EFFECT OF STORAGE IN SLASH ON QUANTITY AND QUALITY OF LODGEPOLE PINE SEEDS AVAILABLE FOR REGENERATION

(Project No. A-80)

by

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ALBERTA/TERRITORIES REGION
FOREST RESEARCH LABORATORY
CALGARY, ALBERTA
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ABSTRACT

The rate of release, quality deterioration and loss to squirrels of slash-borne lodgepole pine seeds were examined on three clear-cut areas in the Foothills Section of Alberta. Three years after logging there was a substantial decrease in the germination capacity of seeds stored in slash. Loss of cones to squirrels was approximately 10 per cent per year. Depletion of seed supply due to release, decrease in germination capacity and loss to squirrels totalled approximately 70 per cent; an annual loss of approximately 25 per cent. It is recommended that scarification be undertaken as soon as possible after logging unless another source of seed is provided. Proximity of cones to the ground and the high temperatures that occur at and near the ground are major factors in rate of seed release and loss of germination capacity. Lopping and scattering is therefore not recommended as a slash treatment on areas scheduled for scarification. Rate of cone opening and seed release increased also with age of cone. Preliminary examination indicated that this resulted from lowered albedo associated with weathering of the cone surface.

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INTRODUCTION

During the past decade a number of post-logging scarification trials have been initiated in the lodgepole pine type in the foothills of Alberta (Ackerman 1960, 1961). Emphasis was placed on the development of scarification equipment and techniques which would provide a receptive seedbed at reasonable cost. It is apparent from the regeneration results that factors such as seed supply are equally important and must be carefully considered in the planning stage if the treatment is to be consistently successful.

The principal source of seed for regeneration following cutting of lodgepole pine is slash-borne serotinous cones. On some areas it is believed that seed loss from the slash-borne cones during the delay between logging and scarification has been an important limiting factor in the regeneration response. This study was initiated to determine the effect of storage in the slash on the quantity and quality of lodgepole pine seeds available for regeneration after clear-cutting.

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Three lodgepole pine stands were selected for study and clearcut during the spring and summer of 1962. Before logging cone serotiny and seed quality were determined by observation and sampling. After logging the amount and quality of slash-borne seeds as affected by time and height above ground were determined by periodic sampling.

AREAS AND SITES

The study areas are located in the High Foothills Section of the Boreal Forest Region (Rowe 1959), at an elevation of approximately 4,500 feet on the pulpwood lease area of North Western Pulp and Power Ltd. in west-central Alberta. Typical topography consists of a series of high, till-capped hills underlain by sandstone bedrock.

Three, 5-acre, even-aged lodgepole pine stands, each a portion of a strip or block clearcut, were selected for study. Stand I was located on top of a minor bedrock-controlled ridge with variable slope, aspect and moisture regime. The soil is a shallow (3-4') sandy loam till over fractured sandstone bedrock. Stand II was located on a flood plain in a main valley bottom. The soil is 3 feet of well-drained fine, sandy to silt loam over coarse gravel. Stand III was located on an upper, north 20 per cent slope of a major foothill. The soil of stand III is a fresh, shallow (3 to 4 feet) sandy loam till over fractured sandstone bedrock. The stands were 90 to 120 years of age and yielded 40 to 50 cords of pulpwood at harvest.

SAMPLING METHODS

Cone and Seed Population Before Logging

The cone population was sampled before logging to determine serotiny, age of cones and quality of seed. All the cones were collected from three or more co-dominant or dominant trees in each stand and the degree of resin-bond rupture and cone age recorded for each cone. Three degrees of resin-bond rupture were recognized: (a) fully open-cone scales free over 81 to 100 per cent of cone surface (b) partly open-scales free over 21 to 80 per cent of cone surface and (c) closed-scales free over 0 to 20 per cent of cone surface.

Accurate ageing of all cones was an impossible task because of the time involved but it was noted that cone colour and texture change with age from a glossy, yellow-brown to a matte grey. This effect of weathering was employed as an index of age, as follows:

1 to 3 years - no evidence of weathering

2 to 7 years - weathered over 5 to 25 per cent of surface area

6 to 13 years - weathered over 25 to 50 per cent of surface area

12 to 20 years - weathered over 50 to 75 per cent of surface area

16 + years - weathered over entire surface area.

