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Growing Juniper: Propagation and Establishment Practices

INFORMATION NOTE

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SUMMARY

Juniper is of conservation concern and while there is interest in the expansion and re-introduction of this species in Britain, there is uncertainty over establishment methods. This Note reports results from recent propagation and establishment trials, and gives interim guidance on best practice.

INTRODUCTION

Juniper (*Juniperus communis* L.) is a priority species (for which the Forestry Commission is the contact point) in the UK Biodiversity Action Plan (DoE, 1994) due to its decline in distribution and general lack of population viability and regeneration. Juniper forms an important component of a range of semi-natural vegetation types and is one of Britain's three native conifer species.

There are two subspecies of juniper: the 'dwarf' juniper and the 'tree' juniper. The 'dwarf' juniper (*Juniperus communis* subsp. *nana* Willd.) is a low-growing, matted shrub with elongated berries and abruptly pointed, boat-shaped leaves. It is mostly confined to mountain and coastal areas. This Note is concerned with the 'tree' juniper (*Juniperus communis* subsp. *communis*); a shrub with a dramatic variety of growth forms (Figure 1). Typical bush shapes are described as columnar or upright (which can be up to 10 metres tall), fountain, spreading and procumbent or prostrate. Characteristically the leaves are in groups of 3, almost at right angles to the stem, and the berries are round (Figure 2). The berry is actually the fused fleshy scales of a cone and contains several seeds (normally 3–5). Populations of 'tree' juniper are mainly centred in two contrasting regions of Britain – on the chalk downs of southern England and in the Scottish Highlands – but important populations exist elsewhere, for example in Northumberland and Dumfries and Galloway.

Juniper is a component of semi-natural upland woodlands dominated by oak, birch and Scots pine (Figure 3), corresponding to Habitat Action Plan (HAP) types Upland Oakwoods (National Vegetation Classification (NVC) types W11/W17 – Rodwell 1991), Upland Birchwoods (W11/W17) and Native Scots pine (W18).

Figure 1

Mature juniper bushes showing a variety of form.

Figure 2

Ripe berries of the 'tree' juniper.

Figure 3

Juniper is a component of semi-natural upland birch woodland.

Extensive stands of woodland dominated by juniper also occur and these have been classed as a unique NVC woodland type: W19 juniper–wood sorrel woodland. Juniper should be considered for inclusion in new planting of these native woodland types (Rodwell and Patterson, 1994), and for enhancement planting in existing woodlands of all types—especially in the diversification of upland conifer forests. Juniper can provide important structural diversity to woodlands, both in the shrub layer and along woodland rides and edges. It is a long-lived shrub, relative to fast-growing willows and alders, with ages of over 100 years recorded (G. Patterson, personal communication) and so it provides structural permanence, once established. Juniper is an important food plant for many invertebrates (35 insects and 3 mites being specifically associated with juniper) (Ward, 1977) and the berries are eaten by a number of birds, including thrushes, fieldfares and waxwings.

Forest and land managers may wish to expand or introduce juniper for a variety of reasons (including the biodiversity benefits discussed above), but there is uncertainty over the best methods of propagation and establishment. Natural regeneration seems hard to obtain predictably in the field (Clifton *et al.*, 1995; Gilbert, 1980), leaving planting as the main option for managers.

Juniper can be difficult to propagate from seed and is slow growing which, when coupled with its susceptibility to browsing, can make establishment difficult.

This Note discusses the results from 3 trial sites designed to assess the effects of different management practices on propagation and establishment success of juniper.

METHODS

Nursery and laboratory experiments were carried out to test treatments used to break seed dormancy when propagating from berries, and to develop best practice for propagation using cuttings. Field trials were set up to look at the effects of shelters, fertilisers and weed control on establishment and growth of juniper from seed and plants. The trials were carried out at 3 upland sites (Table 1).

Table 1

Location and climate zone information for 3 upland sites where the juniper trials were carried out.

	Lochaber	Moray	Pentland Hills
Area of Scotland	NW Highlands	NE Highlands	Scottish Lowlands
Grid reference	NH298015	NJ200275	NT229649
Elevation	130 m	320 m	335 m
Climate zone*	Cool moist	Cool wet	Cool wet

*(Pyatt *et al.,* 2000)

