

GERMINATION AND SURVIVAL OF JACK PINE ON THREE PREPARED CUTOVER SITES

by
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Résumé en français

DEPARTMENT OF FISHERIES AND FORESTRY
CANADIAN FORESTRY SERVICE
PUBLICATION NO. 1283
1970

ABSTRACT

Germination and survival of jack pine (*Pinus banksiana* Lamb.) were studied in southeastern Manitoba on three sites that had been scarified with a middlebuster plow and then clearcut. Germination was significantly greater on a fresh and moderately fresh site than on a dry site. The trough, the base of the south-facing slope, and the base of the north-facing slope of furrows provided the best seedbeds for germination. Mortality was significantly lower on the fresh site, with no significant differences among seedbeds. On the moderately fresh and dry sites, significant but inconsistent differences among seedbeds occurred.

Heat in combination with drought was the main cause of mortality on the dry and moderately fresh sites. Animal damage was also a potential hazard on the latter site. On the fresh site the causes of mortality were distributed with relative evenness.

On the fresh site scarification followed by broadcast seeding with 4 to 8 ounces of seed should provide adequate regeneration. On the moderately fresh site the scarification method used in the study, followed by spot seeding on the trough and the base-of-north-facing-slope seedbeds with 12 ounces of seed per acre, is recommended. A method of site preparation designed to mix mineral soil and humus would probably provide better results and possibly allow broadcast seeding.

Regeneration on the dry site was not satisfactory. More detailed studies of this site are needed and are currently under way.

Published under the authority of the
Minister of Fisheries and Forestry
Ottawa, 1970

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INFORMATION CANADA
OTTAWA, 1970

Catalogue No. Fo 47-1283.



RÉSUMÉ

Dans le sud-est du Manitoba, l'auteur étudia la germination et la survie du Pin gris (*Pinus banksiana* Lamb.) dans trois stations écologiques où l'on venait de scarifier le sol avec un araïre de type middlebuster et de couper les arbres à blanc étoc. La germination s'avéra significativement meilleure en sol frais ou assez frais, comparativement à un sol plutôt sec. Les points les plus favorables à la germination étaient situés dans les raies de sillons et à la base des flancs de rejet nord et sud. Le taux de mortalité baissa significativement en sol frais, sans différence significative d'un semis à l'autre. En sol modérément frais à sec les différences d'un semis à l'autre étaient significatives mais variables.

La chaleur et la sécheresse contribuèrent le plus à la mortalité des jeunes plantes en sol sec à modérément frais; les animaux pouvaient aussi causer certains dommages dans les sols assez frais. En terrain frais, les causes de mortalité étaient relativement égales dans leur distribution.

La régénération forestière en terrain frais peut être assurée par le scarifiage suivi d'un ensemencement à la volée de 4 à 8 onces de graines à l'acre. En terrain modérément frais l'auteur recommande d'utiliser la méthode de scarifiage qu'il décrit, suivie d'ensemencement par points dans les raies et à la base des flancs de rejet nord, avec 12 onces à l'acre; si le sol minéral était préalablement mélangé à l'humus, les résultats seraient probablement meilleurs et permettraient de semer à la volée.

La régénération en sol plutôt sec ne fut pas satisfaisante: à ce sujet des études et expériences supplémentaires sont en cours.

CONTENTS

	Page
INTRODUCTION	1
DESCRIPTION OF AREAS	1
EXPERIMENTAL METHODS	2
GENERAL WEATHER CONDITIONS	4
GERMINATION AND MORTALITY	4
Dry Site	4
Moderately Fresh Site	7
Fresh Site	7
FACTORS AFFECTING SEEDLING GERMINATION AND ESTABLISHMENT .	7
Climatic	7
Biological	12
Time of Germination	14
SEEDLING ESTABLISHMENT POTENTIAL	16
DISCUSSION AND CONCLUSIONS	16
Silvicultural Implications	18
REFERENCES	19

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H.P. Sims¹

INTRODUCTION

Regeneration of jack pine (*Pinus banksiana* Lamb.) after logging has been a major problem throughout the range of this species. In southeastern Manitoba a number of methods of obtaining regeneration have been tested (Johnson, 1955; Jameson, 1953²; Cayford, 1958, 1959) with varied but generally unsuccessful results. These studies and others (Cayford, 1961, 1963, 1966) have indicated that adequate stocking to jack pine results only after fire through an uncut stand, or after scarification followed by slash-scattering or seeding.

In 1960, a study to test the usefulness of scarification obtained with a middlebuster plow was undertaken in southeastern Manitoba. Assessment of germination and survival on the five seedbed types created by this technique was carried out during the period 1962-66 on three jack pine sites common in the area.

DESCRIPTION OF AREAS

The experimental areas are located within the Rainy River (L. 12) Section of the Great Lakes - St. Lawrence Forest Region (Rowe, 1959). The topography of the area is flat to gently rolling.

