O.D.C. 232.324:174.7 Picea glauca

EARLY SURVIVAL AND GROWTH OF WHITE SPRUCE PLANTATIONS, RIDING MOUNTAIN NATIONAL PARK, MANITOBA

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ABSTRACT

Early results from a number of plantations at the Riding Mountain Forest Experimental Area showed that transplant survival was better on fresh to moist sites that had been scalped or disked before planting than on wetter sites or on untreated ground. Height growth showed no relation to site but was better on areas disked before planting than on areas treated by other methods. Summer-planted transplants survived and grew as well as transplants planted in the spring or fall. Elk trampling caused much mortality; frost, especially in low-lying areas, reduced height growth.

EXTRAIT

Dans la région d'expérimentation forestière de Riding Mountain, au Manitoba, la survie des plants est meilleure dans les stations écologiques fraîches à légèrement humides, préalablement scarifiées puis hersées avec un pulvérisateur. Leur hauteur varie directement avec le hersage, mais n'est pas influencée par la station. La saison de transplantation (printemps, été ou automne) produit également bien la reprise. Un grand nombre de sujets sont morts piétinés par les wapitis. Les gelées, surtout en lieux bas, ont réduit la croissance.

ACKNOWLEDGMENT

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R.E. Tucker,[1] J.M. Jarvis[2] and R.M. Waldron[3]

INTRODUCTION

Initial white spruce (*Picea glauca* (Moench) Voss) reforestation programs on Riding and Duck mountains met with little success, and surveys failed to disclose definite reasons for poor survival (Haig 1959).[4] Between 1951 and 1957, therefore, several small plantations were established at the Riding Mountain Forest Experimental Area for the purpose of studying development of white spruce transplants in relation to their environment and obtaining a biological base for development of sound planting techniques.

This report presents the first 10-year results in the form of case histories.[5] Factors affecting transplant survival and development are discussed, and planting procedures are recommended for white spruce on upland clay-loam soils at Riding Mountain and in similar areas in other parts of the Mixedwood Forest Section of the Boreal Forest Region (Rowe 1959).

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[4]Haig, R.A. 1959. Reforestation by planting, 1918-1930, Riding and Duck mountains, Manitoba and Saskatchewan. Canada Department of Northern Affairs and National Resources, Forestry Branch, Forest Research Division, Unpublished manuscript.

[5]For two of the plantations the results cover less than 10 years.

STUDY AREA

The Riding Mountain Forest Experimental Area is situated about 140 miles northwest of Winnipeg. White spruce-trembling aspen (*Populus tremuloides* Michx.) is the characteristic forest type. The terrain is undulating and the parent-soil materials are clay-loam tills. The characteristic soil profile belongs to the Gray Wooded Great Group of the Podzolic Order (Anon. 1960). Fresh to moist sites (Hills 1952) occupy about 95 per cent of the area, and very moist to wet sites occupy the remainder. Hazel (*Corylus cornuta* Marsh.) is the dominant species on fresh to moderately moist sites, reed grass (*Calamagrostis canadensis* (Michx.) Beauv.) on moist to very moist sites, and alder (*Alnus rugosa* (Du Roi) Spreng. var. *americana* (Regel) Fern.) and a variety of grasses and herbs on wet sites. For a detailed description of the forest research area, refer to Waldron (1966).

PLANTATION CASE HISTORIES

Plantation: 1 (= Project MS-160-2; Expt. #1 (J.M. Jarvis *et al.* 1966))

Time of planting: May 1951

Purpose: To compare early survival and growth of 2-2 and 2-3 white spruce stock planted in the spring on (a) hand-scalped spots, (b) machine-disked strips and (c) undisturbed ground.

Methods: The plantation was established on a gentle south-facing slope; the soil was rated a fresh to moderately moist clay-loam till. No tree overstory was present at the time of planting, but lesser vegetation was dominated by grasses and some hazel.

The plantation occupies an area of about 2 acres. Transplants were center-hole-planted at 6-foot intervals in alternate rows on 18-inch-square scalped spots made with grub hoes, 7-foot-wide disked strips made with an Athens plough and untreated ground. At the time of planting 2-2 stock averaged 7 inches in height and 2-3 stock 12 inches.

Results: Survival of 2-3 stock after the first 10 growing seasons was better than that of the 2-2 stock. Survival was best on hand-scalped spots, intermediate on machine-disked strips and poorest on undisturbed ground. Nearly all mortality in the 2-3 stock occurred within the first two growing seasons; in the 2-2 stock, however, appreciable mortality continued for about five years (Table 1).

TABLE 1. PER CENT SURVIVAL OF 2-2 AND 2-3 STOCK PLANTED IN 1951 ON HAND-SCALPED SPOTS, MACHINE-DISKED STRIPS AND UNDISTURBED GROUND

Treatment	Number planted	Per cent survival				
		1951	1952	1953	1956	1960
		2-2 stock				
Hand-scalped spots	496	99	71	59	50	49
Machine-disked strips	496	96	60	52	46	42
Undisturbed ground	496	98	58	42	40	39
		2-3 stock				
Hand-scalped spots	496	99	68	68	68	68
Machine-disked strips	496	99	67	64	64	60
Undisturbed ground	496	97	63	60	60	60

After 10 growing seasons, a greater percentage of the surviving 2-3 than of the surviving 2-2 transplants was in a taller height class (Fig. 1). The average height of 2-3 transplants was 4.5 feet and that of 2-2 transplants was 3.2 feet.

The percentage of survivors in the taller height classes was greater on the treated areas than on the untreated (Fig. 2). The average height of transplants on treated areas was 4.0 feet and on untreated areas 3.6 feet.

Comments: Records reveal that the month of May 1951 was dry and warm. The first soaking rain occurred one week after planting had been completed, and severe frost occurred on two successive nights during the first week of June.

Observations in mid-June 1951 showed:

(1) that frost had damaged most of the new growth on 79 per cent of the seedlings on untreated areas and on 67 per cent of those on treated areas,

(2) that 22 per cent of the transplants on machine-disked strips and 8 per cent of those on hand-scalped spots and undisturbed ground had been killed by elk trampling, and

(3) that in general, transplants on hand-scalped spots and machine-disked strips appeared to be more healthy than those on undisturbed areas and that the 2-3 stock appeared to be more vigorous than the 2-2 stock.

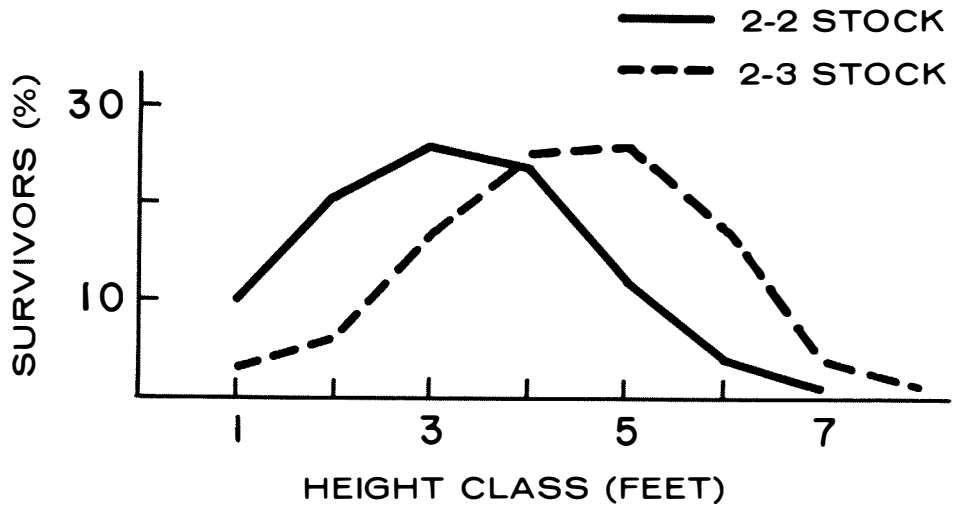


Figure 1. Height distribution of surviving 2-2 and 2-3 stock after 10 growing seasons.

