Propagation of native Arctic and alpine species with a restoration potential

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Arctic and alpine plant communities today are subject to an increasing frequency and intensity of anthropogenic disturbances. Good understanding of reproductive behaviour and regenerative capacity of native species is important in a restoration situation following human disturbance in Arctic and alpine vegetation. Seeds, bulbils or cuttings from 12 native Arctic and alpine species were collected from Longyearbyen in Svalbard and Dovre Mountain on the Norwegian mainland. Propagation ability was tested in greenhouse conditions. Seeds of *Papaver dahlianum*, *Oxyria digyna*, *Luzula arcuata* ssp. *confusa*, and bulbils of *Bistorta vivipara* all had more than 50 % germination. *Dryas octopetala* had less than 10 % germination. Both quick and slow germinators were identified among the tested species. Seed storage temperature (+4 °C, -1 °C and -20 °C) showed no overall effect on germination. The rooting capacity of cuttings from evergreen and deciduous species was tested. *Arctostaphylos uva-ursi*, *Empetrum nigrum* ssp. *hermaphroditum*, *Vaccinium vitis-idaea*, *Salix herbacea* and *S. polaris* had more than 70 % rooting ability, while *Dryas octopetala* and *Cassiope tetragona* had less than 10 %. *Saxifraga oppositifolia* showed large variation in rooting ability, ranging from 20 - 90 %. The species with high germination and rooting ability are used in an extended restoration experiment in the study areas.

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Physical stress and habitat disturbances are the dual adversities that Arctic and alpine plants must adapt to and survive under (Billings 1992; Crawford 1997a). Low temperatures, short growing seasons, low resource availability, and oscillating environmental conditions are the most striking physical characteristics of Arctic habitats (Billings 1974, 1987; Crawford 1997a; Shaver et al. 1997). Habitat instability—both temporally and spatially—is an additional factor affecting Arctic plant survival (Murray 1987; Oksanen & Virtanen 1997), and plays an important role in creating community structures (Picket & White 1985*). Cryoperturbation, solifluction, water and ice movements bring instability to the surface (Walker & Walker 1991), and can bring changes in soil and vegetation qualities (Walker 1997). The survival of plants in the Arctic is probably more related to their ability to resist fluctuations and environmental uncertainties than their ability to adjust to harsh physical conditions (Crawford 1997b).

In addition to natural disturbances, Arctic and alpine plant communities are today subject to an increasing frequency and intensity of anthropogenic disturbances (Reynolds & Tenhunen 1996; Crawford 1997b; Forbes et al. 2001). The scale, frequency and intensity of anthropogenic disturbances are essential to describe their effect on Arctic communities (MacMahon 1997; Shaver et al. 1997). Direct anthropogenic disturbances (Forbes 1997), related to human settlements, mining, military activity and tourism have occurred in the Svalbard archipelago and Dovre Mountains on the Norwegian mainland. Roads, houses and technical installations are traditionally placed on dry, exposed ridges with short snow cover duration compared to the surrounding communities, and relatively minor drainage problems. Human disturbances, varying in size from a few to several hundred m^2, have removed the organic layer and uncovered coarse gravel material in these areas. According to Forbes et al. (2001) dry sites in the high Arctic are a worst case situation when it comes to recovery, and dry sites in general take longer to regenerate than wet sites. Even small-scale human disturbances of vegetation and soil layer might seem harmless to plant communities or landscapes, but cumulative impact from such perturbations can eventually cause severe damage (Forbes et al. 2001).

The main sources for establishment of new vegetation in disturbed sites are from lateral clonal growth in adjacent undisturbed sites, vegetation fragments rooting in the site, germinating seeds, or buried seedbank. Recovery is limited by slow vegetative growth (Crawford 1989; Billings 1992), low and unreliable seed production (Chambers 1989; Oksanen & Virtanen 1997; Bliss & Gold 1999), and shortage of safe sites (Urbanska 1997a). Few native species and irregular seed production have traditionally prevented the use of native species in Arctic and alpine restoration efforts (Miller et al. 1983; Younkin & Martens 1987; Magnusson 1997). The effect of introduced species to local vegetation development is often unpredictable (Cargill & Chapin 1987; Densmore 1992; Forbes & Jefferies 1999). There is also a concern that introduced species can displace original vegetation or breed with locally adapted subspecies (Parker & Reichard 1998). Restoration experiments using native grass species have reported graminoids displacing other species (Densmore 1992; Chambers 1997; Strandberg 1997). Examination of restoration potential in other native species is therefore required.

