that it controls determines when a herbicide can be used safely and effectively within the regime highlighted in Table 6.

For more detail on herbicide types and for essential information on weed susceptibility and crop tolerance refer to FC Field Book 8 *The use of herbicides in the forest*[25], Field Book 14 *Herbicides for farm woodlands and short rotation coppice*[26], FC Technical Paper 28 *Herbicide update*[27] and FC Practice Guide *Reducing pesticide use in forestry*[28]. None of this information overrides the requirement to read and comply with the conditions of use on the product label.

Table 6 Summary of establishment recommendations*

Timing	Operation	Vegetation management treatment stage
Year –1 (before sowing)		
September	Collect own dormant seed if carrying out own pretreatment.	
September–November	Place order for pretreated seed, and non-dormant seed, for delivery the following autumn (**recommended option**).	
December–May	Consider if the site requires drainage.	
Year 0 (sowing year)		
July	Start pretreatment of self-collected seed.	
August–September	Spray established vegetation (before end of August if grassland).	1
September	Collect own non-dormant seed if not purchasing.	
September	Drain site if necessary.	
September	Cultivate, and rip if necessary (at least one to two weeks after initial spray).	
September/October	Spray germinating weeds.	1
October–December	Create seedbed and germination niches. Take delivery of purchased seed. Drill larger seed first, then shallow harrow/rotavate and broadcast sow smaller seed. Roll, brush or rake to incorporate seed.	
Year 1 (after sowing)		
November–February	Fence against browsing mammals.	
February	Apply residual herbicide mix.	2
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	3
March–August	Monitor site for infestations of damaging pests.	
December–March	When trees are fully dormant, if necessary spray contact herbicides to control any established weeds.	4
Year 2 (after sowing)		
January–March	Apply residual herbicide mix (combined with contact herbicide if winter application did not take place due to lack of tree tolerance, or was unsuccessful).	5
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	6
July–August	Monitor the site closely and reapply residual herbicide mix if necessary to control germinating weeds.	7
	Subsequent weed control may not be necessary if trees have established.	
December–March	When trees are dormant, if necessary spray contact herbicides to control any established weeds.	8
Year 3 (after sowing)		
January–March	Apply residual herbicide mix (combined with contact herbicide if winter application did not take place due to lack of tree tolerance, or was unsuccessful).	5
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	6
July–August	Monitor the site closely and reapply residual herbicide mix if necessary to control germinating weeds.	7
December–March	When trees are dormant, if necessary spray contact herbicides to control any established weeds.	8
Year 4 (after sowing)		
January–March	Apply residual herbicide mix (combined with contact herbicide if winter application did not take place due to lack of tree tolerance, or was unsuccessful).	5
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	6
July–August	Monitor the site closely and reapply residual herbicide mix if necessary to control germinating weeds.	7
Year 5 (after sowing)	Trees should be established.	

*See Appendix 2 of this guide for modifications to the summary of establishment recommendations for heavy clay sites subject to winter waterlogging.

Table 7 Herbicide options for the establishment of new woodland by direct sowing.

Active ingredient	Example product	Formulation	Manufacturer/ distributor	Vegetation management treatment stage				
				1 Site preparation established weeds (Year 0)	2 Post-sowing pre-emergence germinating weeds (Year 1)	3 In season established weeds (Year 1)	4 Dormant season established weeds (end Year 1)	5 Pre-emergence germinating weeds, trees dormant (Year 2[a])
Asulam	Asulox	400 g l^{-1}	Aventis 01223 870312	✓✓		↓		
Atrazine	Atlas Atrazine	500 g l^{-1}	Makhteshim 01635 860555				✓[c]	✓[c]
Clopyralid	Dow Shield	200 g l^{-1}	Dow AgroSciences 01462 457272			✓[j]		
Cyanazine	Fortrol	500 g l^{-1}	Makhteshim 01635 860555				✓[c]	✓[c]
Cycloxydim	Laser	200 g l^{-1}	BASF 0161 485 6222			✓✓[i]		
Fluazifop-p-butyl	Fusilade	250 g l^{-1}	Syngenta 0800 1696058			✓[i]		
Glufosinate-ammonium	Challenge	150 g l^{-1}	Aventis 01223 870312	✓✓		↓	✓[f]	
Glyphosate	Roundup Pro Biactive	360 g l^{-1}	Monsanto 01223 849200	✓✓		↓	✓[f]	
Isoxaben	Flexidor 125	125 g l^{-1}	Dow AgroSciences 01462 457272		✓[e]			✓✓
Lenacil	Venzar Flowable	440 g l^{-1}	DuPont 01438 734000					✓✓
Metamitron	Goltix WG	70% w/w	Bayer CropScience 01223 870312					✓✓
Metazachlor	Butisan S	500 g l^{-1}	BASF 0161 485 6222			✓[j]		✓✓
Napropamide	Devrinol	450 g l^{-1}	United Phosphorus 01925 819999		✓✓[e]			✓✓
Paraquat	Gramoxone 100	200 g l^{-1}	Syngenta 0800 1696058	✓✓		↓	✓[f]	
Pendimethalin	Stomp 400 SC	400 g l^{-1}	BASF 0161 485 6222		✓✓[e]			✓✓
Propaquizafop	Falcon	100 g l^{-1}	Makhteshim 01635 860555			✓[i]		
Propyzamide	Kerb Pro Flo	400 g l^{-1}	SumiAgro 01992 563700				✓✓	✓✓