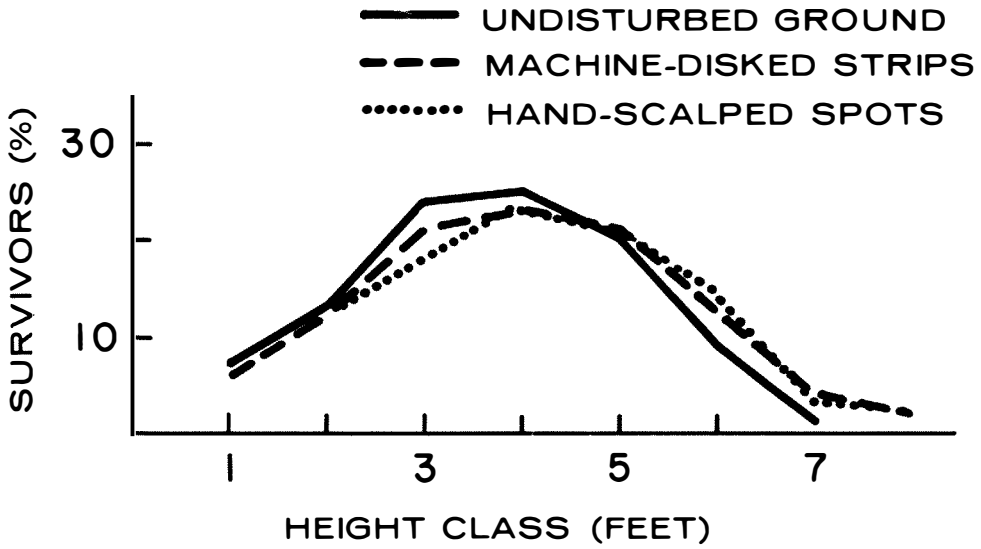


Figure 2. Height distribution of surviving transplants on undisturbed ground, machine-disked strips and hand-scalped spots, after 10 growing seasons.

Plantation: 2 (= Project MS-160-5, Expt. #1 (J.M. Jarvis *et al.* 1966))

Time of planting: May 1951

Purpose: To compare early survival and growth of 2-2 and 2-3 white spruce stock planted under hazel and on ground cleared of hazel.

Methods: The plantation was established on a west-facing mid-slope; the soil was classified as a fresh, clay-loam till. The slope had been cut over, and at the time of planting the overstory consisted of a few scattered trembling aspen with a dense understory of hazel.

The plantation is located on an area about 50 x 130 feet, half having been cleared of hazel and half left undisturbed. Transplants were center-hole-planted (5 x 5 foot spacing) in rows under both conditions. At the time of planting, the 2-2 stock averaged 7 inches in height and the 2-3 stock 12 inches.

Results: Survival of transplants after seven growing seasons was better where hazel had been removed than where it had been left undisturbed. Survival of 2-3 stock was better than that of the 2-2 stock. Most mortality for both stock classes occurred in the first three growing seasons (Table 2).

After seven growing seasons, the height of surviving transplants was virtually the same for both treatments (2.2 feet) (Fig. 3). The percentage of surviving 2-3 transplants in the taller height classes was greater than that of surviving 2-2 transplants in these classes (Fig. 4). The average height was 2.5 feet for 2-3 transplants and 1.7 feet for 2-2 transplants.

TABLE 2. PER CENT SURVIVAL OF 2-2 AND 2-3 STOCK PLANTED IN 1951 UNDER HAZEL AND ON GROUND CLEARED OF HAZEL

Treatment	Number planted	Per cent survival				
		1952	1953	1954	1956	1957
				2-2 stock		
Hazel cleared	47	83	79	79	68	66
Hazel not cleared	47	38	38	17	13	13
				2-3 stock		
Hazel cleared	44	87	86	79	79	73
Hazel not cleared	52	86	79	79	67	63

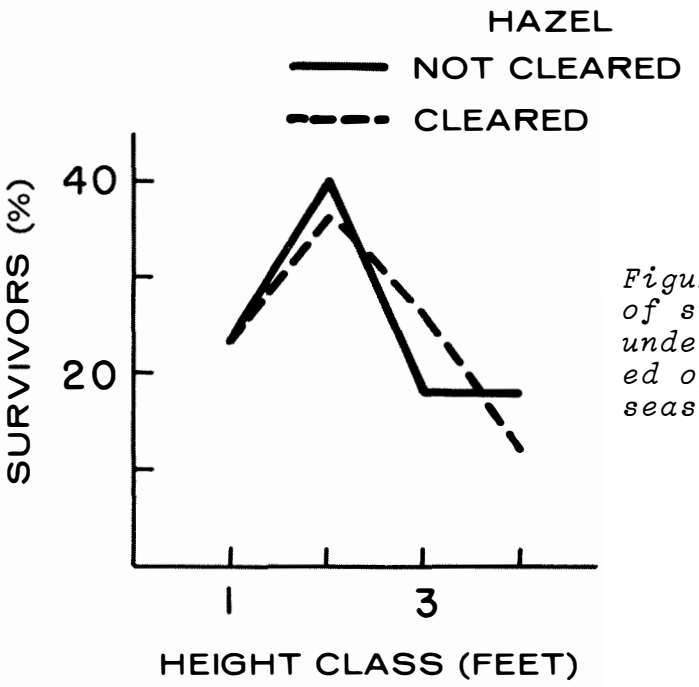


Figure 3. Height distribution of surviving transplants planted under hazel and on ground cleared of hazel, after seven growing seasons.

Figure 4. Height distribution of surviving 2-2 and 2-3 stock after seven growing seasons.

Comments: During planting, the weather was warm and dry, and soil moisture conditions were unfavorable for transplant establishment. On two successive nights in June 1951 frost did considerable damage to the new growth.

Plantation: 3 (= Project MS-160-2; Expt. #2 (J.M. Jarvis *et al.* 1966))

Time of planting: September 1951

Purpose: To compare early survival and growth of 2-3 and 2-4 white spruce stock planted in the fall on (a) hand-scalped spots, (b) machine-disked strips and (c) undisturbed ground.

Methods: The plantation was established on the top and the north-facing side of a low ridge classified as a fresh, clay-loam till. No tree overstory was present, but the area was covered with a dense stand of hazel.

The plantation occupies an area of about 2 acres. Transplants were center-hole-planted at 6-foot intervals in alternate rows on 18-inch-square, scalped spots made with grub hoes, on 7-foot-wide disked strips made with an Athens plough and on untreated ground. At the time of planting, 2-3 stock averaged 10 inches in height and 2-4 stock 12 inches.

Results: After 10 growing seasons, survival of 2-3 stock was better than that of 2-4 stock on disked and undisturbed ground, but on hand-scalped spots survival was the same for both classes. Survival was better on hand-scalped spots and on machine-disked strips than on undisturbed areas. Most mortality occurred in the first four growing seasons after planting (Table 3).

