T H E S I S

THE INFLUENCE OF CUTTING METHODS ON LODGEPOLE PINE REPRODUCTION

Submitted by

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ACKNOWLEDGMENT

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Chapter I

INTRODUCTION

The lodgepole pine region covers a large area centering around Wyoming. It includes most of western Colorado, all of Utah except a strip in the southern part of the state, central and northeastern Nevada, southeastern Idaho, all of western Wyoming, and a narrow strip in Montana east of the Continental Divide. The forests occur at altitudes of 6,500 to 10,500 feet and there are extensive areas of land within the region on which no timber grows (1). The area of the timbered land is 23,000,000 acres, 93 percent of which is publically owned (2).

Lodgepole pine (Pinus contorta var. latifolia S. Wats.) is commercially the most important species in the region. It attains its best development in Wyoming and Colorado. It occupies 3,392,633 acres of the forested area of the two states and supports a sawtimber stand of 10,610,100 M.b.m. (3). The merchantable stands are generally uneven-aged while the younger stands are more commonly even-aged. The average timber volume for a merchantable stand is about 12 M.b.m. per acre while some of the best stands in Wyoming and Colorado may

yield up to 25 M.b.m. per acre.

The chief associates of lodgepole pine are Engelmann spruce (Picea Engelmanni (Parry) Engelm.), alpine fir (Abies lasiocarpa (Hook) Nutt.) and Douglas-fir (Pseudotusga taxifolia (Pair) Britt.). Some aspen (Populus tremuloides Michx.) occurs scattered in the stands. On North exposures at lower elevations and in moist creek bottoms, lodgepole pine grows in mixture with Engelmann spruce and alpine fir. Under these conditions it is a sub-climax species which eventually is replaced by the more tolerant associated species. At the higher elevations on all sites lodgepole pine gives way to the climax Engelmann spruce-alpine fir association. At the lower elevations the lodgepine type gives way to the Douglas fir or ponderosa pine types. Large areas of young growth pure lodgepole pine occur as the result of fire or past cutting practices.

Although lodgepole pine is classed as a sub-climax type, it can be perpetuated as a permanent forest type within its habitat by the application of the proper cutting method and silvicultural practices.

The cutting in lodgepole pine has been conservative and few operations cut more than 5,000,000 board feet annually. Some lumber has been produced and exported from the region in the past few years; but the majority of the cutting is for special products, such as

mine props, telephone poles, and railroad ties. The inherent straight form of the bole and the ease of preservative treatment make lodgepole pine especially desirable for these products. Due to its small size and the small, portable type of mills in the region, little lumber is produced even though as far as quality of lumber lodgepole pine ranks with ponderosa pine (Pinus ponderosa Doug.).

While lodgepole pine is a commercially valuable species, its greatest value is for protection of the vast watershed area within the region. The altitudinal range of 6,500 to 10,500 feet for lodgepole pine is characterized by heavy winter snows and a moderately low relative humidity. The value of protection to this area can only be measured in the increased agricultural production provided by irrigation and the water provided for industrial and domestic purposes.

Problem

Lodgepole pine occurs in dense stands which are often the result of fire burning over an area and causing the release of seed from the indehiscent cones. The release of an enormous amount of seed at one time, plus the fact that the burn exposes the mineral soil providing an excellent seedbed, accounts for most dense, even-aged stands. Unless some process of natural elimination or artificial thinning removes the excess trees,

the stands tend to stagnate in the sapling or pole stage.

However, observation of old cuttings proves that fire is not necessary to reproduce lodgepole pine. The problem encountered is apparently that of regulation of the density of reproduction through cutting methods. Heavy cutting opens the site and allows dense stands of lodgepole pine reproduction to come in; but under a virgin stand of merchantable lodgepole pine little reproduction exists except that of the tolerant Engelmann spruce and alpine fir. This shows the intolerance of lodgepole pine and indicates that a partial canopy should be left as a means of excluding a part of the light from the forest floor in order to control the density of reproduction.

Lodgepole pine produces frequent heavy seed crops, however, the greater part of the seed is locked in the indehiscent cones until heat or atmospheric conditions cause them to open and release the seed. If too much seed is released at one time and other conditions are favorable, then too dense a stand of reproduction will occur. This factor can be partially controlled by the treatment of slash after logging. Through burning of slash either of two conditions may occur: (1) The cones bearing the seed and clinging to the branches (slash) will be destroyed by the burning. Thus, much of the seed is destroyed depending, of course, on the

completeness of the slash burn. (2) The heat from the burning of the slash will release an enormous amount of seed from the cones and as a result too dense a stand of reproduction will be obtained.

Through lopping and scattering of slash the reproduction can be controlled by the slash furnishing a ground cover and not allowing excessive amounts of seed to reach the mineral soil or by suppressing the establishment of young seedlings through shading.

Moisture and temperature, which are limiting factors in the reproduction of lodgepole pine, operate mainly through exposure of the site. Soil moisture has a greater effect than total precipitation. Where excessive soil moisture exists in the lodgepole pine region, on north slopes and creek bottoms, Engelmann spruce and alpine fir tend to reproduce more readily and dominate the reproduction. Excessively dry south slopes tend to be sparsely reproduced by lodgepole pine or are entirely bare. Precipitation and temperature records shown in Table 1 were taken at the Fraser Experimental Forest in the Arapaho National Forest in Colorado and are indicative of the optimum precipitation and temperature required for lodgepole pine growth. The yearly mean temperature is 33.9 degrees Fahrenheit with a mean temperature above 40 degrees Farenheit occurring May through September. The average yearly precipitation is 23.49

inches with the greatest amount occurring in April.

Table 1.--TEMPERATURE AND PRECIPITATION, FRASER EXPERIMENTAL FOREST, ARAPAHO NATIONAL FOREST, COLORADO*

Month	Mean Temperature (Degrees Farenheit)	Precipitation (Inches)
January	13.8	1.94
February	16.5	1.85
March	22.5	1.68
April	31.1	3.50
May	41.9	1.90
June	48.7	1.64
July	54.2	2.42
August	52.8	1.55
September	47.0	2.03
October	38.5	1.75
November	21.7	1.75
December	17.8	1.48
Yearly mean temperature	33.9° F.	
Average yearly precipitation	23.49 in.	

*1940-41-42 records

Object

The purpose of this study is to determine which combination of cutting method, slash disposal treatment and timber stand improvement measures, will give the optimum amount of natural regeneration and the greatest

yield at the end of the rotation without requiring intermediate thinnings. It is desired to use a silvicultural system to perpetuate the lodgepole pine stand that will give the optimum timber yield compatible with maximum watershed protection.

Place and time of work

The reproduction study was conducted at the Fraser Experimental Forest in the Arapaho National Forest in Colorado. The experimental plots on which the survey was made were established in 1939 and the various cutting methods applied in 1940. The plots lie at an altitude of 9,500 feet and the general exposure is North. A reproduction survey was made prior to logging in 1939, then another was made in 1941 immediately after logging to determine the loss from the logging operation. The present study was conducted in the summer of 1948, seven years after logging, to determine what reproduction had become established subsequent to the logging operation.

Chapter II

MATERIALS AND METHODS (4)

The study was made on four experimental blocks of fairly contiguous plots located in the lodgepole pine type on the Fraser Experimental Forest. These blocks and plots are illustrated in Figure 1. Each plot representing a treatment is five acres in size with a 1-chain isolation strip on each side. Minor treatments were applied to one-half of each plot as shown in Figure 2. By applying the second set of minor treatments at right angles to the first, four separate sub-treatments were formed on each plot.

The exact manner in which the two sets of sub-treatments were applied is shown in detail in Figure 3, 4, and 5. Figure 6 illustrates the manner in which the snow stakes used by the division of forest influences were arranged. These stakes were used to conveniently stratify each plot in the reproduction survey as explained later.

Major treatments

Five treatments were applied. They were:

