Generating montane scrub from seeds, and shoot and root cuttings

This guide covers best practice for generating montane scrub plants with particular emphasis on creating planting stock for new schemes, and for enhancing and managing existing populations. For new schemes including uncommon rare willows reference should be made to the Scottish translocation guidance (NSRF 2014).

The Guide is split into three sections:

a) best practice consideration on sourcing plants from which to take seeds, cuttings and/or roots, and identifying new planting sites

b) best practice methods for collecting material, and

c) proven techniques for successful propagation

a) Sourcing seeds, cuttings and/or roots, and identifying new planting sites

This section covers best practice for maintaining and increasing genetic diversity, both **within new planting schemes** and when **enhancing existing populations**. It considers best practice in identifying populations from which to take propagules (seeds, cuttings and/or roots) and also in selecting sites for planting new populations of montane species, especially those species which are currently isolated, fragmentary or otherwise poorly represented in the uplands.

The current state of montane scrub

Montane scrub is severely fragmented in the UK, and these fragments are often small, isolated, and maybe in poor reproductive condition. Within very small populations there may be inbreeding,

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and a loss of genetic diversity. Conversely, between populations, the genetic make-up of populations of the same species in widely separate geographical locations can be very different (WRG 2005, Provan et al. 2008).

Research suggests things are complicated. Consequently, this Guide adopts precautionary principles ensuring the full adaptive potential currently contained in the genetic make-up of UK montane scrub tree and shrub species is retained, and they apply whether planting new populations or augmenting existing ones at higher altitudes (i.e. usually greater than 450 m).

The principles apply to the occurence of all tree species above the timberline as well as more restricted montane willows, including those species that are more widespread at lower altitudes, because it is not known whether higher altitude populations have developed greater suitability to the harsher climate than high forest populations.

Genetic impoverishment has been demonstrated in, the predominantly wind-pollinated, juniper populations in Ireland (Provan et al. 2008).

Genetic degeneration is not widespread in **dwarf birch**, which has a more continuous distribution within its range in the UK. Recent research confirms this, but suggests that some populations may have depended more on vegetative spread – rather than seed (i.e. sexual reproduction) - and so may be less genetically diverse (J. Borrell, pers com.).

Most UK montane willow populations now rarely exceed 100 or even 50 plants. Willows, though, are long-lived, and research has shown that in some willow species there has been little genetic impoverishment, and populations that comprise more than 10 plants tend to be genetically robust (Stamati et al. 2007).

Research on other similarly fragmented and isolated higher plants suggests that hybridisation may be an issue. This tends to occur when small populations are closer to larger populations of widespread, closely related species (Wang et al. 2014. Beatty, Philipp & Provan, 2010)

Maintaining and increasing genetic diversity

A key objective of any montane scrub scheme should be to create viable, self-sustaining and resilient tree and shrub species populations with the potential to adapt to current and future climates. Material for planting must, therefore, be appropriately sourced to provide a good genetic mix in the resulting population whilst taking steps to preserve existing landscape-scale patterns of genetic diversity.

All new proposed planting MUST be within the native range of the species (see http://www.brc.ac.uk/plantatlas/ https://www.snh.scot/sites/default/files/2017-07/A1464519%20-%20Guidance%20Notice%20059%20-%20Native%20Range.pdf)

There are two main approaches to expanding montane scrub and its genetic diversity:

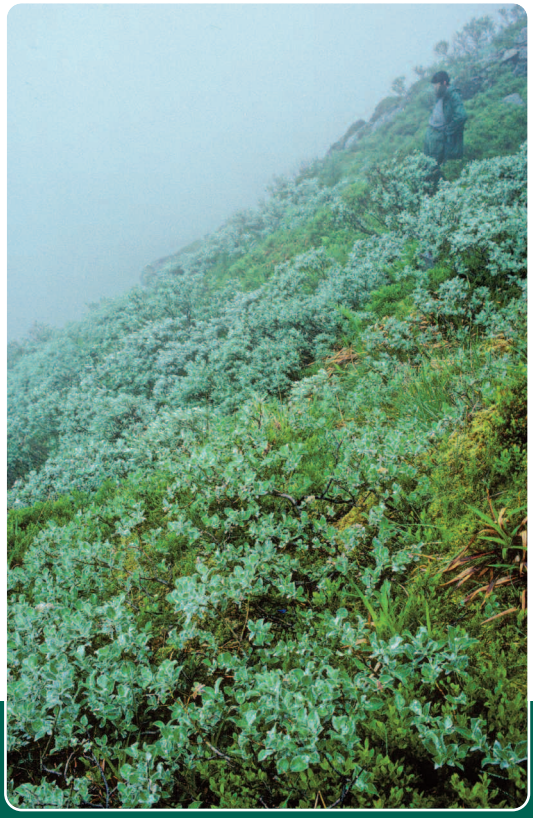
- Large-scale planting at new or historical sites where:
  - Populations of native montane scrub trees or shrub species are not currently present. This includes planting widespread species as well as the more restricted montane willows.
- Reinforcing/augmenting existing populations of:
  - Native woodland where it is at or very close to the natural treeline by natural regeneration or planting of species that are absent.
  - Montane scrub species with additional genetic individuals where current population size is smaller than 50 individuals (i.e. which is considered a viable population – see later).