CHOICE OF SEED OR CUTTINGS

Juniper bushes are dioecious, i.e. they are either male and produce pollen, or female and produce berries. Therefore all seed is produced by out-crossing and contains genetic material from two parents. This allows for novel re-combinations of genetic material from the parents that may provide the offspring with greater potential to adapt to changing environmental conditions. In contrast, plants grown from cuttings have a genetic make-up that is identical to the parent plant. If choice is not constrained by other factors, the use of seed is preferable to propagating from cuttings, as it will maximise the genetic adaptability of the population—provided that many of the bushes within the population are flowering and contributing to seed production. It is also important to maintain large genetic diversity without losing any local distinctiveness of the population. DNA studies of British juniper show that diversity within existing populations is large, even for populations of only a few bushes. The studies (Borders Forest Trust & University of Edinburgh, 1997; Van der Merwe *et al.,* 2000) also showed that the differentiation of populations varies across Britain with those in England, Wales and northern Scotland appearing genetically discrete (even when separated by only 1 km) whereas those of the Scottish Borders showed little between-population diversity. Although juniper growth can alter in response to environmental conditions, bush form is likely to be under some degree of genetic control with the offspring resembling the parent bush in shape (McVean, 1992). The variety of bush forms often seen within a single stand of juniper reflects the genetic variation of the population (Van der Merwe *et al.,* 2000). The genetic studies to date give no information on the possible site-specific adaptive differences between populations, as these would require long-term provenance trials (Borders Forest Trust & University of Edinburgh, 1997).

The implications of these findings for managers are that:

a) When expanding an existing juniper population it is advisable to source material from the bushes that make up that population, and not to mix material from populations that are more than 1 km away (except in the Scottish Borders).

b) When establishing a new juniper population, material should be taken from the closest source within the same seed zone (Herbert *et al.,* 1999), which also has similar environmental conditions to those of the planting site. Additionally, if the manager feels that replicating the genetic character of the juniper in the area is important, then parent plants should be from a single population, or cluster of populations that are within 1 km of each other. Guidance provided by targeted genetic studies, if available, should be used in making this decision.

c) When collecting material for either expansion or establishment, seed/cuttings should be taken from the whole range of bush forms present in the source population, and material should be collected at the same rate from each bush. A minimum of 30 bushes should be sampled when taking cuttings for propagation, and 20 when collecting seed (Borders Forest Trust & University of Edinburgh, 1997). If only a very few bushes in the parent population are flowering, then it may be necessary to source seed more widely, or to supplement with cuttings to ensure that the genetic diversity of the population is captured. Judging which of these options to follow will depend on the distance to the next suitable source population (see (b) above).

Propagation from Seed

Obtaining juniper plants from seed is not easy, and germination times are long and variable (Figure 4). Seeds from ripe berries will not germinate immediately when sown, but require a cold stratification possibly preceded by a warm period (Baskin & Baskin, 2001; Miles & Kinnaird, 1979). Variability in germination time is considered to be an ecological adaptation, increasing chances of establishment in unpredictable habitats and those resulting from catastrophic events (Moore, 2001). At the Lochaber site, germination took a minimum of 3 months (from spring sowing) following a 15 month stratification period (winter, summer and winter) during which the berries were buried outside in a 2:1 mixture of grit and peat. Seedlings continued to emerge for the following 5 years with the peak in germination occurring 2 years and 7 months after the start of the experiment (Figure 5). Virtually identical results were obtained by Miles (Miles & Kinnaird, 1979) in a similar trial carried out using seed collected from the east and central Highlands.

Figure 4

Germination of juniper is slow and sporadic; these one-year-old and one-week-old seedlings were sown at the same time (the tallest is 10 cm).

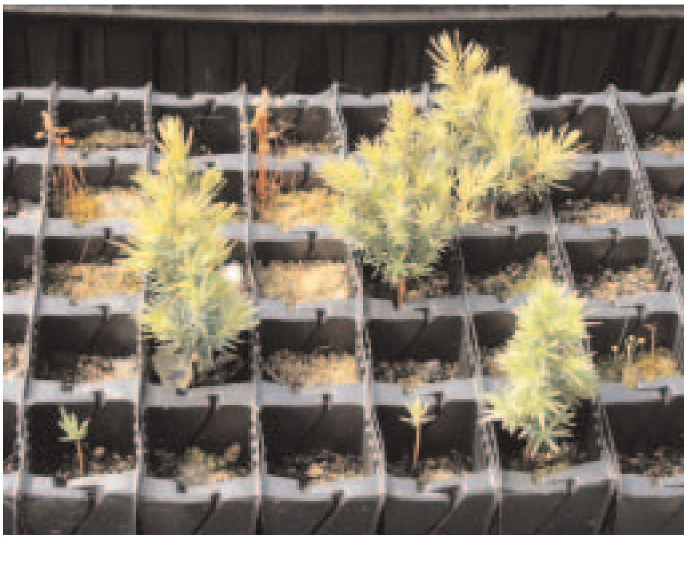
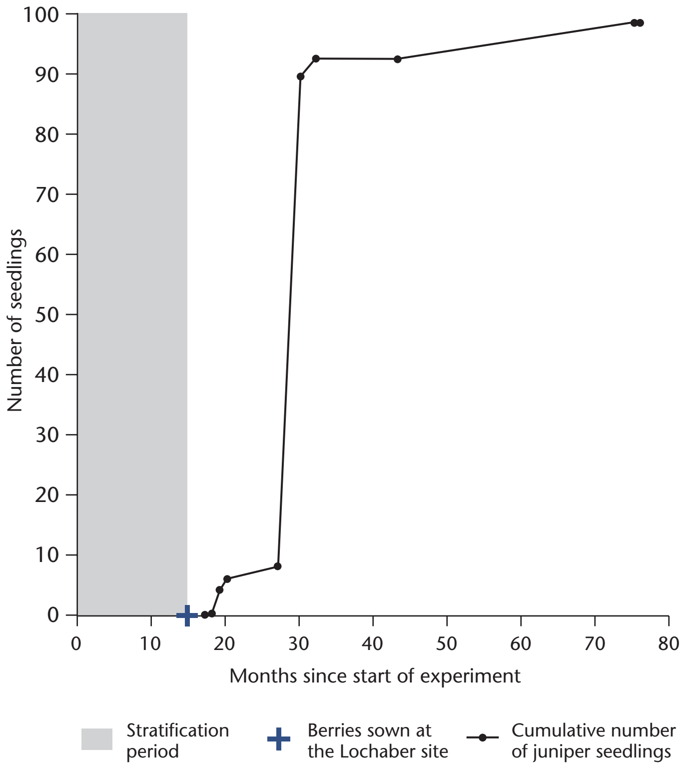


