THE EFFECTS OF STRATIFICATION METHODS ON PAPER BIRCH AND YELLOW BIRCH SEED GERMINATION

By

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ABSTRACT

Tiisler, Thomas. (2022). The effects of stratification methods on paper birch and yellow birch seed germination. Undergraduate Thesis, Lakehead University, Thunder Bay, ON. 42 pp.

Keywords: Germination, silviculture, stratification, climate change, forest management, paper birch (*Betula papyrifera Marsh.*), yellow birch (*Betula alleghaniensis Britt.*), comparing birch species.

This study examines the use of both a typical cold moist stratification method, and an alternative in their ability to affect germination rates in paper birch (*Betula papyrifera*) and yellow birch (*Betula alleghaniensis*). This alternative method entails the freezing and thawing of seeds every second day, while the standard method entails only a single freezing period. Both stratification methods and the experimental control (no stratification) were subjected to a month-long treatment period before germination tests were carried out. The alternative stratification method used in this study performed more poorly than the control, suggesting that freeze-thaw cycles may negatively affect germination of both yellow and paper birch, with germination tests resulting in 1.54% germination in paper birch, and 0.00% germination in yellow birch over a month-long trial period. The traditional method was beneficial to germination in both species, resulting in 67.69% germination for paper birch, and 36.00% germination for yellow birch over a month-long trial period.

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INTRODUCTION

Seed stratification is an essential tool in promoting germination in many species of trees, especially those in temperate and relatively northern climates (Bevington, 1986). Paper birch (*Betula papyrifera*) trees have a large natural range, while yellow birches (*Betula alleghaniensis*) have a comparatively smaller range (Safford, Bjorkbom, & Zasada, 1990). While information on germination and viability is readily available for both species, information comparing stratification methods is scarce. Stratification methods on both species of birch are even less common, with sometimes differing results.

The objective of this study is to determine if there is a significant difference between the germination rates of various stratification methods on both yellow and paper birch seeds, and to see whether a specific stratification method is more effective for one species over another. Two stratification methods will be explored: constant and alternating stratification. My hypothesis is that stratified yellow and paper birch seeds will have significantly higher germination rates compared to unstratified seeds and alternatingly stratified seeds. I also hypothesize that the germination rates of yellow birch seeds will be significantly lower than the germination rates of paper birch seeds, regardless of stratification condition.

LITERATURE REVIEW

Species Overview

Betula papyrifera and *Betula alleghaniensis* are very closely related, with hybridization being relatively common (Barnes, Dancik, & Sharik, 1974). While paper birch has a more boreal distribution, there is some overlap of the species' ranges in Ontario and Quebec.

Yellow birch has historically been the most economically valuable tree in the *Betula* genus (Burton, Anderson, & Riley, 1969; Safford, Bjorkbom, & Zasada, 1990). The area in which it is found naturally ranges from the Maritime provinces across Quebec and into southern Ontario. This species is also very prevalent in the northeastern United States, with its range spreading as far south as northern Georgia, albeit a very small portion (Clausen, 1973; Safford, Bjorkbom, & Zasada, 1990). Yellow birches are monecious, with both male and female flowers appearing on individual trees (Clausen, 1973). Seed production begins as early as seven years of age, with seed crop sizes increasing with tree size and age (Clausen, 1980). It has been noted that yellow birch trees tend to produce seeds cyclically every three years, with the intermediately produced seeds belonging solely to low-vigour specimens (Burton, Anderson, & Riley, 1969). Yellow birch seeds have been found to be normally less viable than paper birch seeds when compared in the same environment (Marquis, 1966).

Paper birch, often referred to as white birch or canoe birch, is the most widespread species of the *Betula* genus in North America. This species' massive range is confined in Canada solely by the tundra, prairies, and some regions of the Rocky Mountains, and extends only into the more northern parts of the contiguous United

States (Safford, Bjorkbom, & Zasada, 1990). Similar to yellow birch, paper birch trees are also monecious, though their seed production begins at 15 years of age (Safford, Bjorkbom, & Zasada, 1990). While paper birch trees tend to produce seeds in alternating years, some populations have been found to produce seeds every year (Safford, Bjorkbom, & Zasada, 1990).

