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Direct seeding in Canada 1900-1972

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Between 1900 and 1972 approximately 337,000 acres were direct seeded in Canada; currently 42,000 acres are being treated annually at an estimated average cost of $27 per acre. These data compare with a 72 year total of 3,000,000 acres planted and a current annual program of 260,000 acres at $55 per acre (Haig and Scott 1972).

Stocking for all species and treatment combinations over the 72-year period averaged 26% on a milacre basis with 1,100 4-year-old seedlings per acre; comparable 'stocking' for current planting programs is approximately 45% or 450 surviving transplants per acre (Anon. 1970). The calculated cost of a stocked quadrat would be $1.04 for direct seeding and $1.22 for planting. At an average sowing rate of 50,000 seeds and a ratio of one seedling per 44 seeds sown, the cost of one 4-year-old seedling was 2 cents; the cost per transplant 12 cents.

To date, only jack pine has been successfully direct seeded. Although all other species sown have been failures, direct seeding of Douglas-fir, black spruce and lodgepole pine have yielded somewhat better results than those achieved for eastern white pine or white spruce.

The use of direct seeding as an operational technique has, in recent years, been increasing at a rapid rate:

Years	Acreage	%
1903–1912	10,020	3
1913–1922	180	* [1]
1923–1932	26,731	8
1933–1942	585	*
1943–1952	24,321	7
1953–1962	28,159	8
1963–1972	246,982	73

[1] Less than 1%.

This increased use appears to be based largely on the spiralling cost of planting bare-root stock, labor shortages, and inconsistent results being obtained with container-grown seedlings rather than on any significant degree of success achieved in the past using direct seeding, either on a research or operational

basis. In 1972, 42,000 acres were direct seeded in Canada, almost double the average (25,000) of the previous 10 years.

Excluding a small number of operational scale direct seeding projects carried out by industry in the early 1900's and in the 1920's, the bulk of the direct seeding carried out between 1900-1955 was research orientated. It wasn't until the mid-1950's and early 1960's that the potential of direct seeding for regenerating burned-over and cut-over areas, for converting hardwood stands to conifers and, for afforesting grass and heathlands was taken seriously and large scale operational programs undertaken. Over the 72-year period 90% of the acreage seeded has been on an operational scale and 10% on research and development of methods, materials (repellents) and equipment. Over the past 5 years (1967-1971) research has been running at about 2%.

Most of the direct seeding in Canada has been carried out in Ontario and Alberta and to a lesser extent in Quebec and British Columbia:

The direct seeding programs have been carried out by the provincial agencies responsible for forest management and for forest research [2] (86%), by industry (13%) and the Canadian Forestry Service (1%).

Province	Acreage (1900–72)	%	Year of 1st recorded seeding	Estimated acreage direct seeded in 1972
Ontario	139,392	41	1905	20,700
Alberta	122,725	36	1911	15,600
Quebec	27,227	8	1908	2,600
British Columbia	15,558	5	1923	2,100
Nova Scotia	10,037	3	1904	0
Manitoba	8,573	3	1904	300
Newfoundland	5,203	2	1950	0
New Brunswick	4,734	1	1923	300
Saskatchewan	3,529	1	1909	200
Prince Edward Island	0	0	—	0

White spruce and jack pine account for most of the acreage direct seeded to date; less important species include lodgepole pine, Douglas-fir, eastern white pine and black spruce. A complete listing is as follows:

Species	Acreage (1900–1972)	%
White spruce	141,623	42
Jack pine	114,171	34
Lodgepole pine	15,201	5
Douglas-fir	13,592	4
E. white pine	13,359	4
Black spruce	13,210	4
Norway spruce	10,114	3
Red pine	6,259	2
Scots pine	3,551	1
Sugar maple	1,234	*
Yellow birch	1,131	*
Balsam fir	903	*
Red spruce	770	*
Western hemlock	578	*
Engelmann spruce	435	*
E. white cedar	285	*
W. red cedar	219	*
Sitka spruce	194	*
Western larch	62	*
Ponderosa pine	47	*
Siberian larch	29	*
W. white pine	6	*
Oak	4	*
Eastern larch	1	*

[2] Principally the British Columbia and Ontario Research Divisions.

Current programs are principally white spruce in Alberta and jack pine in Ontario. As a result of high seed costs direct seeding of Douglas-fir in British Columbia on an operational basis is rare; MacMillan-Bloedel have completely abandoned direct seeding as an economical and effective reforestation technique.

