

THE EFFECT OF SEEDING RATE AND SEEDBED AVAILABILITY
ON JACK PINE STOCKING AND DENSITY
IN NORTHEASTERN ONTARIO

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ABSTRACT

A series of operational trials in the aerial seeding of jack pine (*Pinus banksiana* Lamb.) was conducted in the boreal forest of north-eastern Ontario between 1973 and 1975 to determine the combinations of degree of seedbed availability and seeding rate necessary to regenerate the species to desired stocking levels. From preliminary assessments a working definition of "receptive seedbed" was derived for seeding jack pine. This definition was used to assess site preparation on 11 seeding chances and to determine how much receptive seedbed was available. A Brohm seeder/fixed-wing aircraft combination was used to apply seed at prescribed rates of 10,000, 20,000 or 30,000 viable seeds per acre, and deposition rates were assessed. Stocking and density assessments were conducted in each of the 3 years following seeding. First- and third-year stocking and density results from the 11 seedings are presented and are related to various levels of receptive seedbed availability.

Stocking is directly related to the amount of receptive seedbed available, more so than to the amount of seed applied. A receptive seedbed availability range of 15-35% per milacre is considered optimum but, because of operational constraints in achieving seedbed levels within this range on an area-wide basis, a receptive seedbed distribution standard is proposed that will, in most cases, provide better-than-adequate stocking levels while maintaining site preparation effort at acceptable levels.

Although the Ontario minimum stocking standard of 60% for jack pine can be achieved at virtually any seeding rate from 5,000 seeds per acre and up, the potential for achieving better results in most cases is limited with the deposition rates of less than 14,000 seeds per acre.

Deposition rates approaching 30,000 seeds per acre provide little stocking gain over deposition rates of approximately 20,000 seeds per acre except at very low levels of seedbed receptivity. Deposition rates of approximately 20,000 seeds per acre produce major stocking gains over deposition rates of approximately 10,000 seeds per acre. Stocking increases between the first and third years after sowing usually occur and are often substantial.

The relation of actual and potential densities to seedbed availability and seed deposition rates is discussed. Densities increase rapidly with increasing seedbed availability and may exceed 5,000 stems per acre at higher seeding and seedbed levels. The apparent influence of weather on stocking results is considered. Aspects of the sowing procedure requiring attention are noted.

A method of predicting the probable range of stocking results on a seeding chance, once receptive seedbed availability has been determined, is described. Recommendations are made with respect to seedbed, site preparation, seeding rate and re-treatment on operational seedings.

RÉSUMÉ

Une série d'essais opérationnels d'ensemencement aérien de Pin gris (*Pinus banksiana* Lamb.) ont été effectués dans la forêt boréale du nord-est de l'Ontario entre 1973 et 1975 pour déterminer les combinaisons de degré de disponibilité de lits de germination et de taux d'ensemencement nécessaires à la régénération de l'essence aux niveaux désirés de matériel sur pied. D'après les évaluations préliminaires, une définition valable de "lit de germination réceptif" a été dérivée pour l'ensemencement du Pin gris. Cette définition a été utilisée pour évaluer la préparation de la station relativement à 11 possibilités de semis et pour déterminer la quantité de lits de germination réceptifs disponibles. On a utilisé un semoir Brohm combiné à un aéronef à voilure fixe pour ensemercer à raison de 10,000, 20,000 ou 30,000 graines viables à l'acre et l'on a évalué les taux de dépôt de graines. Des évaluations du matériel sur pied et de la densité ont été effectuées pour chacune des 3 années subséquentes à l'ensemencement. L'auteur présente le matériel sur pied et la densité résultant des 11 semis après un an et trois ans et il les associe aux divers niveaux de disponibilité des lits de germination réceptifs.

Le matériel sur pied est en rapport direct avec la quantité de lits de germination disponibles, davantage qu'à la quantité de graines déposées. Une gamme de disponibilité des lits de germination réceptifs de 15 à 35% par milli-acre est considérée optimale, à cause des contraintes opérationnelles quant à la réalisation des niveaux de lits de germination à l'intérieur de cette gamme sur une base régionale, et l'auteur propose une norme de distribution des lits de germination réceptifs qui, dans la plupart des cas, fournira des niveaux de matériel sur pied adéquats tout en maintenant les efforts de préparation des stations à des niveaux acceptables.

Bien que la norme minimale de matériel sur pied en Ontario (60% pour le Pin gris) puisse être obtenue virtuellement à n'importe quel taux d'ensemencement de 5,000 graines ou plus à l'acre, la possibilité d'obtenir de meilleurs résultats dans la plupart des cas se trouve limitée si les taux de dépôt sont inférieurs à 14,000 graines à l'acre.

Les taux de dépôts approchant 30,000 graines à l'acre fournissent peu de gain par comparaison aux taux d'application d'approximativement 20,000 graines à l'acre, sauf dans les cas de très faibles niveaux de réceptivité des lits de germination. Les taux de dépôt d'environ 20,000 graines à l'acre produisent d'importants gains de matériel sur pied comparativement à des taux de dépôt d'environ 10,000 graines à l'acre. Des augmentations de matériel sur pied entre la première et la troisième années après les semis se produisent habituellement et sont souvent substantielles.

L'auteur disserte sur le rapport entre les densités réelles (et potentielles) et la disponibilité des lits de germination et les

taux de dépôt. Les densités augmentent rapidement en fonction directe de la disponibilité des lits de germination; elles peuvent excéder 5,000 tiges à l'acre selon les niveaux plus élevés d'ensemencement et de lits de germination. Il considère l'influence apparente du climat sur le matériel sur pied obtenu. Il note certains aspects de l'ensemencement qui nécessitent une attention particulière.

L'auteur décrit aussi une méthode de prévision de l'éventail probable des résultats en matériel sur pied sur une possibilité de semis donnée, une fois déterminée la disponibilité de lits de germination réceptifs. Il fait des recommandations concernant les lits de germination, la préparation des stations, les taux d'ensemencement et le re-traitement des graines à utiliser.

ACKNOWLEDGMENTS

I wish to acknowledge the fine efforts and valuable assistance of F.F. Foreman, Forestry Technician, in the conduct of field work and preparation of this report. The cooperation of Ontario Ministry of Natural Resources staff in Chapleau District and General Airspray Limited of St. Thomas, Ontario was essential to the successful completion of the trials and is greatly appreciated. Appreciation is also extended to Dr. J. Régnière and D.W. Beilhartz, Great Lakes Forest Research Centre, for major assistance in developing the statistical aspects of the report.

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INTRODUCTION

Aerial seeding of jack pine (*Pinus banksiana* Lamb.) has been an operational regeneration technique in Ontario since the beginning of the 1960s. Since then the same basic technique has been used to treat several hundred thousand acres¹, i.e., preparation of a seedbed followed by aerial broadcasting of jack pine seed. Most of this work has been carried out by fixed-wing aircraft/Brohm seeder² combinations.

Many fine jack pine stands have resulted from aerial seeding; most, it would appear, fall within the minimum stocking and density standards prescribed by the Ontario Ministry of Natural Resources (OMNR) (Anon. 1971).³ But the density of many, if not most, of these stands is highly variable, and well stocked areas are often interspersed with poorly stocked patches. As the need for more intensive forest management and for greater predictability increases, forest managers will have to become increasingly knowledgeable about the factors affecting success and the ways of manipulating them to provide the greatest likelihood of success.

Scott (1966) identified rate of seed application, degree of site preparation, and weather as the three most important factors affecting the success of aerial seeding. Only the first two are within the direct control of the forest manager. In 1970 the Great Lakes Forest Research Centre (GLFRC), in cooperation with the Chapleau District, OMNR, undertook a series of operational site preparation and seeding trials designed to determine the combination (or combinations) of these two factors most likely to produce desirable stocking and density, and to provide a management guideline for the aerial seeding of jack pine. Riley (1975) described the procedures followed in the first 3 years of trials and reported first-year results of the 1973 trial. The present report provides the first- and third-year results of 11 assessments conducted during the period 1973-1975 including both operational-scale trials by GLFRC and fully operational seedings by the OMNR district covering some 590 acres of scarified and seeded area.

¹ S.I. conversions provided in Appendix A.

² The identification of commercial products and equipment is solely for the information of the reader and does not constitute endorsement by the Great Lakes Forest Research Centre.

³ "Desirable stocking" in the jack pine working group is defined as "more than 60 percent" jack pine based on a milacre quadrat assessment and "desirable (number of) trees per acre" (i.e., density) is defined as "less than 5,000 jack pine and spruce".

SITE DESCRIPTION AND TREATMENT

All trials were conducted in one or the other of two widely separated locations within the Chapleau District of OMNR and within the Missinaibi-Cabonga Section (B.7) of the Boreal Forest (Rowe 1972) (Table 1).

In 1973, and for two of three trials conducted in 1974, treatment took place immediately west and south of The Shoals Provincial Park in the Cosens/Topham Townships area, midway between Chapleau and Wawa. The sites are typical outwash plains with deep, moderately dry to moderately fresh,⁴ sandy soils that supported good stands of mixed jack pine and black spruce (*Picea mariana* [Mill.] B.S.P.) prior to logging. Slash conditions varied from light to moderate with light cone crops present on both the pine and spruce slash. Depth of organic material (L, F and H layers) to mineral soil varied from less than one inch to as much as eight inches.

Site preparation for the 1973 trial area was conducted using cement-filled shark-fin barrels for two of three treatments and a modified Sieco fireplow for the third (Riley 1975). Seedings took place at prescribed rates of 10,000, 20,000 and 30,000 viable seeds per acre.

For the two 1974 trials in this area, two scarification treatments were undertaken. In the first, a GLFRC demonstration, the same Sieco fireplow was used as for the 1973 trial. The second was conducted on an adjacent site where OMNR staff, using Young teeth mounted on a straight bulldozer blade, had undertaken an operational scarification. Because of a last-minute District decision, a mixed seeding of both these areas took place at a prescribed rate of 15,000 jack pine plus 5,000 black spruce seed per acre rather than the requested 20,000 jack pine seed per acre. For reasons outlined later in this report, these two seedings, suitably identified, have been included as part of the 20,000 seed per acre results.

The final trial of 1974 and the 1975 trial were undertaken on operational jobs conducted by OMNR to the northwest of Ramsey. The 1974 area, generally an undulating, deep, moderately dry to moderately fresh gravelly sand, was broken by shallowly covered bedrock outcroppings. Prior to logging, the site supported a stand of jack pine with black spruce admixtures in the depressions and white birch admixtures or groves on the knolls and upper elevations. The 1975 site was similar in topography, soil, and previous stand characteristics to the sites at The Shoals Park although on both of the Ramsey sites the depth of organic material ranged up to approximately ten inches. Jack pine cone crops on these areas were light to moderate with the exception of the block sown at the 10,000 seed per acre rate in 1975 where the cone crop was heavy.

⁴ After Hills (1952).

Table 1. Summary of treatment data by year and operation.

Trial year	Location (Township)	Scarification	Prescribed seeding rate/acre	Area treated (acres) ^a	Remarks	
1973	Cosens	Shark-fin barrels)	10,000 jack pine	50	GLFRC 9-combination ^b operational seeding	
		at 6' and 8' spacing,)	20,000 jack pine	50		
		Sieco fireplow)	30,000 jack pine	35		
1974	Topham	Sieco fireplow	15,000 jack pine	60	GLFRC demonstration seeding	
			5,000 black spruce			
	Topham	Young teeth	15,000 jack pine	30	OMNR operational seeding	
			5,000 black spruce			
	Edith	Young teeth	10,000 jack pine	70	OMNR operational seeding	
			20,000 jack pine	80		
			30,000 jack pine	50		
	1975	Hong Kong	Young teeth	10,000 jack pine	35	OMNR operational seeding
				20,000 jack pine	80	
30,000 jack pine				50		
Total				590		

^a To nearest 5 acres.

^b See Riley (1975) for treatment details.

Both sites were scarified using Young teeth/straight blade combinations. Seedings took place at prescribed rates of 10,000, 20,000 and 30,000 viable seed per acre.

Although different seed lots were used in each year, viability of jack pine seed was 95%+ in all cases. All seed lots were treated with aluminum and latex.

METHODS

The same site preparation and seeding procedures were followed in all trials. Site preparation took place between midsummer and early fall. The amount of seedbed was assessed, aerial seeding with a Brohm seeder/fixed wing aircraft (Piper PA-18A) combination was undertaken in early October, and a systematic trap layout was used to monitor seedfall. Stocking and density were assessed on each trial site in the late summer or early fall of each of the 3 years following treatment.

After the 1973 trial it was determined that, with assessment being done by the milacre-by-milacre method (as described below), it was no longer necessary for GLFRC to conduct its own site preparation. Assessment of operational scarification and seeding by OMNR would provide the data necessary to establish the optimum seeding rate/seedbed availability combinations and to develop a working guideline for operational seedings. Consequently, three OMNR seedings, two in 1974 and one in 1975, were assessed. Another seeding, one to demonstrate the effectiveness of the 25% receptive seedbed/20,000 seed per acre "optimum" combination, which had been suggested from work conducted between 1970 and 1973 (Riley 1975), was undertaken by GLFRC staff in 1974.

Where possible the aircraft was guided by staff wearing fluorescent orange vests. A partial control, i.e., a scarified but unseeded block, was set up in the 1973 area. This control, plus unscarified area on each of the treated sites, served as an indication of the effect of stocking from natural seed (cone crops).

ASSESSMENT

Site Preparation

A correlation between degree of site preparation and stocking and density results requires quantification of the amount of seedbed available that is favorable to the germination, survival and establishment of jack pine seedlings. Work in the trials prior to 1973 resulted in the development of a working definition for such "receptive seedbed".

In the trials being reported upon here, "receptive seedbed" was considered to be:

- (i) exposed mineral soil with a firm base, or
- (ii) a *thin* ($\leq \frac{1}{2}$ in.) duff/mineral soil mix which would readily settle to a firm base, or
- (iii) firm mineral soil with a very thin duff cover, generally not more than $\frac{1}{4}$ in. thick.

Mounded mineral soil, inverted sod layers, upturned stumps with mineral soil, etc., were not considered receptive seedbed. Excessively deep scalping, e.g., to the C horizon, produces a nutritionally poor seedbed which, though technically still mineral soil and tallied as such in the assessment, is a seedbed medium to be avoided wherever possible. Scalping to or just below the organic/mineral soil interface seems to be the ideal scarification treatment.

