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The direct and indirect effects temperature and snow depth have on the germination of the alpine plant *Dryas octopetala*

De direkte og indirekte påvirkningene temperatur og snødybde har på springen til den alpine planten *Dryas octopetala*

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Animal biology

Acknowledgments

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Mina Svendsen Wold
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Abstract

High-arctic ecosystems are facing rapid changes due to climate change. These regions are predicted to be heavily affect and see changes at a higher rate than any other. Temperature and snow depth are two climatic factors that heavily influences the arctic landscape. They affect the flora`s growing season, reproductive success, and seed germination. They can also have an indirect effect on flora by affecting the seed mass, length, and microbial activity. A plant's ability to have *successful* sexual reproduction determines the species genotype and its ability to withstand climatic changes in the future. The purpose of this study was to have in suito snow fence experiments at Adventdalen and temperature manipulation experiments (OTC) at Endalen, that explored how snow depth and temperature affects the germination rate of *Dryas octopetala L* (hereafter *D.octopetala). D.octopetala* is a widely distributed arctic dwarf shrub, that has a long lifespan, relatively early spring activity, and similar reproductive rates as other arctic dwarf shrubs.

The seeds for the temperature treatment were collected by Simone Lang in 2020 and the seeds for the snow-depth treatment were collected by Elizabeth Cooper, in 2020. The germination itself was conducted under optimal conditions in a climate room on agar. Information about the seeds mass, seed length, day germination started, day germination ended, and mold occurrence were registered. The data was analyzed with general linear regression models and ggplots. For the snow depth treatment, the variables "treatment method", "seed mass" and "mold" occurrence seemed to influence the seed's ability to germinate. Seed length had no effect on germination. Snow depth also appears to have an indirect effect on seed mass and mold. For the OTC treatment, treatment, mass, and mold appears to influence seed germination, however treatment to a lesser degree. OTC treatment also appears to have an indirect effect on seed mass and mold occurrence. The results from this experiment indicates that snow depth and temperature have possibly direct and indirect effect on *D.octopetala`s* germination.

Sammendrag

Høyarktiske økosystem står ovenfor hyppig forandring grunnet klimaendringer. Det er forutsett at disse områdene kommer til å bli påvirket i stor grad og kommer til å se forandringene raskere enn noen andre. Temperatur og snødybde er to klimatiske faktorer som i stor grad påvirker det arktiske landskapet. De påvirker lengden på vekst sesongen, reproduktiv suksess og frøspringen til floraen. De kan også ha en indirekte effekt på floraen, ved å påvirke frø masse, lengde og mikrobiell aktivitet. En plantes evne til å ha vellykket seksuell reproduksjon bestemmer artens genotype og dens evne til å motstå klimatiske endringer i framtiden. Formålet med dette studiet var å ha «in-suito» snø gjerdet eksperimenter på Adventdalen (snødybde) og varmebehandlinger (OTC) på Endalen (temperatur), som utforsket hvordan snø dybde og temperatur påvirket springen til *Dryas octopetala L* (heretter kjent som *D.octopetala). D.octopetala* er en bredt utbredt arktisk dvergbusk, som har lang levetid, tidlig våraktivitet og har lignende reproduksjonsrater som andre arktiske dverg busker.

Frøene fra temperatur behandlingen ble innsamlet av Simone Lang i 2020, og frøene for snø dybde behandlingen ble samlet inn av Elizabeth Cooper i 2020. Selve spiringen ble gjennomført under gunstige forhold i et klima-rom på agar. Informasjon om frøenes masse, lengde, dagen spiringen startet, dagen spiring var ferdig og mugg ble registrert. Dataene ble analysert med generell lineær regresjons modeller og ggplot. For snø dybde behandlingene påvirket variablene «behandling», «frø masse» og «mugg», frøets evne til å spire. «Frø lengde» hadde ingen påvirkning på spiringen. Det virket som om snø dybde hadde en indirekte effekt på «frø masse» og «mugg». For OTC behandling hadde variablene «behandling, «masse» og «mugg» en mulig effekt på frø spiringen, men behandling i en minndre grad. Det virker også som om OTC behandlingen har en indirekte effekt på «frø masse» og «mugg» forekomst. Resultatene i dette forsøket indikerer at snø dybde og temperatur har en mulig direkte og indirekte effekt på *D.octopetala`s* spiringsrate.

Table of content

1. Introduction

The increasing levels of greenhouse gases in the atmosphere due to human activities, is one of the major drivers behind climate change (Box et al., 2019). WMO`s 2020 reports indicates that the slight decreases in emission due to covid-19 measures would have limited effect on the general trend (WMO, 2020). Climate change has the power to pose a threat to biodiversity worldwide, and it has already been documented that it can alter the structure and functions of ecosystems (Verrall & Pickering, 2020). The effects it will have on the specific ecosystem depends on the vulnerability of said ecosystem, its adaptive capacity, the conditions to which it is exposed and its geographical location (Cowles, Boldgiv, Liancourt, Petraitis, & Casper, 2018). For example, in Arctic and sub-arctic ecosystems, impacts are equivalent to the expected global conditions in 2050. (IPCC, 2022). Most studies on the effects of climate change on the high arctic, have been conducted in Europe (Verrall & Pickering, 2020). The general trend in Europe is that global warming leads to warmer winters, with less snow cover, more extreme weather events and a higher annual mean temperature (WMO, 2020). However, it is expected to have a different effect on northern Europe, especially in high arctic ecosystems (Verrall & Pickering, 2020; Wipf, Stoeckli, & Bebi, 2009).

The high arctic tundra is an important indicator of the geosphere-biosphere relationship, and these areas are “flagship areas”. Climate change poses a disproportionate risk to high-arctic ecosystems because they are determined by strict climatic parameters (Verrall & Pickering, 2020). Svalbard is an arctic island group at the coast of Norway, with Spitsbergen as the largest island. Current models and findings, indicate that Svalbard is well suited to represent the climatic conditions in the Arctic as a whole (Elvebakk, 1994; SIOS, 2020). Therefore, predicting, and characterizing climate change in Svalbard will be increasingly important in the future (SIOS, 2020; WMO, 2020). In the arctic landscape, snow distribution and temperature are the two main variables that affect the ecosystem (Sonesson & Callaghan, 1991). High latitudes are already seeing the effect of climate change, with warming occurring the fastest at these locations (Cooper, Little, Pilsbacher, & Mörsdorf, 2019). In addition, it is expected that the amount of precipitation will increase primarily in late autumn and during the winter (Cooper et al., 2019). This can lead to exceptionally heavy snowpacks going forward, depending largely on the precipitation and temperature levels (WMO, 2020)

Temperatures are never constant, they vary throughout the day, seasons, and years. When and how temperatures change, determines the effect it will have on species living in the High-arctic (Cooper et al., 2019). Affected flora can experience changes in growing season, temperature, soil moisture, microbial activity etc. Which again will have an indirect effect on plant growth, flowering, and germination (Dollery, Hodkinson, & Jónsdóttir, 2006; Morgner, Elberling, Strebel, & Cooper, 2010). Earlier studies also indicate that temperature can indirectly affect seed traits, like mass and length (Welker, Molau, Parsons, Robinson, & Wookey, 1997). Many High-arctic species must go through a cold-period to germinate. This period is called stratification (Graae, Alsos, & Ejrnaes, 2008). During the winter, temperature must reach minus 0-10 degrees Celsius, for cold stratification to occur (Fernández-Pascual et al., 2021). Spring temperatures must be sufficiently high to promote snowmelt and dormancy breaking, to maximize seed germination (Graae et al., 2008). One of the natural temperature regulators in arctic ecosystems is snow (Cooper et al., 2011; Graae et al., 2008). Snow works as an insulator, keeping the soil temperature warmer than the surrounding atmosphere and prevents large fluctuations in temperature during the winter season. The temperature underneath the snow and the start of the growing season is affected by snow depth. (Cooper et al., 2019; Graae et al., 2008).

Snow cover is a characteristic element of the High artic landscape that controls the microclimate and plant growing conditions of these ecosystems. It directly and indirectly impacts the arctic ecosystem (Wipf et al., 2009). Generally, snow covers the soil and flora for more than half of the year. Snow cover is dependent on, and it is the result of the winter and spring climate (Cooper et al., 2019; Wipf et al., 2009). Arctic and alpine areas have not yet seen a significant change in snow depth, but there has been documentation of earlier melt-out due to warmer spring temperatures. The timing of melt-out determines the start and the possible length of the growing season, with plant phenological development only occurring after this point (Wipf et al., 2009). Larger snow depth can lead to increased soil moisture, shorter growing season, and reduced reproductive success, through a decrease in floral abundance and germination success (Cooper et al., 2019; Gallet et al., 2019). Earlier studies indicate that other factors can influence the germination as well, for instance the size of the seed, the mass of the seed and fungal activity (Bu et al., 2007; Welker et al., 1997).

Snow fences and OTC treatments are well-established methods of researching the effect of temperature and snow depth in the field (Björnsdóttir, Barrio, & Jónsdóttir, 2021; Cooper et al., 2011; Gillespie, Baggesen, & Cooper, 2016). Snow fences accumulates the amount of snow at a specific site, which leads to delayed snow melt timing and growing season (Gillespie et al., 2016). OTC stands for "open-top chambers" (see fig. 4), which is a way to passively enhance the temperature at a specific site (Gillespie et al., 2016). The International Tundra Experiment (ITEX) is an international collaboration that conducts research on the effects increased temperature have on arctic ecosystems (Björnsdóttir et al., 2021). In previous experiments, OTCs elevated the air temperature by 1.5°Celsius during the day and decreased the reduction of temperature by 0.2°Celsius during the night (Björnsdóttir et al., 2021; Cowles et al., 2018). Once installed these experiments do not require the presence of researchers throughout the winter. The study species is the arctic dwarf shrub *Dryas octopetala.* The *D.octopetala* seeds collected from Adventdalen were used for the snow depth treatment, and the seeds from Endalen were used for the OTC treatment.