The studies were carried out on fresh, moderately fresh, and dry sites. These sites are characterized by fine to

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medium sand podzols. Organic horizons range in depth from 1 to 2 inches but on the average do not vary among sites. The solum of the moderately fresh site contains a thin (1-2 inches) horizon of clay and organic colloids, which may be exposed upon scarification. Otherwise the soils have a deep, quite uniform sand profile. The water-table depth ranges from 3 to 7 feet on the fresh site to 8 to 10+ feet on the dry site. Vegetation on the fresh and dry sites is sparse and dominated by ericaceous plants. The moderately fresh site has a denser cover composed of ericaceous plants and deciduous shrubs. Mueller-Dombois (1964) gives a complete description of these sites, classifying them as oligotrophic fresh (fresh), mesotrophic fresh-minus (moderately fresh), and oligotrophic dry (dry).

EXPERIMENTAL METHODS

In the fall of 1962, before logging, seedbeds were mechanically prepared with a tractor-drawn middlebuster plow (Figure 1). This equipment creates a flat-bottomed furrow, approximately 30 inches wide and 3 to 4 inches deep, with an overturned sod ridge on each side. Five distinct seedbeds result - ridge (R), trough (T), undisturbed (U), base of north-facing slope (BNF), and base of south-facing slope (BSF) (Figure 2).

In 1962 only two 1-milacre plots were located on the fresh site, but there were three on each of the other sites. Three 1-milacre plots were established on each of the three sites in 1963 and 1964. Each plot contained 15 seedspots, 1 foot square, three on each of the five seedbeds. Seedspots were broadcast-sown by hand in the spring with 50 seeds each. Seeds were treated with a combination of fungicide and rodent repellent. In the first year after seeding, daily records of germination and mortality were maintained during peak periods; at other times weekly records were kept. In 1963 and 1964 mortality was classified according to cause whenever positive identification was possible. Mortality was tallied in the spring and fall of the second and third years after seeding.

Precipitation was measured with three Beal rain gauges located on each site. The gauges were emptied at weekly intervals. Precipitation data, particularly those relating to periodicity of rainfall, were supplemented by records for Sprague and Piney, Manitoba (Canada Department of Transport, 1962, 1963, 1964). Both stations are within 20 miles of each study area; Piney is within 10 miles of each. Temperature data for 1962 were taken from the monthly weather records of the Department of Transport at Sprague. In 1963 and 1964, air temperature was measured on each site with a thermograph situated at a height of 4.5 feet in a birdhouse shelter.



Figure 1. Middlebuster plow used for scarification.

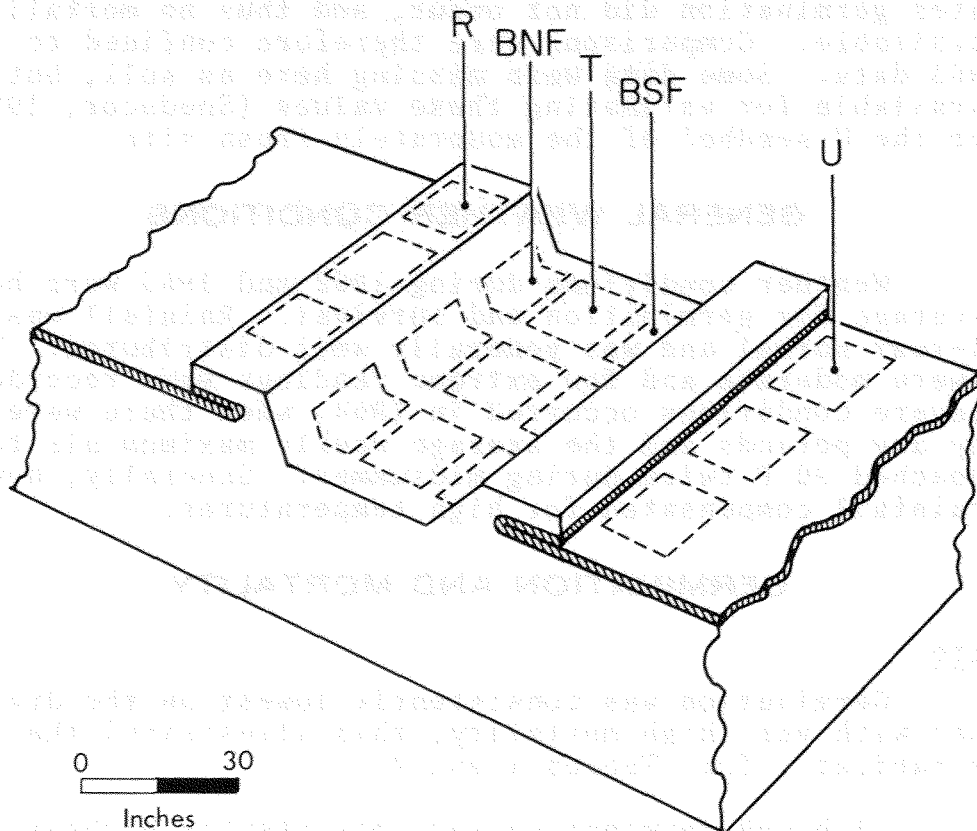


Figure 2. Furrow created by middlebuster plow showing five kinds of seedbed: (U) undisturbed, (T) trough, (BNF) base of north-facing slope, (BSF) base of south-facing slope, and (R) ridge.