Figure 5

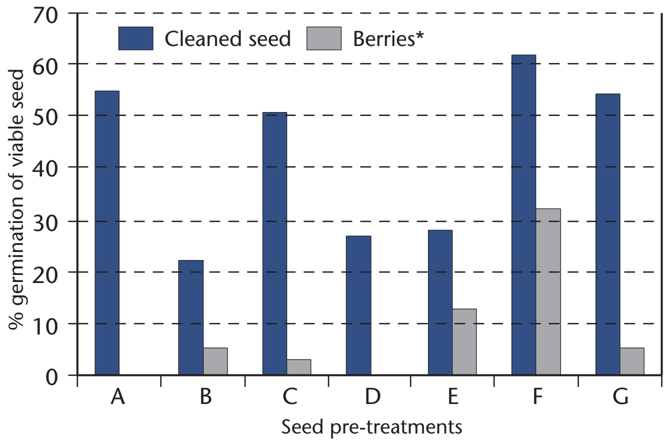
Cumulative count of emerging seedlings over a five and a half year period following a spring sowing of berries at Lochaber. Berries had been stratified in a 2:1 mixture of grit and peat in the ground for 15 months prior to sowing at the Lochaber site.



When propagating juniper from seed for nursery production, it is desirable to have consistent germination times and high germinability (the percentage of seeds that germinate). A series of pre-germination treatments were tested with the aim of finding the best conditions to break seed dormancy. It was found that germinability more than doubled when cleaned seeds were sown instead of whole berries. For all pre-treatments tested, germination did not take place until the second spring after sowing. The highest germinability (50–60% of viable seeds) was recorded when cleaned seeds were exposed to a cool–moist treatment of between 30 and 50 weeks at 0°C, or stratified (by burying outside) for 60 weeks. Freezing (at –13°C for 1 week) during the 'winter' following sowing appeared to reduce germinability, with less than 30% of viable seed germinating in both treatments that included freezing. A warm period (20°C for 13 weeks) did not consistently improve germinability (Figure 6). In a second experiment using cleaned seed, preliminary results suggest that a citric acid (1% solution) or a concentrated sulphuric acid treatment, followed by 12 weeks in cool (4°C), moist conditions significantly ($p<0.05$) improves germinability.

Figure 6

Germination of juniper following seed pre-treatments.



Key to Figure 6

Seed pre-treatment	Pre-treatment (first stage)	Pre-treatment (final stage)
A	Short cold–moist (34 weeks @ 0°C)	17 weeks @ 4°C
B	Medium cold–moist (43 weeks @ 0°C) + freeze	16 weeks @4°C
C	Long cold–moist (51weeks @ 0°C)	17 weeks @ 4°C
D	Short warm–moist/cold–moist (13 weeks @ 20°C + 21 weeks @ 0°C)	17 weeks @ 4°C
E	Medium warm–moist/cold–moist (13 weeks @ 20°C + 30 weeks @ 0°C) + freeze	16 weeks @ 4°C
F	Long warm–moist/cold–moist (13 weeks @ 20°C + 38 weeks @ 0°C)	17 weeks @ 4°C
G	Stratified 60 weeks outdoors	17 weeks @ 4°C

