Revegetation Research at Minto Mine: Year 2 Progress Report

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Background

The rate of mineral resource extraction is increasing as a result of accelerated population growth, industrial development, economic expansion, and technological advancement. Surface mining results in substantial damage to soil structure and properties, microbial communities, and vegetation by disturbing extensive amounts of land (Sheoran et al., 2010). Revegetation is a widely used and accepted practice that aims to prevent soil degradation and erosion during reclamation to maintain the integrity of the landscape and associated lifestyles (Mensah, 2014; Bowman & Baker, 1998). Unfortunately, long-term restoration of mining activities and development in Canada's North have been given little attention (Bowman & Baker, 1998). Research with respect to plant facilitation has been identifying relationships between important ecological issues such as the interaction between biodiversity and ecosystem function (Brooker et al., 2008). Even though members of plant communities compete for the same resources such as water, light, nutrients, and space, they have the capacity to enhance the facilitation and growth of other species through amelioration of their environment (Brooker, 2006). For instance, established plants in stressful environments fix atmospheric nitrogen and promote growth of neighboring plants by increasing soil nitrogen content (Arfin Khan et al., 2014). More specifically, vertical structure such as shrub canopy in cold northern environments can improve soil conditions through increased snow capture and can reduce the loss of soil and seeds (Kreyling, 2019; Peterson, 2001). However, the magnitude of facilitation effects as a result of the physical characteristics of vertical structure compared to biological characteristics of shrubs is undefined.

The objective of this study is to compare the effects of biotic (living) versus abiotic (non-living) structures and to evaluate the suitability of vertical structures in the arrival, facilitation, and growth of northern native plants (Yukon University, 2021).

Introduction

The 2022 project season was productive and generated perceptible trends from data analysis in the survival of smooth-leaf mountain avens (*Dryas integrifolia*) and green alder (*Alnus viridis* subsp. *crispa*) composing the biotic barriers despite unprecedented challenges in regard to snowfall (Figure 1). Above average snowpack in 2021/2022 buried snow fences which limited the effectiveness of the abiotic vertical structures, and early snowfall in fall 2022 limited researchers' ability to collect all desired shrub monitoring measurements. Continued monitoring and data accumulation with reference to snow distribution, local climate, and the survival and growth of shrubs in the biotic barriers were characterized between three site visits. Although the majority of data from this past season has not yet been statistically analyzed, shrub survival and growth appeared to be quite high. Also, project responsibility has changed hands and beginning in spring 2023, Master's candidate Ben Budzey will be working on the project under the supervision of Dr. Katherine Stewart with the University of Saskatchewan and co-supervisor Dr. Guillaume Nielsen with Yukon University. Researchers have selected native plants to be used in the project because they are best adapted to survive and grow in the Yukon and using them ensures that invasive species are not introduced to the mine site. Canada bluejoint (*Calamagrostis canadensis*) and fireweed (*Chamerion angustifolium*) have been selected as the target northern species and will be incorporated into the experiment in 2023. These species have been chosen due to their ability to quickly colonize disturbed sites and their capacity to tolerate soil and environmental conditions that limit the survival of other native plants. Fireweed and bluejoint have been used in remediation projects to successfully revegetate oil-spill sites and coal strip mines through their potential to recover soil properties, limit the invasion of introduced species, supply wildlife with a food source, provide stream bank stability, maintain water quality by filtering runoff, and reduce surface erosion (Dunbar et al., 2011; Payek, 1992).

Figure 1 - Green alder in a biotic barrier.

Project Design

The project was initially designed as a randomized completed block experiment hosted at Minto Mine, YT with biotic and abiotic structures of three different heights for a total of four blocks and six treatments (Figure 2). In 2021, 1000 alders were planted in spring followed by 1,119 mountain avens in the fall. However, soapberry (*Shepherdia canadensis*) seedlings were not received on time to be planted in 2021, further limiting the number of treatments to five (Table 1). Treatments were installed in rows perpendicular to the dominant wind direction (NW), and row spacing is defined on the tallest treatment in each row to prevent impinging between treatments; main effects of treatments are predicted to be between two- and seven-times structure height (Yukon University, 2021; Agriculture and Agri-Food Canada, 2010).