This table gives a summary only of candidate herbicides for use in direct seeding situations. Users must refer to further guidance on usage and crop tolerance given in product labels and in the other publications listed in References and sources of useful information. Products are safe to use as overall sprays only in situations listed. Due to space restrictions this table only lists example products; other approved products may be available containing the same active ingredient and may be equally suitable.

✓✓ Most major species recommended for direct sowing (ash, sycamore, oak, cherry, field maple, birch) are unaffected by herbicide used as instructed in this publication. However, refer to Forestry Commission publications listed in References for full guidance. Minor species such as blackthorn, hazel, hawthorn, dogwood and wayfaring tree are not fully tested but are likely to be tolerant – see text for details.

✓ Some damage possible.

↓ Use only as carefully directed spray.

Treatment stage			Weeds controlled	Approval status	Rate (l ha^{-1})[b]	Cost per treated hectare (£ herbicide only)	Maximum number of applications per year
6 In season established weeds (Year 2[a])	7 In season germinating weeds (Jun–Aug, Year 2[a])	8 Dormant season established weeds (Year 2[a])					
✓✓[g]			Established bracken and docks	Forestry label	5–10	45–90	1
		✓[c]	Some established grasses + herbaceous weeds. Most germinating grass and herbaceous weeds	Forestry label (essential use)	4[c]	12	1
✓✓			Established thistles, some other herbaceous weeds	Forestry full specific off label	0.5–1	35–70	2
		✓[c]	Some established grasses + herbaceous weeds. Most germinating grass and herbaceous weeds	Forestry full specific off label (essential use)	4[c]	50	1
✓✓			Some established grasses	Forestry label	0.75–2.25	25–75	2
✓✓			Some established grasses	Farm forestry label	0.5–1.5	35–100	2
		✓✓[f]	Most established weeds – deep rooted species require repeat applications	Forestry label	5	65	3
		✓[f]	Most established weeds	Forestry label	1[d]–5	5–25	No max.
	✓✓		Some germinating herbaceous weeds	Forestry label	1–2	110	2
	✓		Some germinating grass and herbaceous weeds	Farm forestry full specific off label	4	135	1
	✓		Some germinating and small established grass and herbaceous weeds	Forestry full specific off label	5 kg ha^{-1}	115	2
✓✓	✓✓		Some germinating and small established grass and herbaceous weeds	Forestry label	2.5	55	3
			Some germinating grass and herbaceous weeds	Farm forestry full specific off label	2.2–9	45–200	1
		✓✓[f]	Most established weeds – deep rooted species require repeat applications	Forestry label	3–5.5	25–45	No max.
	✓✓		Some germinating grass and herbaceous weeds	Forestry specific off label	1.5–5	10–35	1
✓✓			Some established grasses	Forestry label	0.7–1.5	25–50	2 l ha^{-1} yr^{-1}
		✓✓	Most established and germinating grasses, some germinating herbaceous weeds	Forestry label	3.75	90	1

[a] Plus subsequently as necessary.
[b] Except Metamitron (kg ha^{-1}).
[c] Use a mixture of 4 l ha^{-1} atrazine with 4 l ha^{-1} cyanazine. Safe only on heavy textured soils, but can control established and germinating weeds. Ash may be sensitive. Atrazine and cyanazine will be withdrawn by 2007.
[d] Lower rates for overall dormant season sprays.
[e] See rate and species information in the text. Other than for ash, sycamore and oak, evidence of herbicide tolerance is limited.
[f] In small scale trials glufosinate ammonium, glyphosate and paraquat at low rates have been safe over fully dormant broadleaves (stem elongation ceased, leaves shed, buds tightly closed, no green bark) but young or stressed seedlings may be more susceptible. Given this risk of damage, pending further evidence, it is best to avoid applications over dormant, small, one-year-old seedlings unless essential. If grass is the dominant weed type, use propyzamide. See earlier text for details.
[g] Asulam is likely to cause chlorosis and slight check in growth if applied directly to actively growing trees.
[h] Products recommended for use in the spring must be applied while trees are still dormant.
[i] In a small-scale experiment, cycloxydim was safely sprayed over young seedlings of ash, oak, cherry, sycamore and beech without causing damage. Propaquizafop and fluazifop-p-butyl were not tested, but are unlikely to cause damage.
j In a small-scale experiment, clopyralid sprayed over young seedlings of ash, oak, cherry, sycamore and beech had no effect on survival, but did cause some growth suppression of oak and beech. Metazachlor had a greater effect on seedling growth, and should only be considered for use on larger trees (>6 ETL) in the later part of the growing season.