In the assessment procedure, approximately one chain of continuous, milacre transect was established for each acre of area scarified, i.e., a 1% sample. Transects were established systematically and were run, where suitable, perpendicular to the general direction of the scarification. Flagged pins were located at each one-chain interval to permit relocation of the line. With the chain serving as a centre-line, the above definition was applied and the amount of receptive seedbed on each milacre plot along the transect was recorded in 10% classes, except for the first class. This class, 0-5% (up to 2 square feet) of the plot in receptive seedbed, was considered to be unscarified for purposes of the assessment, i.e., it constituted insufficient seedbed area to offer any reasonable opportunity for seed catch and therefore was classified as 0% receptive seedbed. Seedbed assessment took place just prior to seeding or in the spring of the year following seeding.

Seedcast

Although seeding rate is set through calibration of the seeding unit in the aircraft (Worgan 1973), seed traps were set out to assess uniformity of coverage and to determine deposition rates.

Small wooden traps, measuring 21 in. on a side and giving 1/15,000 acre trapping area (Foreman and Riley 1979), were set out in two parallel lines at $\frac{1}{2}$ -chain intervals along the lines just prior to seeding. The two lines were set several chains apart and were arranged perpendicular to line-of-flight direction. Seed counts were made immediately after seeding was completed.

Stocking and Density

The sample lines established for seedbed assessment were precisely relocated and the same milacre plots were resurveyed annually for stocking and density. Seedling occurrence was noted as being on receptive seedbed (as defined) or not. Stocking, i.e., tree occurrence only, was recorded for each milacre along the sample line. Density, i.e., the number of trees occurring, was determined on the milacre plot at each $\frac{1}{2}$ -chain interval along the sample line. The occurrence of conifer species other than jack pine was also noted.

Weather

Weather data in this report are those obtained from the OMNR offices at Chapleau (for The Shoals Park area) and at Ramsey.⁵

RESULTS

Site Preparation

Table 2 shows, by prescribed seeding rate, and for all years and seeding rates combined, the number of milacre plots sampled in each seedbed class, the percentage of plots sampled falling into each class and the percentage of the total receptive seedbed occurring in each seedbed class, either through harvesting activity or through the prescribed site preparation treatment. (Appendix B gives the number of sampled milacres for each seedbed class on each seeding operation.) The multiplier used to calculate the percent seedbed in each class is simply the midpoint of the class except in the case of the 0-5% class which, as explained earlier, was considered unreceptive.

In all cases, at least one third of all the plots fell within the "no seedbed" class. In all cases also, the first two seedbed classes combined (i.e., 0-15%) contained over half of all plots. It will be shown below that stocking success is directly related to the amount of receptive seedbed available and that very low amounts of receptive seedbed seriously affect the likelihood of a milacre becoming stocked.

Seedcast

Seed trappings indicated catches that, with only two exceptions in 10 individual seedings,⁶ were consistently below the prescribed seeding rate (Table 3). Ironically, one of the two catches which did match or exceed the prescribed rate was the seeding of 1974 in Topham Township (Sieco) where a seeding rate of 15,000 jack pine and 5,000

⁵ As recorded in the weather data records of the Forest Fire Research Project, GLFRC.

⁶ No trapping conducted on Topham, 1974 (Young teeth) seeding.

Table 2. Sample plot and receptive seedbed occurrence by seedbed class.

Prescribed seeding rate	Receptive seedbed class (%)											Total
	0-5	6-15	16-25	26-35	36-45	46-55	56-65	66-75	76-85	86-95	96-100	
<u>10,000</u>												
No. of milacres	388	198	138	112	54	39	31	19	17	13	21	1030
% of total	37.7	19.2	13.4	10.9	5.2	3.8	3.0	1.8	1.7	1.3	2.0	100.0
Multiplier	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	.975	
% of area in receptive seedbed	0.0	1.9	2.7	3.3	2.1	1.9	1.8	1.3	1.4	1.2	1.9	19.5
<u>20,000</u>												
No. of milacres	860	449	407	296	166	124	85	44	34	36	36	2537
% of total	33.9	17.7	16.0	11.7	6.5	4.9	3.4	1.7	1.3	1.4	1.4	99.9
% of area in receptive seedbed	0	1.8	3.3	3.5	2.6	2.4	2.0	1.2	1.0	1.3	1.4	20.4
<u>30,000</u>												
No. of milacres	477	191	126	107	58	40	21	9	10	7	14	1060
% of total	45.0	18.0	11.9	10.1	5.5	3.8	2.0	0.8	0.9	0.7	1.3	100.0
% of area in receptive seedbed	0	1.8	2.4	3.0	2.2	1.9	1.2	0.6	0.7	0.6	1.3	15.7
<u>All seeding rates</u>												
No. of milacres	1725	838	671	515	278	203	137	72	61	56	71	4627
% of total	37.3	18.1	14.5	11.1	6.0	4.4	3.0	1.6	1.3	1.2	1.5	100.0
% of area in receptive seedbed	0	1.3	2.9	3.3	2.4	2.2	1.8	1.1	1.0	1.1	1.5	19.1

black spruce per acre was prescribed. Virtually no black spruce seed was caught in that seeding and the catch figure includes jack pine seed only. (The lack of black spruce catch may reflect the segregation that normally occurs when particles of unequal size and density in mix are subjected to vibration, as is the case in aerial applications. In this case the lighter and smaller black spruce seed would have "risen" in the batch, with the jack pine settling toward the feed auger at the bottom. As a result jack pine would have been sown early (as was the case here) with only minute quantities of black spruce seed being distributed. This would also account for the higher than prescribed catch of jack pine observed.)

Table 3. Seedcatch data (seed/acre).

Seeding	Prescribed seeding rate		
	10,000	20,000	30,000
1973 (Cosens)	7,150	19,000	28,000
1974 (Topham)	N/A	20,000	N/A
1974 (Edith)	9,450	24,750	23,870
1975 (Hong Kong)	7,200	12,000	23,550
Mean	7,950	18,950	25,140

Mean catches were 7,950, 18,950 and 25,140 seeds per acre at prescribed seeding rates of 10,000, 20,000 and 30,000 seeds per acre, respectively, but catches varied widely within each seeding rate. A sub-study undertaken in 1975 (Foreman and Riley 1979) showed that short-falls between prescribed and deposited rates are real and predictable and should not be considered the result of inadequate sampling procedures. Such discrepancies are, for the most part, the result of imprecise seeder calibration and flying procedures (Foreman and Riley 1979, Silc and Winston 1979). Hence, any prescribed rate can be considered "nominal" only.

Stocking

Table 4 shows first- and third-year stocking percentages for each seeding job and the mean for all jobs at each prescribed seeding rate. Despite generally unacceptable stocking levels one year after seeding, stockings were, with one exception, above or very close to the minimum stocking standard by the third year after seeding. With but one

exception, the relative stocking success position of each seeding within a seeding rate did not change between first- and third-year assessments.

Table 4 also shows the percentage change by job and seeding rate and the mean percentage changes in stocking that occurred between the first and third assessments after sowing. *Stocking increased in all cases.* In most the increases were substantial. Apparently, delayed germination and natural seeding have compensated for seedling mortality and have provided a net increase in stocking. Since two of the three site preparation techniques used, namely the fireflow and the Young teeth, tend to move cones away from prepared seedbed and leave relatively few in a position where their seed can contribute to stocking, it must be assumed that delayed germination of applied seed is the major contributor to these overall increases.

Beyond this there appears to be little substantive information or practical guidance that can be drawn from a direct comparison of overall stockings, either within or between seeding rates. Anomalies occur and there are few recognizable relationships. The reason for this is straightforward. Mean stocking and individual job stocking camouflage the picture considerably since, in a normal assessment, little or no account is taken of the amount and distribution of receptive seedbed available at the time of seeding, the amount of seed actually applied, or the weather conditions prevailing between seeding and the time of assessment and the effect that these factors have on stocking achieved.

Further analysis of the assessment data does, however, provide greater insight into these relationships. The following six figures indicate the amounts of receptive seedbed required to obtain various stocking levels one and three growing seasons after sowing with the particular aircraft/seeding device combination used throughout the trials.

The curves are developed from the regression equation:⁷

$$Y = 1 - e^{-n[q_1X + q_2(1-X)]}$$

Each of Figures 1-6 is made up of five curves which represent stockings to be obtained from a range of growing conditions from "bad" to "good" (growing conditions, mainly weather but also microsite, being reflected in the q values of the equation). The uppermost and lowermost curves indicate the best and worst stockings obtainable under the range of growing conditions encountered in the trials. The middle curve indicates mean stockings to be obtained under average growing conditions

⁷ The derivation and use of the equation are discussed in Appendix E.

Table 4. First and third year stocking results and percent change in stocking between first- and third-year assessments.

	First year			Third year			Percent change			Mean Change
	10M	20M	30M	10M	20M	30M	10M	20M	30M	
Cosens, 1973	38.3	58.4	61.4	58.6	76.2	73.6	+53.0	+30.5	+19.9	+34.5
Topham, 1974 (Sieco)	-	74.7	-	-	84.0	-	-	+12.4	-	+12.4
Topham, 1974 (Teeth)	-	66.4	-	-	83.6	-	-	+25.9	-	+25.9
Edith, 1974	35.4	49.6	43.4	57.5	72.9	70.5	+62.4	+47.0	+62.8	+57.4
Hong Kong, 1975	44.0	43.3	52.0	60.5	48.1	60.0	+37.5	+11.1	+15.4	+21.3
Mean	38.6	57.7	53.5	58.7	72.3	70.0	+51.0	+25.4	+32.7	<u>+34.4</u>
Control	-----	19.3	-----	-----	28.6	-----	-----	48.2	-----	

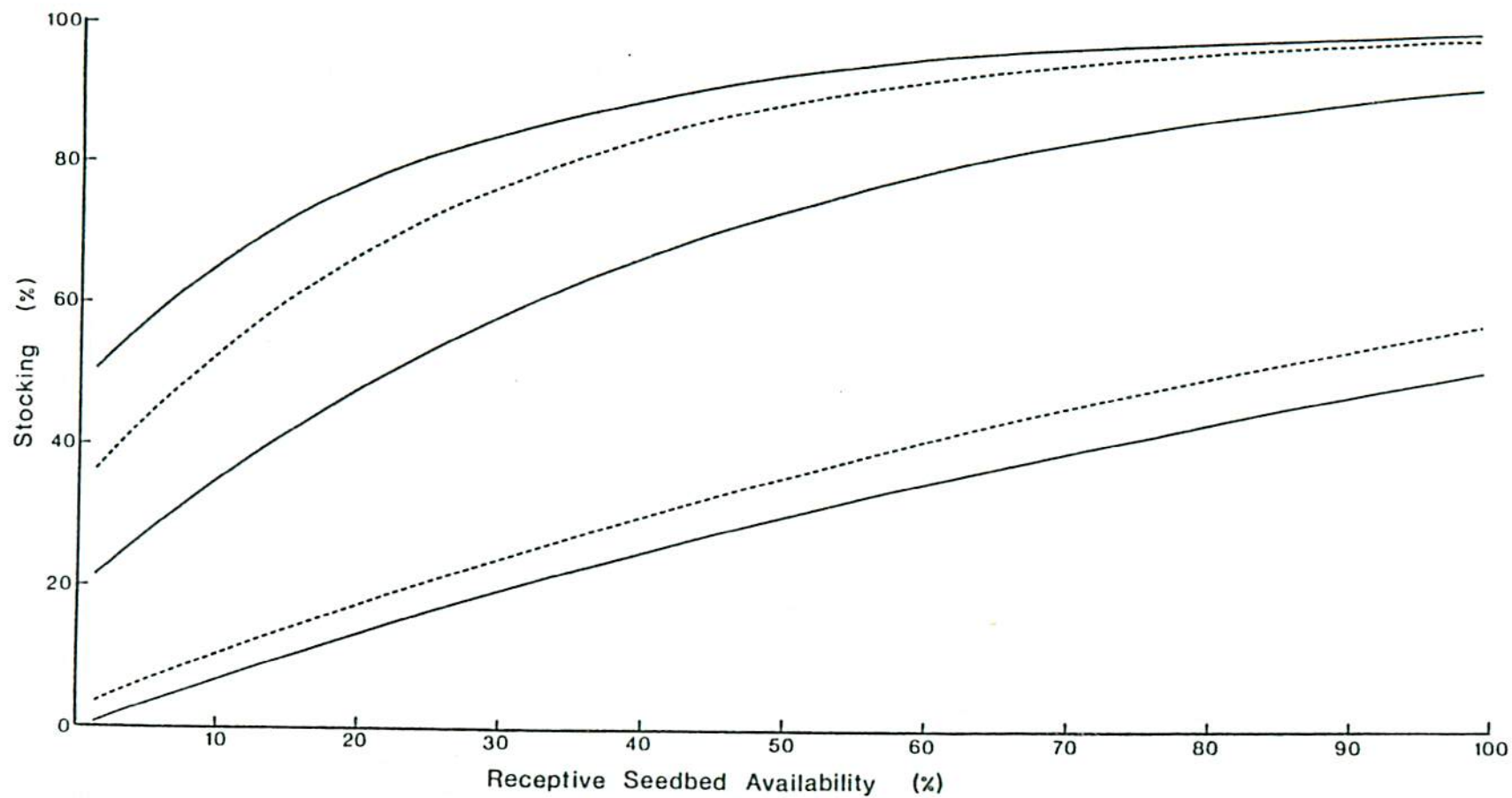


Figure 1. Stocking probability curves for a range of growing conditions by seedbed availability class for a deposition rate of 10,000 seeds per acre one year after seeding.