After 10 growing seasons the percentage of surviving 2-4 transplants in the taller height classes was

TABLE 3. PER CENT SURVIVAL OF 2-3 AND 2-4 STOCK PLANTED IN 1951 ON HAND-SCALPED SPOTS, MACHINE-DISKED STRIPS AND UNDISTURBED GROUND

Treatment	Number planted	Per cent survival				
		1952	1953	1954	1956	1961
		2-3 stock				
Hand-scalped spots	379	91	79	75	70	61
Machine-disked strips	376	88	86	81	73	61
Undisturbed	371	85	66	62	58	52
		2-4 stock				
Hand-scalped spots	402	79	77	75	66	61
Machine-disked strips	398	73	73	69	65	51
Undisturbed	396	65	56	56	48	44

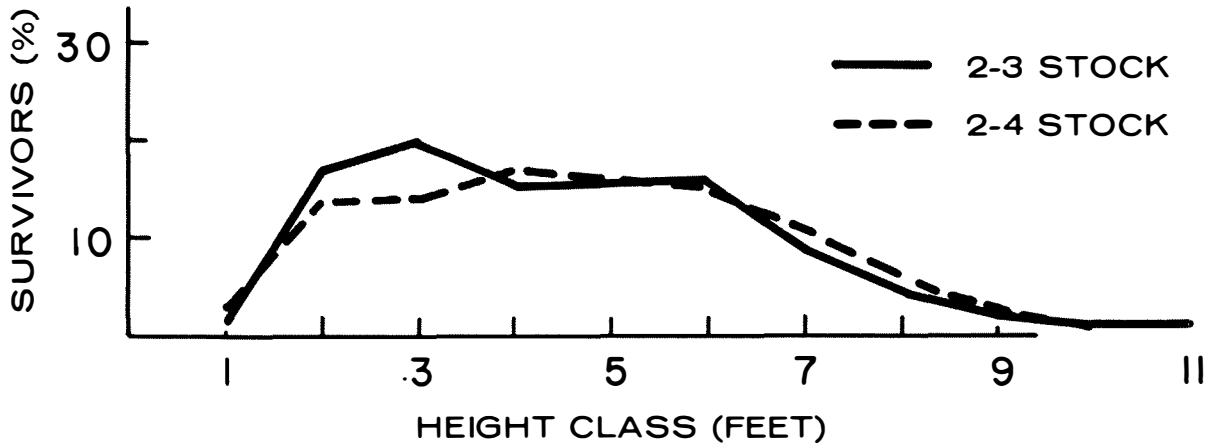


Figure 5. Height distribution of surviving 2-3 and 2-4 stock after 10 growing seasons.

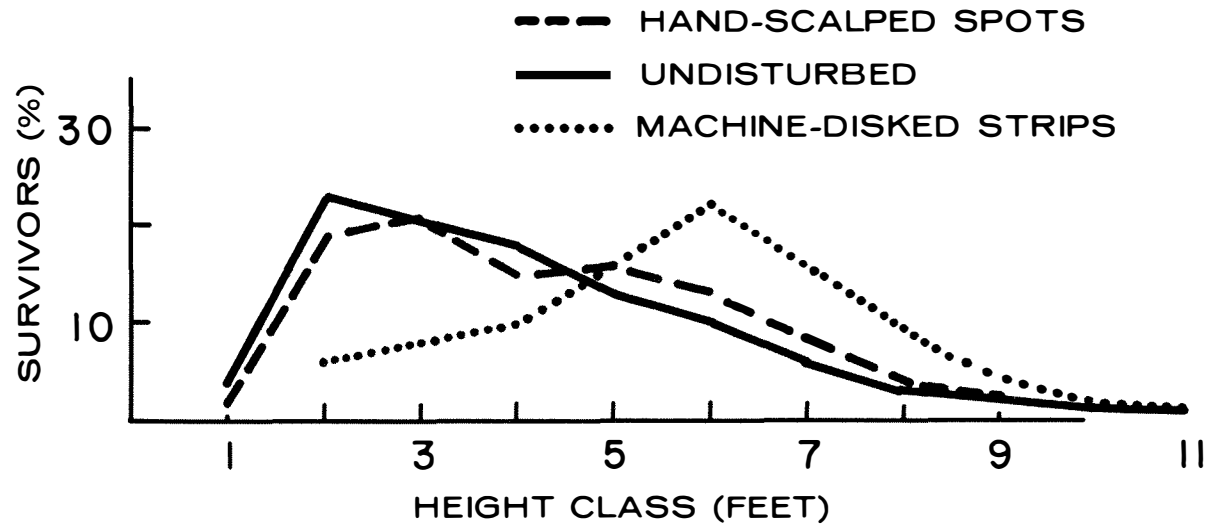


Figure 6. Height distribution of surviving transplants planted on hand-scalped spots, undisturbed ground and machine-disked strips, after 10 growing seasons.

slightly greater than that of the surviving 2-3 stock (Fig. 5). The average height was 4.8 feet for 2-4 transplants and 4.4 feet for 2-3 transplants. Machine-disked strips had taller transplants than either hand-scalped spots or undisturbed ground (Fig. 6). The average height of transplants was 5.5 feet on machine-disked strips, 4.3 feet on hand-scalped spots and 4.1 feet on undisturbed ground.

Comments: At the time of planting, the weather was dull and showery and the ground was moist. A survey in 1952 revealed that 11 per cent of the transplants on machine-disked strips and 7 per cent of those on hand-scalped and untreated ground had been killed by elk trampling.

Plantation: 4 (= Project MS-160-2; Expt. #3 (J.M. Jarvis *et al.* 1966))

Time of planting: May 1952

Purpose: To compare early survival and growth of 2-2 and 2-3 white spruce stock planted in the spring on bulldozed and undisturbed ground.

Methods: The plantation was established on a south-facing mid-slope; the soil was rated as a fresh, clay-loam till. No tree overstory was present, but the area supported a dense cover of hazel.

The plantation occupies four rectangular blocks, each 50 x 100 feet. Half of each block was bulldozed and half left undisturbed. Transplants were center-hole-planted (3 x 3 foot spacing) under each condition. At the time of planting, 2-2 stock averaged 6 inches in height and 2-3 stock 9 inches.

Results: After 10 growing seasons, the survival of 2-2 stock was better than that of 2-3 stock. Survival was better on bulldozed areas than on undisturbed areas. Most mortality occurred in the first three growing seasons (Table 4).

After 10 growing seasons a greater percentage of surviving 2-3 transplants was in taller height classes than the 2-2 stock (Fig. 7). Average height was 3.8 feet for 2-3 transplants and 3.5 feet for 2-2 transplants. Also a greater percentage of the survivors was taller on undisturbed areas than on bulldozed areas (Fig. 8). The average height of transplants on bulldozed and undisturbed areas was 3.7 feet.

TABLE 4. PER CENT SURVIVAL OF 2-2 AND 2-3 STOCK PLANTED IN 1952 ON BULLDOZED AND UNDISTURBED AREAS

Treatment	Number planted	Per cent survival		
		1952	1956	1961
			2-2 stock	
Bulldozed	432	86	76	67
Undisturbed	432	84	51	40
			2-3 stock	
Bulldozed	432	57	43	38
Undisturbed	432	77	44	34

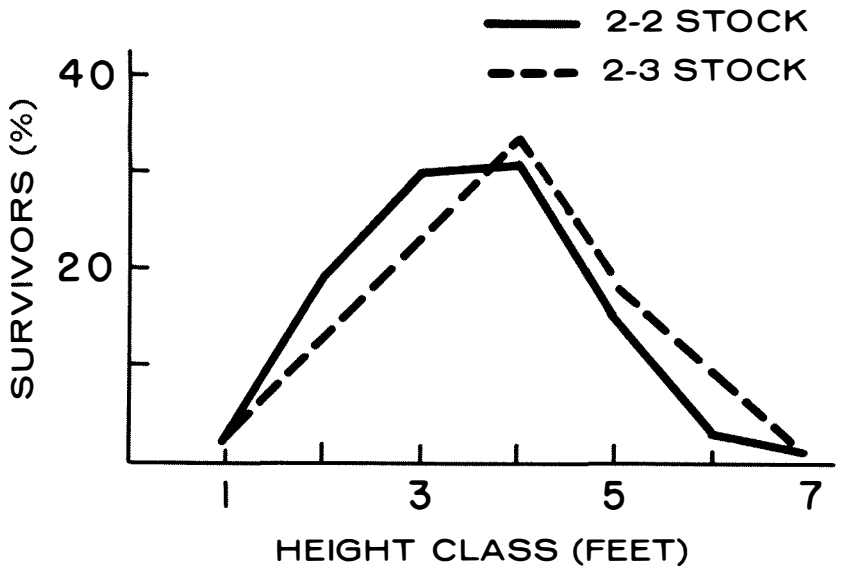


Figure 7. Height distribution of surviving 2-2 and 2-3 stock after 10 growing seasons.