Good understanding of reproductive behaviour and regenerative capacity of native species is important in a restoration situation following human disturbance in Arctic and alpine vegetation (Urbanska 1997b). Arctic and alpine species are generally characterized by vegetative reproduction, low seed production, and low seedling recruitment (Marchand & Roach 1980; Sonesson & Callaghan 1991). However, the importance of sexual reproduction must not be underestimated in Arctic and alpine ecosystems (Söyrinki 1939; Chapin & Shaver 1985; Murray 1987; McGraw & Fetcher 1992; Oksanen & Virtanen 1997). Establishment from propagules is unreliable and low in tundra vegetation (MacMahon 1987), and seedling recruitment shows large interannual variations (Chambers 1989; Bliss & Gold 1999). Germination success is affected by characteristics of the seeds, such as seed morphology and germination responses (Chambers & MacMahon 1994). In addition, various environmental factors at the microsite, for example, surface attributes, microclimatic conditions, presence of animals, and mycorrhiza status, influence the probability of each seed to germinate (Matthews 1992; Chambers & MacMahon 1994; Chambers 1995a, b). Only a minority of Arctic species exhibit seed dormancy (Amen 1966; Billings 1974; Gartner 1983). Harper (1977) distinguishes between innate, induced and enforced dormancy, and there are examples of Arctic and alpine species within all these types (Urbanska & Schütz 1986). Meso- and macroclimatic conditions of a particular year or of previous years influence seed development, since flower development starts the previous season, or seasons, in several Arctic plants (Bell & Bliss 1980; Diggle 1997; Khodachek 1997). A favourable combination of environmental conditions for germination may not occur every year under Arctic and alpine conditions (Billings 1974; Bell & Bliss 1980).

Vegetative regeneration plays an important role in the establishment and recovery of Arctic and alpine ecosystems. Production of vegetative units, like bulbils, is one adaptation to short and cold growing seasons (Crawford 1989). Viviparous species are able to produce propagation units even in years unfavourable for seed production (Forbes & Jefferies 1999), and are shown to establish successfully on Arctic disturbed patches (Forbes 1996). Rooting from lateral branches or from branches in contact with soil are other ways of vegetative reproduction. Propagation of new plants from cuttings is a well established technique in horticulture, and is based on the natural rooting potential of lateral branches. A cutting is a vegetative part separated from a mother plant, which under certain environmental conditions forms new roots (Hartmann et al. 1997). The balance of root-promoting hormones and carbohydrates in individual cuttings is crucial to rooting capacity. The level of these components depends on such factors as species, genotype, generative state, age of mother plant, time of year, etc. (e.g. Ericsson 1988; Hartmann et al. 1997). Rooting ability of cuttings varies within families, genera and even species (Hartmann et al. 1997).

The aim of this study is to deduce the restoration potential of several native Arctic and alpine species by examining reproductive capacity, involving both seeds and vegetative reproduction units. The questions asked are:

1. What is the germination ability of seeds and bulbils in selected Arctic species under greenhouse conditions, and how is germination affected by seed storage temperature?
2. What is the rooting capacity of woody cuttings from selected Arctic and alpine species under greenhouse conditions?

This study is part of a more extensive project, where the species with high germination and rooting ability are used in a restoration experiment in the study areas from which the propagules and cuttings were collected (Hagen in prep).

Materials and methods

Study areas

Seeds, bulbils and cuttings were collected from the Svalbard archipelago and on Dovre Mountain, Norway. The Svalbard study area (78° N, 16° E) is a high Arctic, permafrost area. Plant material for this study was collected within 1 km from the settlement of Longyearbyen, at 20 - 40 m asl. Roads, mining and infrastructure installations fragment the settlement surroundings, and there is a growing tourist industry in the area. Dryadion communities (Rønning 1965) dominate, but a variety of heath, wetland and snow-bed communities are also reported (Brattbakk 1984). Most technical installations are located in Dryas heath communities, but are expanding into wetland vegetation (personal observations).