*An average of 4.2 seeds per berry was assumed

Birds are considered to be important dispersal agents for juniper. The fruit surrounding the seed is thought to contain a germination inhibitor; when the fruit is broken down during the acid digestion in the bird's gut, the chances of the defecated seed germinating is thought to increase (Meyer & Witmer, 1998). This is consistent with the results from this investigation and with the circumstantial evidence suggesting that more seedlings germinate close to bird perches and fence lines than in areas where berries have just fallen from bushes. Juniper seed is reported to have double dormancy; an external dormancy resulting from a thick seed coat and internal or embryo dormancy due to the physiological immaturity of the embryo (Anon, 1948). The requirement for a long cold period is thought to be necessary for the embryo to mature and acid treatments for the digestion of the seed coat. Based on experimental results, it is recommended that the following treatments are carried out in order to break dormancy. The seed is removed from the fruit and soaked in a 1% citric acid solution for 4 days. The seed is then stored in well-aerated conditions, at 4°C for a minimum of 30 weeks before sowing. Direct sowing of berries in the field is not recommended.

Propagation from cuttings

Taking cuttings is the most reliable and rapid method of propagating juniper (Figure 7). Plantable stock can be produced in 2 years compared to the 3–4 years needed to produce plantable material from seed (once the seeds have germinated). Vegetative propagation may be the only available option when trying to regenerate an area of juniper from remnant or isolated bushes (which represent the local population) that are unlikely to produce viable seed. Seed viability is thought to decrease with age and with the increased pest and disease burden (Wilson & King, 2001). As DNA studies have shown that enormous variation remains even within relict populations of juniper (Van der Merwe *et al.*, 2000), the number of bushes that it would be necessary to propagate from in order to produce a viable population may only be small. Thirty bushes is the recommended minimum, but attempts at restoration should still be made even when fewer parent bushes are available.

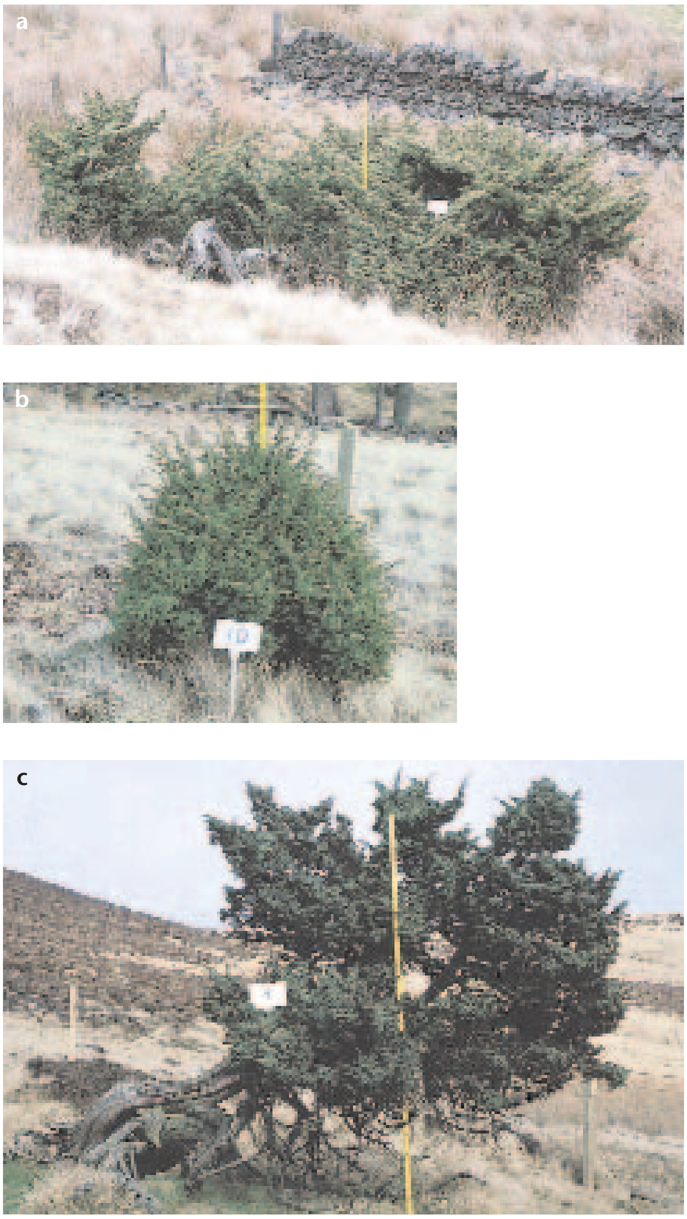
Figure 7

One-year-old juniper cuttings.

A remnant population of juniper on the Pentland Hills, Midlothian, was used to study the feasibility of propagating from isolated bushes. Both time of year of taking cuttings and performance of the individual bushes as stock plants were assessed. Ten bushes were selected and cuttings were taken in September, February and March. Some bushes did appear to make better stock plants; the least vigorous of all the bushes used in the experiment produced cuttings with the lowest survival rate (14%). The time of year cuttings were taken was important, cuttings taken in February had the greatest survival rate (67%) (Figure 8).