Figure 2 – Minto Mine revegetation experiment layout revised for 2022

Table 1 – Summary of experiment treatments.

Treatment Height	Biotic Structure	Abiotic Structure
Tall	Green alder	0.65 m snow fence
Medium	~~Soapberry~~	0.35 m snow fence
Short	Smooth-leaf mountain avens	0 m control

To determine whether seed capture is facilitated by vertical structure, three 0.25m wide transects with a uniform seedbed were installed straddling each treatment from -1 to 7x the treatment height (Figure 3). Temperature and soil moisture sensors have been installed along the centre transect in Blocks 1-3 at -1, 1, 3, and 7x the treatment height (Yukon University, 2021).

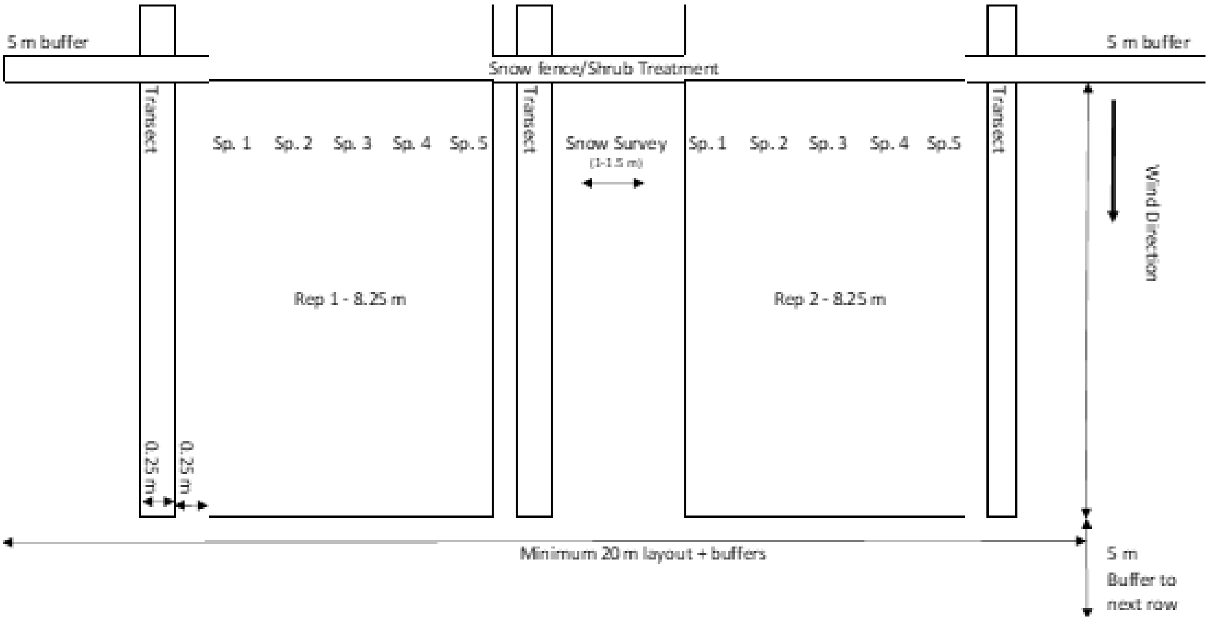

Figure 3 – Within block layout of transects and germination/seedling plot replicates.

In 2023, small plots will be created at -1, 1, 3, and 7x the height of the shelter to evaluate the effect of vertical structure on the establishment and growth of Canada bluejoint and fireweed seedlings (Figure 4). A similar layout will be used as expressed in Figure 4 without the incorporation of germination plots due to high likelihood of germination failure. Shrub heights in each treatment will be averaged from measurements in 2023 to determine treatment height (Yukon University, 2021). Paired comparisons for both Canada bluejoint and fireweed will be tested between spring vs. fall planting, and plant performance will be tested by planting six seedlings in 0.5 x 0.15m plots. A distance of 0.25m between plots will be maintained, and seedling survival and height will be sampled in 2024 (Yukon University, 2021).