Identifying propagule collection sites – key considerations

- As populations of many species are adapted to their local environment, it is important to collect propagation material from populations whose sites closely match the characteristics of the planting site. Key factors to consider are climate (rainfall, wind and annual temperatures), aspect, altitude, surrounding vegetation and geology.
- Collect propagation material from multiple populations to promote high levels of genetic diversity and decrease the risk of inbreeding depression in the planted population.
- Collect from donor populations situated within close geographical proximity to the planting site. Where possible source from within a 10 km radius. Material from outwith the UK would be inappropriate.
- When collecting propagation material sample from as many individuals as possible across the whole population. Plantings based on material collected from only a few individuals must be avoided, particularly if clonal origin.
- Ensure the good health of plants being used in a schemes and check for current policy and guidance on tree diseases. In particular see guidance on Juniper (DEFRA 2017, FCS 2013). Otherwise ensure no planting stock in carrying disease (e.g. rusts in willow) that may be inadvertently imported into an existing population.

Where populations have more than 10 plants, planting material should be sourced from the population and from other populations in the vicinity.

If a population has less than 10 plants, planting material should be sourced from other proximal populations, ideally within 10 km.



Identifying new planting sites – key considerations

- Where a planting site is within 10 km of an important population (greater than 100 individuals) it is strongly recommended that the new planting material is collected from the large population.
- When establishing a new population, plant sufficient individuals to ensure a minimum of 50 individuals surviving after five years. A loss rate of up to 25% per annum for the first five years has been found in montane willows (WWSAG, in press).

Managing existing montane willow – key principles for population genetics

- A **viable population** of a montane willow species is regarded as one exceeding 50 genetic individuals (Marriot et al. 2015), where the 50 are spread over no more than 0.3 ha, and where 50% of the individual plants are no more than 10 m apart (Gilbert 2017). **There is a presumption against planting at these populations.**
- An **unviable population** generally occurs where there are fewer than 50 genetic individuals and/or where more than half the plants are over 10m apart and/or spread over an area greater than 0.3 ha. These populations may contain genetically robust groups of individual species, but due to the low numbers (with a possibly skewed sex ratio) are not viable in the longer term. **Planting to increase the viability of these populations is advised.**

b) Collecting material (seeds, cuttings and/or roots)

This section describes two principal methods for collecting propagation material (i.e. '**propagules**') from the wild: as seeds and as cuttings/roots. Both have advantages and disadvantages which need to be considered according to the circumstances.

Users may choose to collect or arrange for the collection of propagules, and then send these to commercial nurseries for growing on. Alternatively, section c) provides information which users may find useful for propagating the materials themselves.

This guide focusses on scarce woody montane species (ie montane willows, prostrate juniper, dwarf birch and aspen see BPG1) as there is limited practical advice in the literature on their collection and propagation. However, many of the principles discussed will also be useful when including more common forest tree species such as downy birch, rowan and Scots pine in a new treeline planting species mix.

Seeds, or cuttings, or roots?
- deciding what type of propagule to collect

Ideally, all planting stock would be grown from wild origin seed to maximise genetic diversity. However, collecting seed from plants in their natural setting is often difficult or sometimes impossible. The issues vary from species to species.

- The proportion of live (viable) seed may be low or variable. This may be due to climate, predation/herbivory, lack of pollinators or inadequate sex ratio (in dioecious species).
- Remnant populations may be very remote and the plants difficult to access on site.
- For short-lived seed species (such as willows in particular), the time of collection can be unpredictable, and several visits may be needed in a season to catch the right stage of seed development.

Some montane scrub species are **dioecious** i.e. having separate male and female plants. These are **aspen**, **juniper** and **willows**.

- Where the population is heavily browsed, flower, and therefore, seed production may be significantly reduced, although the numbers may still be adequate for a very small project.
- For large schemes, sufficient seed may not be available, and collection may need to be phased over several years.
- Some species simply produce seed infrequently.

For example, at the time of writing (Summer 2017), aspen last produced abundant seed in Scotland during the late 1990s).

Collection of seed from wild populations can be feasible, and is likely to be much more successful where locally-based staff/volunteers are involved, who know the site well and can make regular visits. It is also worth remembering that a few catkins will provide seed for tens, if not hundreds, of plants, whereas the same number of cuttings will produce only a small number of plants (but see page 11).

Where collection of sufficient seed from wild populations is impractical or otherwise not feasible, **taking cuttings (from stems or roots)** may be required. If there is an ongoing demand for a large number of plants, these can be grown on as stock plants in a 'cuttings/seed orchard' (see later) for further vegetative propagation and/or off-site seed sources.

Collectors must:

- **Identify** an appropriate, viable source population with suitable genetic make-up (see section a)).
- Obtain **written consent** (from the landowner and SNH).
- Comply with the **regulations on biological collecting, permissions** and **access** to sites.
- Prevent **compromising wild populations** by collecting excessive amounts of seed or cuttings.
- Strictly follow current **biosecurity protocols** to reduce the risk of inadvertently transmitting pests and pathogens on and between sites.
- and follow **health and safety** measures, particularly for bushes restricted to steep slopes, crags and gullies.