Between June 20 and August 1 of 1963, average temperatures of the top 5 mm of soil were measured on each seedbed by means of maximum thermometers. Each thermometer was placed in a shallow depression with the bulb flush with the soil surface and covered with a layer of soil one particle in thickness. The thermometer stems were protected from insolation by strips of burlap.

The treatments were repeated in both time and place, and therefore the data were first analyzed as nine separate experiments (3 sites x 3 years). In all analyses percentages were transformed to $\arcsin \sqrt{\text{Percentage}}$. The results of these individual analyses indicated that the data were suitable for a combined analysis of variance of all experiments. In this analysis of variance treatment means were used. As the results showed no significant interaction between years, site or treatments, t-tests were used to determine the significance of differences between individual treatments and sites (Cochran and Cox, 1957, Chapter XIV). Analysis of the mortality data was limited by missing values. Comparisons could not be made with the 1964 data because on the R and U seedbeds of some of the sites germination did not occur, and thus no mortality data were available. Comparisons were therefore confined to the 1962 and 1963 data. Some data were missing here as well, but enough were available for estimating these values (Snedecor, 1956) on all but the U seedbed of the moderately fresh site.

GENERAL WEATHER CONDITIONS

Weather conditions during 1962 and 1963 were better than average for germination and survival. Rainfall was above the 21-year normal and was generally well distributed. Temperatures were moderate and few extreme readings were recorded. More severe conditions occurred in 1964, when there were two lengthy dry periods and the average weekly maximum air temperature reached 90 F twice during midsummer. Generally, however, high rainfall compensated for high temperatures.

GERMINATION AND MORTALITY

Dry Site

Germination was consistently lowest on the dry site. Combined with very high mortality, this illustrated the severity of the habitat. (See Tables 1 and 2.)

Although germination was consistently highest on the BNF seedbed and lowest on the R seedbed, significant differences (5% level) among seedbeds occurred only in 1962. Mortality on the different seedbeds was extremely variable over the 3-year period. (See Tables 1 and 2.)

TABLE 1. PERCENT GERMINATION- ON PREPARED SEEDBEDS ON THREE SITES IN SOUTHEASTERN MANITOBA - 1962-63-64

Site	Year	Percent germination					All seedbeds
		R	U	T	BNF	BSF	
Fresh	1962 ^a	7.0	3.1	52.8	45.8	44.6	30.6
	1963 ^b	6.2	6.4	23.3	17.8	13.0	13.3
	1964 ^c	0.2	0.0	24.5	35.8	17.9	15.7
Moderately Fresh	1962 ^a	9.0	0.3	27.9	25.6	11.4	14.9
	1963 ^b	2.4	8.1	16.8	15.2	13.0	11.1
	1964 ^c	2.8	0.0	38.4	38.9	22.8	20.6
Dry	1962 ^a	2.8	3.9	11.9	24.3	18.6	12.3
	1963 ^b	1.9	4.1	3.1	7.2	2.4	3.8
	1964 ^c	0.0	2.8	1.2	6.1	0.5	2.1

^aBased on seed viability of 86.0% at time of sowing.

^bBased on seed viability of 91.7% at time of sowing.

^cBased on seed viability of 95.4% at time of sowing.

^dPercentages for any site or seedbeds connected by same line not significantly different at 5% level (moderately fresh and fresh sites calculated on basis of 3 years' average; years not significantly different).

TABLE 2. FIRST-YEAR MORTALITY ON PREPARED SEEDBEDS ON THREE SITES IN SOUTHEASTERN MANITOBA - 1962-63-64

Site	Year	Percent mortality ^a					All seedbeds
		R	U	BSF	BNF	T	
Fresh	1962	22.2	37.5	6.0	4.7	7.4	8.4
	1963	80.8	51.8	37.0	24.3	28.9	36.3
	1964 ^b	100.0	-	35.1	31.7	20.0	28.8
Moderately Fresh	1962	34.3	100.0 ^b	20.4	18.2	23.1	22.1
	1963	100.0	79.4	88.9	61.9	57.1	71.0
	1964 ^b	100.0	-	58.2	56.3	72.1	63.8
Dry	1962	38.3	54.6	33.3	15.2	26.4	30.7
	1963	80.0	76.5	75.0	26.7	38.5	51.3
	1964 ^b	100.0	58.3	-	65.4	40.0	62.2

^aBased on number of seedlings germinated.

^bNot included in comparison.

^cPercentages for any site or seedbed connected by same line not significantly different at 5% level.

An early surge of germination occurred on the BSF and U seedbeds in 1964 and accounts for the minor peak of May 20 to 26 on the average graph (Figure 5). In 1962 and 1963 the occurrence of germination on individual seedbeds did not deviate from the site average.