1. Commercial Clear Cut
2. Reserved volume 2M.b.m.

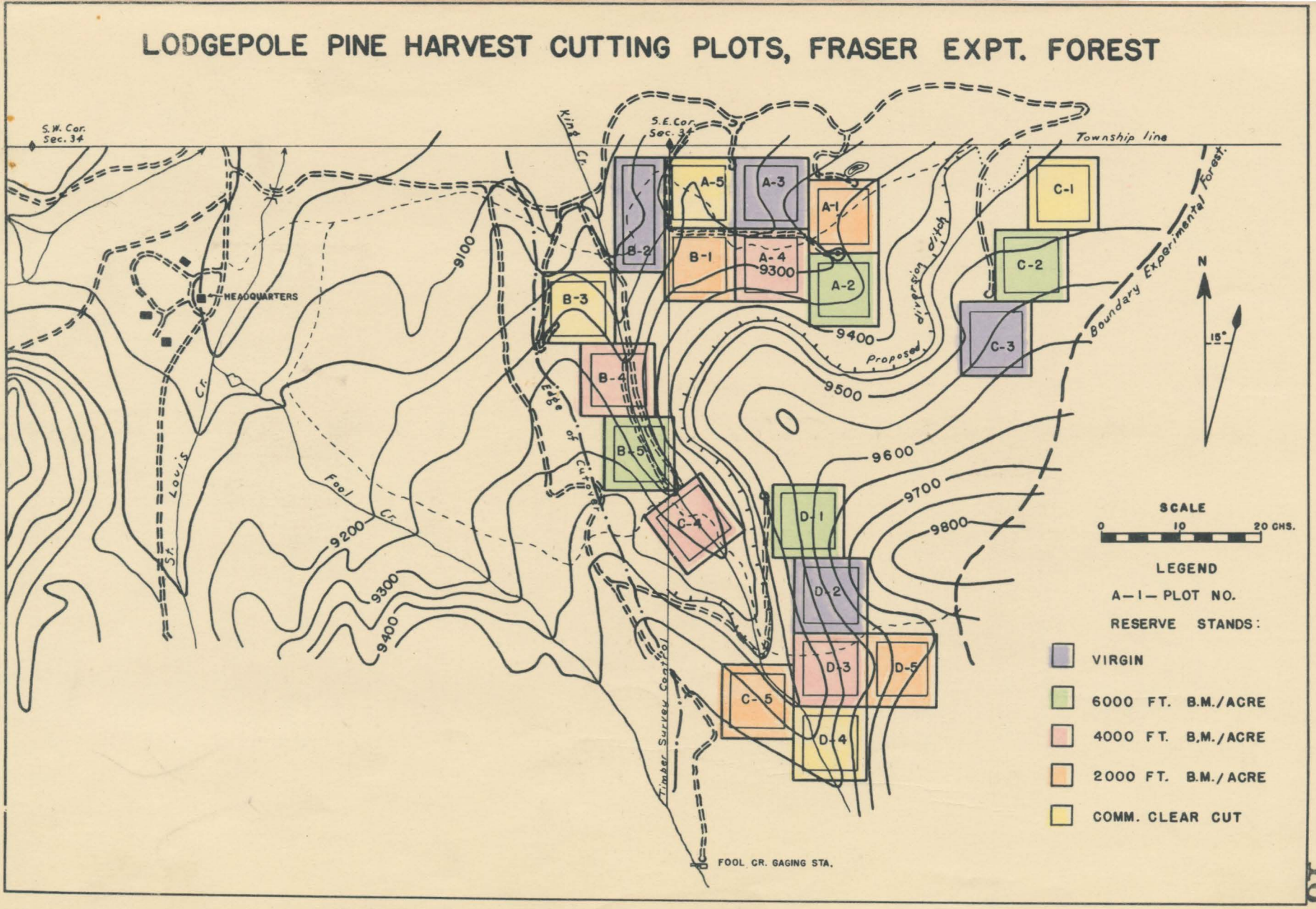
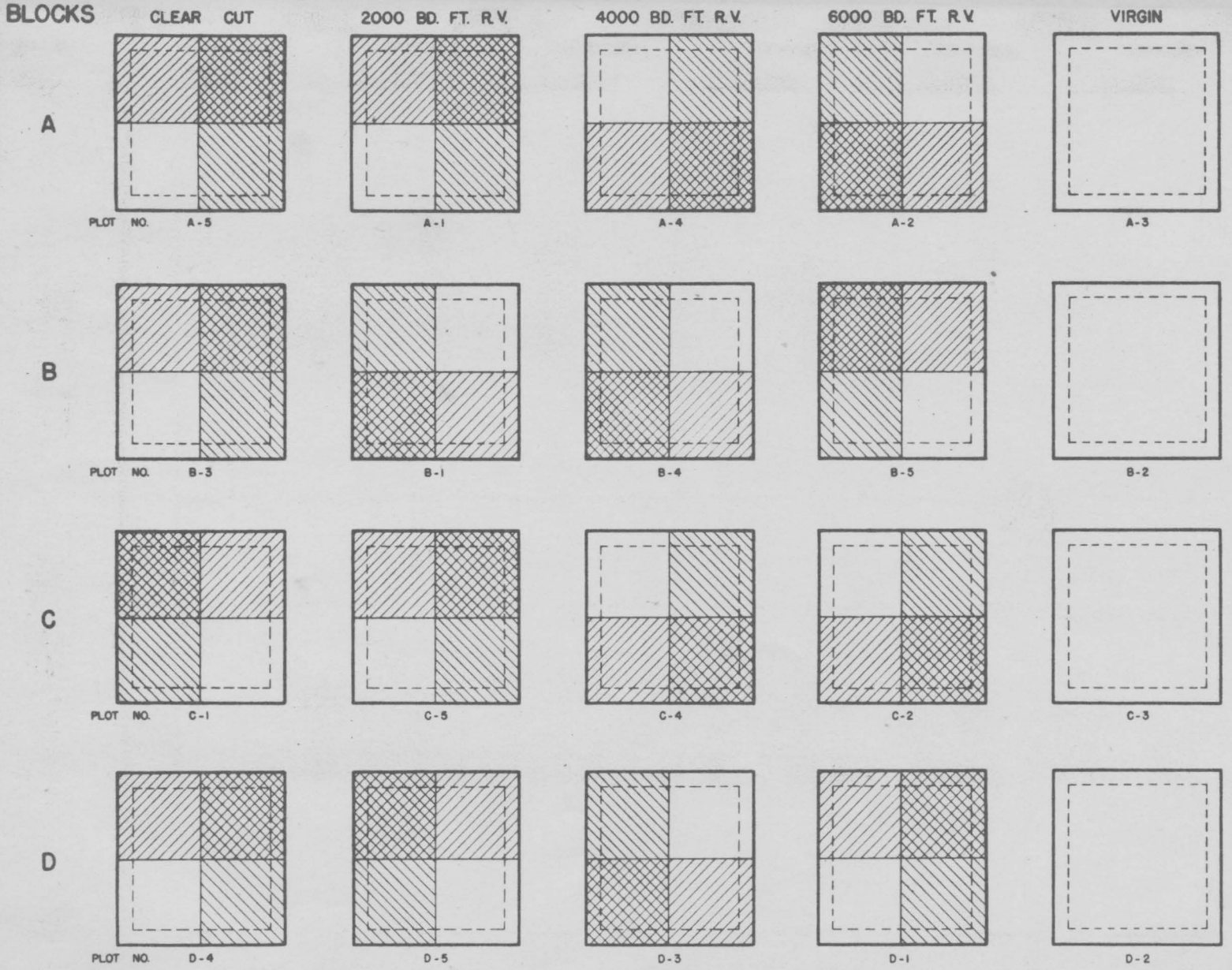


Fig. 1 --Location of lodgepole pine harvest cutting plots.

LODGEPOLE PINE HARVEST CUTTING STUDY

MAJOR TREATMENTS



SUB TREATMENTS

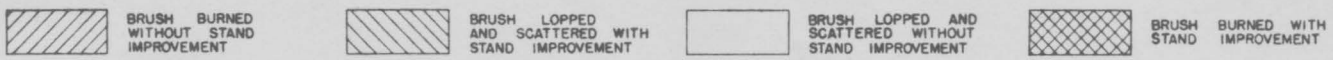


Fig. 2 --Location of minor treatments within major treatments.

LODGEPOLE PINE HARVEST CUTTING STUDY

(SUB TREATMENTS AND SNOW STAKE LOCATIONS)

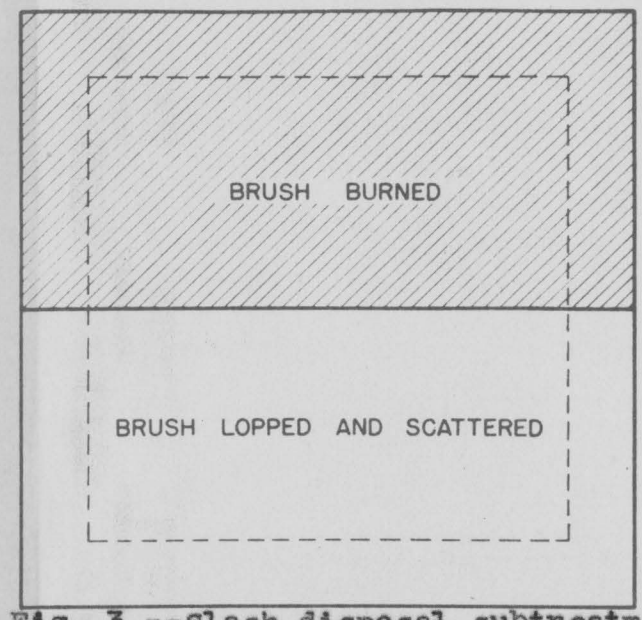


Fig. 3 --Slash disposal subtreatment.

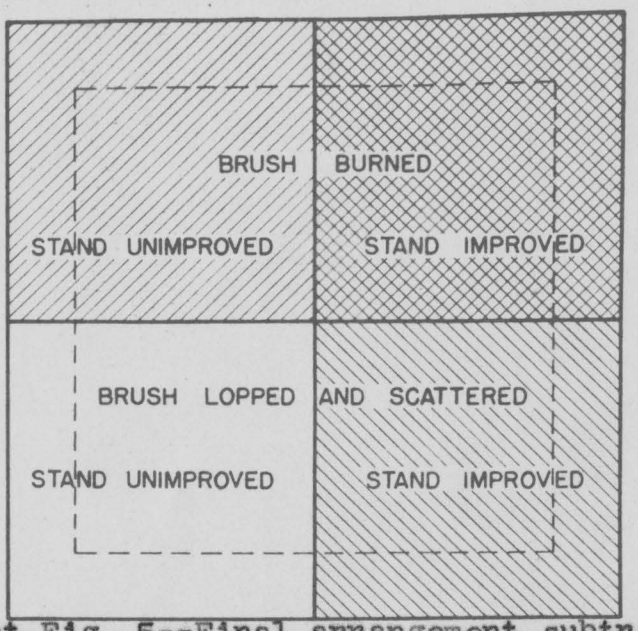


Fig. 5--Final arrangement subtreatmts.

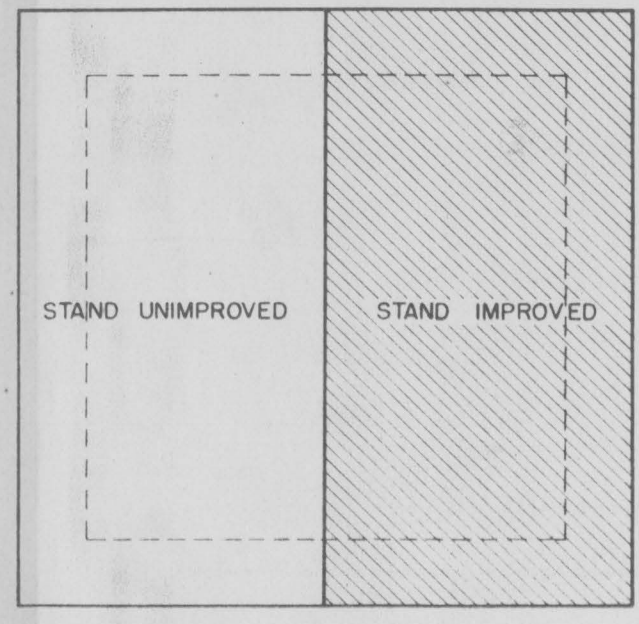


Fig. 4 --Stand improvement subtreatment.

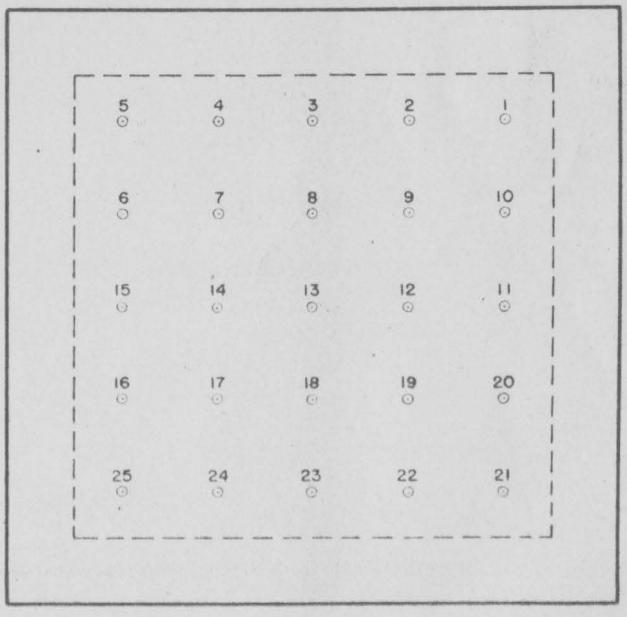


Fig. 6 --Snow stake locations.

3. Reserved volume 4M.b.m.

4. Reserved volume 6M.b.m.

5. Virgin or Check Treatment

These treatments do not conform exactly to standard silvicultural systems, their approximate equivalents are, however, as follows:

Treatment	Approximate Silvicultural Equivalent
Commercial Clear Cut	Clear Cut
Reserved volume 2M.b.m.	Seed Tree
Reserved volume 4M.b.m.	Heavy Selection
Reserved volume 6M.b.m.	Selection or Shelterwood
Virgin	Natural Selection

Commercial Clear Cut.--This treatment required the removal of all trees over 9.6 inches in diameter breast high regardless of species and vigor. The only material left after cutting was that which was too small for sawlogs. This system of cutting has been used widely in the lodgepole pine type and its advantages and disadvantages are fairly well known.