I aimed to determine (1) how snow depth and temperature manipulation (OTC) affects the germination rate of *D.octopetala,* and (2) whether snow depth and temperature manipulation will have indirect effects that influence the germination rate of *D.octopetala.* I hypothesized that; (1) Increases in snow depth and temperature will have a negative effect on the germination of *D. octopetala* seeds. Meaning that I expect that more seeds will germinate in the control treatments, than on sites that have been manipulated. If my hypothesis is wrong, I expect that seeds from manipulated sites will have a higher germination frequency. If there is no connection between treatment method and germination, I expect to see a random pattern. Further I (2) hypothesized that increased temperature and snow depth will have a positive effect on seed mass, seed length and mold occurrence. Meaning that I expect that manipulated sites will have seeds that are larger and longer and a higher mold occurrence, comparatively. If my hypothesis is wrong, I expect that control sites will have larger and longer seeds and higher mold occurrence compared to manipulated sites. If there is no connection between increased temperature and these variables, I expect to see a more random pattern, that do not follow any specific trend.

2. Methods

2.1 Study Sites

Seed collection occurred at two different locations. The seeds for the snow-depth experiment were collected in Adventsdalen (78°10′N, 16°06′E), which is a large valley in Spitsbergen, Svalbard (Cooper et al., 2011; Gillespie et al., 2016; Müller, Cooper, & Alsos, 2011), (See fig.1). The seeds were collected by Elizabeth Cooper, from the 29th to the 30th of September in 2020. Adventsdalen has been used in numerous experiments that look at the effect snow depth has on ecology and phenology, by using snow manipulation experiments in the field. In part because it is less sheltered than other sites surrounding Longyearbyen (Müller et al., 2011), it has a larger amount of soil and moisture than other sites (Müller et al., 2011), and there are large variations in the landscape (Cooper et al., 2011). This leads to large variation in snow depth, from 20cm at ridges, to 3m in hallows (Cooper et al., 2011). In short, the site has the natural variation commonly found in the Arctic. (Cooper et al., 2011; Müller et al., 2011).

Adventsdalen is a typical arctic ecosystem, in that it has annual mean temperatures below zero (Gillespie et al., 2016), is underlaid by permafrost (Cooper et al., 2011), thin soil layer (Mallik, Wdowiak, & Cooper, 2011) and a large amount of the annual precipitation falls as snow (Gillespie et al., 2016). The vegetation is characteristic for high arctic ecosystems as well; the plants are in general below 20cm, can withstand strong winds, have a short growing season, and are exposed to low temperatures (Mallik et al., 2011). The dominant species in the area are; *Cassiope tetragona, Salix Polaris and Dryas octopetala L.* on slight ridges (Cooper et al., 2019).

The seeds for the OTC treatment were collected from ITEX sites in Endalen *(78°10′39″*N 15°41′39″Ø*)*, by Simone Lang, in September 2020. Endalen is a tributary valley of Adventsdalen, that is approximately 4km southeast of Longyearbyen. Longyearbyen is Norway`s northern most settlement, and the most populated area on Svalbard (Harris, Kern-Luetschg, Christiansen, & Smith, 2011), (see fig. 1).

Endalen has been used in ITEX experiments for over three decades. ITEX is a collaboration of 11 different countries that study the effects of climate change on the high artic. The mean annual temperature at Svalbard Airport (Longyearbyen), which is the closest location with a weather station, from September 2019-sept. 2020 was -4.2°C. However, the last decades are characterized by higher temperatures, with an increase of 2.5 °Celsius compared to the long-term average (Cooper et al., 2019; Førland, Benestad, Hanssen-Bauer, Haugen, & Skaugen, 2011). Endalen is a south-facing hillside in the west of Spitsbergen, where *Dryas octopetala* is the dominant vegetation type (Dollery et al., 2006).

Figure 1 : Map (©topoSvalbard.npolar.no, (TopoSvalbard, 2022) of the study sites. The snow depth treatment was located in Adventdalen, the OTC treatment was located in Endalen. Longyearbyen is the closest site that registers temperature. These areas are located at Svalbard.

2.2 Study species


Figure 2 : Photo (©Rigmor Wang, arstdatabanken.no) (Wang, 2022) *of the dwarf, arctic shrub,* D.octopetala L

Dryas octopetala (D.octopetala) is an alpine/high arctic dwarf shrub that has a wide distribution in the northern hemisphere (see fig. 2), (Elkington, 1971; Welker et al., 1997). Dwarf shrubs are an important component of the Arctic ecosystems, and are described as the "climax" of the succession process, and often dominate or co-dominate the habitat (Baddeley, Woodin, & Alexander, 1994). *D.octopetala* has traits that are characteristic of High Arctic flora. The flora is generally below 20cm, can withstand strong winds, have a short growing season, low reproductive success and are exposed to low temperatures (Elkington, 1971; Mallik et al., 2011). *D.octopetala* dominates the vegetative cover in harsh habitats, for instance outcrops or areas with thin snow cover during the winter. Because it is an evergreen shrub, it is relatively quickly active after snowmelt (Welker et al., 1997).

D.octopetala faces many challenges to reproduce. Including a short growing season, harsh climatic conditions and obligatory interactions with insects (Wookey et al., 1995). As a consequence, high arctic species like *D.octopetala* reproduce and spread over a short time frame annually. This can be accomplished by lateral spread of vegetative ramets that form large mats in isolated patches (Wookey et al., 1995), or by sexual reproduction in the form of seedlings. Sexual reproduction is important to ensure genetic diversity and to colonize new areas (Fernández-Pascual et al., 2021). The level of sexual reproduction varies greatly between years. Earlier studies indicate that seeds with a larger mass, have a higher chance of germinating (Welker et al., 1997). If the seed production is successful, the seeds are driven by their long style feather (see 1, appendix) and spread by the wind. However, the likelihood of seeing a seedling in the field is low, indicating that climatic factors limit the growth of the seed even after a successful germination (Wookey et al., 1995).

2.3 Study design

2.3.1 Snow cover

At Adventdalen snow fences were used to create 3 different plot types based on snow depth: control, medium and deep (See fig. 3). There were in total 33 sites, with three different plot types being distributed on 11 different locations. The fences were 1.5m tall and 6.2m long and were aligned perpendicular to the prevailing south-eastern winter winds. (For further information, see:(Cooper et al., 2011)). Snowmelt gradients reflect how natural conditions might change over time (Dollery et al., 2006). Snow affects the landscape by insulating the ground, keeping it warmer and more stable during the winter period.

In Adventdalen the winter period lasts for roughly 227 days, 175 of which have snow cover (Cooper et al., 2011). The snow can also affect the date of spring snowmelt, the larger the amount of snow, the later snowmelt will occur. Previous studies have shown that it can delay snowmelt with as much as two weeks (Cooper et al., 2011). Deeper snow levels can also lead to delayed phenological development, reduce the amount of flowers and affect soil moisture (Cooper et al., 2011). In this experiment there were fewer flowers on deep treatment locations, than at the control and medium sites. The summer of 2020 was significantly warmer than average, and consequently it is expected that the seeds will have a larger rate of germination and seed viability.

Figure 3 : Photo (©Elizabeth Cooper, (Cooper, Dullinger, & Semenchuk, 2011)). Photo of snow fences at Adventdalen in Svalbard

2.3.2 OTC

The seeds from Endalen were collected by Simone Lang, from 3 different OTCs. OTC stands for "Open Top Chambers" which is a plastic enclosure with an open top (see fig. 2). They have a standard hexagonal ITEX-design, with a base diameter of 1,5m (Dollery et al., 2006). There were established 4 OTC sites, and 10 control sites. OTCs are frequently used to simulate the effects of global warming, by passively increasing air-temperatures in field experiments. Compared to the control sites, the chambers can have an increased air temperature of up to 1,8 °Celsius (Welshofer, Zarnetske, Lany, & Thompson, 2018). However, a similar study from Endalen in 2003 found an increase of around 1,2 °Celsius compared to the controls (Dollery et al., 2006). As mentioned in 2.3.1 snow cover, 2020 was an exceptionally warm year with high summer temperatures at both Adventdalen and Endalen, and it is expected to influence the results.

Figure 4: Photo (©Cassandra Elphinstone, (Elphinstone, 2018)). Illustrating open-top chamber (OTC), at Alexandra fiord on Ellesmere island in 2018.

2.3.3 Seed stratification

All the seeds from each site, were collected and stored in numbered envelopes. Some locations did not have as many seeds (see table1 and 2, appendix), due to site and treatment differences. The seeds were sent from Elizabeth Cooper (Snow treatment), and Simone Lang (OTC) to Reuben Erik Roos. The seeds were then stored in a fridge in Weishallen SKP until their stratification. To preserve the integrity of the seeds they were stored in a sealed container, in the dark, at an average temperature of +4 °Celsius. The natural processes that occur during the winter, keeps the seeds from germinating until conditions are optimal for reproduction. Because of this adaptation, it is necessary for it to go through a stratification period. The method used in the stratification of the seeds, is based on the experiments from (Billault-Penneteau, Sandré, Folgmann, Parniske, & Pawlowski, 2019), where they stratified, amongst others, *Dryas octopetala*. The stratification process followed this pattern; first 2 days (-2 °Celsius), following 2 days (+ 2 degrees), the next 6 days (-2 °Celsius), the following 4 days (+2), and lastly 3 weeks (-4 °Celsius). After the stratification period, they were again stored at +4 degrees as the seeds were measured.