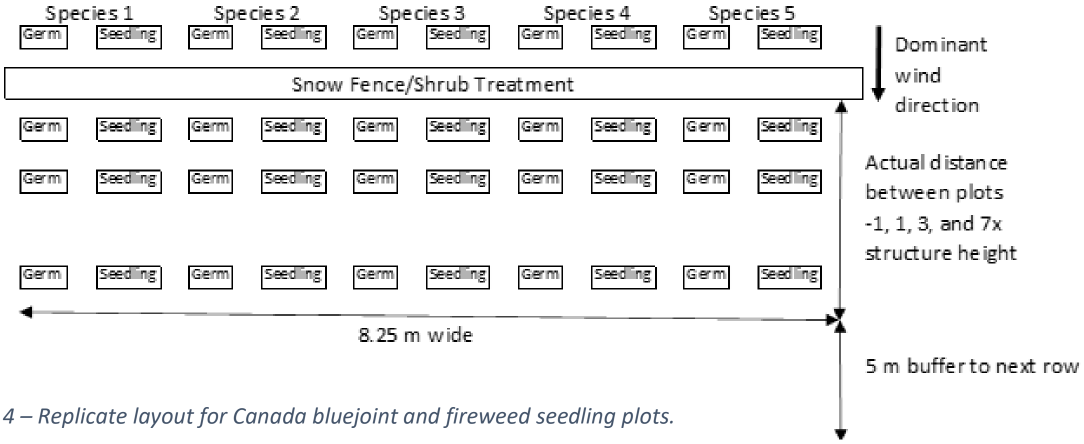

Figure 4 – Replicate layout for Canada bluejoint and fireweed seedling plots.

Field Measurements in 2022

Snow Water Equivalency

Water resources at revegetation sites are increasingly important in arid climates. Annual snow melt constitutes a considerable portion of total runoff at the Mine's mountainous catchments. Therefore, monitoring the spatial and temporal distribution of snow is critical for examining water resources and predicting subsequent runoff (Jonas et al., 2009). As a result, snow water equivalency (SWE) along with snow depth measurements were completed on-site to characterize snow cover in April 2022 (Table 2).

Table 2 – 2022 snow depth and SWE characteristics from Blocks 1-4 in cm.

Block	Snow Depth				SWE			
	Mean	SE (n =5)	Min	Max	Mean	SE (n = 5)	Min	Max
1	82.8	1.5	77	85	7.6	0.98	4	10
2	81	3.59	71	93	9.2	3.26	4	22
3	79.8	4.12	68	93	19.6	1.33	16	24
4	51	2.51	44	59	12	1.41	8	16

Snow depth and SWE were identified by conducting five representative samples along the edge of each block since high snowfall prevented researchers from identifying treatments and taking incremental measurements along the rows. These measurements were completed using a probe with a scale to capture depth and core weight of the sample used to determine SWE. Snow core samples for SWE were weighed and expressed in centimeters since 1g of snow is equal to $1cm^3$ of water.

Based on ten years of annual snow surveys at the Minto Mine, the average SWE on March 1 was 9.50cm and 9.68cm on April 1 (EBA, 2010). This data suggests that Minto received above average snowfall in winter 2021/2022 with the mean SWE being 12.1cm between 20 measurements from Blocks 1-4.

Shrub Survival and Structure Monitoring

Shrub survival and structure monitoring measurements were completed between two site visits in July and October 2022 to evaluate the integrity of the biotic barriers (Appendix A). The biotic barriers experienced a high survival rate with mountain avens enduring the highest mortality. Mountain avens in Blocks 1 and 2 experienced a survival rate of 94.8% (n = 256) while Block 3 had the lowest survival rate of 90.7% (n = 245). Alder in Blocks 1 and 2 had a survival rate of 100% (n = 270).

The following methodology is described in the Year 1 Progress Report (Yukon University, 2021). Ten randomly selected alders and mountain avens in each of the four replicates were examined for growth characteristics (Table 3 & 4). Selected mountain avens that did not survive were replaced with new randomly selected individuals. Alders were sampled for stem count, stem diameter, annual growth, maximum canopy height, and canopy area. On the other hand, only height and flower count were sampled for mountain avens. Reproduction is energetically costly for flowering plants as they must undergo major physiological changes to produce seeds and flowers (Chretien et al., 2022). Flowering in mountain avens suggests these individuals were in adequate health to endure reproduction. Mountain avens in Blocks 1-3 had a flowering rate of 36.7%, 31.9%, and 34.1%, respectively.