Before starting any site work, get written consent from:

- The landowner - if it's not yourself, and
- Scottish Natural Heritage (as the statutory nature conservation agency) - if the site is designated as a SSSI/SAC. Contact **http://www.snh.gov.uk/contact-us/offices/** unless you already know your site's Area officer).

On designated sites, collection of propagules will need consent (as an 'Operation Requiring Consent' (ORC) and this should be requested early in the year as it can be a lengthy process. Annual or ongoing consent may be required.

Access to land - the Scottish Outdoor Access Code **www.outdooraccess-scotland.com/** explains your rights and responsibilities with respect to land access, which are also summarised here **www.snh.org.uk/pdfs/publications/access/full%20code.pdf**

Plant collecting - wild plants are part of our enjoyment of the natural world. All wild plant species are protected by law, and the law in Scotland is explained here **www.snh.gov.uk/protecting-scotlands-nature/protected-species/which-and-how/plants-fungi/**

See also Frachon (2013).

Seed collection must ensure that it does not have a negative impact on the wild population, and collectors are advised to comply with regulations on **plant collecting and access to land**.

To help safeguard this, an SNH consent license will normally state the maximum percentage of catkins that it is permissible to collect.

Seed collectors may be tempted to take what can be reached - for montane willows especially. It is essential to ensure that:

- *collection is from more than one bush;*
- *the collector can see similar numbers of inaccessible catkins;*
- *and collection is unlikely to be repeated annually for a number of years.*

Collecting seed – practicalities

The timing of seed maturity will vary with altitude and species, and from year-to-year depending on how late the seasons are (e.g. how late snow clears, how warm the spring is). Several visits will often be necessary to catch the perfect window for collection.
Seed production varies between years. Where time permits (such as when plants are not required by a deadline, for example, to meet grant requirements), it may be preferable to:

- Collect seed over a number of years (in populations where few catkins are produced each year); and/or
- Wait until there is a good seed year; and/or
- Use an alternative method of propagation (such as taking stem or root cuttings).

Where a population is small and intermixed with another species, there is no guarantee the seeds are true to the mother species (due to possible hybridisation). This can be the case with montane willows, and dwarf birch populations near tree birches. If it is known in a mixed willow population that there are no males from a different species within 5 m of the female carrying catkins, or there is a closer male of the right species, the seed is likely to be true.

Health and safety

Normal procedures and equipment will be needed when working in mountainous environments (warm clothing, good footwear, navigation equipment etc.) and roped access will often be required.

Consider the use of specialist contractors with recognised accreditation (such as through the Industrial Rope Access Trade Association (IRATA) http://www.irata.org/)

It may be possible to work with qualified volunteers such as the local Mountain Rescue team, which may also provide them with innovative training opportunities.

Collectors must be suitably insured and fit to undertake the work.

Biosecurity is a rapidly evolving aspect of forestry and land management, as research and practice develops, and new pests and pathogens come into consideration.
See **https://www.forestry.gov.uk/biosecurity for the latest regulations, advice and best practice**

Healthy plants produce lots of catkins, for example this male woolly willow, top, and female whortle-leaved willow (bottom)

For **willows and aspen**, the timing of seed collection is critical as viability declines rapidly. For these species, catkins should be collected as soon as they start to dehisce (i.e. produce "fluff"). Seed from different willow species will mature at different times of year. The pattern observed at Ben Lawers (earliest to latest) is:

1. Eared willow (*Salix aurita*).
2. Dark-leaved willow (*S. myrsinifolia*) and downy willow (*S. lapponum*).
3. Woolly willow (*S. lanata*) and whortle-leaved willow (*S. myrsinites*).

Short periods of sunny weather can markedly accelerate the onset of maturity.

Dwarf birch seed collection is straightforward. Seeds in catkins are usually ripe from August and remain on bushes until November on lightly or unbrowsed bushes.

If the plants are heavily browsed, flowering is normally limited and so seed production is very low.

In general, bushes are found in much more accessible micro-sites than montane willows, and larger populations produce more viable seed.

Juniper and **rowan** have relatively large seeds and are viable for reasonably long periods. Juniper berries should be collected during the late summer or autumn when they are purple and plump. The berries take 18 months to 2 years to mature, and so some bushes have green as well as purple berries. The green ones are from the current year and will be mature the following autumn. Note also that Juniper berries may take a long time (up to 18 months) to germinate.

Juniper berries and **dwarf birch seeds**, are more durable than willow and aspen but should be carefully stored before sowing to avoid loss to rodents and fungus. To avoid risk of transfer of *Phtytophthora austrocedri*, juniper seed should be cleaned of berry flesh and dried.

Very occasionally, **aspen** has a good seed year and collection of many thousands of seeds from accessible trees is relatively straightforward (once the selection of clones has been decided). In normal years though, very few clones produce seed.