2.3.4 Seed trait measurement

From July-November each individual seed was measured and weighed in its entirety with feather style (see fig. 1a and 1b in appendix), and just the seed (fig. 1c in appendix). The length of the seed was measured to the closest mm, using a ruler. The mass of the seed was measured using a microbalance, which calibrates the weight of the seed to the 4th decimal of a microgram. Due to the time-consuming nature of this experiment, the seed number was limited to 100 for each treatment method. The seeds were chosen randomly from the envelope, however any seed with visible damage were not included if others were available. If, as for treatment D11Deep (see table 1, appendix), there were fewer than 100 seeds all the seeds in the envelope were used, regardless of their condition. After they were measured the seeds were placed into individual paper envelopes and marked with an ID specific to that seed.

2.3.5 Seed germination

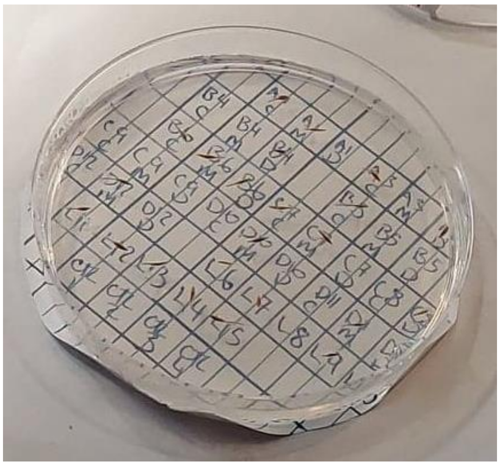


Figure 5 : Photo of the organization of seed treatments on the petridishes.

The seeds were germinated on agar dishes, placed in a climate room and the date of germination and mold was registered. The use of agar dishes was based on previous studies (Billault-Penneteau et al., 2019) and a test run (see table 3 and 4, appendix). The agar was prepared by Annie Aasen. In total there were 2,5l agar distributed on 100 petri dishes. The agar was diluted to 15g per liter and the incubated. The agar was poured into the petri dishes under sterile conditions. To ensure that the results were randomized, every treatment method and experiment was represented on each petri dish. All the seeds with an ID ending in 1 (from 1-100), were placed on petri dish 1 and so on. The petri dishes were marked, to easily identify which seed were from which treatment (see figure 5). To prevent premature germination, the completed petri dishes were again placed in a dark room at +4 °Celsius. For ten days, from November 8th to November 18th, the seeds were placed in a climate room. The climate room had constant light and temperature at 15°celsius, to match the summer conditions at Svalbard (Cooper et al., 2011).

The start of germination and a completed germination were both determined by visual confirmation. Figure (7) shows an example of a seed in the beginning of the germination process. Figure (6) shows an example of a seed with completed germination (both leaves are fully outside of the seed). This was self-evident because the plant would “pop out” of the seed.

Figure 7 : Dryas octopetala seeds with a started germination process.

Figure 6 : Depicts a D.octopetala seed with completed germination.

To keep track, a “map” was used to register the day germination started for the individual seed, when the germination was completed and whether or not mold occurred (see figure 2 in the appendix). One dash across the number meant germination had started, a cross meaning germination was completed and a red dot marking where mold had occurred. The 12 variables in the snow fence treatment were: snow fence (AI-D12), treatment (control, medium, deep), block it was located in (A,B,C,D), petri dish location, ID number, total length of the seed (with feather style), length of seed, total mass of seed (with feather style), start of germination (0=no germination,1-10= day of germination), ended germination (0=no germination,1-10= day of germination) and mold (0=no mold, 1=mold). (See figure 3 in appendix for an example of mold occurrence).

2.3.6 Statistics

The statistical analyses were conducted in the software R, version 492 (R Development Core Team, 2022), using the packages glm, darma, tidyverse and ggplot2 (Team, 2021). The analyses were based on generalized linear regression models with the function; glm (factor~factor, family =binomial). With the family specification making it a logistic regression model. The models were used to explore how the response variable (germination), is affected by the explanatory variables; treatment, mass, and mold, for both snow treatment and OTC. Where relevant, the model coefficient estimates, standard error (SE) and p-values (Pr (>|z|) are reported in the text. P-values that are below 0.05 ($p<0.05$), are considered to be statistically significant. After the fitting, the darma package was used to assess the model`s residuals for each parameter. Based on the residual analyses, the models appear to fit. The dataset consisted of both numerical, binary, and categorical variables. To explore whether germination did or did not take place, the numerical “Start” variable were used to create a new variable “germ” (0=no germination, 1=germination). Figures were made with the packages “tidyverse” and “ggplot2”, to visualize the data with boxplots and histograms.

3 Results

3.1 Snow fence results

There were in total 3103 seeds from the snow depth treatment (see Table 1). 68.3% of the control seeds, 67,6% of the medium seeds and 61,4% of the deep seeds started their germination process. Further analysis was made to explore whether the variable "treatment" had a statistically significant effect on the seed germination (table 2). Pr (>|z|) marked it as statistically significant. Table 3 shows the result of a generalized linear regression model, with mass added as an explanatory value. Pr (>|z|) marked it as statistically significant. There were no significant differences in the start day or end day of germination, for the different treatment methods (fig X and X in the appendix is for the OTC treatment, however it was the same for snow depth treatment.).

The average seed mass for germinating seeds was 0.5 micrograms (fig. 8), however there are outliers that range from close to zero and above 1. The weight off the seeds that did not germinate range from around 0 and to 0,75 with the mean mass being ap. 0,19 micro grams. Seed mass was not normally distributed (fig. 9). Most of the seeds were between 0.45 and 0.55. With approximately 900 of the 31303 snow treatment seeds, falling in this category. At either end the numbers fall of, in accordance with normal distribution. However, there is a spike of seeds in the 0.5-0.2 range that disrupts the normalcy. How mass is affected by snow depth is illustrated in figure 10. The mean weight for seeds in the control treatment being close to 0.48, medium slightly lower at 0.46 and deep 0.40. There was some variation in mass depending on the location the snow treatment was located on (fig. 11).

There was no significant correlation between seed length and germination (see figure 4 and 5 in the appendix, these figures are from the OTC treatment, but the results were the same for snow depth). However, mold had a p(>|z|), below 0.05, indicating that it is statistically significant. The highest mold occurrence was 16,9% for control, 15,8% for medium treatment and 9,2% for the deep treatment. The percentage of completed germination for the control seeds were 66,1% for control, 59,8% for medium and 55,5% of the deep seeds.

Table 1 : Overview of the seeds that germinated and did not germinate, the percentage of how many seeds started and completed their germination process and the occurrence of mold. Each represented for all of the treatment methods in snow depth; control, medium and deep.

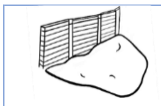
	**Total amount of seeds**	**Germination frequency (start)**	**Start Germination (%)**	**End germination (%)**	**Mold**
Control	1099	751	68,3%	66,1%	16,9%
Medium	999	675	67,6%	59,8%	15,8%
Deep	1005	617	61,4%	55,5%	9,2 %

Table 2 : Illustrates the results of a logistical regression model with binary response variables "germ", and the response variable "treatment".

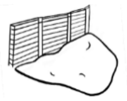
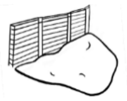
	**Estimate**	**Standard Error (SE)**	**Pr (>|z|)**
(Intercept)	0.76920	0.06485	2e-16***
Medium	-0.03523	0.9366	0.706788
Deep	-0.30534	0.09167	0.0008866***

Table 3 : Illustrates the result of a logistical regression model with binary response variables “germ”, with “treatment” and “mass” added as explanatory values.

	**Estimate**	**Standard Error (SE)**	**Pr (>|z|)**
(Intercept)	-3.1738	0.1558	<2e-16 ***
Medium	0.1965	0.1228	0.1095
Deep	0.2944	0.1209	0.0149
Mass	9.7825	0.3339	<2e-16***

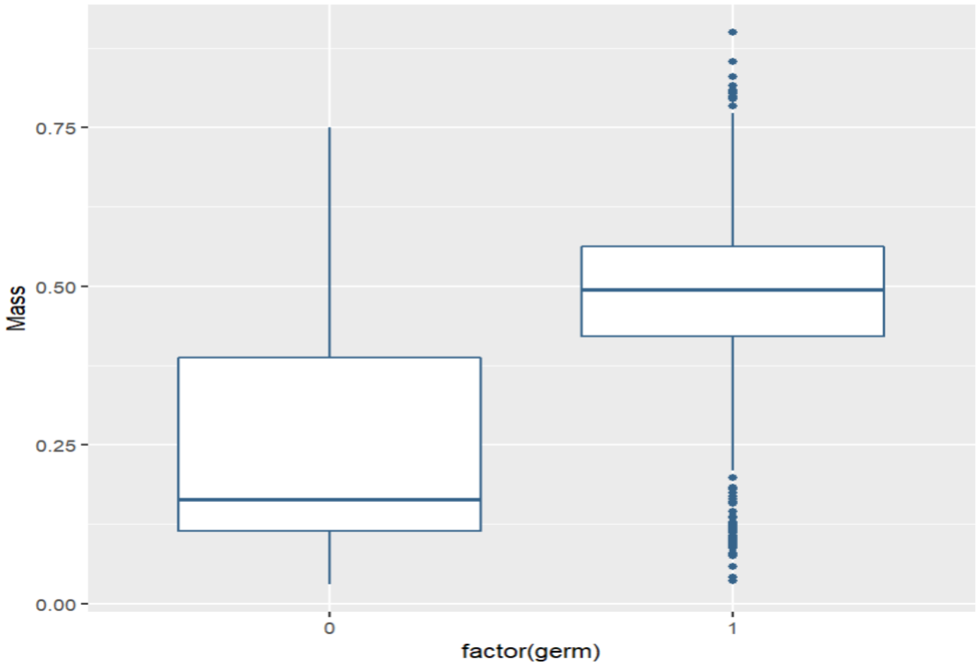


Figure 8 : Boxplot that illustrates the correlation of the mass of the seed and the logistical value of the germination. 0 being no germination occurred, and 1 meaning germination occurred.