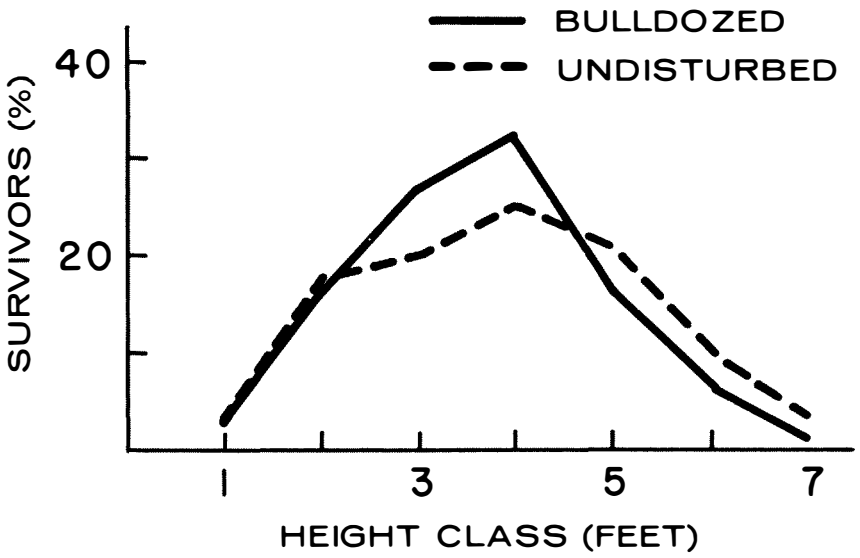


Figure 8. Height distribution of surviving transplants on bulldozed and undisturbed areas after 10 growing seasons.

Comments: The weather before and during planting was dry, and soil moisture conditions, particularly on scalped areas, were not conducive to good transplant establishment.

During the summer, exposed clay-loam soil on bulldozed areas was very dry and transplants appeared to be suffering from extreme exposure.

Plantation: 5 (= Project MS-160-3; Expt. #1 (J.M. Jarvis *et al.* 1966))

Time of planting: May 1953

Purpose: To study the effect of spacing on early survival and growth of white spruce transplants.

Methods: The plantation was established on a gentle slope, and the soil was classed as a moderately moist clay-loam till. No tree overstory was present, but the site supported a stand of hazel.

The plantation occupies nine blocks: three 12 feet square, three 22 feet square, and three 44 feet square. Before planting, windfall and slash were removed from the area with a bulldozer and an Athens plough was used to chop up the hazel and cultivate the site. Transplants were center-hole-planted at 1 x 1 foot spacing in each of the 12-foot squares, 2 x 2 foot spacing in each of the 22-foot squares and 4 x 4 foot spacing in each of the 44-foot squares. At the time of planting, 2-2 transplants averaged 6 inches in height.

Results: After 10 growing seasons, transplant survival was inversely related to distance between transplants (Table 5). However, the average height of survivors was directly related to planting distance (Fig. 9). The average heights of transplants at 4 x 4, 2 x 2 and 1 x 1 foot spacings are 4.4, 4.1 and 4.0 feet respectively. Most mortality on all treatments occurred in the first three growing seasons (Table 5).

TABLE 5. PER CENT SURVIVAL OF TRANSPLANTS PLANTED IN 1953 AT VARIOUS SPACINGS

Treatment	Number planted	Per cent survival	
		1956	1962
4 x 4 foot spacing	300	79	62
2 x 2 foot spacing	300	89	65
1 x 1 foot spacing	300	95	77

Comments: Soil and weather conditions were ideal for transplant establishment at the time of planting. Grasses quickly reinvaded the plantation, and much of the early mortality was caused by smothering by grasses during the winter, flooding in the spring and trampling by elk.

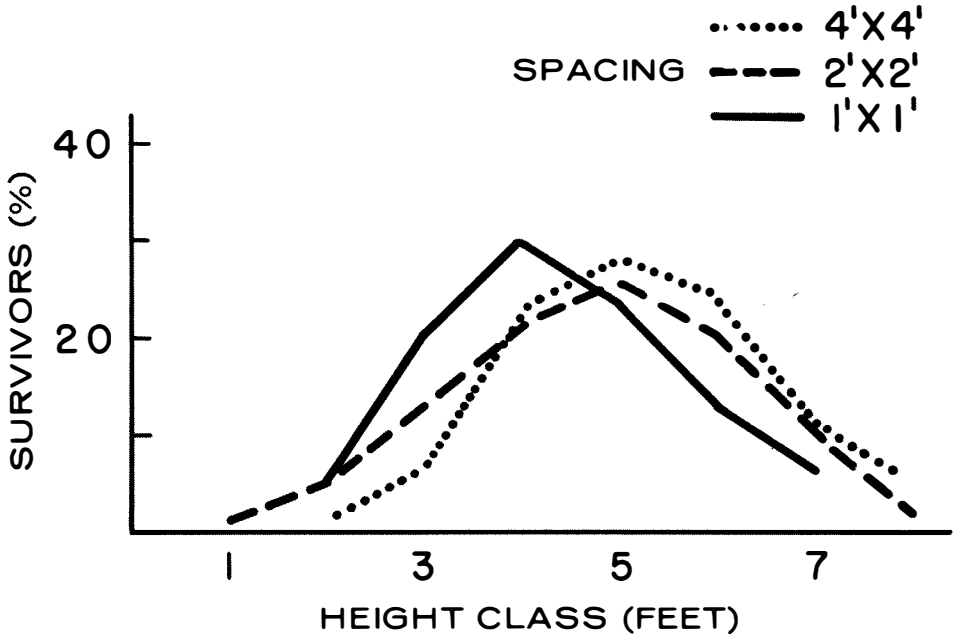


Figure 9. Height distribution of surviving transplants planted at various spacings, after 10 growing seasons.

Plantation: 6 (= Project MS-160-1; Expt. #1 (J.M. Jarvis *et al.* 1966))

Time of planting: May 1953

Purpose: To compare early survival and growth of 3-0 and 2-2 white spruce transplants planted on moderately moist and moist sites.

Methods: The plantation was established on a relatively level, moderately moist to moist clay-loam site. No tree overstory was present, but the site supported a dense stand of grass.

The plantation occupies two blocks: one approximately 190 by 210 feet, the other about 100 by 140 feet. In the spring, 2-2 transplants were center-hole-planted (4 x 4 foot spacing) on the former block and 3-0 transplants were center-hole-planted (4 x 4 foot spacing) on the latter block. At the time of planting, 2-2 stock averaged 6 inches in height and 2-3 stock 9 inches.

Results: After 10 growing seasons, the survival of 2-2 and 3-0 stock was very poor. Most mortality occurred in the first three growing seasons after planting (Table 6). Ten years after planting 2-2 survivors were, on the average, taller than 3-0 survivors (2.4 vs. 1.9 feet) (Fig. 10)