All cones from the sample trees were opened by immersion, dried and all seeds extracted by tumbling. Ten samples of 100 seeds were taken from each age class of cone and germination tests conducted to determine seed quality. The germination test was incubation at 70°F for a period of 14 days. This test, one of a number investigated, was found to give prompt and nearly complete germination of viable seed.

Cone and Seed Population After Logging

The cone population was sampled after logging to determine number of cones and seed per acre, vertical distribution of cones in the slash and the rate of cones opening and seed release.

To determine the number of cones per acre and vertical distribution, cone counts were made on 320 milliacre quadrats located systematically on each 5-acre sample area. During the count, the position of each cone relative to the ground surface was described as: (a) on the ground, (b) 1 to 7 inches above the ground or (c) more than 7 inches above the ground.

To determine the rate of cone opening and seed release after logging, 640 cones were taken from each of 3 height-above-ground strata (a total of 1920 cones) on each area on the following dates.

Area I	May/62	July/62	Sept/62	May/63	Sept/63	Sept/64
Area II		July/62	Sept/62	May/63	Sept/63	Sept/64
Area III			Sept/62	May/63	Sept/63	Sept/64

On each date the cone sample was obtained by selecting, from each stratum, the 2 cones nearest the centre stake of each of the 320 milliacre quadrats. The age-class and degree of resin-bond-rupture were determined for each cone and all seeds extracted, counted and tested for viability, as described previously.

To determine loss of cones to squirrels and change in cone position owing to snow pack and settling of the slash, repeat cone counts were made on 10 per cent of the sample quadrats in September of 1963 and 1964.

RESULTS

Cone and Seed Population Before Logging

Degree of serotiny

A summary of observations on the degree of cone opening on live, dominant and co-dominant trees, by cone age and area, is given in Table 1. The effect of cone age on cone opening is evident for all three areas. The proportion of cones either open, or partially open, increases with age of cone. Although this makes it difficult to classify the serotiny of the cone populations, if it is assumed that non-serotinous cones open at, or shortly after maturity, and the effect of age on cone opening results from weathering, then the proportion of unweathered, 1 to 3 year-old cones completely open should be a reasonable index. On this basis the cone populations of areas I and III are classified as completely serotinous and the population of area II as 90 per cent serotinous.

Table 1: The Percentage of Lodgepole Pine Cones Open, Partly Open and Closed, Before Logging by Age and Area.

Cone Condition	Cone Age Class - Years					
	1-3	2-7	6-13	12-20	16+	All
	Percentage of Cones					
Area I - Basis; 3 trees, 1309 cones						
Open	-	-	-	-	2	1
Partly Open	-	-	1	13	19	10
Closed	100	100	99	87	79	89
Area II - Basis; 7 trees, 8613 cones						
Open	10	7	15	17	44	18
Partly Open	4	1	6	16	16	10
Closed	86	92	79	67	40	72
Area III - Basis; 3 trees, 1811 cones						
Open	-	-	-	2	15	6
Partly Open	-	-	9	21	38	23
Closed	100	100	91	77	47	71

Seed quality

The germinative capacity* of the seed is indicated, by age of cone and area, in Table 2. The differences in germinative capacity between cone ages are considered a measure of periodic or

* The percentage of all seeds that germinate

annual differences in seed crop quality, not the effect of storage on the tree. There was no apparent difference in the percentage of sound seeds that did not germinate, or in real germination percentages** which were over 92 per cent for all ages and areas. This suggests that storage on the tree had no effect on viability.

Table 2: Germinative Capacity of Lodgepole Pine Seeds Before Logging, by Cone Age and Area.

Area	Cone Age Class - Years					
	1-3	2-7	6-13	12-20	16+	All
	Percentage Germination*					
I	51+3	52+1	60+1	56+1	63+1	56+1
II	81+2	79+3	69+5	75+3	75+3	76+3
III	72+2	No Data	72+3	82+5	64+6	72+4

* Percentage of all seeds that germinate plus apparently sound seeds that did not germinate.

