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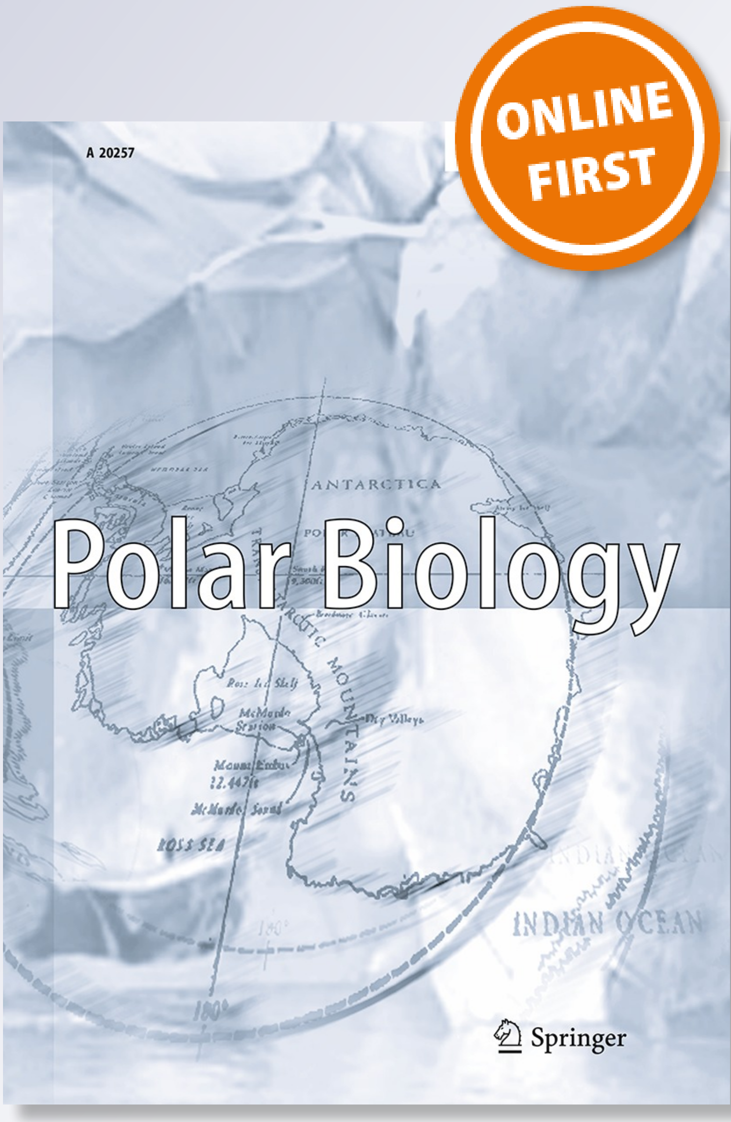

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ORIGINAL PAPER

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

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I. G. Alsos (✉)
Tromsø University Museum, 9037 Tromsø, Norway
e-mail: inger.g.alsos@uit.no

I. G. Alsos · E. Müller · P. B. Eidesen
The University Centre in Svalbard, Post Office Box 156, 9171 Longyearbyen, Norway

E. Müller
Department of Arctic and Marine Biology, Faculty of Biosciences, Fisheries and Economics, University of Tromsø, 9037 Tromsø, Norway

Introduction

Climate change, invasive species, land use, and other human impact may threaten a large part of the words 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 predominately 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)