Reliable information on the viability of seed used in direct seeding is lacking. Available information indicates that jack pine seed was of high quality – between 80-100% viable. Evidence indicates that the viability of white spruce seed was low (Johnson 1973) – probably closer to 50%. Viability of the other tree species was extremely variable.

Seed treatment to protect against rodents and birds was used as early as 1924 but it wasn't until the late 1940's that detailed research was undertaken. In the early years seed was treated with red lead and sown with farm drills or broadcast as untreated seed. Later a variety of rodenticides, fungicides and lubricants were introduced. Of the more important chemicals used, combinations of endrin, arasan and aluminium flakes were the most significant (72%):

Seed treatment	Acreage	%
	(1900–1972)	
Endrin-aluminium	111,373	33
Arasan-endrin-aluminium	72,213	21
Arasan	43,644	13
Arasan-endrin	10,495	3
Endrin	3,786	1
Aluminium	1,618	*
Sub total (A.E.A.)	243,129	72
Captan-50W	6,900	2
Poison baits (1080)	2,351	1
Tetramine	1,310	*
Red lead	1,071	*
Other	1,244	*
Total treated	256,005	76
Not treated	80,973	24

It is interesting to note that the use of untreated seed in recent years is on the increase, reflecting to some extent the fact that some of the chemicals developed have not proven entirely reliable and that some (endrin) are dangerous to man if not handled with adequate precautions (Scott 1970). In the case of Captan-50W, research proved that this fungicide was detrimental to seed when surface sown (i.e. reduced germination and increased germinate abnormality) but was insignificantly so when seed was sown as deep as in nursery seedbeds (Cayford and Waldron 1967). The use of tetramine and poison baits on the west coast has been halted; although currently used by New Brunswick, red lead is of historic interest only. In 1971, 68% of the seed sown was untreated or coated with lubricants (aluminium) only and 32% treated with repellents as compared to 2% and 98% respectively in 1967.

The majority of the direct seeding to date has been carried out in the autumn:

Season of sowing	Acreage	%
	(1900–72)	
Spring (Apr.-May)	55,324	16
Summer (June-Aug.)	15,244	5
Autumn (Sept.-Nov.)	222,550	66
Winter (Dec.-Mar.)	43,860	13

In recent years winter sowing has shown a slight increase due mainly to the development of a motorized tree seed broadcaster designed for use on snowmobiles (Brown 1969). Most summer seeding was carried out in early June; very little direct seeding has taken place in July and August.

Direct seeding has been carried out under a wide variety of vegetative conditions including areas devastated by wildfire, cut-overs, and in undisturbed forests (hardwood conversions):

In more recent years (1967-71) emphasis has been on cut-overs; better fire detection and suppression techniques have significantly reduced the acreage of wildfires requiring regeneration inputs. Johnson (1973) recently recommended that due to poor results conversion of hardwood sites should not be attempted until improved techniques can be applied.

Vegetative conditions	Acreage (1900–72)	% (1900–72)	% (1967–71)
Cut-overs	168,367	50	76
Wildfires (burned standing)	95,888	26	8
Undisturbed forests (conversion)	63,557	19	14
Cut-overs followed by wildfire	8,122	3	2
Barrens (grassland and heath)	880	*	*
Abandoned farmland	164	*	*

Excluding areas subjected to wildfires, mineral soil seedbeds were generally prepared – either mechanically or manually – prior to direct seeding. Bulldozer and blade (standard straight plus a variety of more recently developed blades including Young's teeth, and V) has been most often used, followed by the Ontario barrel scarifiers and anchor chains:

Scarification Equipment	Acreage (1900–72)	% (1900–72)	% (1967–71)
Bulldozer (plus a variety of blade designs)	134,049	40	54
Barrels and anchor chains (drags)	72,694	22	30
Prescribed burning	13,916	4	1
Hand implements	12,185	4	3
Athens disc, middlebuster plough	10,219	3	2
SFI, Imsett, Bracke.	8,029	2	4
Other	3,944	1	*
No site preparation	81,941	24	6

Presently the bulldozer, together with either blade or drag scarifiers, account for 84% of the scarification equipment in use. Ploughs and discs have never been too popular and reflect early attempts at scarification; prescribed burning has been used principally in B.C. although other provinces have used the techniques on an experimental basis. The SFI, Imsett and Brackekultivatorn are more recent innovations and require further field testing (Hall 1970).

