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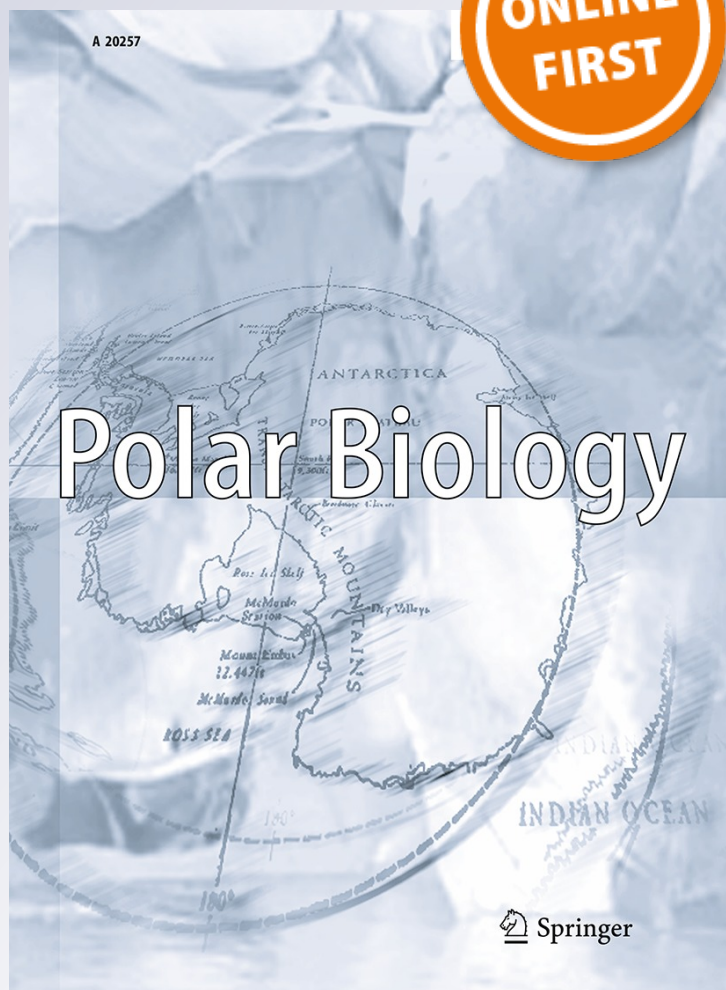
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Germinating seeds or bulbils in 87 of 113 tested Arctic species indicate potential for ex situ seed bank storage

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Abstract Arctic plant species are expected to lose range due to climate change. One approach to preserve the genetic and species diversity for the future is to store propagules in seed vaults. However, germinability of seeds is assumed to be low for Arctic species. We evaluated ex situ storage potential of 113 of the 161 native angiosperms of Svalbard by studying seed ripening and germination. Seeds or bulbils were collected, and germinability was tested after one winter of storage in the Svalbard Global Seed Vault. Twenty-six of the species did not produce ripe propagules, 8 produced bulbils, and 79 produced seeds. Bulbils sprouted to high percentages. Seeds of 10 species did not germinate, 22 had low germination (<20 %), 34 had germination of 21–70 %, and 13 had high germination percentages (>70 %). More than 70 % of the species belonging to Asteraceae, Brassicaceae, Caryophyllaceae, Juncaceae, Rosaceae, and Saxifragaceae germinated. Cold tolerant, common species had higher germination percentages than relatively thermophilous, rare species. Germination percentages were six times higher than observed

in 1969 ($n = 51$) and 0.7 times that observed in 2008 ($n = 22$), indicating that recent climate warming improves germination in the Arctic. While in situ conservation is of vital importance, ex situ conservation in seed banks is a potential complementary conservation strategy for the majority of Arctic vascular plant species. For species that did not germinate, other methods for ex situ conservation should be sought, for example, growing in botanical gardens.

Keywords Arctic · Bulbils · Conservation · Seed germination · Rare · Red List

Introduction

Climate change, invasive species, land use, and other human impact may threaten a large part of the world's flora (Sala et al. 2000; Pimentel 2011; Thuiller et al. 2011). To meet these challenges, many nations now collect and bank seeds for restoration purposes, ex situ conservation, and relocation (Vitt et al. 2010). While large efforts are made to bank the entire flora of, for example, the USA and UK (<http://www.nps.gov/plants/sos/>, <http://www.kew.org/>), the Arctic flora is so far underrepresented in these seed banks. A relatively low proportion of the Arctic flora is rare and considered endangered (Talbot et al. 1999; Elven et al. 2011); however, even common species may be threatened as the expected profound changes in Arctic climate (ACIA 2006) may reduce species ranges by 40 % followed by considerable loss of genetic diversity (Alsos et al. 2012a). Also, increased human activities combined with climate change increase the risk of establishment of alien species (Ware et al. 2012), which may have negative effect on the native flora. A prerequisite for storing seeds is that they are

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viable, but knowledge of germinability of seeds and bulbils of the Arctic flora is still scarce. In earlier studies, the proportion of species producing viable seeds and their germination percentages were found to be lower in the Arctic than in other regions (Sørensen 1941; Bliss 1958; Eurola 1972; Bell and Bliss 1980). However, a recent study of 22 Arctic species indicated increased germination, partly owing to increased temperature (Müller et al. 2011). Knowledge of germinability of seeds and bulbils for more species is required to evaluate if Arctic flora can be additionally conserved ex situ in seed vaults.

Many factors are likely to influence seed production and viability in the Arctic. Two main factors are the short growing season and the low temperatures, which are especially pertinent for relatively thermophilous species that may only be able to set viable seeds in infrequent years of high summer temperatures (Sørensen 1941; Wookey et al. 1995; Alsos et al. 2003). Low temperatures also reduce pollinator activity (Hodkinson et al. 1998) and drive the reproduction mode towards asexuality (Peck et al. 1998), which may influence successful reproduction and seed set. Although some species reproduce with asexual (apomictic) seeds, many essentially rely on runners or bulbils for dispersal (Wehrmeister and Bonde 1977; Murray 1987; Dormann et al. 2002). Bulbils are analogous to seeds in terms of dispersal, but they are generally more vulnerable as they lack the protection of a seed coat. Thus, their prospects for long-term storage may be low (Walck et al. 2010). However, while asexual reproduction is successful and important in the Arctic flora, it is rarely exclusive, and ripe seeds of most species may be found in favourable sites or years, even for those species mainly reproducing by bulbils (Murray 1987).

The flora of the Arctic archipelago Svalbard is typical for the mid-to-high Arctic flora as insect-pollinated herbs, in terms of species number, are dominating (Brochmann and Steen 1999). Different from most low-to-mid Arctic sites, there are no bumble bees on the archipelago, and pollination is mainly by flies (Diptera) (<http://svalbardinsects.net/>, Coulson and Refseth 2004). It is assumed that 97 of 161 angiosperms in Svalbard reproduce mainly sexually (Brochmann and Steen 1999). In the most comprehensive study on germination from Svalbard, 19 of 63 mainly common species did not germinate, whereas those that did germinate generally had low germination rates (Eurola 1972). However, more recent studies on five (Hagen 2002) and 22 (Müller et al. 2011), mainly common species, show higher germination rates. Very rare (1–4 localities) and rare (5–25 localities) species constitute 36 % of the flora of Svalbard (Brochmann and Steen 1999). Due to the geographic isolation of the archipelago, a separate evaluation of threats to the species has been made, and 54 of them have been redlisted; 10 as critically endangered, 10 as

endangered, and 17 as near threatened (Solstad et al. 2010). The majority of rare species are relatively thermophilous (Elven and Elvebakk 1996; Engelskjøn et al. 2003). These may have colonized the archipelago during the Holocene hypsithermal 8000–4000 BP (Alsos et al. 2002, 2007), when the climate was 1–2 °C warmer than today (Birks et al. 1994), and may persist in the current climate predominantly by clonal growth (Alsos et al. 2002). With a warming climate, recruitment of the thermophilous species may also increase, as has been observed for common Arctic species (Müller et al. 2011).

The aims of this study were to (1) collect seeds or bulbils from as many species as possible of Svalbard's native vascular flora, (2) test whether germinability of species is appropriate for ex situ conservation in seed banks, (3) test whether germinability is related to thermal requirements, rarity, or ability to reproduce clonally, and (4) compare with earlier studies to see if germination has recently increased. New test of germination is planned again after 5 and 10 years. However, as we present data on 55 species not studied in Svalbard before, and as this is the largest study of germination in Arctic plants since Sørensen's studies in Greenland (Sørensen 1941), we present the results of germination after 1 year of storage here.

Materials and methods

Collection and storage of seeds

Seeds were collected in paper bags between 27 August and 19 September 2008 in the Isfjorden area of Svalbard (Appendix 1 of Electronic supplementary material, Fig. 1). If possible, seeds were shaken out of the plants to ensure that only mature seeds were collected. However, if the plants were wet, seed capsules were collected and left in paper bags at 5–8 °C in 35 % relative humidity (RH) to dry. Seeds that were obviously not ripe were not collected. Seeds of species which did not seem 100 % ripe (*Arnica angustifolia*, *Carex glacialis*, *Carex marina* ssp. *pseudolagopina*, *Coptidium pallasii*, *Micranthes hieracifolia* ssp. *hieracifolia*, *Petasites frigidus* ssp. *frigidus*, and *Ranunculus wilanderi*) were left in paper bags at 5–8 °C until 19 September to permit ripening, after which they were assumed to be ripe. Nuts of *Empetrum nigrum* were washed out of the berries. Herbarium vouchers were collected and deposited at Tromsø University Museum (TROM).

For this first germination test following one winter of storage, and also for each of two tests planned for the future, seeds were counted and placed in sealed aluminium bags. The bags were placed at –2 °C on 15 or 24 September 2008 and stored outside at about –6 °C from 1 October. A temperature logger (Tinytag Plus 2 TGP-4020)

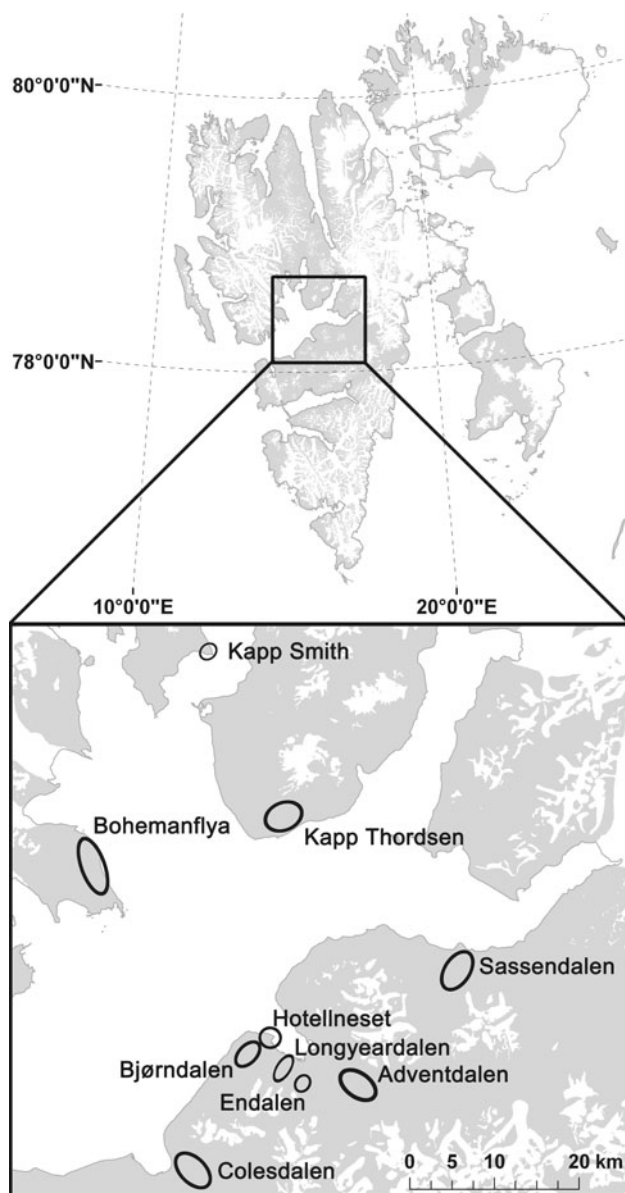


Fig. 1 Sites where seeds were collected for studies of germination and for long-term storage in the Svalbard Global Seed Vault

was placed in one of the boxes 2 October. The temperature dropped to $-10\text{ }^{\circ}\text{C}$ during the night of 2 October. On 3 October, the seed boxes were placed in the Svalbard Global Seed Vault where the temperature was about $-14\text{ }^{\circ}\text{C}$. The box with the seeds for germination trials was taken out of the Svalbard Global Seed Vault on 27 April 2009. Thus, this first year of storage resembles what seeds of Arctic species experience under natural conditions as they ripe in autumn and normally do not germinate within the season they are produced (Söyrinki 1939; Sørensen 1941). As a period of frost usually enhance germination in Arctic species (Söyrinki 1939), no fresh seeds were germinated.