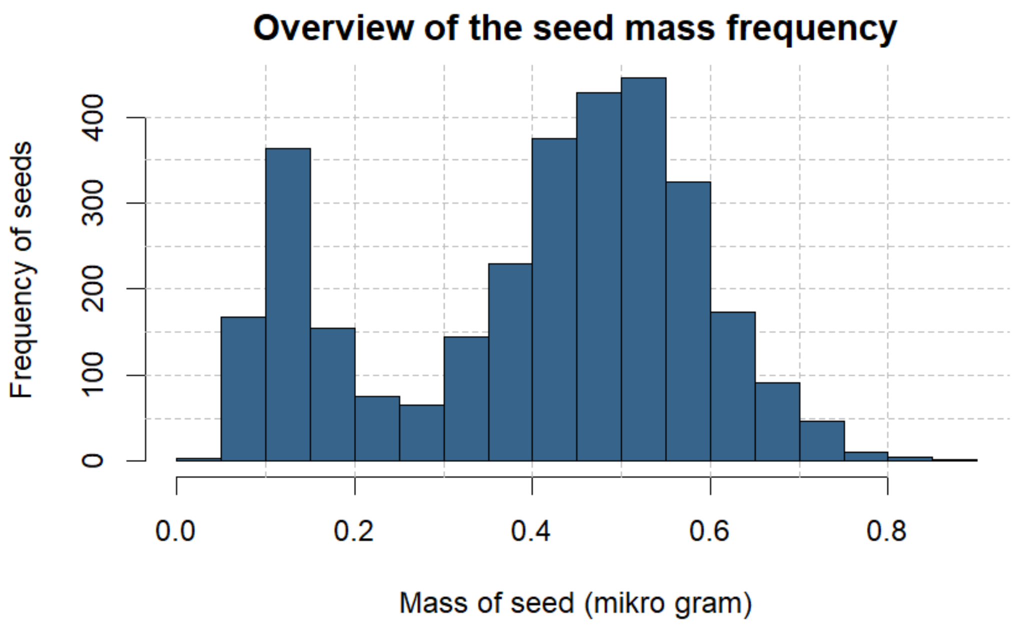


Figure 9 : Histogram that illustrates the number of seeds (frequency) had a specific weight (mass).

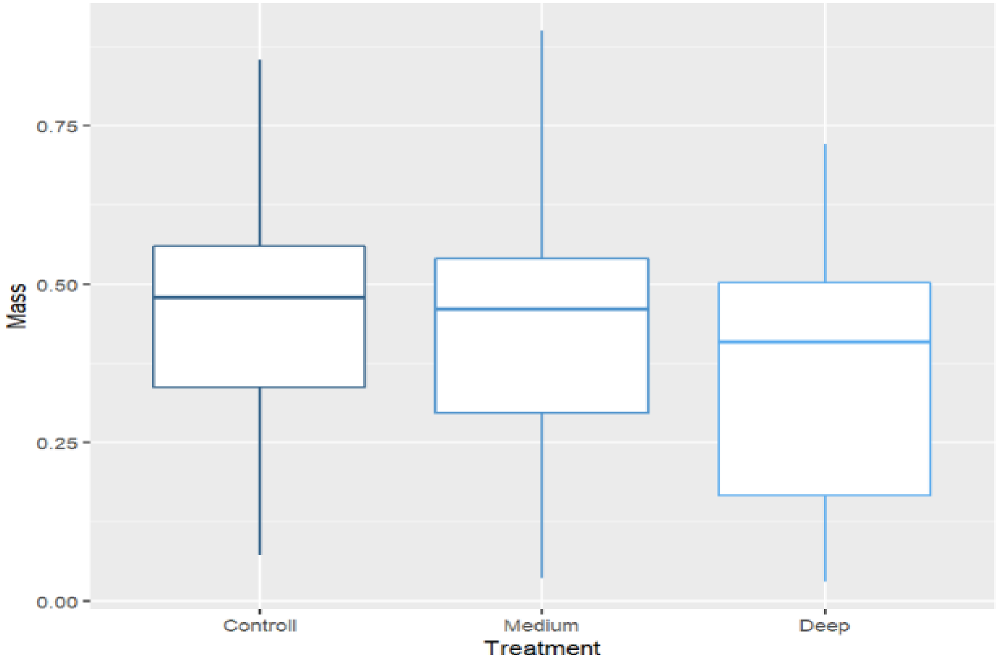


Figure 10 : Boxplot illustrating the relationship between seed mass on the y-axis, and the snow treatment methods on the x-axis

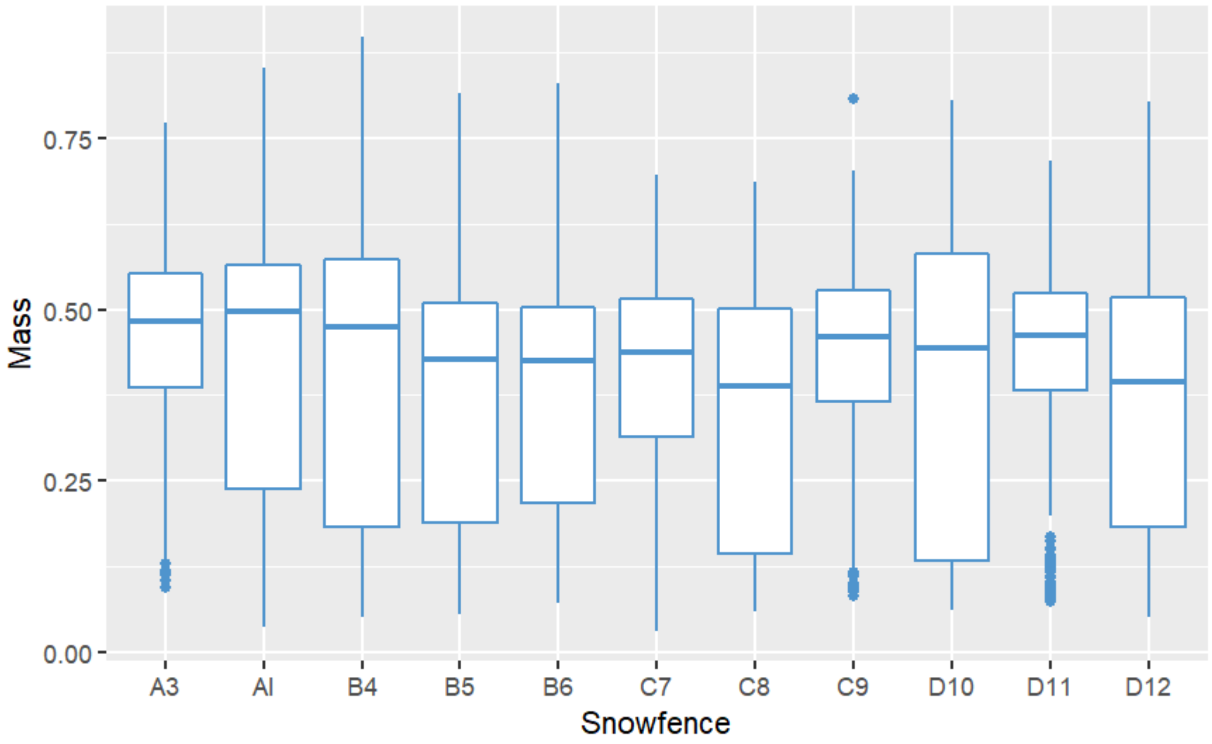
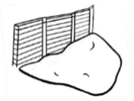


Figure 11 : Boxplot illustrating the relationship between seed mass on the y-axis, and the snow treatment methods on the x-axis

Table 4 : Illustrates the result of a logistical regression model the binary variable germ, with mold as an explanatory value.

	**Estimate**	**Standard Error (SE)**	**Pr (>|z|)**
(Intercept)	0.72705	0.04129	<2e-16 ***
Medium	-0.48101	0.10528	4.9e-06 ***

3.2 OTC results

There were in total 1000 seeds from the OTC treatment (see Table 5). 53,1% of the control seeds and 60% of the OTC seeds started their germination process. Further analysis was made to explore whether the variable "treatment" had a statistically significant effect on the seed germination (table 6). Pr (>|z|) marked it as slightly statistically significant, with a value of 0.00272 . Table 7 shows the result of a generalized linear regression model, with mass added as an explanatory value. Pr (>|z|), now marked both treatment and mass as statistically significant. There were no significant differences in the start day or end day of germination, for the different treatment methods (see fig. 4 and 5 in the appendix).