Moderately Fresh Site

Germination on the moderately fresh site was generally intermediate in relation to that on the dry and the fresh sites but was significantly different only from that on the dry site (Table 1). Mortality was as high as on the dry site and significantly higher than on the fresh site (Table 2).

Arrangement of seedbeds in order of germination was identical to that on the fresh site. There were no significant differences in mortality between seedbeds in 1962 (U was not included owing to insufficient data). Mortality in 1963 was very high for all seedbeds, and significant differences did occur. Missing values prevented comparable analysis of 1964 data. (See Tables 1 and 2.)

Fresh Site

Although total germination was higher on the fresh site than on the moderately fresh site in 2 of the 3 years (Table 1), the difference was not significant. Mortality was significantly higher on the latter site, however (Table 2), thus accentuating the germination difference considerably.

The occurrence of germination and mortality on seedbeds of the fresh site differed from the site average only in 1963, when mortality occurred earlier on the R seedbed. A definite peak in mortality followed immediately after peak germination in each year (Figures 3, 4, and 5).

The arrangement of the seedbeds in order of germination indicated a consistent pattern in all 3 years. Germination on the R and U seedbeds was significantly lower than on the remaining three seedbeds in all years (Table 1). No significant differences in mortality occurred among seedbeds in 1962 and 1963 (1964 was not analyzed owing to missing values). Although mortality on the R seedbed in 1963 was very high, large within-treatment variation rendered nonsignificant the differences between this and other seedbeds. (See Table 2.)

FACTORS AFFECTING SEEDLING GERMINATION AND ESTABLISHMENT

Climatic

In all years germination commenced when weekly mean maximum air temperature had reached 65 F (Figures 3, 4, and 5).

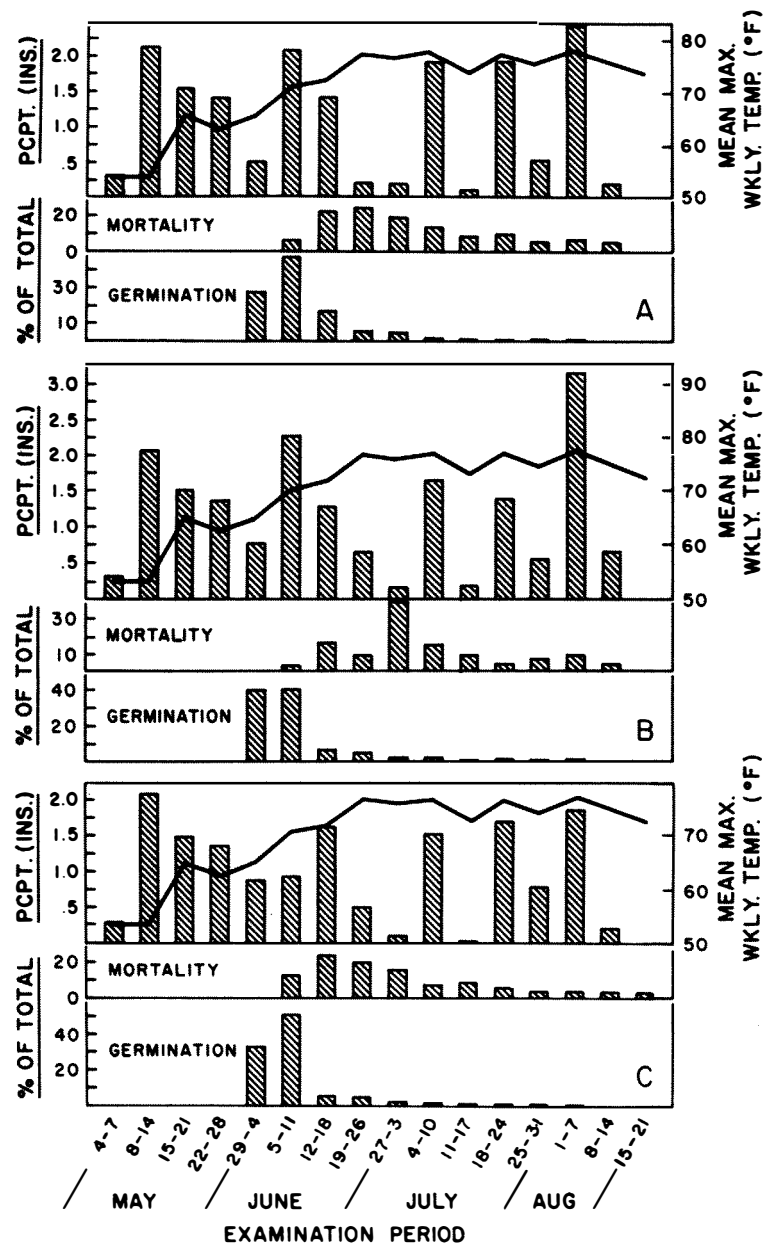


Figure 3. Relation of germination and mortality to climatic factors, 1962:
A - dry site; B - moderately fresh site;
C - fresh site.