Treatment stage 1: Site preparation – established weeds

Good site preparation will lessen the need for subsequent herbicide use. In addition, it is easier to carry out than post-germination treatments. Any established weeds on the site should be killed with a pre-plant spray of a foliar acting herbicide. Four main herbicides are available (Table 7), but a glyphosate-based product (e.g. Roundup Pro Biactive, 360 g l^{-1} glyphosate, applied at 5 l ha^{-1}) will give good control of a wide range of established weed species. Established grassland should be sprayed off before the end of August to reduce the risk of damagingly high leatherjacket (*Tipula* spp.) populations in the following year. Weedy arable sites should be sprayed before the end of September (before important weed species die back).

After 1–2 weeks, the site should be fully cultivated (and ripped if necessary) when site conditions are suitable (not too wet or dry) to achieve a firm fine tilth. Weeds should be allowed to germinate, then sprayed again with 5 l ha^{-1} glyphosate (e.g. Roundup Pro Biactive, 360 g l^{-1} glyphosate), 2–3 weeks after the initial cultivation. Spraying should be delayed until the end of September to ensure the widest range of germinating weed species (such as cleavers) have emerged and are susceptible to control. A further cultivation may be necessary to create germination niches prior to sowing in autumn. On sites subject to winter waterlogging, this should be delayed until the spring.

Treatment stage 2: Post-sowing pre-emergence treatment – germinating weeds

Post-sowing, pre-seedling-emergence weed control is essential and will reduce the need for subsequent herbicide use. Small scale Forestry Commission trials indicate the following herbicides can be applied post-sowing to clean sites, to give control of newly germinating weed seeds without damaging later emerging tree seedlings. Mixtures of the herbicides listed here and in Table 7 are often the best approach to maximise weed species controlled. For details on weed susceptibility and herbicide mixes, see *Herbicides for farm woodlands and short rotation coppice*[26] and *Herbicide update*[27].

In this treatment stage, while the recommendations for ash and sycamore are derived from a number of direct seeding sites, for other species recommendations are based only on small-scale screening experiments. Users are advised to treat a small test area first before engaging on large-scale applications.

- Ash or sycamore – a tank mix of 6.6 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide) with 5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin).
- Ash or sycamore on very sandy, light-textured soils – a tank mix of 2.2 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide) with 5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin).
- Beech, hazel, spindle or blackthorn – a tank mix of 6.6 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide) with 5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin).
- Oak, hawthorn or whitebeam – a tank mix of 2.2 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide) with 5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin).
- Sweet chestnut – 5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin), or 1 l ha^{-1} isoxaben (as Flexidor, 125 g l^{-1} isoxaben).
- Wayfaring tree – 6.6 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide).
- Norway maple – a tank mix of 2.2 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide) with 2.5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin).
- Field maple – a tank mix of 2.2 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide) with 1.5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin).
- Cherry, rowan, crab apple, hornbeam or dogwood – 2.2 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide).
- Birch is only moderately tolerant to 2.2 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide).
- Buckthorn or alder are moderately tolerant to 1.5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin).

Tree seed should be sown to the correct depth (see Seedbed preparation and sowing, page 11), and there should be at least a two-week delay between treatment and subsequent tree seed germination. Precise treatment timings will therefore depend on sowing date and ground conditions but, in general, all post-sowing pre-emergence herbicides, with the exception of napropamide, should be sprayed between late February and the middle of March, whether sowing has taken place in the autumn or spring. Napropamide is less effective in the spring, and therefore should not be used after the end of February. Hence, after autumn sowings, mixtures of napropamide and pendimethalin should be sprayed between November and February.

Species such as ash, sycamore and oak appear to tolerate higher rates of pre-emergence herbicide than other species, and using lower rates of herbicide will result in poorer weed control, and hence greater seedling losses in the first year. For this reason, it is far easier to practise weed control in pure sowings of ash, sycamore or oak, with other species sown in discrete groups easily treatable with mechanised sprayers. Where intimate mixtures include less tolerant species, it may be most practical to base the herbicide regime on the major species, accepting some losses amongst the minor species (example 1). When more susceptible species form a particularly important or dominant part of the design, use the lower rates tolerated by these species (example 2).