Table 3 – 2022 alder seedling characteristics from forty randomly selected seedlings.

Characteristic	Mean	SE (n = 40)	Min	Max
Spring Height (cm)	33.71	±1.38	20	49
Fall Height (cm)	49.13	± 2.09	26	74
Root Collar Diameter (mm)	0.46	±0.02	0.3	0.8
Shoot #	1.60	±0.14	1	4

Table 4 – 2022 mountain avens characteristics from forty-two randomly selected seedlings.

Characteristic	Mean	SE (n = 42)	Min	Max
Spring Height (cm)	6.76	±0.46	0	13
Flowers #	0.62	±0.15	0	4

The survival of green alder in Blocks 3 and 4 along with survival and height measurements for smooth-leaf mountain avens in Blocks 3 and 4 were not completed as they were buried by snow in the October site visit. Vegetation cover measurements were also not completed due to time constraints.

Logger and Photopoint Downloads

In 2021, a Hobo USB Microstation was installed to log data using an Onset Photosynthetic Light Smart Sensor, Davis Wind Speed and Direction Smart Sensor, Davis Rain Gauge Smart Sensor, Decagon EC-5 Soil Moisture Sensor, and an Onset Smart Temperature Sensor (Yukon University, 2021). Additional Hobo External Temperature and Relative Humidity and EM50 loggers were connected to four probes buried perpendicular to both biotic and abiotic structures. Hobo EC-5 Soil Moisture Smart Sensors or Decagon 5TM Soil Moisture Sensors and four Maxim Integrated iButton Thermochron F5 temperature data loggers were installed at intervals along the centre of the transect in each replicate based on -1, 1, 3, and 7x the treatment height (Yukon University, 2021). However, six of these loggers were unidentified, leaving only nine sets of loggers in Blocks 1-3 at treatments four, five, and six. Missing loggers were not replaced in Fall 2022 due to early arrival of snow. Together, these loggers collected a suite of data including vegetation water content, precipitation, soil moisture, wind speed, temperature, and relative humidity (Figure 5). Although most weather data have not yet been analyzed, plots were created to express variations in dew point, relative humidity, and temperature (Appendix B).

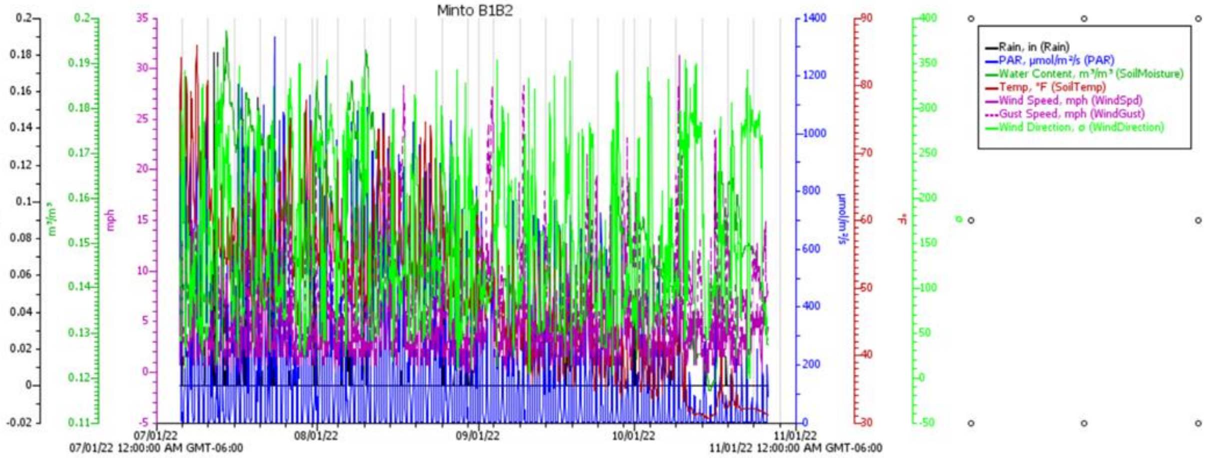

Figure 5 – 2022 Block 1 and 2 Hobo logger data including rain (in), photosynthetically active radiation (PAR) (µmol/m²/s), soil moisture (m³/m³), soil temperature (°F), wind speed (mph), wind gust speed (mph), and wind direction.