Figure 8

Three bushes selected for propagation from a remnant population. Bush 6 (a) and 10 (b) were better stock plants than bush 4 (c). Cuttings from 6 (d) and 10 (e) had a growth form similar to that of the parent bush.



Re-establishment of the cuttings back on to the site in the Pentland Hills has been successful (Figure 9). The cuttings were planted out when they were approximately 2 years old, 10 cm tall and occupied 1.5 litre containers. Weed control with glyphosate (at a rate of 0.05 l m^{-2}), was carried out in August and the bushes were planted after the ground was screefed. The February and March cuttings were planted in May, and the September cuttings

Figure 9

Juniper established at Pentland Hills from cutting experiment.

in July the following year. Survival after 8 years was significantly different (p<0.01) for the February and March cuttings (92%) compared to the September cuttings (58%). It is likely that the differences in weather conditions at time of and following planting affected survival as much as the history of the cuttings themselves.

A method for propagating from cuttings has been developed based on these findings. It is recommended that 10 cm long hardwood cuttings should be taken in February or March, rather than softwood cuttings taken in the autumn which are prone to fungal attack. Material should be taken from the tips of the branches and should include the previous year's growth. Cuttings should be inserted into trays of compost (an equal mix of peat, bark and perlite) with no requirement for hormone rooting powder. The cuttings should be kept in a mist house held at 95–100% relative humidity for 12 weeks, and rooting normally commences at 6–8 weeks. After a further 12 weeks, misting should be gradually reduced so that at 16 weeks the plants can withstand ambient greenhouse conditions. In October plants should be potted-on and allowed to grow for a further year before planting out—when the plants should be around 30–40 cm tall (Harrison, personal communication).

PROTECTION DURING ESTABLISHMENT USING SHELTERS

Juniper berries and seed are very palatable to small rodents (Gilbert, 1980; Miles & Kinnaird, 1979) and direct sowing in the field without protection has proved to be unsuccessful (Kerr, 1968). At Lochaber, tree shelters designed to provide rodent and bird protection significantly increased germination (p<0.05) and establishment success of direct-sown juniper. Thirty-two percent of viable seed germinated in the shelters compared with 14% where no shelters were used. After 5½ years, juniper seedlings had established at 60 of the 200 locations sown. Seventy-five percent of these plants were in shelters. The shelters used in this experiment were 15 cm tall, with a rigid plastic mesh cover, and were inserted in to the soil to a depth of 5 cm.

Juniper seedlings are vulnerable to herbivore damage from mice, rabbits, sheep and deer, although mature juniper appears to be more resistant to heavy grazing (Gilbert, 1980). Juniper is relatively slow growing, typically 3–5 cm per year (G. Patterson, personal communication) and growth rate is normally more than halved when the bushes are grazed. Protection from grazing may therefore be necessary for successful establishment. The effect of using shelters of two different heights (0.6 m and 1 m tall, 4 × 4 cm square 'shrub-shelters') on survival and growth of juniper plants in the absence of stock, deer and rabbit grazing was assessed at Moray. Shelters functioned for 5 years in the field after which time they began to disintegrate and collapse. Plants protected by the 0.6 m shelters had a significantly ($p<0.05$) higher survival rate (97%) than the plants with 1.0 m shelters (86%); survival of unsheltered plants (89%) was not significantly different. Shelters had a positive and significant ($p<0.001$) effect on plant height increment, (6–7.5 cm per year compared with 4 cm per year without shelters). The positive effect of tree shelters on growth and survival did not continue after the shelters were removed. In the eight years following shelter removal, plants from each treatment grew at an average of 4 cm per year and overall differences in plant height were no longer significant.

Shelters also appear to have an effect on form. There were significantly ($p<0.05$) more plants with 'upright' and 'fountain' appearance and fewer with 'collapsed' and 'prostrate' appearance in the shelters of both sizes than those plants not sheltered. During the experiment, there was concern that forcing growth in the shelters may weaken plants, making them liable to collapse after shelter removal, but this did not prove to be the case. Diversity of growth form may be advantageous when the aim is to create a structural shrub layer, and this use of shelters should be considered. In conclusion, short shelters (0.6 m) are beneficial and improve early plant growth and may subtly affect growth form; they should be removed at about 5 years, before they collapse and disintegrate.