Example 1
Ash (45%), sycamore (45%), cherry (5%) and birch (5%).
Use 6.6 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide) plus 5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin), accepting some damage is likely to cherry and birch, but overall survival ought to be acceptable due to good weed control.

Example 2
Ash (75%), field maple (25%) in an intimate mixture, with the field maple forming a key element of the design.
Use 2.2 l ha^{-1} napropamide (as Devrinol, 450 g l^{-1} napropamide) with 1.5 l ha^{-1} pendimethalin (as Stomp, 400 g l^{-1} pendimethalin).

Treatment stage 3: In season treatment – established weeds

Young first-year seedlings are more vulnerable to herbicide damage than established transplants. With good pre- and post-sowing weed control no further weeding should be required in the first growing season. However, should grasses establish extensively, experiments suggest it is possible to overspray small seedlings safely with cycloxidim. Although not tested, fluazifop-p-butyl and propaquizafop are also likely to be safe.

Some weed species, mainly Compositae and particularly thistles, can be controlled with applications of clopyralid. Established trees (>1-year-old) are unaffected. Small-scale experiments suggest that young seedlings are also tolerant of overall sprays of clopyralid. However, some leaf damage and growth suppression is possible although overall survival is unlikely to be affected, so unless the Compositae weeds are competing severely with seedlings, it is safer to delay any treatment until the following spring or summer.

Metazachlor could also be used to control very small seedling weed growth, and give continued residual control of germinating plants. However, small-scale experiments suggest very young trees (2–6 extended true leaves) treated early in the season, are likely to be damaged and have their growth checked (more so than from applications of clopyralid), although survival is unlikely to be severely affected. Larger seedlings (6–8 extended true leaves), treated later in the season when growth has started to harden (after June, depending on location and season) are more tolerant.

Therefore metazachlor should only be used if severe infestations of very young weeds are occurring, amongst trees that are at least 6 extended true leaves in size, in the later half of the growing season once young tree leaves have started to harden.

Mixtures of cycloxydim, clopyralid and metazachlor do not appear to be any more damaging than the individual herbicides applied separately.

Broad spectrum herbicides such as glyphosate, glufosinate ammonium or paraquat could be used as very carefully directed sprays, but such applications are likely to be costly and difficult to carry out without damaging dense, irregularly spaced seedlings.

Treatment stage 4: Dormant season treatment – established weeds

Control of established weeds at the end of the tree seedling's first growing season can be difficult to achieve without damaging trees, even when they are fully dormant.

At the end of the first growing season when trees are fully dormant – i.e. stem elongation has ceased, leaves have been shed, buds are tightly closed and leader growth hardened – established weeds can be controlled by an overall application of glufosinate ammonium (as Challenge, 150 g l^{-1} glufosinate ammonium, at 5 l ha^{-1}). However, under the current approval, this compound can only be applied between 1 March and 31 October. Therefore any application must be made as soon as possible after 1 March, as long as weeds are green and actively growing, but trees have not yet started to grow.

An application of glufosinate ammonium during this period is often impractical as trees may not be fully dormant. As an alternative, paraquat (e.g. as Gramoxone, 200 g l^{-1} paraquat) may be sprayed at 3 l ha^{-1} or a (360 g l^{-1}) glyphosate product at 1 l ha^{-1}, over fully dormant trees at any time in winter. The use of paraquat or glyphosate allows greater flexibility in timing since applications can be made throughout the winter, however tree tolerance is sometimes variable, particularly with glyphosate[29]. Paraquat is a safer choice for dormant season sprays of broadleaved species[30].

The above recommendations are based upon trials involving nursery trees* and two-year-old direct sown broadleaved seedlings, where no damage was recorded[29,30]. These trials suggest that well-established fully dormant trees (with no young green fleshy growth visible on the stems) are unlikely to suffer from extensive spray damage. However, one-year-old direct sown seedlings with thin or green bark, or seedlings arising from under mature tree canopies after natural regeneration, can be more susceptible to paraquat or glyphosate. Young ash seedlings can be particularly sensitive to glyphosate. However, small-scale experiments have shown that paraquat (e.g. as Gramoxone, 200 g l^{-1} at rates of 3–5.5 l ha^{-1}) can be well tolerated by one-year-old, open grown ash seedlings, even when they are very small as a result of weed competition in their first growing season, providing seedlings are deeply dormant with no green bark present[30]. Given the variable nature of tree tolerance amongst small, one-year-old seedlings, it may be best to limit any applications to small areas where weed invasion has been particularly severe. If grass is the dominant weed, use propyzamide as an alternative treatment (see next section).

For added tree safety, paraquat or glyphosate could be used through hand-held directed sprayers such as guarded knapsack sprayers, dribble bars or weed-wipers. However, such applications are likely to be costly and difficult to achieve with dense, irregularly spaced seedlings.