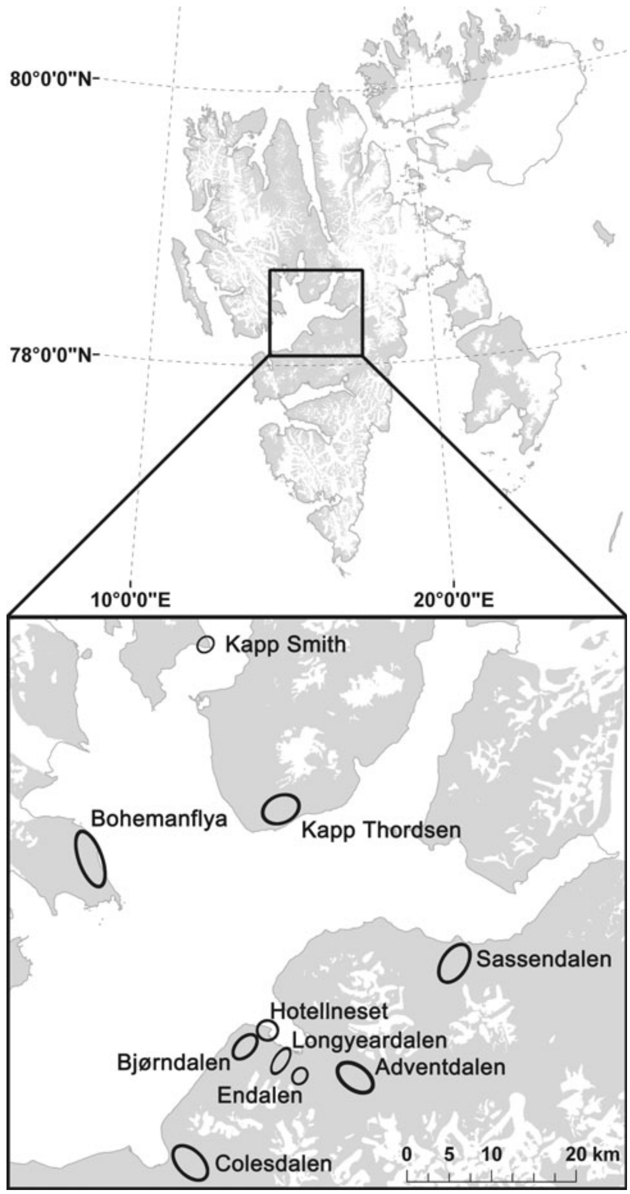

Fig. 1 Sites where seeds were collected for studies of germination and for long-term storage in the Svalbard Global Seed Vault

was placed in one of the boxes 2 October. The temperature dropped to −10 °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 °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 °C, or put directly to germination at 24 h 10 °C, 24 h 20 °C, or 12 h 10 °C and 12 h 20 °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 µmol 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	%
Alopecurus borealis	0
Arabis alpina	6.6
***Arctagrostis latifolia* (EN)**	–
Arctophila fulva	–
Arenaria pseudofrigida	30.5
Arnica angustifolia	0.7
***Betula nana* var. *tundrarum* (NT)**	0
Bistorta vivipara[a]	100.0
Braya glabella ssp. *purpurascens*	60.3
Calamagrostis neglecta ssp. *groenlandica*	–
***Campanula rotundifolia* ssp. *gieseckiana* (VU)**	–
Cardamine polemonioides	–
***Carex bigelowii* ssp. *ensifolia* (CR)**	–
Carex fuliginosa ssp. *misandra*	0
***Carex glacialis* (VU)**	8.1
***Carex krausei* (VU)**	67.1
Carex lachenalii	14.1
***Carex lidii* (VU)**	–
***Carex marina* ssp. *pseudolagopina* (VU)**	0
Carex maritima	2.7
Carex nardina ssp. *hepburnii*	0
Carex parallela ssp. *parallela*	–
Carex rupestris	2.0
Carex saxatilis ssp. *laxa*	–