WEED CONTROL DURING ESTABLISHMENT

Bare ground may be considered essential for the regeneration of juniper, and the control of competing vegetation is important for seedling growth. Lack of weed control is detrimental to young plants (less than 20 cm tall), and this may be due to shading or the provision of cover for voles which damage the juniper stems (Fitter & Jennings, 1975). Juniper is considered intolerant of deep shade (less than 1.6% daylight) (Grubb *et al.*, 1996), but has been shown to establish and grow successfully in 20.5% daylight—the light levels that would be encountered in a 40-year-old, thinned Scots pine forest (Humphrey, 1996). Weed control tends to be standard practice when establishing forest trees, and larger transplants (40–60 cm) are recommended where weeds are more vigorous (Morgan, 1999). Some advantages of controlling weeds within the root zone of the establishing plant have been shown for trees, resulting in greater survival and increased growth rates. This has been attributed to reduced competition for moisture and nutrients, and increases in spring soil temperatures, as well as reduced shading and vole damage (Hodge, 1995).

The effect of weed control on the survival and growth of juniper was investigated on a fairly fertile (poor to medium soil nutrient regime (Pyatt *et al.*, 2000) grass-dominated site in Moray (see Table 2). Small (25 cm) juniper plants were kept either weed-free with frequent (more than annual) herbicide treatment, or were given annual herbicide treatment, or left unweeded. Treatments were repeated each year for 5 years. Both 'weed-free' and annual weed control applications significantly ($p<0.01$) improved the survival and growth of the juniper plants.

Table 2

Comparison of the mean growth of juniper following different herbicide treatments for the first 5 years after planting and for the following 5 year period at Moray. Figures followed by the same letter are not significantly ($p<0.05$) different from each other.

	No weed control	Annual weed control	Weed-free
Increment from planting to year 5			
Bush height increment (cm)	30.0 a	39.1 b	43.2 b
Root collar diameter increment (mm)	10.9 a	20.7 b	20.1 b
Shoot length increment (cm)	39.9 a	54.0 b	58.3 b
Increment from 5 to 10 years			
Bush height increment (cm)	34.6 a	38.5 a	38.4 a
Root collar diameter increment (mm)			
Shoot length increment (cm)	40.0 a	56.1 a	63.0 b

Nearly all (98%) of the 'weed-free' bushes survived the first 5 years after planting, whereas less than half (46%) of the unweeded bushes survived. Survival of the bushes receiving annual herbicide treatment (84%) was significantly better than that of the unweeded bushes but not of the 'weed-free' bushes. Significant differences in height, root collar and shoot length increment were recorded after 5 years. The effect was still evident in shoot growth but not bush height growth, ten years after planting, even though there had been no weed control for 5 years. Despite the impacts on growth rate, herbicide treatment did not appear to affect the form of the bushes.

FERTILISERS DURING ESTABLISHMENT

Juniper occurs in a wide variety of habitats in Britain, including upland and lowland calcareous grassland, upland and lowland heathland, limestone pavement, upland oak–birch woodland and Scots pine woodland (Wilson & King, 2001). Despite this wide range of habitats, a common factor is that the associated soils tend to have low available nitrogen but a wide range of pH (D.G. Pyatt, personal communication). Low nitrate (NO_3^-) availability is usually associated with either a low or a high pH. Extreme alkalinity, as found in calcareous soils, decreases the rate at which nitrogen is mineralised in a form available to plants (Avery, 1990). In acid soils, such as those associated with Scots pine woodland or heathland, small amounts of nitrogen are available to plants in the form of ammonium (NH_3^+). Juniper has been assigned a low nitrogen indicator value (3 on a scale of 1–9) and medium (5) pH indicator value (Hill *et al.*, 1999). These ratings support the view that juniper has a low nitrogen requirement but does not show a preference for either alkaline or acid soils.

In Britain, many poor soils are deficient in phosphorus and require fertiliser input at planting to ensure that trees reach canopy closure, when nutrient cycling within the crop should become self-sustaining (Taylor, 1991). Juniper fertiliser experiments were undertaken on contrasting sites at Lochaber and Moray: an upland brown earth on Dalradian schist and slate with poor to medium soil nutrient regime (Pyatt *et al.*, 2000), and a peaty podzol on Moine–granite gneiss with very poor soil nutrient regime, respectively.

At Moray, phosphate was applied at the standard forestry rate (450 kg ha^{-1} unground rock phosphate) to deliver 60 kg of phosphorous per hectare. Juniper showed no significant response to fertiliser after 3 or 5 growing seasons; for all treatments survival was good (91%) and annual height growth and shoot growth was 5.8 cm and 12.6 cm, respectively. Upland brown earths are not generally deficient in the nutrients required for tree growth and response to phosphate fertiliser was not expected. The Moray soil contained 'medium' levels of phosphorus (5.8–6.6 mg l^{-1} extractable phosphate) which is considered adequate for tree growth (D.G. Pyatt, personal communication).

At Lochaber, nitrogen (N), potassium (K) and two rates of phosphate (P) were applied (Table 3). The response of three different populations was assessed in terms of height and root collar diameter increment after two seasons of growth, and the effects of individual fertiliser treatments and interaction between treatments analysed (Table 4).