Spot and aerial broadcast have been the two most common seeding techniques used; surprisingly ground broadcast has not been used very frequently while mechanical seeding using heavy equipment is still in the research and development stage:

Type of seeding	Acreage (1900–72)	% (1900–72)	% (1967–71)
Spot	154,262	46	41
Broadcast-aerial	131,383	39	48
-ground	46,450	14	8
Mechanical with heavy equipment	4,883	1	3

Spot seeding has largely been carried out using the Brohm, Swedish and M & B hand seeders, "walking sticks", home made shakers such as oil cans, or by hand. Helicopters and fixed wing aircraft have been used for aerial seeding; the latter appears to be gaining in popularity in more recent years (a 60-40 split between 1967-71). On-the-ground broadcast seeding has been carried out using the standard cyclone seeder or more recently with motorized seeders mounted on snowmobiles:

Seeding equipment	Acreage (1900–72)	% (1900–72)	% (1967–71)
Hand	88,894	26	13
Hand seeders & shakers	82,535	25	28
Helicopters	71,092	21	29
Fixed-wing aircraft	60,967	18	19
Cyclone seeder	21,661	6	4
Scarification and seeding equipment	8,527	3	5
Motorized seeders on snowmobiles	3,302	1	2

The use of aerial seeding is presently on the increase while spot seeding with its heavy reliance on manpower appears to be on the decline (51% 1900-72 compared to 41% 1967-71).

Between 1900 and 1972 a total of 116,000 lb. of seed were sown; the average rate of sowing for all species and treatment combinations was 50,000 seeds per acre:

Rate of sowing (seeds/acre)	Acreage (1900–72)	%
0– 10,000	90,705	27
10,001– 20,000	97,187	29
20,001– 30,000	29,753	9
30,001– 40,000	9,497	3
40,001– 50,000	25,047	7
50,001–100,000	29,272	9
100,001–200,000	19,467	6
200,001 +	36,050	10

However rate of sowing was variable depending principally on the seeding technique and the species, and to a lesser extent on seed size and seed viability. For spot seeding and for the larger seeded species such as Douglas-fir, eastern white and red pines, 5,000 to 30,000 seeds per acre have been used; most of the white spruce acreage was spot seeded at a rate of 50,000 seeds per acre. Aerial seeding of jack pine has been carried out with 20,000-40,000 and black spruce with 60,000-80,000 seeds per acre (Scott 1966a). Heavier rates, up to 200,000 + seeds per acre, have been used for the small-seeded species such as western hemlock and eastern white cedar.

It is extremely difficult to evaluate with any high degree of certainty the stocking results documented in this review (1) because data are available for only 40% of the total acreage treated, (2) because of the large number of species, factors and treatment combinations and, (3) the fact that the majority of the seeding has taken place in the past 5 (44%) to 10 (73%) years.

Nevertheless, from the information available it would appear that over the broad spectrum direct seeding has not been an unqualified success – rather the opposite would appear to be true. Only 26% of the direct seeded acreage for which data is available had milacre stockings exceeding 40% at an average seedling age of 4 years:

Stocking (% milacre)	Acreage (1900–72)	%
0– 20	203,999	61
21– 40	44,369	13
41– 60	47,527	14
61– 80	31,589	9
81–100	9,494	3

Similarly only 29% of the direct seeded acreage had 1,000 or more 4-year-old seedlings per acre:

Stocking (seedlings/acre)	Acreage (1900–72)	%
0– 500	204,826	61
501– 1,000	32,839	10
1,001– 2,000	46,416	14
2,001– 5,000	43,248	13
5,001–10,000	8,762	2
10,001 +	887	*

Smithers (1965) in his report "Direct seeding in eastern Canada" determined the success of both operational and research direct seeding projects carried out prior to 1963 using a rating system based on species, seedling age, and percent milacre stocking. That rating system, to which Douglas-fir has been added, is outlined here:

Success Category	Stocking	
	Jack, lodgepole and eastern white pine, Douglas-fir	White and black spruce
	% milacre	
Satisfactory		
1 year	60+	70+
2 years	50+	60+
3 years plus	40+	50+
4 years plus		40+
Moderate		
1 year	40–59	50–69
2 years	40–49	50–59
3 years plus	30–39	40–49
4 years plus		30–39
Failure		
1 year	<40	<50
2 years	<40	<50
3 years plus	<30	<40
4 years plus		<30

Using the above standards it becomes apparent that only jack pine has been successfully direct seeded (Table 1). Clearly direct seeding of white spruce and eastern white pine have been complete failures; stocking results for Douglas-fir, black spruce and lodgepole pine, while double that of the previous two species, fall below that required for even a success rating of "moderate".