Reserved volume of 2M.b.m.--Under this system of cutting a growing stock of 2M.b.m. of the thriftiest trees was left. In the selection of trees for the reserve stand, vigor was considered with spacing, form and external defect such as crook, porcupine damage, fire scars, and forking. This method simulates the seed tree

method of cutting, but differs in that no special attention is paid to a tree's capacity to produce seed. This is considered sound procedure in the cutting of lodgepole pine since it regenerates easily under a wide range of site conditions.

Reserved volume of 4M.b.m.--The only difference between this and the preceding system of cutting is in the reserved stand. Two thousand additional board feet selected from the best trees in the original stand were left in the growing stock. The method simulates the heavy selection method of cutting but seeks not only to insure adequate restocking of the area but control over the number of seedlings and the development of poles in the understory as well.

Reserved volume of 6M.b.m.--This method of cutting required the removal of approximately one-half of the original volume. The best trees in the stand should be left, but because of the unusually large volume to be reserved, difficulty was encountered in securing a sufficient number of good "leave trees." To allow for this deficiency, it was necessary to reserve trees from cutting which would not ordinarily be left under good silvicultural practice. The early stage of the method simulates both shelterwood and selection cutting. The manner in which the reserved stand eventually is cut will determine largely the method of cutting it most closely

approaches. Barring any unforeseen conditions such as insect epidemic or unusually heavy windfall, subsequent cutting will be governed by the amount of reproduction which becomes established and the growth of the reserved stand.

Virgin or Check.--No cutting was performed under this treatment. The main reasons for the inclusion of virgin stands were: (1) To provide a criterion by which any changes may be detected in stand composition, stand structure, stand distribution, plant cover, and long-time productivity which results from the continuous removal of timber in the other treatments. (2) To provide plots upon which the original marking by treatments can be illustrated for both administrative and investigative purposes. (3) To make possible the comparisons of growth and reproduction on 2, 4, and 6M.b.m. reserves released by cutting and similar reserves unreleased; and (4) To provide an estimate of normal mortality unaffected by treatment.

Minor treatments

Stand improvement.--In addition to the major treatments, two sets of sub-treatments were applied to each plot. On one of the two halves of each plot divided by a north-south line, improvement of the stand below 9.6 inches diameter breast high was performed; on the

other half, no treatment was applied but trees that would ordinarily be left after stand improvement are indicated in order to aid in the future analysis of results.

Cutting under the stand improvement was similar to that used in the merchantable stands; all defective and poorly formed trees were cut, and whenever dense pole stands were encountered they were thinned from below.

Slash disposal.--The second set of minor treatments which deal with slash disposal were applied to the east and west halves of each plot. On one-half of the plot, slash was burned, on the other half it was lopped and scattered. The burning of slash was progressive; that is, it was done as logging proceeded rather than as a separate operation after the experimental area had been completely cut-over. This resulted in all the cones being burned so the only sources of seed left available for reproduction were: (1) Seed already on the ground; (2) Seed cast from cones in trees remaining in stand.

Lopping and scattering of brush followed the instructions given in the Timber Management Handbook for Rocky Mountain Region (R-2) (5). They are as follows:

> All felled trees will be limbed to the tip. Branches will be trimmed off close to the trunk. Such scattering will be required as is necessary to remove slash from down timber and stumps and to eliminate piles which will not flatten to the ground with heavy snows. Experience has shown that little is gained by insisting upon unnecessary refinements, such as cutting up larger branches or moving the slash to any extent merely

> for the sake of spreading it out in a thin mat. Much work can be saved if fellers will refrain as far as practicable from throwing trees toward the same spot or on top of each other. It is also strongly urged that arrangements be made for tops to be lopped as felling takes place. If tops are properly lopped, little additional scattering is necessary as a general rule. "Lopping and Scattering" as used hereafter contemplates scattering in accordance with this standard.

The stand distribution before and after cutting is illustrated in Figure 7. It shows not only the condition of the merchantable stand after cutting, but the sub-merchantable stand also. The greatest number of saw-log trees was harvested by the commercial clear cut treatment and the smallest number by the 6M.b.m. reserve treatment. This left the greatest number of merchantable growing trees on the 6M.b.m. reserve plots and no merchantable growing trees on the commercial clear cut plots. The greatest number of merchantable trees left as reserve volume was in the 10-inch D.B.H. class. There was approximately the same number of trees in the sub-merchantable stand on all plots before the cutting methods were applied. The prop and pole harvest removed an amount from each plot which further equalized the remaining sub-merchantable stand on all plots after cutting. The sub-merchantable stand for the unimproved half plots includes only those trees which would have been left had timber stand improvement been applied to them.

One virgin or check plot (B-2) was established

LODGEPOLE PINE HARVEST CUTTING STUDY

STAND DISTRIBUTIONS BY TREATMENTS

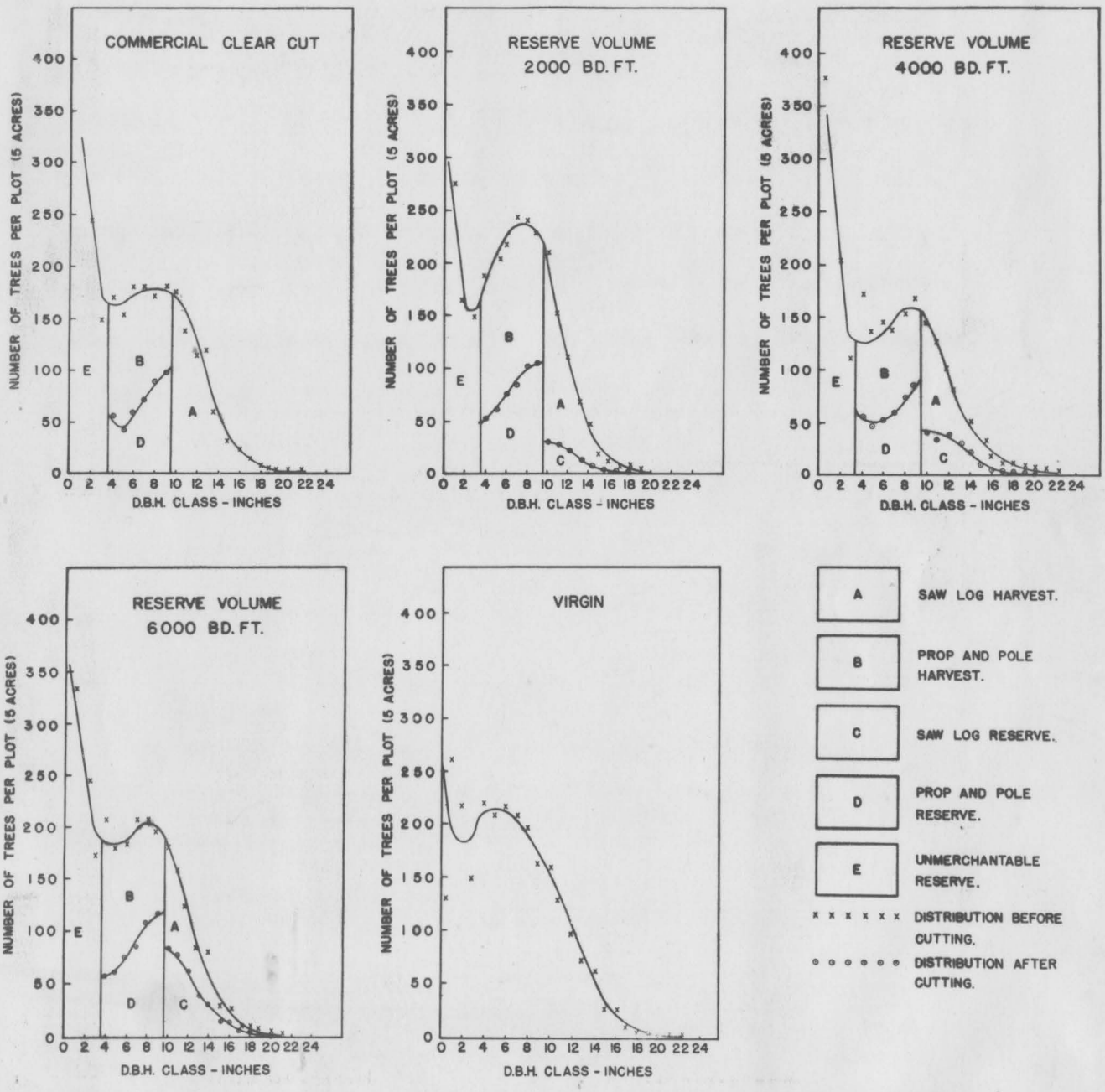


Fig. 7--Stand distributions by treatments before and after cutting.

as a model to follow in the marking practices on the other plots and as an example to show those who are unfamiliar with the procedure the manner in which the treatments were applied. This is accomplished by a system of paint markings on the trees. Examples are shown and explained by photographs in Figure 8.

The logging and treatments applied were carried out by local labor under the strict supervision of the staff members of the Fraser Experimental Forest. All skidding was done by horses as is common in most lodgepole pine cutting operations and skid trails were located to hold subsequent erosion to a minimum.

The stand per acre in board feet by plots prior to treatment is shown in Table 2. The mean volume was 12,040 board feet per acre before cutting treatments were applied.

Table 2.--STAND PER ACRE IN BOARD FEET BY PLOTS PRIOR TO TREATMENT

Block	Treatment					
	Clear Cut	2000	4000	6000	Virgin	Mean
A	7,645	9,340	12,789	11,502	11,308	10,517
B	14,340	10,450	11,052	13,883	13,310	12,607
C	17,037	10,158	13,064	12,109	13,587	13,191
D	12,933	11,467	11,913	13,581	9,326	11,844
Mean	12,989	10,354	12,205	12,769	11,883	12,040

2-4-6M.b.m.
Reserve volume tree

4-6M.b.m.
Reserve volume tree

6M.b.m.
Reserve volume tree

Fig. 8 --System of paint markings in plot B-2 illustrating Reserve volume trees.

The first reproduction survey was made in 1939 prior to logging and treatment of the experimental plots. Sampling intensity was set at 21 percent. This proved more intensive than necessary and as a result the 1941 and 1948 reproduction surveys were carried out with a sampling intensity of 14 percent. The method of carrying out the survey is explained in the following section.

The plots enclose an area of five acres and are 7.073 chains on a side. Snow stakes are placed on the plots at regular intervals. These stakes divide the plot into 25 equal parts (Plot B-2 is an exception as is shown in Figure 9). The stakes are at the center of each square as illustrated in Figure 10. The squares are numbered consecutively from 1 to 25, starting at the NE corner as in the sections of a township. Each square is 141.4 links on a side, and contains an area of 1/5-acre. In order to make the sample as representative as possible the 25 1/5-acre squares are split in half, making a north and south strata of 1/10-acre each. Thus, a single 1/10-acre strata is 141.4 links by 70.7 links.

The sampling strips in the blocks are 10 links wide and are run north and south across the 1/10-acre blocks and are, therefore, 70 links long. From Figure 11 it can be seen that there are 14 possible strips in each 1/10-acre block. Two strips, (three in 1939 survey) drawn at random, were run in each 1/10-acre block.