Cone and Seed Population After Logging

Number and vertical distribution of cones

The number of cones and their vertical distribution immediately after logging in 1962 and in the fall of 1963 and 1964 are shown in Table 3.

The proportion of cones in each height stratum immediately after logging was remarkably uniform for all areas. The greatest proportion of cones was in the 7"+ level because the slash was not lopped after logging. Settling and packing of the slash by snow cover resulted in a general trend towards an increase in the proportion of cones situated in the lower levels.

** The percentage of apparently sound seeds that germinate.

Table 3: Number per Acre and Vertical Distribution of Slash-borne Lodgepole Pine Cones by Area

Sampling Date	Cone Level Relative to Ground Surface							
	Ground		1" - 7"		7"+		All	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Area I								
May 1962	25,000	24	36,000	34	44,000	42	105,000	100
Sept 1963	34,000	37	25,000	28	31,000	35	90,000	100
Sept 1964	22,000	29	25,000	34	28,000	37	75,000	100
Area II								
July 1962	46,000	26	56,000	32	74,000	42	177,000	100
Sept 1963	61,000	40	39,000	26	53,000	34	153,000	100
Sept 1964	40,000	31	40,000	31	48,000	38	128,000	100
Area III								
Aug. 1962	28,000	24	37,000	32	50,000	44	115,000	100
Sept 1963	37,000	38	26,000	26	36,000	36	99,000	100
Sept 1964	24,000	29	26,000	32	33,000	39	83,000	100

Recounts in September, 1963 and 1964, indicated a 28 per cent loss between date of logging in 1962 and September, 1964. It is assumed squirrels were responsible.

Rate of cone opening

The rate of cone opening in the slash, by cone level and area is illustrated in Figure 1. The effect of cone level is evident.

The pattern of cone opening as affected by age of cone is shown in Figure 2. The rate of cone opening increased with age of cone on all areas. These data substantiate the previously indicated influence of cone age (Table 1) observed on standing trees.

Cone opening data for the entire cone population, all ages and levels, is summarized in Table 4. These data were derived by weighting according to the number of cones in each height-above-ground stratum.

In September of 1964, three seasons after logging, approximately 50 per cent of the cones were fully open and had, presumably, released all seed. On this date there was no significant difference between the three areas. The effect of later logging on area III, apparent until May of 1963, was subsequently obscured by a relatively rapid rate of cone opening during the 1963 and 1964 seasons.