An analyses of factors affecting the stocking success of jack pine and white spruce direct seeded between 1953 and 1972 reveals — ALTHOUGH THIS 'REVELATION' SHOULD NOT BE TAKEN AS CONCLUSIVE PROOF — that certain situations are more conducive to successful stocking than others (Table 2). It should be stressed that these data represent averages based on unequal sampling in which only one factor is examined at a time; an examination of comparable factor combinations would allow for more reliable conclusions to be drawn. Nevertheless, a number of observations can be made.

Table 1. Success of direct seeding programs between 1900 and 1972 for 6 selected species.

Species	Stocking Success [1] 1900 — 1972 (% of acreage treated) Satisfactory	Moderate	Failure	Average Stocking (% milacre)	Average Seedling Age (years)	Overall Success Rating [1]	Minimum % Stocking rq'd for Satisfactory Rating [2]	Basis No. Trials	Basis No. Acres	Acres Treated (1900-72)
Jack pine [3]	39	13	48	40	2.5	Moderate	45	195	46,400	114,200
Douglas-fir	6	23	71	31	2	Failure	50	83	10,900	13,600
Lodgepole pine	22	14	64	25	3	Failure	40	46	4,000	15,200
Black spruce	5	10	85	23	3	Failure	50	35	2,200	13,200
E. white pine	2	2	97	13	4	Failure	40	22	3,800	13,300
White spruce [3]	2	*	98	12	4	Failure	40	79	19,500	141,600

[1] After Smithers (1965).
[2] Using age of seedlings (years) given in column 6.
[3] Data for jack pine and white spruce from 1963–1972 programs only.

Table 2. Factors affecting the stocking success of direct seeded jack pine and white spruce, 1953 – 1972.

Factor	Average Stocking [1] and Success Category [2] 1953-1972 Jack Pine % Stocking	Jack Pine Success Category	White Spruce % Stocking	White Spruce Success Category
Year:				
1900 – 1952 } 1953 – 1962 }	40	M	15	F
1963 – 1972	40	M	12	F
Seed Treatment:				
None	27	F	–	–
A.E.A.	48	S	12	F
Arasan	42	M		
Captan-50W	25	F	15	F
Season of Sowing:				
Spring	55	S	37	M
Summer [3]	69	S	10	F
Autumn	41	M	11	F
Winter	23	F	20	F
Vegetative Conditions:				
Cut-overs	43	M	22	F
Wildfire	25	F	10	F
Cut-over-wildfire	25	F	–	
Undisturbed (conversion)	–	–	11	F
Scarification Equipment:				
Athen's disc	28	F	–	
Barrels, chains	36	M	–	
Bulldozer, blades	69	S	12	F
Imsett, SFI	41	M	–	
None	17	F	10	F

Factor	Jack Pine		White Spruce	
	% Stocking	Success Category	% Stocking	Success Category
Type of Seeding:				
Spot	44	M	10	F
Broadcast-ground	42	M	19	F
-aerial	39	M	10	F
Mechanical	36	M	–	
Seeding Equipment:				
Cyclone	38	M	19	F
Helicopters	36	M	10	F
Fixed wing	48	S	–	
Scarifiers and Seeders	48	S	–	
Hand or hand seeders	44	M	10	F
Rate of Sowing:				
0–10,000	26	F	10	F
10,001–20,000	44	M	12	F
20,001–30,000	52	S	–	
30,001–40,000	43	M	–	
40,001–50,000	33	F	10	F
50,001+	25	F	17	F

[1] Based on a minimum of 500 acres per factor.
[2] Based on Smither's (1965) stocking standards and an average seedling age of 2.5 years for jack pine and 4.0 years for white spruce.
[3] Generally seeded in early June or 'late spring'.

It is apparent that the degree of success achieved through direct seeding of jack pine has not changed over the past 72 years. However, it is apparent that seed treatment with the arasan-endrin-aluminium combination, or more recently with Arasan alone has been beneficial. Research has shown that the benefits of treating seed with repellents can be attributed to increased germination or reduced rodent and bird losses. The detrimental effects of Captan — 50W on seed have been previously reported (Cayford and Waldron 1967). The success of direct seeding is more related to the weather than to the season of the year. Nevertheless, over the long run (20 years), it would appear from this data that sowing in April, May or June has yielded, on the average, higher stocking than either autumn or winter seeding. As pointed out by many (Smithers 1965), direct seeding on burned seebeds is not normally successful; exposures of mineral soil on cut-over situations would appear to be more conducive to success. The bulldozer together with a wide variety of blade designs apparently produces the optimum seedbeds for jack pine germination and early survival; also suitable for seedbed preparation are the barrels and chains and the more recently developed Imsett and SFI scarifier — seeders; in the latter case further testing is warranted before wholesale application with this equipment.