LODGEPOLE PINE HARVEST CUTTING STUDY

FRASER EXPERIMENTAL FOREST

DATE: _____ UNIT: B-2

RECORDER: _____ OBSERVER: _____

TREATMENT: _____

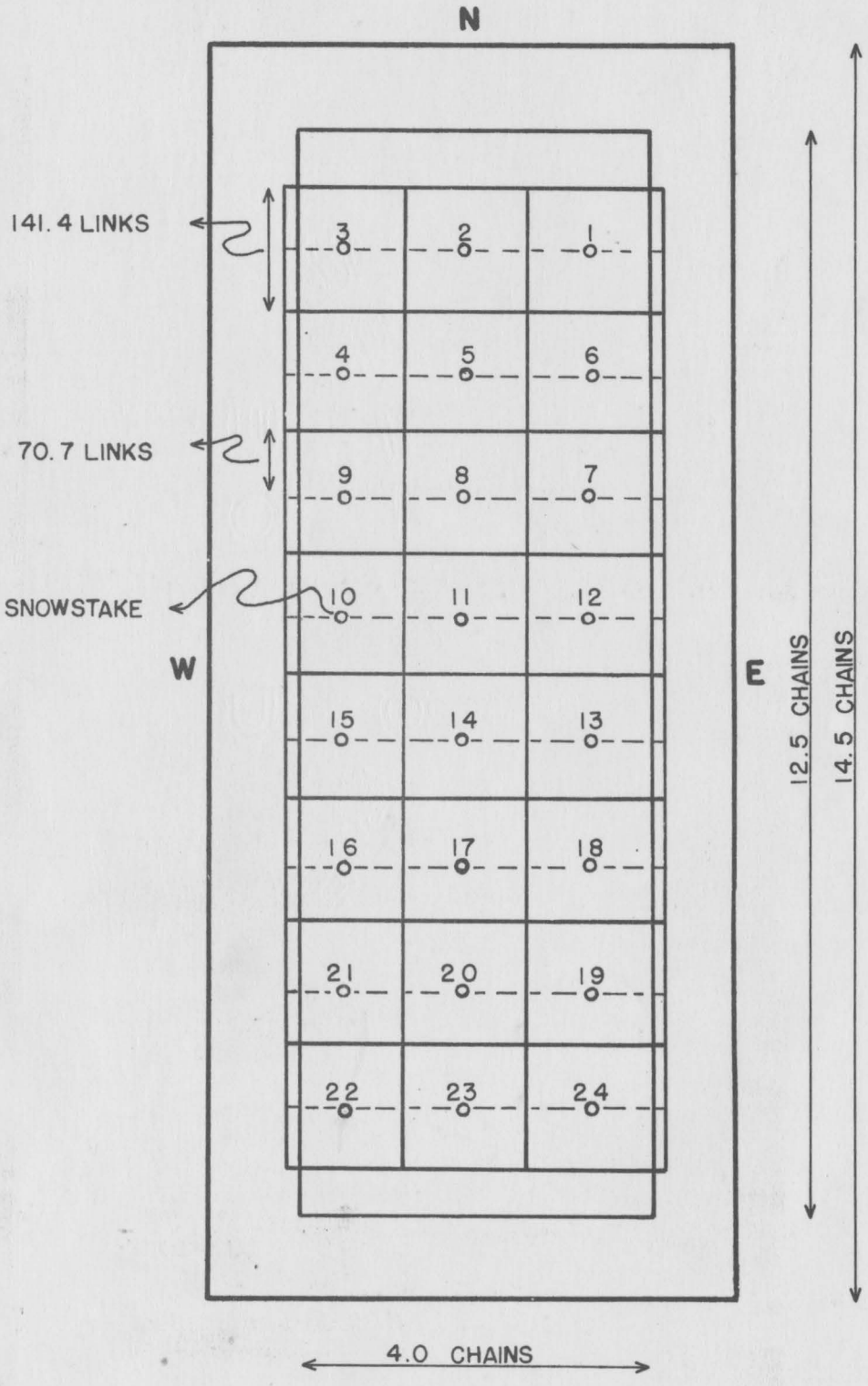


Fig. 9 --Layout of Plot B-2.

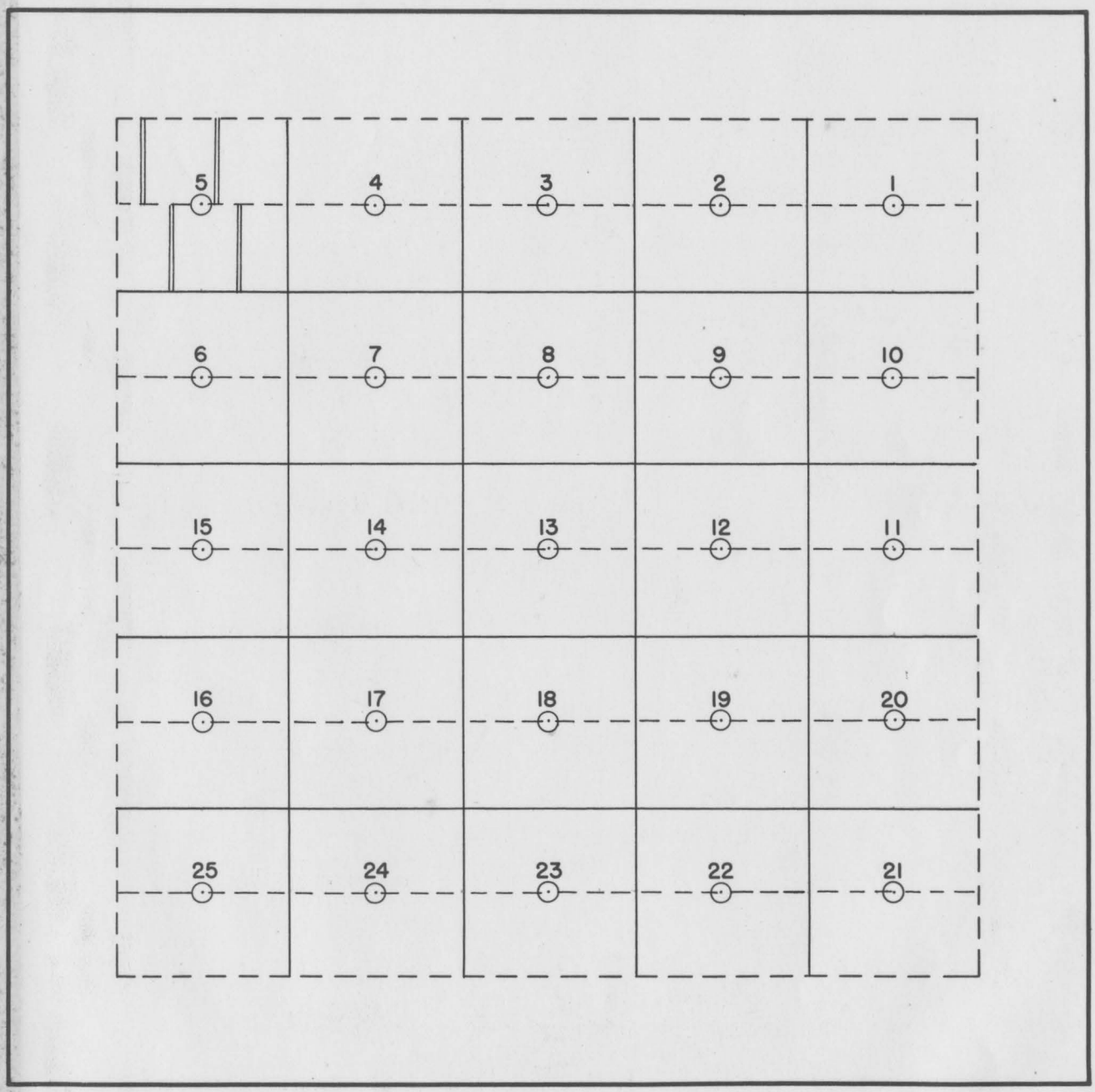
LODGEPOLE PINE HARVEST CUTTING STUDY

FRASER EXPERIMENTAL FOREST

DATE: _____ UNIT: _____

RECORDER: _____ OBSERVER: _____

TREATMENT: _____



REMARKS:

Fig. 10 --Stratification of plots for reproduction inventory.

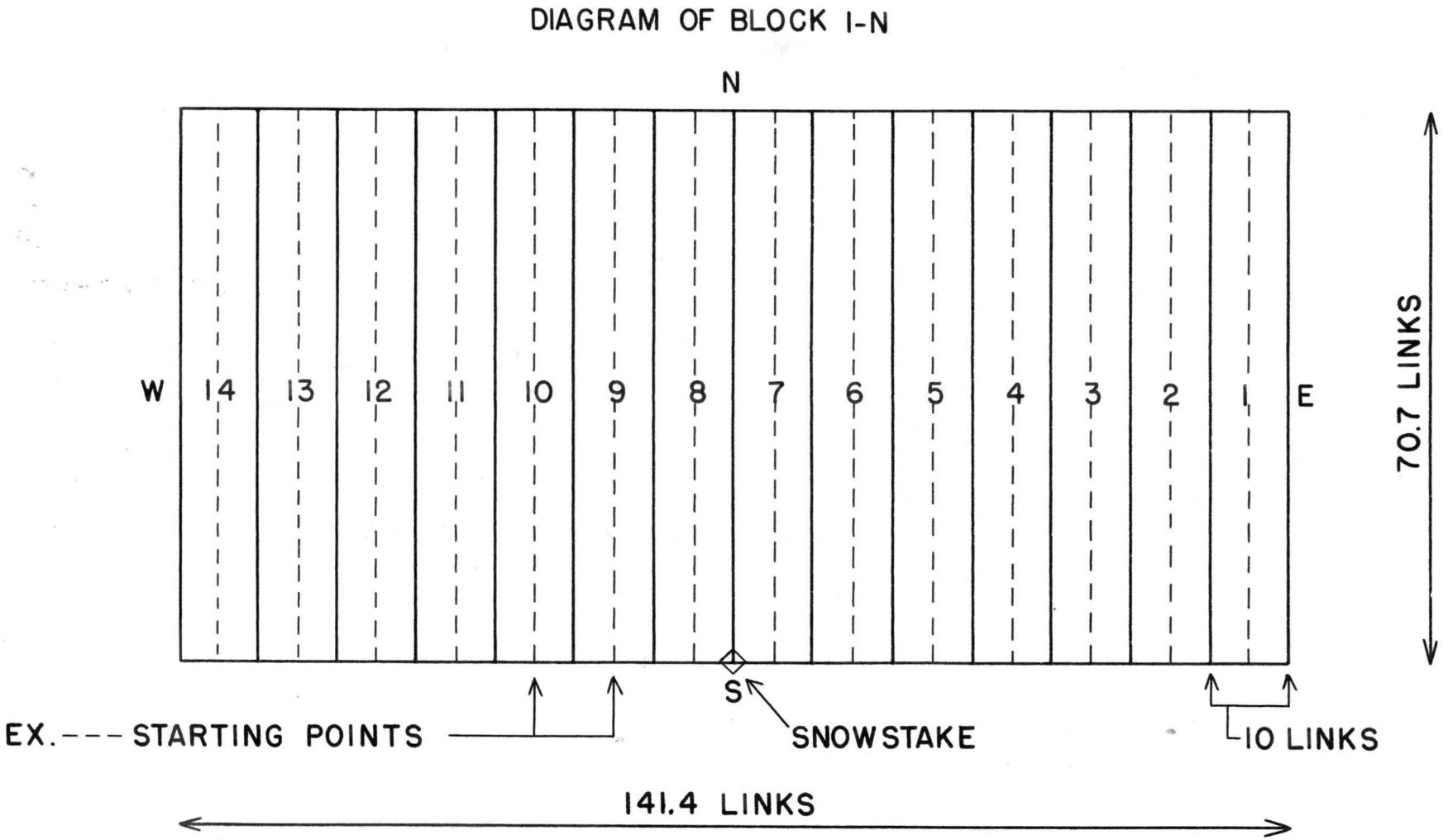


Fig. 11 --Subdivision of a stratum into transects.