Table 1 continued

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

Table 1 continued

Species	%
Pedicularis dasyantha var. *dasyantha*	0
Pedicularis hirsuta	17.3
Petasites frigidus ssp. *frigidus*	0
Phippsia algida	2.4
Phippsia concinna	95.7
***Pleuropogon sabinii* (NT)**	–
Poa abbreviata ssp. *abbreviata*	36.6
Poa alpina var. vivipara[a]	99.3
Poa arctica ssp. *arctica* sem.	59.5
Poa glauca	–
Poa pratensis ssp. *alpigena seminiferous*	–
Poa pratensis ssp. *alpigena* viv.[a]	96.7
Polemonium boreale	–
Potentilla hyparctica ssp. *hyparctica*	38.8
Potentilla pulchella	93.6
Puccinellia phryganodes ssp. *vilfoidea*	–
***Puccinellia vahliana* (NT)**	52.0
Ranunculus hyperboreus ssp. *arnelli*	40.1
Ranunculus nivalis	49.2
Ranunculus pygmaeus	69.0
***Ranunculus wilanderi* (EN)**	27.8
***Rubus chamaemorus* (CR)**	–
Sagina nivalis	97.3
Salix polaris	83.8
Salix reticulata	–
Saxifraga aizoides	–
Saxifraga cernua[a]	94.5
Saxifraga cespitosa ssp. *cespitosa*	13.4
Saxifraga hirculus ssp. *compacta*	4.1
Saxifraga oppositifolia ssp. *oppositifolia*	61.1
Saxifraga platysepala	–
Saxifraga rivularis ssp. *rivularis*	12.7
Saxifraga svalbardensis[a]	88.2
Silene acaulis ssp. *acaulis*	77.3
Silene involucrata ssp. *furcata*	66.9
Silene uralensis ssp. *arctica*	26.2
Stellaria humifusa	94
Stellaria longipes taxon *crassipes*	–
Taraxacum arcticum agg.	55.2
Trisetum spicatum ssp. *spicatum*	32.4
***Vaccinium uliginosum* ssp. *microphyllum* (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* × *soerensenii*, *Festuca edlundia*, *Ranuculus 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 × 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 lme 4 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	*n*	*df*	Residual deviance	*F* value	*p*
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