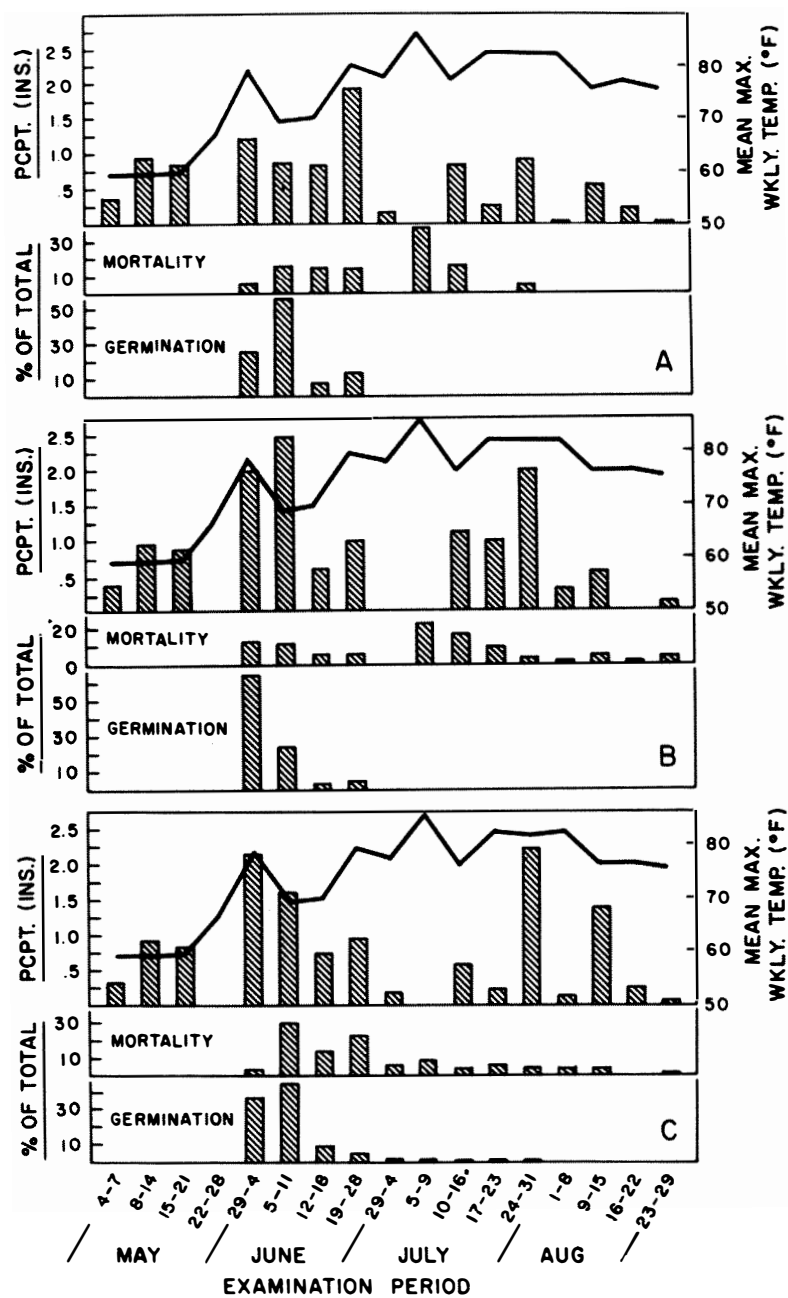


Figure 4. Relation of germination and mortality to climatic factors, 1963:
 A - dry site; B - moderately fresh site;
 C - fresh site.
 *Rainfall mainly on July 16.