*1/2U1/2 and 1U1 broadleaved planting stock grown for half a season then undercut and grown on for another half season, or grown for a year, undercut, then grown on for a further year.

Treatment stage 5: Pre-emergence treatment – germinating weeds

Year 2 and subsequent years if necessary

Once established weeds have been controlled, residual soil acting herbicides should be applied to the weed-free site to control germinating weeds.

Tank mixes of soil acting herbicides can be used – the precise combination will depend on the anticipated weed problems. Refer to FC Field Books 8 *The use of herbicides in the forest*[25] and 14 *Herbicides for farm woodlands and short rotation coppice*[26] and FC Technical Paper 28 *Herbicide update*[27] for details of weed susceptibilities and tree tolerance. Commonly used mixes are propyzamide and pendimethalin or isoxaben; metazachlor and pendimethalin or isoxaben; and atrazine and cyanazine (on heavy textured soils only).

The low-rate paraquat applications could be applied to fully dormant trees in March in a three-way mix, e.g. paraquat, metazachlor and pendimethalin. However, because of the concern over tree tolerance, particularly with one-year-old trees (as discussed in treatment stage 4), if grasses form the dominant weed cover on a site, propyzamide should be used. Propyzamide is an alternative to the regime of overall sprays of glufosinate ammonium or paraquat followed by soil acting herbicides; it will not only control the established grasses, but will also provide residual control of germinating grasses and some herbaceous weeds in the following growing season. Pendimethalin or isoxaben may be added to the mix to give better control of subsequent herbaceous weed germination.

Apply soil acting herbicides to cover all soil prior to weed emergence. Maximum efficiency is achieved through applications to moist soil with rainfall following soon after treatment (note that a rain-free period is required if contact herbicides are used in the mix, glyphosate 12 hours, paraquat 1 hour).

Treatment stage 6: In season treatment – established weeds

Year 2 and subsequent years if necessary

There is only a limited range of herbicides that can be safely sprayed over actively growing trees to control established weeds. Application of any of these products, in particular asulam and metazachlor, should only be made after very tender early tree growth has started to harden. The most appropriate product will depend on the specific weed species present.

- Cycloxidim, propaquizafop, or fluazifop-p-butyl will control many established grass species.
- Clopyralid will control thistles and a limited range of other herbaceous weeds, such as mayweed or bindweed.
- Asulam will control docks and bracken, although it may cause some chlorosis and check in growth of actively growing trees.
- Metazachlor is safe to use, but will only control very small established weeds.

An alternative regime would be to use directed sprays of broad spectrum herbicides such as glyphosate, glufosinate ammonium or paraquat, through handheld directed sprays, such as guarded knapsacks, dribble bars or weedwipers. However, such applications are likely to be costly and difficult to achieve with dense, irregularly spaced seedlings.

Treatment stage 7: In season treatment – germinating weeds

Year 2 and subsequent years if necessary

A better option to allowing weeds to establish then controlling them (as described in treatment stage 6) is to very carefully monitor the site for signs of weed germination from early summer onwards. Weed germination can indicate that pre-emergence herbicides applied the previous spring are no longer effective. To limit further germination, immediately seedling weeds begin to emerge, a suitable pre-emergence herbicide can be reapplied (if already used check that repeat applications of that herbicide are permitted) to moist soils. Metazachlor is probably the best herbicide to use for this purpose, as it will also control some very small seedling weeds.

Treatment stage 8: Dormant season treatment – established weeds

End of season dormant sprays are much safer once trees have become larger, usually midwinter following the end of the second growing season. See treatment stage 4.

Subsequent weeding

The steps described up until the end of the second year (treatment stages 5–8), should be repeated as necessary for a further 1–3 years, until the trees have become established and dominate the weed cover, or when mechanised access becomes impracticable. Given good seed pretreatment, sowing and handling, and good site preparation and initial weed control, most direct-sown woodlands should be well established after two or possibly three years.

Post-establishment treatment

The ideal stocking rate after 2–5 years should be around 10 000 stems per hectare, with trees relatively evenly spaced throughout the site. However, given the unpredictable nature of seed and seedling survival this target may be exceeded in some parts of the woodland and not met in others.

Once established, it is important to monitor the growth and development of a direct-sown woodland and decide whether any further silvicultural interventions are required. The aim of these operations should be to maintain the health and vigour of the new woodland. If timber production is an objective, it is important to select evenly spaced well-formed dominant trees of good health and vigour on which to concentrate future volume increment. Where intimate mixtures of a number of species are sown, intervention may be required to prevent suppression of more minor, slower growing species.