Two Reconyx HP2X Hyperfire 2 Professional Covert IR Cameras were set up at photopoint locations to overlook the blocks and monitor site conditions and weather variations by taking a daily photo at 1300hrs. A snow scale was added in front of each camera to assist in visualizing changes in snow depth over the course of winter (Figure 6 & 7).

Figure 6 – Reconyx Block 3 & 4 Photopoint July 2023

Figure 7 – Reconyx Block 3 & 4 Photopoint November 2021

Weather station, transect sensors, and time lapse photo data were downloaded during each site visit to provide a record of short-term climatic information. Monitoring variations in weather and soil properties provides insight to revegetation research since plant facilitation, growth, and survival are limited by environmental conditions. Data collection assists in identifying trends and the significance of cause-and-effect relationships by cross-referencing parameters that express interaction.

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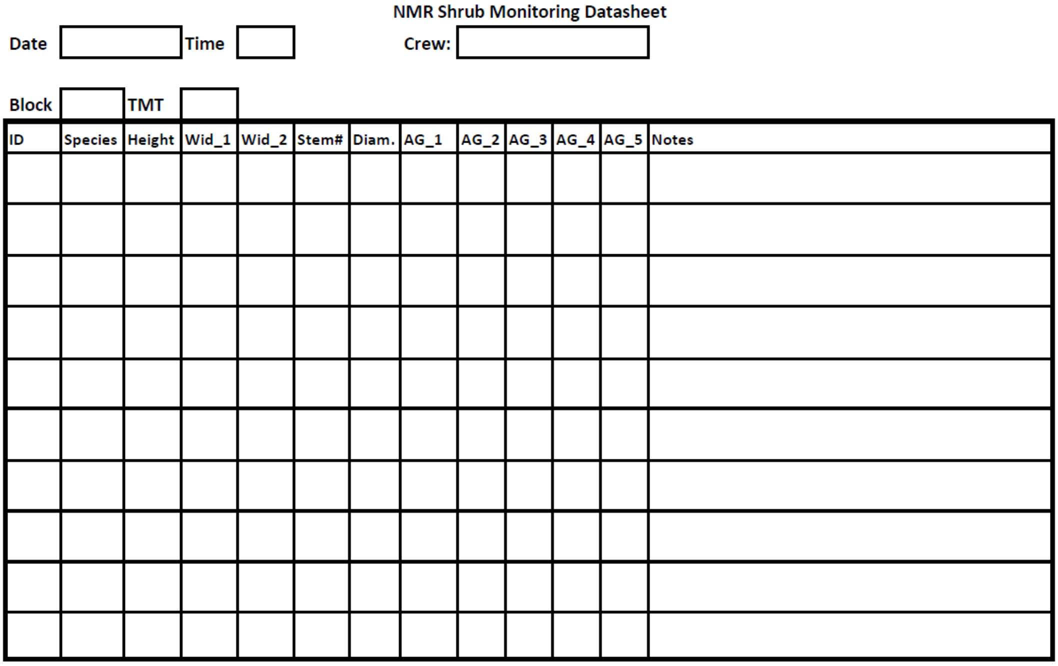
Appendix A1 – Northern Mine Remediation Shrub Monitoring Datasheet