Current research on aspen is building up a picture of which clones have a greater propensity to flower so that collections can be made on a more regular basis. Organisations such as Coille Alba (**www.coillealba.org.uk**), Eadha Enterprises (**www.eadha.co.uk**) and Trees for Life (**https://treesforlife.org.uk/**) are now undertaking ex-situ fertilisation of flowering trees, collecting flower laden branches of males and females, and pollinating and harvesting seed in a controlled environment.

High-altitude aspen is often inaccessible for seed collection and the removal of flower-laden branches. Vegetative propagation through root cuttings or micro-propagation may be an alternative approach in such cases where insufficient accessible clones at high elevation exist. Once propagated, some of this material can eventually be used to create ex-situ cuttings/seed orchards.

Willow and **aspen seeds** are short-lived (up to 7 days for willows) and should be sown as soon as possible after collection.

Seed collecting principles:

- Where there are a large number of bushes (**i.e. more than 20 individuals**) to collect from, aim to:
  - **Take samples from at least 20-30 widely separated** individuals across the population's area to reduce the chances of unknowingly collecting from a few large clones.
  - **Collect from the full range of phenotypes** (i.e. the whole range of traits an individual species shows) avoiding bias towards a particular form.
- **For threatened species** (such as woolly willow *Salix lanata*), **where the population exceeds 20 individuals**, it is recommended to collect no more than 20% of the ripe seed on the day of collection.
- **For populations of between 10 & 20 individuals** collect less than 10% of the viable seed.
- **DO NOT** collect from isolated populations (i.e. greater than 1 km from another) of less than 10 individuals.
- **For rare and restricted populations**, it is preferable to store seed in separate individual bags and keep records of each mother plant.

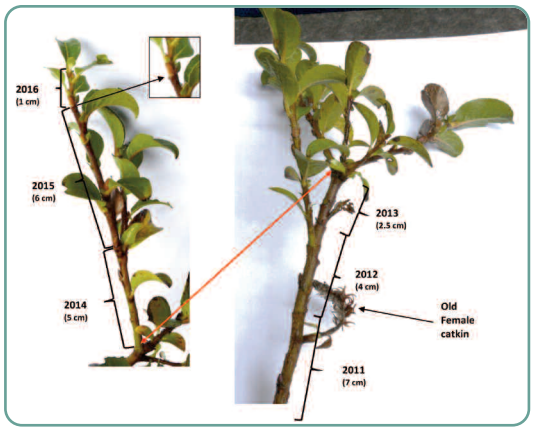
Dwarf birch seed (top) has only very narrow "wings", while tree birch (bottom) has wings that are wider than the seed. The catkin bracts, too, are quite a different shape.

Collection of cuttings and roots – practicalities

As with seed collecting, care must be exercised to not compromise existing populations, and collectors must comply with the same regulations on biological collecting, permissions and access.

In dioecious species it is not possible to tell a cutting's sex unless the cut material flowers. If the population already has a biased sex ratio, planting out additional cutting-origin plants without knowing their sex may exaggerate the bias, and not contribute to the population's viability.

If a population is genetically weak (a possibility in, for example, willow populations with fewer than10 individuals), planting out additional clonal material from the same population will not increase the number of genetic individuals nor increase the viability of the population. In a worst case scenario, this may actually decrease the chance of the population surviving. New genetic material from close, viable populations should be used.



Cutting taken in summer 2016, before the end of the growing season. It is best to take cuttings during the closed season, October to March.

Principles for collecting cuttings and roots:

- For willows, take 1 or 2 cuttings, depending on the size of the parent, which include approximately 3 years' growth and are at least pencil diameter at the widest.
- For dwarf birch and juniper ensure the cuttings include at least 2 years' growth. Do not take a cutting if doing so will reduce the overall size of the plant to less than two-thirds of the original.
- Collect from at least 40 bushes, or, if fewer than 40, collect from all those that are accessible bearing in mind that bushes closer than 2m may be clones. This may include cuttings collected from very small groups, or individual plants.

- Select vigorous plants (where several years growth is clearly visible) - stem cuttings taken from old plants take longer to root or may fail to root. This is particularly the case for juniper where old cuttings have been shown to produce physiologically old plants which tend not to produce viable seed (Ward 1982).
- Make every effort to collect from male and female bushes/trees in dioecious species.

The drying out of cuttings is often responsible for propagation failure.

To avoid water loss through transpiration, place the cuttings in a polythene bag regularly misted and kept under shade if sunny. The cuttings may also be wrapped in moss prior to putting into bags.

Aspen

- can be propagated from root cuttings, individual suckers, or, where large numbers of plants are required, through micro-propagation by plant tissue culture
- any collection should ideally be made from 40 or more clones to ensure sufficient genetic diversity
- root cuttings are ideal where small numbers of plants are required
- lengths of root are normally collected early in the year (January to May), and these should be kept moist in plastic bags prior to propagation in the poly-tunnel during summer
- if micro-propagation is required to produce sufficient plants, stem cuttings should be collected in February. These can be grown from root cuttings and should include a bud from the previous growing season.

Dwarf birch

Grows very successfully from seed, but if necessary can be grown from cuttings using 1 to 2 year-old shoots collected in early spring before bud burst.