The Dovre Mountain is an alpine area in central Norway (63° N, 10° E). Cuttings for this experiment were collected inside a military firing range at 1000 m asl. Forest limit in the area is about 900 m asl. The site is covered with lime-deficient gravel and sand material, dominated by *Salix* bushes and heath vegetation (Larsson et al. 1985). Roads, vehicle tracks, firefields and military installations fragment the 165 km^2 military area, and the most severe disturbances are located in dry heath communities.

In both study areas individual disturbances vary in size from a few m^2 to several km in length, and in several cases the organic layer has been completely removed, exposing coarse gravel material. In several disturbances additional gravel has been supplied on top of the existing vegetation layer.

Propagation

Collection and storage—Twelve species were selected (Table 1). *Papaver dahlianum, Luzula arcuata* ssp. *confusa* and *Oxyria digyna* are typical pioneer species in disturbed dry sites

Table 1. Species and propagation units, origin of plant material, and sample size (N) used in the experiment. Nomenclature follows Lid & Lid (1994).

Species	Plant group	Origin	Propagation unit	N
Arctostaphylos uva-ursi	evergreen shrub	Dovre	cuttings	756
Bistorta vivipara	forb	Svalbard	bulbils	1200
Cassiope tetragona	evergreen shrub	Svalbard	cuttings	687
Dryas octopetala	evergreen shrub	Svalbard	cuttings	674
Dryas octopetala	evergreen shrub	Svalbard	seeds	1200
Empetrum nigrum ssp. *hermaphroditum*	evergreen shrub	Dovre	cuttings	756
Luzula arcuata ssp. *confusa*	forb	Svalbard	seeds	1200
Oxyria digyna	forb	Svalbard	seeds	1200
Papaver dahlianum	forb	Svalbard	seeds	1200
Salix herbacea	deciduous shrub	Dovre	cuttings	390
Salix polaris	deciduous shrub	Svalbard	cuttings	640
Saxifraga oppositifolia	forb	Svalbard	cuttings	644
Vaccinium vitis-idaea	evergreen shrub	Dovre	cuttings	601

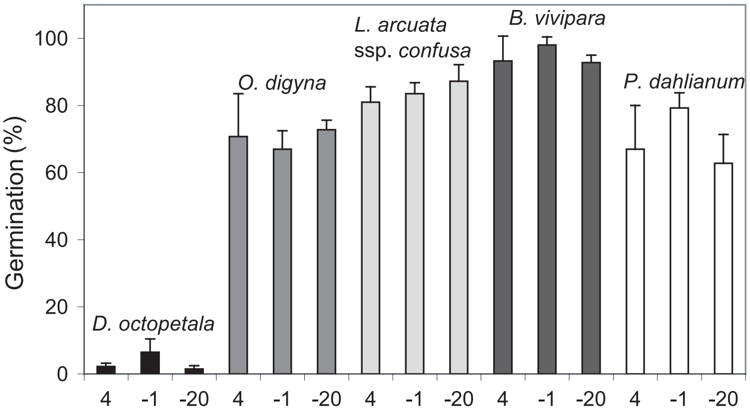

Fig. 1. Germination (%) for five species at three storage temperatures (+4, -1 and -20 °C) at the end of the experiment (99 days). Each bar shows average germination and s.d. of four replicates (sample sizes shown in Table 1).

in Svalbard; they are also common species in undisturbed ridge and heath communities in the area. Seeds were collected within or adjacent to disturbed sites. Seeds and cuttings from *Dryas octopetala* and cuttings from *Salix polaris* were collected in undisturbed Dryas heath. The species had high seed production, and sufficient seed quantity for this study was easily accessible. Cuttings of *Saxifraga oppositifolia* were collected from unstable gravel localities along a riverbed. Dovre cuttings of *Salix herbacea* were collected from undisturbed snow-bed vegetation, and cuttings of dry tolerant evergreen species were collected in low alpine heath vegetation adjacent to human disturbed sites. The heath species are late invaders in disturbed sites, but *Arctostaphylos uva-ursi* and, rarely, *Empetrum nigrum* subsp. *hermaphroditum* occur as survivors in disturbed sites at Dovre. Cuttings from Svalbard and all seeds and bulbils were collected in the middle of August 1998. Cuttings from Dovre were collected in September 1998. The deciduous species had senesced at collection and the majority of leaves had fallen. Cuttings from all species were about 5 cm long, and taken from the outermost 10 cm of main and lateral branches. No roots were present at planting time. Plant material was collected from ten or more mother plants per species.