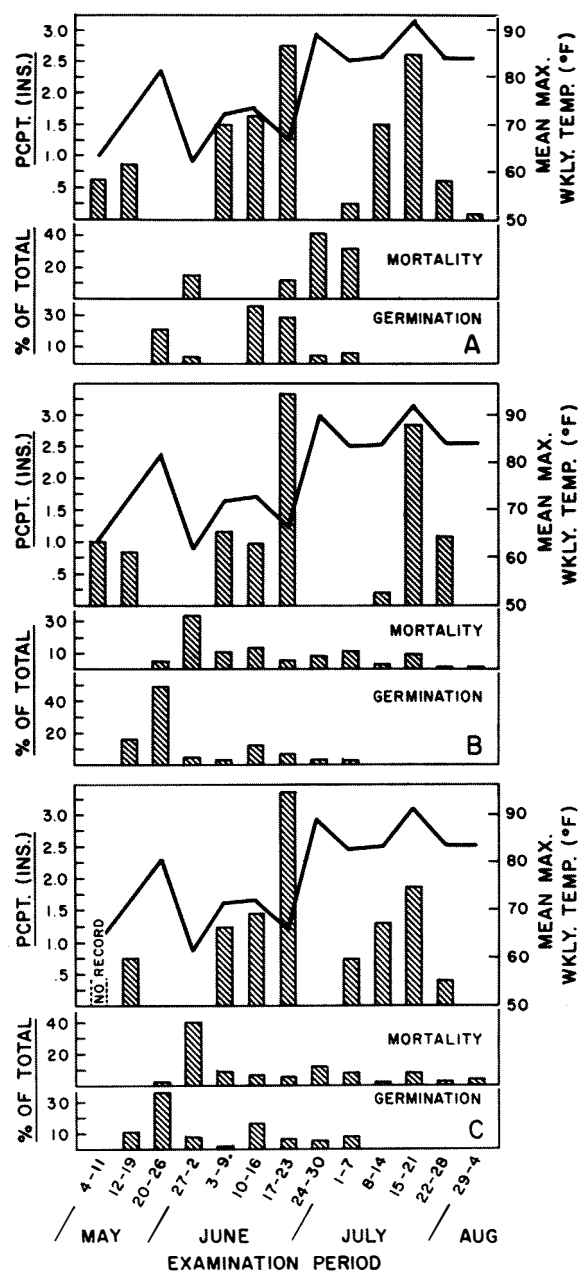


Figure 5. Relation of germination and mortality to climatic factors, 1964: A - dry site; B - moderately fresh site; C - fresh site.

*Rainfall mainly on June 8.

Thus warm temperatures may be the reason for the early germination of 1964, when temperatures reached this value nearly 3 weeks earlier than usual.

Heat combined with drought was a major cause of mortality on the dry and moderately fresh sites (Table 3).

In 1963 almost 50% of mortality on the dry site occurred during the prolonged dry period from June 28 to July 16. More than 80% of mortality during this period was attributed to heat and drought. In 1964 the major peak in germination on the dry site was late in relation to the peaks on other sites and was followed immediately by a severe dry period; 70% of total mortality occurred at this time (Figure 5) and was almost entirely attributed to heat and drought.

On the moderately fresh site heat and drought accounted for more than half of total mortality in 1963. The weather that prevailed during the period from June 29 to July 9 was the chief cause (Figure 4). Many of the seedlings weakened during this period did not recover with replenished moisture; more than 90% of the mortality occurring between June 29 and July 23 resulted from heat and drought. In 1964, 42% of total mortality on the moderately fresh site occurred during the droughty period from May 20 to June 8. Temperatures were extreme and frost and heat and drought accounted for 95% of mortality during this period. A second, more severe dry period resulted in approximately 30%

TABLE 3. DISTRIBUTION BY CAUSE OF TOTAL FIRST-YEAR MORTALITY FOR EACH SITE

Site	Year	Percent of total mortality			
		Cause			
		Heat and drought	Damping-off	Animal	Other
Dry	1963	50	15	6	29
	1964	65	0	3	32
Moderately fresh	1963	51	11	24	14
	1964	42	2	5	51
Fresh	1963	30	32	16	22
	1964	10	21	7	62

of total mortality. Damage during this period (Figure 5) was probably lessened by the hardier condition of the older seedlings. Overall, heat and drought alone accounted for more than 40% of mortality in 1964 on the moderately fresh site, while frost caused approximately 15%.

On the fresh site mortality from heat and drought occurred mainly during July and August of 1963 but was not so prevalent as on the other two sites in that year. In 1964 no definite incidence of heat and drought damage was noted on the fresh site until late July. Although precipitation was nil during a 3-week period in late May (Figure 5), cool weather prevailed and heat and drought were not considered a factor in mortality. On the whole, only 10% of mortality was attributed to heat and drought. Thirty-two percent of total mortality was caused by frost during the week of May 27.

The small study of seedbed surface temperatures carried out in 1963 covered the period of most extreme climatic conditions of that year. More than 50% of total mortality occurred during the period, including most of that attributed to heat and drought.

The severity of the dry site is illustrated by the greater average, extreme, and duration of extreme temperatures (Table 4). Temperatures on the moderately fresh site were not so severe as on the dry site, but drought was probably a dominant factor owing to exposure of the B_t horizon on the furrow bottoms. While moist, this horizon provides a good seedbed for germination but forms a hard droughty surface during periods of hot, dry weather. The effect on germination is illustrated by the high mortality on the T seedbed of the moderately fresh site (Tables 2 and 4).

As expected, conditions were most severe on the R, U, and BSF seedbeds of the dry and moderately fresh sites.

A detailed study of moisture conditions was not carried out, but cursory data collected, though incomplete, did indicate that moisture conditions on the fresh site remain considerably better than on the dry and moderately fresh sites during prolonged dry periods. This is borne out by the relatively low incidence of heat and drought mortality on the R, U, and BSF seedbeds, particularly in comparison with the seedbeds of the moderately fresh site where seedbed temperatures were similar.

Biological

Damping-off and animal damage were of minor importance on the dry site in 1963 and 1964. Damage caused by animals was a major factor on the moderately fresh site in 1963 (Table 3).