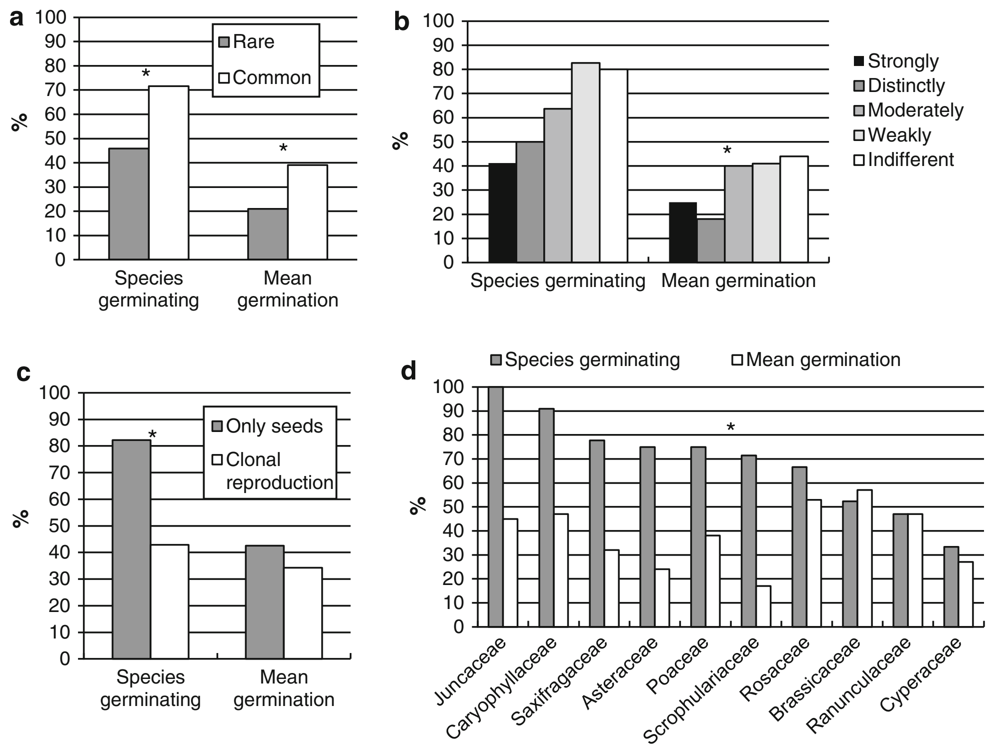

Fig. 2 Effect of species traits on the proportion of species germinating ($n \leq 113$) as well as mean germination percentage of species with ripe seeds ($n \leq 79$). **a** Rarity in Svalbard, **b** thermal requirements, **c** ability to reproduce clonally, and **d** plant family (only families with 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	$y \sim$ Rarity * Clonal + (1|Family/Species)	6	753.50	782.1	803.4		
2	$y \sim$ Rarity + Clonal + (1|Family/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 Eurola (1972). The following species characterized as having no viable seeds based on a tetrazodium test by Eurola (1972), germinated in our study: *Carex lachenalii* (14 %), *C. ursina* (62 %), *Hierochlöe 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 Eurola (1972) did germinate in our study: *Cassiope tetragona* ssp. *tetragona*, *Dryas octopetala*, *Minuartia rubella*, *Ranuculus 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 Eurola (6 %).

The mean germination percentages were higher in the study by Müller 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 Sørensen (1941). All 37 species that germinated in Sørensen's study also germinated in our study except *Betula nana*, *Euphrasia wettsteinii*, and *Minuartia biflora*. Ten of 15 species that did not germinate in Sørensens's study germinated in our study. In addition, six of 15 species were Sørensen 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 (Sørensen 1941; Bliss 1958), and more in accordance with other reports from the Arctic (Mooney and Billings 1961; Bliss and Gold 1999; Müller 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 Eurola (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 Eurola (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 Sørensen's study (Sørensen 1941) strengthens the view that germination in Arctic species is increasing due to current climate warming (Müller 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 constrains. In the species of assumed hybrid origin, *Carex lidii* and *Eriophorum* × *sorensenii*, lack of seeds could be due to problems with chromosome paring 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 *Ranuculus 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 (Karsdóttir and Aradóttir 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 platysepala*, 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 Håpnes 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 ripe 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
Alopecurus borealis	09-Sep	Bjørndalen	Moist grassland	HEP, CJW, ASc	78.226	15.328
Arabis alpina	06-Sep	Kapp Smith	Fine gravel below bird cliff	IGA, SWS, TW, KJ	78.660	15.116
Arctagrostis latifolia	02-Sep	Kapp Thordsen	*Salix polaris/ Saxifraga oppositifolia* heath	IGA	78.458	15.476
Arctophila fulva	04-Sep	Bohemanflya	Wet grassy area with slowly flowing water	IGA, EM	78.414	14.676
Arenaria pseudofrigida	12-Sep	Hotellneset	*Silene acaulis* tundra	EM, SSS, HEP, ASc, SL	78.249	15.508
Arnica angustifolia	08 and 09 Sep	Colesdalen	S exposed rocky slope	EM, AS, CH, AB	78.106	15.126
Betula nana var. *tundrarum*	09-Sep	Colesdalen	S slope in depressions	EM, AS, CH, ASC	78.104	15.131
Bistorta vivipara	27-Aug	Endalen	Snow bed and river bank	EM, CJW, JV, IGA	78.197	15.810
Braya glabella ssp. *purpurascens*	05-Sep	Bohemanflya	Sandy moraine ridges	IGA, PBE	78.470	14.509
Calamagrostis neglecta ssp. *groenlandica*	18-Sep	Hotellneset	Moist grassland	EM	78.249	15.508
Campanula rotundifolia ssp. *gieseckiana*	09-Sep	Colesdalen	S exposed slope with gravel	EM	78.105	15.124
Cardamine polemonioides	09-Sep	Colesdalen	Moist mire beside open flowing water	EM	78.107	15.064
Carex bigelowii ssp. *ensifolia*	12-Sep	Hotellneset	Mire	IGA	78.243	15.488
Carex fuliginosa ssp. *misandra*	09-Sep	Sassendalen	*Dryas* heath	SSS, REP, InGA	78.343	16.947
Carex glacialis	06-Sep	Kapp Smith	Open steep scree below bird cliff	IGA, SWS	78.660	15.115
Carex krausei	09-Aug	Kapp Smith	Steep scree below bird cliff	IGA, SWS, BES	78.662	15.125
Carex lachenalii	10-Sep	Colesdalen	Mire with some open water	EM	78.098	15.146
Carex lidii	09 and 10 Sep	Kapp Thordsen, Sassendalen	Rich mire	IGA, SL	78.458, 78.322	15.505, 17.035
Carex marina ssp. *pseudolagopina*	10-Sep	Sassendalen	Rich mire	IGA, UBM	78.342	16.950
Carex maritima	10-Sep	Sassendalen	Rich mire	InGA, REP, SSS, UBM	78.342, 78.322	16.950, 17.035
Carex nardina ssp. *hepburnii*	10-Sep	Sassendalen	Dry calcareous ridge	IGA, SSS, UBM	78.353	16.927