Factors affecting seed germination and viability

Germination of both yellow and paper birch relies on ample soil moisture, and a reduction of exposure to high soil temperatures, with a shaded environment providing assistance in both variables (Marquis, 1966; Willis, Walters, & Farinosi, 2016). A study conducted by Linteau investigated a variety of scenarios, with factors including the degrees of cover, and three soil conditions, with weather phenomena, daily evaporation, and temperature also recorded (1948).

Linteau (1948) found that germination and early survival of yellow birch seeds were mainly affected by the density of canopy cover, as it accounted for large differences in microclimatic conditions. Paper birch seeds were found to germinate twice as often in shaded sites than in full sun sites (Safford, Bjorkbom, & Zasada, 1990). Yellow birch germination was found to be most favourable at sites with moderate tree cover, and very moist soil conditions (Linteau, 1948). This may be due to the availability of light, as it has been found that, in unstratified yellow birch seeds, the water soluble dormancy inhibitor located in the pericarp is broken down by light (Clausen, 1973). Photoperiod length was also found to be a major factor for paper birch germination, with longer photoperiods resulting in greater germination rates (Bevington, 1986). This effect was also observed to be greater with seeds sourced in northern areas with colder climates (Bevington, 1986).

Moisture is the limiting factor for seed germination. Without ample water, the seeds will not germinate. Yellow birch germination was found to be most favourable at sites with moderate tree cover and very moist soil conditions (Linteau, 1948). Moisture is also required for stratification methods, as without it, the effects are merely cold preservation (Benowicz *et al.*, 2000; Bevington, 1986). In fact, too much moisture is not an issue for germination, as seed germination tests in pure water substrate yielded germination rates comparable to other mediums (Yelenosky, 1961).

Temperature is an incredibly important factor when considering germination. High soil temperatures for both species can lead to lower levels of germination because they are generally associated with reduced soil moisture. The effects of high soil temperature can be mitigated by supplemental water (Linteau, 1948; Winget & Kozlowski, 1965). Temperature can also dictate the effects of seed dormancy, with cold moist stratification being an important tool in promoting germination in seeds (Benowicz *et al.*, 2000; Bevington, 1986; Yelenosky, 1961). However, seeds for both species can germinate without stratification, with paper birch seeds from trees in northern, colder climates relying more on light-based stimuli for exiting dormancy rather than temperature (Bevington, 1986). However, yellow birch seeds exhibit much lower germination rates without cold stratification (Clausen, 1973).

In their study "Genetic Variation Among Paper Birch," Benowicz *et al.* (2000) found differences in germination, frost hardiness, growth, and gas exchange amongst populations of paper birch in British Columbia. They found that the speed and rates of germination were significantly higher in the populations with lower winter temperatures, though they used unstratified seeds in their germination tests (Benowicz *et al.*, 2000). It was also shown that seeds from more northern climates responded to shorter periods of chilling than seeds gathered from more southern climates (Benowicz *et al.*, 2000). This is most likely due to the fact that northern seed sources have thinner, more translucent pericarps than southern seeds, allowing more light to pass through to the seed embryo, which in turn allows them to germinate based on light rather than requiring over-wintering (Bevington, 1986). However, it has been shown that all studied paper birch populations, regardless of climate, had higher germination capacity after undergoing stratification (Benowicz *et al.*, 2000; Bevington, 1986; Yelenosky, 1961).

As stated previously, northern climates and latitudes correlate to different germination rates based on environment. Yellow birch seed quality and germination rates have been historically very variable, with this often being attributed to local conditions during pollination, fertilization, and seed development (Clausen, 1980; Marquis, 1969). The effect of seed origin has been observed, with trees located in the Maritimes producing fewer seeds, while trees located in Wisconsin and Minnesota generally produce more (Clausen, 1980). Both paper and yellow birch produce relatively large quantities of seed under optimal conditions that can be dispersed long distances (Marquis, 1969). A good indicator of yellow birch seed viability, regardless of locality, has been shown to be seed crop size, with larger crops resulting in a higher percentage of viable seeds, and smaller crops resulting in a lower percentage of viable seeds (Clausen, 1973). Much like yellow birch, paper birch seed viability and germination rates are positively correlated with seed crop size, with larger crops yielding a higher percentage of viable seeds (Bjorkbom, Marquis, & Cunningham, 1965). Seed weight also tends to be a factor, with heavier seed weights indicating a higher germinative capacity due to the fact that a heavy seed indicates seed maturity, and the absence of decay (Bjorkbom, Marquis, & Cunningham, 1965).