This gives a total of 100 strips (150 in 1939 survey) to a plot. Each of the 70 link strips contains 7 milacres (10 x 10 links) which are used in determining the percentage of stocking.

The strips are numbered from 1 to 14 in an east to west direction. The letters N and S are used to designate whether or not the strip selected is in the north or south half of a square.

Survey procedure

Equipment

1 - Abney level (percent limb)

1 - 141.4 link tape with sleeve at 70.7 link mark

1 - 70 link tape

2 - Diameter tapes

1 - Slope correction table (See Table 3)

1 - Tatum holder

1 - Template (3 ft. sticks fastened at right angles)

2 - 5 link measuring sticks

Tabulation forms (RS-10)(Rev 6/5/41)(See Figure 12)

4 - Chaining pins

1 - 4-H pencil

Equipment used is shown by photograph, Figure 13A.

Table 3.--SLOPE CORRECTION TABLE

Percent	Angle degrees	Cosine Angle	Slope Distance
6	3°26'	.9982	70.13
7	4°00'	.9976	70.17
8	4°34'	.9968	70.22
9	5°09'	.9960	70.28
10	5°43'	.9950	70.35
11	6°17'	.9940	70.42
12	6°51'	.9929	70.50
13	7°24'	.9917	70.59
14	7°58'	.9903	70.69
15	8°32'	.9889	70.79
16	9°05'	.9875	70.89
17	9°39'	.9859	71.00
18	10°12'	.9842	71.12
19	10°45'	.9825	71.25
20	11°19'	.9806	71.38
21	11°52'	.9786	71.53
22	12°24'	.9767	71.67
23	12°57'	.9746	71.82
24	13°30'	.9724	71.99
25	14°02'	.9702	72.15
26	14°34'	.9679	72.32
27	15°07'	.9654	72.51
28	15°39'	.9629	72.71
29	16°10'	.9605	72.88
30	16°42'	.9578	73.08
31	17°13'	.9552	73.28
32	17°45'	.9524	73.50
33	18°16'	.9496	73.72
34	18°47'	.9467	73.94
35	19°17'	.9439	74.16
36	19°48'	.9409	74.40
37	20°18'	.9379	74.63
38	20°48'	.9348	74.88
39	21°18'	.9317	75.13
40	21°48'	.9285	75.39

Form RS - 10 (Rev.6/5/41 BL)

Plot No._____ Date_____

Block No._____ Crew_____

Strip No.								
Stocking				Species				
	LP	ES	AF	Ht.Class Feet	LP	ES	AF	Total
1				- 1				
2				1 - 3				
3				3 - 4.5				
4				dbh class				
5				0 - 0.5"				
6				1"				
7				2"				
				3"				
Strip No.				Total				
1				- 1				
2				1 - 3				
3				3 - 4.5				
4				dbh class				
5				0 - 0.5"				
6				1"				
7				2"				
				3"				
Strip No.				Total				
1				- 1				
2				1 - 3				
3				3 - 4.5				
4				dbh class				
5				0 - 0.5"				
6				1"				
7				2"				
				3"				
				Total				

Fig. 12 --Tabulation Form RS-10 (Rev 6/5/41) for recording of data.

Fig. 13A --Equipment used in Reproduction Survey.

Fig. 13B --Snowstake and Template.

Fig. 13C --Height Measurement with Measuring Stick.

Crew

Two men are required for the survey. Both of the men measure and count reproduction and in addition, one of the men tallies the data on Form RS-10.

Order of procedure

(a) Cruiser takes "0" end of 141.7 link tape and walks westward from snow stake No. 1 until tallyman slips sleeve at 70.7 link mark over snow stake. Tallyman lines cruiser in with snow stake No. 2 and cruiser anchors "0" end of tape (A conspicuously colored jakestaff attached to the "0" end of the tape facilitates alignment and anchoring). Tallyman takes "141.7" end of tape and walks eastward from snow stake No. 1 while cruiser remains at "0" end of tape. Tallyman stretches tape and is aligned by cruiser, then anchors "141.7" end of tape.

(b) Tallyman calls out N and S strips to be run and cruiser walks eastward from "0" end of tape setting chaining pins at points in middle of strips to be run (Colored ribbon or cloth attached to chaining pins to indicate N and S strip facilitates operation).

(c) Tallyman lines up template along chain and on snow stakes, giving a right angle and a north or south line in middle of strip to be run. The photograph, Figure 13B, illustrates the procedure.

(d) Cruiser pulls out "70" link tape in

designated direction and takes Abney reading. Tallyman makes slope correction (Table 3) and anchors tape with chaining pin. Cruiser stretches tape and anchors "70" link end.

(e) Cruiser and tallyman walk down "70" link tape, each man taking a strip 5 links wide on each side of the tape and count and measure the reproduction. The 5 link width is determined by a measuring stick which is also used to measure height of reproduction from scale on stick. The measuring stick is shown in the photograph, Figure 13C.

(f) Tallyman records data. Upon completion, set-up is moved to snow stake No. 2, etc. and same procedure followed. Crew changes job for each new set-up.

Stocking is determined for each milacre (10 x 10 links) in the strip by agreement of cruiser and tallyman. Stocking is considered as the dominant seedling or species in the milacre. The order of preference of species in stocking is: (1) Lodgepole Pine; (2) Engelmann Spruce; (3) Alpine Fir. In other words, if reproduction of all these species is present in one milacre, the stocking is given to the lodgepole pine seedling. The age and size are recorded under appropriate species for each milacre under the "stocking" section of Form RS-10. A tally of all other reproduction is recorded by size and age under "species" section of Form RS-10.

The sizes recorded are shown on Form RS-10, all reproduction under 4.5 feet tall being measured by height and all above that by diameter breast high. Age is recorded as subsequent (reproduction established since logging) or advanced (reproduction established prior to logging). All reproduction in 1939 and 1941 surveys was therefore recorded as advanced. Age was determined in the 1948 survey by counting the number of whorls of branches on the stems of the reproduction. All reproduction with eight or more whorls was recorded as advanced while less than eight whorls was recorded as subsequent. In all cases where the whorls were not distinct, it was left to the judgment of the cruiser and tallyman to determine and record the age class. Advanced reproduction was recorded by dash and subsequent reproduction by dot on Form RS-10.

Chapter III

ANALYSIS OF DATA

The first reproduction survey was made on the experimental plots in 1939 before the area was disturbed by logging. It was found that an average of 1602 seedlings per acre under 4.5 feet in height existed on the plots in a virgin condition. The number, distribution, and loss of seedlings is shown in Table 4. After the plots were logged, a reproduction survey was made in 1941 to determine the number of seedlings which had been lost due to treatments applied in logging. The average number of seedlings per acre dropped to 911, showing an average loss of 43 percent of the original reproduction.

Table 4.--SEEDLINGS PER ACRE BEFORE AND AFTER CUTTING

	Treatment				
	Clear Cut	2M.b.m.	4M.b.m.	6M.b.m.	Mean
Before cutting	1607	1686	2094	1059	1602
After cutting	1088	907	1020	628	911
Losses	519	779	1074	431	701
Adjusted losses	520	744	847	689	--
Percent loss	32	46	51	41	43

There was no apparent relationship between the volume removed from the plots by the various treatments and the destruction of reproduction. The commercial clear cut plots from which the greatest volume was removed showed less loss of reproduction than the plots on which reserve stands were maintained. This would indicate that establishment and use of the main skidways causes the greatest loss of reproduction as the pattern and length of main skidways would be approximately the same in any of the plots regardless of treatment. The minor or branch skidways, of which there would be a greater number on the plots with the greater volume removed, are probably not covered enough times in succession to kill the reproduction. The logging of the commercial clear cut plots was carried out at a time when a 10-inch layer of snow covered the ground. This snow cover undoubtedly furnished some protection to the seedlings from skid damage and accounts for the smaller percentage of loss of reproduction on the commercial clear cut plots.

A survey of the milacre stocking of the plots and the number of seedlings per acre was made in 1941 immediately after logging and again in 1948, seven years after logging. The percentage of milacres stocked is shown in Table 5. The milacre stocking on all plots in 1941, immediately after logging, was approximately 40 percent. In 1948 the stocking ranged from an upper limit

of 80 percent on the commercial clear cut plots down to 62 percent on the 6M.b.m. reserve volume plots. The milacre stocking gain in the seven year period was 40 percent on the commercial clear cut plots and ranged downward to a 32 percent gain in milacre stocking on the 6M.b.m. reserve volume plots.

Table 5.--COMPARISON BY MAJOR TREATMENT OF PERCENT OF MILACRES STOCKED AND PERCENT GAIN FROM 1941 TO 1948

Major Treatment	Percent Milacres Stocked		Percent Gain
	1941	1948	
Commercial Clear Cut	39.6	80.1	40.5
2M.b.m. reserve	39.4	76.2	36.8
4M.b.m. reserve	40.3	76.2	35.9
6M.b.m. reserve	29.9	62.3	32.4
Virgin	--	51.4	--

The number of seedlings per acre is shown in Table 6. The number of advanced seedlings in 1941 and 1948 was approximately the same. The 1948 subsequent seedlings represent the reproduction which has become established since 1941. The greatest number of subsequent seedlings, an average of 2666 per acre, established on the commercial clear cut plots with a downward trend in number to the 6M.b.m. reserve volume plots on which an average of 1478 subsequent seedlings per acre were established.

Table 6.--COMPARISON BY MAJOR TREATMENT OF NUMBER OF SEEDLINGS PER ACRE IN 1941 AND 1948

Major Treatment	Number of Seedlings per Acre		
	1941 Advanced	1948 Subsequent	1948 Advanced
Commercial Clear Cut	1088	2666	1062
2M.b.m. reserve	907	2216	990
4M.b.m. reserve	1021	2416	1126
6M.b.m. reserve	628	1478	701
Virgin	854	312	995

The comparison shows the greatest gain in milacre stocking and number of seedlings per acre on the commercial clear cut treatment indicating that the greater the volume removed and the more the canopy is opened by cutting method, the more lodgepole pine reproduction is obtained. The 2M.b.m. and 4M.b.m. reserve treatments show a smaller percentage gain in milacre stocking and fewer seedlings per acre gain, however, the differences between the reserve treatments themselves is not significant. The opening of the site and canopy must be severe to get maximum reproduction.