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

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

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

Silene acaulis ssp. *acaulis*	27-Aug	Hotellneset	Heath	CJW	78.249	15.513
Silene involucrata ssp. *furcata*	27-Aug	Hotellneset	Tundra	EM	78.249	15.513
Silene uralensis ssp. *arctica*	19-Sep	Endalen	Scree	IGA	78.188	15.761
Stellaria humifusa	12-Sep	Hotellneset	Beach	SL, EM, IGA, ASc, HEP	78.249	15.510
Stellaria longipes taxon *crassipes*	10 and 15 Sep	Colesdalen, Longyeardalen	Grazed tundra and heath	EM, IGA	78.113, 78.215	15.034, 15.680
Taraxacum arcticum agg.	10-Sep	Colesdalen	Small slope, heavy grazed grass tundra	EM, AS, CH	78.112	15.051
Trisetum spicatum ssp. *spicatum*	10-Sep	Sassendalen	Moderate Snow bed	SSS, REP, InGA, SL	78.342	16.969
Vaccinium uliginosum ssp. *microphyllum*	10-Sep	Colesdalen	Heath dominated by *V. uliginosum*	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
Alopecurus borealis	27	20	Covering structure removed. Seeds look empty
Arabis alpina	27	20	Seeds were overgrown by green algae
Arenaria pseudofrigida	27	20	
Arnica angustifolia	27	20	Pappus removed. The majority of seeds may be without developed embryo
Betula nana var. *tundrarum*	27	20	
Bistorta vivipara	27	20	
Braya glabella ssp. *purpurascens*	27	20/10	
Carex fuliginosa ssp. *misandra*	80	20/10	
Carex glacialis	80	20/10	Uncertain if seeds were fully ripe
Carex krausei	56	20/10	
Carex lachenalii	80	20/10	
Carex marina ssp. *pseudolagopina*	80	20/10	The majority of seeds may be without developed embryo
Carex maritima	80	20/10	
Carex nardina ssp. *hepburnii*	79	20/10	
Carex rupestris	79	20/10	
Carex subspathacea	79	20/10	
Carex ursina	79	20/10	
Cassiope tetragona ssp. *tetragona*	30	20	Seeds attacked by fungi
Cerastium arcticum	26	20/10	
Chrysosplenium tetrandrum	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
Cochlearia groenlandica	26	10	2nd stratification for 38 days and 2nd germination at 20/10° C
Coptidium lapponicum	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
Coptidium pallasii	0	20/10	Uncertain if seeds were 100 % ripe. Same stratification as above. Treated with bleach day 6 of warm stratification due to mould
Deschampsia alpina	0	20	
Draba alpina	26	20	Rubbed with sandpaper
Draba arctica ssp. *arctica*	26	20	Rubbed with sandpaper
Draba glabella	26	20	Rubbed with sandpaper
Draba lactea	26	20	Rubbed with sandpaper
Draba nivalis	26	20	Rubbed with sandpaper
Draba rupestris (syn. *D norvegica*)	28	20	Rubbed with sandpaper
Draba subcapitata	28	20	Rubbed with sandpaper
Dryas octopetala	26	20/10	Pappus removed
Dupontia fisheri morph *"psilosantha"*	29	20	Seeds look empty
Empetrum nigrum	0	20/10	10 weeks warm stratification at 20° C followed by 10 weeks cold stratification at 1° C