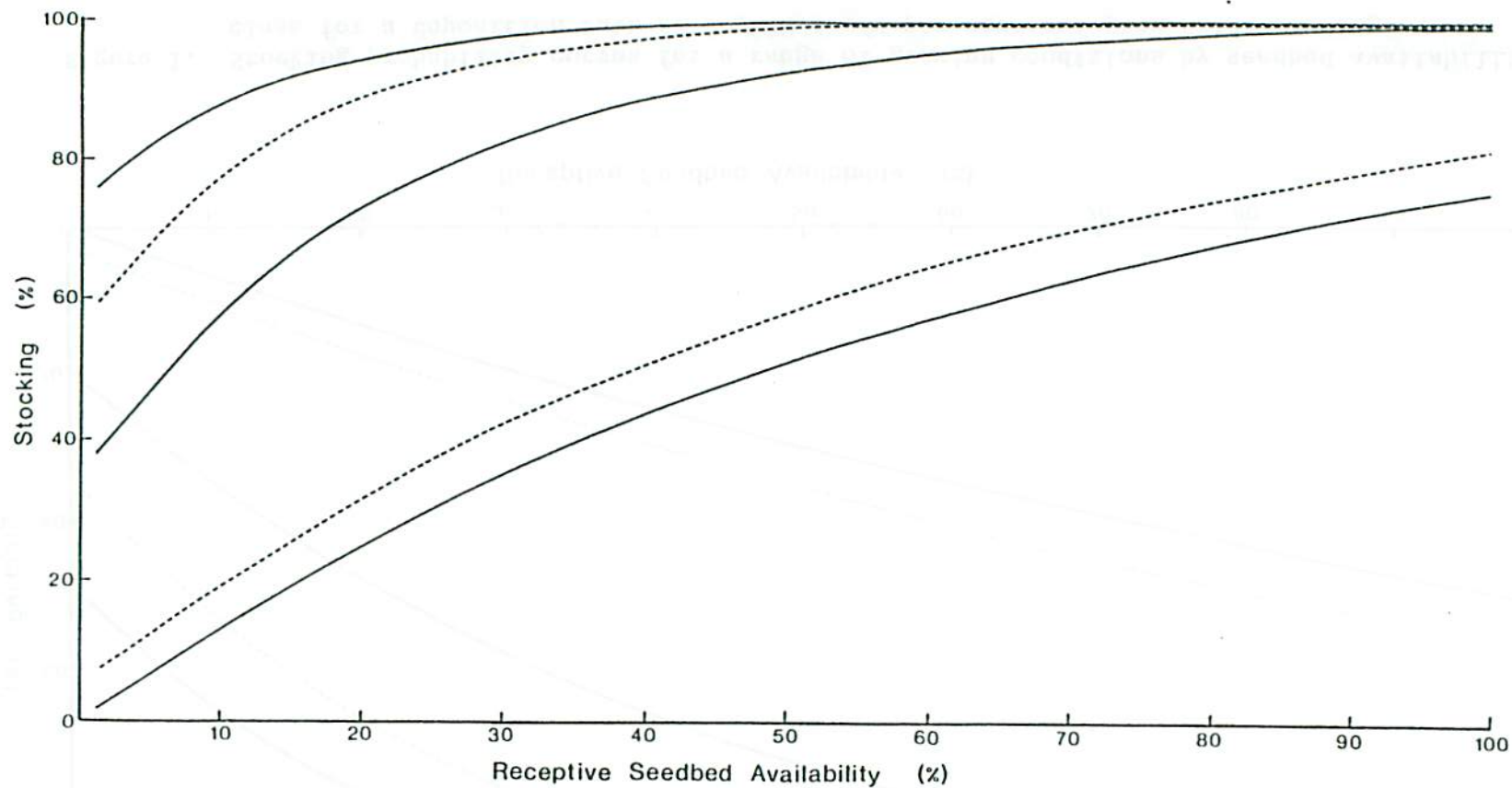


Figure 2. Stocking probability curves for a range of growing conditions by seedbed availability class for a deposition rate of 20,000 seeds per acre one year after seeding.

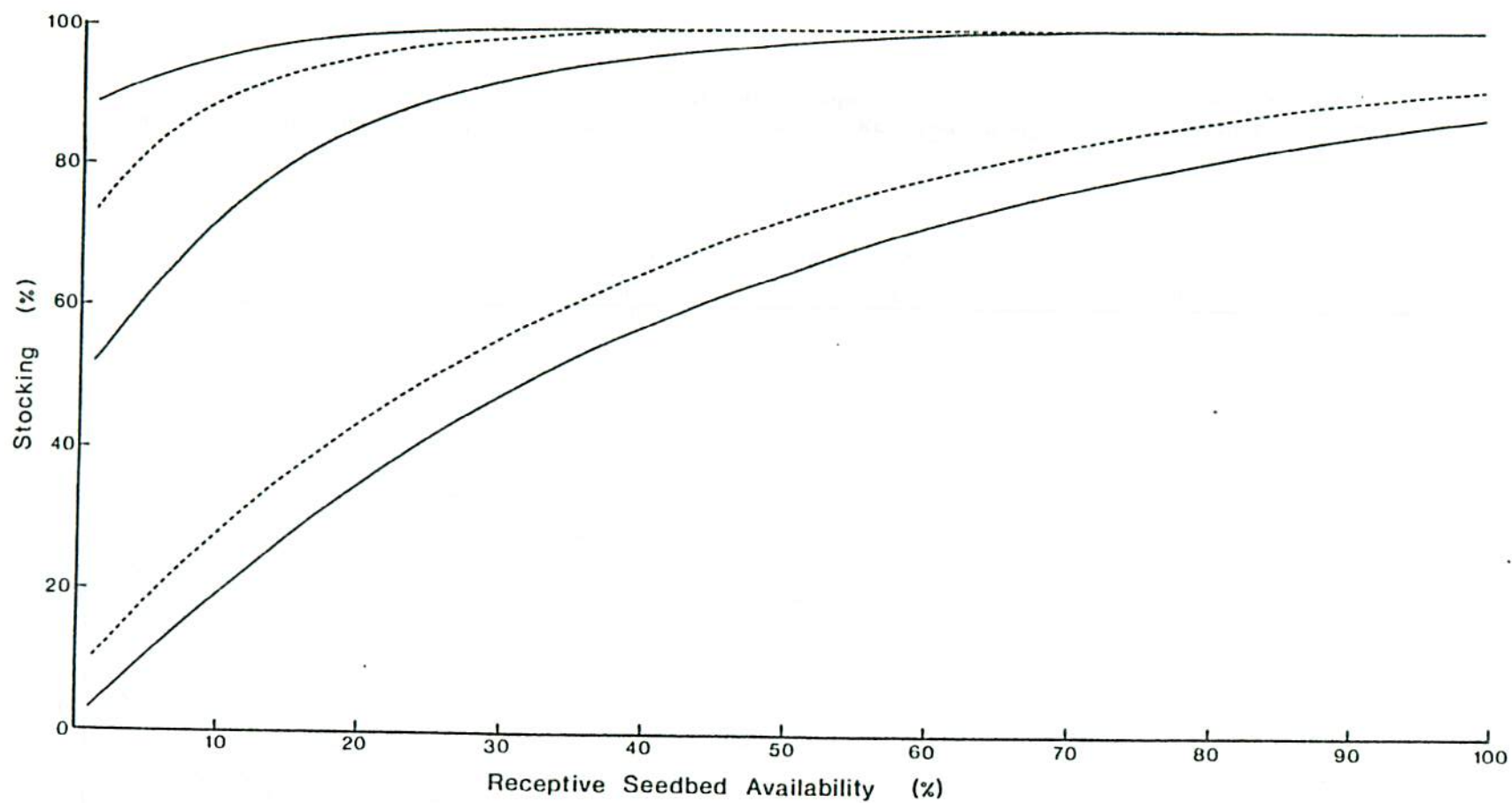


Figure 3. Stocking probability curves for a range of growing conditions by seedbed availability class for a deposition rate of 30,000 seeds per acre one year after seeding.

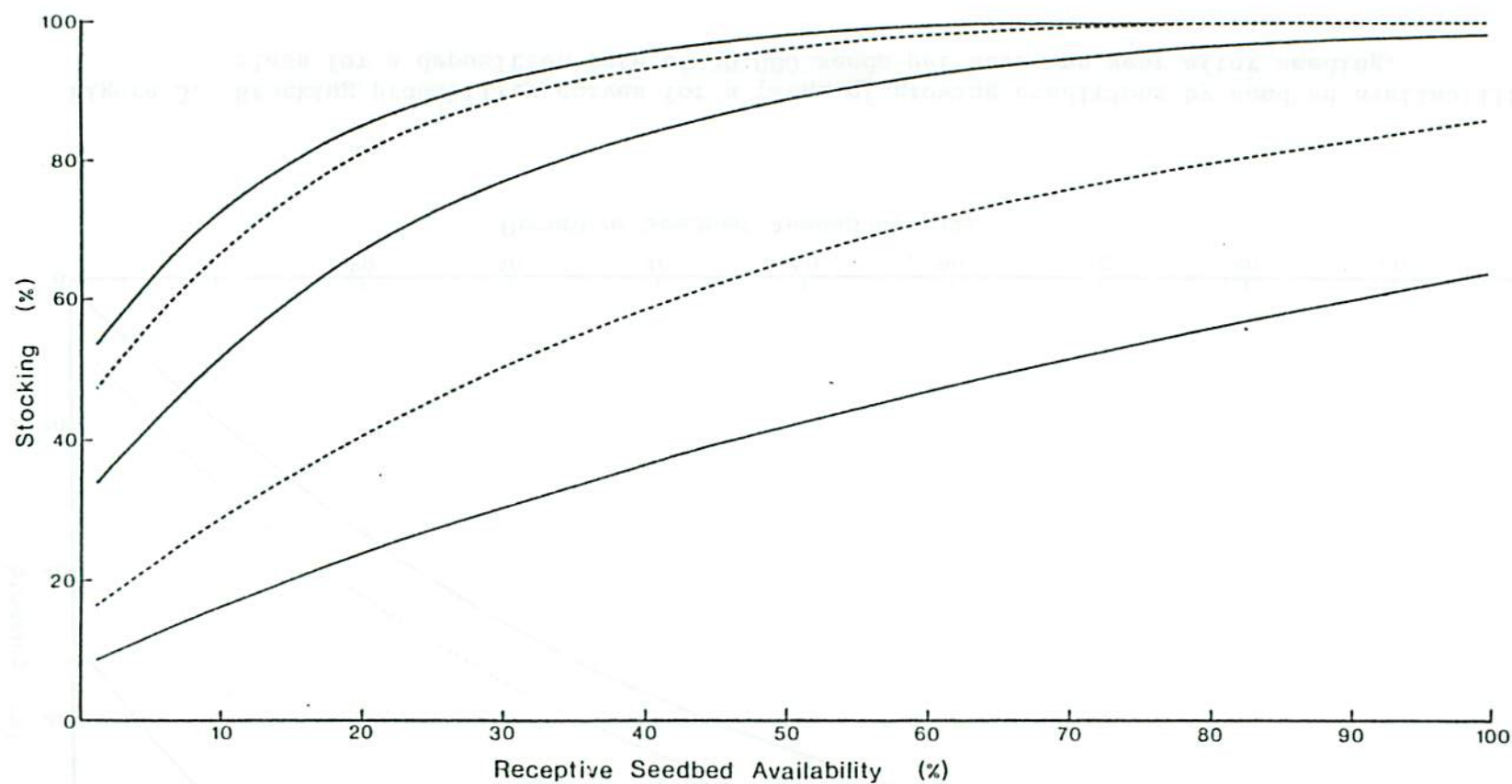


Figure 4. Stocking probability curves for a range of growing conditions by seedbed availability class for a deposition rate of 10,000 seeds per acre three years after seeding.

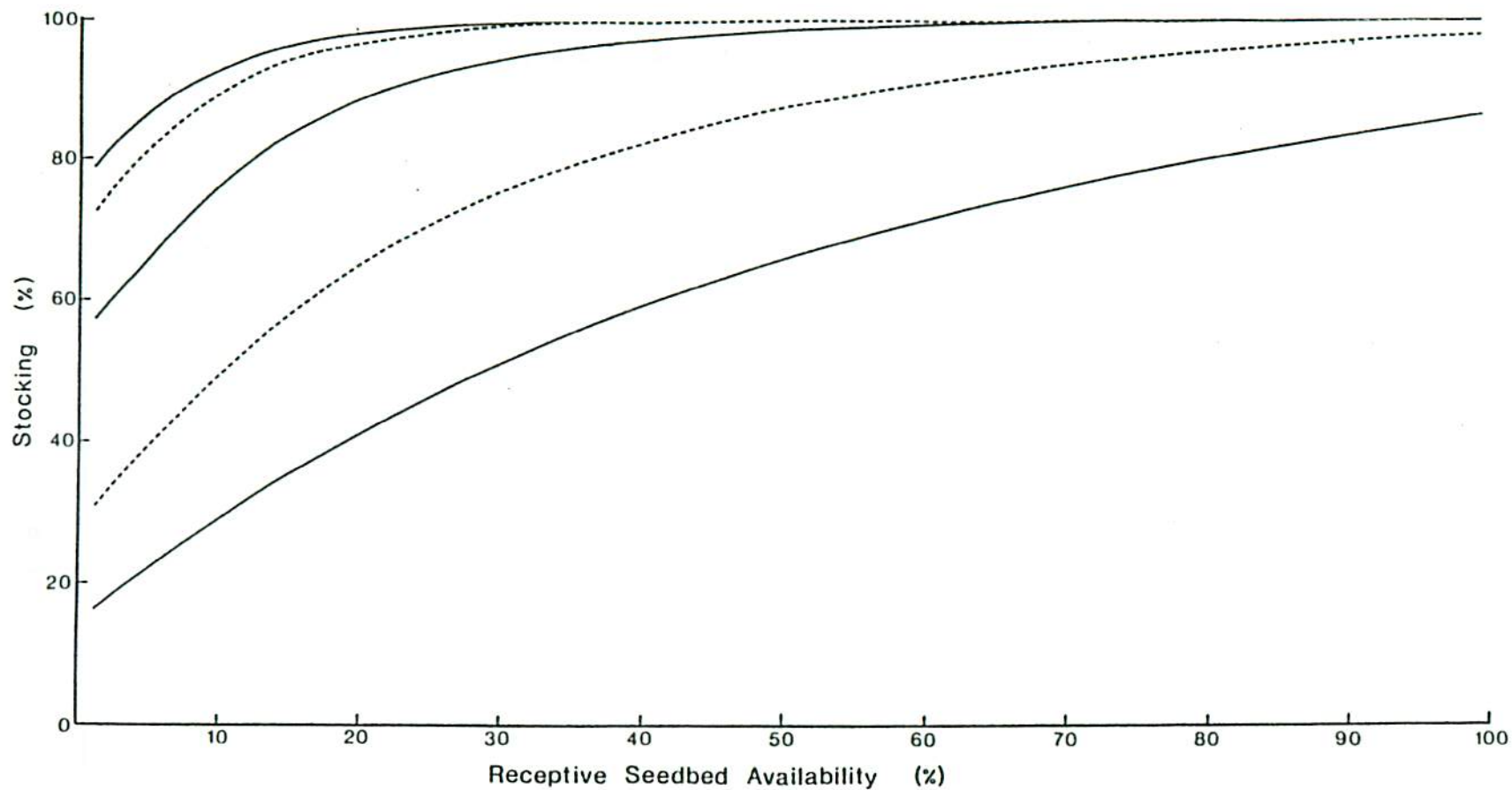


Figure 5. Stocking probability curves for a range of growing conditions by seedbed availability class for a deposition rate of 20,000 seeds per acre three years after seeding.