Stocking of the virgin plots was not determined in the 1941 survey so no comparison can be made on the trend of reproduction under the virgin stand. There was a noticeable increase in stocking and seedling increase on the 6M.b.m. reserve plots due to the opening of the

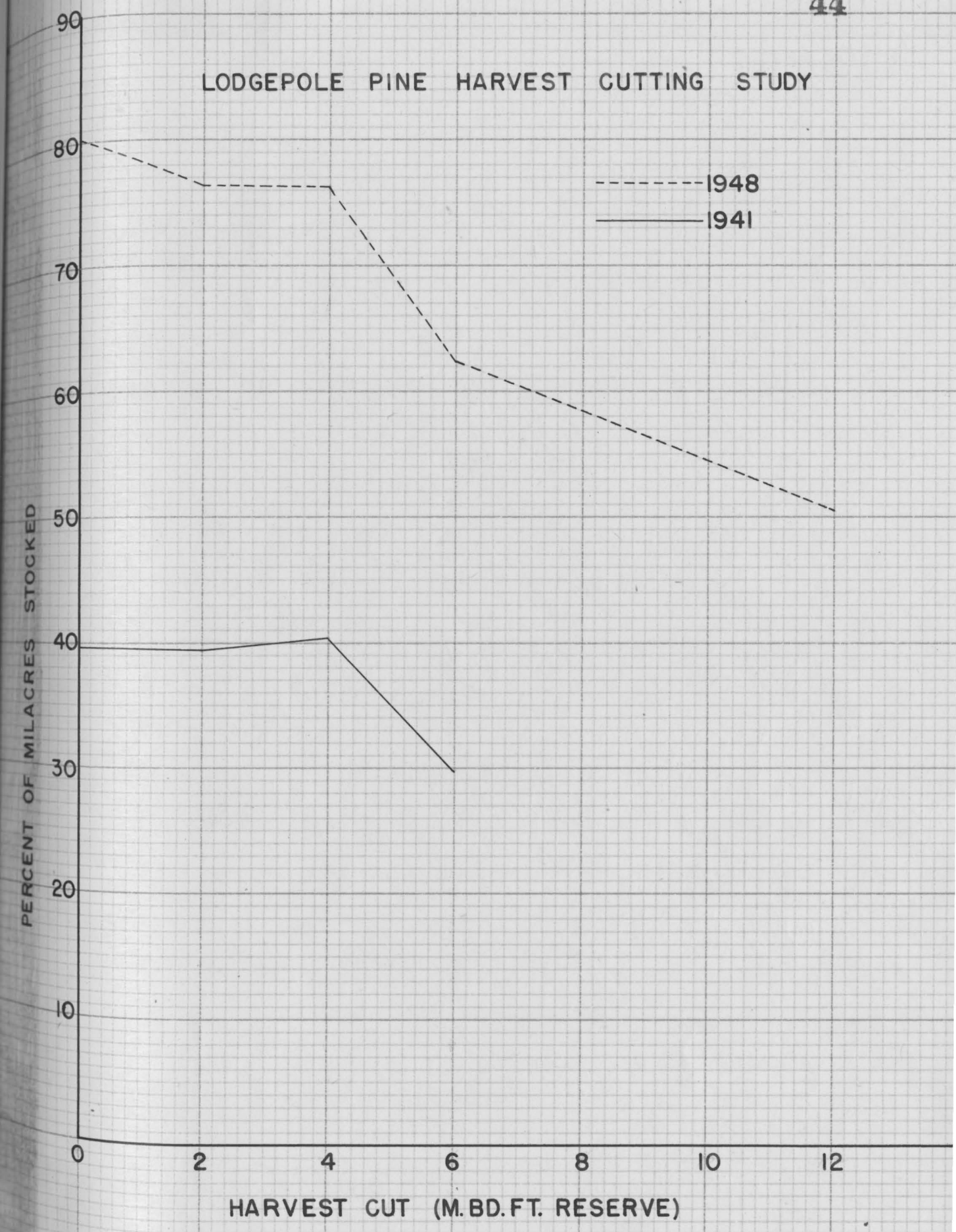
canopy somewhat and the better opportunity for seed to reach the mineral soil and become established aided by the disturbance of the duff in skidding.

Graph I shows the percentage of milacres stocked in 1941 and 1948. The greatest increase in stocking occurred on the plots with the greater volume removed and the trend of the curve was downward from this with no comparison available for the virgin plots as stocking was not obtained in the 1941 survey.

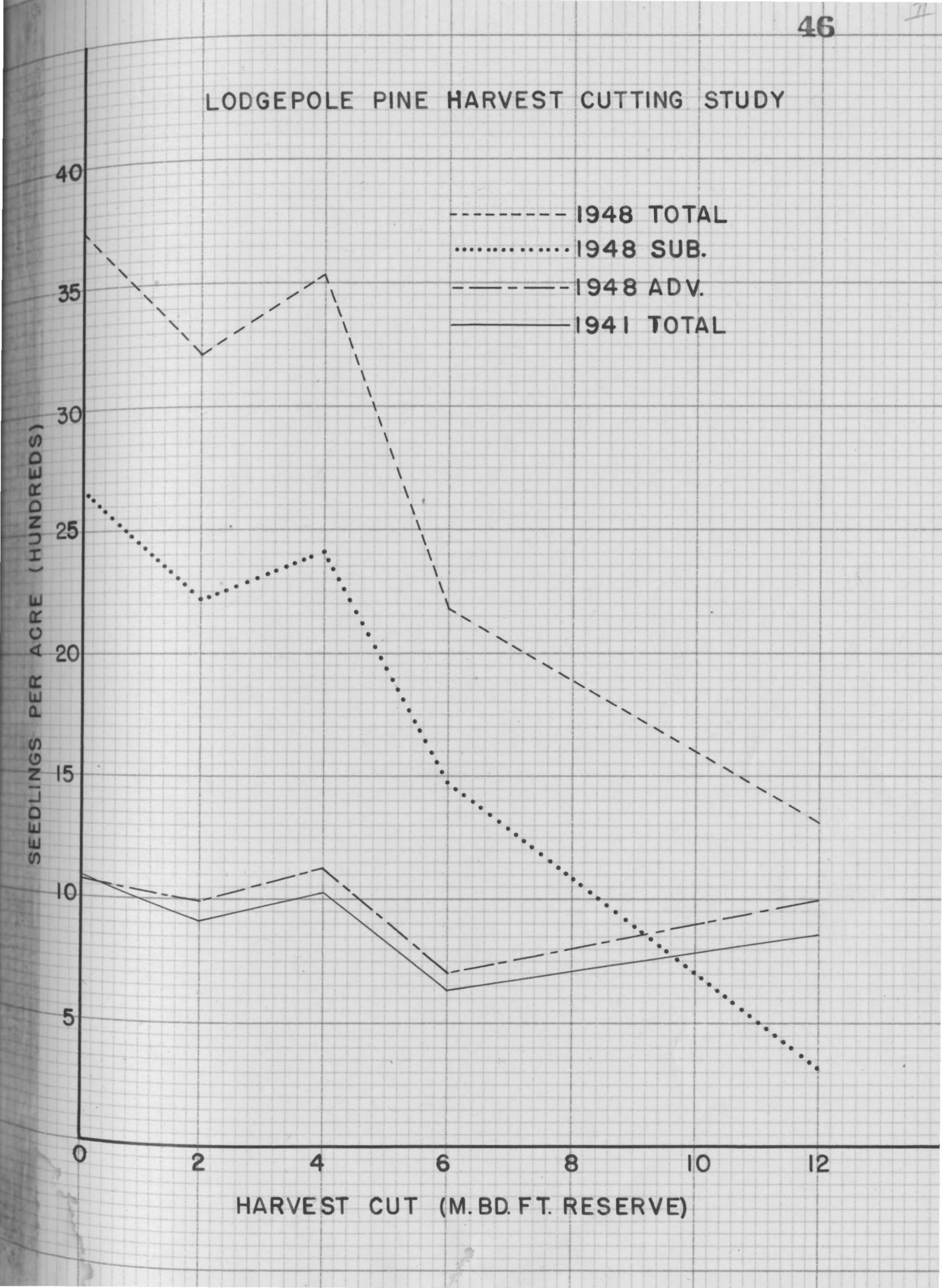
Graph II shows the total number of seedlings per acre in 1941 and 1948. The number of seedlings established since logging and treatment of the plots is represented by the 1948 subsequent curve. The greatest number of seedlings have become established on the commercial clear cut plots with a downward trend to almost one-half this number on the 6M.b.m. reserve volume plots. The advanced reproduction in 1941 and 1948 should be the same in number and follow the same curve on the graph if the sampling method was adequate and accurate and if no catastrophe occurred in this period. The closeness of these curves on the graph indicates a very close relation of the 1941 sampling to the 1948 sampling. This tends to prove the accuracy of the sampling method and technique.

The effect of minor treatments on the reproduction within the major treatment plots was studied along

GRAPH I. --Comparison by major treatment of percent of milacres stocked in 1941 and 1948.


LODGEPOLE PINE HARVEST CUTTING STUDY
1948
1941
PERCENT OF MILACRES STOCKED
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
HARVEST CUT (M. BD. FT. RESERVE)

GRAPH II. --Comparison by major treatment of number of seedlings per acre in 1941 and 1948.


LODGEPOLE PINE HARVEST CUTTING STUDY
1948 TOTAL
1948 SUB.
1948 ADV.
1941 TOTAL
SEEDLINGS PER ACRE (HUNDREDS)
40
35
30
25
20
15
10
5
0
2
4
6
8
10
12
HARVEST CUT (M. BD. FT. RESERVE)

with the cutting method applied. Table 7 shows the effect of slash disposal treatment on the milacre stocking in 1941 and 1948. The average milacre stocking of all plots in 1941, immediately after logging, was approximately 40 percent. In 1948, the commercial clear cut plots with slash burned show a milacre stocking of 83 percent while the same plots with brush lopped and scattered show a milacre stocking of 78 percent. The increased milacre stocking by burning of slash over lopping and scattering of slash was only 5 percent. The 6M.b.m. reserve volume plots show a milacre stocking in 1948 of 63 percent with slash burned and 61 percent with slash lopped and scattered. The increased stocking which can be attributed to the burning of slash is 2 percent.