Redmond & Robinson (1954) utilized seed dissection methods to examine the variation in viability of seeds between individual trees. They found that isolated trees have lower seed viability than non-isolated individuals due to low conspecific pollen availability (Clausen, 1973; Redmond & Robinson, 1954).

Yellow birch germination occurs faster when sewn on humus or decayed wood seedbeds than on mineral soil seedbeds. However, the total germination rate is similar on all seedbed types (Redmond & Robinson, 1954; Winget & Kozlowski, 1965). Lower soil horizons will obstruct germination, while higher soil horizons promote germination, with organic humus layers being the preference (Hoyle, 1965). Paper birch germination occurs best on mineral soil, with humus and undisturbed litter being less favourable (Safford, Bjorkbom, & Zasada, 1990). In fact, paper birch seeds sown in humus show a 50% reduction in germination when compared to mineral soil, and those sown in undisturbed litter germinate only 10% of the time compared to mineral soil (Safford, Bjorkbom, & Zasada, 1990).

Stratification methods

Both yellow and paper birch exhibit seed dormancy, with stratification being an effective tool to counter this. However, it has also been shown that unstratified yellow birch seeds can germinate in light, due to the dormancy being induced by a water-soluble inhibitor in the pericarp which is broken down by light (Yelenosky, 1961; Clausen, 1973). In their study on the impact of geographic differences on germination of paper birch seeds, Bevington stored seeds at -23 ℃ until they were used, with a maximum storage of 1 year (1986). These seeds were then prechilled in a 3-4 ℃ chamber before being set in an 18 ℃ chamber and allowed to germinate (Bevington, 1986). The findings were that longer stratification periods resulted in higher overall germination rates, and higher germination speeds (Bevington, 1986). Redmond & Robinson's study (1954) used a novel cold moist stratification method, beginning with storing the seeds at 5°C in a moist setting for two months, then dry storing the seeds at 0°C for another two months before starting germination tests.

Benowicz *et al.* found that seeds gathered from paper birch populations located in more northern climates had a higher germination capacity even without stratification, which they suggested was unnecessary (2000). However, it should be mentioned that seeds sourced from more southern regions were suggested to undergo stratification due to the great effect it had on germination rates (Benowicz *et al.*, 2000). It was also shown that seeds from more northern climates were able to respond to shorter periods of chilling than seeds gathered from more southern climates, which required longer periods (Benowicz *et al.*, 2000). Despite this, it has been shown that all studied paper birch populations, regardless of climate, had higher germination capacity after undergoing stratification (Benowicz *et al.*, 2000; Bevington, 1986; Yelenosky, 1961). Most studies utilized one stratification method, with some omitting stratification. The few studies that did utilize multiple stratification methods mainly used a control group of unstratified seeds, mainly to test if stratification was required (Benowicz et al., 2000; Bevington, 1986). Studies that compare more than one stratification method are rare.

METHODS

Seed Collection and preparation

Collection of seeds took place in mid-October in local forests in the Thunder Bay area, at approximately 48.28, -89.39 DD. We also used previously collected seeds from the university greenhouse that had been originally obtained October 2020. Seeds were collected from 3 seedlots in the area and were bulked together before storage. All seeds were dry-stored prior to starting the experiment. Stratification treatments took place from January to March 2022 in the Lakehead greenhouse. The species *Betula alleghaniensis* Britt., and *Betula papyrifera* Marshall, were compared. The following experiments were conducted in accordance with the procedures outlined in "Seeds of Woody Plants in the United States" (USDA Forest Service, 1989).

Treatments and tests

A total of 100 seeds from each species were used in three different treatments: one unstratified control group, one exposed to a freezer-fridge moist stratification alternating from -18°C to 3°C daily for one month, and one exposed to a cold moist stratification at -18°C for one month. Two tests were done post-stratification to determine germination and viability: a float test and a paper towel medium germination test. A total of 50 seeds from each species were used for the float test, while all of the seeds from each treatment were used in the soil medium test, for a total of 300 seeds used from each species. The germination testing took place over the course of 30 days, with daily monitoring to count how many seeds had germinated each day.