Stratification and germination of seeds

Usually 3×50 seeds of each species were put in Petri dishes (9 cm in diameter) with 10 % agar solution and covered with a lid to ensure high moisture conditions. Thereafter, the seeds were either stratified for a period at $1\text{ }^{\circ}\text{C}$, or put directly to germination at 24 h $10\text{ }^{\circ}\text{C}$, 24 h $20\text{ }^{\circ}\text{C}$, or 12 h $10\text{ }^{\circ}\text{C}$ and 12 h $20\text{ }^{\circ}\text{C}$ (Appendix 2 of Electronic supplementary material). Stratification and germination conditions selected for each species were based on an extensive review of seed germination trials of the same species or genera (not shown), or after recommendations from Lindsay Robb at the Millenium Seed Vault (personal communication). The light temperature was 4,000 K (Osram 35 W, 840 HE) and the brightness was 3,300 lm (manufacturer's information). The proton flux was approximately $40\text{ }\mu\text{mol}$ per square meter per second measured with a quantum flux sensor at the level of the seeds. If the germination percentage obtained was low, but the seeds still seemed viable, a new germination test was attempted following an additional period of stratification (Appendix 2 of Electronic supplementary material). Only final germination percentages are given in Table 1.

Table 1 Germination percentages of species from the Arctic Archipelago of Svalbard

Species	%
<i>Alopecurus borealis</i>	0
<i>Arabis alpina</i>	6.6
<i>Arctagrostis latifolia</i> (EN)	–
<i>Arctophila fulva</i>	–
<i>Arenaria pseudofrigida</i>	30.5
<i>Arnica angustifolia</i>	0.7
<i>Betula nana</i> var. <i>tundrarum</i> (NT)	0
<i>Bistorta vivipara</i> ^a	100.0
<i>Braya glabella</i> ssp. <i>purpurascens</i>	60.3
<i>Calamagrostis neglecta</i> ssp. <i>groenlandica</i>	–
<i>Campanula rotundifolia</i> ssp. <i>gieseckiana</i> (VU)	–
<i>Cardamine polemonioides</i>	–
<i>Carex bigelowii</i> ssp. <i>ensifolia</i> (CR)	–
<i>Carex fuliginosa</i> ssp. <i>misandra</i>	0
<i>Carex glacialis</i> (VU)	8.1
<i>Carex krausei</i> (VU)	67.1
<i>Carex lachenalii</i>	14.1
<i>Carex lidii</i> (VU)	–
<i>Carex marina</i> ssp. <i>pseudolagopina</i> (VU)	0
<i>Carex maritima</i>	2.7
<i>Carex nardina</i> ssp. <i>hepburnii</i>	0
<i>Carex parallela</i> ssp. <i>parallela</i>	–
<i>Carex rupestris</i>	2.0
<i>Carex saxatilis</i> ssp. <i>laxa</i>	–

Table 1 continued

Species	%
<i>Carex subspathacea</i>	49.6
<i>Carex ursina</i>	62.0
<i>Cassiope tetragona</i> ssp. <i>tetragona</i>	7.8
<i>Cerastium arcticum</i>	33.8
<i>Cerastium regelii</i> ssp. <i>caespitosum</i>	–
<i>Chrysosplenium tetrandrum</i>	25.0
<i>Cochlearia groenlandica</i>	14.2
<i>Coptidium lapponicum</i>	0
<i>Coptidium pallasii</i> (NT)	0
<i>Deschampsia alpina</i> ^a	100.0
<i>Deschampsia sukatschewii</i> ssp. <i>borealis</i>	–
<i>Draba alpina</i>	72.4
<i>Draba arctica</i> ssp. <i>arctica</i>	84.1
<i>Draba glabella</i>	54.4
<i>Draba lactea</i>	71.2
<i>Draba nivalis</i>	86.9
<i>Draba rupestris</i> (syn. <i>D norvegica</i>)	36.7
<i>Draba subcapitata</i>	78.9
<i>Dryas octopetala</i>	26.2
<i>Dupontia fisheri</i> morph “ <i>psilosantha</i> ”	35.9
<i>Empetrum nigrum</i>	29.3
<i>Erigeron humilis</i>	41.5
<i>Eriophorum</i> × <i>sorensenii</i> (NT)	–
<i>Eriophorum scheuchzeri</i> ssp. <i>arcticum</i>	6.9
<i>Eriophorum triste</i>	–
<i>Euphrasia wettsteinii</i> (EN)	0
<i>Festuca baffinensis</i>	18.3
<i>Festuca brachyphylla</i> (VU)	46.4
<i>Festuca edlundiae</i>	22.9
<i>Festuca rubra</i> ssp. <i>richardsonii</i>	–
<i>Festuca viviparoides</i> ssp. <i>viviparoides</i> ^a	98.7
<i>Hierochloë alpina</i>	14.4
<i>Honckenya peplodes</i> ssp. <i>diffusa</i> (NT)	4.0
<i>Juncus albescens</i>	90.9
<i>Juncus biglumis</i>	74.2
<i>Koenigia islandica</i>	45.9
<i>Luzula confusa</i>	13.5
<i>Luzula nivalis</i>	26.6
<i>Luzula wahlenbergii</i> (NT)	20.0
<i>Mertensia maritima</i> ssp. <i>tenella</i>	12.2
<i>Micranthes foliolosa</i> ^a	70.6
<i>Micranthes hieracifolia</i> ssp. <i>hieracifolia</i>	42.8
<i>Micranthes nivalis</i>	62.7
<i>Minuartia biflora</i>	–
<i>Minuartia rossii</i> (NT)	33.3
<i>Minuartia rubella</i>	6.8
<i>Oxyria digyna</i>	36.2
<i>Papaver dahlianum</i>	2.0

Table 1 continued

Species	%
<i>Pedicularis dasyantha</i> var. <i>dasyantha</i>	0
<i>Pedicularis hirsuta</i>	17.3
<i>Petasites frigidus</i> ssp. <i>frigidus</i>	0
<i>Phippsia algida</i>	2.4
<i>Phippsia concinna</i>	95.7
<i>Pleuropogon sabinii</i> (NT)	–
<i>Poa abbreviata</i> ssp. <i>abbreviata</i>	36.6
<i>Poa alpina</i> var. <i>vivipara</i> ^a	99.3
<i>Poa arctica</i> ssp. <i>arctica</i> sem.	59.5
<i>Poa glauca</i>	–
<i>Poa pratensis</i> ssp. <i>alpigena seminiferous</i>	–
<i>Poa pratensis</i> ssp. <i>alpigena viv.</i> ^a	96.7
<i>Polemonium boreale</i>	–
<i>Potentilla hyparctica</i> ssp. <i>hyparctica</i>	38.8
<i>Potentilla pulchella</i>	93.6
<i>Puccinellia phryganodes</i> ssp. <i>vilfoidea</i>	–
<i>Puccinellia vahliana</i> (NT)	52.0
<i>Ranunculus hyperboreus</i> ssp. <i>arnelli</i>	40.1
<i>Ranunculus nivalis</i>	49.2
<i>Ranunculus pygmaeus</i>	69.0
<i>Ranunculus wilanderi</i> (EN)	27.8
<i>Rubus chamaemorus</i> (CR)	–
<i>Sagina nivalis</i>	97.3
<i>Salix polaris</i>	83.8
<i>Salix reticulata</i>	–
<i>Saxifraga aizoides</i>	–
<i>Saxifraga cernua</i> ^a	94.5
<i>Saxifraga cespitosa</i> ssp. <i>cespitosa</i>	13.4
<i>Saxifraga hirculus</i> ssp. <i>compacta</i>	4.1
<i>Saxifraga oppositifolia</i> ssp. <i>oppositifolia</i>	61.1
<i>Saxifraga platysepala</i>	–
<i>Saxifraga rivularis</i> ssp. <i>rivularis</i>	12.7
<i>Saxifraga svalbardensis</i> ^a	88.2
<i>Silene acaulis</i> ssp. <i>acaulis</i>	77.3
<i>Silene involucrata</i> ssp. <i>furcata</i>	66.9
<i>Silene uralensis</i> ssp. <i>arctica</i>	26.2
<i>Stellaria humifusa</i>	94
<i>Stellaria longipes</i> taxon <i>crassipes</i>	–
<i>Taraxacum arcticum</i> agg.	55.2
<i>Trisetum spicatum</i> ssp. <i>spicatum</i>	32.4
<i>Vaccinium uliginosum</i> ssp. <i>microphyllum</i> (CR)	–

Species in bold are redlisted. Redlist categories (in brackets) are CR critical endangered, EN endangered, VU vulnerable, and NT near threatened. ^a Bulbil. Species without ripe seeds are listed with “–”

Characteristics of species

Type of propagule (seeds or bulbils) and family was noted for all species. Rarity in Svalbard (very rare = 1–4

populations, rare = 5–25 populations, and common) was given according to Elven and Elvebakk (1996) except for two species where the taxonomy later has been clarified; *Carex bigelowii* ssp. *ensifolia* is found one place (Solstad et al. 2010) and *F. edlundia* is common (Alsos et al. 2012a). We classified the species into five groups of thermophily (strongly, distinctly, moderately, weakly, indifferent) according to Elvebakk (1989) except for species not classified by him: *Carex krausei*, *Eriophorum* × *sorensenii*, *Festuca edlundia*, *Ranunculus wilanderi*, *Saxifraga rivularis* ssp. *rivularis*, and *S. svalbardensis*. For these species, we used Elvebakk's criteria combined with known distribution (Alsos et al. 2012a). Clonal modes of propagations were according to Brochmann and Steen (1999) except for *C. bigelowii* ssp. *ensifolia* which was according to Brooker et al. (2001). Species producing runners, stolons, or bulbils were classified as clonal, and others as non-clonal (including species with apomictic seeds). No data on reproduction were available for *Eriophorum* × *sorensenii*. Nomenclature follows Elven et al. (2011).