TABLE 4. RELATIONSHIP OF FIRST-YEAR MORTALITY TO
SEEDBED TEMPERATURES FOR EACH SITE

Site	Seedbed	Percent ^a mortality (heat and drought)			Average daily max surface temp (°F) (1963)	Extreme max surface temp (°F) (1963)	Days with surface temp ≥120 F (1963)	Period of temp measurement ^c (days)
		1963	1964	Avg				
Dry	R	38 ^b	-	38	116	143	21	43
	T	15	20 ^b	17	106	134	10	43
	U	29	42	34	121	151	24	43
	BNF	10	42	25	103	130	6	41
	BSF	70	50 ^b	67	123	153	28	43
Moderately fresh	R	60	58	59	118	150	22	43
	T	28	27	28	97	126	3	43
	U	44	-	44	119	143	22	43
	BNF	28	21	23	93	117	0	43
	BSF	46	33	38	97	128	1	43
Fresh	R	12	0 ^b	11	119	148	26	43
	T	7	3	5	94	110	0	43
	U	11	-	11	121	147	27	43
	BNF	11	1	4	94	114	0	43
	BSF	17	9	12	101	120	1	43

^aExpressed as percent of total germination per seedbed.

^bPercentages based on fewer than 10 seedlings.

^cJune 20 to August 1 inclusive.

Mortality occurred during the periods from May 29 to June 28 and from August 3 to October 4. The damage took two forms: during the first period the cotyledons were badly chewed, but the entire stem was usually left; during the second period, the entire seedling was removed, the stem being clipped at ground level. The species of rodent or insect causing the damage was not identified in either case, but grasshoppers are suspected in the latter period: this period coincided with a noticeable increase in the grasshopper population, and similar damage to Douglas-fir seedlings in British Columbia (Illingworth, 1966) was associated with two species of grasshoppers, of which *Melanoplus fasciatus* (F. Walker) is also very common on jack pine sites in southeastern Manitoba. Mortality attributed to unknown causes occurred among the seedlings mainly during the period of May 29 to June 28. Many were missing, possibly having been removed by insects or rodents. In 1964 animal damage did not seem to be a major mortality factor on any of the three sites, but 107 seedlings disappeared from the moderately fresh site. If insects or rodents were the cause of these losses, the incidence of animal damage was similar to that of 1963.

In 1963 damping-off occurred entirely during June on the fresh site and accounted for almost a third of total mortality (Table 3). Animal damage was evident but not a major mortality factor. In 1964, 40% of total mortality on the fresh site occurred during a 3-week period in late May (Figure 5). Much of this mortality occurred immediately after germination and was attributed to damping-off. Animal damage was of minor importance on the site in 1964, but 30% of total mortality was made up of missing germinants. Insects often removed entire seedlings, and seedlings killed by damping-off could easily be washed or blown from the plots.

Time of Germination

In 1962 and 1963 germination began during the last week of May and the first week of June and was 75 to 90% completed by June 11. Quite a different pattern occurred in 1964: on the two fresh sites germination began very early in May and was more than 50% completed by June 2. On the dry site it began 1 week later, and 65% occurred between June 10 and 23.

Mortality was related to period of germination in 1963 and 1964 (Table 5). From these data it appears that early germinants have a slightly higher chance of survival. However, if germination is too early, heavy mortality may occur, as in 1964. The data suggest that in terms of survival the last week of May and the first 2 weeks of June is the optimum time to obtain germination.

TABLE 5. SEASONAL MORTALITY OF GERMINATION

Germination period		<u>Number germinants/Percent mortality</u>			
		Dry	Moderately fresh	Fresh	Average
<u>1963</u>					
May	29 - June 4	19/58	150/65	102/31	271/52
June	5 - 11	43/40	61/79	122/38	226/49
	12 - 18	6/67	7/86	28/57	41/63
	19 - 28	10/80	10/100	14/36	34/68
	29 - July 4	-/-	2/100	6/17	8/38
July	5 - 30	-/-	1/100	6/17	7/28
<u>1964</u>					
May	12 - 19	-/-	74/74	34/62	108/70
	20 - 26	9/67	218/62	124/32	351/51
	27 - June 2	1/0	22/50	28/18	51/31
June	3 - 9	-/-	15/47	6/0	21/33
	10 - 16	16/75	55/67	56/32	127/53
	17 - 23	13/69	28/86	24/25	65/60
	24 - 30	1/0	10/90	16/12	27/41
July	1 - 7	2/0	11/27	29/7	42/12
	8 - Sept. 22	3/33	9/22	20/15	32/19

SEEDLING ESTABLISHMENT POTENTIAL

In Table 6, survival is expressed as a seeds-per-seedling ratio for 1-, 2-, and 3-year-old seedlings. Variation in ratios increased with the dryness of the site. The 3 years compared very closely on the fresh site, particularly on the most favorable seedbeds (T, BNF, BSF). The variation was considerably greater on the R and U seedbeds. Also of significance is the very small change in the ratio after the first year, which indicates that on the fresh site a seedling surviving 1 year is very well established.