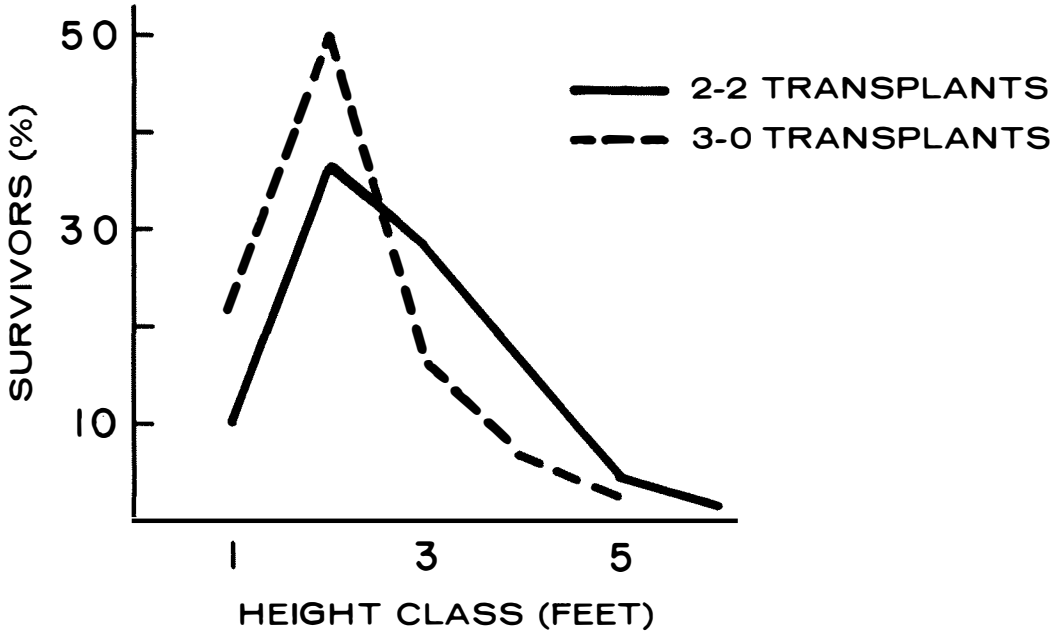


Figure 10. Height distribution of surviving 2-2 and 3-0 transplants after 10 growing seasons.

TABLE 6. PER CENT SURVIVAL OF 2-2 AND 3-0 STOCK PLANTED IN 1953 ON MODERATELY MOIST AND MOIST SITES

Stock class	Number planted	Per cent survival	
		1956	1962
2-2	1,800	23	13
3-0	816	22	10

Comments: Weather conditions before and during planting were favorable for transplant establishment. Observations in 1956 showed that practically all mortality on both areas resulted from smothering by grasses during the winter and flooding in the spring, and that new growth on surviving seedlings had suffered severe frost damage.

Plantation: 7 (= Project MS-160-4 (J.M. Jarvis *et al.* 1966))

Time of planting: June to September, 1953

Purpose: To compare early survival and growth of white spruce transplants planted throughout the summer.

Methods: The plantation was established on a relatively level, fresh, clay-loam till. No tree overstory was present, but the site supported hazel and grass.

The plantation occupies three blocks, each 50 x 100 feet. Before planting, the entire area was thoroughly disked with an Athens plough. Each Monday morning from the beginning of June to mid-September, fifteen 2-2 white spruce transplants were set out in a row in each block.

Results: After 10 growing seasons results indicated that the time of planting had no effect on transplant survival or on the average height of the survivors (Table 7).

TABLE 7. PER CENT SURVIVAL AND AVERAGE HEIGHT OF TRANSPLANTS PLANTED THROUGHOUT THE SUMMER OF 1953 AFTER 10 GROWING SEASONS

Date of planting in 1953	Number planted	Per cent survival 1963	Average height in 1963 (feet)
June 1	45	53	4.3
9	45	53	3.7
15	45	40	3.9
22	45	47	3.4
29	45	60	4.5
July 7	45	51	4.0
13	45	42	4.2
20	45	58	4.3
27	45	60	4.1
Aug. 3	45	58	3.9
10	45	42	3.5
17	45	53	3.7
24	45	33	3.6
31	45	53	3.8
Sept. 8	45	56	4.3

Comments: The total precipitation for the summer of 1953 was well above the long-term average (11.8 vs. 8.9 inches).

Plantation: 8 (= Project MS-160-4 (J.M. Jarvis *et al.* 1966))

Time of planting: May to September, 1954

Purpose: To compare early survival and growth of white spruce transplants planted throughout the summer.

Methods: The plantation was established on a relatively level area; the soil was classed as a fresh clay-loam till. No tree overstory was present, but the site supported a stand of hazel and grass.

The plantation occupies three blocks, each 50 x 100 feet. Before planting, the area was slightly scarified as an indirect result of removing windfall and slash from the area with a bulldozer. Each Monday morning from the last of May to the middle of September approximately fifteen 2-3 transplants were center-hole-planted in rows in each of the three blocks.

Results: After 10 growing seasons, the time of planting had no apparent effect on transplant survival or on the average height of the survivors (Table 8).

TABLE 8. PER CENT SURVIVAL AND AVERAGE HEIGHT OF TRANSPLANTS PLANTED THROUGHOUT THE SUMMER OF 1954 AFTER 10 GROWING SEASONS

Date of planting in 1954	Number planted	Per cent survival 1964	Average height in 1964 (feet)
May 31	47	32	2.4
June 14	46	30	3.0
15	46	24	2.0
21	45	42	2.8
28	45	42	2.6
July 5	44	36	2.8
12	46	41	2.9
19	46	48	2.4
26	45	42	2.8
Aug. 2	45	49	2.3
9	46	59	2.9
16	47	53	2.8
23	45	49	2.6
30	46	37	2.8
Sept. 6	45	42	2.5
13	45	49	2.3

Comments: The total precipitation for the summer of 1954 was well above the long-term average (12.7 vs. 8.9).

Plantation: 9 (= Project MS-160-1; Expt. #2 (J.M. Jarvis *et al.* 1966))

Time of planting: May 1954

Purpose: To compare early survival and growth of four sizes of white spruce planting stock.

Methods: The plantation was established on a gentle slope. The soil was rated as a fresh, clay-loam till. No tree overstory was present, but the site supported a dense stand of hazel with some grass.

The plantation occupies four square plots, each 50 x 50 feet. In the spring, all stock classes were center-hole-planted on untreated ground in each of the four plots. At the time of planting, 2-4 stock averaged 12 inches in height, 2-3 stock 9 inches, 3-2 stock 7 inches and 3-1 stock 5 inches.

Results: After 10 growing seasons, the survival and the average height of the survivors were directly related to stock size at the time of planting. The average height of 2-4 stock was 3.1 feet, of the 2-3 stock 3.0 feet, of 3-2 stock 2.4 feet and of 3-1 stock 2.1 feet (Fig. 11). Most mortality occurred in the first five growing seasons after planting (Table 9).

Figure 11. Height distribution of four sizes of surviving transplants after 10 growing seasons.

TABLE 9. PER CENT SURVIVAL OF FOUR SIZES OF STOCK PLANTED IN 1954

Stock class	Number planted	Per cent survival		
		1956	1959	1963
2-4	196	76	71	48
2-3	196	64	56	40
3-2	196	73	66	39
3-1	196	53	47	27

Comments: Weather conditions before and during planting were favorable.

Plantation: 10 (= Project MS-160-5; Expt. #2 (J.M. Jarvis *et al.* 1966))

Time of planting: May 1954

Purpose: To study the effect of hazel on early survival and growth of planted white spruce.

Methods: The plantation was located on a relatively level, fresh clay-loam site. No tree overstory was present, but lesser vegetation consisted of a dense stand of hazel.

The plantation occupied six square plots, each 33 x 33 feet. In the spring, 3-2 transplants were center-hole-planted (3 x 3 foot spacing) on each of the six plots. In the autumn, hazel on three plots was sprayed with an aqueous solution of 2,4-D, which released the transplants during the following growing season.

Results: After four growing seasons, survival and average height of the transplants were greater on the released plots than on plots that received no treatment (Table 10).

TABLE 10. PER CENT SURVIVAL AND AVERAGE HEIGHT OF RELEASED AND UNRELEASED TRANSPLANTS, FOUR GROWING SEASONS AFTER PLANTING

Treatment	Number planted	Per cent survival 1957	Average height 1957 (inches)
Hazel sprayed	147	57	17
Hazel undisturbed	147	29	11

Comments: The plantation was destroyed in the spring of 1958.

Plantation: 11 (= Project MS-160-5; Expt. #5 (J.M. Jarvis *et al.* 1966))

Time of planting: May 1955

Purpose: To study the effect of site on early survival and growth of planted white spruce.

Methods: The plantation consists of a series of 12 subplantations, about 6 chains long and 12 feet wide. In the spring, 2-3 transplants were set out in rows on untreated ground at approximately 4-foot intervals. Site conditions within the subplantations vary from fresh to wet, and soils from clay to clay-loam.