Comparison with other studies

There are four previous studies on germination from Svalbard that includes a minimum of three species. Eurola (1972) collected seeds in the vicinity of Longyearbyen and the climatically similar location Svea in 1969. In addition, he collected some seeds along altitudinal gradients. His mean values from Longyearbyen and Svea are used if he collected the species there; otherwise, data from other sites were used. Hagen (2002) and Müller et al. (2011) collected seeds in the vicinity of Longyearbyen in 1998 and 2008, respectively. For Müller, germination percentages obtained at 18 °C in the phytotron were used. Hagen (2002) displays the germination in graphs and no exact percentages are given. Alsos et al. (2003) collected seeds of three thermophilous species in Colesdalen; none of them germinated.

To compare with another Arctic region of similar climate, we used the data of Sørensen (1941). He collected seeds of 99 species in 1934 at Eskimonæs, Northeastern Greenland, and germinated them in the field at the same site. He further collected bulbils of two species and noted lack of ripe seeds in 22 species. This is the only extensive germination study we are aware of which is in the same bioclimatic subzone (subzone C) as the sampling sites in Svalbard. Comparisons were done at species level ignoring that for some species different subspecies occur in the two regions.

Statistics

To test the strength of association between family and thermophily, we initially applied a linear model. However, as the model fit was very poor, we treated thermophily as a

variable with five categories and applied a Cramer's V (Acock and Gordon 1979). To test the strength of other two-way association between rarity, thermophily, family, and clonality, we applied Chi square tests for $2 \times X$ contingency tables. Only families with at least three species represented were included. Standard deviations for germination percentages of each species were calculated with a formula for binomial data (Collett 2003).

To assess the effect of propagule type, thermophily, rarity, clonality, and family on germination, we applied generalized linear models (GLM) with a quasibinomial error distribution. Each GLM was set up with one predictor variable. Further, to test the influence of the above-mentioned predictor variables also on the proportion of species with ripe seeds, each species that germinated was marked as successful and each species that did not germinate, or for which no seed was initially found, was marked as not successful.

To test for interactions between predictor variables and estimate the biological effect of these variables on germination, a linear mixed effect model (LME) with a binomial error distribution was fitted to the data. As rarity and thermophily was associated, we choose the predictor variable with less levels (rarity). Rarity (levels: rare and common) and main reproduction mode (levels: clonal reproduction present and clonal reproduction absent) were used as categorical predictor variables with fixed effects and plant family as random effect with species nested within family as random effect. For these, the R package lme4 version 0.999999-0 (<http://lme4.r-forge.r-project.org/>) was used. All calculations were done in R 2.14.0 (R Core Team 2012).

Results

Of the 113 species observed in this study, 79 had ripe seeds and 8 had bulbils (Table 1). In addition, 26 species were without ripe seeds (Table 1). All species with bulbils germinated at high percentages (71–100 %).

Of the 79 species with seeds, seeds of 10 species did not germinate; 12 species had very low germination (<10 %); 10 had low germination (10–20 %); 23 had intermediate germination (21–50 %); 11 had high germination (51–70 %); and 13 had very high germination (>70 %, Table 1). The mean germination was 35 %.

Of the 24 species that germinated to >50 %, all are common in Svalbard with the exception of two species (Appendix 3 of Electronic supplementary material). Five of the 13 species showing very high (>70 %) germination were of the genus *Draba*. Surprisingly, the two strongly thermophilous species *Juncus albescens* and *Carex krausei* had germination percentages of 91 and 67 %, respectively.

Among the 36 species that either did not germinate or for which no ripe seeds were observed, 22 were strongly or

distinctly thermophilous species, and seven were rare, and six very rare (Appendix 3 of Electronic supplementary material). Of the ten species that did not germinate, there were three species of *Carex*, two of *Coptidium*, one graminoid (*Alopecurus borealis*), one shrub (*Betula nana* var. *tundrarum*), one Asteraceae (*Petasites frigidus* ssp. *frigidus*), and the hemiparasites *Euphrasia wettsteinii* and *Pedicularis dasyantha* var. *dasyantha* (Table 1).

We found seeds in all except four non-clonal species: *Deschampsia sukatschewii* ssp. *borealis*, *Minuartia biflora*, *Polemonium boreale*, and *Saxifraga aizoides* (Table 1, Appendix 3 of Electronic supplementary material). Further, seeds of six non-clonal species did not germinate. Seven of the non-clonal species without germinable seeds were common, one rare, and two very rare (Appendix 3 of Electronic supplementary material).

Assumed ripe seeds were found in 12 redlisted species and seeds of eight of these germinated. Another eight redlisted species were examined but had no ripe seeds (Table 1).

Effect of species characteristics

There was an association between thermophily and rarity ($\chi^2 = 43.80$, $df = 5$, $p < 0.001$), as all rare species were strongly thermophilous or distinctly thermophilous

(Appendix 3 of Electronic supplementary material). There was also an association between thermophily and family (Cramer's $V = 0.43$, $M; N = 10; 5$, $p = 0.042$). There was no association between family and rarity ($\chi^2 = 7.16$, $df = 9$, $p = 0.620$). Further, there was no association between clonality and rarity ($\chi^2 = 0.012$, $df = 1$, $p = 0.913$), family ($\chi^2 = 15.08$, $df = 9$, $p = 0.089$), or thermophily ($\chi^2 = 4.55$, $df = 4$, $p = 0.337$).

Plant family had a significant influence on germination percentages (Table 2). The applied GLM with plant family as predictor variable for germination percentages had the lowest deviance of all used models (Table 2), and thus, plant family had a comparatively high influence on germinability of seeds. The family that had the highest germination rate was Brassicaceae (57 %), followed by Caryophyllaceae (46 %) and Juncaceae (44 %). Scrophulariaceae (6 %) had the lowest germination percentages, followed by Asteraceae (18 %) and Cyperaceae (20 %; Fig. 2; Table 2). Germination, however, increased with increasing cold tolerance of the species. Also germination percentages were higher for common species than for rare species (Fig. 2; Table 2). Thermophile species either did not produce seeds (e.g. *Betula nana* and *Rubus chamaemorus*) or germinated to comparatively low percentages (e.g. *Arnica angustifolia* and *Carex glacialis*,

Table 2 Effect of species characteristics on germination percentages of seeds from Svalbard

Predictor variable	Level	Germination (%)	Lower SE	Upper SE	Number of Species	<i>n</i>	<i>df</i>	Residual deviance	<i>F</i> value	<i>p</i>
Propagules	Bulbils	94.09	90.24	96.48	8	23	254	5,509.6	87.54	<0.001
	Seeds	35.03	33.09	37.01	79	233				
Clonal reproduction	Clonal	25.32	21.87	29.12	20	233	231	5,213.4	8.26	0.004
	Non-clonal	38.32	35.99	40.71	59					
Thermophily	Continuous 1–5	4.4x + 15.87 ^a	12.78 ^a	19.54 ^a	79	233	231	4,957.1	22.03	<0.001
Rarity	Rare	20.46	16.77	24.72	15	43	231	5,129.6	12.58	<0.001
	Common	38.26	36.03	40.54	64	190				
Family ^b	Asteraceae	18.32	12.21	26.55	4	11	216	3,966.6	5.43	<0.001
	Brassicaceae	56.98	51.72	62.08	10	30				
	Caryophyllaceae	46.32	41.02	51.71	10	29				
	Cyperaceae	20.15	16.31	24.62	11	33				
	Juncaceae	43.84	36.63	51.31	5	15				
	Poaceae	35.02	30.43	39.90	12	36				
	Ranunculaceae	29.98	23.26	37.69	6	16				
	Rosaceae	52.06	42.47	61.51	3	9				
	Saxifragaceae	31.10	25.57	37.23	7	21				
Scrophulariaceae	5.91	2.70	12.41	3	9					

Test statistics for generalized linear models (GLMs) with quasibinomial error distribution are given for all characteristics. Species indicates the number of species included in the particular level, *n* is the total number of replicates included at a particular level. Test statistics is ANOVA with *F* tests. Species reproducing by bulbils are only included in the first test, whereas species without ripe seeds in the year of study were excluded from all tests. Germination percentages and SE were backtransformed from the quasibinomial models

^a Germination percentage and SE of the intercept

^b Plant families with less than three species are excluded

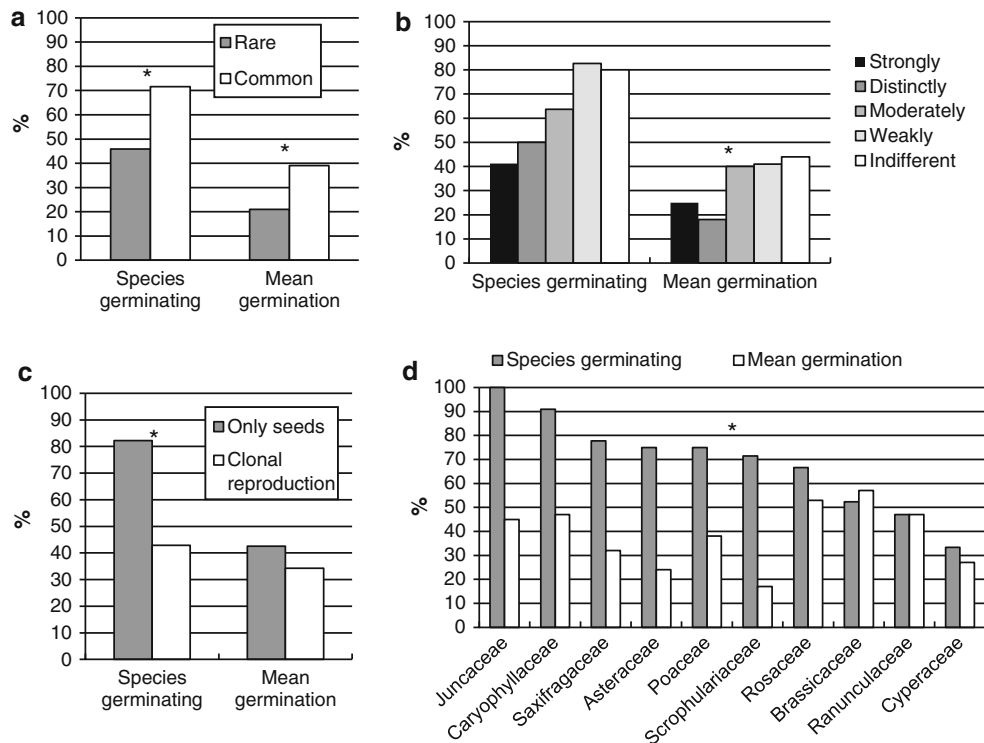


Fig. 2 Effect of species traits on the proportion of species germinating ($n \leq 113$) as well as mean germination percentage of species with ripe seeds ($n \leq 79$). **a** Rarity in Svalbard, **b** thermal requirements, **c** ability to reproduce clonally, and **d** plant family (only families with at least three species included, see Table 1). Effect of traits on species

germination was tested separately for the proportion of species germinating and mean germination percentages. Significant effects ($p < 0.05$, Table 3) are indicated by stars. The star in **d** applies to mean germination only

Table 3 Effect of rarity, clonal reproduction, family, and species on germination in 79 species from Svalbard analysed by linear mixed effect model (LME)

No.	Model term	df	Deviance	AIC	BIC	χ^2	p
1	$y \sim \text{Rarity} * \text{Clonal} + (1 \text{Family}/\text{Species})$	6	753.50	782.1	803.4		
2	$y \sim \text{Rarity} + \text{Clonal} + (1 \text{Family}/\text{Species})$	5	754.80	781.7	799.5	1.621	0.203

Model simplification for the given data with two predictor variables (fixed effects) and Family as random effect and Species nested in Family as random effect. No. model number, df degree of freedom, AIC Akaike information criterion, BIC Bayesian Information Criterion, χ^2 for model comparison. The AIC, BIC, and number of variables show that model 2 fits the data best

Appendix 3 of Electronic supplementary material). Similarly, the proportion of species that germinated was higher in common than rare species ($z = -2.008$; $p = 0.045$) as well as non-clonal than clonal species ($z = -2.800$, $p = 0.005$), whereas there was no effect of the thermophily or family on the proportion of species that germinated ($p > 0.05$, Fig. 2).