Collected seeds were dried at room temperature and stored at three different temperatures (+4 °C, -1 °C and -20 °C) until February 1999. All cuttings were wrapped in moist mosses and transported in plastic bags. Cuttings from evergreen species were not stored before planting. Cuttings from deciduous species were wrapped in moist cloths and stored at -1 °C until March 1999.

Greenhouse germination and rooting—No examination of seeds with respect to germination viability was carried out prior to the germination experiment. Seeds were sown in peat soil covered with a thin layer of sand, at 22 °C. Four replicates of 100 seeds were sown for each species and storage temperature. The seeds were allowed to germinate in three consecutive periods. These germination periods lasted 33, 35 and 31 days and were divided by close-down periods of 4-5 weeks at 4 °C with no light or water. During the first three weeks in each germination period pots were kept in darkness and 14 hours of daylight were offered for the remainder of the periods. The samples were stirred every third week. Germination data were collected every third day during the most intensive germination activity, otherwise once a week. Seeds with any cotyledon emergence were considered germinated.

Cuttings of the evergreen species were planted a few days after collection in peat soil mixed with perlite (2:1 volume ratio) covered by a thin layer of sand, in 4 × 4 cm peat pots. An equal number of cuttings were placed under two different moisture regimes, one with a fog system and the other with saturated moist air in an enclosure tent of polyethylene (see Hartmann et al. 1997). The fog system is the most advanced method, offering a smooth and stable supply of foggy conditioned water. The polyethylene tent was used to test the adequacy of a simpler method. All cuttings were kept under low temperature (0-4 °C) during winter; the temperature was gradually increased from February to March (up to 22 °C).