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

Ranunculus pygmaeus	0	20/10	
Ranunculus wilanderi	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
Sagina nivalis	37	20/10	
Salix polaris	37	20	
Saxifraga cernua	0	20	
Saxifraga cespitosa ssp. *cespitosa*	37	20	
Saxifraga hirculus ssp. *compacta*	37	20/10	Seeds seams empty/bad
Saxifraga oppositifolia ssp. *oppositifolia*	37	20	
Saxifraga rivularis ssp. *rivularis*	37	20	
Saxifraga svalbardensis	0	20	
Silene acaulis ssp. *acaulis*	0	20	
Silene involucrata ssp. *furcata*	0	20	
Silene uralensis ssp. *arctica*	0	20	Moved to 20/10° C after 4 weeks which increased germination
Stellaria humifusa	35	20	
Taraxacum arcticum agg.	35	20	2 flower heads collected
Trisetum spicatum ssp. *spicatum*	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: Eurola (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	Eurola 1972	Müller et al. 2011	Other Svalbard	Sørensen 1941
Alopecurus borealis	Poaceae	s	common	5	A,R	98	0.00	0.00	0/0.7	8.7	-	ns
Arabis alpina	Brassicaceae	s	rare	2	N	137	6.57	2.12	-	-	-	-
Arctagrostis latifolia	Poaceae	ns	rare	2	R	-	-	-	-	-	-	ns
Arctophila fulva	Poaceae	ns	common	4	R	-	-	-	-	-	-	-
Arenaria pseudofrigida	Caryophyllaceae	s	common	4	N	151	30.46	3.75	-	-	-	ns
Arnica angustifolia	Asteraceae	s	rare	2	A	148	0.68	0.67	-	-	-	+
Betula nana var. *tundrarum*	Betulaceae	s	rare	1	N	140	0.00	0.00	-	-	ns (A)	(+)
Bistorta vivipara	Polygonaceae	b	common	5	B	145	100.00	0.00	-	26.7	90-100 (H)	+
Braya glabella ssp. *purpurascens*	Brassicaceae	s	common	4	N	146	60.27	4.05	-	-	-	+
Calamagrostis neglecta ssp. *groenlandica*	Poaceae	ns	rare	2	R	-	-	-	-	-	-	-
Campanula rotundifolia ssp. *gieseckiana*	Campanulaceae	ns	very rare	1	R	-	-	-	-	-	ns (A)	ns
Cardamine polemonioides	Brassicaceae	ns	common	4	S	-	-	-	-	-	-	-
Carex bigelowii ssp. *ensifolia*	Cyperaceae	ns	very rare	1	R	-	-	-	-	-	-	0
Carex fuliginosa ssp. *misandra*	Cyperaceae	s	common	4	N	62	0.00	0.00	0.5/10.0	-	-	0
Carex glacialis	Cyperaceae	s	very rare	1	N	148	8.11	2.24	-	-	-	-
Carex krausei	Cyperaceae	s	very rare	1	N	149	67.11	3.85	-	-	-	-
Carex lachenalii	Cyperaceae	s	common	2	N	142	14.08	2.92	0/0	-	-	0
Carex lidii	Cyperaceae	ns	rare	2	R	-	-	-	-	-	-	-
Carex marina ssp. *pseudolagopina*	Cyperaceae	s	very rare	1	N	142	0.00	0.00	-	-	-	-
Carex maritima	Cyperaceae	s	common	2	R	150	2.67	1.32	-	-	-	-

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

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

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

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