Table 7.--COMPARISON OF PERCENT OF MILACRES STOCKED IN 1941 AND 1948 BY SLASH DISPOSAL TREATMENT

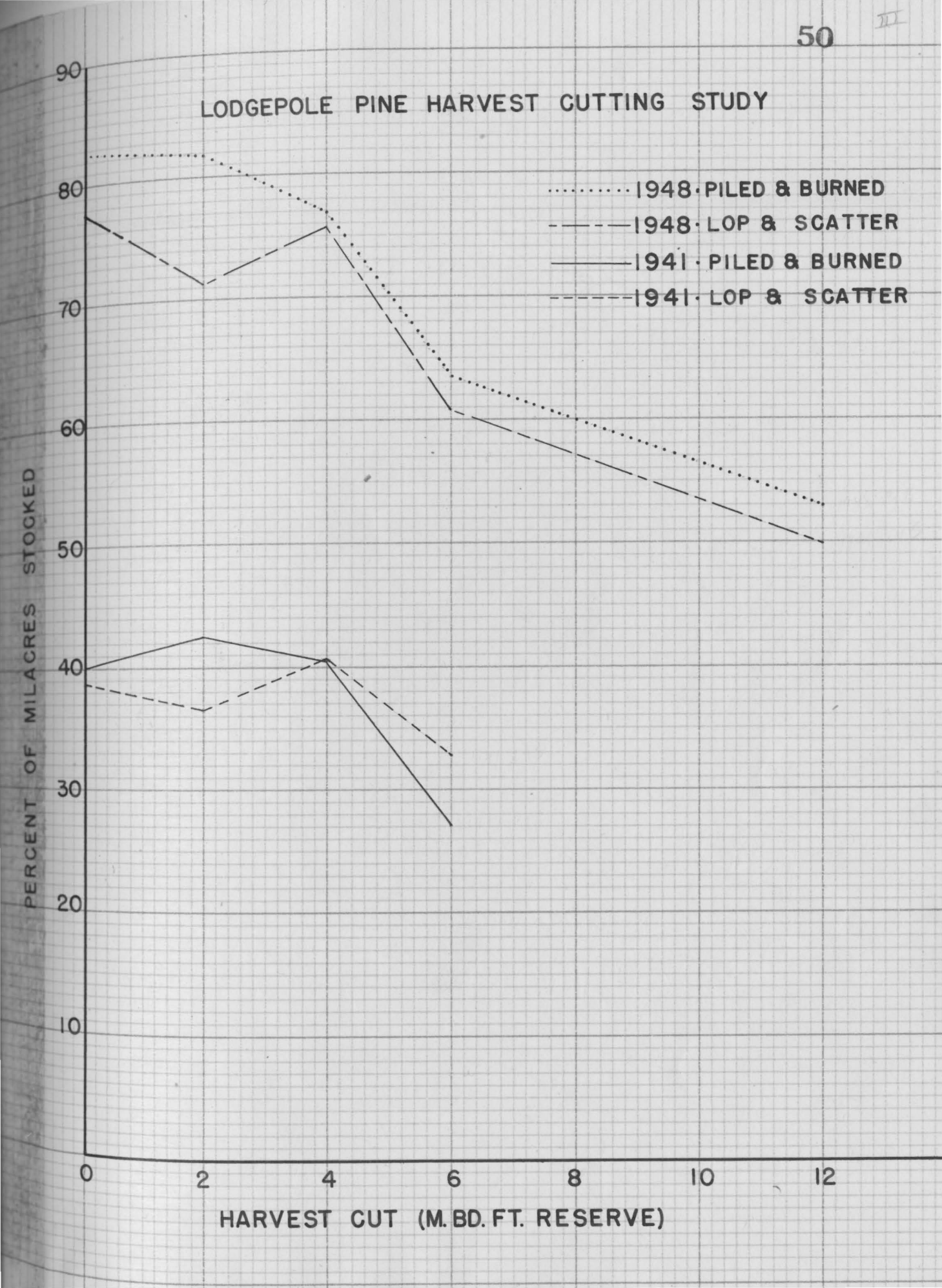
Major Treatment	Minor Treatment					
	Slash Burned			Slash Lopped & Scatter		
	1941	1948	Gain	1941	1948	Gain
Commercial Clear Cut	40.0	82.6	42.6	38.7	77.6	38.9
2M.b.m. reserve	42.4	81.8	39.4	36.5	70.6	34.1
4M.b.m. reserve	40.4	76.8	36.4	40.7	75.7	35.0
6M.b.m. reserve	27.0	63.4	36.4	32.8	60.9	28.1
Virgin	--	52.9	--	--	49.9	--

The percentage of milacres stocked was higher for each major treatment on the plots where slash was piled and burned. This is shown in Graph III. The difference is not great enough, however, to indicate any distinct advantage of piling and burning slash over lopping and scattering. It is desired in obtaining lodgepole pine reproduction to obtain 100 percent milacre stocking, but at the same time, the optimum number of seedlings per acre should be below that which results in stagnated stands. Graphs III and IV indicate that lopping and scattering of slash approaches this optimum. The number of seedlings per acre was reduced in all cutting methods as shown in Table 8 by lopping and scattering of slash while the milacre stocking indicated by Table 7 was not noticeably reduced.

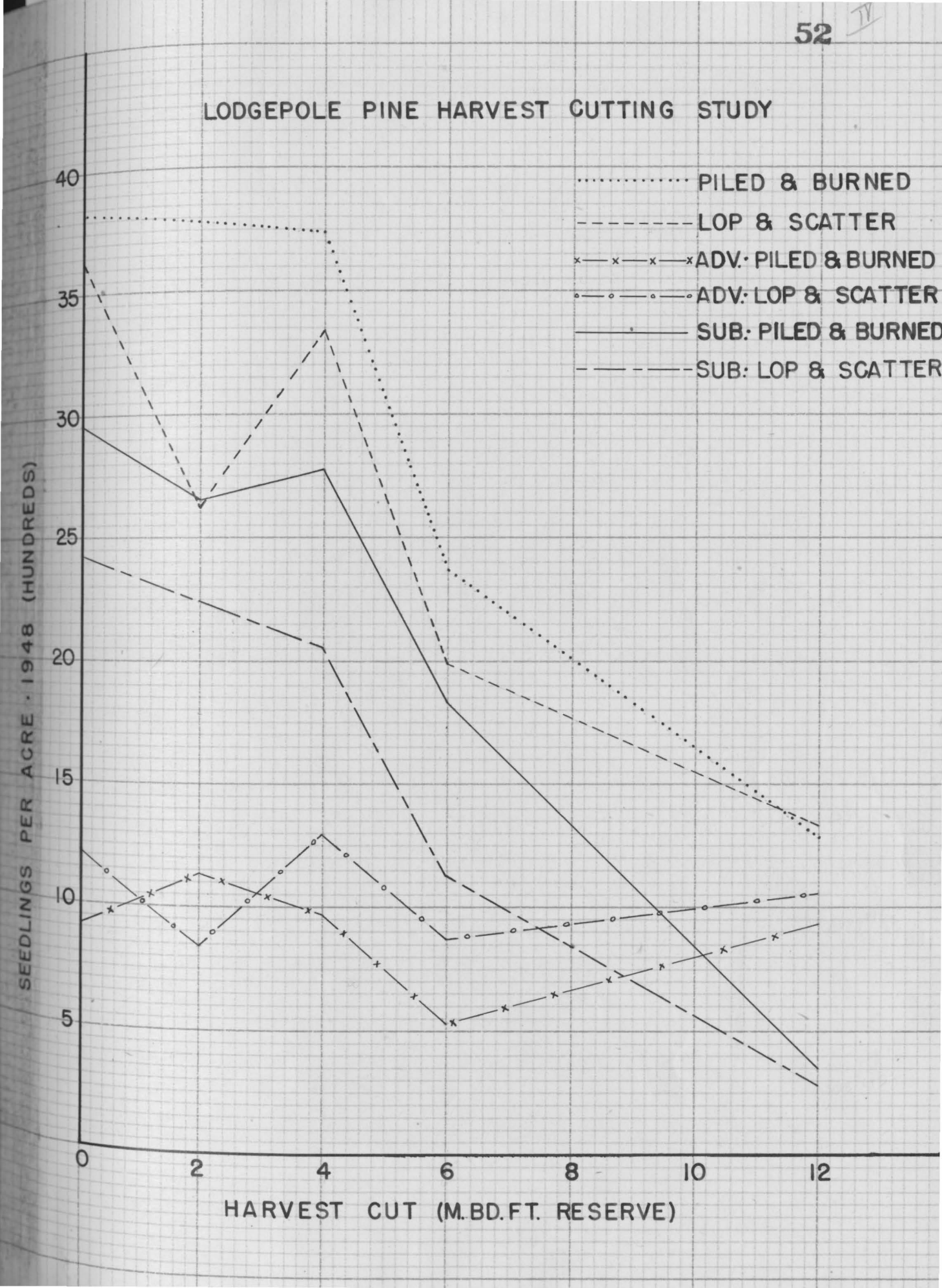
Table 8.--NUMBER OF SEEDLINGS PER ACRE IN 1948 BY SLASH DISPOSAL TREATMENT

Major Treatment	Minor Treatment			
	Slash Burned		Slash Lopped & Scatter	
	Advanced	Subsequent	Advanced	Subsequent
Commercial Clear Cut	912	2909	1212	2422
2M.b.m. reserve	1136	2649	843	1783
4M.b.m. reserve	962	2774	1290	2049
6M.b.m. reserve	531	1834	870	1123
Virgin	937	346	1053	277

GRAPH III. --Comparison by slash disposal treatment of percent of milacres stocked in 1941 and 1948.


LODGEPOLE PINE HARVEST CUTTING STUDY
1948 · PILED & BURNED
1948 · LOP & SCATTER
1941 · PILED & BURNED
1941 · LOP & SCATTER
PERCENT OF MILACRES STOCKED
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
HARVEST CUT (M. BD. FT. RESERVE)

GRAPH IV. --Comparison of number of seedlings per acre in 1948 by slash disposal treatments.


LODGEPOLE PINE HARVEST CUTTING STUDY
PILED & BURNED
LOP & SCATTER
ADV. PILED & BURNED
ADV. LOP & SCATTER
SUB. PILED & BURNED
SUB. LOP & SCATTER
SEEDLINGS PER ACRE - 1948 (HUNDREDS)
40
35
30
25
20
15
10
5
0
2
4
6
8
10
12
HARVEST CUT (M.BD.FT. RESERVE)

The mat formed by the lopped and scattered slash prevents a part of the seed from reaching mineral soil for germination. It also provides partial shading of the ground which is apparently unfavorable to the lodgepole pine seedlings after their first two or three years of growth. Some of the seedlings are eliminated by this shading.

The percentage gain in milacres stocked and the increase in number of seedlings per acre was no greater on the plots where stand improvement measures had been applied than on the plots with no stand improvement. Tables 9 and 10 are included to show that the effects of timber stand improvement minor treatment are not significant in the reproduction of lodgepole pine.