Many directly sown woodlands will be close to existing trees or hedges which may contain climbing plants such as old man's beard (*Clematis vitalba)* and honeysuckle *(Lonicera periclymenum)*. These can rapidly invade and swamp and kill young trees, and may need to be controlled in boundary hedges or new woodland as they spread. Bramble (*Rubus fruticosus*) and ivy *(Hedera helix*) can also invade and swamp young trees, but tend to cause fewer problems and should not be removed unnecessarily as they are valuable food plants for insects and birds. Climbing woody weeds can be controlled by herbicides[25] or through repeated annual cutting. Other non-climbing woody species such as blackthorn (*Prunus spinosa)*, goat willow (*Salix capraea)* and birch (*Betula pubescens* or *B. pendula)* can also colonise. Judgements will have to made about whether to control these species based on the degree of competition with the sown species and the objectives of management. For example, moderate invasions (up to 10% of the sown species) of blackthorn, willow or birch, where germination of sown tree seed was poor, may add welcome extra diversity to a new woodland.

Generally, in woodlands established successfully from direct sowing, trees will be at denser spacings and their size will be more variable compared with planted woodlands. At some stage direct-sown trees will need to be respaced to prevent the intense competition which produces thin, weak stems. Early respacing may also be necessary depending on specific recreation or conservation objectives. However, the variability of the trees and the lack of research and experience in this area make it difficult to give specific recommendations on when to start respacing. For the purposes of timber production, the following factors should be considered:

1. Respacing should not be considered until 3 years after canopy closure has occurred on the majority of the area. Selection of trees is a compromise between the vigour of a tree, its form, location and species components. Such selection is easier to carry out after a period of canopy closure.

2. Respacing can be expensive: quoted costs range from £300 to £800 per hectare[31]. However, if it is possible to delay the intervention until a marketable product can be removed this can offset some of the costs.

3. Species vary in their ability to respond to increased light levels following thinning to lessen competition. Oak, beech and sycamore are relatively responsive, cherry is intermediate, and ash and sweet chestnut are relatively unresponsive. For example, the crown depth (tip of tree to lowest live branch) of the latter two species should not be allowed to contract due to shading to less than one-third of the total height of the tree.

4. If respacing occurs early on, and large gaps in a woodland canopy are created, the stumps of trees can quickly re-grow and re-enter and compete with the overstorey. To prevent this, cut stumps can be killed using herbicides in a combined clearing saw/sprayer or by separately spraying cut stumps with a knapsack sprayer or spot gun[25]. A better option is to time the respacing to ensure the canopy of crop trees is sufficiently high that it can close any gaps before coppice can grow tall enough to compete with it. Unwanted stems could be subject to a repeated annual cut, but this is usually prohibitively expensive.

Direct seeded cherry and ash after four growing seasons, 2 m pole in foreground.

In general, most respacing operations are started when the height of the crop is between 2 m and 4 m. Where trees are dense, respacing should be carried out gradually, for example by reducing stocking from 50 000 to 10 000 trees per hectare on the first intervention and to more normal levels of 2500–3500 trees per hectare 2 or 3 years later.

There are two methods of respacing both of which have been designed to reduce costs by only treating a proportion of the woodland. In both methods vigorous, well-formed stems are selected and competing trees are removed to concentrate volume increment on the chosen trees.

Rack cutting

Parallel racks, 1 m wide, are cut every 12–16 m through the woodland. Subject to point 4 above this can be done at an early age when costs will be lower. Respacing is then carried out for 3–4 m on both sides of the rack, so that up to half the area is treated. Generally, the respacing is carried out at the same time as rack cutting. The racks improve access and so reduce the cost of respacing, while dividing the stand for management purposes. For more information see the report by Lanier[32] who discusses the use of this system in France.

The Garfitt method

Respacing is concentrated on small areas containing two selected stems (>2 m apart), with the aim of developing a series of small areas of two cleared stems, each area at approximately 7–8 m intervals throughout the woodland. Each favoured tree is cleared to a distance of 1.2 m radius and the intervening matrix is untouched. For a more detailed description see the study by Garfitt[33].

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The Offical Testing Station for Forest Tree Seed is located at: Forestry Commission, Alice Holt Lodge, Farnham, Surrey, GU10 4LH. Tel: 01420 22255.

Appendix 1

Establishment cost models

The establishment models in Tables A1.1–A1.4 compare planting 2500 stems per hectare (and establishing a grass sward in the inter-rows) with direct seeding to achieve 10 000–50 000 stems per hectare on a lowland ex-arable site, and assume mechanised sowing of seed. Precise costings will obviously vary depending on species, length of weeding required, degree of mechanisation, whether an initial grass sward is already present etc. but it is the comparison between the two systems that is illustrative. Given that seed costs are similar to or less than the cost of purchasing plants (to keep to this rule may of course severely restrict species choice), the establishment model predicts direct seeding to cost around two thirds that of conventional planting.