Results: After 10 growing seasons, survival was poor on all sites. However, the results show a trend of decreasing survival with increasing moisture (Table 11).

Height growth, after 10 growing seasons, showed no relation to site (Fig. 12). The average height of transplants on the fresh site was 2.2 feet, on the moderately moist site 2.0 feet, on the moist site 2.0 feet and on the very moist site 2.5 feet.

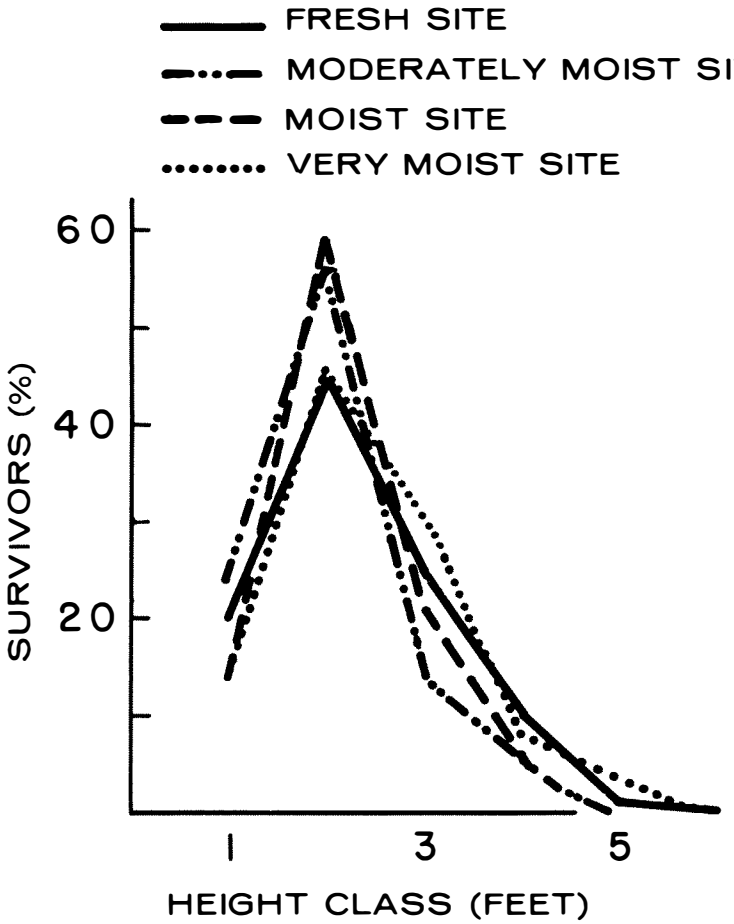


Figure 12. Height distribution of transplants planted on various sites, after 10 growing seasons.

TABLE 11. PER CENT SURVIVAL OF TRANSPLANTS PLANTED IN 1955 ON VARIOUS SITES

Sites	Number planted	Per cent survival	
		1958	1964
Fresh	1,407	41	17
Moderately moist	1,978	36	14
Moist	944	31	11
Very moist	813	10	6
Wet	10	0	0

Comments: None.

Plantation: 12 (= Project MS-160-5, Expt. #4 (J.M. Jarvis *et al.* 1966))

Time of planting: May 1957

Purpose: To study the effect of hazel and size of planting stock on early survival and growth of white spruce.

Methods: The planting area was a fresh clay-loam till supporting scattered mature aspen with a dense hazel understory. The plantation was established in five blocks; each block was divided into six 40 x 20 foot plots with a 10-foot surround. Three plots in each block were cleared of hazel, and three were left undisturbed.

In the spring, 2-0, 2-2 and 3-2 stock were planted. At the time of planting, height averaged 4 inches for 2-0 stock, 8 inches for 2-2 stock and 12 inches for 3-2 stock.

Results: After 10 growing seasons, survival was better on areas cleared of hazel than on areas left undisturbed. Survival was best for 2-2 stock. Where hazel was not removed, the taller 3-2 stock had better survival than the smaller 2-0 stock; however, where hazel had been removed, survival was about the same for 3-2 and 2-0 stock (Table 12).

After 10 growing seasons, the average height of survivors on cut areas was greater than that of survivors on uncut areas (3.6 feet vs. 1.6 feet) (Fig. 13). The average height 10 years after planting, regardless of planting condition, was directly related to size of stock at time of planting (Figs. 14 and 15). The average height

TABLE 12. PER CENT SURVIVAL OF VARIOUS SIZES OF STOCK PLANTED IN 1957 UNDER HAZEL AND ON GROUND CLEARED OF HAZEL

Stock class	Number planted	Per cent survival									
		1958		1959		1962		1964		1966	
		Cut	Not cut	Cut	Not cut	Cut	Not cut	Cut	Not cut	Cut	Not cut
2-0	500	83	16	75	12	68	9	64	7	61	5
2-2	500	91	64	89	59	84	47	82	40	81	36
3-2	500	80	40	68	32	62	26	62	25	60	23

of 3-2, 2-2 and 2-0 stock on cut areas was 5.0, 3.7 and 2.2 feet respectively and that for uncut areas was 2.3, 1.5 and 0.9 feet respectively.

Comments: None.

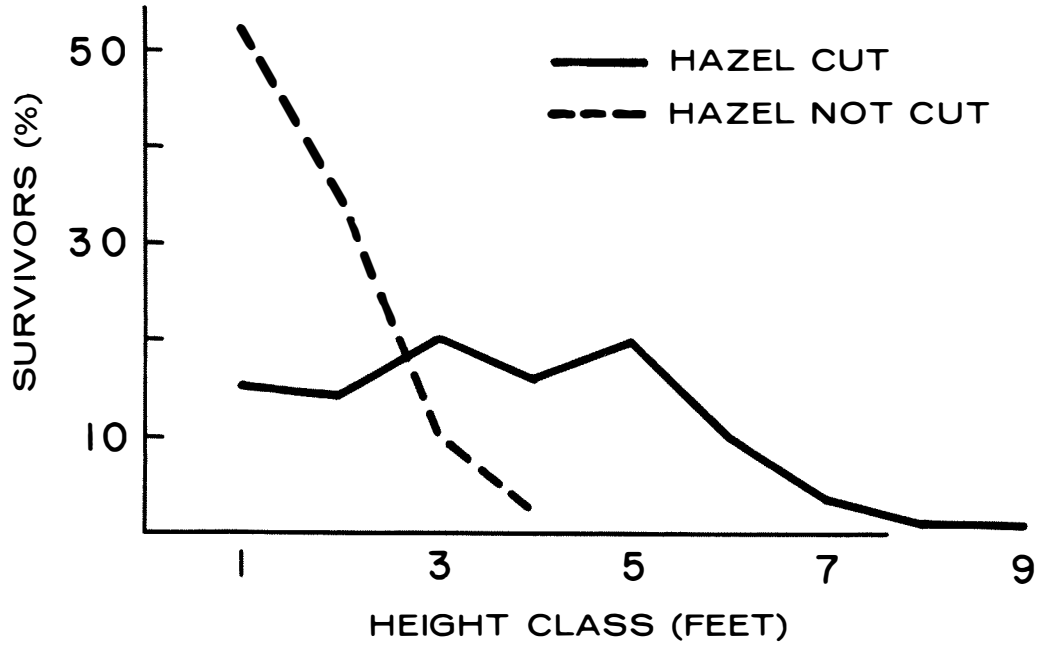


Figure 13. Height distribution of surviving transplants planted under hazel and on ground cleared of hazel, after 10 growing seasons.