STATISTICAL ANALYSIS

Float test results and greenhouse germination results were compared in a Chi-square test to determine whether the values obtained were expected:

$$\sum \chi^2_{i\text{-}j} = \frac{(O - E)^2}{E}$$

Where O represents the observed value, E represents the expected value, with the sum of each test squared being the result (McHugh, 2013). A general Chi-square test was done to determine significance within all treatments for each species, as well as comparing each method with each other. Results were also compared between the same treatment of both species. Additionally, due to a sharp difference between the results of the alternative stratification and that of the other treatments, a Chi-square test was also conducted within the treatments of each species excluding the alternative stratification method. All Chi-square tests were conducted utilizing an alpha value of 0.05 to determine p-values.

RESULTS

The first germinants appeared on day 11 for the control and stratified paper birch treatments (Figure 2). Stratified yellow birch seeds did not begin germinating until day 14 (Figure 3), and control paper birch seeds did not begin germinating until day 16. Seeds subjected to the alternating stratification did not germinate for yellow birch, but a single paper birch germinant appeared on day 26. Peak germination rates were observed on day 13 for control paper birch, day 14 for stratified paper birch, 15 for stratified yellow birch, and day 17 (tied with day 25) for control yellow birch. Raw data for germination results can be found in Appendices I-VII.

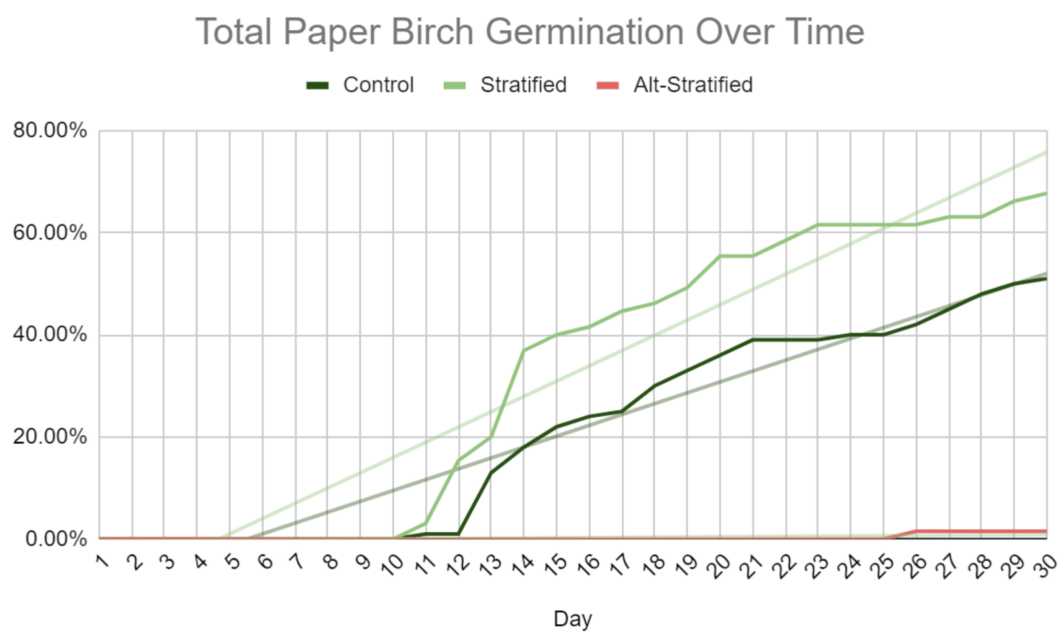

Figure 1. Germination results from stratified and unstratified paper birch seeds.