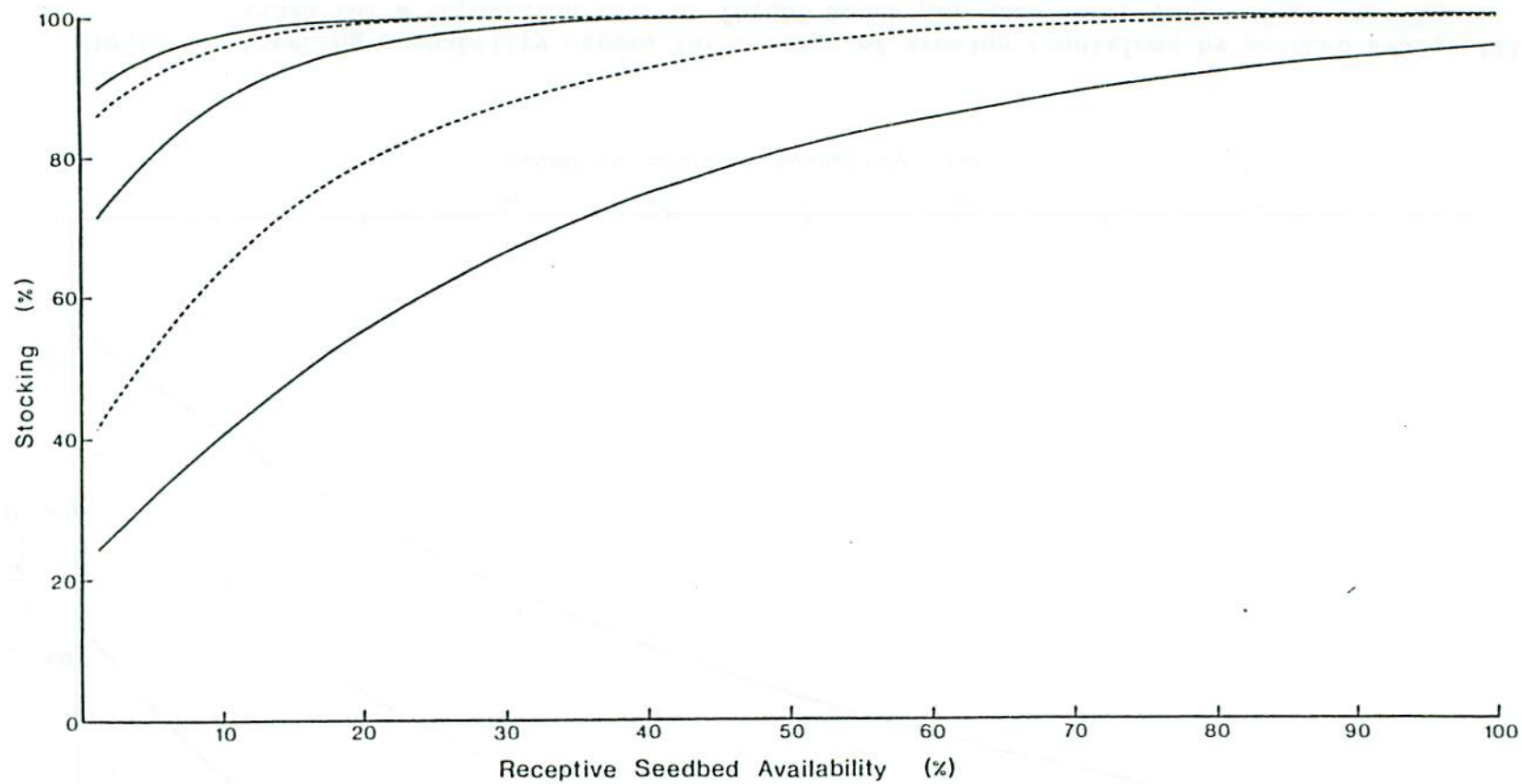


Figure 6. Stocking probability curves for a range of growing conditions by seedbed availability class for a deposition rate of 30,000 seeds per acre three years after seeding.

while the two remaining, intermediate curves represent mean stockings \pm one standard deviation (of q). This last indicates that there is a 65% probability that stocking will fall between these two curves and an 82.5% probability (more simply, in four seedlings out of five, or 80% of the time) that stocking will occur above the lower of the two curves.

Figures 1-3 show stocking curves for *actual* seeding rates of 10,000, 20,000 and 30,000 seeds per acre (selected to correspond to the prescribed rates of the trials) one growing season after sowing at various levels of seedbed availability. Figures 4-6 show similar curves for the third growing season after sowing. In each case the stocking shown for a given percentage of receptive seedbed is derived from all the plots occurring in the selected seedbed class, i.e., the stocked plots to total plots (in the class) ratio. The curve is not extended to the Y-axis since a Y-intercept would imply a specific stocking for zero receptive seedbed. In fact, seedbed values for this class range up to 5%. Much of the stocking which does occur in this class is found on the small patches of receptive seedbed available and the contribution to stocking from plots with no receptive seedbed, or defined non-receptive seedbed, is much lower than would be shown by an extension of the curves to the Y-intercept.

At the lower levels of receptive seedbed availability, stocking generally increases rapidly with relatively minor increases in receptive seedbed. The rate of stocking increase declines rapidly, however, as seedbed availability continues to increase. The curves tend to level off at intermediate and higher levels of receptive seedbed, indicating little gain in stocking even with major increases in receptive seedbed availability.

It is apparent that, for a given level of receptive seedbed availability and with equivalent growing conditions, there are stocking gains to be had by increasing the amount of seed applied but the gains decrease significantly as the seeding rate becomes progressively greater. It is apparent also from the curves that stocking increases with time, a further illustration of the trends shown in Table 4.

Analysis of the limited amount of control data⁸ shows (Table 4) that the stocking achieved on scarified but unseeded areas, i.e., from natural seeding, is far below both the overall stockings of seeded areas and the minimum stocking standard. Of the plots stocked, most were stocked with trees growing on the available receptive seedbed.

Trees found on non-receptive seedbed were few and thus the contribution made to overall stocking by non-receptive seedbed was very

⁸ Data available for first and second growing seasons after sowing only.

limited. Of the 2429 stocked plots assessed on the seeded areas after one growing season, 184 were found to have trees on non-receptive seedbed only. As a result, the contribution to stocking of such plots is just 7.6%. By the third year this contribution had increased to 10.1%. Throughout the assessment it was observed that the percentage of plots stocked with trees on both receptive and non-receptive seedbed is very limited and does not likely exceed that for stocking on non-receptive seedbed alone. Thus, in these trials, the total number of plots with trees on both receptive and non-receptive seedbed is unlikely to be more than approximately double the number of plots with trees on non-receptive seedbed only.

The poor stocking that occurs on non-receptive seedbed is illustrated in Figure 7. The photograph, taken in 1978, shows a segment of the Cosens 1973 seeding chance. To the left, there was no site preparation and only minimal stocking after 5 years whereas to the right, receptive seedbed availability was moderate and stocking was high. Both areas were sown at a prescribed seeding rate of 30,000 seeds per acre.



Figure 7. Stocking results on modified Sieco fireflow site preparation (to right) and on unscarified ground (to left). Both areas have been seeded at a prescribed rate of 30,000 seeds per acre.

Natural stocking by other species, principally black spruce, contributed relatively little by the third year after seeding. On average 5.2% of all plots were stocked to spruce. The range of spruce stockings over all jobs was <1-9.4%. This indicates that spruce would be only a minor component of the new stands if indeed it survived the suppression of the much faster growing jack pine. On average the stockings in Table 4 are increased by only 2.4% as a result of natural spruce seedlings or layerings remaining from the previous stand, i.e., from plots stocked to spruce only.

Density

Because the number of plots sampled for density was much lower than the number sampled for stocking, fewer conclusions can be drawn from the information. The data are presented to provide the manager with some insight into density trends at the different seeding rates and the effect that increasing amounts of receptive seedbed and the passage of time have on density.

Because the numbers of plots assessed for individual seedbed classes on each job were relatively limited, all seeding jobs at each seeding rate have been combined for this analysis. Table 5 indicates the frequency distribution of milacres assessed by seedbed class and gives tree densities per milacre and per stocked milacre for each seedbed class one and three years after sowing. First- and second-year data are given for the control plot established in Cosens Township.

The expected trend toward increased densities as the amount of receptive seedbed increases is readily evident. Less expected were the substantial increases in density which occurred between the first- and third-year assessments. This was the rule rather than the exception, as in only 4 out of the 36 seedbed cases shown was there a decrease. These increases support the similar increases observed in stocking and would seem to confirm the influence of delayed germination suggested earlier.

Density increases are clearly established as the sowing prescription increases from 10,000 to 20,000 seeds per acre. This is true of all seedbed classes in both the first and the third years. Less clearly established is the relationship between densities at the 20,000 rate and the 30,000 rate. It is true that seed catches showed a smaller increase than the 50% prescribed (i.e., 18,950 to 25,140 seeds per acre) but substantial additional seed was sown which should be reflected in higher densities at the 30,000 rate. In spite of this the 20,000 rate shows higher densities in the 20% and 30% seedbed classes than does the 30,000 rate, and the overall density per milacre, and hence per acre, is higher for the 20,000 rate. The reason for this is unknown but the question may be largely academic. The density levels attained would seem to be adequate or more than adequate by the third year in all seedbed classes at all seeding rates. The only cause for concern may be that density is too high.

Table 5. First and third year density results.

Prescribed seeding rate	Receptive seedbed class (%)											Total	Density (trees/ac.)
	0-5	6-15	16-25	26-35	36-45	46-55	56-65	66-75	76-85	86-95	96-100		
<u>10,000/ac.</u>													
No. of milacres	76	40	33	19	4	7	6	7	4	5	5	206	
No. of trees/milacre (first year)	0.2	0.8	1.5	1.7	3.7	1.4	0.5	2.9	4.0	2.0	1.0	1.0	1000
No. of trees/stocked milacre (first year)	1.5	1.7	2.7	2.5	3.7	3.3	3.0	4.0	4.0	2.5	2.5	2.5	2500
No. of trees/milacre (third year)	0.7	1.9	2.8	3.3	4.2	2.9	1.2	3.3	3.7	2.0	1.4	1.9	1900
No. of trees/stocked milacre (third year)	2.1	3.1	3.8	4.2	4.2	4.0	2.3	4.6	3.7	2.5	1.7	3.2	3200
<u>20,000/ac.</u>													
No. of milacres	182	89	87	51	26	24	18	11	7	7	9	511	
No. of trees/milacre (first year)	0.5	1.6	2.8	3.7	4.3	4.0	5.3	4.4	5.4	3.9	7.9	2.2	2200
No. of trees/stocked milacre (first year)	1.8	2.5	3.6	4.6	5.4	4.4	5.6	4.8	5.4	5.4	8.9	3.8	3800
No. of trees/milacre (third year)	1.5	2.6	4.9	5.4	4.3	5.0	6.3	5.0	5.0	8.0	6.3	3.4	3400
No. of trees/stocked milacre (third year)	3.0	3.3	5.5	6.0	5.1	5.7	6.3	5.5	5.0	8.0	6.3	4.6	4600
<u>30,000/ac.</u>													
No. of milacres	91	33	27	24	12	11	8	2	--	--	4	212	
No. of trees/milacre (first year)	0.6	1.9	2.7	2.5	5.0	4.0	6.2	6.5	--	--	3.0	2.0	2000
No. of trees/stocked milacre (first year)	2.5	2.7	3.0	3.1	5.5	4.9	7.1	6.5	--	--	4.0	3.5	3500
No. of trees/milacre (third year)	1.7	3.8	3.7	3.2	5.4	6.7	8.2	8.0	--	--	4.0	3.3	3300
No. of trees/stocked milacre (third year)	2.9	4.4	4.0	3.7	5.9	6.7	8.2	8.0	--	--	4.0	4.3	4300
<u>Control (Cosens, 1973)</u>													
No. of milacres	44	10	8	8	2	--	--	--	--	--	--	72	
No. of trees/milacre (first year)	0.1	1.0	0.2	2.0	--	--	--	--	--	--	--	0.4	400
No. of trees/stocked milacre (first year)	1.0	3.0	1.0	5.3	--	--	--	--	--	--	--	2.8	2800
No. of trees/milacre (second year)	0.2	0.7	1.6	1.7	2.0	--	--	--	--	--	--	0.7	700
No. of trees/stocked milacre (second year)	1.7	1.7	3.2	2.8	2.0	--	--	--	--	--	--	2.3	2300

The increases in density which occur as one moves from the average for all plots in each seedbed category to the average for stocked plots only are also shown and follow the same trends as discussed above. For example, the third-year density in the 20% seedbed class at 20,000 seeds per acre on all plots, stocked or not, was 4900 seedlings per acre. For stocked plots only the density was 5500 seedlings per acre. The obvious implication is that, as seedbed availability and distribution increase, there will be corresponding increases in density per acre.

In the case of the control block, densities were generally lower. The disproportionately high densities per milacre and per stocked milacre which occur in the 10% and 30% seedbed classes in the first year (they are higher than the parallel numbers for the 10,000 rate) are the result of cone clumps which released substantial quantities of seed on two milacres. Without these two milacres, densities per acre after one year would have been 100 and 1100 seedlings per acre, respectively, rather than 400 and 2800. By the second year overall density per acre had increased to 700 whereas the average number of trees per stocked milacre had decreased to 2.3. The situation after the third growing season is unknown but again the question would seem to be academic since so few of the milacres on the control block were stocked (see Table 4).

Weather

Tables 6 and 7 show monthly (May-September) rainfall and temperature data for the seeding sites for the years 1974-1976 inclusive. Normals are as provided by the Department of the Environment (Anon. 1973). The Chapleau data are used for the Cosens and Topham Township sites, approximately 25 miles away, and the Ramsey data for the Edith and Hong Kong Township sites, some 10 miles away.

It can be seen from Table 6 that in 1974 the overall May-September rainfall was slightly higher than normal and that for the critical June-August period actual rainfall was virtually identical with the normal but was spread over 41 days rather than the normal 34 days. In 1975 data are incomplete but during the June-August period actual rainfall was much less than normal (41% and 65% for Chapleau and Ramsey, respectively) and occurred over roughly three-quarters of the normal number of days. In 1976 rainfall at Ramsey was lower still, being approximately one-third of normal.

Daily mean maximum temperatures *at noon* in each year (Table 7) were generally below the Department of the Environment daily mean maxima but, from the observed temperature ranges, it is apparent that some very high maximum readings occurred during July and August of 1975 and 1976.

Table 6. Actual and normal rainfalls in vicinity of seeded areas during first growing season after seeding.