There is little to choose between seeding techniques as apparently they have all been equally successful in distributing the seed on suitable seedbeds; fixed wing aircraft may provide better coverage than the helicopter, and the scarifier-seeders appear to be promising. Although the data are somewhat contradictory it would appear that on the average 20,000 — 30,000 jack pine seeds are adequate for obtaining satisfactory stocking [3].

It is difficult to analyze factors affecting success when results indicate a complete failure, and the analysis of the direct seeding of white spruce is no exception. Truthfully nothing can be said here that would prove useful although a case might be made for spring seeding.

In summary it can be stated that, with the exception of jack pine, direct seeding in Canada

[3] The success achieved by sowing so few seeds (1/5 lb./acre) can probably be attributed, in part, to the fact that a considerable number of seedlings are obtained from cone-bearing slash following site preparation for direct seeding. The use of barrels or anchor chains to obtain satisfactory stocking of jack pine regeneration from cone-bearing slash — without direct seeding — is a proven operational silvicultural technique in current practise in northwestern Ontario, northern Manitoba and Saskatchewan.

between 1900-1972 has on the average been a failure. It is believed that with perhaps some minor operational modifications and site selection, direct seeding of jack pine could be made more successful. For the other species it would appear that an indepth analysis of the reasons for failure is required. I personally believe that adequate information on the ecology and silviculture of direct seeding the principle conifers is available now. What is needed is not more research, but better application of existing knowledge.

With improved operational application, direct seeding could become a viable silviculture technique in reforestation programs.

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APPENDIX I

Table 1. Costs of direct seeding in 1972.

Site preparation ($ per acre):	
Bulldozer and blades	– 16.00
Barrels and chains	– 15.00
Prescribed burning	– 9.00
SFI, Imsett, Bracke.	– 8.00
Hand tools (grub hoe, etc.)	– 19.00
Seeding ($ per acre):	
Aerial	– 1.00
Cyclone (on ground)	– 6.00
Cyclone on snowmobile	– 2.00
Hand (Brohm, Shakers, etc.)	– 8.00
Seed ($ per lb.):	
Spruce, black	– 41.00
, Englemann	– 25.00
, Norway	– 10.00
, red	– 15.00
, Sitka	– 20.00
, white	– 15.00
Pine, eastern white	– 11.00
, jack	– 25.00
, lodgepole	– 45.00
, red	– 20.00
Fir, balsam	– 4.00
Douglas-fir	– 16.00
Seed treatment ($ per lb.):	
Arasan, endrin, aluminium flakes	– 0.50
Filler ($ per acre):	
Sol-speedi-dri	– 0.20

APPENDIX II

Smither's (1965) in his report "Direct Seeding in Eastern Canada" determined the success of direct seeding jack pine and white spruce based on the stocking standards outlined on page 11. Briefly his results showed that jack pine was successfully stocked on 53% of the trials undertaken; 23% were moderately stocked and 24% were failure. Comparable data for white spruce were 27%, 25% and 48% respectively.

The above results are based on data collected on eastern Canada (including Manitoba) prior to 1963. Pre 1963 data collected during this analysis for white spruce and jack pine seeding projects carried out in Saskatchewan, Alberta and British Columbia were incorporated with the data analyzed by Smithers. This additional data did not change Smithers' results by more than 1 or 2 per cent. This revised data is compared with results achieved since 1963 in the following table:

Assuming the differences revealed by this data to be significant then it could be concluded that the success of direct seeding has decreased somewhat over the past decade. Such a decrease could be expected since the extrapolation of techniques from small test trials or research plots to large scale operations inevitably leads to poorer results due to the difficulty of getting the seed on suitable micro site following site preparation on a macro scale. However, it is doubtful that the above data shows any real trends. The current success of direct seeding based on acreage treated is outlined in the main body of the report and indicates rather emphatically that the success of direct seeding of jack pine has improved (almost double) dramatically in recent years. Little change in the success of direct seeding white spruce was noted.

Success Category	% of Trials in Each Success Category			
	jack pine		white spruce	
	1900–62	1963–72	1900–62	1963–72
Satisfactory	55	53	32	29
Moderate	22	15	22	13
Failure	23	32	46	58
Basis: no. of trials	84	195	60	79