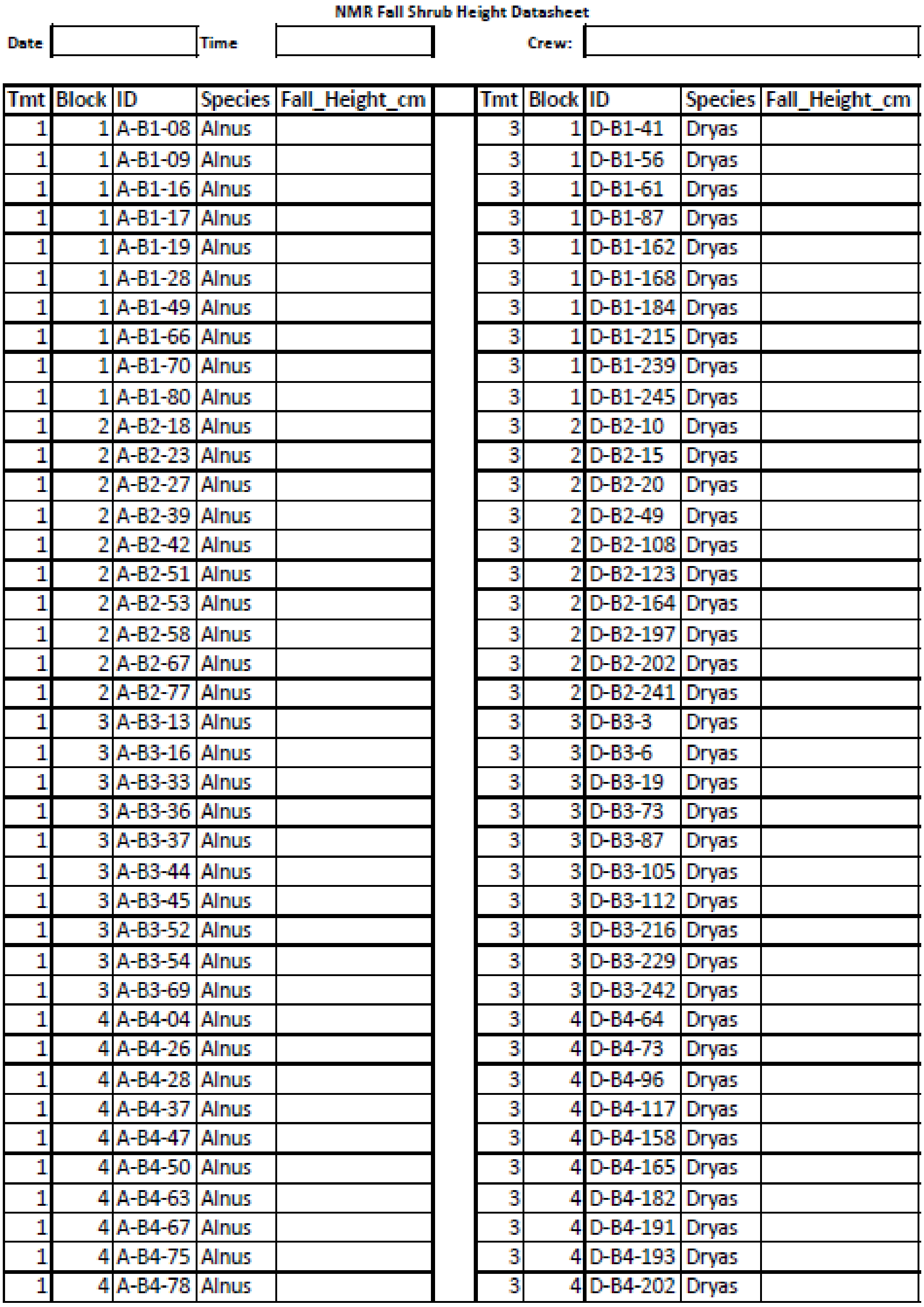
NMR Shrub Monitoring Datasheet

Date ______ **Time** ______ **Crew:** ______

Block ______ **TMT** ______

ID	Species	Height	Wid_1	Wid_2	Stem#	Diam.	AG_1	AG_2	AG_3	AG_4	AG_5	Notes

Appendix A2 – Northern Mine Remediation Fall Shrub Height Datasheet

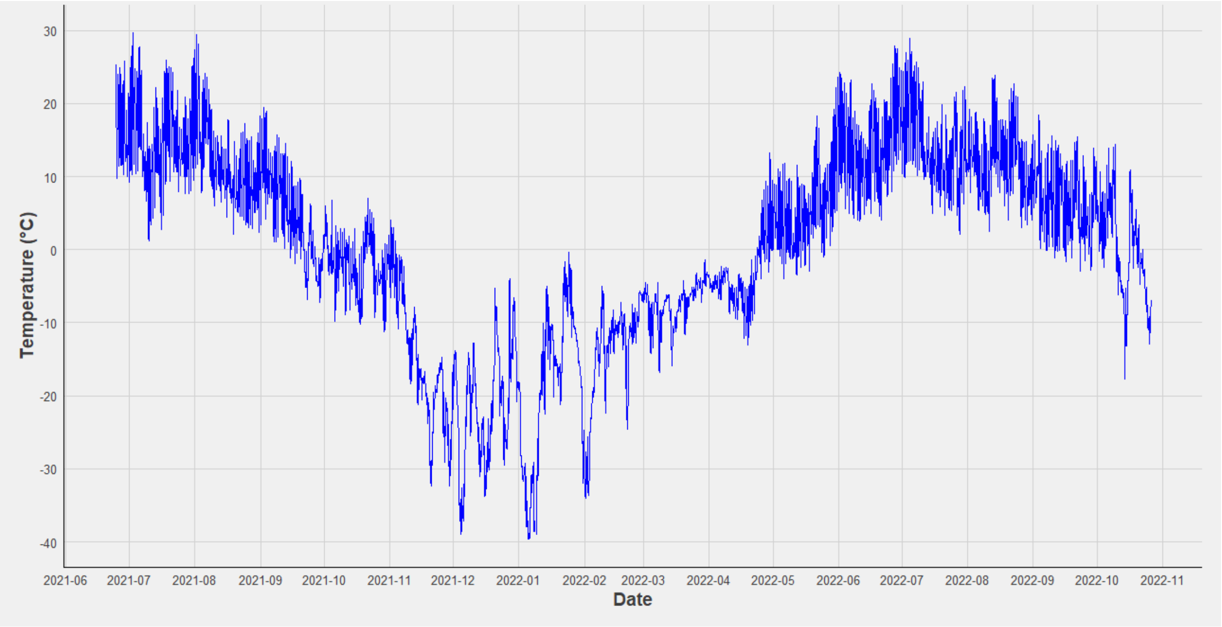


NMR Fall Shrub Height Datasheet

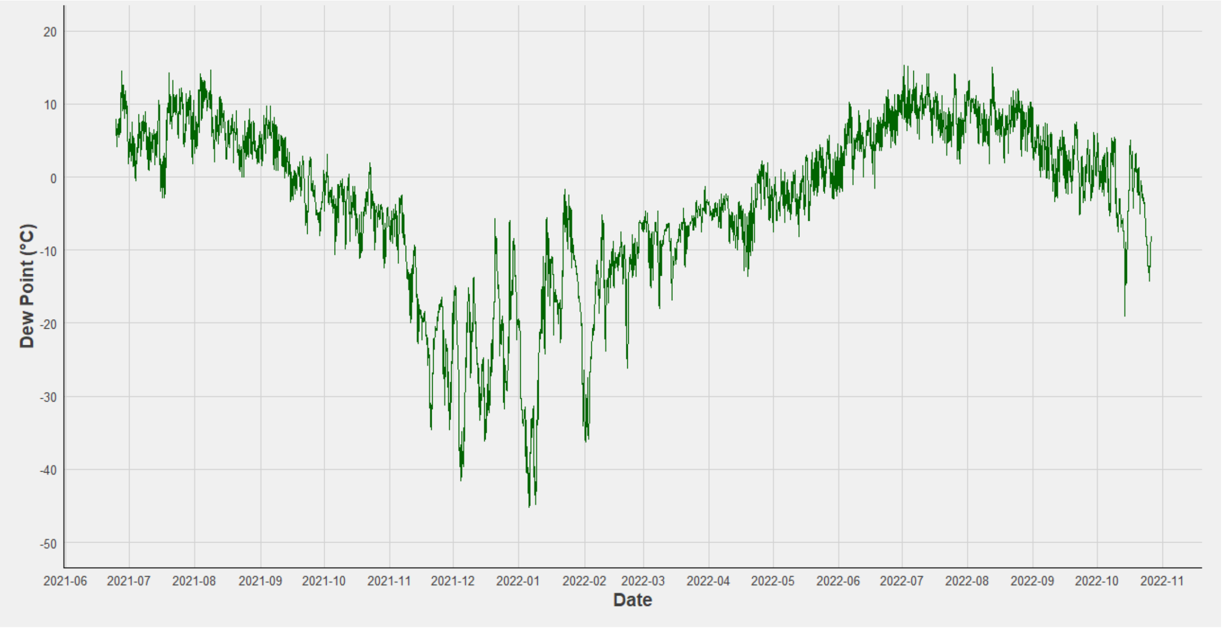
Date ______ Time ______ Crew: ______

Tmt	Block	ID	Species	Fall_Height_cm		Tmt	Block	ID	Species	Fall_Height_cm
1	1	A-B1-08	Alnus			3	1	D-B1-41	Dryas	
1	1	A-B1-09	Alnus			3	1	D-B1-56	Dryas	
1	1	A-B1-16	Alnus			3	1	D-B1-61	Dryas	
1	1	A-B1-17	Alnus			3	1	D-B1-87	Dryas	
1	1	A-B1-19	Alnus			3	1	D-B1-162	Dryas	
1	1	A-B1-28	Alnus			3	1	D-B1-168	Dryas	
1	1	A-B1-49	Alnus			3	1	D-B1-184	Dryas	