Weather station		Rainfall (inches)					
		May	June	July	August	September	Total
<u>Actual</u>							
Chapleau	1974	1.95	3.84	1.63	4.93	5.50	17.85
	% of normal	72	116	53	134	131	105
	Days measurable rainfall	(14)	(14)	(12)	(15)	(16)	(71)
Chapleau	1975	3.66	2.79	0.70	0.60	4.19	11.94
	% of normal	136	85	23	16	100	70
	Days measurable rainfall	(10)	(14)	(7)	(5)	(12)	(48)
Ramsey	1975	*	2.83	1.56	2.17	*	6.56
	% of normal		88	51	59		65 ^b
	Days measurable rainfall		(12)	(6)	(5)		(23)
Ramsey	1976	*	1.41 ^a	0.98	1.02	*	3.41
	% of normal		44	31	33		36 ^b
	Days measurable rainfall		(9)	(7)	(6)		(22)
<u>Normal^c</u>							
Chapleau		2.70	3.31	3.06	3.69	4.20	16.96
	Days measurable rainfall	(12)	(11)	(11)	(12)	(14)	(60)
Ramsey		2.48	3.20	3.20	3.11	3.49	15.48
	Days measurable rainfall	(9)	(11)	(10)	(11)	(12)	(53)

* Insufficient data to provide a monthly reading.

^a Data for period June 7-30 only.

^b Based on June to August normals.

^c As provided by Environment Canada (Anon. 1973).

Table 7. Actual and normal temperature data in vicinity of seeded areas during first growing season after seeding.

Weather station		Temperature (Mean noon - °F)				
		May	June	July	August	September
<u>Actual</u>						
Chapleau	1974	49	65	70	64	51
	Range	(27-74)	(47-81)	(60-85)	(51-78)	(38-70)
Chapleau	1975	64	66	72	70	52
	Range	(44-82)	(46-84)	(52-97)	(59-91)	(43-70)
Ramsey	1975	*	68	75	72	*
	Range		(47-85)	(53-95)	(59-93)	
Ramsey	1976	*	71 ^a	71	71	*
	Range		(57-80) ^a	(57-84)	(50-90)	
<u>Normal</u>						
Chapleau	Maximum ^b	60	70	74	71	61
	Minimum ^b	35	44	49	46	40
	Mean	48	58	62	59	50
Ramsey	Maximum ^b	60	70	74	71	61
	Minimum ^b	37	47	52	50	42
	Mean	49	58	63	60	52

* Insufficient data to provide a monthly reading.

^a Data for period June 7-30 only.

^b Mean daily maxima and minima for month.

DISCUSSION

It is presupposed in this discussion that the primary objective of the forest manager in undertaking an aerial seeding operation for the regeneration of jack pine is acceptable stocking results at reasonable cost. This report, and this section in particular, is designed to assist the manager in achieving this goal.

Seedcast

It must be re-emphasized that actual seed depositions rarely meet prescribed seeding levels. When following the method described below to estimate expected stockings, the manager should use actual seed deposition values (to the nearest thousand seeds per acre) rather than prescribed seeding rates. Ideally, seed deposition rates should be determined by trapping at the time of seeding. If this is not possible an approximation of the deposition rate can be obtained from Foreman and Riley (1979), who showed that, under current operational practice, deposition rates can average 20-25% below prescribed rates. These values (e.g., a deposition rate of 15,000-16,000 seeds per acre at a prescribed rate of 20,000 seeds per acre) may be used for the selection of stocking probability values and should provide reasonable stocking estimates. In estimations of seed deposition the shortfall should be reduced only when it is known that a high degree of care will be taken in calibration and flying procedures or when the seeder has been calibrated for a given swath width but the swath width actually flown is deliberately reduced. For example, Foreman and Riley (1979) showed that for a calibrated swath width of 75 feet, the deposition rate increases to approximately 100% of the rate prescribed as the flown swath width approaches 60 feet.

In the following discussion all seeding rates referred to denote deposition rates unless otherwise specified.

Stocking

The results presented above have firmly established that stocking tends to increase substantially between the first and third years after sowing. Therefore, it is appropriate to concentrate this portion of the discussion on third-year results, those to be achieved toward the end of the establishment period.

Figures 4-6 show various levels of stocking expectation after three growing seasons at each of three deposition rates. Further inspection of these figures provides additional insight into the relationship between seeding rate and stocking.

If Figures 4 and 5 (10,000 and 20,000 rates) are superimposed it will be seen that the mean curve of the 10,000 rate almost exactly coincides with the 80% probability curve of the 20,000 rate. Further, all

curves of the 10,000 rate fall below the mean curve of the 20,000 rate. From this it is suggested that a deposition rate of 10,000 seeds per acre will almost always provide poorer stocking results than a deposition rate of 20,000 seeds per acre. From a comparison of the mean curves the average stocking differential between the two rates, three years after sowing, is approximately 19% within the operationally feasible receptive seedbed range (<45%).

If Figures 5 and 6 (20,000 and 30,000 rates) are superimposed the relationship between these two seeding rates is much less clearcut. While there is a stocking advantage to be had by applying 30,000 rather than 20,000 seeds per acre, the advantage is much less pronounced than that for the 20,000 rate over the 10,000 rate. The average stocking differential between the two rates, three years after seeding, is approximately 7% within the operationally feasible receptive seedbed range.

In both cases the greatest stocking gains to be had from increasing seeding rate are found at the lowest seedbed levels. The gains become increasingly smaller as seedbed availability increases. In comparison with the 10,000 rate, the 20,000 rate gives average stocking gains of 26%, 17% and 11% at seedbed levels of 10%, 30% and 50%, respectively. The gains for the 30,000 rate over the 20,000 rate are 12%, 5% and 1%, respectively for the same seedbed levels. Absolute stocking levels obtainable would appear to justify the selection of a sowing rate of 20,000 rather than 10,000 seeds per acre. On the other hand, absolute stocking levels attainable at a sowing of 20,000 seeds per acre and the relatively minor gains to be had from applying 30,000 seeds per acre would seem to make the application of the higher rate of questionable value. This, plus the findings of Foreman and Riley (1979) concerning seed distribution, suggest that application rates much beyond 20,000 seeds per acre may be wasteful of seed when the Brohm seeder is used.

From the results it would appear that the forest manager can almost invariably expect to observe stocking increases on a seeding chance with the passage of time. Moreover, stocking increases may continue for a number of years. Sutton (1979) suggested that, although there appears to be nothing in the literature on the duration of delayed germination, the chances of germination from applied or residual natural seed after five or more years would seem very slight. Nevertheless, he observed continued ingress of jack pine seedlings beyond this period on a plantation near Sultan, Ontario, on which only light slash loadings were left after harvesting. Sutton found that 53% of planted trees, six years after planting, were bearing cones and that 33% of all planted trees bore open cones. After a seeding operation, therefore, eight-year-old trees might be expected to be adding new seed, thereby providing the opportunity for further increases in stocking as long as some suitable seedbed and openings of sufficient size are available.

Lyon and Thomson (1979) also found continued jack pine ingress on a burned and aerially seeded site in the Nipigon area. Their observations recorded an increase in stocking of 10% between the sixth and seventeenth years after seeding where stocking at the sixth year was only 55%. Neither the Sutton report nor the Lyon and Thomson report attempts to describe the seedbed condition on which seedlings occurred.

One point would seem to be clear from these trials and this discussion of jack pine ingress. *Jack pine stocking is likely to be at its lowest at the end of the first growing season after seeding.* High early stocking should be the prescribed goal to obtain a high level of utilization of site potential and to take advantage of associated growth and form benefits. But the manager should use caution in deciding to re-treat marginal or "grey area" stockings too soon after the original seeding.

Site Preparation

In order to develop further the relationships among seeding rates, seedbed availability and stocking, the following assumption has been made. If for a given seeding rate, the stocking level is deemed to be satisfactory on milacres with, say, at least 20% receptive seedbed, then 1000 milacres, each scarified to the same degree, should provide satisfactory stocking on an acre as a whole. A similar situation should exist if all milacres on an entire work site are also scarified to a minimum of 20%. (It is assumed that seed distribution is reasonably uniform.)

Stocking probability values similar to those shown graphically in Figures 1-6 are presented in tabular form in Appendix C. The stockings to be achieved from given levels of receptive seedbed availability over a range of "good" and "bad" growing conditions are shown for seeding rates from 5,000 to 30,000 seeds per acre for both one and three growing seasons after sowing.

Any stocking goal is, of course, the decision of the individual forest manager. The tables and the following discussion of site preparation considerations should be of use in attempts to attain such a goal. If the aim is to achieve at least 80% stocking on average by the third year, the mean values of Table C2, Appendix C, show that at least 35% receptive seedbed per milacre (the division between the 30% and the 40% seedbed classes) is required up to a deposition rate of 11,000 seeds per acre. From 12,000 to 14,000 seeds per acre, at least 25% receptive seedbed is required per milacre and it is not until 23,000 or more seeds per acre are deposited that receptive seedbed requirements drop below 15%. Similarly, if the aim is to achieve at least 60% stocking in most cases (i.e., four times out of five), the 80% probability values can be used. In such cases at least 35% receptive seedbed per milacre is required up to a deposition rate of 13,000 seeds per acre. From 14,000

to 17,000 seeds per acre at least 25% receptive seedbed per milacre is required and only when the seeding rate reaches 27,000 seeds per acre does the seedbed requirement drop below 15%.

As has been emphasized, these relationships are based on the premise that all 1000 milacres of an acre are scarified to the selected level of seedbed preparation. Clearly this is not practical in field operations. However, the extreme imbalance (to the lower end of the scale, see Table 2) of seedbed preparation obtained over the course of these trials with a variety of site preparation tools is highly unsatisfactory. Common sense tells us that it is futile to attempt to regenerate a new stand from seed without providing adequate quantities of receptive seedbed properly distributed. If, to avoid the use of high seed deposition rates, at least 15% of a plot must be in receptive seedbed for that plot to have an acceptable chance of becoming stocked, then it is quite clear that over half of the milacre plots in these trials had unacceptably low stocking probabilities.

While it may not be practical to prepare 100% of all milacres to minimum seedbed levels, there must be a concerted effort to minimize the number of milacres on a seeding job with unacceptably low stocking probabilities, i.e., those which fall into the 0-15% seedbed classes. For reasons of cost and perhaps exposure, one should avoid preparing too many milacres to very high levels of seedbed. A limit of 35% receptive seedbed per milacre is suggested as the maximum for which to strive.

It should be evident to the practitioner that, not only is it not feasible to prepare all milacres to a certain level of receptive seedbed, it is also not feasible to ensure, at least operationally, that all milacres are even scarified. It is recommended, therefore, that the site preparation goal be one in which most milacres on a seeding chance fall above the 15% seedbed level and that most of these fall within the 16-35% seedbed range if acceptable overall stocking levels are to be obtained within an economical seedbed availability range and at reasonable seeding rates.

It must be recognized that it is, in fact, available *area* of seedbed per milacre that is of concern rather than percentage of available seedbed per milacre. The milacre was the sample plot size selected for these trials and, as long as all sampling was conducted on the basis of milacre plots, percentages could be used in comparisons. For different plot sizes, of course, the actual area of seedbed available must be calculated and the receptive seedbed percentages of the tables in Appendix C converted to area as well if the tables are to be used. For example, one milacre equals 43.56 square feet. A 20% seedbed availability indicates that there are 8.71 square feet ($43.56 \times .20$) of seedbed on that milacre. For any given set of table values, the 8.71 square feet gives a certain stocking probability which will be constant regardless of plot size but, for plots of other than milacre size, the percentage of available seedbed will be something other than 20%.

Plots are the means by which the effectiveness of the seedbed preparation operation is assessed. In this case the milacre was used because it is a common assessment unit and because, with adequate sample, it readily indicates to the manager if enough of his area is properly prepared and if the seedbed is sufficiently distributed through the area to enable proper utilization of the site's potential. It is for this reason that overall seedbed percentages should be used with caution when the success of a site preparation operation is being determined; e.g., knowing that an area is scarified to 25% receptive seedbed is of little value if, in fact, it means that one quarter of the area has been prepared to 100% optimum seedbed while the remainder has received no preparation. In the assessment of a site an adequate and representative sample of the whole area must be taken.

As has been noted, the tables in Appendix C provide stocking probabilities for given levels of available seedbed per milacre over a range of "good" and "bad" growing conditions. Potential overall stocking for an area would be the weighted stockings of all plots in all seedbed classes for any selected seeding rate and growing condition level.

Table 8 shows the probable third-year stocking ranges that would have been determined from Appendix C prior to seeding, using the appropriate receptive seedbed availability values from each seeding chance (Appendix B), and compares them with the third year stockings actually achieved. In seven of the 11 seedings, actual stockings were very close to estimated stockings for the weather conditions encountered. In three of the 11 seedings, actual stockings differed from the estimated stockings⁹ but in each case stocking was well above the 80% probability level estimation. In only one of the 11 seedings was actual stocking below the 80% probability estimation. The method therefore seems to be a valid means of estimating the range of stockings to be obtained from aerial seeding of jack pine and the tables can be used by the manager for the following purposes:

- 1) *to estimate the stocking range that should be expected for any deposition rate that may be selected, before seeding occurs.*
- 2) *to estimate the stocking range that should be expected from the deposition rate actually used.*
- 3) *to determine, after one growing season, if satisfactory progress is being made toward the attainment of the third-year stocking goal.*

⁹ On one of these seeding chances (Hong Kong, 1975-7200 seeds per acre deposited) the stocking is much higher than expected for the poor weather conditions encountered. It is known that on this particular site the ground was generally fresher than it was in the surrounding area and there was a high cone loading. No explanation is available for the apparently aberrant stockings in the other two cases.

Table 8. Comparison of actual and estimated third-year stockings.

Seeding operation	Seeding rate (/ac)	Actual stocking 3rd year (%)	Weather conditions	Estimated stocking %			Comment ^b
				80%	Mean	Maximum	
<u>10,000</u>							
Cosens, 1973	7150	58.6	Good	25.0	44.0 *	61.9	1) Well above average
Edith, 1974	9450	57.5	Intermediate	40.2 *	61.1	76.8	1) Well below average
Hong Kong, 1975	7200	60.5	Poor	29.8	49.5 *	67.0	2) Above average
<u>20,000</u>							
Cosens, 1973	19000	76.2	Good	53.7 *	77.2	90.7	2) Just below average
Topham, 1974 (Sleco)	20000	84.0	Intermediate	60.3	82.6 *	93.8	1) Just above average
Topham, 1974 (Teeth)	20000	83.6	Intermediate	63.9 *	83.8	94.1	1) Just below average
Edith, 1974	24750	72.9	Intermediate	61.7 *	82.7	93.9	1) Below average
Hong Kong, 1975	12000	48.1	Poor	42.1 *	63.8	80.0	1) Well below average
<u>30,000</u>							
Cosens, 1973	28000	73.6	Good	65.5 *	86.3	95.9	2) Well below average
Edith, 1974	23870	70.6	Intermediate	50.3 *	75.4	90.9	1) Just below average
Hong Kong, 1975	23550	60.0	Poor	* 65.1	84.3	94.6	3) Below 80% probability

^a Seeding rates rounded to nearest thousand in calculation of estimates.