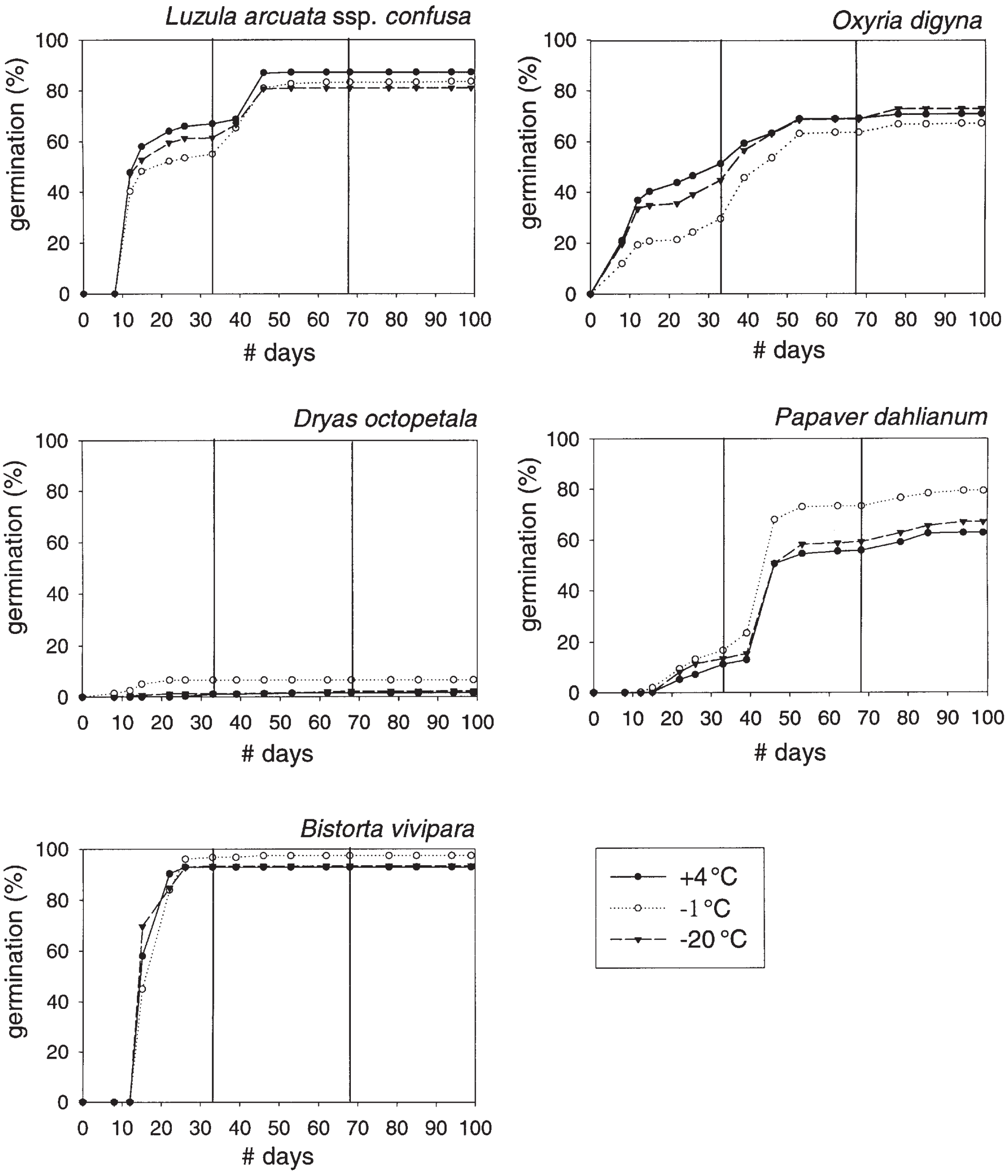

Fig. 2. Germination progress for each species and storage temperature (+4, -1 and -20 °C) during the experiment. Each curve is the mean value of four replicates. The vertical lines illustrate 4-5 week long breaks separating three germination periods. Horizontal axes show number of days from sowing, excluding the breaks.

No artificial light was supplied, and normal daylength increased from 8 to 11 hours during this period. From March to April the cuttings were kept at a stable temperature of 22 °C with 18h photoperiod; a fungicide treatment was offered to repulse mould attack. Cuttings from the deciduous species were planted and treated as the evergreen species after the six month storage period, but only at saturated moist air conditions. All cuttings were examined for emerged roots at the end of April 1999. All cuttings with visible roots were considered rooted.

Data analysis

Repeated measures analysis of variance (ANOVA) (Zar 1996) was used to test the effects of species, storage temperature and time on germination proportions. Time (the end of each germination period) was considered a three level factor. Statistical analysis of the data was performed using SPSS, version 10.0 for Windows (SPSS, Inc. 1999). To improve the normality and homogeneity assumptions, *Dryas octopetala* was not included in this test.

Results

Seeds and bulbils

Most species had between 60 % and 98 % germination (Fig. 1). Highest total germination rate was observed in bulbils from *Bistorta vivipara*, while *Luzula arcuata* ssp. *confusa* had the highest level of seed germination rate. With less than 10 % germination, *Dryas octopetala* showed weaker germination than the other species (Fig. 1).

The species effect on germination was significant (Table 2). A post hoc Tukey test for multiple comparisons suggested that the germination level of each species differs significantly from all other species ($p < 0.001$). Seed storage temperature had no separate effect on germination, but the species by treatment effect was significant (Table 2). *Papaver dahlianum* had the highest germination proportion for seeds stored at -1 °C, while *Oxyria digyna* had the lowest germination proportion for this storage temperature (Fig. 2).

Time affected germination, and the germination progress was both species and treatment (seed storage temperature) specific (Table 2). All species started to germinate during the first two weeks of the experiment (Fig. 2). For *Bistorta vivipara* and *Dryas octopetala* no further germination was observed in subsequent germination periods. More seeds of *Luzula arcuata* ssp. *confusa* germinated during the second period (34 - 68 days), and for *Oxyria digyna* and *Papaver dahlianum* germination was also observed during the third period (69 - 99 days).