1	1	A-B1-66	Alnus			3	1	D-B1-215	Dryas	
1	1	A-B1-70	Alnus			3	1	D-B1-239	Dryas	
1	1	A-B1-80	Alnus			3	1	D-B1-245	Dryas	
1	2	A-B2-18	Alnus			3	2	D-B2-10	Dryas	
1	2	A-B2-23	Alnus			3	2	D-B2-15	Dryas	
1	2	A-B2-27	Alnus			3	2	D-B2-20	Dryas	
1	2	A-B2-39	Alnus			3	2	D-B2-49	Dryas	
1	2	A-B2-42	Alnus			3	2	D-B2-108	Dryas	
1	2	A-B2-51	Alnus			3	2	D-B2-123	Dryas	
1	2	A-B2-53	Alnus			3	2	D-B2-164	Dryas	
1	2	A-B2-58	Alnus			3	2	D-B2-197	Dryas	
1	2	A-B2-67	Alnus			3	2	D-B2-202	Dryas	
1	2	A-B2-77	Alnus			3	2	D-B2-241	Dryas	
1	3	A-B3-13	Alnus			3	3	D-B3-3	Dryas	
1	3	A-B3-16	Alnus			3	3	D-B3-6	Dryas	
1	3	A-B3-33	Alnus			3	3	D-B3-19	Dryas	
1	3	A-B3-36	Alnus			3	3	D-B3-73	Dryas	
1	3	A-B3-37	Alnus			3	3	D-B3-87	Dryas	
1	3	A-B3-44	Alnus			3	3	D-B3-105	Dryas	
1	3	A-B3-45	Alnus			3	3	D-B3-112	Dryas	