Juniper

- in recent trials, cuttings taken from August to September were more successful than those taken at the end of winter or early spring
- material taken from young bushes is more successful than that collected from mature or over mature plants, and it also produces more productive individuals
- beware biasing collecting towards male plants as these often have good growth, and are more suited to taking cuttings from.

Juniper biosecurity – especial care must be taken to avoid taking cuttings from populations with *Phytophthora austrocedri*. See **https://forestry.gov.uk/paustrocedrae** to identify this disease and for measures to restrict its spread.

Willows

- are best propagated from hardwood cuttings, with 2, 3 or 4 year-old wood taking most successfully. Softwood cuttings have proved less successful.
- cuttings should be collected during the dormant season - which is between October and early March, and at the latest as the snow retreats and buds begin to flush. In spring flower buds are often available and these can be sexed by examination with a lens or binocular microscope.

Cuttings/seed orchard

Establishing a cutting/seed orchard is a potential way to reduce the disadvantages of both seed and cutting origin material.

An orchard should comprise individuals of known genetic provenance (i.e. from a distinct geographic area) and, in the case of dioecious species, a mix of sexes. Each individual plant should be labelled with the location of the mother plant and the sex (where known). This information will aid decisions when taking cuttings or effecting controlled pollination for a particular planting scheme.

Best practice dictates that (controlled) seed production would be based on pollination between:

- plants originating within 10 km of each other and the new upland planting site they are being grown for,
- plants grown in similar climatic conditions, and at similar altitudes,
- and pollen collected from all males (at least two), and all females present.

Where the 10 km guide is not feasible mountain massifs provide a useful unit. For example the Cairngorm National Park area. Distinct genetic differences between widely separated populations have been found in Scotland where this has been studied (Salmella et al., 2011), and particularly between east and west. It is advised that a seed orchard should be composed of plants from at least 20 separate individuals originating from within a defined geographical area.

The plants produced from these crosses can then be planted out to increase the viability of any small populations, or to create new populations, within the geographical area of origin.

Setting up a cuttings/seed orchard will allow the full genetic resource of a population or populations to be preserved. However, in controlled conditions it is more likely that plants will flower and set seed eventually which, if there is inadequate oversight, maintenance or record keeping, may 'pollute' any genetic controls.

Each individual wild-origin live plant collection should be made up of plants that are from the same geographical area and that may at some point in their past have been part of the same gene-flow pool. This will – at least initially – give a known genetic base from which to collect propagules from in the future.

Essentials for species identification, collecting equipment and record keeping

Species identification may not be straightforward (even for experts). To give you a hand see the Species Identification Guide for photographs of individual willow species and dwarf and downy birch in winter.

- Hybridisation is common between willow species and can occur between dwarf birch and downy birch.
- It can be difficult to recognise differences between dwarf juniper and common juniper and the two can grow together on the same site.
- Detailed note and record taking may be crucial in aiding identification:
  - Take detailed written field notes including, where possible, the sex of dioecious species, and
    - For rare or threatened species keep propagules from each mother plant in separate labelled bags;
    - For more common species keep propagules from each population similarly separate.
- Take high-resolution photographs (of the plant and its associated ground flora). The most useful are detailed images of twigs, leaves and/or buds.
- Similarly a specimen sample must include as many diagnostic characters as possible – such as mature as well as young wood, leaves, and buds.

Bear in mind that:

Too many notes or photographs are never too many!
And remember – it's easier to look through notes and photos than it is to go back out on site.

What equipment is needed?
This includes established equipment for use in the field, plus some useful additional extras:

- GPS, camera and notebook (paper or electronic) for recording each population and individual bushes.
- Various collecting bags:
  - Paper bags for dry seed.
  - Cloth bags for fleshy seed (both to allow air circulation).
  - Polythene bags for stem & root cuttings (to reduce water loss).
- Permanent marker pen to annotate each bag with a unique collecting number.
- Secateurs, and consider using
  - A telescopic /long-handled pruner (ideally one that maintains a grip on the sample), and/or
  - A walking stick or similar (to carefully reach, hook and pull outer branches towards you or a colleague).

c) Propagation

When propagules have been collected they can be sent away to a nursery for growing on. However, growing on material oneself may be a preferred or desired route to take. This section focuses on small-scale or nursery practice to produce plants of a sufficient quality to survive in challenging high-elevation environments. It provides techniques, for individual species and genera, that have been developed from research and experience.

Some key considerations:

- Good record keeping and labeling is essential. This will ensure the genetic integrity of plants from a population or populations is known, traceable and ensured. The rarer a species and smaller its population, the more precise should record keeping and labelling be. This will also help in deciding that the range of clones originally collected can still be represented in similar proportions when plants are dispatched for planting out.
- Whether growing plants from seed or cuttings, a balance needs to be struck between supplying the optimal growing conditions and preparing the plant for the severe climatic conditions that it is likely to encounter.