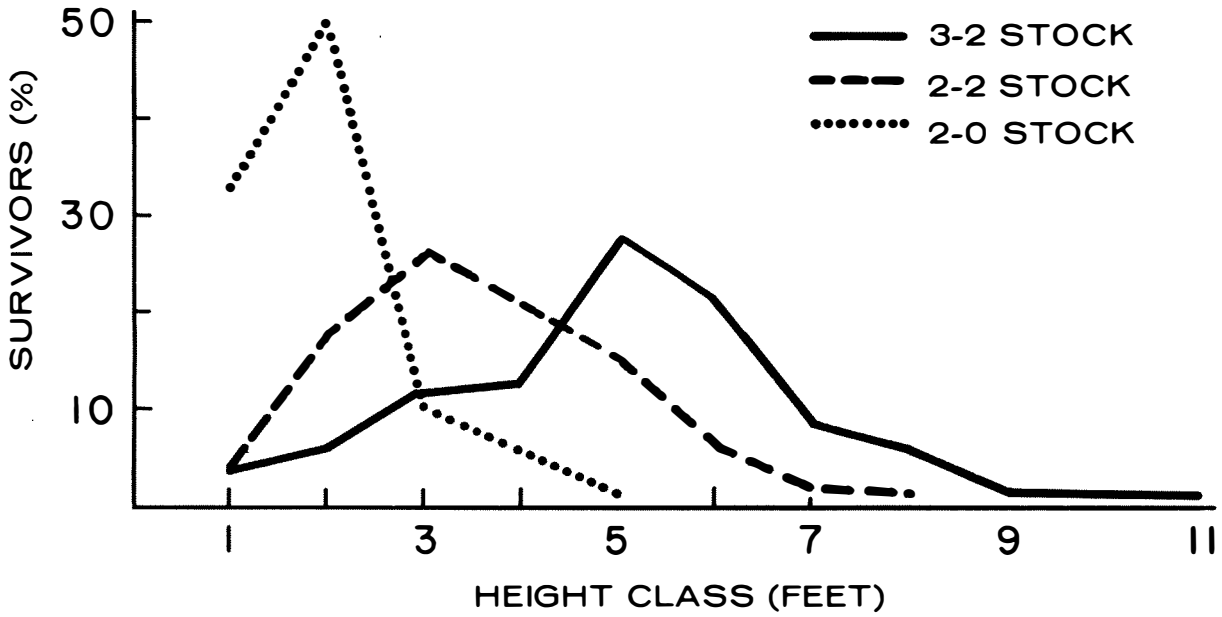


Figure 14. Height distribution of surviving 3-2, 2-2 and 2-0 stock planted on ground cleared of hazel, after 10 growing seasons.

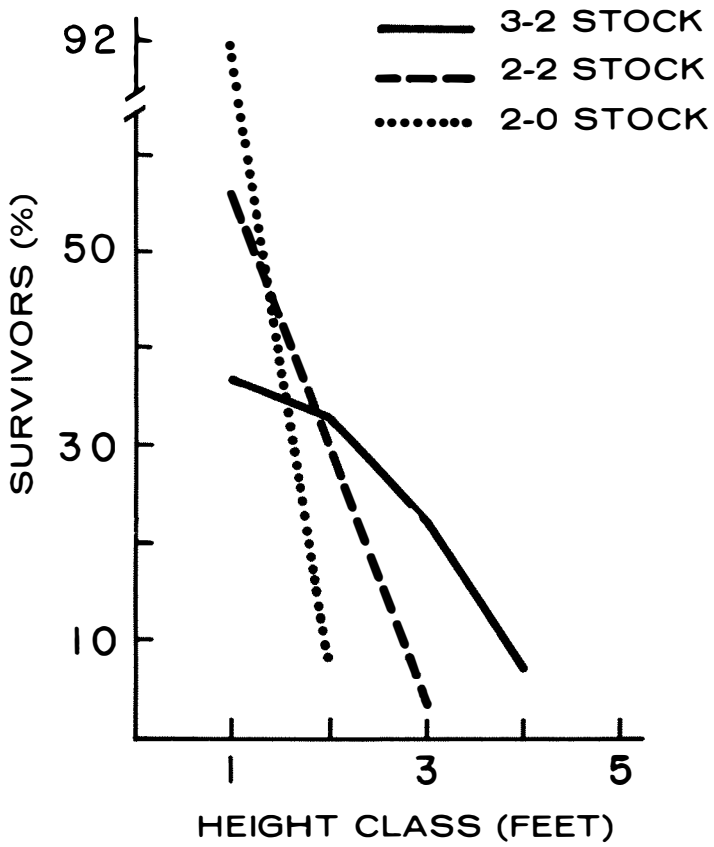


Figure 15. Height distribution of surviving 3-2, 2-2 and 2-0 stock planted under hazel, after 10 growing seasons.

DISCUSSION

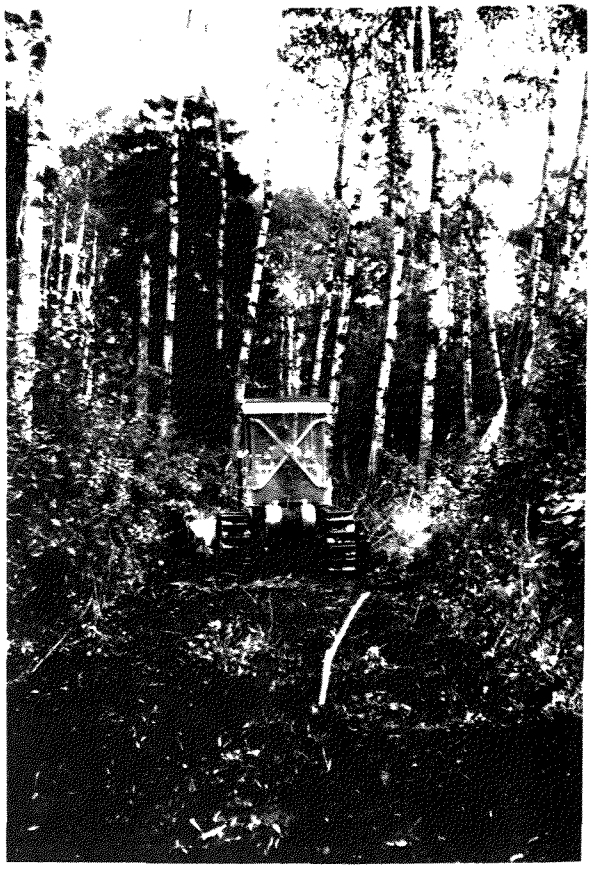
Results from the various plantations reveal a number of strong trends. Although the plantations are not directly comparable, these trends provide a good base on which to develop biologically sound planting techniques.

Among the most significant trends revealed is that plantations on treated areas had better survival than those on untreated areas (plantations 1, 2, 3, 4, 10 and 12). Preplanting site treatments (scalping or disking, Figs. 16 and 17) to provide an environment relatively free from above- and belowground competition from shrubs, herbs and grasses, generally produced best survival (plantations 1, 3 and 4). Treatments that removed or killed only aerial parts of competing vegetation are better than no treatment (plantations 2, 10 and 12), but benefits are short-lived and seedlings sooner or later suffer as much competition as those on untreated areas (Fig. 18).

Overall, transplants grew better (4.7 feet) on disked areas than on scalped (4.1 feet) or undisturbed (3.8 feet) areas (plantations 1 and 3). This has been attributed to an improved soil structure brought about by disking. Gray Wooded soils are characterized by a heavy clay B horizon with a blocky structure that inhibits good root development (Büsgen and Münch, 1929). Disking decreases bulk density and produces a nutty soil structure, which improves the rooting environment. Roots of transplants thus expand more readily, and the result is better height growth. The effect of disking on root development is illustrated in Fig. 19.

Survival results in relation to age of stock were inconclusive. For instance, plantations 1, 2, 6 and 9 showed that older stock survived better than younger stock, whereas plantations 3, 4 and 12 did not. Perhaps the most important point revealed here is that certain lots of transplants performed better than others. All lots of transplants were handled and planted with care, and it might therefore be suspected that difference in mortality for a given condition was the result of different provenance, stock vigor or poor handling in the nursery.