- ^b
- 1) Actual stocking as expected for weather conditions encountered.
 - 2) Actual stocking not as expected for weather conditions encountered but well above 80% probability level.
 - 3) Actual stocking below 80% probability level but above minimum obtainable level.

* Position of estimated stocking as determined by Appendix C.

An example of the procedure to be followed in making these determinations is given in Appendix D. For 1) above, an adequate knowledge of the amount of seedbed available in each of the seedbed classes is required. A 1% sample of the seeding chance is recommended for the purpose. For 2) above, the same seedbed information plus a reliable estimate of the amount of seed actually applied is required. For 3) above, the information for 1) or 2) is required as well as a reliable estimate of overall first-year stocking on the seeding chance in question. No. 3 above is possible because the first- and third-year q values obtained from these trials are positively correlated (correlation significant at the .05 level). This means that a stocking "success" after one year is likely to remain a stocking "success" after three years and, similarly, a stocking "failure" after one year is likely to be a stocking "failure" after three years. "Success" and "failure" are, of course, dependent on the level of stocking required by or acceptable to the forest manager.

At present there is no formalized standard for receptive seedbed levels in Ontario for aerial seeding of jack pine. The need for a standard is real. It would provide a guideline for attaining at least minimum stocking levels, and a basis for the development of performance requirements in site preparation contracts. It would also enable the forest manager to determine, during the site preparation operation, if a contractor and/or equipment are achieving the levels of receptive seedbed required for a desired level of stocking.

Consequently, the following standard, based on the findings of these trials, is proposed for the control of site preparation operations for the aerial seeding of jack pine in northeastern Ontario.

- 1) *Milacres with 0-5% receptive seedbed shall not exceed 20% of the total number of milacres sampled.*
- 2) *Milacres with 6-15% receptive seedbed shall not exceed 20% of the total number of milacres sampled.*
- 3) *Milacres with 36-100% receptive seedbed shall not exceed 20% of the total number of milacres sampled.*
- 4) *Milacres with 16-35% receptive seedbed shall not be less than 40% of the total number of milacres sampled.*

To be effective this standard must be based on the definition of receptive seedbed as provided earlier in this report. Site preparation in accordance with the standard will provide an overall receptive seedbed level of approximately 25%.

The standard, which could be designated the "20/20/40/20 standard", is a working standard and is operationally practicable. Appendix A shows

that the seedbed breakdown for the 1974 Sieco fireplow treatment in Topham Township is 22/20/38/20 and for the 1974 Young teeth treatment in the same township it is 22/18/30/30. The Sieco operation conforms almost exactly. In the Young teeth operation the uppermost level is high but the critical low seedbed level area is virtually according to prescription. Reference to Table 4 reveals that these two operations also provided the best stockings of the 11 areas in the trials, 84.0% and 83.6%, respectively. None of the other operations approaches the requirements of the standards.

Table 9 shows the actual stocking achieved on each seeding operation and the stocking that would have been achieved had the criteria of the site preparation standard been met. Stockings would have been higher in all cases but one had the standard been met. In some cases the percent increase would have been very limited but in others it would have been quite substantial. The limited gains of the two Topham seedings occur, of course, because the seedbed distribution is very close to the standard. The limited gain of the Hong Kong, 1975 (30,000) seeding and the reduction in the Edith, 1974 (10,000) seeding are due to their having >30% of the milacres in the 36%+ seedbed range. This tended to offset the moderately high levels that occurred in the 0-5% seedbed class with the result that adherence to the standard could not be expected to improve substantially the actual stocking achieved and, as is evidenced, might even reduce stocking. As noted previously, one must avoid the unnecessary expense of creating higher seedbed levels and the possibility that the expanse of seedbed created may be so great that germinant survival may be endangered in terms of marginal temperature and moisture conditions. With the exclusion of the Topham 1974 seedings (because they are virtually in accordance with the standard), average percentage changes in stocking by applying the site preparation standard to the remaining seedings were 7.5%, 9.9% and 13.3% for prescribed sowing rates of 10,000, 20,000 and 30,000, respectively.

Weather

Weather is the single most critical element of success beyond the control of the manager. It could mean the difference between success and failure no matter how well controlled the regeneration operation may otherwise have been. It must be recognized that the predictive value of the tables in Appendix C is tied directly to the weather conditions encountered on these trials. The several years of the trials have, however, covered a range of weather conditions from generally unsuitable for good survival to quite normal. Therefore, the tables can be used with a fair degree of confidence to estimate probable stockings on future aerial seeding operations. Only weather extremes beyond those encountered should reduce the value of the tables for predictive purposes.

Table 9. Comparison of actual and "standard" stockings, three growing seasons after sowing.

Seeding operation	Stocking percent		% Change
	Actual ^a	Standard ^b	
<u>10,000</u>			
Cosens, 1973	58.6	68.9	+17.6
Edith, 1974	57.5	55.7	- 3.1
Hong Kong, 1975	60.5	65.3	+ 7.9
All			+ 7.5
<u>20,000</u>			
Cosens, 1973	76.2	82.3	+ 8.0
Topham, 1974 (Sieco)	84.0	85.5	+ 1.8
Topham, 1974 (Teeth)	83.6	85.5	+ 2.3
Edith, 1974	72.9	80.0	+ 9.7
Hong Kong, 1975	48.1	53.8	+11.9
All			+ 6.7
<u>30,000</u>			
Cosens, 1973	73.6	83.6	+13.6
Edith, 1974	70.6	86.9	+23.1
Hong Kong, 1975	60.0	61.9	+ 3.2
All			+13.3

^a From Table 4.

^b Calculated according to the method shown in Appendix D. The 40% of plots in the 16%-35% seedbed grouping and the 20% of plots in the 36%-100% seedbed grouping have been distributed over the seedbed classes in proportion to their occurrence under "All seeding rates", Table 2.

Note

These trials were undertaken in only one segment of the province, the Chapleau-Gogama area. The results may be considered directly applicable to that area only or to areas with similar soil, climatic and tree species characteristics. Nevertheless, these principles can be used as guidelines for good jack pine aerial seeding practice across the province and, with experience, the manager can use the data in modified form to plan successful jack pine seeding programs regardless of location.

CONCLUSIONS

Aerial seeding of jack pine is, with few limitations, a viable and successful regeneration technique for moderately dry to moderately fresh, sandy, outwash soils in the Chapleau-Gogama area.

Prescribed seeding rates may be considered nominal only. The amount of seed deposited is generally lower than that prescribed.

There are stocking gains to be had by increasing the amount of seed applied but the rate of gain decreases significantly as the deposition rate becomes progressively greater. A deposition rate of 10,000 seeds per acre provides substantially lower stockings than a deposition rate of 20,000 seeds per acre. Except at the lowest receptive seedbed levels the stocking to be gained from a deposition rate of 30,000 seeds per acre is not justifiably better than that to be gained from a deposition rate of 20,000 seeds per acre.

Stocking increases between the first and third years after sowing, through delayed germination of applied seed or from natural seed, occur almost invariably and are often substantial. This is an important factor in the early determination of the potential success or failure of a seeding operation.

Stocking is directly related to the amount of receptive seedbed available, more so than to the amount of seed applied (within the range of seed depositions in these trials). Stocking at acceptable levels requires adequate levels of seedbed availability regardless of seeding rate. Scarified and unseeded areas (using the scarification techniques of these trials) and unscarified areas, even with seed added, will result in stocking levels far below minimum standards.

Receptive seedbed must be well distributed through the area. If all milacres have a minimum of 25% receptive seedbed, a high level of assurance of achieving 60% stocking after three years will be provided under most operating conditions at deposition rates of 14,000 seeds per acre or greater. If all milacres have a minimum of 15% receptive seedbed, 80% stocking should be attained on average, and under the best of conditions nearly 90% should be attained, after three years at deposition rates of 15,000 seeds per acre or greater.

In general, as the amount of receptive seedbed per acre falls below 20-25%, the stocking probability is reduced rapidly. As the amount of receptive seedbed per milacre is increased beyond 20-25%, stocking probability continues to climb but does so at rates of increase that make the gains increasingly costly in terms of effort required to create the necessary seedbed levels.

Since to have all milacres scarified to a given receptive seedbed level is impractical, the "20/20/40/20 seedbed standard" described in this report will assist in attaining minimum stocking standards. This standard is operationally achievable and results in an overall receptive seedbed level of approximately 25%.

Using the tables provided in this report, the manager can obtain preliminary estimates of the stockings likely one and three years after seeding *at the time of the site preparation operation and before seeding takes place* for any selected seed deposition rate. The adequacy of the site preparation can thereby be evaluated while there is still time to rectify any deficiencies, without damage to the incoming stand. These preliminary estimates can be verified or adjusted, after sowing, by assessing deposition rates during the seeding operation. Finally, progress toward the third-year stocking goal can be assessed at the end of the first year after seeding.

Density increases rapidly with increasing seedbed availability. Densities increase strongly as seeding rates go from 10,000 to 20,000 seeds per acre but much less strongly between 20,000 and 30,000 seeds per acre. Up to 45% receptive seedbed availability, densities may exceed the suggested provincial maximum of 5,000 stems per acre toward the upper end of the range, with up to 6,000 stems per acre being obtained depending on the seeding rate prescribed and the level of stocking attained.

RECOMMENDATIONS

- 1) The seedbed created in site preparation operations must be suitable for germination and survival of jack pine. These trials have provided a working definition for such receptive seedbed. The definition should be used to determine adequate levels of suitable seedbed referred to in 2) below and the application of the predictive data of this report. "Receptive seedbed" is defined as follows:
 - a) *exposed mineral soil with a firm base, or*
 - b) *a thin ($< \frac{1}{2}$ in.) duff/mineral soil mix which would readily settle to a firm base, or*
 - c) *firm mineral soil with a very thin duff cover, generally not more than $\frac{1}{4}$ in. thick.*
- 2) Adequate levels of receptive seedbed should be provided. The number of milacres occurring with seedbed levels of 0-15% and 36-100% should be minimized. As a guide, the following standard may be employed to provide the overall level and distribution of seedbed necessary to attain minimum stocking standards and well beyond in most cases:

- a) *Milacres with 0-5% receptive seedbed shall not exceed 20% of the total number of milacres sampled.*
 - b) *Milacres with 6-15% receptive seedbed shall not exceed 20% of the total number of milacres sampled.*
 - c) *Milacres with 36-100% receptive seedbed shall not exceed 20% of the total number of milacres sampled.*
 - d) *Milacres with 16-35% receptive seedbed shall not be less than 40% of the total number of milacres sampled.*
- 3) To ensure a minimum 60% stocking most of the time (four times out of five) deposition rates of less than 15,000 seeds per acre should be avoided. To achieve this, apply seed at a prescribed rate of 20,000 seeds per acre and strive, through careful calibration and flying procedure, to bring the deposition rate as close as possible to the prescribed rate. Do not seed at a prescribed rate of 30,000 seeds per acre or at high deposition rates as they are wasteful of seed and do little to enhance stockings that would be achieved from deposition rates at or near 20,000 seeds per acre.
 - 4) The manager should be thoroughly familiar with the applicator and application requirements and limitations as described by Foreman and Riley (1979), and by Silc and Winston (1979).
 - 5) Decisions to declare a seeding a failure and/or to re-treat should be made with caution as delayed germination, residual natural seed and seedling ingress by other means may substantially increase initial jack pine stockings. Where adequate levels of receptive seedbed have been prepared such decisions should be delayed as long as possible, i.e., until the third year after sowing, until unstocked receptive seedbed is in danger of becoming non-receptive or until it is apparent that acceptable stockings will not be realized.

Although adherence to these recommendations will not produce fully stocked stands, it will certainly remove much of the risk attending aerial seeding of jack pine and will go a long way toward ensuring successful seeding operations with minimum waste of seed and within acceptable site preparation cost limits.

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APPENDICES

APPENDIX A

S.I. CONVERSIONS

1 acre	=	0.405 hectares
1 milacre	=	4.047 square metres
1 inch	=	2.54 centimetres
1 chain	=	20.117 metres
1 square foot	=	0.093 square metres
1 mile	=	1.609 kilometres
1 foot	=	30.48 centimetres
t° Fahrenheit	=	$5 (t - 32) / 9^{\circ}$ Celsius

APPENDIX B

Number of Milacre Plots Sampled on Each Seeding by Receptive Seedbed Class

Seeding rate	Receptive seedbed class (%)											Total
	0-5	6-15	16-25	26-35	36-45	46-55	56-65	66-75	76-85	86-95	96-100	
<u>10,000/acre</u>												
Cosens, 1973	253	120	69	69	31	19	17	3	6	2	1	590
Edith, 1974	67	45	36	19	10	15	7	8	9	11	13	240
Hong Kong, 1975	68	33	33	24	13	5	7	8	2	-	7	200
Total	388	198	138	112	54	39	31	19	17	13	21	1030
<u>20,000/acre</u>												
Cosens, 1973	195	106	88	92	40	21	2	5	2	-	4	555
Topham, 1974 (Sieco)	132	123	142	84	51	39	22	4	3	-	-	600
Topham, 1974 (Young teeth)	56	44	48	27	16	16	14	6	6	10	7	250
Edith, 1974	251	75	61	48	27	26	25	13	6	15	15	562
Hong Kong, 1975	226	101	68	45	32	22	22	16	17	11	10	570
Total	860	449	407	296	166	124	85	44	34	36	36	2537
<u>30,000/acre</u>												
Cosens, 1973	183	94	79	72	40	20	6	2	2	2	-	500
Edith, 1974	224	63	30	18	3	6	6	2	3	3	2	360
Hong Kong, 1975	70	34	17	17	15	14	9	5	5	2	12	200
Total	477	191	126	107	58	40	21	9	10	7	14	1060

APPENDIX C

Table C1. Stocking probability values by receptive seedbed class one year after sowing.