Table A1.1 Establishment cost (£ ha^{-1}) for planted ash (based on 4 ha site)

Operation	Year										
	0	1	2	3	4	5	6	7	8	9	10
Rabbit fence	390										
Initial spray (mechanised 40, herb 25)	65										
Cultivate (2 passes + rip)	150										
Spray germinating weeds	65										
Seed grass	15										
Grass seed (50 kg x 2.5)	125										
Cut (x2)	60										
Roll/rake	15										
Pre-plant spray planting lines	65										
Plants (2500 x 25p)		625									
Planting		250									
Spray (handheld, residuals, 50% area)		115									
Inter-row swipe		70	70	70	70	70	70	70	70	70	70
Beat up assessment		20									
Beat up (10%)		250									
Spray (handheld 50% contact + residuals)			120	120	120						
Spray (selective grass/thistle)			105	105	105						
Fence/track/ride maint.		15	15	15	15	15	15	15	15	15	15
Total per year	950	1345	310	310	310	85	85	85	85	85	85
Grand total	**3735**										
Discount rate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Discount factor	1	0.94	0.89	0.84	0.79	0.75	0.70	0.67	0.63	0.59	0.56
Discounted cost	950	1268.87	275.90	260.28	245.55	63.52	59.92	56.53	53.33	50.31	47.46
Total discounted cost	**3332**										

Note: Figures in green do not vary with treatment.

Table A1.2 Establishment cost (£ ha^{-1}) for direct sown ash (based on 4 ha site)

Operation	Year										
	0	1	2	3	4	5	6	7	8	9	10
Rabbit fence	390										
Initial spray (mechanised 40, herb 25)	65										
Cultivate (2 passes + rip)	150										
Spray germinating weeds	65										
Sow seed		15									
Cost of seed (200 000 ha^{-1})		900									
Roll/rake		15									
Post-sowing herbicide (mech, 100%)		195									
Spray (mech. 100% contact + residuals)			195	195							
Spray (selective grass/thistle)			75	75							
Fence/track/ride maint.		15	15	15	15	15	15	15	15	15	15
Selective respacing (clearing saw)											550
Total per year	670	1140	285	285	15	15	15	15	15	15	565
Grand total	**3035**										
Discount rate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Discount factor	1	0.94	0.89	0.84	0.79	0.75	0.70	0.67	0.63	0.59	0.56
Discounted cost	670	1075.47	253.65	239.29	11.88	11.21	10.57	9.98	9.41	8.88	315.49
Total discounted cost	**2616**										

Note: Figures in green do not vary with treatment.

Table A1.3 Establishment cost (£ ha^{-1}) for planted mixed oak, ash, cherry, hawthorn, field maple

Operation	Year										
	0	1	2	3	4	5	6	7	8	9	10
Rabbit fence	390										
Initial spray (mechanised 40, herb 25)	65										
Cultivate (2 passes + rip)	150										
Spray germinating weeds	65										
Seed grass	15										
Grass seed (50 kg x £2.5)	125										
Cut (x2)	60										
Roll/rake	15										
Pre-plant spray planting lines	65										
Plants (2500)		650									
Planting		250									
Spray (handheld, residuals, 50% area)		115									
Inter-row swipe		70	70	70	70	70	70	70	70	70	70
Beat up assessment		20									
Beat up (10%)		250									
Spray (handheld 50% contact + residuals)			120	120	120						
Spray (selective grass/thistle)			105	105	105						
Fence/track/ride maint.		15	15	15	15	15	15	15	15	15	15
Total per year	950	1370	310	310	310	85	85	85	85	85	85
Grand total	**3760**										
Discount rate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Discount factor	1	0.94	0.89	0.84	0.79	0.75	0.70	0.67	0.63	0.59	0.56
Discounted cost	950	1292.45	275.90	260.28	245.55	63.52	59.92	56.53	53.33	50.31	47.46
Total discounted cost	**3355**										

Note: Figures in green do not vary with treatment.

Table A1.4 Establishment cost (£ ha^{-1}) for direct-sown mixed native broadleaved ash (140 000, cherry (10 000), oak (10 000), birch (60 000), field maple (20 000)

Operation	Year										
	0	1	2	3	4	5	6	7	8	9	10
Rabbit fence	390										
Initial spray (mechanised 40, herb 25)	65										
Cultivate (2 passes + rip)	150										
Spray germinating weeds	65										
Sow seed		15									
Cost of seed (200 000 ha^{-1}, £13 kg^{-1})		1143									
Roll/rake		15									
Post-sowing herbicide (mech, 100%)		195									
Spray (mech. 100% contact + residuals)			195	195							
Spray (selective grass/thistle)			75	75							
Fence/track/ride maint.		15	15	15	15	15	15	15	15	15	15
Selective respacing (clearing saw)											550
Total per year	670	1383	285	285	15	15	15	15	15	15	565
Grand total	**3278**										
Discount rate	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Discount factor	1	0.94	0.89	0.84	0.79	0.75	0.70	0.67	0.63	0.59	0.56
Discounted cost	670	1304.72	253.65	239.29	11.88	11.21	10.57	9.98	9.41	8.88	315.49
Total discounted cost	**2845**										

Note: Figures in green do not vary with treatment.