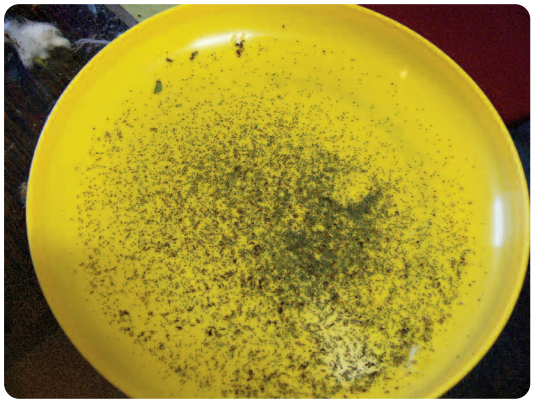
Date:		**Recorder:**		**Site:**		
			Location			
Parent no	**Species**	**Eastings**	**Northings**	**Altitude**	**Photo no.**	**Notes - to include:** Size of parent Number & size of cuttings Site description

E.G.:

Date:	18.10.2006	**Recorder:**	DG	**Site:**	Meall Mhor	
Parent no	**Species**	**Eastings**	**Northings**	**Altitude**	**Photo no.**	**Notes:**
MM6	S. mysinites	210973	756011	580	817	growing on the top of a relatively in accessible rock, S repens-type also present Medium bush: W150, H150, D20, 9 shoots (current yr grwth) taken for cuttings

Propagating from seed

Willows



- If seed is collected from more than one willow species, the nursery should be arranged to minimise the chance of hybridisation. Willows are insect pollinated and stock beds of different species should ideally be separated by at least 100 metres.
- Willow catkins need to be processed quickly after collection. Remove woolly seed from catkins then separate seed from the fluff in some form of centrifuge. For small quantities, this can be done by rapidly stirring fluff in a jar, however, where larger quantities need to be processed, some mechanisation will be helpful.
- Once cleaned, space willow seed evenly over the surface of shallow seed trays. Water from the base and cover with a ventilated lid to prevent seed from blowing off, but allow air movement. Germination is very fast, occurring within 1-3 days. Seed trays should be kept damp but not wet. It is recommended to use a sterilised low-nutrient growing medium to encourage root growth and expansion – roots will form better as they search for the nutrients.
- Willow seedlings are highly susceptible to damping off, and good hygiene, proper aeration, and a weekly application of fungicide can prevent damping-off diseases.
- Pricking out seedlings is optional. This can be done after a few days, and up to one month following germination - after which losses increase significantly. Alternatively, seedlings can be left as sown and inserted in root trainers the following March.

Low-tech Seed extraction methods include:

- Using a very fine sieve (small enough so that willow seeds cannot pass through) and a vacuum cleaner to suck the fluff through the sieve, leaving the seed behind.
- NTS, at Killin, use a sweet, or any large, jar with holes drilled in the lid: many 1.5 mm holes drilled in one corner to make a sieve, and a hole to accommodate the drill. The drill bit is replaced with a flail made from suitable wire or cable ties bunched together to fit the jar size (see photos above).

Juniper

- Most juniper seeds take two winters before germination, but some will germinate after 3, 4 or more winters. Seed can be mixed in a free-draining medium or sown directly into trays. A warm treatment can be applied until the seed coat splits, followed by a short cold period in a refrigerator.
- Trays/pots should then be left outside in a shady location to stratify further (simply using winter temperature) and be protected from rodents. Seedlings should be pricked out a few weeks after germination.
- Regular checking of trays is needed as seedlings may germinate any time during or after the two-year period.

Stratification is the process of treating stored or collected seed prior to sowing to simulate natural conditions that a seed must endure before germination. Some seeds are dormant and require periods of frost, warmth, and/or periods of dryness and moisture, and generally will not sprout until these conditions have been met. The time taken to stratify seeds depends on species and their requirements (see Table 1).

Some juniper growing tips:

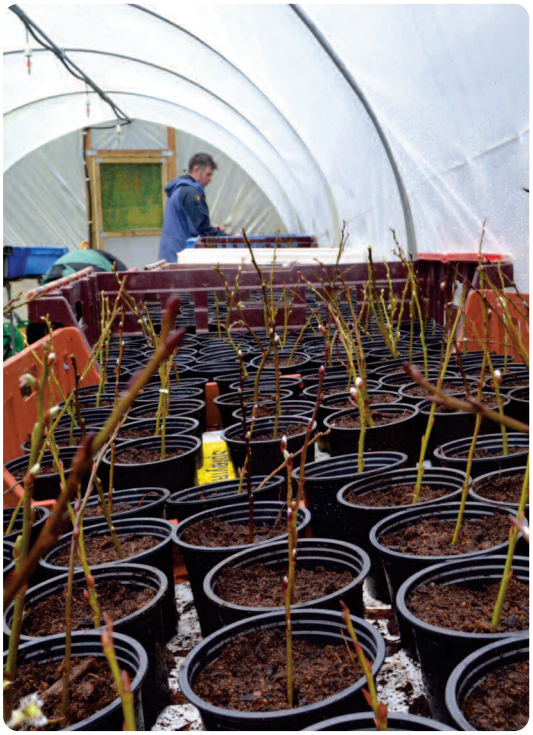
- coarse grit can be used as a top dressing if sowing into trays, to suppress weeds, reduce seed predation and avoid the wind blowing seeds away (a technique used by the Royal Botanic Garden Edinburgh **www.rbge.org.uk/**).
- Trees for Life (**https://treesforlife.org.uk/**) use a free-draining mix with added sand, which junipers grow well in. The seed is mixed with the compost and stratified in pots, and only sown into trays as seed begins to germinate.
- at the Killin nursery, the National Trust for Scotland (**https://www.nts.org.uk**) sow directly into trays and stack these during stratification to reduce growth of liverworts – which can inhibit seedling emergence.