Table 2. Repeated measures ANOVA of the effect of species, treatment (seed storage temperature) and time to seed and bulbil germination. Time levels are defined as germination at the end of three germination periods (33, 68 and 99 days).

Source of variation	df	MS	F	Sign.
Species	3	14437.581	125.300	<0.001
Treatment	2	10.549	0.092	0.913
Species * treatment	6	392.345	3.405	0.009
Error	36	115.225		
Time	2	10488.757	742.080	<0.001
Time * species	6	1863.275	131.827	<0.001
Time * treatment	4	125.601	8.886	<0.001
Time * species * treatment	12	19.675	1.392	0.190
Error (time)	72	14.134		

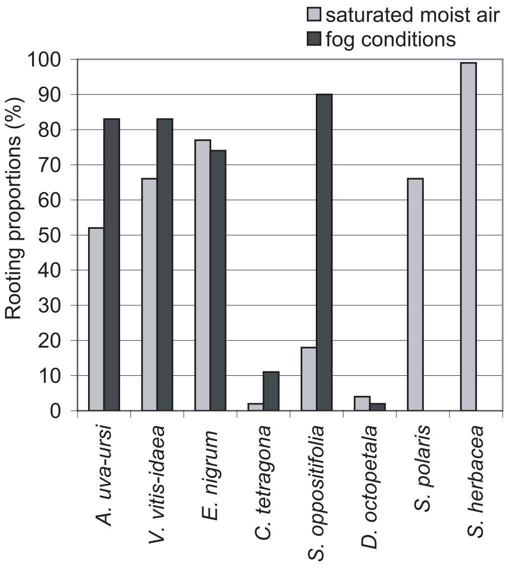

Fig. 3. Rooting proportions of species propagated by cuttings. The experiment was conducted at two different moisture regimes: saturated moist air and fog conditions. However, *Salix polaris* and *S. herbacea* were propagated only under saturated moist air conditions. For N, see Table 1.

Cuttings

Roots were observed on selected cuttings from all evergreen species within two months after planting. During winter further development was restricted due to low greenhouse temperature and short day-length. Root development continued as temperature increased during spring. Root growth and development of the already rooted cuttings continued from April, but no additional cuttings developed roots. At the end of April roots were observed in all species, but in very different proportions (Fig. 3). The “good rooters” in this study (with more than 50 % rooting under both moisture conditions) are *Arctostaphylos uva-*

ursi, Empetrum nigrum ssp. *hermaphroditum* and *Vaccinium vitis-idaea*. The "weak rooters" (with less than 10 % rooting) are *Dryas octopetala* and *Cassiope tetragona* (Fig. 3). *Saxifraga oppositifolia*, which responded differently to the two conditions, is a "good rooter" at fog conditions (Fig. 3).

Cuttings from the deciduous *Salix polaris* and *S. herbacea* showed spontaneous rooting and bud break immediately after planting. Two months after planting both species had more than 60 % rooting (Fig. 3).

Discussion

Seeds

The species in this germination experiment were offered optimal environmental conditions for seedling emergence: high temperature, sufficient moisture and stable soil. The optimum germination temperature for most non-dormant seeds is between 20 and 25 °C (Hartmann et al. 1997), and this is also the situation for Arctic plants (Gartner 1983; Khodachek 1993).