No interaction between the predictor variables was found and the interaction term was removed from the model without significant differences between the models (Table 3). The result of the final model is that the predictor variable (rarity) had a significant influence on germination proportions (Table 3). The proportion of germinated seeds in rare species was significantly lower than the proportion of seeds germinating from common species (z value =

-2.680 ; $p = 0.007$). The second predictor variable (main reproduction mode) had also a significant influence on germination proportions. A significantly larger proportion of the seeds germinated from species that is not reproducing clonally compared to the proportion of seeds that germinated from species with a clonal reproduction option (z value = -2.113 ; $p = 0.035$). Overall, the uniform result of the GLMs and the LME (Tables 2, 3) is, beside the strong influence of species and family traits, that rarity has the strongest influence on seed germination.

Comparison with other studies

In total, 51 of the species studied here had also been studied by Euroala (1972). The following species characterized as

having no viable seeds based on a tetrazodium test by Euroala (1972), germinated in our study: *Carex lachenalii* (14 %), *C. ursina* (62 %), *Hierochl e alpina* (14 %), and *Stellaria humifusa* (94 %); in contrast, no ripe seeds of *Poa glauca*, *Poa pratensis* ssp. *alpigena*, *Polemonium boreale*, or *Stellaria longipes* were found in either of the studies (Appendix 3 of Electronic supplementary material). In addition, the following species that did not germinate in the study by Euroala (1972) did germinate in our study: *Cassiope tetragona* ssp. *tetragona*, *Dryas octopetala*, *Minuartia rubella*, *Ranunculus nivalis*, *Micranthes hieracifolia* ssp. *hieracifolia*, and *Saxifraga hirculus* ssp. *compacta*. The mean germination percentages for the 51 species were six times higher in our study (36 %) compared to Euroala (6 %).

The mean germination percentages were higher in the study by M ller et al. (49 %) than in this study (34 %, $n = 22$). Lack of germination in three thermophilous species as observed by Alsos et al. (2003) was also observed in this study. Germination percentages were similar to Hagen (2002) for *Bistorta vivipara* and *Dryas octopetala*, but lower in our study for the three other species (Appendix 3 of Electronic supplementary material).

There were 67 species also studied by S rensen (1941). All 37 species that germinated in S rensen's study also germinated in our study except *Betula nana*, *Euphrasia wettsteinii*, and *Minuartia biflora*. Ten of 15 species that did not germinate in S rensen's study germinated in our study. In addition, six of 15 species were S rensen found no ripe seeds, germinated in our study (Appendix 3 of Electronic supplementary material).

Discussion

The proportion of species with viable propagules (79 with seeds and eight with bulbils of 113 species) and the germination percentages obtained (mean 35 %) are both high compared to some previous studies from Svalbard (Appendix 3 of Electronic supplementary material) and other Arctic regions (S rensen 1941; Bliss 1958), and more in accordance with other reports from the Arctic (Mooney and Billings 1961; Bliss and Gold 1999; M ller et al. 2011). Thus, the ability to bank propagules of Arctic species for future restoration and conservation purposes is generally high. The low proportion (<50 %) of rare species germinating is of concern, as they are of highest conservation need, and alternative management strategies to seed banking and in situ conservation must be sought.

The generally improved germination observed in this study compared to Euroala (1972) could be partly due to improved stratification and germination treatment technique applied in our study, but also due to a greater temperature sum during the year of our study (1 May–30

September 2008, 489.6 K, mean 3.2  C) in comparison with Euroala (1 May–30 September 1969, 376.0 K, mean 2.5  C). Also, the higher proportion of species that germinated in our study compared to S rensen's study (S rensen 1941) strengthens the view that germination in Arctic species is increasing due to current climate warming (M ller et al. 2011).

Germination in relation to rarity, thermal requirements, and clonality

The strong association between rarity and thermophily suggests that thermal requirements limit recruitment in rare plants, which in turn limit their distribution. Rare and thermophilous species also do not germinate from natural Arctic seed banks (Cooper et al. 2004). However, germinability may vary strongly among years (Laine et al. 1995), and sexual reproduction may occur only in infrequent, favourable years, as indicated by the levels of genetic diversity found in some rare, thermophilous species (Alsos et al. 2002). For some species, poor recruitment could be due to factors other than thermal constraints. In the species of assumed hybrid origin, *Carex lidii* and *Eriophorum* \times *sorensenii*, lack of seeds could be due to problems with chromosome pairing as observed in other hybrids (Comai 2005). In *Carex marina* ssp. *pseudolagopina* and *Coptidium pallasii*, lack of germination may be due to difficulties in breaking dormancy, as physiological and morphophysiological dormancy probably is evident in each of these species, respectively (Baskin and Baskin 2001). In the hemiparasite *Euphrasia wettsteinii*, which most regularly set ripe seeds in Svalbard as it is annual, host stimulus is not required but germination may be sensitive to stratification conditions (Liebst and Schneller 2008).

In contrast, the unexpected high germination percentages recorded in some rare and thermophilous species indicate that distribution of rare species may be limited by factors other than germinability of seeds. *Juncus albescens*, of which 91 % seeds germinated in this study, could be limited by factors such as availability of rich mire sites (cf. (Elvebakk 1994)), whereas *Carex krausei*, which had a germination rate of 67 %, could be a recent immigrant that has further dispersal potential as it has only recently been discovered at two sites in Svalbard (Artsdatabanken 2010). The relatively high germination percentage (28 %) of the endemic, assumed apomictic species *Ranunculus wilanderi* (Jonsell 2001), is based on 18 seeds only: due to the small population size (Artsdatabanken 2010), the total seed production is low and may constrain any spread of this endangered species. For all three species, also the seedling survival stage may be limiting, as seedling survival may be low even in common species (Karsd ttir and Arad ttir 2006). Low seedling survival in nature may, however, not

be a problem for management purposes as high survival rates may be obtained in horticulture as observed for *R. wilanderi*, which is now conserved ex situ in Tromsø Arctic-Alpine Botanical Garden.

As we have collected seeds mainly in the warmest sites of Svalbard, we missed rare species that are cold tolerant. However, most rare species are thermophilous. Among the 54 species on the redlist for Svalbard (Artsdatabanken 2010), 30 are classified as strongly thermophilous, 11 as distinctly thermophilous, and two as moderately thermophilous (Elvebakk 1989). Further, four are classified as weakly thermophilous and five are unclassified by Elvebakk (1989). Only *Draba pauciflora* and *Puccinellia vahliana*, both near threatened, are classified as temperature indifferent. The latter germinated to 52 % in our study indicating that cold tolerant rare species may be limited by other factors than temperature.

Lack of germinable seeds in 23 common species was unexpected. It is unlikely that they obtained their current distribution in Svalbard (Alsos et al. 2012a) by vegetative reproduction alone. Exceptions are *Cerastium regelii*, *Puccinellia phryganodes* ssp. *villfoidea*, and *Stellaria longipes*, which achieve efficient dispersal by shoots (and possible *Poa pratensis* ssp. *alpigena*, where the relationship between viviparous and seminiferous forms is unclear, Elven et al. 2011). Although ten of the species are somewhat thermophilous and may only reproduce infrequently (*Carex parallela* ssp. *parallela*, *C. saxatilis*, ssp. *laxa*, *Coptidium lapponicum*, *Eriophorum triste*, *Deschampsia sukatschewii* ssp. *borealis*, *Poa glauca*, *Polemonium boreale*, *Salix reticulata*, *Petasites frigidus* ssp. *frigidus*, and *Pedicularis dasyantha* var. *dasyantha*), the other ten are rather hardy and thus not expected to be constrained by the current climate. For *Carex nardina* ssp. *hepburnii* and *C. fuliginosa* ssp. *misandra*, the germination failure may be related to breaking of dormancy, as this can be problematic in sedges generally (Budelsky and Galatowitsch 1999; Schütz 2000). Five of the species, *Alopecurus borealis*, *Festuca rubra* ssp. *richardsonii*, *Minuartia biflora*, *Pedicularis dasyantha* var. *dasyantha*, and *Saxifraga platyse-pala*, germinated to low percentages from seeds or seed banks in other studies from Svalbard (Eurola 1972; Cooper et al. 2004; Müller et al. 2011), indicating that the lack of ripe seeds or germination in our study may be due to, for example, annual variation. Similarly, for *Arctophila fulva*, *Cardamine polemonioides*, and *Saxifraga aizoides*, lack of ripe seeds can also be a result of annual variation, although we are not aware of any other germination tests of these species from Svalbard. For the latter one, sexual reproduction must take place as it has no means of clonal reproduction.

The higher proportion of non-clonal than clonal species germinating was expected as non-clonal species rely on

reproduction by seeds for long-term survival, and due to the trade-off between biomass investment in generative and vegetative plant structure (Herben et al. 2012). Lack of germinable seeds in ten non-clonal may be related to unripe seeds in the year of study or difficulties of breaking dormancy as discussed above. Also, delimitation of clonality is not straightforward (Klimešová and Doležal 2011), and even species that we classified as non-clonal following Brochmann and Steen (1999) may regenerate by short lateral shoots as, for example, the tussock forming grass *Deschampsia sukatschewii* ssp. *borealis*. Species may also survive for long periods due to high age as, for example, *Betula nana* (up to 147 years, Miller 1975) and may therefore sustain a population even with infrequent reproduction.

Perspectives for seed banking

The overall high germination rate (71–100 %) of bulbils confirms that this is an efficient means of recruitment. Thus, bulbils may be useful at least for short-term storage. For the bulbil producing species studied here, storing seeds may not be an alternative as no seeds of these species have been observed in Svalbard (Brochmann and Håpnæs 2001; Alsos et al. 2012a). Only *Poa pratensis* is commonly semeniferous, but no ripe seeds were found (Table 1). Thus, future test should be undertaken to determine if the bulbils remain viable even after some years of storage and are thus useful for ex situ conservation in seed vaults.

Of the species for which seeds were found but germination failed or was low, the viability of the seeds should be checked, for example, using a Tetrazodium test (Peters 2007). If the seeds are viable, different stratification and germination conditions should be tested. While the majority of cold adapted species produced viable seeds and thus are relatively easy to collect for a seed bank, most thermophilous species failed to produce viable seeds. To overcome the limitations caused by low temperatures, successful seed production could be obtained by artificially warming the plants using, for example, open top chambers (Klady et al. 2011). Although we expect that global warming on the long term will have a positive effect on recruitment in most of these species as it may increase seed production and viability (Klady et al. 2011), there is a risk that the species will get lost under current climate if both population sizes and/or levels of genetic diversity are low (Alsos et al. 2002, 2007; Frankham et al. 2009). Thus, ex situ conservation in, for example, botanical gardens should be used to conserve the current genetic diversity found in Arctic populations. As this requires a large effort per species, species should be prioritized according to Red List status.

For non-clonal species without viable seeds, ex situ conservation in, for example, botanical gardens may be

challenging. However, seeds may ripen in botanical gardens due to more optimal conditions. Also, propagation of new plants from cuttings is a well-established method in horticulture and has been successful also for non-clonal species from the Arctic (Hagen 2002).