Dwarf birch

- Dwarf birch seed should be stored in a fridge over winter and sowed without additional stratification in the early spring. Sown seed germinates quickly.
- All seedlings should be taken out of the greenhouse/poly-tunnel to harden off, starting between July and September of the year they are sown.
- It has been found there is a trade-off between plant size, number of plants produced, cost per plant, and plant viability. A strategy of producing greater numbers of smaller plants has been found to be more successful than propagating fewer larger plants. This is not only more successful when planted out on the hill but also in the nursery as plants are subjected to less risk from nursery pests such as vine weevils.
- Montane planting generally does not take place until the early summer depending on the climatic conditions in any year. All plants, therefore, should receive one winter in the nursery.
- Hybrid seed has been collected from dwarf birch populations growing close to downy/silver birch woodlands. Hybrids should not be re-introduced back to the wild. As an insurance, any plant that does not show very characteristic (i.e. near circular leaves) should be rejected.

The amount of nursery staff resources, and the aptitude and care taken will have a substantial impact on the level of success. Committed and intensive work to grow woolly willow from seed at the Royal Botanic Garden Edinburgh resulted in 90% of seed germinating and over 50% of seedlings establishing as plants. The method used was to thin seedlings into small clumps 2 months after sowing, pot up clumps in 8x8x8.5 square pots and then insert individual seedlings into Rootrainer™ the following spring. These were moved to an outdoor shade tunnel to harden-off.

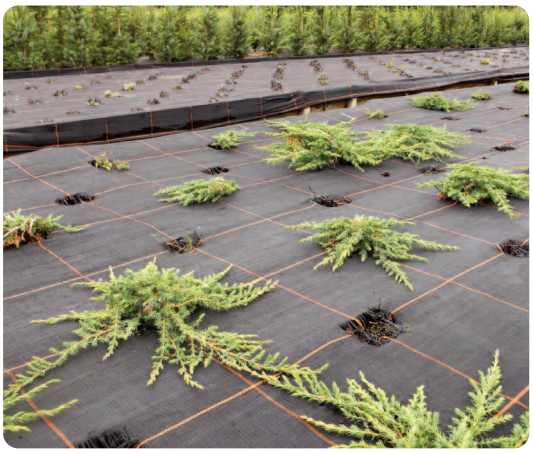
Propagating from cuttings



Willows

- Hardwood willow cuttings should be inserted into a free-draining, sterilised compost. Products such as vermiculite and perlite (or sand) can be added to aid drainage (some may choose not to use these products, due to cost and sustainability issues). A mix containing 1:1 horticultural sand/Melcourt sylvamix growing media is used at the Royal Botanic Garden Edinburgh. Initially, compost should have a low-nutrient status, free from fertiliser – this encourages roots to develop as they search for nutrients.
- Once rooting has started, cuttings are individually potted into cells (e.g. Rootrainer™). An addition of nutrients at this stage can aid the development of strong plants but any additions should be depleted prior to planting out. Short-term fertiliser regimes include:
  - use of liquid phosphate feed, stopping one month before planting out; OR
  - use of slow release fertiliser added to the compost but ensuring that it is used up in the nursery.

Juniper



- Juniper cuttings are a lot more demanding than those from willows. Material from young plants/stock plants is much easier to strike than that from mature or over mature bushes. Material from old, over mature bushes produces physiologically old plants with reduced productivity and should be avoided. Use of under-heated beds in poly-tunnels has proved very successful in some cases – producing 10 cm roots in 6 weeks.

- Fog units are much better than mist units: they produce a constantly humid atmosphere as opposed to a deluge of larger water droplets followed by dry periods. Check cuttings for development of *Phytophthora austrocedri* throughout the production cycle and especially prior to dispatch.

Aspen

- Aspen root cuttings are best planted in boxes of compost/leaf-mould inside a poly-tunnel after collection. Young suckers approximately 10 cm high can then be cut off from the root, dipped in hormone rooting powder and inserted into trays (e.g. 12 cm deep Rootrainer™), and placed in high humidity, such as in a misting unit to root. This process takes between two and three weeks, after which the cuttings can be grown on inside a poly-tunnel, before hardening off outside. Suckers can continue to be 'harvested' from the root cuttings between May and September approximately twice per week for one year.

- Micro-propagation is a relatively new technique to the nursery industry but is proving a useful method for aspen. The process is specialised, and involves having each aspen clone DNA-tested to ensure that it is a unique individual (it is not uncommon for one aspen clone to cover a wide area in non-contiguous stands). A suitable micro-propagation laboratory can then be commissioned to produce the required number of plantlets from each clone. The resulting plantlets will require to be grown on in a tree nursery.