Seed storage temperature had no separate effect on germination in this experiment, although a "time × treatment" interaction existed. Most alpine species require high temperature to germinate, and only a few germinate at low temperatures (Bliss 1985). This can be a selective mechanism to prevent fall or spring germination, when high frost frequency will increase seedling mortality (Bliss 1985). In general, Arctic species have weak or no seed dormancy (Amen 1966; Gartner 1983; Chapin 1993), allowing germination whenever physical conditions permit. Non-dormant seeds tend to germinate simultaneously and have higher mortality rates (Amen 1966; Gartner 1983). *Oxyria digyna* is described as both non-dormant (Mooney & Billings 1961; Bonde 1969) and with a slight cold-moist stratification requirement (Eurola 1972; Bell & Bliss 1980). However, the chilling temperature required is fulfilled by normal Arctic summer temperature, and thus does not block germination (Bell & Bliss 1980). Both *Luzula arcuata* ssp. *confusa* and *Papaver dahlianum* had a marked peak in the germination rate at the start of the second germination period of the experiment. *L. arcuata* ssp. *confusa* seeds are suggested to have dormancy related to repeated winter frost (Eurola 1972; Khodachek 1993), while other studies indicate that *L. arcuata* ssp. *confusa* and *P. radicatum*, a close relative to *P. dahlianum*, are non-dormant (Bell & Bliss 1980). The germination proportions in the present experiment are higher than in the other cited experiments without close-down periods. This indicates some partial dormancy in seeds from *L. arcuata* ssp. *confusa*, possibly further released by close-down periods. *P. dahlianum* also seem to have partial dormancy. Germination is slow, starting at the end of the first germination period, and was possibly suspended by the close-down period. It is uncertain whether the germination in the second and third periods is just a continuation of the first germination period, or reflects further released dormancy from the close-down period.

Among the Arctic species there are both good and weak, and quick and slow germinators (Eurola 1972; Khodachek 1993; Bliss & Gold 1999). Other studies confirm *Dryas octopetala* as a weak germinator (Eurola 1972; Khodachek 1997). Seed viability was not examined before the germination experiment. Injured or immature seeds might have influenced the total germination level. Natural occurrence of *D. octopetala* seedlings in Svalbard differs considerably among undisturbed sites, and between disturbed and undisturbed sites (pers. obs.; E. J. Cooper, pers. comm. 2001). Seed viability in *D. octopetala* is markedly improved by elevated ambient air temperature (Wookey et al. 1995). *Oxyria digyna, Papaver dahlianum* and *Luzula arcuata* ssp. *confusa* are among the most common pioneer species in Svalbard, and all had high germination rates in this experiment. They are all wind dispersed and produce numerous seeds, a feature proposed to characterize species frequently found in early successional stages (Matthews 1992). All seeds in this study were collected at the end of a warm summer (average air temperature June–August was 6.0 °C, whereas the normal summer average is 4.2 °C) (data available from Norwegian Meteorological Institute). Increased air temperature has a positive influence on seed viability and germination ability in several Arctic and alpine species (Urbanska & Schütz 1986; Chambers 1989; Khodachek 1997; Bliss & Gold 1999). Slow germinators can be defined as those with most germination more than two weeks after sowing (Eurola 1972). According to this definition *P. dahlianum* and *D. octopetala* are slow germinators, and *L. arcuata* ssp. *confusa* and *O. digyna* are quick germinators.

Bulbils

The quick and high proportion of bulbil germination of *Bistorta vivipara* in this experiment corresponds with other studies (Söyrinki 1939; Bonde 1969; Molau 1993). As an adaptation to stress and disturbance, development of vegetative units increases the plants' ability to reproduce successfully even in short and cold summers (Billings 1974; Murray 1987; Crawford 1989). *B. vivipara* reproduces almost exclusively asexually by bulbils, but the development of seeds can occasionally be observed in Arctic and alpine populations (Söyrinki 1989; Bauert 1996), and the fact that populations are often genetically variable indicates that sexual reproduction plays a role (Diggle 1998; Karlsson 2000). Viviparous species are late flowering, and the bulbils have a higher germination rate than seeds from the same species (Molau 1993). The "seedlings" from bulbils of *B. vivipara* in this experiment had very high mortality, and most individuals died during the first ten days after germination. Environmental conditions, such as high temperature and dehydration are possibly the reason for high greenhouse mortality. High mortality of small *B. vivipara* plants was also observed under natural conditions at the study site (Hagen in prep.).

Cuttings

Most *Salix* species are easy to propagate via cuttings, and this is also the case for several Arctic and alpine willows (Chmelar 1974; Densmore et al. 1987; Keigley 1988). The high rooting ability observed for *Salix herbacea* and *S. polaris* in this experiment was therefore expected. Optimum growth temperature of 15 °C and increased growth at long photoperiods (more than 18h) is reported in *S. polaris* (Paus et al. 1986). Rooting capacity varies among seasons, and collecting cuttings in late winter might have increased the rooting rate (Houle & Barbeux 1998). The gender of the mother plant was not taken into consideration in this experiment, but female mother plants of other *Salix* species have been reported to root more profusely than male plants (Singh 1986; Houle & Barbeux 1998).