Table 3

Application rates of fertilisers to juniper at Lochaber.

Nutrient	Amount and type of fertiliser applied	Amount of nutrient
Nitrogen	350 kg ha^{-1} of urea (standard rate)	150 kg ha^{-1}
Potassium	200 kg ha^{-1} muriate of potash (standard rate)	100 kg ha^{-1}
Phosphate	340 kg ha^{-1} of rock phosphate (0.75 standard rate)	45 kg ha^{-1}
	675 kg ha^{-1} of rock phosphate (1.5 standard rate)	90 kg ha^{-1}

Table 4

Mean juniper growth measured over 2 years in a fertiliser experiment at Lochaber, where N, P and K was applied at rates given in Table 3. Significant responses are shown in bold.

	Height increment (cm)	Root collar diameter increment (mm)
Plants with N	**14.01**	**5.94**
Plants without N	**11.07**	**3.21**
Plants with K	12.76	4.31
Plants without K	12.32	4.83
Plants with 'high' P (1.5 times standard rate)	12.91	4.86
Plants with 'low' P (0.75 times standard rate)	12.61	4.29

Significant effects of N application on height and root collar diameter growth were seen. P and K, when applied singly, had no significant effect on growth but when applied with N, produced significant growth responses. Greater response was seen with higher levels of P compared to the lower levels, when coupled with N. Height increment was greater in plants that received N plus K and root collar diameter increment was greater where P was applied at the higher level with N. Synergy from combined nutrients is an expected response (Benzian, 1965). There was no fertiliser effect on survival, which was good throughout (93% on average). Plants of different local origins (Black Isle and Torrachilty Forest near Dingwall) appeared to differ in their responses to N and P application, which suggests that juniper may show genetic adaptation to local site conditions.

In general forestry terms, a very poor peaty podzol is likely to be deficient in both N, and P, and lacking K in areas where the peat is greater than 30 cm thick. It is therefore not surprising that juniper responded positively to fertiliser applications, but the absence of effect on survival rate suggests that juniper is well-adapted to nutrient-poor conditions and fertiliser application is rarely necessary. The results of this experiment suggest that, in the absence of shading and weed competition, juniper can tolerate a wide range of soil nutrient conditions. This is consistent with the conclusions that juniper seedling growth on calcareous soil is limited by available light rather than phosphate and nitrogen supply (Grubb, 1996).

SUMMARY RECOMMENDATIONS

- Plants grown from seed of local origin should be used when establishing areas of juniper or when introducing juniper to a new site. Care should be taken to source material from sites with similar ecological conditions to the site to be planted and which occur within the same seed zone. When expanding an existing population, it is advisable not to mix material from different populations that are more than about 1 km apart (unless there is evidence from genetic studies to sample more widely). This option could be considered when establishing a new population. Seed should be collected from a minimum of 20 bushes that show the full range of growth forms. If the objective is to expand juniper on a site where there are a considerable number of bushes and establishment time is limited, then propagating plants from cuttings taken from as many bushes as possible (at least 30) is an option. To expand a moribund, remnant or heavily-grazed population (with few bushes flowering and fruiting) where there is evidence to suggest that it represents a distinct population, e.g. by its isolated condition, propagation from cuttings is the only option.

- In order to break dormancy, seed should be removed from the berries and subjected to a long cool–moist treatment, while well-aerated at about 4°C, for at least 30 weeks. A pre-treatment of soaking the seeds in a 1% citric acid solution may be beneficial. After sowing, germination may take up to 12 months, although shorter times have been achieved. Seedlings should be grown-on in containers until they are a minimum of 20 cm tall (normally about 3–4 years old) before planting out. Direct sowing of berries in the field is not recommended (but if used would benefit from bird and rodent proof shelters).

- Cuttings should be taken in spring from the more vigorous bushes, inserted in to trays of compost, and maintained at high humidity (i.e. in a mist house) for a minimum of 12 weeks. Humidity should then be gradually reduced over a period of 4 weeks. In October the plants should be potted-up and allowed to grow-on for a further year before planting on to site, at which point they should be 30–40 cm tall.

- Weed control is of key importance when establishing juniper plants in the field. An annual application of herbicide, such as glyphosate, to control weeds in the area of the root zone appears sufficient to ensure good survival and growth. Managers should also consider the use of alternative methods of weed control, e.g. newspaper mulch-mats (Woods, personal communication).

- Shelters are beneficial in controlling rabbit, hare and sheep browsing when fencing is not an option. If used, shelters should be short (0.6 m tall) and removed before they collapse and disintegrate (after about 5 growing seasons, dependent on shelter material and climate of site).

- Juniper survival is not enhanced by the addition of fertilisers, although improved growth on very poor sites has been shown to result from N application, and P and K when applied with N (results seen over the duration of a 2-year experiment).