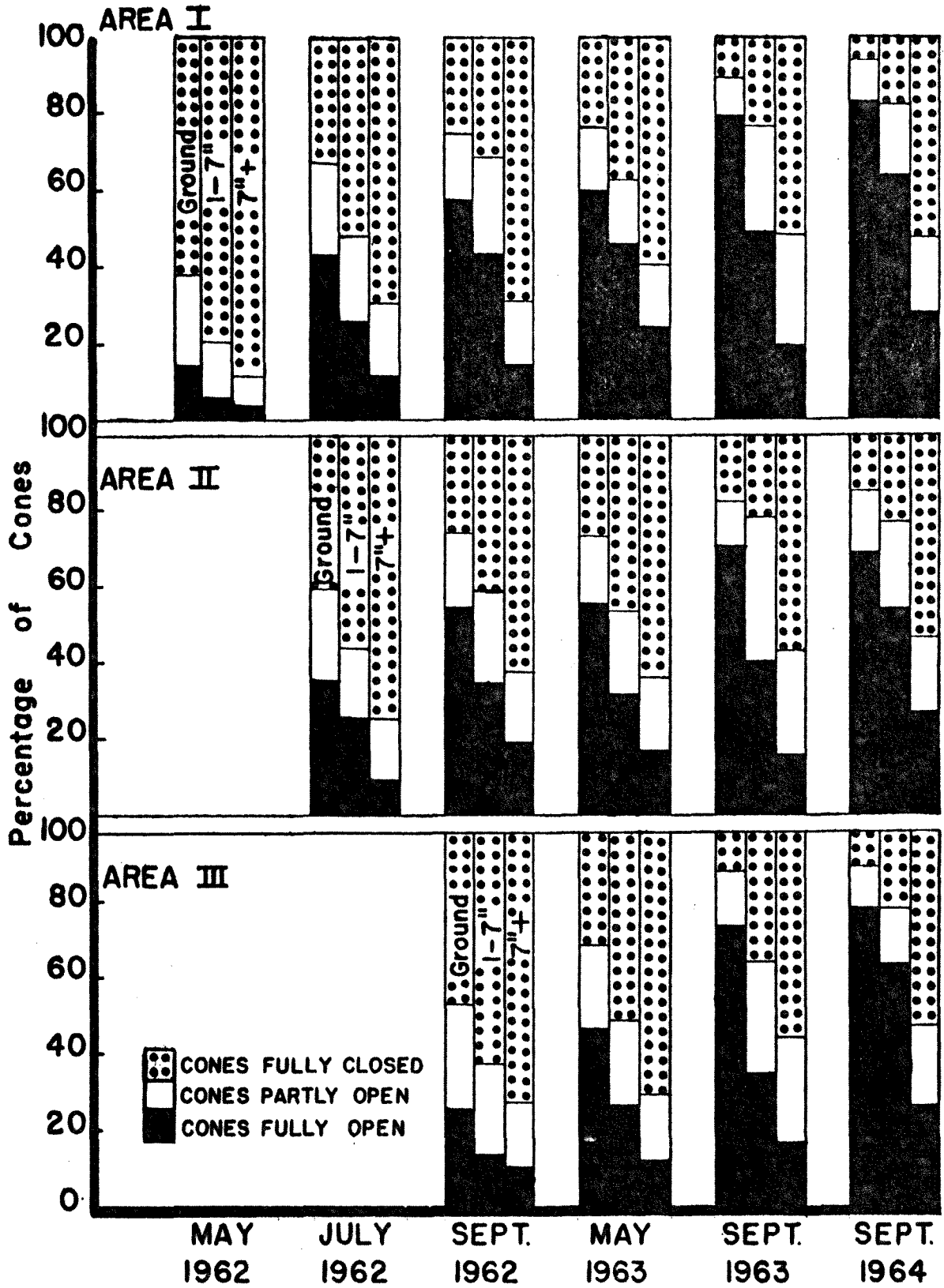

Figure 1 Rate of Lodgepole Pine Cone Opening After Logging by Cone Level Relative to Ground Surface and Area — All Ages of Cones