Deposition rate	Stocking probability level	Receptive seedbed class										
		0	10	20	30	40	50	60	70	80	90	100
5000	Minimum	.009	.035	.068	.100	.131	.161	.190	.218	.245	.271	.296
	80%	.023	.053	.090	.126	.161	.194	.226	.257	.286	.315	.342
	Mean	.125	.194	.273	.352	.419	.479	.533	.582	.625	.664	.698
	Maximum	.319	.411	.515	.600	.670	.728	.776	.815	.843	.875	.897
6000	Minimum	.011	.042	.081	.119	.155	.190	.223	.255	.286	.315	.343
	80%	.028	.063	.107	.150	.190	.228	.265	.300	.333	.365	.395
	Mean	.148	.228	.323	.406	.479	.543	.599	.649	.692	.730	.763
	Maximum	.370	.470	.580	.667	.736	.791	.834	.868	.896	.917	.934
7000	Minimum	.013	.048	.094	.137	.179	.218	.255	.291	.325	.357	.388
	80%	.033	.073	.124	.172	.218	.261	.302	.340	.376	.411	.443
	Mean	.171	.261	.366	.456	.533	.599	.656	.705	.747	.783	.813
	Maximum	.417	.524	.637	.723	.789	.839	.877	.906	.928	.945	.958
8000	Minimum	.015	.055	.107	.155	.201	.245	.286	.325	.362	.396	.429
	80%	.037	.083	.140	.194	.245	.292	.336	.378	.417	.454	.488
	Mean	.193	.292	.406	.501	.581	.648	.705	.752	.792	.825	.853
	Maximum	.460	.572	.686	.769	.831	.876	.909	.933	.951	.964	.974
9000	Minimum	.017	.062	.119	.173	.223	.271	.315	.357	.396	.433	.468
	80%	.042	.093	.156	.216	.271	.322	.370	.414	.455	.493	.529
	Mean	.214	.322	.443	.542	.624	.691	.746	.792	.829	.859	.884
	Maximum	.500	.615	.728	.808	.864	.904	.932	.952	.966	.976	.983
10000	Minimum	.018	.069	.132	.190	.245	.296	.344	.388	.429	.468	.504
	80%	.046	.102	.172	.237	.296	.351	.401	.448	.491	.530	.567
	Mean	.235	.351	.478	.580	.663	.729	.782	.825	.859	.887	.909
	Maximum	.537	.653	.765	.840	.891	.926	.950	.966	.977	.984	.989
11000	Minimum	.020	.075	.144	.207	.266	.320	.371	.417	.460	.500	.537
	80%	.051	.112	.188	.257	.320	.378	.431	.480	.524	.564	.602
	Mean	.255	.378	.511	.615	.698	.762	.813	.853	.884	.909	.928
	Maximum	.571	.688	.796	.867	.913	.943	.963	.976	.984	.990	.993
12000	Minimum	.022	.082	.156	.224	.286	.344	.397	.445	.490	.531	.569
	80%	.055	.122	.203	.277	.344	.404	.460	.510	.555	.596	.634
	Mean	.275	.404	.542	.647	.729	.791	.839	.876	.905	.927	.944
	Maximum	.603	.720	.824	.889	.930	.956	.972	.983	.989	.993	.996
13000	Minimum	.024	.088	.167	.240	.306	.366	.421	.472	.518	.560	.598
	80%	.060	.131	.218	.296	.366	.430	.487	.538	.584	.626	.663
	Mean	.294	.429	.570	.677	.757	.817	.862	.896	.922	.941	.956
	Maximum	.632	.748	.847	.908	.944	.966	.980	.988	.993	.995	.997
14000	Minimum	.026	.095	.179	.256	.325	.388	.445	.497	.544	.587	.625
	80%	.064	.140	.232	.315	.388	.454	.512	.564	.611	.653	.690
	Mean	.313	.454	.598	.704	.782	.839	.882	.913	.936	.953	.965
	Maximum	.660	.773	.868	.923	.955	.974	.985	.991	.995	.997	.998
15000	Minimum	.027	.101	.191	.271	.344	.409	.468	.521	.569	.612	.651
	80%	.069	.150	.247	.333	.409	.477	.537	.590	.637	.678	.715
	Mean	.331	.477	.623	.728	.804	.859	.898	.927	.947	.962	.973
	Maximum	.685	.796	.886	.936	.964	.980	.989	.994	.996	.998	.999
16000	Minimum	.029	.107	.202	.287	.362	.430	.490	.544	.592	.636	.674
	80%	.073	.159	.261	.351	.430	.499	.560	.613	.660	.701	.738
	Mean	.348	.499	.647	.751	.824	.876	.913	.938	.957	.969	.978
	Maximum	.708	.816	.901	.947	.971	.985	.992	.996	.998	.999	.999
17000	Minimum	.031	.114	.213	.301	.380	.449	.511	.566	.615	.658	.696
	80%	.077	.168	.275	.368	.449	.520	.582	.636	.682	.723	.759
	Mean	.366	.520	.669	.772	.842	.891	.925	.948	.964	.975	.983
	Maximum	.730	.835	.914	.956	.977	.988	.994	.997	.998	.999	1.000
18000	Minimum	.033	.120	.224	.316	.397	.468	.531	.587	.636	.679	.717
	80%	.082	.177	.288	.385	.468	.540	.603	.657	.703	.743	.778
	Mean	.382	.540	.690	.791	.859	.905	.936	.957	.971	.980	.987
	Maximum	.750	.852	.926	.963	.982	.991	.995	.998	.999	.999	1.000

^a Mean value minus 1 standard deviation indicating the level above which stocking should occur 4 times out of 5.

(continued)

APPENDIX C

Table C1. Stocking probability values by receptive seedbed class one year after sowing.
(concluded)

Deposition rate	Stocking probability level	Receptive seedbed class										
		0	10	20	30	40	50	60	70	80	90	100
19000	Minimum	.035	.126	.235	.330	.414	.487	.551	.607	.656	.698	.736
	80% ^a	.086	.186	.302	.401	.487	.560	.623	.676	.722	.762	.796
	Mean	.399	.560	.709	.808	.873	.916	.945	.964	.976	.984	.989
	Maximum	.768	.866	.936	.969	.985	.993	.997	.998	.999	1.000	1.000
20000	Minimum	.036	.132	.246	.344	.430	.504	.569	.625	.674	.717	.754
	80% ^a	.090	.194	.315	.417	.504	.578	.641	.695	.741	.779	.812
	Mean	.415	.578	.728	.824	.886	.927	.953	.969	.980	.987	.992
	Maximum	.785	.880	.945	.974	.988	.995	.997	.999	.999	1.000	1.000
21000	Minimum	.038	.139	.256	.358	.446	.521	.587	.643	.692	.734	.771
	80% ^a	.095	.203	.328	.433	.521	.596	.659	.713	.758	.795	.827
	Mean	.430	.596	.745	.839	.898	.936	.959	.974	.984	.990	.993
	Maximum	.801	.892	.952	.979	.991	.996	.998	.999	1.000	1.000	1.000
22000	Minimum	.040	.145	.267	.371	.461	.538	.604	.660	.709	.750	.786
	80% ^a	.099	.212	.340	.448	.538	.613	.676	.729	.773	.810	.841
	Mean	.445	.613	.761	.852	.909	.943	.965	.978	.987	.992	.995
	Maximum	.816	.903	.959	.982	.992	.997	.999	.999	1.000	1.000	1.000
23000	Minimum	.042	.151	.277	.384	.476	.554	.620	.677	.725	.766	.801
	80% ^a	.103	.220	.353	.462	.554	.630	.693	.745	.788	.824	.854
	Mean	.460	.629	.776	.864	.918	.950	.970	.982	.989	.993	.996
	Maximum	.830	.913	.964	.985	.994	.998	.999	1.000	1.000	1.000	1.000
24000	Minimum	.043	.157	.287	.397	.491	.569	.636	.692	.740	.780	.814
	80% ^a	.107	.228	.365	.477	.569	.645	.708	.759	.802	.837	.866
	Mean	.474	.645	.790	.876	.926	.956	.974	.985	.991	.995	.997
	Maximum	.842	.921	.969	.988	.995	.998	.999	1.000	1.000	1.000	1.000
25000	Minimum	.045	.163	.297	.410	.505	.584	.651	.707	.754	.794	.827
	80% ^a	.112	.237	.377	.491	.584	.660	.722	.773	.815	.849	.876
	Mean	.488	.660	.803	.886	.934	.962	.978	.987	.993	.996	.998
	Maximum	.854	.929	.973	.990	.996	.999	.999	1.000	1.000	1.000	1.000
26000	Minimum	.047	.169	.307	.422	.518	.599	.665	.721	.767	.806	.838
	80% ^a	.116	.245	.388	.504	.598	.675	.736	.786	.827	.860	.886
	Mean	.501	.674	.816	.895	.941	.966	.981	.989	.994	.997	.998
	Maximum	.865	.936	.977	.991	.997	.999	1.000	1.000	1.000	1.000	1.000
27000	Minimum	.049	.174	.317	.434	.532	.612	.679	.734	.780	.818	.849
	80% ^a	.120	.253	.400	.518	.612	.688	.750	.799	.838	.870	.895
	Mean	.515	.688	.827	.904	.947	.971	.984	.991	.995	.997	.998
	Maximum	.875	.943	.980	.993	.998	.999	1.000	1.000	1.000	1.000	1.000
28000	Minimum	.050	.180	.326	.446	.545	.626	.692	.747	.792	.829	.860
	80% ^a	.124	.261	.411	.530	.626	.702	.762	.810	.849	.879	.904
	Mean	.527	.701	.838	.912	.952	.974	.986	.992	.996	.998	.999
	Maximum	.884	.949	.983	.994	.998	.999	1.000	1.000	1.000	1.000	1.000
29000	Minimum	.052	.186	.336	.458	.557	.639	.705	.759	.803	.840	.869
	80% ^a	.128	.269	.422	.543	.639	.714	.774	.821	.859	.888	.912
	Mean	.540	.714	.848	.919	.957	.977	.988	.994	.997	.998	.999
	Maximum	.893	.954	.985	.995	.998	.999	1.000	1.000	1.000	1.000	1.000
30000	Minimum	.054	.192	.345	.469	.570	.651	.717	.771	.814	.849	.878
	80% ^a	.132	.277	.433	.555	.651	.726	.785	.832	.868	.896	.919
	Mean	.552	.726	.858	.926	.962	.980	.990	.995	.997	.999	.999
	Maximum	.901	.958	.987	.996	.999	1.000	1.000	1.000	1.000	1.000	1.000

^a Mean value minus 1 standard deviation indicating the level above which stocking should occur 4 times out of 5.

APPENDIX C

Table C2. Stocking probability values by receptive seedbed class three years after sowing.

Deposition rate	Stocking probability level	Receptive seedbed class										
		0	10	20	30	40	50	60	70	80	90	100
5000	Minimum	.050	.082	.124	.163	.201	.237	.271	.304	.335	.365	.393
	80% ^a	.098	.156	.227	.293	.353	.407	.453	.504	.546	.584	.619
	Mean	.205	.305	.419	.514	.594	.660	.716	.763	.801	.834	.861
	Maximum	.344	.478	.615	.716	.791	.846	.886	.916	.938	.954	.966
6000	Minimum	.060	.098	.146	.192	.236	.277	.316	.352	.387	.420	.451
	80%	.116	.184	.266	.340	.407	.466	.520	.568	.612	.651	.686
	Mean	.241	.354	.479	.579	.661	.726	.779	.822	.856	.884	.906
	Maximum	.397	.542	.682	.780	.847	.894	.926	.949	.965	.975	.983
7000	Minimum	.070	.113	.169	.221	.269	.315	.358	.398	.435	.470	.503
	80%	.134	.211	.303	.384	.456	.519	.575	.625	.669	.707	.741
	Mean	.275	.399	.532	.636	.717	.779	.828	.866	.896	.919	.937
	Maximum	.446	.597	.737	.829	.888	.927	.952	.969	.980	.987	.991
8000	Minimum	.079	.129	.190	.248	.301	.351	.397	.440	.479	.516	.551
	80%	.152	.238	.338	.426	.501	.567	.624	.674	.717	.754	.787
	Mean	.307	.441	.580	.685	.763	.822	.867	.900	.925	.943	.958
	Maximum	.490	.647	.783	.867	.918	.950	.969	.981	.988	.993	.996
9000	Minimum	.089	.143	.211	.274	.332	.385	.434	.479	.520	.558	.593
	80%	.169	.263	.371	.464	.543	.610	.668	.717	.758	.794	.824
	Mean	.338	.480	.623	.727	.802	.857	.896	.925	.946	.961	.971
	Maximum	.532	.690	.821	.896	.940	.965	.980	.988	.993	.996	.998
10000	Minimum	.098	.158	.232	.300	.361	.417	.468	.515	.558	.597	.632
	80% ^a	.186	.288	.403	.500	.581	.649	.706	.754	.794	.827	.855
	Mean	.368	.517	.662	.764	.835	.885	.919	.944	.961	.972	.981
	Maximum	.569	.727	.852	.920	.956	.976	.987	.993	.996	.998	.999
11000	Minimum	.107	.172	.252	.324	.389	.448	.501	.549	.592	.632	.667
	80%	.203	.311	.433	.533	.616	.684	.740	.786	.824	.855	.880
	Mean	.396	.551	.697	.796	.862	.907	.937	.958	.971	.981	.987
	Maximum	.604	.761	.878	.937	.968	.984	.992	.996	.998	.999	.999
12000	Minimum	.116	.186	.272	.348	.416	.477	.532	.581	.624	.664	.699
	80%	.219	.334	.462	.565	.648	.715	.770	.814	.849	.878	.901
	Mean	.423	.582	.728	.823	.885	.925	.951	.968	.979	.987	.991
	Maximum	.636	.790	.899	.951	.977	.989	.995	.997	.999	.999	1.000
13000	Minimum	.125	.200	.291	.370	.441	.504	.560	.610	.654	.693	.727
	80%	.235	.356	.489	.594	.677	.744	.796	.838	.871	.898	.919
	Mean	.449	.611	.756	.847	.904	.940	.962	.976	.985	.991	.994
	Maximum	.666	.815	.917	.962	.983	.992	.997	.999	.999	1.000	1.000
14000	Minimum	.134	.214	.309	.392	.466	.530	.587	.637	.681	.720	.753
	80%	.251	.378	.514	.621	.704	.769	.820	.859	.890	.914	.933
	Mean	.474	.639	.781	.867	.920	.951	.971	.982	.989	.993	.996
	Maximum	.693	.838	.931	.971	.987	.995	.998	.999	1.000	1.000	1.000
15000	Minimum	.143	.227	.327	.414	.489	.555	.612	.662	.706	.744	.777
	80% ^a	.266	.399	.539	.646	.729	.792	.840	.878	.906	.928	.945
	Mean	.497	.664	.804	.885	.933	.961	.977	.987	.992	.995	.997
	Maximum	.717	.858	.943	.977	.991	.996	.999	.999	1.000	1.000	1.000
16000	Minimum	.152	.241	.345	.434	.512	.579	.636	.686	.729	.766	.798
	80%	.281	.419	.562	.670	.751	.813	.859	.894	.920	.940	.954
	Mean	.520	.688	.824	.901	.944	.968	.982	.990	.994	.997	.998
	Maximum	.740	.875	.953	.982	.993	.997	.999	1.000	1.000	1.000	1.000
17000	Minimum	.161	.254	.362	.454	.533	.601	.658	.708	.750	.786	.817
	80%	.296	.438	.584	.692	.772	.831	.875	.908	.932	.949	.962
	Mean	.541	.709	.842	.914	.953	.975	.986	.992	.996	.998	.999
	Maximum	.761	.890	.961	.986	.995	.998	.999	1.000	1.000	1.000	1.000
18000	Minimum	.169	.266	.378	.473	.554	.622	.679	.728	.770	.805	.835
	80%	.310	.457	.605	.713	.791	.848	.889	.920	.942	.957	.969
	Mean	.562	.730	.858	.926	.961	.979	.989	.994	.997	.998	.999
	Maximum	.781	.904	.968	.989	.996	.999	1.000	1.000	1.000	1.000	1.000

^a Mean value minus 1 standard deviation indicating the level above which stocking should occur 4 times out of 5.