Figure 12 illustrates the effect treatment have on seed mass. The mean mass is the same for the OTC treatment and Control, slightly under ap. 0.39 micrograms. Seed mass was not normally distributed (fig. 13). Most of the seeds were between 0.35 and 0.45. With approximately 900 of the 31303 snow treatment seeds, falling in this category. At either end the numbers fall of, in accordance with normal distribution. However, there is a spike of seeds in the 0.5-0.2 range that disrupts the normalcy. There was some variation in mass depending on the location the snow treatment was located on (fig. 14).

There was no significant correlation between seed length and germination (see fig. 6, appendix. The figure is from the snow depth treatment; however OTC had the same pattern. Mold had a p(>|z|), below 0.05, indicating that it is statistically significant (Table 8). The highest mold occurrence was at OTC treatment with 24,9% and 14.25% from control seeds. 16,9% for control. 53.3% of the OTC seeds completed germination. Even though there was a 10,65% higher occurrence of mold in the seeds from the OTC treatment.

Table 5 : Is an overview of the total amounts of seeds under the snow fence treatment that germinated and did not germinate.

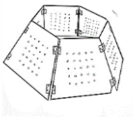
	**Total amount of seeds**	**Germnation frequency (start, end)**	**Start germination (%)**	**End germination(%)**	**Mold**
Control	1000	531, 470	53,1%	47%	14,25%
OTC	400	240, 213	60%	53,3%	24,9%

Table 6 : General linear model of the binary variable "germ" of the seeds from the OTC treatment and the "treatment" variables for the seeds.

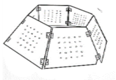
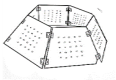
	**Estimate**	**Standard Error (SE)**	**Pr (>lzl)**
(Intercept)	0.08614	0.6334	0.17382
Treatment OTC	0.36117	0.12050	0.00272 **

Table 7 : General linear model with the binary variable "germ" of the seeds from the OTC treatment, and the "treatment" of the seeds and "mass" added as an explanatory value.

	**Estimate**	**Standard Error (SE)**	**Pr (>lzl)**
(Intercept)	-3.1519	0.2123	<2e-16 ***
TreatmentOTC	0.5525	0.1435	0.000119 ***
Mass	9.7069	0.5424	<2e-16 ***

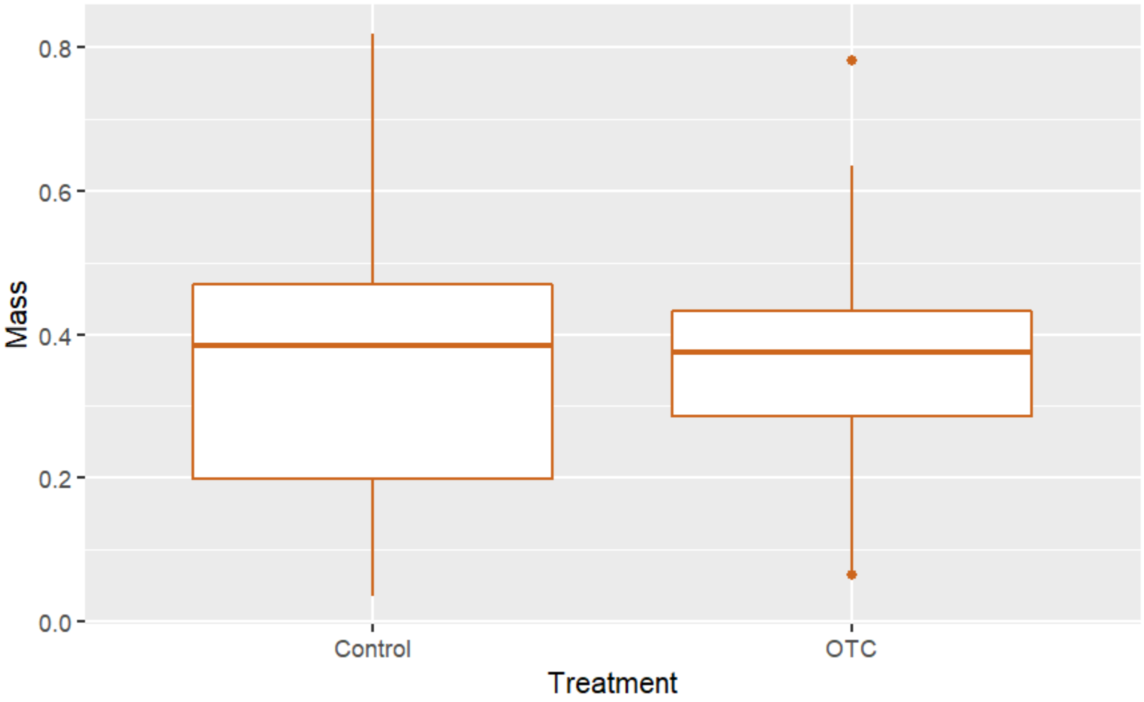


Figure 12 : ggboxplot with the seed mass on the y-axis and treatment method on the x-axis.

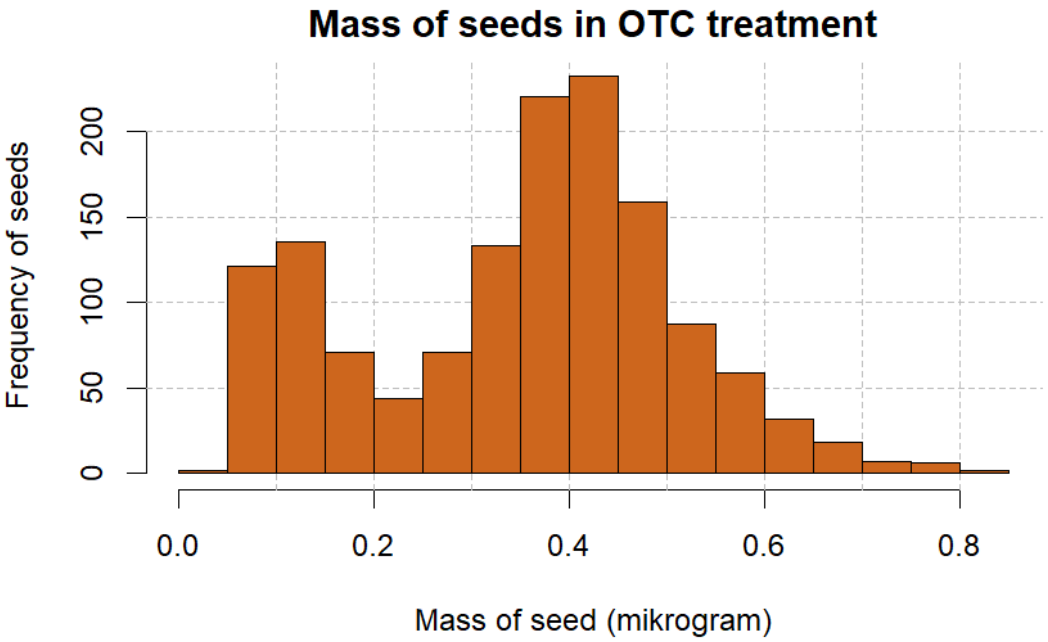


Figure 13 : illustrates the mass (mikrogram) of the seeds rom the OTC treatment.

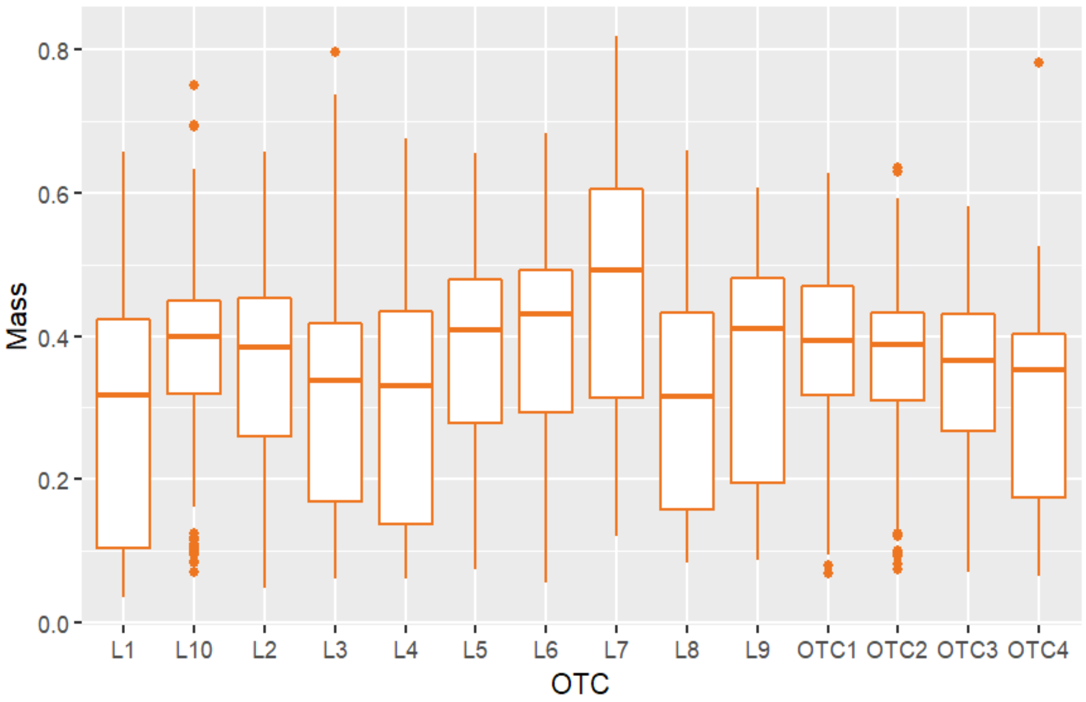
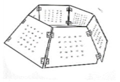


Figure 14 : ggboxplot with the seed mass on the y-axis, and the binairy factor of germination (0=no germination, 1=germination)

Table 8 : General linear regression model of the germination of the seeds from the OTC and snow-depth treatment, with mold as an explanatory value.