The longevity of seeds should be tested repeatedly. Seeds from cool, wet conditions are shorter lived than those from hot, dry environments (Probert et al. 2009), and germinability is reduced over time in alpine species (Mondoni et al. 2011). In seeds of Arctic species, however, germinability may be retained over long periods by seed storage at freezing temperatures (Billings and Mooney 1968), although the report of germination of 10,000 year old *Lupinus arcticus* seeds (Porsild et al. 1967) is disputed (Godwin 1968; Gugerli 2008).

For species with low germination percentages, whether this is due to low proportion of viable embryos or due to lack of knowledge of adequate germination methods, larger amount of seeds should be collected to ensure sufficient amount of seeds that are likely to germinate. To account for annual variation, collections should be done over several seasons. Also, for all species seeds from more populations should be collected to obtain a representative cover of the total genetic diversity of the species. While ideally seeds from the entire range should be collected, populations likely to go extinct due to climate change, as identified by, for example, species distribution models (Alsos et al. 2012b), should be targeted (Vitt et al. 2010). For Arctic species, species distribution modelling indicates that these will mainly be populations at the southern parts of their ranges (Parmesan 2006; Alsos et al. 2012b).

Conclusions

As the proportion of species germinating and their germination percentages were higher than assumed by many previous studies, seed banks may be a viable strategy for ex situ conservation also of the Arctic flora. Improved knowledge of seed ecology and ongoing climate warming are two factors that likely contribute to the high germination. Sampling of seeds should cover a broad geographical range, paying especially attention to regions where populations are expected to extirpate due to climate change, to obtain seeds representative for the majority of the genetic diversity within species. For species without viable seeds, alternative methods of ex situ conservation need to be evaluated.

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Appendix 1. Collection data for seeds. All seeds were collected in 2008 except *Carex krausei* which was collected in 2009.

Species	Coll. date	Collection place	Habitat	Collector	Latitude	Longitude
<i>Alopecurus borealis</i>	09-Sep	Bjørndalen	Moist grassland	HEP, CJW, ASc	78.226	15.328
<i>Arabis alpina</i>	06-Sep	Kapp Smith	Fine gravel below bird cliff	IGA, SWS, TW, KJ	78.660	15.116
<i>Arctagrostis latifolia</i>	02-Sep	Kapp Thordsen	<i>Salix polaris</i> / <i>Saxifraga oppositifolia</i> heath	IGA	78.458	15.476
<i>Arctophila fulva</i>	04-Sep	Bohemanflya	Wet grassy area with slowly flowing water	IGA, EM	78.414	14.676
<i>Arenaria pseudofrigida</i>	12-Sep	Hotellneset	<i>Silene acaulis</i> tundra	EM, SSS, HEP, ASc, SL	78.249	15.508
<i>Arnica angustifolia</i>	08 and 09 Sep	Colesdalen	S exposed rocky slope	EM, AS, CH, AB	78.106	15.126
<i>Betula nana</i> var. <i>tundrarum</i>	09-Sep	Colesdalen	S slope in depressions	EM, AS, CH, ASC	78.104	15.131
<i>Bistorta vivipara</i>	27-Aug	Endalen	Snow bed and river bank	EM, CJW, JV, IGA	78.197	15.810
<i>Braya glabella</i> ssp. <i>purpurascens</i>	05-Sep	Bohemanflya	Sandy moraine ridges	IGA, PBE	78.470	14.509
<i>Calamagrostis neglecta</i> ssp. <i>groenlandica</i>	18-Sep	Hotellneset	Moist grassland	EM	78.249	15.508
<i>Campanula rotundifolia</i> ssp. <i>gieseckiana</i>	09-Sep	Colesdalen	S exposed slope with gravel	EM	78.105	15.124
<i>Cardamine polemonioides</i>	09-Sep	Colesdalen	Moist mire beside open flowing water	EM	78.107	15.064
<i>Carex bigelowii</i> ssp. <i>ensifolia</i>	12-Sep	Hotellneset	Mire	IGA	78.243	15.488
<i>Carex fuliginosa</i> ssp. <i>misandra</i>	09-Sep	Sassendalen	<i>Dryas</i> heath	SSS, REP, InGA	78.343	16.947
<i>Carex glacialis</i>	06-Sep	Kapp Smith	Open steep scree below bird cliff	IGA, SWS	78.660	15.115
<i>Carex krausei</i>	09-Aug	Kapp Smith	Steep scree below bird cliff	IGA, SWS, BES	78.662	15.125
<i>Carex lachenalii</i>	10-Sep	Colesdalen	Mire with some open water	EM	78.098	15.146
<i>Carex lidii</i>	09 and 10 Sep	Kapp Thordsen, Sassendalen	Rich mire	IGA, SL	78.458, 78.322	15.505, 17.035
<i>Carex marina</i> ssp. <i>pseudolagopina</i>	10-Sep	Sassendalen	Rich mire	IGA, UBM	78.342	16.950
<i>Carex maritima</i>	10-Sep	Sassendalen	Rich mire	InGA, REP, SSS, UBM	78.342, 78.322	16.950, 17.035
<i>Carex nardina</i> ssp. <i>hepburnii</i>	10-Sep	Sassendalen	Dry calcareous ridge	IGA, SSS, UBM	78.353	16.927

<i>Carex parallela</i> ssp. <i>parallela</i>	01, 06 and 09 Sep	Kapp Smith, Kapp Thordsen, Sassendalen (2 places)	Rich mire	IGA	KS: 78.669, KT: 78.458, Sa1: 78.335, Sa2: 78.335	KS: 15.182, KT: 15.505, Sa1: 16.978, Sa2: 16.980
<i>Carex rupestris</i>	09-Sep	Sassendalen	Ridge	SL, SSS, RP	78.321	17.014
<i>Carex saxatilis</i> ssp. <i>laxa</i>	10-Sep	Sassendalen	Rich mire	IGA, UBM	78.342	16.950
<i>Carex subspathacea</i>	19-Sep	Longyeardalen	Wetland at seashore	IGA, SSS, HEP, CH	75.532	15.430
<i>Carex ursina</i>	05-Sep	Bohemanflya	Sandy moraine ridges	PBE, IGA	78.469	14.508
<i>Cassiope tetragona</i> ssp. <i>tetragona</i>	18-Sep	Longyeardalen	<i>Cassiope</i> heath	PBE, EM, CJW, AB	78.208	15.587
<i>Cerastium arcticum</i>	27-Aug	Hotellneset	Heath	JV	78.249	15.513
<i>Cerastium regelii</i> ssp. <i>caespitosum</i>	12-Sep	Longyeardalen	Disturbed site, open gravel	IGA	78.215	15.680
<i>Chrysosplenium tetrandrum</i>	04-Sep	Bohemanflya	Seepage	IGA, EM	78.431	14.624
<i>Cochlearia groenlandica</i>	08-Sep	Hotellneset	Beach ridge	SL, SSS, REP, IGA	78.249	15.524
<i>Coptidium lapponicum</i>	09-Sep	Colesdalen	Wet moss tundra	EM	78.101	15.134
<i>Coptidium pallasii</i>	04-Sep	Bohemanflya	Mire with small ponds	IGA, EM	78.414	14.669
<i>Deschampsia alpina</i>	12-Sep	Longyeardalen	Open gravel along river	IGA, SSS	78.218	15.689
<i>Deschampsia sukatschewii</i> ssp. <i>borealis</i>	09 and 10 Sep	Sassendalen	Wetland and dried river	IGA, SL, SSS, REP	78.342, 78.329	16.950, 16.991
<i>Draba alpina</i>	02-Sep	Kapp Thordsen	Fine-grained, moist open habitat	SL, CH, HEP, IGA	78.460	15.482
<i>Draba arctica</i> ssp. <i>arctica</i>	05-Sep	Bohemanflya	Open moraine	IGA, PBE	78.470	14.509
<i>Draba glabella</i>	10-Sep	Colesdalen	Dry gravel	EM	78.117	15.026
<i>Draba lactea</i>	02-Sep	Kapp Thordsen	Fine-grained, moist open habitat	SL, CH, HEP, IGA	78.460	15.482
<i>Draba nivalis</i>	09-Sep	Colesdalen	Dry gravel	EM, AS, CH	78.117	15.026
<i>Draba rupestris</i> (syn. <i>D norvegica</i>)	10-Sep	Colesdalen	Dry gravel	EM	78.117	15.026
<i>Draba subcapitata</i>	18-Sep	Hotellneset	Exposed ridge	AB	78.249	15.513
<i>Dryas octopetala</i>	02-Sep	Kapp Thordsen	<i>Dryas</i> heath	HEP, CH, MTD, SL	78.458	15.492
<i>Dupontia fisheri</i> morph " <i>psilosantha</i> "	04-Sep	Bohemanflya	Mire	IGA, EM	78.445	14.586
<i>Empetrum nigrum</i>	17 and 18 Sep	Longyeardalen	Sheltered depression in <i>Cassiope</i> heath	IGA, PBE, EM, CJW, AB	78.208	15.587
<i>Erigeron humilis</i>	10-Sep	Colesdalen	Moist tundra	EM	78.119	15.023
<i>Eriophorum triste</i>	02-Sep	Kapp Thordsen	Mire/along small stream	SL, CH, HEP, IGA	78.461	15.484
<i>Eriophorum scheuchzeri</i> ssp. <i>arcticum</i>	02-Sep	Kapp Thordsen	Wetland	SL, CH, HEP, IGA	78.461	15.484
<i>Eriophorum</i> × <i>sorensenii</i>	27-Aug	Endalen	Wetland	KK	78.197	15.810
<i>Euphrasia wettsteinii</i>	08-Sep	Colesdalen	Moist tundra	AB, EM, AS	78.120	15.020