(continued)

APPENDIX C

Table C2. Stocking probability values by receptive seedbed class three years after sowing.
(concluded)

Deposition rate	Stocking probability level	Receptive seedbed class										
		0	10	20	30	40	50	60	70	80	90	100
19000	Minimum	.178	.279	.394	.492	.573	.642	.699	.747	.788	.822	.850
	80% ^a	.324	.475	.625	.732	.808	.863	.902	.930	.950	.964	.975
	Mean	.582	.749	.873	.936	.967	.983	.992	.996	.998	.999	.999
	Maximum	.798	.915	.973	.992	.997	.999	1.000	1.000	1.000	1.000	1.000
20000	Minimum	.186	.291	.410	.509	.592	.660	.717	.765	.804	.837	.864
	80% ^a	.338	.492	.644	.750	.824	.877	.913	.939	.957	.970	.979
	Mean	.600	.766	.886	.944	.973	.987	.993	.997	.998	.999	1.000
	Maximum	.815	.926	.978	.994	.998	.999	1.000	1.000	1.000	1.000	1.000
21000	Minimum	.195	.303	.426	.526	.610	.678	.735	.781	.820	.851	.878
	80% ^a	.352	.509	.662	.767	.839	.889	.923	.947	.964	.975	.983
	Mean	.618	.783	.898	.952	.977	.989	.995	.998	.999	.999	1.000
	Maximum	.830	.935	.982	.995	.999	1.000	1.000	1.000	1.000	1.000	1.000
22000	Minimum	.203	.315	.441	.543	.627	.695	.751	.797	.834	.864	.889
	80% ^a	.365	.526	.679	.782	.852	.900	.932	.954	.969	.979	.986
	Mean	.635	.798	.908	.958	.981	.991	.996	.998	.999	1.000	1.000
	Maximum	.843	.943	.985	.996	.999	1.000	1.000	1.000	1.000	1.000	1.000
23000	Minimum	.211	.327	.455	.559	.643	.711	.766	.811	.847	.876	.900
	80% ^a	.378	.541	.695	.797	.865	.910	.940	.960	.973	.982	.988
	Mean	.652	.812	.918	.964	.984	.993	.997	.999	.999	1.000	1.000
	Maximum	.856	.950	.988	.997	.999	1.000	1.000	1.000	1.000	1.000	1.000
24000	Minimum	.219	.338	.469	.574	.659	.726	.781	.824	.859	.887	.909
	80% ^a	.391	.557	.710	.810	.876	.919	.947	.965	.977	.985	.990
	Mean	.667	.825	.926	.969	.987	.994	.998	.999	1.000	1.000	1.000
	Maximum	.868	.956	.990	.998	.999	1.000	1.000	1.000	1.000	1.000	1.000
25000	Minimum	.227	.349	.483	.589	.674	.741	.794	.836	.870	.897	.918
	80% ^a	.403	.572	.725	.823	.886	.927	.953	.970	.981	.988	.992
	Mean	.682	.838	.934	.973	.989	.995	.998	.999	1.000	1.000	1.000
	Maximum	.878	.961	.992	.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000
26000	Minimum	.235	.361	.497	.604	.688	.754	.807	.848	.880	.906	.926
	80% ^a	.415	.586	.739	.835	.896	.934	.958	.974	.983	.990	.993
	Mean	.696	.849	.940	.977	.991	.996	.999	.999	1.000	1.000	1.000
	Maximum	.888	.966	.993	.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
27000	Minimum	.243	.371	.510	.618	.702	.767	.818	.858	.890	.914	.933
	80% ^a	.427	.600	.752	.846	.904	.941	.963	.977	.986	.991	.995
	Mean	.710	.860	.947	.980	.992	.997	.999	1.000	1.000	1.000	1.000
	Maximum	.897	.970	.994	.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
28000	Minimum	.251	.382	.523	.631	.715	.780	.830	.868	.898	.921	.939
	80% ^a	.439	.613	.764	.856	.912	.947	.967	.980	.988	.993	.996
	Mean	.723	.869	.952	.982	.994	.998	.999	1.000	1.000	1.000	1.000
	Maximum	.905	.974	.995	.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
29000	Minimum	.258	.393	.535	.644	.727	.791	.840	.877	.906	.928	.945
	80% ^a	.450	.626	.776	.866	.920	.952	.971	.983	.990	.994	.996
	Mean	.735	.879	.957	.985	.995	.998	.999	1.000	1.000	1.000	1.000
	Maximum	.913	.977	.996	.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
30000	Minimum	.266	.403	.547	.656	.739	.802	.850	.886	.914	.934	.950
	80% ^a	.461	.638	.787	.875	.926	.957	.975	.985	.991	.995	.997
	Mean	.747	.887	.961	.987	.996	.998	.999	1.000	1.000	1.000	1.000
	Maximum	.920	.980	.997	.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000

^a Mean value minus 1 standard deviation indicating the level above which stocking should occur 4 times out of 5.

APPENDIX D

CALCULATION OF PROBABLE STOCKING RANGE

An estimate of the range of stocking results to be expected in the first and third years after seeding, from any given site preparation job and seed deposition rate, can be calculated from the data provided in this report. It is presupposed that seed is distributed in a manner as good as that provided by the Brohm seeder/fixed-wing aircraft combination used in the trials described.

Method

1. Determine the amount of receptive seedbed (as defined) available on the seeding chance through a representative sample using milacre sample plots. Record the number of milacres by receptive seedbed class as indicated in Table D1.
2. Calculate the percentage of plots falling in each seedbed class

$$\text{i.e., \%} = \frac{\text{No. of plots in seedbed class}}{\text{Total plots sampled}} \times 100$$

3. Select the estimated or actual deposition rate and record the minimum, 80%, mean and maximum stocking probability values from the first or third year tables by seedbed class as shown.
4. Calculate the contribution to overall stocking made by each seedbed class for each set of table values,

$$\text{i.e., \%} = (2) \times (3)$$

5. Sum values derived in (4) to determine the stocking estimate for each set of table values used.

Results

From the example it can be seen that, if the third-year tables are used, the stocking estimates for the particular seeding chance and a deposition rate of 19,000 seeds per acre are approximately 91% under the best growing conditions and approximately 34% under the worst growing conditions. There is an 80% chance that stocking will be above approximately 54% and the average expectation will be approximately 77%.

At this point the manager has been given an indication of the likely stocking range and average results to be expected three years after seeding. With this information, and using his own knowledge and experience, he is in a position to make an informed decision on the

APPENDIX D (continued)

desirability of seeding the site at that seeding rate and with the receptive seedbed available or of taking an alternative route, e.g., increased seeding rate, rescarification, planting, etc.

The work from which the example was taken was the 1973 seeding in Cosens Township where a deposition rate of 19,000 seeds per acre was obtained. As can be seen from Table 4, actual stocking on this job through field assessment three years after seeding was 76.2%.

In order to determine, after one year, if attainment of acceptable stocking by the third year is likely the following steps should be taken:

- 1) Obtain a reliable estimate of first-year stocking on the seeding chance.
- 2) Calculate the range of stocking results to be expected for the first and third years after sowing, for the appropriate deposition rate, in the manner described above, using the appropriate probability tables. (Note that receptive seedbed availability must have been determined previously.)
- 3) Compare the actual first-year stocking of 1) with the first-year estimates of 2) and determine the approximate position of the actual stocking within this range, e.g., well above average, about average, well below average but above the 80% level, below the 80% level, etc.
- 4) Relate this position to the same position in the third-year stocking range estimates. If the third-year position indicates an acceptable stocking level, the chances are high that stocking on the seeding chance (after one year) is developing well and will be at an acceptable level by the third year. On the other hand, if the third-year position indicates an unacceptable level, stocking on the seeding chance is likely developing poorly and acceptable stocking levels will probably not be attained by the third year after sowing.

It is important to note that this method cannot be used to *pin-point* expected third-year stocking on the basis of first-year results. Third-year stocking can only be approximated.

Example

First- and third-year stocking range estimates for the Cosens 1973 example are as follows:

APPENDIX D (concluded)

	Stocking estimates (%)	
	First-year	Third-year
Minimum	19.0	34.4
80%	25.3	53.7
Mean	61.4	77.2
Maximum	87.7	90.7

By field assessment the first-year stocking was determined to be 58.4%. From the first-year estimates it can be seen that this is just below average (61.4%). Because of the positive correlation of the q values in the regression equation it can be anticipated that stocking after three years on this job will occupy approximately the same position, i.e., just below average. From the third-year estimates it can be seen that the minimum stocking standard of 60% is *well* below average. Therefore, the stocking results from the first year's assessment indicate that the stand should exceed the minimum standard by the third year and that, by or near the time of stand establishment, stocking will be at an acceptable level. The actual third-year stocking was 76.2%, just below average.

If first-year stocking had been 25%, just below the 80% probability level, there would be good reason to suspect that third-year stocking would be below the 60% stocking minimum and therefore unacceptable. In such cases early action to improve stocking might be warranted.

As noted, the foregoing method of relating third-year to first-year stocking is not precise but, in conjunction with the stocking increase discussions and Table 4 of the report, it provides practical guidance and permits early indication of the likelihood of success in the aerial seeding of jack pine. It also provides the basis for informed corrective action when necessary or desirable.

APPENDIX D

Table D1. Example of calculation of probable stocking range for third year after seeding (selected deposition rate of 19,000 seeds per acre).

	Receptive seedbed class (%)											Total
	0-5	6-15	16-25	26-35	36-45	46-55	56-65	66-75	76-85	86-95	96-100	
No. of milacres sampled	195	106	83	92	40	21	2	5	2	-	4	555
% of total	35.14	19.10	15.86	16.58	7.21	3.78	0.36	0.90	0.36	-	0.72	100.01
Minimum stocking values ^a	.178	.279	.394	.492	.573	.642	.699	.747	.788	.822	.850	
Contribution to overall stocking (%)	6.3	5.3	6.2	8.2	4.1	2.4	0.3	0.7	0.3	-	0.6	<u>34.4</u>
80% probability stocking values ^a	.324	.475	.625	.732	.808	.863	.902	.930	.950	.964	.975	
Contribution to overall stocking (%)	11.4	9.1	9.9	12.1	5.8	3.3	0.3	0.8	0.3	-	0.7	<u>53.7</u>
Mean stocking values ^a	.582	.749	.873	.936	.967	.983	.992	.996	.998	.999	.999	
Contribution to overall stocking (%)	20.5	14.3	13.8	15.5	7.0	3.7	0.4	0.9	0.4	-	0.7	<u>77.2</u>
Maximum stocking values ^a	.798	.915	.973	.992	.997	.999	1.000	1.000	1.000	1.000	1.000	
Contribution to overall stocking (%)	28.0	17.5	15.4	16.4	7.2	3.8	0.4	0.9	0.4	-	0.7	<u>90.7</u>

^a From stocking probability tables, third year, Appendix C.

APPENDIX E

It is assumed that seed has been distributed randomly by the aircraft over the seeding chance and that seed landing on the milacres of the seeding chance is therefore distributed according to the Poisson Law. By extension of the theory, numbers of trees becoming established are similarly distributed. This permits stocking to be described by the general equation:

$$Y = 1 - e^{-n[q_1 X + q_2(1-X)]}$$

where:

Y = stocking probability by seedbed class where Y takes values between 0 and 1

X = proportion of a milacre in receptive seedbed where X takes values between 0 and 1

n = average seeding rate per milacre (the deposition rate per acre \div 1000)

q_1 = probability of one seed producing a living tree after a certain time on receptive seedbed

q_2 = probability of one seed producing a living tree after a certain time on non-receptive seedbed

e = a constant = 2.7183

The values X and n can be set or determined by the forest manager and e is a constant. Hence, the variables q_1 and q_2 are the only ones causing any concern. The values of q depend upon:

- a) weather
- b) the relative quality of receptive and non-receptive seedbed
- c) the length of the time period in question
- d) seed quality

The last may be eliminated from further consideration since correction is made for seed quality (i.e., viability) in the seeder calibration process. The first three are the major causes of variation in q in the field.

From the first- and third-year results of these trials q values have been estimated by non-linear regression analysis and the following values derived:

APPENDIX E (concluded)

	First year		Third year	
	q ₁	q ₂	q ₁	q ₂
Maximum	.4540	.0673	.6790	.0690
Minimum	.0701	.0001	.1000	.0080
Mean	.2400	.0213	.3950	.0370
Mean plus 1 standard deviation	.3962	.0399	.5970	.0580
Mean minus 1 standard deviation	.0838	.0027	.1930	.0160

These values have been used in the derivation of the stocking probability values of Appendix D and the curves of Figures 1-6.

Example

Determination of the average stocking probability of milacres with 20% receptive seedbed when the seed deposition rate on the seeding chance is 20,000 per acre (after 3 years).

$$\begin{aligned}
 Y &= 1 - 2.7183^{-20[(.3950 \times .20) + .0370 (1 - .20)]} \\
 &= 1 - 2.7183^{-2.172} \\
 &= 1 - .114 = .886 \text{ or } 88.6\%
 \end{aligned}$$

Interpretation

Under average growing conditions a single milacre has a .886 probability of becoming stocked *and* stocking on all milacres with 20% receptive seedbed and 20,000 seeds sown per acre can be expected to be 88.6% on average after three growing seasons.

Similarly, the probability values for maximum, minimum and 80% stocking probability for these conditions are .978, .410 and .644, respectively. Minor differences due to rounding may occur between values obtained from the formula as shown and the table values.