	**Estimate**	**Standard Error (SE)**	**Pr (>|z|)**
(Intercept)	-3.1519	0.2004	<2e-16 ***
Mold	9.6008	0.0.5371	<2e-16 ***

4 Discussion

4.1 Discussion of method

Snow fences and OTCs passively influence the treatment sites, by accumulating snow drift and increasing temperature. That allows us to compare plant response to the treatment with the plant response to the controls (Gehrmann, Ziegler, & Cooper, 2021). By keeping the plants under natural conditions with only passive interference, I believe the results will to a greater degree, represent natural germination patterns of *D.octopetala*. A further benefit is the inexpensive setup, that requires little to no resources after being established. A possible downside to this method is that no measurements of snow or temperature were made throughout the winter season. There might have occurred circumstances that affected the results (for instance, trash accumulation at the field site or larger snow depth). That could help explain figure 11 and 14, that indicates that germination is connected to and vary depending on the location. However natural variation is expected (Cooper et al., 2011). The experiment only lasted a year. This gives limited insight into the long term trends and effects of climate change (Gehrmann et al., 2021).

Earlier experiments have attempted to manipulate snow depth manually, by shoveling away snow, or by increasing snow melt rates by using dark cloth (Wipf et al., 2009). This could have been beneficial if the desired outcome is to have the exact same amount of snow on each location. However possible side effects of active manipulation is; the snow becoming more compact or changes in light penetration (Wipf & Rixen, 2009). The method that might give the most realistic outcome, given the current climate models, is a combination of experimentally increased snowmelt and spring/summer warming (Cooper et al., 2011; Wipf et al., 2009). This could have been accomplished if the OTC experiment and snow depth experiment were combined.

In this experiment, seeds were collected on site in collaboration with well-established experiment structures. However, I did not participate in the collection of the seeds, which can limit my ability to analyze the data. If there were obvious visual differences that have not been considered etc. For instance in regard to, Site C7 Deep, C8 Medium, and D11 Deep, that all had fewer seeds or no seeds at all (see table 1, appendix). In addition, there are many other possibly explanatory factors that could have been considered in this experiment; like soil surface temperature, soil moisture, snowmelt, the date each plot became 50% snow free etc., which have been registered in other experiments conducted in the arctic (Gillespie et al., 2016).

The weighing and measuring of the seeds were not conducted under sterile conditions; however, the desk and equipment were sterilized daily with alcohol. This was a very meticulous and time-consuming process. It might have been beneficial to take the average weight of 1000 seeds for each treatment method and taken the average weight, but I deemed it a necessary sacrifice to get specific data from each seed. I made a conscious attempt to pick seeds at “random”. However, I do not know if I was unconsciously biased in my choices. If the seeds showed signs of visible damage, including breakage or splits, they were not used if other seeds were available.

Before I started the germination process, I wanted to test the effects of different treatments. In the first test run I compared the germination success of seeds when grown on agar or paper (see fig. 3 in the appendix). Agar was more successful, but also had a larger occurrence of mold. In the second test I compared the germination success of normal *D.octopetala* seeds compared to seeds dipped in alcohol (see fig 4 in appendix). The alcohol treatment surprisingly increased the occurrence of mold. Therefore, I decided not to sterilize the seeds. However, in an experiment conducted by Billault et al., they used 30% H_2O_2 to sterilize the seeds, which was 99% effective (Billault-Penneteau et al., 2019).

The process of placing the seeds on the petri dishes was time consuming, and it took in total more than 27 hours for four people to accomplish it. To prevent premature germination, the completed petri dishes were placed in a dark refrigerator with temperature around 4°C. This process was not completed under sterile conditions, as it was done in a living room with the help of people not used to lab equipment. However, this was done to minimize the time difference the seeds spent on agar. If this had been conducted under sterile conditions, it could have reduced the amount of mold. Previous studies suggests that fungi growth can lead to seed death (Billault-Penneteau et al., 2019). And as shown in table 1, some seeds died before completing germination. The petri dishes closest to the fan had a higher level of condensation, than seeds closer to the door. These petri dishes completed germination more quickly and dried out earlier than the others. However, I do not believe that this affected the results in a significant way, because the seeds were randomized by having each treatment represented on each petri dish. The results from fig. 7 in the appendix indicating that there was no significant correlation between petri dish location and germination.

Everyday around 14.00, I went into the climate room and took picture of every petri dish. To have approximately the same time between registrations. Due to the sharp light in the climate room, the photo quality was not always great, making it hard to distinguish the results. I would then write down all the seeds that started their germination process that day, and all that completed their germination process. I made a reference map that I used to cross out seeds, as to not register them twice. Started germination was symbolized with /, completed germination with X and mold with a red dot. No one checked my progress or findings, so the only way to know if I made a mistake, is with the reference map. It would have been beneficial for two people to go through, to minimize chances of error. With more than 4000 seeds divided on 100 petri dishes, with small squares and numbers, it is easy to make mistakes.

4.2 Discussion of snow treatment

4.2.1 Direct effects

During seed collection Elizabeth Cooper observed that there were fewer flowers and seeds at deep treatment sites. Many of the plants had died. At certain locations there were very few seeds, and at a specific site, there were no seeds at all (see table 1 in the appendix). This match previous findings in Adventdalen, were increased snow depth led to a reduced quantitative reproductive success and shrub death. At these sites 80% of control plots had *D. octopetala* occurrence, whilst deep plots only had 42% occurrence. (Cooper et al., 2011; Cooper et al., 2019). Proposed explanations include; later melt-out date, shorter growing period, shorter reproductive period or even increased soil moisture (Cooper et al., 2011). In addition, increased snow depth can also lead to increases in temperature. Given the setup of my experiment, and the intertwined nature of climatic variables, it is impossible to know which of these variables have the largest effect on seed germination. All variables are *directly* affected by snow depth, due to the limitations of, my experiment they all fall under the variable “Treatment”.

The results of the snow depth experiment, indicates a possible correlation between treatment and germination percentage (see table 1). Control seeds had the largest frequency of germination at 68,3%. Medium seeds were 0,7% less likely to germinate, compared with the control. Deep treatment seeds had the lowest germination frequency. Of deep treatment seeds, only 61,4% started their germination process, which is 6,9% less than the control, and 6,2% lower than seed from the medium treatment. Table 2, indicate that there is a statistically significant correlation between the snow fence treatment and germination of *D.octopetala.* This is supported by previous studies, that indicate that changes in snow cover have a significant effect on plant reproduction (Wipf et al., 2009). However a previous study estimated that snow regime was responsible for 11.5% of the variation in community composition, indicating that it is not the only explanatory value. (Cooper et al., 2019)

Snow depth can also affect the date of spring snowmelt, the larger the amount of snow, the later snowmelt will occur (Cooper et al., 2011). Previous studies have shown that it can delay snowmelt with as much as two weeks (Cooper et al., 2011). Deeper snow levels can also lead to delayed phenological development, reduce the amount of flowers and affect soil moisture (Cooper et al., 2011). Research conducted by Wipf & Rixen, indicate that increased snow depth led to changes in life stage phenology. In general, dwarf shrubs show large changes in phenology after changes in snow melt timing. *D.octopetala* is an evergreen shrub, that start phenological processes soon after snow melt (Wipf et al., 2009). However, there was not a significant connection between treatment (control, medium, deep), and which day germination began or completed in this research (see fig. 4 and 5 in the appendix, the boxplots are from OTC treatment, but they had a similar pattern for snow depth as well). Earlier experiments that looked at *D.octopetala* found that there was no difference in when dispersal occurred for treatment and control seeds (Cooper et al., 2011). Although increased snow decreased the effective growing season length, it did not have a significant effect on the rate of phenological development. Indicating that phenological processes are under strong genetic control and that the species were not able to adjust development times in consort with environmental changes. Snow also protects the arctic flora from frost damage during the winter, keeping the soil temperature warmer and more stable (Briceño, Harris-Pascal, Nicotra, Williams, & Ball, 2014). It has low thermal conductivity, so it can keep soil temperatures close to 0 degrees, even if the ambient is below 0. (Briceño et al., 2014).

4.2.2 Indirect effects

Seed traits like mass and germination are central to plant life histories and their fitness (Bu et al., 2007). Earlier it was thought that seed was more or less constant within a species, but newer research indicates that it can vary greatly (Bu et al., 2007). Studies indicate that seeds with larger seed mass exhibit a higher rate of germination (Panchen, Frei, & Henry, 2021). If that is the case, *D.octopetala* could exhibit higher reproductive success under future climate models. The plant's capacity to reproduce through seed germination is one of the determining factors for the regeneration of plant communities (Bu et al., 2007). An estimate of germination capacity is important to determine sexual reproductive efficiency (Bu et al., 2007). In a study made by Bu et al, they found a negative correlation between seed mass and germination, however this does not follow the general trend (Bu et al., 2007).