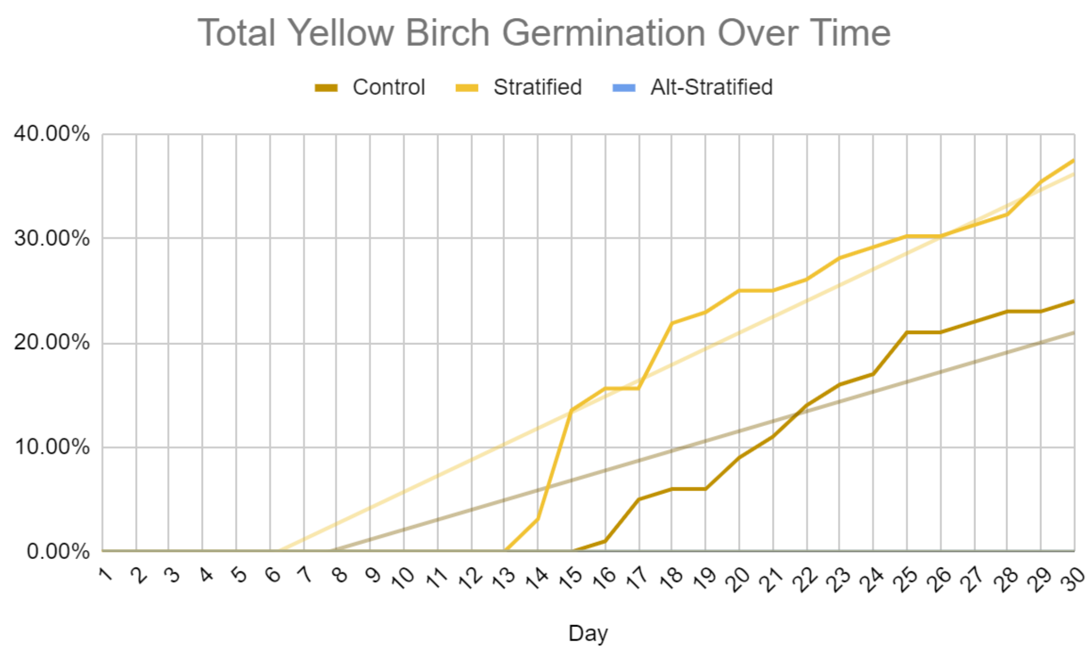

Figure 2. Germination results from stratified and unstratified yellow birch seeds.

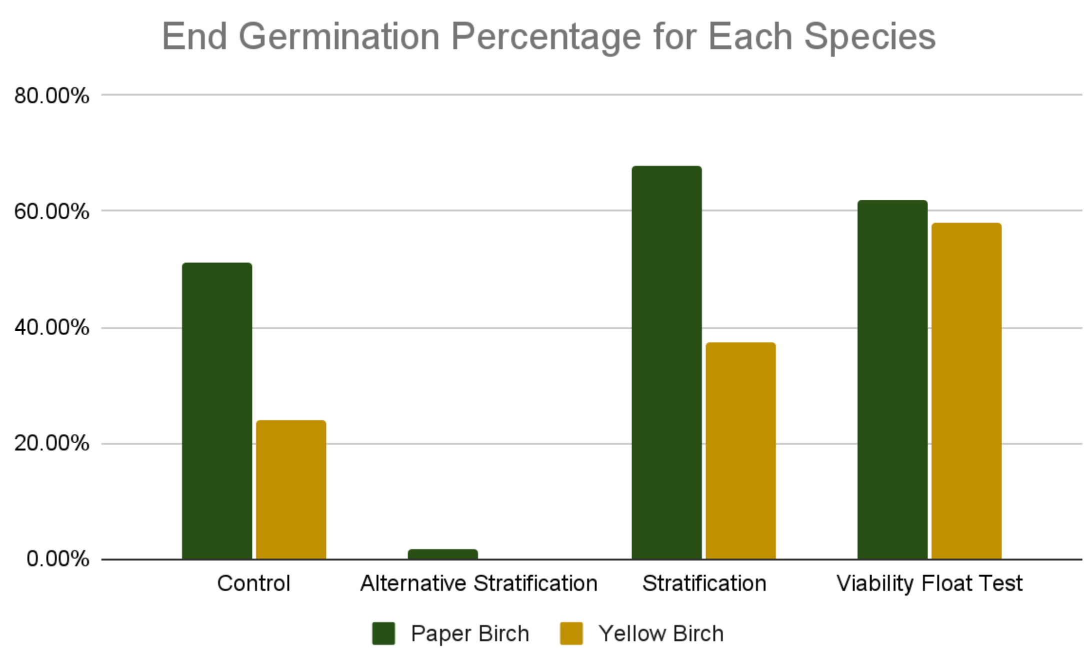

Figure 3. Final germination results by method and species.

Tables 1 to 4 detail multi-tailed Chi-square tests within each species comparing methods. All treatment methods were found to be significantly different for each species. When excluding the alternative stratification method, paper birch was found to have no significant difference between viability tests, stratification, and control treatments, while yellow birch treatments and methods remained significantly different.