Saxifraga oppositifolia exhibits great ecotypic variation, and is by several authors recognized as two morphs, prostrate and cushion (Brysting et al. 1996; Rønning 1996; Crawford 1997). Kume et al. (1999), in a Svalbard study, found that the prostrate form was superior in vegetative propagation by shoot fragments, while the cushion form was superior in sexual reproduction. Cuttings from both morphs were collected in this experiment, and unequally separated between the two greenhouses, probably causing the different rooting rates.

Both *Cassiope tetragona* and *Dryas octopetala* showed weak rooting capacity in the present study. Under natural conditions both *C. tetragona* and *D. octopetala* spread laterally by vegetative ramets along the ground, and weak adventitious roots are formed (Söyrinki 1939; Oksanen & Virtanen 1997). For many clonal plants recruitment from seeds is important only during the initial colonization, and thereafter the species spreads largely by clonal growth (Bazzaz 1996).

Vaccinium vitis-idaea, *Arctostaphylos uva-ursi* and *Empetrum nigrum* ssp. *hermaphroditum* were all good rooters in this experiment. Under natural conditions these species have a prostrate growth, and form new roots along the branches. The use of cuttings is a recognized propagation method for *V. vitis-idaea* (e.g. Lehmushovi 1993). *A. uva-ursi* is not reported to be a particularly good rooter, but can be improved by selected treatment combinations, like mycorrhiza inoculation (Linderman & Call 1977; Nelson 1987; Hartmann et al. 1997). Propagation of *E. nigrum* ssp. *hermaphroditum* by cuttings is rarely described in the literature. However, some practical experience exists, indicating both good (Salemaa in prep.) and poor (I. Fredriksen, pers. comm. 1999) rooting capacity. Additions of auxins or mycorrhiza inoculation are possible ways to improve root formation in cuttings (Norton & Norton 1985; Verkade 1986; Ripa 1993), although *E. nigrum* ssp. *hermaphroditum* and *A. uva-ursi* are reported to root well without any additional auxin (Salemaa in prep.). The selection of mother plants is reported to have a significant effect on rooting capacity, as hormon content and other physiological traits has individual variation within species (e.g. Snow 1939; Hartmann et al. 1997).

Relevance for restoration

The results of this experiment permit the evaluation of some species' suitability for restoration endeavours. Seeds of *Luzula arcuata* ssp. *confusa, Oxyria digyna*, *Papaver dahlianum* and bulbils of *Bistorta vivipara* germinated well in this experiment, however the bulbil "seedlings" had high mortality. Cuttings of *Salix herbacea, S. polaris, Vaccinium vitis-idaea, Arctostaphylos uva-ursi, Empetrum nigrum* ssp. *hermaphroditum* and probably a prostrate morph of *Saxifraga oppositifolia* root well. During the greenhouse propagation period, lasting between two field-growing seasons (8 months), it was possible to produce new plants attaining the same size as several-year-old congeners in nature. These species are easy to propagate and can be used in further restoration research; the results are currently being utilized in an extended restoration project in the two study areas (Hagen in prep.). The ability of the propagated individuals to survive, grow and reproduce in the field will be crucial in evaluating the species' utilization in restoration.

Due to high population sizes and high morphologic diversity in the selected species, this experiment did not pay any attention to the genetic aspect of conservation. However, this must be taken into consideration in a possible large-scale restoration project (see Fenster & Dudash 1994; Frankham 1995).

Restoration projects based on the use of native species propagated in greenhouses are few, but important, and such experiences can contribute to the development of self-sustaining plant coummunities, and reduce the use of commercially available invasives traditionally used in Arctic and alpine restoration (e.g. Urbanska et al. 1987; Urbanska 1995). In addition to the ecological evaluations, economic considerations, local cultural preferences, time limitations etc. must be given serious attention prior to practical use of these species in restoration projects (Hagen et al. in prep.). Transplanting propagated material is a rather costly solution and has to be balanced against an increased revegetation success.

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