Appendix 2

Summary of establishment recommendations for heavy clay sites

Modifications to Table 6 (page 15) for heavy clay sites subject to winter waterlogging.

Timing	Operation	Vegetation management treatment stage
Year –1 (before sowing)		
September	Collect own dormant seed if carrying out own pretreatment.	
September–November	Place order for pretreated seed, and non-dormant seed, for delivery following spring (**recommended option**).	
December–May	Consider if the site requires drainage.	
Year 0 (sowing year)		
July	Start pretreatment of self-collected seed.	
August–September	Spray established vegetation (before end of August if grassland).	1
September	Collect own non-dormant seed if not purchasing.	
September	Drain site if necessary.	
September	Cultivate, and rip if necessary (at least one two weeks after initial spray).	
September/October	Spray germinating weeds.	1
November–February	Fence against browsing mammals.	
March	Spray established weeds, if necessary.	1
March	As soon as ground dries out, create seedbed and germination niches. Take delivery of purchased seed. Drill larger seed first, then shallow harrow/rotavate and broadcast sow smaller seed. Roll, brush or rake to incorporate seed.	
Year 1 (after sowing)		
March	(Immediately post-sowing) Apply residual herbicide mix.	2
March–August	Monitor the site for infestations of damaging pests.	
May–August	Monitor site for **heavy** infestations of grass or Compositae weeds, spray if necessary.	3
December–March	When trees are dormant, if necessary spray contact herbicides to control any established weeds.	4
Year 2 (after sowing)		
January–March	Apply residual herbicide mix (combined with contact herbicide if winter application did not take place due to lack of tree tolerance, or was unsuccessful).	5
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	6
July–August	Monitor the site closely and reapply residual herbicides if necessary to control germinating weeds.	7
	Subsequent weed control may not be necessary if trees have established.	
December–March	When trees are dormant, if necessary spray contact herbicides to control any established weeds.	8
Year 3 (after sowing)		
January–March	Apply residual herbicide mix (combined with contact herbicide if winter application did not take place due to lack of tree tolerance, or was unsuccessful).	5
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	6
July–August	Monitor the site closely and reapply residual herbicides if necessary to control germinating weeds.	7
December–March	When trees are dormant, if necessary spray contact herbicides to control any established weeds.	8
Year 4 (after sowing)		
January–March	Apply residual herbicide mix (combined with contact herbicide if winter application did not take place due to lack of tree tolerance, or was unsuccessful).	5
May–August	Monitor site for heavy infestations of grass or Compositae weeds, spray if necessary.	6
July–August	Monitor the site closely and re-apply residual herbicides if necessary to control germinating weeds.	7
Year 5 (after sowing)	Trees should be established.	

This Practice Guide contains detailed recommendations for the establishment of new broadleaved woodlands by direct seeding, a silvicultural system whereby tree seed is sown by hand or machine into a prepared seedbed at a site intended for woodland creation. The technique has a number of potential advantages over conventional tree planting for new woodlands. It can for example:

- allow selection for better quality timber through higher stocking rates;
- give a more rapid establishment of a woodland environment;
- utilise farm scale techniques and machinery;
- be cheaper;
- offer a means of reducing herbicide inputs.

Woodland stands created by direct seeding tend to have a variety of spacings with randomly occurring open areas, as advocated for new native woodlands, and the technique may be useful for establishing links between existing fragmented areas of ancient semi-natural woodland. Direct seeding also appears promising for creating larger-scale woodlands, particularly where rapid establishment of a woodland cover is desirable, for example in community woodlands.

However, compared with planting, direct seeding has a number of potential disadvantages, outlined in this guide, that must be carefully considered on a case by case basis before reaching a decision on the applicability of the technique. Even when it is considered appropriate, direct seeding is usually more technically challenging, and the outcome less predictable, than conventional planting.

Direct seeding may be worth considering for new broadleaved woodland establishment on good quality lowland sites with lighter textured soils, where mechanised access is possible, and providing ash, sycamore or oak form a dominant part of the species mix. Seed must be appropriately pretreated to overcome dormancy, and seedlings should be protected from browsing mammals and competition from weeds. Currently, direct seeding is not recommended for the establishment of any tree species on restock sites where seed-eating mammals are abundant. It is also not particularly well suited to heavy textured soils subject to winter waterlogging.

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