1	3	A-B3-52	Alnus			3	3	D-B3-216	Dryas	
1	3	A-B3-54	Alnus			3	3	D-B3-229	Dryas	
1	3	A-B3-69	Alnus			3	3	D-B3-242	Dryas	
1	4	A-B4-04	Alnus			3	4	D-B4-64	Dryas	
1	4	A-B4-26	Alnus			3	4	D-B4-73	Dryas	
1	4	A-B4-28	Alnus			3	4	D-B4-96	Dryas	
1	4	A-B4-37	Alnus			3	4	D-B4-117	Dryas	
1	4	A-B4-47	Alnus			3	4	D-B4-158	Dryas	
1	4	A-B4-50	Alnus			3	4	D-B4-165	Dryas	
1	4	A-B4-63	Alnus			3	4	D-B4-182	Dryas	
1	4	A-B4-67	Alnus			3	4	D-B4-191	Dryas	
1	4	A-B4-75	Alnus			3	4	D-B4-193	Dryas	
1	4	A-B4-78	Alnus			3	4	D-B4-202	Dryas	

Appendix B1 – Minto temperature line chart from June 21, 2021 to October 26, 2022



Appendix B2 – Minto dew point line chart from June 21, 2021 to October 26, 2022



Appendix B3 – Minto relative humidity line chart from June 21, 2021 to October 26, 2022