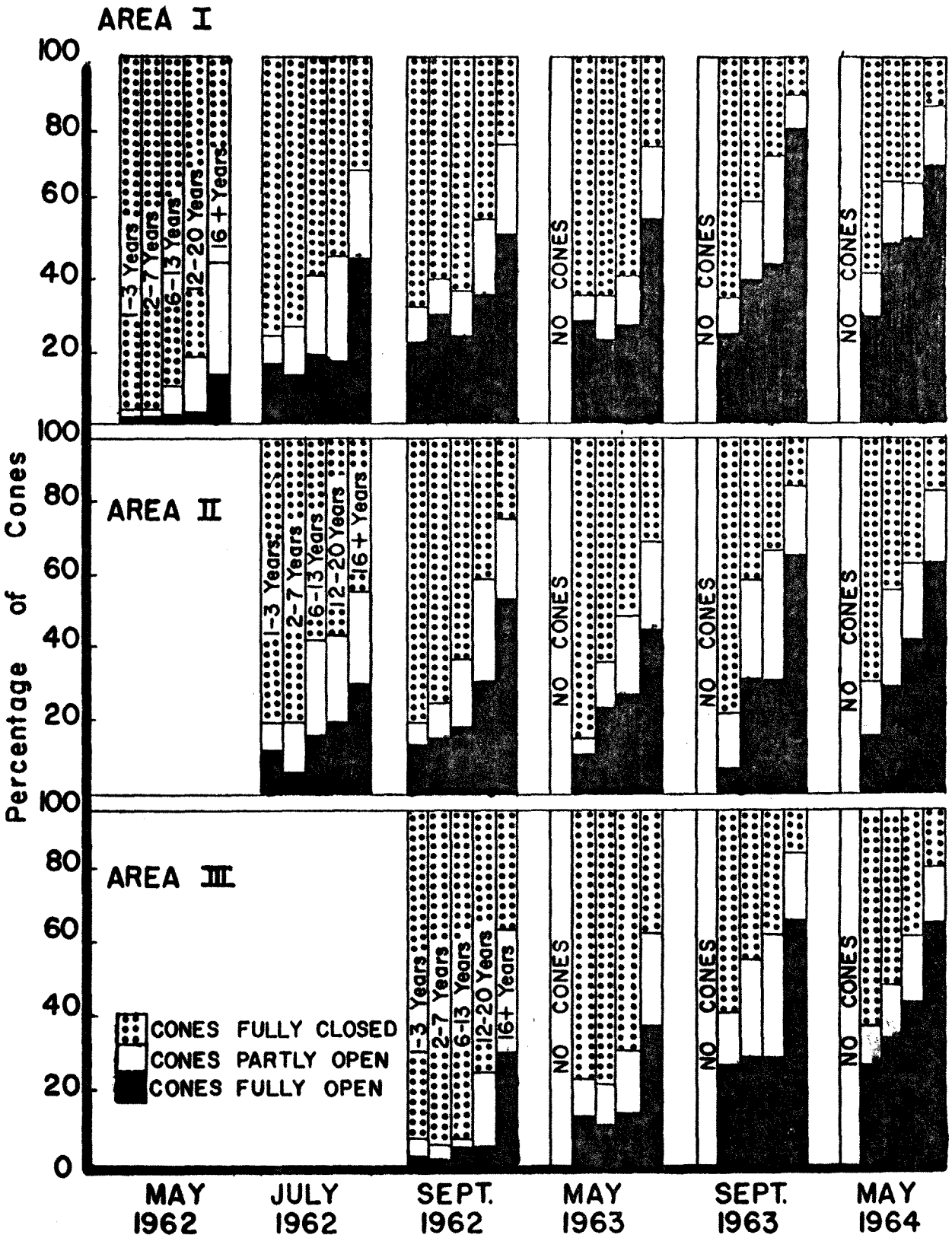

Figure 2 Rate of Lodgepole Pine Cone Opening After Logging by Cone Age and Area— All Cone Levels

Table 4: The Rate of Opening of All Slash-borne Lodgepole Pine Cones by Area.

Cone Condition	Sampling Date					
	May/62	July/62	Sept/62	May/63	Sept/63	Sept/64
	Percentage of All Cones					
Area I - Logged April - May, 1962						
Open	5	23	34	40	50	56
Partly Open	16	22	20	17	22	17
Closed	79	55	46	43	28	27
Area II - Logged May - June, 1962						
Open	-	20	31	31	42	47
Partly Open	-	20	22	20	28	21
Closed	-	60	47	49	30	32
Area III - Logged August, 1962						
Open	-	-	15	25	44	53
Partly Open	-	-	22	21	24	16
Closed	-	-	63	54	32	31

Seed quality

A summary of data relating to germinative capacity is given in Table 5, by cone level, sampling date and area.

Table 5: Germinative Capacity of Slash-borne Lodgepole Pine Seeds by Level of Cones, Sampling Date and Area

Cone Level	Sampling Date					
	May/62	July/62	Sept/62	May/63	Sept/63	Sept/64
	Percentage Germination*					
Area I - Logged April - May, 1962						
Ground	64+8	65+9	56+4	62+8	41+8	30+7
1" - 7"	63+7	61+5	61+11	60+10	57+14	51+5
7"+	73+6	76+4	61+7	61+6	61+13	67+8
Area II - Logged May - June, 1962						
Ground	-	66+11	49+12	60+7	51+15	40+8
1" - 7"	-	70+7	54+8	58+13	46+11	38+20
7"+	-	67+5	61+15	62+7	65+8	46+19
Area III - Logged August, 1962						
Ground	-	-	52+7	53+7	34+20	28+8
1" - 7"	-	-	68+8	61+7	40+10	52+12
7"+	-	-	66+8	59+9	62+14	42+15

* Percentage of all seeds that germinate plus apparently sound seeds that did not germinate.