The weather conditions of 1962, 1963, and 1964 do not represent the extreme range to be expected. The results, however, give some indication of the relative variability to be expected in regeneration success on the three sites. In this respect it is interesting to note the results of Cayford and Dobbs (1967), who found that 24 seeds were necessary to produce one 3-year-old seedling on a dry site (from 1964 through 1966). This ratio is much below the 153:1 for the same 3 years covered in this study and illustrates that geographical variability, largely due to local weather conditions, as well as annual variability, is to be expected on this critical site type. The seeds-per-seedling ratios for the fresh site compared much more closely, being 10:1 in this study and 38:1 in Cayford and Dobbs' study.

DISCUSSION AND CONCLUSIONS

Weather conditions during the study period were quite variable and therefore, from the consistency of the results, it may be concluded that successful seedling establishment will increase with moisture regime, at least to the level of fresh. It is also possible to select the optimum seedbed with respect to germination, although seedbed differences, while consistent, were not always significant on the dry site.

The effect of site is reflected in the total germination and mortality of the individual seedbeds. The dry habitat accentuates microclimatic effect, with the result that all seedbeds are severe environments for germination. The fresh site has a moderating effect on microclimatic factors that influence mortality, but germination differences are more apparent. Total germination and mortality increase and decrease respectively from dry to fresh habitat.

On the dry and moderately fresh sites, heat and drought is a major cause of mortality and is most prevalent on R, U, and BSF seedbeds. Animal damage is also a critical factor on the moderately fresh site. On the fresh site, the causes of mortality are distributed with relative evenness, although mortality follows more closely behind germination than on other sites, probably because of the potential of this site for damping-off.

TABLE 6. SEEDS-PER-SEEDLING RATIO FOR 1- TO 3-YEAR-OLD JACK PINE

		Seedbed																	
		R			T			U			BNF			BSF			Average		
		Age (years)																	
Site	Seeding year	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Dry	1962	77	97	387	10	10	10	32	43	55	7	8	9	7	8	8	12	13	14
	1963	206	413	413	52	52	52	103	206	206	19	20	20	206	206	206	54	61	61
	1964	>429	>429	>429	143	143	214	86	86	143	43	48	48	>429	>429	>429	119	126	153
Moderately fresh	1962	16	30	39	5	5	5	>387	>387	>387	5	5	6	11	11	11	9	10	11
	1963	>413	>413	>413	14	16	16	59	83	206	17	52	59	69	69	69	31	47	52
	1964	>429	>429	>429	9	12	13	>429	>429	>429	6	7	8	10	15	15	13	17	19
Fresh	1962	18	26	29	2	2	2	52	52	52	2	2	3	2	2	2	4	4	4
	1963	83	83	83	6	8	8	32	41	41	7	9	9	12	14	15	12	14	15
	1964	>429	>429	>429	5	5	6	>429	>429	>429	4	4	4	8	9	10	9	9	10

Silvicultural Implications

On the basis of the results obtained, broadcast seeding is recommended for the fresh site. Germination was relatively high on this site and survival adequate on all seedbeds except in 1964 on the R and U.

The method of scarification used is considered adequate: in 41 trials seedbed distribution averaged 28% mineral-soil furrow, 23% mineral-soil ridge, and 49% undisturbed (unpublished data, Manitoba-Saskatchewan Region). Although statistically significant differences in germination occurred between the R and U and the T and BNF seedbeds, survival was so high on the former that this difference cannot be considered significant in terms of adequate seedling catch. Substantially less seed could be used on the fresh site than would be needed on the other two. Under conditions of the study, 4 to 5 ounces of viable seed per acre seem adequate and 7 to 8 ounces should result in adequate survival under more severe conditions. These quantities would provide approximately 1,500 to 2,000 seedlings per acre at the end of the first year and 1,200 by age 3 years.

Although germination was high on the moderately fresh site, mortality was usually high there also. Germination on the R and U seedbeds was not consistent. With the site preparation used, spot seeding on the T and BNF seedbeds would provide the best results. On the basis of figures of lowest germination and highest mortality, 6' x 6' spot seeding with 12 ounces of seed per acre would provide for the survival of 4,000 seedlings per acre at the end of the first year and 1,200 by the end of 3 years. On the average, survival after 1 year was much better than this. However, a better method of preparation could probably be devised for this site. Furrowing sometimes exposes the B_t horizon, which compacts and dries and thus causes severe moisture and temperature conditions and heavy mortality. Also, with furrowing, the lush vegetation remains on the undisturbed portions of the area and also sprouts from exposed roots on the warm ridge seedbed. The result is overtopping and suppression of seedlings on the BNF and T seedbeds. A method of site preparation designed to mix the mineral soil and the humus on this site would probably provide better results, because the seedlings would not have their initial start in furrow bottoms below the level of vegetation. It might also allow broadcast seeding.

Results on the dry site were not satisfactory, and differences in germination and survival among seedbeds were not conclusive. More detailed studies of the environment of this site are currently under way.

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1283-11-70-3.6M