Mass was found to be a statistically significant variable that affect germination (see table 7) Control, medium and deep treatment are represented at each snow fence. There appears to be variation in seed mass dependent on snow fence location. The average mass for all of the snow-fences are between 0,4-0,5 micrograms. Snow-fences A3, C7, C9 and D11 have little variation, with most being concentrated around the mean and only some outliers. B4, C8 and D10 have large variations around the mean. Figure 13 gives an overview of seed frequency distributions of all the seeds, depending on mass. The largest seed frequency (approximately) is within the weight group of 0.45-0.55 micrograms, with the frequency decreasing at each side, 380 seeds at 0.4-0.45. And 325 seeds at 0.6. However, there is an increase in the seed frequency with 0.1-0.15, with ap. 360 seeds. Figure 11 is a boxplot illustrating the correlation of seed mass (without style feather), and treatment method. The findings from figure 11 indicates that there is a slight negative correlation between mass and treatment. Seeds from the control treatment had the largest mean mass and a larger seed frequency close to the mean mass. The seeds from the medium treatment had a slightly smaller average mass (around 0.06 microgram less) but had outliers that were larger than any outlier from the control. The deep treatment seeds had the smallest mean mass, around 0,375 micrograms, and the largest variation in size. It indicates a slight decrease in the mass of the seed, in accordance with the treatment.

There was a relatively large difference between seeds that started germinating and the seeds that completed it. Of the 68,3% of control seeds that started germination, 66,1% of seeds completed it. From the medium seeds 67,6% started their germination, and 59,8% completed it. Which is a decline of almost 8%. From deep seed treatment 61,4% started germination, and 55,5% completed it. Which is a decline of almost 6%. The difference in seeds that *began* their germination process and those that *completed* it, indicates that there was something that stopped the seeds phenological development. Most of the seeds with mold, did not complete their germination process. This is supported by earlier papers, that also found that seeds exposed to fungi would die relatively quickly (Billault-Penneteau et al., 2019). The largest difference in seeds that started but did not complete their germination was the medium treatment. This negative trend occurred even though control seeds had a markedly higher percentage of mold occurring at 16,9%, medium slightly less at 15,8 % and only 9,2% of deep treatment seed had mold occurrence, 7,7% less than the control. Indicating that the mold occurrence has a negative effect on germination, this is further supported by table 4. That indicates that mold has a statistically significant effect on germination. In most circumstances where germination began, but was not completed, there was mold on the seed. It is difficult to conclude whether the fungi originated from nature or was due to human handling.

4.3 Discussion effects of OTC treatment

4.3.1 Direct effects of OTC treatment

The result from the OTC treatment indicates that there might be a positive connection between increases in temperature and germination (table 5). Of the 1000 seeds from the control treatment, 531 seeds started the germination process and 470 completed the process. Meaning that ap. 53% of the total amount of control seeds started their germination process, and 47% completed it. There were significantly fewer seeds collected from the OTC treatment. Of the 400 seeds that were collected, 240 started the germination process and 213 completed it. With 60% of the total amount of seeds from the OTC treatment starting the germination percentage, and 53,3% completing the germination process within the ten days.

There appears to be a slight positive correlation between OTC treatment and germination. Which is supported by table 6, by the Pr (>|z|)<0.05. However, with a value at 0.00272, it is not quite as conclusive as earlier models. The positive correlation could further be explained by difference in sample size. With the seeds from the OTC treatment not being representative for the population. However increased seed viability from OTC treatments have been consistently higher in previous studies (Panchen et al., 2021). Most likely due to earlier melt outs compared to control sites. If climatic conditions continue to change in according to expected models, the reproductive success of *D.octopetala* can increase in the future. It has been suggested that the low reproductive success of arctic dwarf shrubs, are due to the hars environmental conditions they are exposed to (Graae et al., 2008). 2020 was an abnormally warm year, with an abnormally warm summer (see fig 8, appendix). And previous studies indicate that warmer summers leads to increased germination rate (Graae et al., 2008). The rates of germination seen in this experiment, could be slightly inflated, compared to a year with average temperature.

4.3.2 Indirect effects

Earlier studies indicate that seed mass can increase when exposed to higher temperatures. However, this was not supported by this study (figure 12). The results indicate that the mean mass was approximately the same for each treatment. The main difference being that control seeds had larger variation, which is explained in part due to it having more than double the sample size. Based on figure 20, there appears to be variation in seed mass depending on the location. The average seed mas varies between 0,3-0,5micrograms. L1, stands out as the location with seeds with less mass, with the majority of seeds being between 0,1 and 0,4. L7 had the largest mass of seeds, with the majority being between 0,3 and 0,6 micrograms. The seeds from the OTC treatment had the average seed mass around 0,4micrograms and have relatively little variation in mass compared to the control treatment locations. Figure 7 indicates that, when mass was added as an explanatory value, the p-value for both treatment and mass were highly statistically relevant.

Based on the results (table 8), mold is highly statistically relevant for sed germination. This is in part, as mentioned in the snow fence discussion, that mold can lead to seed death and ended germination. There seemed to a positive relationship between mold occurrence and OTC treatment. With the OTC treatment having more than 10% higher occurrence of mold. Studies indicate that higher temperature in the arctic soil, the more microbial activity is found (Semenchuk, Christiansen, Grogan, Elberling, & Cooper, 2016)Even with this difference , the ap. 7% more of the seeds from the OTC treatment started the germination process, and 6% more finished it compared to the control. Indicating that mold is not the only explanatory variable. But any arctic dwarf shrubs are infected by mycorrhizal fungi (Baddeley et al., 1994)

4.4 Future research

In the future there should be created a standardized protocol for winter measurements, which works independent of the given ecosystem and spatial scale (Wipf & Rixen, 2010) It is important that they are long-term experiments, like ITEX and Coopers snow fences, to get an overview of the long term effects of climate change (Cooper et al., 2011). It is important to continue to explore the direct effects snow depth and increased temperature have on the germination of arctic flora, both to preserve biodiversity but also to predict future effects of climate change (Gillespie et al., 2016). In an area with low reproductive success (Vik, Jørgensen, Kauserud, Nordal, & Brysting, 2010).

Climatic variables like temperature and snow affect basically every facet of an ecosystem. Interdisciplinary collaboration can give insight into complex climatic variables, to get an overview of direct and indirect effects, that have previously been under explored (Wipf et al., 2009). One example of this is the effect seed mass have on germination and what affects the mas of the seed (Wipf et al., 2009). Mass had statistically significant effect in this experiment. However well-designed, large-scale snow manipulation experiments are difficult and require a lot of work and resources. For instance simulating episodic extreme events like winter and spring thawing. (Wipf & Rixen, 2010)

5. Conclusion

In this experiment, I used seed collected from snow fence sites and OTC sites at Svalbard to explore how the abiotic factors snow depth and temperature affect the germination of the alpine plant *D.octopetala*. For the snow treatment I found that; treatment, mass and mold have the largest effect on germination. More seeds from control sites germinated, compared to medium and deep snow treatment, with the contrast being even larger for the seeds that completed germination. However, the results are not only dependent on treatment. The findings indicate that variables that are indirectly affected by snow depth and temperature, like mass and mold occurrence mass have a larger explanatory value than treatment, based on the glm models. With seeds at a certain weight being more likely to germinate. However, seeds from control sites were in average larger than the seeds from medium and control. With some deep treatment sites even showing signs of fewer seeds or plant death. There was not an obvious difference in the time frame seeds completed their germination process, matching previous studies. The seeds from the OTC treatment had the opposite reaction. Seeds that were exposed to the OTC treatment were more likely to germinate, compared to the control treatment. Both for started and for completed germination. This being the case, even though seeds from OTC treatment were significantly more likely to experience mold. Mass was an important explanatory value for germination in the OTC treatment as well, with seeds at a certain weight being more likely to germinate. However, the mean weight for each treatment method was the same. The findings in this experiment indicates that there are many factors that affect *D.octopetala*`s ability to germinate, even under relatively “optimal” conditions. There are good study sites and experiment setups in place at Adventdalen and Endalen, that will continue to study the effects of climate change at Svalbard. Because climactic factors are interconnected, further research on the impacts they have on each other and the ecosystem is required.

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Appendix

Table 1: Overview of the number of seeds from the different snow fence locations (Adventdalen) that were germinated. Differences in number is in part due to fewer seeds found on the different locations, and mistakes occurring during the germination process (A3 medium and A3 deep were lost in the process).

DRYAS SEEDS COLLECTED FROM SNOW FENCE TREATMENT				
Block	Fence	Control	Medium	Deep
A	A1	100	100	100
	A3	100	99*	99*
B	B4	100	100	100
	B5	100	100	100

	B6	100	100	100
C	C7	100	100	66*
	C8	100	Missing*	100
	C9	100	100	100
D	D10	100	100	100
	D11	100	100	39*
	D12	100	100	100

Table 2: Overview of the number of seeds from the different OTC`s (Endalen) that were germinated. Differences in number is in part due to fewer seeds found in the seeds, and mistakes occurring during the germination process.