There was a substantial and continual deterioration in the germinative capacity of the seed on all three areas. Furthermore, the deterioration was most rapid for seeds from cones on the ground. This result is in agreement with Tackle (1954) who noted that the germination capacity of seeds from cones on the ground was significantly lower than that of seeds from cones above the ground after 6 years.

The percentage of apparently sound seeds that did not germinate (Table 5) may be considered a measure of the effect of storage in the slash on real germination percentage. A significant reduction in real germination is not yet evident indicating that the decline in germination capacity is attributable for the most part to an increase in the proportion of empty seeds owing to more rapid release of filled seeds. A very small but increasing loss of seeds to insects was also detected.

Rate of seed release

The mean number of viable seeds per cone immediately after logging and on each sampling date thereafter is given in Table 6. The most rapid rate of seed release has occurred from cones situated at or near the ground, on all areas.

Table 6: Mean Number of Viable Slash-borne Lodgepole Pine Seeds per Cone, by Cone Level, Sampling Date and Area.

Cone Level	Sampling Date					
	May/62	July/62	Sept/62	May/63	Sept/63	Sept/64
	Mean Number of Viable Seeds per Cone					
Area I - Logged April - May, 1962						
Ground	11.2	9.4	6.5	7.8	2.9	1.8
1" - 7"	14.6	12.0	9.0	10.4	7.7	5.8
7"+	17.0	18.5	11.3	12.6	11.3	12.6
Area II - Logged May - June, 1962						
Ground	-	10.1	5.6	6.7	4.5	3.2
1" - 7"	-	14.4	8.4	9.9	6.7	4.2
7"+	-	14.9	13.0	11.4	12.7	7.7
Area III - Logged August, 1962						
Ground	-	-	8.5	7.1	2.8	1.8
1" - 7"	-	-	14.8	12.2	6.3	6.3
7"+	-	-	14.6	12.1	12.5	6.7

The number of viable seeds per acre on each sampling date, presented in Table 7, was derived for each area from the mean number of seeds per cone (Table 6) and the cone counts, adjusted for losses to squirrels (Table 3). The mean number of viable seeds per cone is not an absolute measure of the rate of seed release on an area basis because the cone population is also changing.

Table 7: Number of Viable Slash-borne Lodgepole Pine Seeds per Acre, by Sampling Date and Area.

	Sampling Date				
	May/62	July/62	Sept/62	Sept/63	Sept/64
Area I - Logged April - May, 1962					
No. per Acre-m	1,551	1,478	982	641	542
Percentage Release	0	5	37	59	65
Area II - Logged May - June, 1962					
No. per Acre-m	-	2,386	1,698	1,210	664
Percentage Release	-	0	29	49	72
Area III - Logged August, 1962					
No. per Acre-m	-	-	1,519	714	425
Percentage Release	-	-	0	53	72

By September 1964, three summers after logging on area I and 2 to 3 summers on areas II and III, depletion due to seed release, decrease in germinative capacity and loss to squirrels totalled approximately 70 per cent of the potential viable seed supply. This represents an annual loss of approximately 25 per cent. It is anticipated that by September, 1965 very little viable seed will remain.

Seed loss on area III has been more rapid than on areas I and II. This is a result of more rapid cone opening (Table 4) and deterioration in seed quality (Table 5). The reason for this difference is not known.

CONCLUSIONS AND RECOMMENDATIONS

The principal findings to date are:

1. Storage of lodgepole pine seeds on standing, live trees had no effect whatsoever on viability.
2. There has been a substantial reduction in the germination capacity of the slash-borne seeds three years after logging. This loss resulted mostly from more rapid release of filled, viable seeds and a corresponding increase in the proportion of empty seeds remaining in the slash. Evidence for a loss of viability of originally sound seeds is not yet conclusive.
3. Loss of cones, presumably to squirrels and chipmunks totalled 28 per cent between summer, 1962 and fall, 1964: an annual loss of approximately 10 per cent.
4. Two to three summers after logging depletion totalled approximately 70 per cent of the potential, viable seed supply due to seed release, decrease in germinative capacity and loss to squirrels. This represents a mean annual loss of approximately 25 per cent.