<i>Festuca baffinensis</i>	09-Sep	Sassendalen	Open gravel along dried river	REP, SSS, InGA	78.321	17.016
<i>Festuca brachyphylla</i>	27-Aug	Hotellneset	Exposed, open fine gravel	IGA	78.249	15.513
<i>Festuca edlundiae</i>	27-Aug	Hotellneset	Exposed, open fine gravel	IGA, EM	78.249	15.481
<i>Festuca rubra</i> ssp. <i>richardsonii</i>	19-Sep	Endalen	Heath	IGA	78.188	15.761
<i>Festuca viviparoidea</i> ssp. <i>viviparoidea</i>	12-Sep	Longyeardalen	Disturbed gravel	RP, SSS, HEP, SL, EM	78.217	15.680
<i>Hierochloë alpina</i>	09-Sep	Colesdalen	Heath	AB, CH, ASc	78.133	14.986
<i>Honckenya peploides</i> ssp. <i>diffusa</i>	12-Sep	Hotellneset	Beach	ASc, EM, SL, HEP, SSS, IGA	78.249	15.510
<i>Juncus albescens</i>	09-Sep	Sassendalen	Rich mire	SL, IGA, InGA, UBM, REP, SSS	78.342	16.950
<i>Juncus biglumis</i>	01-Sep	Kapp Thordsen	Wet, open mire	EM	78.466	15.650
<i>Koenigia islandica</i>	19-Sep	Hotellneset	Open, moist soil	PBE	78.249	15.473
<i>Luzula confusa</i>	01-Sep	Kapp Thordsen	Heath	SL, CJW	78.466	15.650
<i>Luzula nivalis</i>	19-Sep	Endalen	Moist moss tundra	IGA, HEP, SSS, CH	78.188	15.761
<i>Luzula wahlenbergii</i>	18-Sep	Longyeardalen	Mire	IGA	78.217	15.654
<i>Mertensia maritima</i> ssp. <i>tenella</i>	11-Sep	Colesdalen	Beach	EM, AS, CH, AB	78.115	15.020
<i>Micranthes foliolosa</i>	04-Sep	Bohemanflya	Moss tundra	IGA, EM	78.444	14.581
<i>Micranthes hieracifolia</i> ssp. <i>hieracifolia</i>	09-Sep	Colesdalen	Heavily grazed moist tundra	EM	78.116	15.021
<i>Micranthes nivalis</i>	10, 12, and 19-Sep	Adventdalen, Longyeardalen, Sassendalen	Moist tundra	EM, AB, IGA	Ad: 78.190, Lo: 78.217, Sa: 78.353	Ad: 15.813, Lo: 15.680, Sa: 16.927
<i>Minuartia biflora</i>	10-Sep	Sassendalen	Snow bed	SL	78.343	16.947
<i>Minuartia rossii</i>	02-Sep	Kapp Thordsen	Heath/ open soil	IGA	78.463	15.498
<i>Minuartia rubella</i>	10-Sep	Sassendalen	Disturbed moss tundra	InGA, IGA, UBM	78.353	16.927
<i>Oxyria digyna</i>	01-Sep	Kapp Thordsen	Snow bed	CH	78.466	15.650
<i>Papaver dahlianum</i>	10-Sep	Hotellneset	Exposed gravel	HEP, CJW, (ASc)	78.246	15.383
<i>Pedicularis dasyantha</i> var. <i>dasyantha</i>	01-Sep	Kapp Thordsen	Heath	EM, IGA	78.466	15.650
<i>Pedicularis hirsuta</i>	01-Sep	Kapp Thordsen	Heath	EM, IGA	78.466	15.650
<i>Petasites frigidus</i> ssp. <i>frigidus</i>	01-Sep	Kapp Thordsen	Moss tundra	IGA, EM, CH, HEP, MTD	78.467	15.650
<i>Phippsia algida</i>	04-Sep	Bohemanflya	Open fine gravel	IGA, EM	78.433	14.614
<i>Phippsia concinna</i>	18 and 19 Sep	Longyeardalen	Roadside, fine gravel	IGA	78.217	15.654
<i>Pleuropogon sabinii</i>	04-Sep	Bohemanflya	Along river	PBE, CJW	78.470	14.384
<i>Poa abbreviata</i> ssp. <i>abbreviata</i>	10-Sep	Sassendalen	Exposed ridge	IGA	78.343	16.947

<i>Poa alpina</i> var. <i>vivipara</i>	12-Sep	Longyeardalen	Snow bed	AS, HEP	78.217	15.680
<i>Poa arctica</i> ssp. <i>arctica</i> seminiferous type	19-Sep	Endalen	Heath	IGA	78.188	15.761
<i>Poa glauca</i>	12-Sep	Longyeardalen	Scree	IGA, EM, ASc, SL	78.217	15.680
<i>Poa pratensis</i> ssp. <i>alpigena</i> seminiferous type	19-Sep	Endalen	Moist <i>Cassiope</i> heath	IGA	78.188	15.761
<i>Poa pratensis</i> ssp. <i>alpigena</i> viviparous type	12-Sep	Longyeardalen	Moderate Snow bed	HEP	78.217	15.680
<i>Polemonium boreale</i>	08-Sep	Colesdalen	Disturbed gravel	CH, AS	78.116	15.025
<i>Potentilla hyparctica</i> ssp. <i>hyparctica</i>	27-Aug	Hotellneset	Ridge along road	JV	78.249	15.481
<i>Potentilla pulchella</i>	27-Aug	Hotellneset	Ridge along road	CJW	78.249	15.481
<i>Puccinellia</i> <i>phryganodes</i> ssp. <i>vilfoidea</i>	19-Sep	Longyeardalen	Salt march	IGA	75.532	15.430
<i>Puccinellia vahliana</i>	01-Sep	Kapp Thordsen	Scree	EM, IGA	78.458	15.492
<i>Ranunculus</i> <i>hyperboreus</i> ssp. <i>arnelli</i>	08-Sep	Colesdalen	Wet mire with some open water	AS, EM, CH	78.101	15.129
<i>Ranunculus nivalis</i>	02-Sep	Kapp Thordsen	Snow bed	IGA, EM, SL, CH, MTD	78.464	15.545
<i>Ranunculus</i> <i>pygmaeus</i>	01-Sep	Kapp Thordsen	Snow bed	SL	78.466	15.650
<i>Ranunculus wilanderi</i>	02 and 10 Sep	Kapp Thordsen	Rich moss tundra	IGA, EM, SL	78.458	15.491
<i>Rubus chamaemorus</i>	02 and 09 Sep	Colesdalen, Kapp Thordsen	Heath and moss tundra	IGA, SL, CH, MTD, EM	Co: 78.136, 78.129, KT: 78.461	Co: 14.990, 15.003, KT: 15.548
<i>Sagina nivalis</i>	18-Sep	Bjørndalen	Sandy riverplain	HEP, CJW, PBE	78.226	15.328
<i>Salix polaris</i>	27-Aug	Hotellneset	<i>Salix polaris</i> heath	KK	78.249	15.513
<i>Salix reticulata</i>	06-Sep	Kapp Smith	Moss tundra	IGA	78.669	15.182
<i>Saxifraga aizoides</i>	06 and 10 Sep	Kapp Smith, Sassendalen	Gravel and river bank	IGA, SL	KS: 78.669, Sa: 78.342	KS: 15.182, Sa: 16.969
<i>Saxifraga cernua</i>	09 and 10 Sep	Colesdalen	S exposed slope	CH, AS	78.100	15.000
<i>Saxifraga cespitosa</i> ssp. <i>cespitosa</i>	27-Aug	Hotellneset	Ridge along road	IGA	78.249	15.481
<i>Saxifraga hirculus</i> ssp. <i>compacta</i>	18-Sep	Hotellneset	Moist tundra	EM	78.249	15.473
<i>Saxifraga</i> <i>oppositifolia</i> ssp. <i>oppositifolia</i>	01-Sep	Kapp Thordsen	Heath	CH	78.466	15.650
<i>Saxifraga platysepala</i>	15-Sep	Longyeardalen	Open soil along small stream	IGA	78.215	15.654
<i>Saxifraga rivularis</i> ssp. <i>rivularis</i>	18-Sep	Bjørndalen	Along stream	PBE, CJW, EM	78.222	15.321
<i>Saxifraga</i> <i>svalbardensis</i>	10 and 19 Sep	Bjørndalen, Hotellneset, Longyeardalen	Moss tundra	PBE, HEP, CJW, IGA	Lo: 78.220, Bj: 78.226	Lo: 15.673, Bj: 15.328

<i>Silene acaulis</i> ssp. <i>acaulis</i>	27-Aug	Hotellneset	Heath	CJW	78.249	15.513
<i>Silene involucrata</i> ssp. <i>furcata</i>	27-Aug	Hotellneset	Tundra	EM	78.249	15.513
<i>Silene uralensis</i> ssp. <i>arctica</i>	19-Sep	Endalen	Scree	IGA	78.188	15.761
<i>Stellaria humifusa</i>	12-Sep	Hotellneset	Beach	SL, EM, IGA, ASc, HEP	78.249	15.510
<i>Stellaria longipes</i> taxon <i>crassipes</i>	10 and 15 Sep	Colesdalen, Longyeardalen	Grazed tundra and heath	EM, IGA	78.113, 78.215	15.034, 15.680
<i>Taraxacum arcticum</i> agg.	10-Sep	Colesdalen	Small slope, heavy grazed grass tundra	EM, AS, CH	78.112	15.051
<i>Trisetum spicatum</i> ssp. <i>spicatum</i>	10-Sep	Sassendalen	Moderate Snow bed	SSS, REP, InGA, SL	78.342	16.969
<i>Vaccinium uliginosum</i> ssp. <i>microphyllum</i>	10-Sep	Colesdalen	Heath dominated by <i>V. uliginosum</i>	EM	78.105	15.127

AB - Allan Buras
 AS - Anders Søyland
 ASc - Andrea Schmidt
 CH - Charmain Hamilton
 CJW – Chris J. Ware
 EM - Eike Müller
 HEP - Hanne Eik Pilskog
 IGA - Inger Greve Alsos
 InGA - Ingvild Greve Alsos
 JV – Jochem Veenboer
 KJ – Kåre Johansen
 KK – Kim Klein
 MTD - Martin Torp Dahl
 PBE - Pernille Bronken Eidesen
 REP - Roman Egorovich Petrov
 SL - Sylvi Lundgren
 SSS - Sergey Semyonovich Sivtsev
 SWS - Snorre Winger Steen
 TW – Torunn Winsnes
 UBM - Ulf B. Mikalsen

Appendix 2. Overview of applied stratification (strat.) and germination methods.

Species	Cold strat. (days)	Germ. temp (° C)	Comment
<i>Alopecurus borealis</i>	27	20	Covering structure removed. Seeds look empty
<i>Arabis alpina</i>	27	20	Seeds were overgrown by green algae
<i>Arenaria pseudofrigida</i>	27	20	
<i>Arnica angustifolia</i>	27	20	Pappus removed. The majority of seeds may be without developed embryo
<i>Betula nana</i> var. <i>tundrarum</i>	27	20	
<i>Bistorta vivipara</i>	27	20	
<i>Braya glabella</i> ssp. <i>purpurascens</i>	27	20/10	
<i>Carex fuliginosa</i> ssp. <i>misandra</i>	80	20/10	
<i>Carex glacialis</i>	80	20/10	Uncertain if seeds were fully ripe
<i>Carex krausei</i>	56	20/10	
<i>Carex lachenalii</i>	80	20/10	
<i>Carex marina</i> ssp. <i>pseudolagopina</i>	80	20/10	The majority of seeds may be without developed embryo
<i>Carex maritima</i>	80	20/10	
<i>Carex nardina</i> ssp. <i>hepburnii</i>	79	20/10	
<i>Carex rupestris</i>	79	20/10	
<i>Carex subspathacea</i>	79	20/10	
<i>Carex ursina</i>	79	20/10	
<i>Cassiope tetragona</i> ssp. <i>tetragona</i>	30	20	Seeds attacked by fungi
<i>Cerastium arcticum</i>	26	20/10	
<i>Chrysosplenium tetrandrum</i>	26	10	Surface sterilized with bleach prior to stratification. Low germination during first germination period. 2nd freezing and cold stratification followed by 2nd germination period. Technical problems caused temperature variation between - 10 ° and 31° C
<i>Cochlearia groenlandica</i>	26	10	2nd stratification for 38 days and 2nd germination at 20/10° C
<i>Coptidium lapponicum</i>	0	20/10	Seeds very small and may have been partly unripe. Warm stratification at 10° C for 10 weeks, then cold stratification at 1° C for 10 weeks, then germination at 20/10° C. Treated with bleach day 6 of warm stratification due to mould
<i>Coptidium pallasii</i>	0	20/10	Uncertain if seeds were 100 % ripe. Same stratification as above. Treated with bleach day 6 of warm stratification due to mould
<i>Deschampsia alpina</i>	0	20	
<i>Draba alpina</i>	26	20	Rubbed with sandpaper
<i>Draba arctica</i> ssp. <i>arctica</i>	26	20	Rubbed with sandpaper
<i>Draba glabella</i>	26	20	Rubbed with sandpaper
<i>Draba lactea</i>	26	20	Rubbed with sandpaper
<i>Draba nivalis</i>	26	20	Rubbed with sandpaper
<i>Draba rupestris</i> (syn. <i>D. norvegica</i>)	28	20	Rubbed with sandpaper
<i>Draba subcapitata</i>	28	20	Rubbed with sandpaper
<i>Dryas octopetala</i>	26	20/10	Pappus removed
<i>Dupontia fisheri</i> morph “ <i>psilosantha</i> ”	29	20	Seeds look empty
<i>Empetrum nigrum</i>	0	20/10	10 weeks warm stratification at 20° C followed by 10 weeks cold stratification at 1° C