Bare root Vs containerised propagation

Containers are the easiest method for producing most of these montane species, and may be best for planting late in the spring at high elevations, when bare-root plants may no longer be dormant. Hardwood willow cuttings, however, can be grown well in outside beds and then planted bare-rooted if planting conditions allow.

Dispatch

When being dispatched, plants should be:

- identified to avoid 'look-alike` species or hybrids going into the wild;
- checked to make sure they are not diseased or harbouring pests/exotic fauna (such as New Zealand flatworms/eggs, *Phytophthora austrocedri* on Juniper, or rusts on willows)
- weeded to ensure that ruderal/competitive plants from the nursery are not taken into the wild.
- checked for catkins, which should be removed to avoid introduction of hybridized seed.

For cuttings, unless the aim is to follow the performance of individual clones, plants should be dispatched in mixed clonal bundles.

Use of different cell sizes

Trees for Life have found 12cm deep Rootrainer™ (32 in a tray) to be good for producing aspen, juniper and willow plants. Dwarf birches do not produce such a good root system and maybe better in short cells (e.g. 8cm deep), to produce a good plug plant.

Table 1 - Propagation by seed [adapted from Sullivan (2002)]

Species	Collection	Dormancy/ Stratification	Sowing	Germination	Growing on
Aspen	Years of high seed production are infrequent. Seed matures in June. Remove fluff using screen and vacuum cleaner.	No dormancy. Sow immediately. Can be stored at 6% moisture content, -2°C for 1 year.	Thinly on moist seed compost, ensuring good contact. Do not exclude light.	Within 24 hours. Viability high.	Ensure adequate soil moisture. Transplant when required.
Dwarf Birch	Seed matures in August.	Will not germinate below 12°C. Germinates without stratification.	Thinly on moist peat-substitute compost. Do not exclude light.	Low percentage, increased by Gilbberelic acid at $1gl^{-1}$.	Seedling root growth very slow. Grown in short containers for two years to produce a good plug plant.
Juniper	A proportion of cones mature in autumn of second year. Some cones take three years and others never ripen. Collect in October before seed fall and predation. Sub-species *communis* normally has 3 seeds per cone, sub-species *nana*, 1. Remove seed from cones before sowing or stratification.	Stratify in free-draining compost/sand for at least two winters. Dormancy of some seed can be broken by moist stratification at 2-3°C for 4 weeks and then >10°C for 4 weeks, repeated.	Sow immediately after collection and cleaning or, in spring after stratification. Thinly on the surface of moist seed compost. Cover with compost or sand and keep moist.	Viability varies, lower for seed from old plants. Spasmodic germination, occurring throughout the growing season and in successive years. Maximum germination in second or third year.	Transplant when required.
Willows	Seed matures late June-early August, very variable. Collect catkins as soon as first dehiscence occurs. Rub capsules gently so that they split, allowing fluff to expand in a dry place. Then separate seed.	No dormancy. Sow immediately seed is mature.	Thinly on surface of seed compost, ensure good contact of seed with surface. Cover with glass to prevent rain splashes, ensure ventilation.	Within 24 hours. Initial viability high, decreasing to zero in a few days.	Ensure high soil moisture. Transplant when required, normally in spring following sowing.

Table 2 - Vegetative propagation [adapted from Sullivan (2002)]

Species	Timing	Type	Culture	Rooting	Growing on
Aspen cuttings	June July.	Softwood cuttings from vigorous shoots. Treat with hormone rooting powder.	Insert in open media, maintain high humidity (e.g. mist bench).		Wean, harden off and pot up as required.
Aspen suckers & root cuttings	During dormant season. February to April.	Suckers removed with a small section of root. Root cuttings (15 - 20 mm diameter) taken from the tree side of sucker, or from other surface roots at least 2 m from trunk.	Cut any sucker height back by half. Pot up into container appropriate to the size of root.	Already rooted.	Re-pot only if required before planting.
Juniper	Variable, but rooting percentage can be very low. Good results have been obtained from cuttings taken in spring, just before growth starts. However, in some cases, late summer cuttings have been more successful.	Cutting with heal of ripened wood at base. Take cuttings from juvenile material if possible (young bushes in the wild or from stock hedges). Treat with hormone rooting powder.	Insert in open media. Water in with proprietary fungicide. Do not over-water. Rooting is enhanced with bottom heat (20°C).	Formation of callus usually occurs rapidly, this may persist for some weeks before roots begin to form.	Harden off and pot up as required.
Willow	During dormant season.	Hardwood cutting of two or more years old at least 5 mm thick shoots.	Insert outdoors to more than half their depth. Check for frost lift in winter.	Cuttings inserted before soil temperatures fall will root almost immediately.	Pot up as required.
Dwarf birch	Dormancy, before bud burst in spring.	I or 2 year old wood, can be cut down to approximately 10 cm lengths. Treat with hormone rooting powder.	Insert outdoors in well-draining substrate to half depth. Check for frost lift. Can establish earlier in root trainers under cover.	Rooting within 3 months.	Pot up as required.

Acknowledgements

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