- The advice given in this Note is limited by the range and quality of the experiments to date. Only 3 site types were used for the field experiments and most of the establishment practices were investigated at only one of these sites. Nevertheless, this is the most comprehensive set of experiments conducted so far in the UK.

ACKNOWLEDGEMENTS

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REFERENCES

ANON (1948).
Woody-plant seed manual. US Government Printing Office, Washington D.C.

AVERY, B.W. (1990).
Soils of the British Isles. CAB International, Wallingford.

BASKIN, C.C. AND BASKIN, J.M. (2001).
Seeds: ecology, biogeography and evolution of dormancy and germination. Academic Press Inc., San Diego.

BENZIAN, B. (1965).
Experiments on nutrition problems in forest nurseries.
Forestry Commission Bulletin 37. HMSO, London.

BORDERS FOREST TRUST & UNIVERSITY OF EDINBURGH (1997).
*Common juniper (*Juniperus communis *L.): a review of biology and status in the Scottish Borders.*
Occasional Paper No. 1. Borders Forest Trust, Jedburgh.

CLIFTON, S.J., RANNER, D.S. AND WARD, L. (1995).
The conservation of juniper in Northumbria.
English Nature Research Report 152.
English Nature, Peterborough.

DEPARTMENT OF ENVIRONMENT (1994).
UK biodiversity action plan. HMSO, London.

FITTER, A.H. AND JENNINGS, R.D. (1975).
The effects of sheep grazing on the growth and survival of seedling juniper. *Journal of Applied Ecology* **12**, 637–642.

GILBERT, O.L. (1980).
Juniper in Upper Teesdale. *Journal of Ecology* **68**, 1013–1024.

GRUBB, P.J., LEE, W.G., KOLLMANN, J. AND WILSON, J.B. (1996).
Interaction of irradiance and soil nutrient supply on growth of seedlings of ten European tall-shrub species and *Fagus sylvatica. Journal of Ecology* **84**, 827–840.

HERBERT, R., SAMUEL, S. AND PATTERSON, G. (1999).
Using local stock for planting native trees and shrubs.
Forestry Commission Practice Note 8.
Forestry Commission, Edinburgh.

HILL, M.O., MOUNTFORD, J.O., ROY, D.B. AND BUNCE, R.G.H. (1999).
Ellenberg's indicator values for British plants.
ECOFACT Volume 2 Technical Annex.
Institute of Terrestrial Ecology, Huntingdon.

HODGE, S.J. (1995).
Creating and managing woodlands around towns.
Forestry Commission Handbook 11. HMSO, London.

HUMPHREY, J.W. (1996).
Introduction of native ground flora species to a pine plantation in NE Scotland.
Aspects of Applied Biology **44**, 9–16.

KERR, A.J. (1968).
Tyron Juniper Wood National Nature Reserve.
Nature Conservancy Council, Edinburgh.

McVEAN, D.N. (1992).
Notes on some forms of the common juniper in Scotland.
Scottish Forestry **46**, 145–147.

MEYER, G.A. AND WITMER, M.C. (1998).
Influence of seed processing by frugivorous birds on germination success of three North American shrubs.
American Midland Naturalist **140**, 129–139.

MILES, J. AND KINNAIRD, J.W. (1979).
Establishment and regeneration of birch, juniper and Scots pine in the Scottish Highlands.
Scottish Forestry **33**, 102–119.

MOORE, P.D. (2001).
The guts of seed dispersal. *Nature* **414**, 406–407.

MORGAN, J. (1999).
Forest tree seedlings: best practice in supply, treatment and planting. Forestry Commission Bulletin 121.
Forestry Commission, Edinburgh.

PYATT, D.G., RAY, D. AND FLETCHER, J. (2000). *An ecological site classification for forestry in Great Britain*. Forestry Commission Bulletin 124. Forestry Commission, Edinburgh.

RODWELL, J.S. (1991). *British plant communities. Volume I: woodlands and scrub*. Cambridge University Press, Cambridge.

RODWELL, J. AND PATTERSON, G. (1994) Creating new native woodlands. Forestry Commission Bulletin 112. HMSO, London.

TAYLOR, C.M.A. (1991). *Forest fertilisation in Britain*. Forestry Commission Bulletin 95. HMSO, London.

VAN DER MERWE, M., WINFIELD, M.O., ARNOLD, G.M. AND PARKER, J.S. (2000). Spatial and temporal aspects of the genetic structure of *Juniperus communis* populations. *Molecular Ecology* **9**, 379–386.

WARD, L.K. (1977). The conservation of juniper: the associated fauna with special reference to southern England. *Journal of Applied Ecology* **14**, 81–120.

WILSON, P.J. AND KING, M. (2001). *A report on progress with implementation of the Species Action Plan for juniper* Juniperus communis *during 2000–2001, No. 187*. Plantlife, London.

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