<i>Erigeron humilis</i>	29	20	Pappus removed
<i>Eriophorum scheuchzeri</i> ssp. <i>arcticum</i>	26	10	Pappus removed
<i>Euphrasia wettsteinii</i>	26	10	Germination first at 10 ° C for 4 weeks, then 20 ° C for 12 weeks. 2nd cold stratification at 1° C for 6 weeks followed by germination at 10 ° C.
<i>Festuca baffinensis</i>	26	20	Removed covering structure. Hard to see if the seeds contain embryo
<i>Festuca brachyphylla</i>	28	20	Removed covering structure
<i>Festuca edlundiae</i>	28	20	Removed covering structure. Some empty seeds
<i>Festuca viviparoidea</i> ssp. <i>viviparoidea</i>	0	20	
<i>Hierochloë alpina</i>	28	20	Remove covering structure
<i>Honckenya peploides</i> ssp. <i>diffusa</i>	28	20/10	After 11 weeks germination, a 2nd cold stratification of 6 weeks at 1° C was done followed by new germination at 20/10° C
<i>Juncus albescens</i>	28	20	
<i>Juncus biglumis</i>	28	20/10	
<i>Koenigia islandica</i>	78	20	
<i>Luzula confusa</i>	28	20	
<i>Luzula nivalis</i>	28	20	
<i>Luzula wahlenbergii</i>	28	10	
<i>Mertensia maritima</i> ssp. <i>tenella</i>	37	20	The seeds may have been unripe
<i>Micranthes foliolosa</i>	0	20	
<i>Micranthes hieracifolia</i> ssp. <i>hieracifolia</i>	37	20/10	The seeds may have been unripe. After 14 weeks of germination, seeds were given a 2nd cold stratification at 1° C for 5 weeks followed by germination at 20/10° C
<i>Micranthes nivalis</i>	37	20	
<i>Minuartia rossii</i>	28	20	After 6 weeks of where only one seed germinated, the seeds were moved to 10° C, which enhanced germination.
<i>Minuartia rubella</i>	28	20	
<i>Oxyria digyna</i>	28	20	
<i>Papaver dahlianum</i>		20	3 weeks of warm stratification at 20° C followed by cold stratification at 1° C for 17 weeks. Germination at 20° C, but agar dried out.
<i>Pedicularis dasyantha</i> var. <i>dasyantha</i>	139	20/10	Seeds were forgotten at cold stratification, but still looked ok.
<i>Pedicularis hirsuta</i>	139	20/10	Seeds were forgotten at cold stratification, but still looked ok.
<i>Petasites frigidus</i> ssp. <i>frigidus</i>	28	20	Seeds may have been unripe
<i>Phippsia algida</i>	28	20	Remove covering structure. After a germination period of 11 weeks, a 2nd stratification period of 5 weeks at 1° C. 2nd germination first at 10° C for 2 weeks, than 20/10° C.
<i>Phippsia concinna</i>	28	20	Covering structure removed. Seeds looked empty
<i>Poa abbreviata</i> ssp. <i>abbreviata</i>	28	20/10	Covering structure removed. Seeds looked empty
<i>Poa alpina</i> var. <i>vivipara</i>	0	20	
<i>Poa arctica</i> ssp. <i>arctica</i> <i>seminiferous</i> type	28	20/10	Removed covering structure. Uncertain if seeds were ripe, but the germination % indicate they were
<i>Poa pratensis</i> ssp. <i>alpigena</i> <i>viviparous</i> type	0	20	Covering structure removed
<i>Potentilla hyparctica</i> ssp. <i>hyparctica</i>	28	20	Pappus removed
<i>Potentilla pulchella</i>	28	20	Pappus removed
<i>Puccinellia vahliana</i>	28	20/10	Some seeds looked empty
<i>Ranunculus hyperboreus</i> ssp. <i>arnelli</i>	0	20/10	Some seeds may have been unripe
<i>Ranunculus nivalis</i>	0	20/10	Some seeds may have been unripe

<i>Ranunculus pygmaeus</i>	0	20/10	
<i>Ranunculus wilanderi</i>	135	20/10	Seed lot divided into assumed ripe and assumed unripe seeds, and germination percentages refer to the assumed ripe ones only. After 5 weeks of no germination at 20/10° C, the seeds were moved to 10° C, after which a few seeds germinated indicating that the species needs warm stratification
<i>Sagina nivalis</i>	37	20/10	
<i>Salix polaris</i>	37	20	
<i>Saxifraga cernua</i>	0	20	
<i>Saxifraga cespitosa</i> ssp. <i>cespitosa</i>	37	20	
<i>Saxifraga hirculus</i> ssp. <i>compacta</i>	37	20/10	Seeds seams empty/bad
<i>Saxifraga oppositifolia</i> ssp. <i>oppositifolia</i>	37	20	
<i>Saxifraga rivularis</i> ssp. <i>rivularis</i>	37	20	
<i>Saxifraga svalbardensis</i>	0	20	
<i>Silene acaulis</i> ssp. <i>acaulis</i>	0	20	
<i>Silene involucrata</i> ssp. <i>furcata</i>	0	20	
<i>Silene uralensis</i> ssp. <i>arctica</i>	0	20	Moved to 20/10° C after 4 weeks which increased germination
<i>Stellaria humifusa</i>	35	20	
<i>Taraxacum arcticum</i> agg.	35	20	2 flower heads collected
<i>Trisetum spicatum</i> ssp. <i>spicatum</i>	35	20	

Appendix 3. Germination percentages and species characteristics of Arctic species from Svalbard tested for germination. Reproduction (R) by seeds (s) or bulbils (b), or no ripe seeds found (ns). Rarity (1 = scattered or at least locally common, 2 = rare (5-25 localities known), 3 = very rare (1-4 localities), Thermophily (Ther, 1 = strongly, 2 = distinctly, 3 = moderately, 4 = weakly, and 5 = indifferent), Vegetative means of reproduction (Veg, A = asexual seeds, B = bulbils, N = no vegetative reproduction, R = runners, S = shoots), n = number of seeds germinated, % germ = percentage of germinated seeds, and sd = standard deviation. For comparison, mean germination percentages obtained by other studies are given: Euroala (1972) are given as germination/Tetrazodium test, Müller et al 2011 (germination at 18°C), other Svalbard (A = Alsos et al. 2003, H = Hagen 2002), and Sørensen 1941 (ns = no ripe seeds found, 0 = no seeds germinated, (+) poor germination, + = germination).

Species	Family	R	Rarity	Ther	Veg	n	% germ	±sd	Euroala 1972	Müller et al. 2011	Other Svalbard	Sørensen 1941
<i>Alopecurus borealis</i>	Poaceae	s	common	5	A,R	98	0.00	0.00	0/0.7	8.7	-	ns
<i>Arabis alpina</i>	Brassicaceae	s	rare	2	N	137	6.57	2.12	-	-	-	-
<i>Arctagrostis latifolia</i>	Poaceae	ns	rare	2	R	-	-	-	-	-	-	ns
<i>Arctophila fulva</i>	Poaceae	ns	common	4	R	-	-	-	-	-	-	-
<i>Arenaria pseudofrigida</i>	Caryophyllaceae	s	common	4	N	151	30.46	3.75	-	-	-	ns
<i>Arnica angustifolia</i>	Asteraceae	s	rare	2	A	148	0.68	0.67	-	-	-	+
<i>Betula nana</i> var. <i>tundrarum</i>	Betulaceae	s	rare	1	N	140	0.00	0.00	-	-	ns (A)	(+)
<i>Bistorta vivipara</i>	Polygonaceae	b	common	5	B	145	100.00	0.00	-	26.7	90-100 (H)	+
<i>Braya glabella</i> ssp. <i>purpurascens</i>	Brassicaceae	s	common	4	N	146	60.27	4.05	-	-	-	+
<i>Calamagrostis neglecta</i> ssp. <i>groenlandica</i>	Poaceae	ns	rare	2	R	-	-	-	-	-	-	-
<i>Campanula rotundifolia</i> ssp. <i>gieseckiana</i>	Campanulaceae	ns	very rare	1	R	-	-	-	-	-	ns (A)	ns
<i>Cardamine polemonioides</i>	Brassicaceae	ns	common	4	S	-	-	-	-	-	-	-
<i>Carex bigelowii</i> ssp. <i>ensifolia</i>	Cyperaceae	ns	very rare	1	R	-	-	-	-	-	-	0
<i>Carex fuliginosa</i> ssp. <i>misandra</i>	Cyperaceae	s	common	4	N	62	0.00	0.00	0.5/10.0	-	-	0
<i>Carex glacialis</i>	Cyperaceae	s	very rare	1	N	148	8.11	2.24	-	-	-	-
<i>Carex krausei</i>	Cyperaceae	s	very rare	1	N	149	67.11	3.85	-	-	-	-
<i>Carex lachenalii</i>	Cyperaceae	s	common	2	N	142	14.08	2.92	0/0	-	-	0
<i>Carex lidii</i>	Cyperaceae	ns	rare	2	R	-	-	-	-	-	-	-
<i>Carex marina</i> ssp. <i>pseudolagopina</i>	Cyperaceae	s	very rare	1	N	142	0.00	0.00	-	-	-	-
<i>Carex maritima</i>	Cyperaceae	s	common	2	R	150	2.67	1.32	-	-	-	-