Table 1. Chi Square test comparing all methods for yellow birch (x2 critical value = 7.815).

	Viability	Control	Alternative Stratification	Stratification	total
Germinated	29	24	0	36	89
Non-germinated	21	76	98	60	255
total	50	100	98	96	344
E1,1	12.936	25.872	24.837	25.355	
	37.064	74.128	71.163	72.645	
X2	19.948	0.135	5.017	25.355	50.455
	6.962	0.043	1.751	8.849	17.610
					68.065

Table 2. Chi Square Test comparing float test, stratification, and control results for yellow birch (x2 critical value = 5.991).

	Viability	Control	Stratification	total
Germinated	29	24	36	89
Non-germinated	21	76	60	157
total	50	100	96	246
E1,1	18.089	34.732	36.179	
	31.910	61.268	63.821	
X2	6.5819	0.0463	4.010	10.727
	3.7307	0.0267	2.324	6.081
				16.808

Table 3. Chi Square test comparing all methods for paper birch (x2 critical value = 7.815).

	Viability	Control	Alternative Stratification	Stratification	total
Germinated	31	51	1	44	127
Non-germinated	19	49	64	21	153
total	50	100	65	65	280
E1,1	22.678	45.357	29.482	29.482	
	27.321	54.643	35.518	35.518	
X2	3.053	0.702	27.516	7.149	38.420
	2.534	0.583	22.840	5.934	31.891
					70.312

Table 4. Chi Square Test comparing float test, stratification, and control results for paper birch (x2 critical value = 5.991).

	Viability	Control	Stratification	total
Germinated	31	51	44	126
Non-germinated	19	49	21	89
total	50	100	65	215
E1,1	29.302	58.606	38.093	
	20.698	41.395	26.907	
X2	0.098	0.988	0.916	2.001
	0.139	1.397	1.297	2.833
				4.834

Chi-square tests results indicated that germination rates differed significantly between all treatments for yellow birch (Table 5). However, paper birch germination was not significantly different when comparing the viability and control tests and when comparing stratification and viability tests (Table 6). When comparing methods between species, Chi-square tests indicated that viability tests and alternative stratification methods did not differ significantly, while stratified and control groups were significantly different (Table 7).

Table 5. Chi Square Test results among methods in yellow birch, with values that are considered not significantly different bolded (x2 critical value = 3.841).

	Viability	Control	Alternative Stratification	Stratification
Viability	0 (N/A)	16.864	70.692	5.594
Control	16.864	0 (N/A)	26.764	4.202
Alternative Stratification	70.692	26.764	0 (N/A)	45.123
Stratification	5.594	4.202	45.123	0 (N/A)

Table 6. Chi Square Test results among methods in paper birch, with values that are considered not significantly different bolded (x2 critical value = 3.841).

	Viability	Control	Alternative Stratification	Stratification
Viability	0 (N/A)	**1.627**	51.441	**0.404**
Control	**1.627**	0 (N/A)	44.653	4.494
Alternative Stratification	51.441	44.653	0 (N/A)	62.842
Stratification	**0.404**	4.494	62.842	0 (N/A)

Table 7. Chi Square Test results between methods and species, with values that are considered not significantly different bolded (x2 critical value = 3.841).

Viability	Control	Alternative Stratification	Stratification
0.167	15.552	**1.520**	14.133

DISCUSSION

The increase of germination rates in both species of stratified birch seeds suggests a positive correlation between stratification and germination rates. This can be confirmed by comparing the results of other studies where similar results were obtained for paper birch (Benowicz *et al*, 2000; Bevington, 1986; Yelenosky, 1961). This was also supported by previous yellow birch germination studies (Yelenosky, 1961; Clausen, 1973). While these results were expected based on prior studies, the difference between the effects of stratification on each species is relatively unknown. While this study found that stratification had a greater effect on germination rates in paper birch (an increase of 16.69% compared to 13.50% for yellow birch), these effects may be different if given a longer study period. More studies should be conducted to confirm these findings. Additionally, while all combinations of yellow birch treatments were found to be significantly different, the viability test, stratified, and control groups were found to all be not significantly different when compared together. However, when comparing each method with each other individually, it was shown that stratified and control groups were significantly different. While this suggests that stratification has a significant positive effect on paper birch germination, it should also be noted that the paper birch germination results for stratified seeds exceeded the viability test. This could suggest that the viability testing utilized was ineffective or inaccurate. Another potential cause could be that the seed selection for the stratified group had been subject to bias due to human error in the sowing process. This could be explained as not all seeds initially set for the stratified and alternatively stratified seed lots had been used due to the difficulty in finding them in the vermiculite. This could have led to larger, healthier seeds being used due to their ease of visibility, while smaller less visible seeds that would have otherwise decreased the germination percentage being omitted.