For a given condition, transplants surviving from large planting stock were generally taller 10 years after planting than those surviving from small stock (plantations 1, 2, 3, 4, 6 and 12). The little difference in height, however, suggests that the smaller stock grew just as fast as the larger stock. The relation between size of stock and survival or height growth is not necessarily direct and simple. Some authors report better survival and growth for larger seedlings (Ostrom and Ferrer 1942; Clausen 1963), while others have found that this is not necessarily true (Evans and Duyker 1964; Hermann 1964).



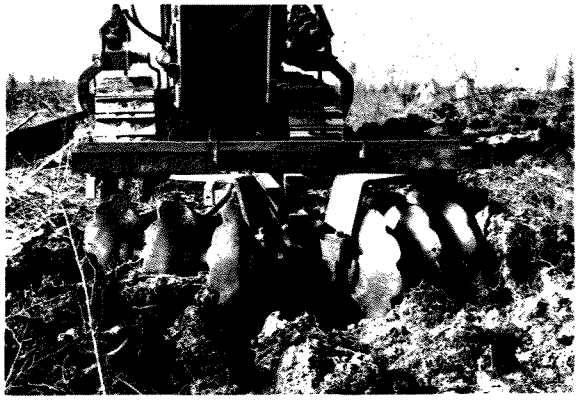


Figure 16 (above left). Scalping with a bulldozer to reduce vegetative competition.

Figure 17 (top right). Disking with an Athens plough to reduce vegetative competition.

Figure 18 (lower right). General view of a hazel stand on an untreated area. Note the 10-year-old white spruce transplant in the foreground.

Planting at various times throughout the summer (plantations 7 and 8) had little effect on survival and height growth. As mentioned earlier (see plantations 7 and 8), precipitation during the summer months, when these two plantations were established, was well above normal and the same results might not have occurred with normal or below-normal precipitation. However, Crossley (1956) and Ackerman and Johnson (1962) also found no excessive mortality due to planting throughout the summer months, although height growth was increased by planting early.

On moist sites, close spacing apparently results in better survival than wide spacing (plantation 5). This is perhaps related to the protection one transplant affords another against smothering by grass (Fig. 20). Growth, on the other

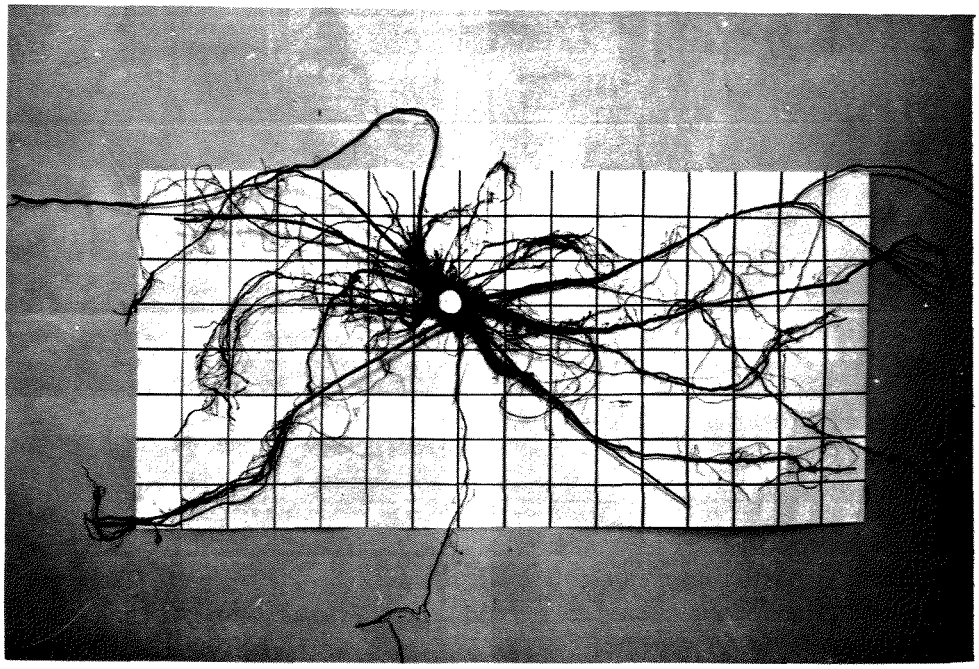


Figure 19 (a). A 15-year-old white spruce root system developed on a disked strip. Note the strong root orientation in a single plane. This corresponds to the direction of the disked strip.

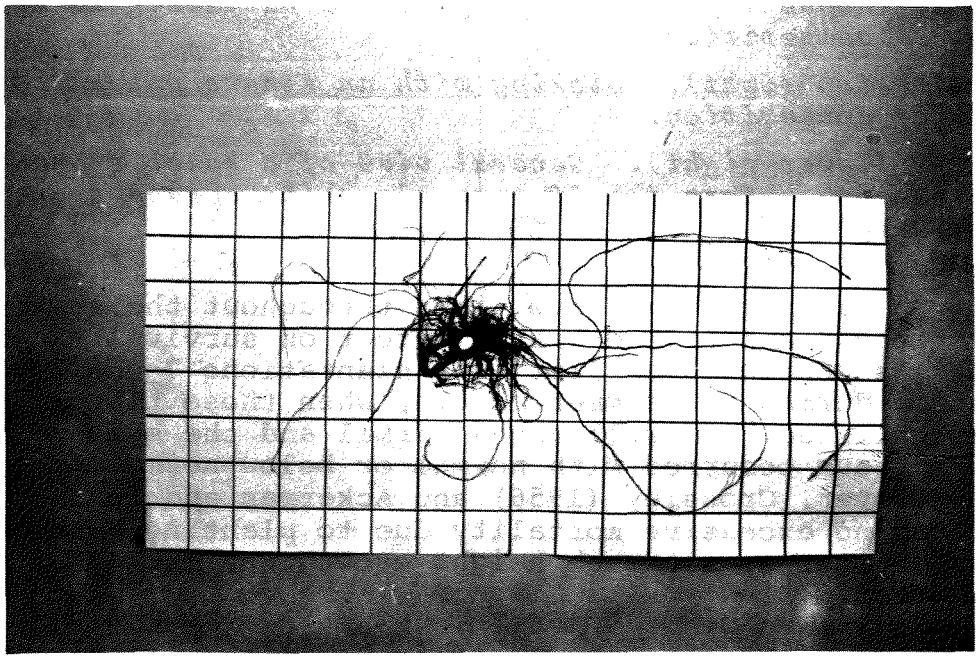


Figure 19 (b). A 15-year-old white spruce system developed on undisturbed ground. Each square is equal to 16 square inches.

Figure 20. General view of a grass stand on untreated ground.

hand, is apparently reduced by close spacing, perhaps because of greater competition between transplants as they get larger.

Results from plantation 11 show that transplant survival was best on fresh sites and decreased as sites got wetter, while height growth showed no relation to site. It was observed (plantations 5 and 6) that much of the mortality on the moister sites was the result of smothering by grass during the winter and flooding in the spring. Much of the mortality on fresh sites (plantation 2) was attributed to drought as well as to competition from ground vegetation.

Observations indicated that frost damage to needles and buds occurred on all plantations. The occurrence of frost damage was more frequent on very moist to wet sites than on fresh to moist sites. This is attributed to the former sites being usually associated with low-lying areas that have poor air drainage. Rowe (1955) observed that repeated frost damage could kill a seedling; thus some mortality on very moist to wet sites might be attributed to this phenomenon.

Transplants on disked strips suffered more damage from elk trampling than those on undisturbed areas (plantation 1). Apparently elk use these cleared strips as pathways to avoid the dense vegetation.

On the basis of these results, it is suggested that planting in Riding Mountain National Park and similar areas in the Mixedwood Forest Section of the Boreal Forest Region be confined to fresh to moist sites. On these sites, planting should be done only on areas that have been scalped and preferably on areas that have been disked as well. If scarification is done in strips, it is suggested that obstacles be placed across them to reduce mortality from trampling. Plantations established in accordance with these recommendations should normally have a survival of 50 per cent or greater after 10 growing seasons.

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