<i>Carex nardina</i> ssp. <i>hepburnii</i>	Cyperaceae	s	common	3	N	148	0.00	0.00	-	-	-	0
<i>Carex parallela</i> ssp. <i>parallela</i>	Cyperaceae	ns	common	2	R	-	-	-	-	-	-	ns
<i>Carex rupestris</i>	Cyperaceae	s	common	4	R	148	2.03	1.16	-	-	-	0
<i>Carex saxatilis</i> ssp. <i>laxa</i>	Cyperaceae	ns	common	2	R	-	-	-	-	-	-	ns
<i>Carex subspathacea</i>	Cyperaceae	s	common	4	R	137	49.64	4.27	-	-	-	ns
<i>Carex ursina</i>	Cyperaceae	s	common	4	N	142	61.97	4.07	0/0	-	-	0
<i>Cassiope tetragona</i> ssp. <i>tetragona</i>	Ericaceae	s	common	2	N	217	7.83	1.82	0/29.2	76.0	-	0
<i>Cerastium arcticum</i>	Caryophyllaceae	s	common	5	N	148	33.78	3.89	5.7/45.0	16.0	-	-
<i>Cerastium regelii</i> ssp. <i>caespitosum</i>	Caryophyllaceae	ns	common	5	S	-	-	-	-	-	-	-
<i>Chrysosplenium tetrandrum</i>	Saxifragaceae	s	common	4	R	148	25.00	3.56	-	-	-	(+)
<i>Cochlearia groenlandica</i>	Brassicaceae	s	common	5	N	148	14.19	2.87	13.0/60.0	-	-	+
<i>Coptidium lapponicum</i>	Ranunculaceae	s	common	2	R	135	0.00	0.00	-	-	-	-
<i>Coptidium pallasii</i>	Ranunculaceae	s	rare	1	R	140	0.00	0.00	-	-	-	-
<i>Deschampsia alpina</i>	Poaceae	b	common	5	B	114	100.00	0.00	-	-	-	-
<i>Deschampsia sukatschewii</i> ssp. <i>borealis</i>	Poaceae	ns	common	2	N	-	-	-	-	-	-	-
<i>Draba alpina</i>	Brassicaceae	s	common	4	N	203	72.41	3.14	14.2/48.2	-	-	-
<i>Draba arctica</i> ssp. <i>arctica</i>	Brassicaceae	s	common	3	N	138	84.06	3.12	-	-	-	-
<i>Draba glabella</i>	Brassicaceae	s	common	2	N	147	54.42	4.11	-	-	-	+
<i>Draba lactea</i>	Brassicaceae	s	common	5	N	132	71.21	3.94	-	-	-	+
<i>Draba nivalis</i>	Brassicaceae	s	common	5	N	137	86.86	2.89	1.0/28.0	-	-	+
<i>Draba rupestris</i> (syn. <i>D. norvegica</i>)	Brassicaceae	s	rare	2	N	139	36.69	4.09	-	-	-	-
<i>Draba subcapitata</i>	Brassicaceae	s	common	5	N	142	78.87	3.43	38.5/58.3	-	-	+
<i>Dryas octopetala</i>	Rosaceae	s	common	4	(R)	149	26.17	3.60	0/31.5	55.3	<10 (H)	+
<i>Dupontia fisheri</i> morph “ <i>psilosantha</i> ”	Poaceae	s	common	3	R	145	35.86	3.98	5.1/4.3	-	-	ns
<i>Empetrum nigrum</i>	Empetraceae	s	common	2	N	150	29.33	3.72	-	-	-	-
<i>Erigeron humilis</i>	Asteraceae	s	common	2	N	130	41.54	4.32	-	53.3	-	-
<i>Eriophorum triste</i>	Cyperaceae	ns	common	1	R	-	-	-	-	-	-	-
<i>Eriophorum scheuchzeri</i> ssp. <i>arcticum</i>	Cyperaceae	s	common	4	R	146	6.85	2.09	5.4/4.9	10.0	-	(+)
<i>Eriophorum</i> × <i>sorensenii</i>	Cyperaceae	ns	very rare	2	-	-	-	-	-	-	-	-
<i>Euphrasia wettsteinii</i>	Scrophulariaceae	s	very rare	1	N	139	0.00	0.00	-	-	-	+

<i>Festuca baffinensis</i>	Poaceae	s	common	3	N	175	18.29	2.92	-	-	-	-
<i>Festuca brachyphylla</i>	Poaceae	s	very rare	1	N	125	46.40	4.46	-	-	-	+
<i>Festuca edlundiae</i>	Poaceae	s	common	4	N	140	22.86	3.55	-	-	-	-
<i>Festuca rubra</i> ssp. <i>richardsonii</i>	Poaceae	ns	common	4	R	-	-	-	0.5/2.0	-	-	ns
<i>Festuca viviparoidea</i> ssp. <i>viviparoidea</i>	Poaceae	b	common	5	B	151	98.68	0.93	-	-	-	-
<i>Hierochloë alpina</i>	Poaceae	s	common	1	R	90	14.44	3.71	0/0	-	-	ns
<i>Honckenya peploides</i> ssp. <i>diffusa</i>	Caryophyllaceae	s	rare	2	R	150	4.00	1.60	-	6.7	-	-
<i>Juncus albescens</i>	Juncaceae	s	rare	1	N	132	90.91	2.50	-	-	-	+
<i>Juncus biglumis</i>	Juncaceae	s	common	5	N	147	74.15	3.61	20.3/10.0	-	-	ns
<i>Koenigia islandica</i>	Polygonaceae	s	common	3	N	146	45.89	4.12	-	-	-	+
<i>Luzula confusa</i>	Juncaceae	s	common	5	(R)	148	13.51	2.81	27.5/12.6	78.7	80-90 (H)	+
<i>Luzula nivalis</i>	Juncaceae	s	common	5	N	158	26.58	3.51	0.3/21.5	25.3	-	0
<i>Luzula wahlenbergii</i>	Juncaceae	s	rare	1	N	145	20.00	3.32	-	-	-	-
<i>Mertensia maritima</i> ssp. <i>tenella</i>	Boraginaceae	s	rare	2	N	147	12.24	2.70	-	-	-	-
<i>Micranthes foliolosa</i>	Saxifragaceae	b	common	5	B	109	70.64	4.36	-	-	-	+
<i>Micranthes hieracifolia</i> ssp. <i>hieracifolia</i>	Saxifragaceae	s	common	4	N	138	42.75	4.21	0/3.3	-	-	0
<i>Micranthes nivalis</i>	Saxifragaceae	s	common	5	N	142	62.68	4.06	2.3/14.9	-	-	+
<i>Minuartia biflora</i>	Caryophyllaceae	ns	common	3	N	-	-	-	1.0/-	-	-	+
<i>Minuartia rossii</i>	Caryophyllaceae	s	common	4	S	90	33.33	4.97	-	-	-	-
<i>Minuartia rubella</i>	Caryophyllaceae	s	common	5	N	147	6.80	2.08	0/20.0	-	-	+
<i>Oxyria digyna</i>	Polygonaceae	s	common	5	N	149	36.24	3.94	5.6/39.1	92.7	60-70 (H)	+
<i>Papaver dahlianum</i>	Papaveraceae	s	common	5	N	154	1.95	1.11	0.2/12.5	0	60-80 (H)	0
<i>Pedicularis dasyantha</i> var. <i>dasyantha</i>	Scrophulariaceae	s	common	2	N	151	0.00	0.00	0.6/22.6	1.3	-	-
<i>Pedicularis hirsuta</i>	Scrophulariaceae	s	common	4	N	150	17.33	3.09	0.5/23.2	0	-	0
<i>Petasites frigidus</i> ssp. <i>frigidus</i>	Asteraceae	s	common	2	R	139	0.00	0.00	-	-	-	-
<i>Phippsia algida</i>	Poaceae	s	common	5	N	125	2.40	1.37	15.5/10.0	-	-	+
<i>Phippsia concinna</i>	Poaceae	s	common	5	N	138	95.65	1.74	35.0/45.0	-	-	-
<i>Pleuropogon sabinii</i>	Poaceae	ns	rare	3	R	-	-	-	-	-	-	-
<i>Poa abbreviata</i> ssp. <i>abbreviata</i>	Poaceae	s	common	5	A	145	36.55	4.00	-	-	-	+
<i>Poa alpina</i> var. <i>vivipara</i>	Poaceae	b	common	5	B	149	99.33	0.67	-	-	-	-

<i>Poa arctica</i> ssp. <i>arctica</i> seminiferous type	Poaceae	s	common	5	R	148	59.46	4.04	2.3/15.0	-	-	+
<i>Poa glauca</i>	Poaceae	ns	common	1	A	-	-	-	0/0	-	-	ns
<i>Poa pratensis</i> ssp. <i>alpigena</i> seminiferous type	Poaceae	ns	common	5	R	-	-	-	0/0	-	-	ns
<i>Poa pratensis</i> ssp. <i>alpigena</i> viviparous type	Poaceae	b	common	5	B,R	150	96.67	1.47	-	-	-	-
<i>Polemonium boreale</i>	Polemoniaceae	ns	common	2	N	-	-	-	0/0	-	-	-
<i>Potentilla hyparctica</i> ssp. <i>hyparctica</i>	Rosaceae	s	common	5	A	147	38.78	4.02	7.3/52.3	-	-	+
<i>Potentilla pulchella</i>	Rosaceae	s	common	4	A	140	93.57	2.07	17.0/52.5	-	-	+
<i>Puccinellia phryganodes</i> ssp. <i>vilfoidea</i>	Poaceae	ns	common	5	S, R	-	-	-	-	-	-	ns
<i>Puccinellia vahliana</i>	Poaceae	s	common	5	R	123	52.03	4.50	-	-	-	+
<i>Ranunculus hyperboreus</i> ssp. <i>arnelli</i>	Ranunculaceae	s	common	5	R	147	40.14	4.04	1.6/12.5	-	-	-
<i>Ranunculus nivalis</i>	Ranunculaceae	s	common	3	N	65	49.23	6.20	0/43.8	-	-	0
<i>Ranunculus pygmaeus</i>	Ranunculaceae	s	common	4	N	142	69.01	3.88	0.5/0	-	-	(+)
<i>Ranunculus wilanderi</i>	Ranunculaceae	s	very rare	1	A	18	27.78	10.56	-	-	-	-
<i>Rubus chamaemorus</i>	Rosaceae	ns	rare	1	R	-	-	-	-	-	-	-
<i>Sagina nivalis</i>	Caryophyllaceae	s	common	5	N	109	97.25	1.57	23.6/20.5	-	-	+
<i>Salix polaris</i>	Salicaceae	s	common	5	R	142	83.80	3.09	1.2/0.8	76.7	-	-
<i>Salix reticulata</i>	Salicaceae	ns	common	2	R	-	-	-	-	-	-	-
<i>Saxifraga aizoides</i>	Saxifragaceae	ns	common	3	N	-	-	-	-	-	-	0
<i>Saxifraga cernua</i>	Saxifragaceae	b	common	5	B	164	94.51	1.78	3.1/9.5	95.3	-	-
<i>Saxifraga cespitosa</i> ssp. <i>cespitosa</i>	Saxifragaceae	s	common	5	N	142	13.38	2.86	5.6/4.1	-	-	-
<i>Saxifraga hirculus</i> ssp. <i>compacta</i>	Saxifragaceae	s	common	4	N	148	4.05	1.62	0/5.1	3.3	-	ns
<i>Saxifraga oppositifolia</i> ssp. <i>oppositifolia</i>	Saxifragaceae	s	common	5	(R)	141	60.99	4.11	1.9/11.6	72.0	-	+
<i>Saxifraga platysepala</i>	Saxifragaceae	ns	common	5	R	-	-	-	0.6/8.3	-	-	-
<i>Saxifraga rivularis</i> ssp. <i>rivularis</i>	Saxifragaceae	s	common	5	R	157	12.74	2.66	7.0/0	-	-	+
<i>Saxifraga svalbardensis</i>	Saxifragaceae	b	common	4	B,R	152	88.16	2.62	-	-	-	-
<i>Silene acaulis</i> ssp. <i>acaulis</i>	Caryophyllaceae	s	common	4	N	150	77.33	3.42	-	94.0	-	(+)
<i>Silene involucrata</i> ssp. <i>furcata</i>	Caryophyllaceae	s	common	2	N	157	66.88	3.76	23.0/28.0	98.7	-	+

<i>Silene uralensis</i> ssp. <i>arctica</i>	Caryophyllaceae	s	common	4	N	149	26.17	3.60	19.2/7.7	99.3	-	+
<i>Stellaria humifusa</i>	Caryophyllaceae	s	common	4	B	150	94.00	1.94	0/0	-	-	0
<i>Stellaria longipes</i> taxon <i>crassipes</i>	Caryophyllaceae	ns	common	5	B	-	-	-	0/-	-	-	-
<i>Taraxacum arcticum</i> agg.	Asteraceae	s	common	3	A	58	55.17	6.53	2.3/48.3	-	-	+
<i>Trisetum spicatum</i> ssp. <i>spicatum</i>	Poaceae	s	common	3	N	145	32.41	3.89	2.0/10.0	-	-	+
<i>Vaccinium uliginosum</i> ssp. <i>microphyllum</i>	Ericaceae	ns	very rare	1	R	-	-	-	-	-	ns (A)	0