In terms of the alternative stratification method, the results paint a different picture. The alternative stratification method was deemed significantly different from the other stratification methods and viability test in both species. Although further testing is required to see at which threshold this begins to have impact, this suggests a near absolute negative impact on seed germination. Only one seed germinated from the paper birch seed lot, while none germinated from the yellow birch seed lot. This may be due to a potential human error wherein this seed may have accidentally been moved to the alternative germination area from the control area during watering. Another issue that may have altered the germination is a lack of water. On day 13 of the germination trial, the germination containers had run out of water and had partially dried mainly in the centre. Since the alternate-stratified seeds were located directly in the centre of each germination container, this could suggest that this was the issue for a lack of germination. However, seeds closer to the centre from both control and stratified groups had also experienced water-loss but remained relatively unaffected. Although apparent, it should also be noted that the alternative stratification method found to be not significantly different between the two species, suggesting a similar negative effect on both species. Previous studies have shown that freeze-thaw cycles can have detrimental effects on seed germination and early growth in plants (Connolly & Orrock, 2015). The results of this study suggest that these findings could also be applied to both yellow birch and paper birch, which due to the alternative stratification, have drastically reduced germination rates. In cases where climate change causes weather where snow cover is minimal, while night temperatures are low, conditions similar to the alternative stratification method could impact seed germination in the environment (Simons, Goulet, & Bellehumeur, 2010; Drescher & Thomas, 2013).

CONCLUSION

This study demonstrated a significant positive effect of traditional stratification treatments on both yellow and paper birch. However, the alternative stratification method was not effective at producing germinants in both species. While this negates application of this method for commercial germination, it may indicate a potential issue in future seed crops as a result of climate change. Additional studies should be conducted focusing on the extent at which freeze-thaw cycles begin to affect birch seeds both in terms of temperature and number of cycles, as these are likely to be the factors most affected by climate change. The results of this study show that the alternative stratification conditions provided are detrimental to seed growth in both paper birch and yellow birch, while traditional stratification is effective in increasing germination rates for both paper and yellow birch species.

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APPENDICES

Appendix I. Float test viability results of stratified and unstratified yellow and paper birch seeds.

Yellow Birch		Paper Birch	
Viable	Non-Viable	Viable	Non-Viable
29	21	31	19

Appendix II. Germination results from the control yellow birch seeds.

Day	Number of germinants	Total germinants	Percent germination
1	0	0	0.00%
2	0	0	0.00%
6	0	0	0.00%
3	0	0	0.00%
4	0	0	0.00%
5	0	0	0.00%
7	0	0	0.00%
8	0	0	0.00%
9	0	0	0.00%
10	0	0	0.00%
11	0	0	0.00%
12	0	0	0.00%
13	0	0	0.00%
14	0	0	0.00%
15	0	0	0.00%
16	1	1	1.04%
17	4	5	5.21%
18	1	6	6.25%
19	0	6	6.25%
20	3	9	9.38%
21	2	11	11.46%
22	3	14	14.58%
23	2	16	16.67%
24	1	17	17.71%
25	4	21	21.88%
26	0	21	21.88%
27	1	22	22.92%
28	1	23	23.96%
29	0	23	23.96%
30	1	24	25.00%

Appendix III. Germination results from the stratified yellow birch seeds.