DRYAS SEEDS COLLECTED FROM OTC TREATMENT		
Location	Treatment	Number of seeds
L1	Control	100
L2	Control	100
L3	Control	100
L4	Control	100
L5	Control	100
L6	Control	100
L7	Control	99
L8	Control	100
L9	Control	100
L10	Control	100
OTC1	OTC	100
OTC2	OTC	100
OTC3	OTC	100
OTC4	OTC	100

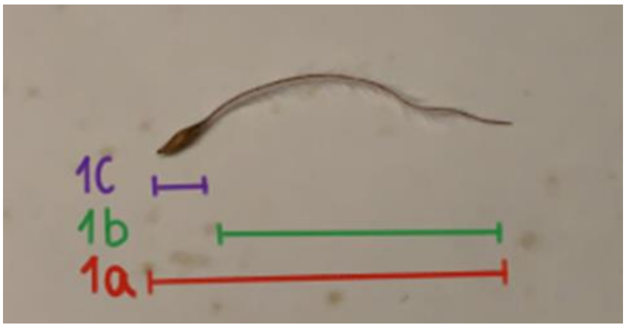


Figure 1 : Illustration of the different parts of the D.octopetala that was measured in the method. 1a is the entirety of the seed, 1b is just the feather style and 1c is just the seed.

Table 3: Overview of the test results on germination on paper. The majority did not germinate. All of the seeds that had mold occurrence did not germinate.

Test germination on paper

Germination	15%
No germination	85%
Mold	39%

Table 4: Overview of the test results on agar. Approximately half of the seeds were first dipped in alcohol in an effort to sterilize them. This led to a higher amount of mold. Germination on agar was 50% higher on agar than on paper (see table 3 in appendix), which is why the second experiment was conducted on agar.

Test germination on agar

	Alcohol (160 seeds)	Non-alcohol (170)
Germination	23%	50%
No germination	77%	50%
Mold	40%	16%

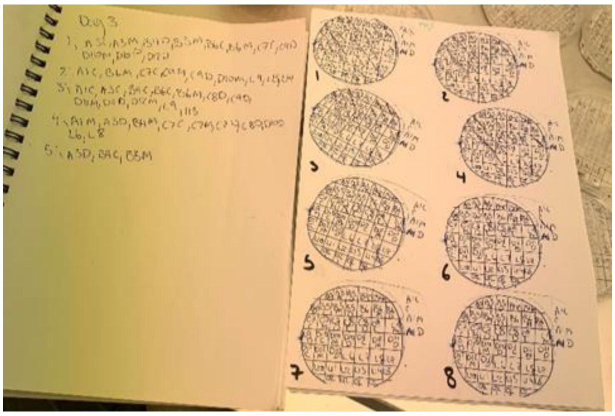


Figure 2 : Photo of the «map" used to get an overview of start of germination (/), end germination (X) and mold (red dot), during seed germination from the 8th-18th of November.

Figure 3 : Photo illustrating what was registered as "mold".

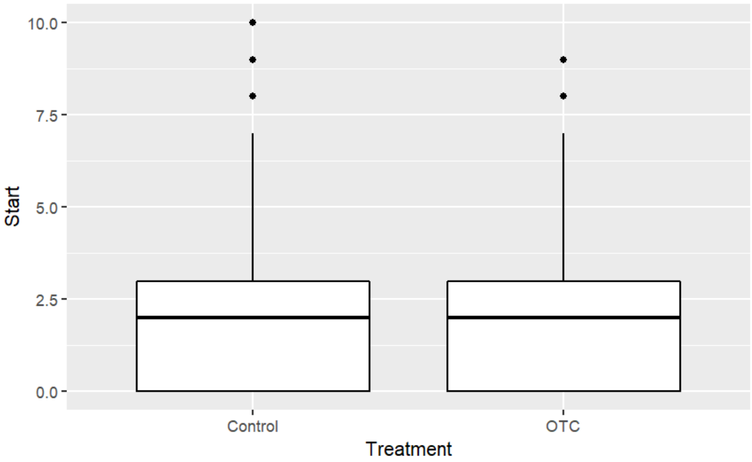


Figure 4: Is a boxplot that illustrates the distribution of the days germination began for each treatment method.

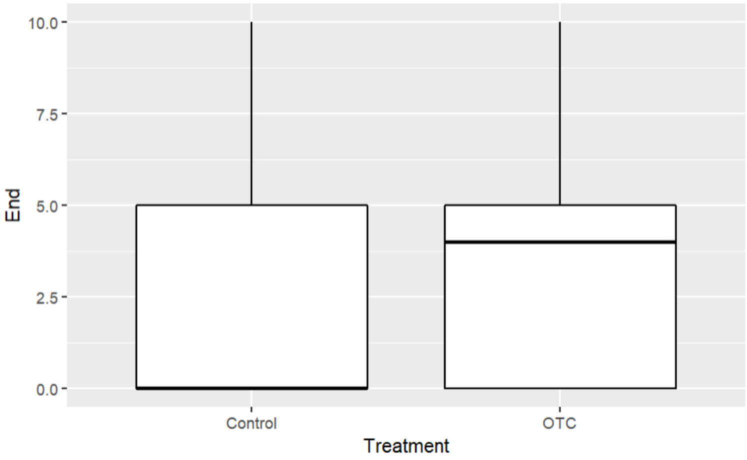


Figure 5: Is a boxplot that illustrates the distribution of the days germination was completed for the control and OTC treatment.

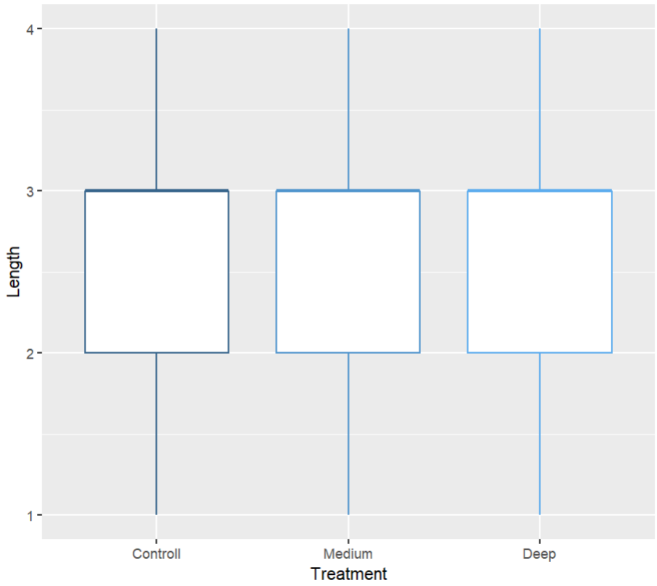
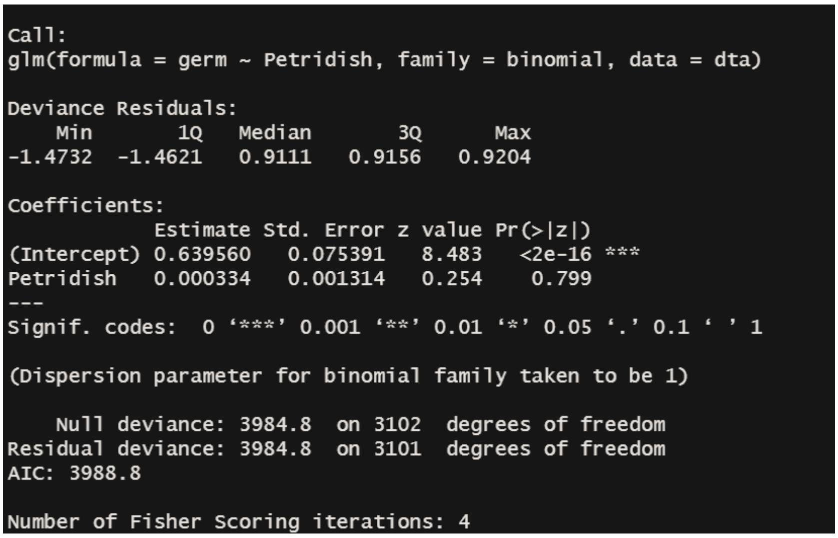


Figure 6: Box plot illustrating the correlation between treatment method and length. The seed length was the same, independent of treatment method. There was no apparent correlation.



```
Call:
glm(formula = germ ~ Petridish, family = binomial, data = dta)

Deviance Residuals:
    Min       1Q   Median       3Q      Max  
-1.4732  -1.4621   0.9111   0.9156   0.9204  

Coefficients:
            Estimate Std. Error z value Pr(>|z|)    
(Intercept) 0.639560   0.075391   8.483   <2e-16 ***
Petridish   0.000334   0.001314   0.254    0.799    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 3984.8  on 3102  degrees of freedom
Residual deviance: 3984.8  on 3101  degrees of freedom
AIC: 3988.8

Number of Fisher Scoring iterations: 4
```

Figure 7: General linear model with the binary “germ” variable of the seeds from the OTC, with petri dishes as an explanatory value.

Table 4: Overview of the monthly temperature at Svalbard Airport for 2019, 2020 and the mean temperatures from 2000-2022. Information attained from; https://verstat.no/temperaturstatistikk-for-svalbard/ (Verstat, 2022)

	2019	**2020**	**2000-2020**
January	-10,3°C	-13.4 °C	-9,2°C
Feburary	-11.1 °C	-15.5 °C	-9.9°C
March	-12.6 °C	-16.2°C	-12.4°C
April	-3.9 °C	-8.9°C	-8.2°C
May	-2.3 °C	-0.1°C	-1.5°C
June	4.8 °C	4.5 °C	4°C
July	8.4 °C	9.8 °C	7.4°C
August	6.2 °C	7.2 °C	6.3°C
September	2.6 °C	3.2°C	2.4°C
October	-4.6 °C	-2.2°C	-2.8°C
November	-7.2 °C	-2.9°C	-5.8°C
December	-10.8°C	-7.0°C	-8°C

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