The factors affecting cone opening and seed release were not studied in detail. Nevertheless the increase in rate of cone opening, seed release, and loss of germination capacity with proximity to the ground surface has been substantiated. In addition, considerable evidence has been accumulated that rate of cone opening and seed release increases with age of cone.

An annual loss of 25 per cent of the potential, viable seed supply prompts the recommendation that regeneration treatments such as scarification with dependence upon the slash-borne seed supply, should be undertaken as soon as possible after logging. If cones are abundant, as on the three sample areas of this study, a delay

of one year may not be important. However, seedbed treatment 2 or more years after logging, without provision of an additional source of seed, is questionable.

It is emphasized that the rate of seed release observed in this study is for areas of unlopped slash. The fact that a large proportion of the cones in the slash were above the high temperature regimes near the ground has undoubtedly acted to slow the release of seed. Since seed release from lopped slash will be substantially greater, lopping is not recommended on areas scheduled for scarification.

The fact that the abundance of cones varies widely from stand to stand needs no additional documentation. Although stand and site factors contributing to this variation are of interest, the needs of management are best satisfied by a prescarification survey of cone abundance and by either confining seedbed treatment to areas that have an adequate supply or by providing additional seed.

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APPENDIX - SUPPLEMENTARY STUDIES

Crossley (1956) noted that cones situated less than 6½ inches above the ground attain significantly higher temperatures and opened more rapidly than cones situated above that level. It was also noted that, in general, true air temperatures of at least 80°F were necessary before cones situated near the ground heat sufficiently to open. In the same study it was concluded that age of cone has little relation to ease of resin bond rupture.

In the present study additional evidence of the effect of height above ground and cone age was obtained by two small supplementary experiments. During 1962 a number of cones of age classes 1 to 3, 6 to 13 and 16+ years were suspended fully exposed, at ground level and at 1, 3, 6 and 12 inches above the ground on area II. Rupture of the resin bond was noted and associated with on-site measurements of true air temperature and cloud conditions. Under direct solar radiation, the lowest daily maximum true air temperatures (°F) to rupture the resin bond were as follows:

Cone Position	Age of Cones - Years		
	1 to 3	6 to 13	16+
Ground	70°	65°	61°
1"	83°	70°	67°
3"	83°	70°	67°
6"	None	None	67°
12"	None	None	None

Note that cones situated 12 inches above the ground did not open during the 1962 summer season regardless of cone age. No cone opening was observed unless there were periods of direct solar radiation during the warm part of the day. During the summer months in the Hinton region the warm part of the day is usually accompanied by a build-up of cloud cover. As a result, cone opening occurred at lower true air temperatures during the spring and fall months than during the summer months.

These data apply only to fully exposed cones. Cone opening in the slash may occur at lower or higher air temperatures, depending on cone position relative to shade and nearby radiating or reflecting bodies. The data does illustrate however, that cone opening can occur at true air temperatures considerably lower than previously thought.

The effect of age of cone on cone opening is thought to result from weathering, which changes the color and texture of the cone surface and lowers the albedo. Rupture of the resin bond is known to require a cone tissue temperature in the neighbourhood of 113°F (Cameron 1953, Clements 1910, Crossley 1956). Attainment of this "critical" temperature at any given radiation level is believed to be facilitated by the lowered albedo of the older cones. The validity of this hypothesis was examined in the laboratory by exposing 1 to 3 and 16+ year-old cones to a number of different radiation levels with heat lamps, and measuring surface air temperatures (°F) by copper constantan thermocouples. The results are tabulated below:

Radiation Level	Cone Age-Years 1 to 3	16+	Temperature Difference
1	84.9°	87.3°	+ 2.4°
1 x 2	95.7°	99.5°	+ 3.8°
1 x 3	104.7°	110.3°	+ 5.6°
1 x 4	107.8°	115.0°	+ 7.2°

Cone surface temperature was measurably higher for the older cones at all radiation levels. At radiation levels sufficiently high to induce cone opening (1 x 4), air temperatures at the cone surface were approximately 7° higher for the old cones. This difference is considered adequate to account for the effect of age on cone opening observed in this study. An alternative hypothesis, that there may be a chemical change, with time, in the bonding material that effects a lowering of the critical temperature has not been examined.