Day	Number of germinants	Total germinants	Percent germination
1	0	0	0.00%
2	0	0	0.00%
6	0	0	0.00%
3	0	0	0.00%
4	0	0	0.00%
5	0	0	0.00%
7	0	0	0.00%
8	0	0	0.00%
9	0	0	0.00%
10	0	0	0.00%
11	0	0	0.00%
12	0	0	0.00%
13	0	0	0.00%
14	3	3	3.00%
15	10	13	13.00%
16	2	15	15.00%
17	0	15	15.00%
18	6	21	21.00%
19	1	22	22.00%
20	2	24	24.00%
21	0	24	24.00%
22	1	25	25.00%
23	2	27	27.00%
24	1	28	28.00%
25	1	29	29.00%
26	0	29	29.00%
27	1	30	30.00%
28	1	31	31.00%
29	3	34	34.00%
30	2	36	36.00%

Appendix IV. Germination results from the alternatively stratified yellow birch seeds.

Day	Number of germinants	Total germinants	Percent germination
1	0	0	0.00%
2	0	0	0.00%
6	0	0	0.00%
3	0	0	0.00%
4	0	0	0.00%
5	0	0	0.00%
7	0	0	0.00%
8	0	0	0.00%
9	0	0	0.00%
10	0	0	0.00%
11	0	0	0.00%
12	0	0	0.00%
13	0	0	0.00%
14	0	0	0.00%
15	0	0	0.00%
16	0	0	0.00%
17	0	0	0.00%
18	0	0	0.00%
19	0	0	0.00%
20	0	0	0.00%
21	0	0	0.00%
22	0	0	0.00%
23	0	0	0.00%
24	0	0	0.00%
25	0	0	0.00%
26	0	0	0.00%
27	0	0	0.00%
28	0	0	0.00%
29	0	0	0.00%
30	0	0	0.00%

Appendix V. Germination results from the control paper birch seeds.

Day	Number of germinants	Total germinants	Percent germination
1	0	0	0.00%
2	0	0	0.00%
6	0	0	0.00%
3	0	0	0.00%
4	0	0	0.00%
5	0	0	0.00%
7	0	0	0.00%
8	0	0	0.00%
9	0	0	0.00%
10	0	0	0.00%
11	1	1	1.00%
12	0	1	1.00%
13	12	13	13.00%
14	5	18	18.00%
15	4	22	22.00%
16	2	24	24.00%
17	1	25	25.00%
18	5	30	30.00%
19	3	33	33.00%
20	3	36	36.00%
21	3	39	39.00%
22	0	39	39.00%
23	0	39	39.00%
24	1	40	40.00%
25	0	40	40.00%
26	2	42	42.00%
27	3	45	45.00%
28	3	48	48.00%
29	2	50	50.00%
30	1	51	51.00%

Appendix VI. Germination results from the stratified paper birch seeds.

Day	Number of germinants	Total germinants	Percent germination
1	0	0	0.00%
2	0	0	0.00%
6	0	0	0.00%
3	0	0	0.00%
4	0	0	0.00%
5	0	0	0.00%
7	0	0	0.00%
8	0	0	0.00%
9	0	0	0.00%
10	0	0	0.00%
11	2	0	3.08%
12	8	2	15.38%
13	3	10	20.00%
14	11	13	36.92%
15	2	24	40.00%
16	1	26	41.54%
17	2	27	44.62%
18	1	29	46.15%
19	2	30	49.23%
20	4	32	55.38%
21	0	36	55.38%
22	2	36	58.46%
23	2	38	61.54%
24	0	40	61.54%
25	0	40	61.54%
26	0	40	61.54%
27	1	40	63.08%
28	0	41	63.08%
29	2	41	66.15%
30	1	43	67.69%

Appendix VII. Germination results from the alternatively stratified paper birch seeds.

Day	Number of germinants	Total germinants	Percent germination
1	0	0	0.00%
2	0	0	0.00%
6	0	0	0.00%
3	0	0	0.00%
4	0	0	0.00%
5	0	0	0.00%
7	0	0	0.00%
8	0	0	0.00%
9	0	0	0.00%
10	0	0	0.00%
11	0	0	0.00%
12	0	0	0.00%
13	0	0	0.00%
14	0	0	0.00%
15	0	0	0.00%
16	0	0	0.00%
17	0	0	0.00%
18	0	0	0.00%
19	0	0	0.00%
20	0	0	0.00%
21	0	0	0.00%
22	0	0	0.00%
23	0	0	0.00%
24	0	0	0.00%
25	0	0	0.00%
26	1	1	0.00%
27	0	1	0.00%
28	0	1	0.00%
29	0	1	0.00%
30	0	1	1.54%