Table 9.--COMPARISON OF PERCENT OF MILACRES STOCKED IN 1941 AND 1948 BY TIMBER STAND IMPROVEMENT TREATMENT

Major Treatment	Minor Treatment			
	Stand Improvement		No Stand Improvement	
	1941	1948	1941	1948
Commercial Clear Cut	34.0	85.1	44.9	75.1
2M.b.m. reserve	37.9	74.6	40.9	77.7
4M.b.m. reserve	34.5	77.3	45.3	75.0
6M.b.m. reserve	26.8	58.6	32.8	65.6
Virgin	--	46.8	--	54.9

Table 10.--NUMBER OF SEEDLINGS PER ACRE IN 1948 BY TIMBER STAND IMPROVEMENT TREATMENT

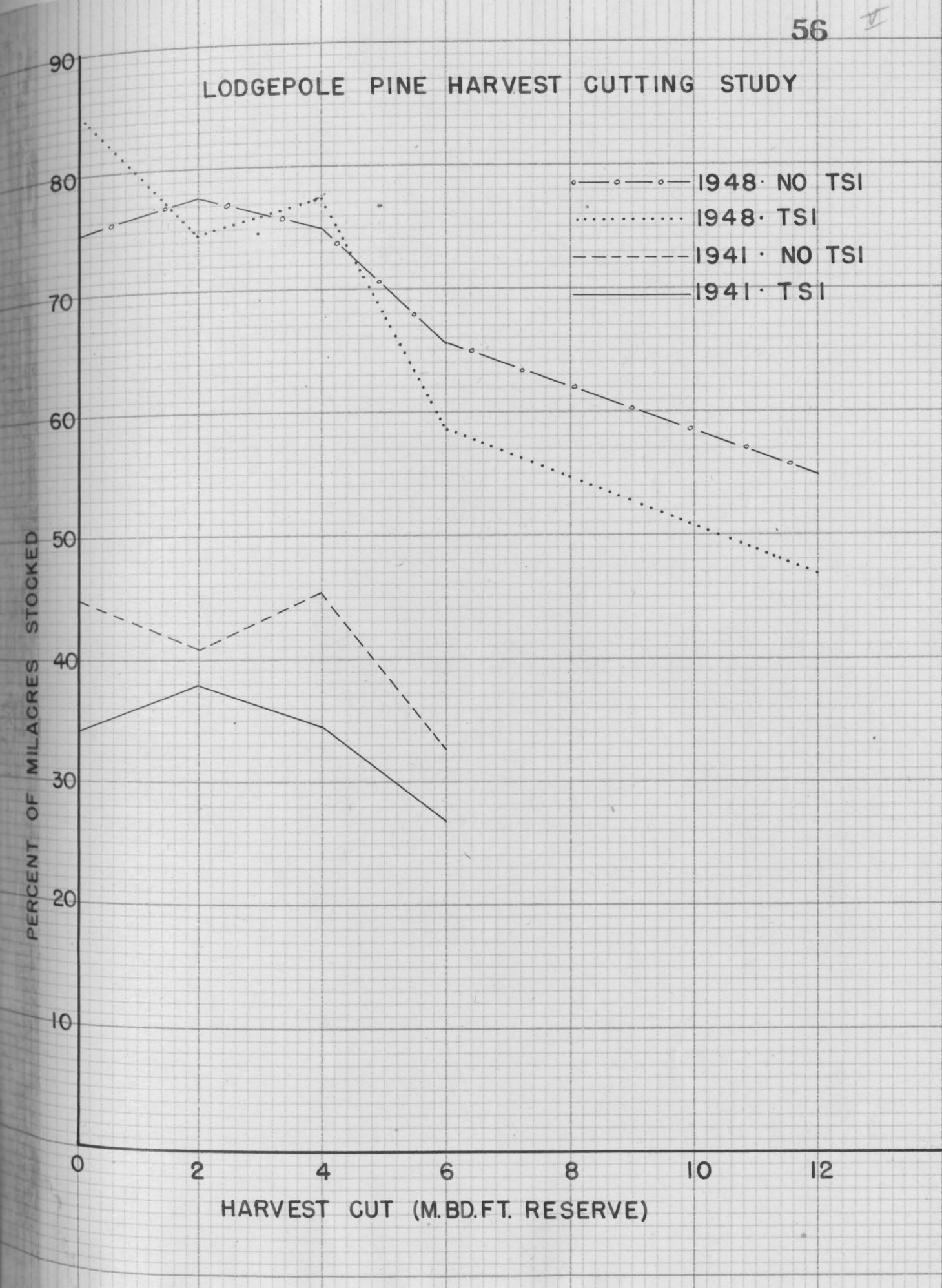
Major Treatment	Minor Treatment			
	Stand Improvement		No Stand Improvement	
	Advanced	Subsequent	Advanced	Subsequent
Commercial Clear Cut	1299	3061	852	2210
2M.b.m. reserve	854	1836	1124	2611
4M.b.m. reserve	1187	2648	1068	2174
6M.b.m. reserve	668	1247	767	1713
Virgin	840	295	1140	325

Graphs V and VI show that no significant correlation exists between reproduction on plots with timber stand improvement and those without timber stand improvement.

Lodgepole pine reproduces prolifically when the site is opened by removal of a large percentage of the volume of a stand, Figures 14, 15, and 16. The growth of the reproduction is vigorous on the areas where the canopy has been removed and light is made available from the top and sides as shown in Figures 17 and 18.

The seed of lodgepole pine requires a mineral soil for establishment. Reproduction establishes in abundance on old skid trails where the mineral soil has been exposed. On reserve volume plots where windthrow had taken place due to opening of the stand, lodgepole

GRAPH V. --Comparison by timber stand improvement treatment of percent of milacres stocked in 1941 and 1948.


LODGEPOLE PINE HARVEST CUTTING STUDY
1948 · NO TSI
1948 · TSI
1941 · NO TSI
1941 · TSI
PERCENT OF MILACRES STOCKED
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
HARVEST CUT (M.BD.FT. RESERVE)

GRAPH VI. --Comparison of number of seedlings per acre in 1948 by timber stand improvement treatments.

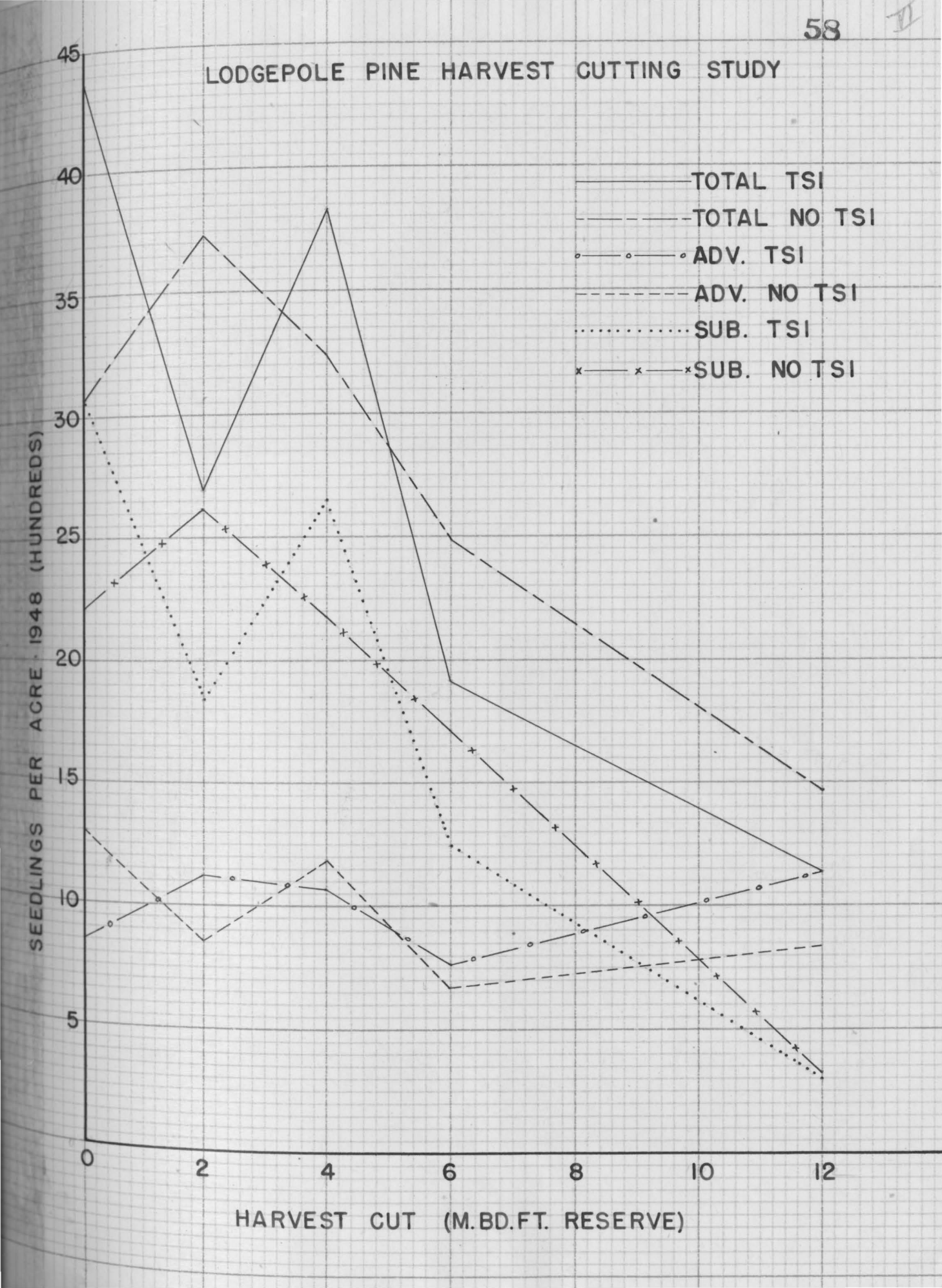

LODGEPOLE PINE HARVEST CUTTING STUDY
TOTAL TSI
TOTAL NO TSI
ADV. TSI
ADV. NO TSI
SUB. TSI
SUB. NO TSI
SEEDLINGS PER ACRE 1948 (HUNDREDS)
45
40
35
30
25
20
15
10
5
0
2
4
6
8
10
12
HARVEST CUT (M.BD.FT. RESERVE)

Fig. 14 -- Commercial Clear Cut Plot B-3 showing opening of stand.

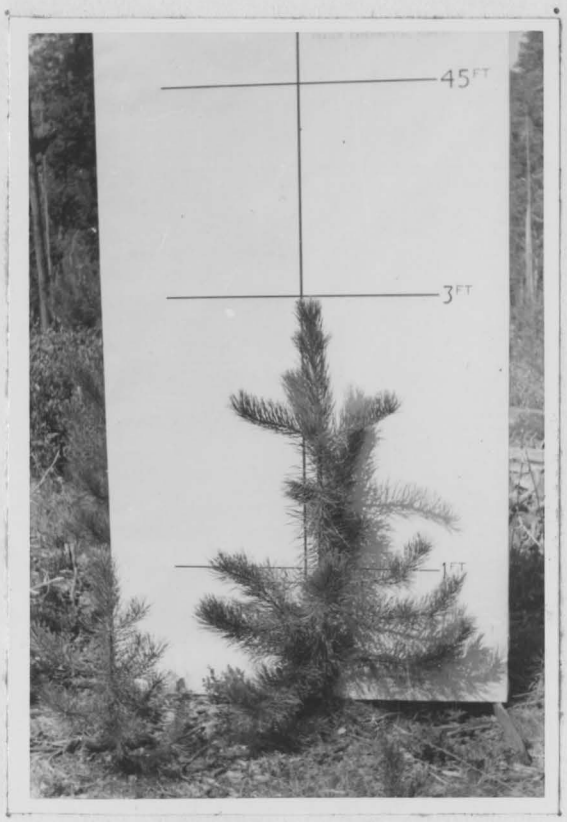


Fig. 15 --Subsequent Reproduction under 3 feet tall on Commercial Clear Cut Plot.

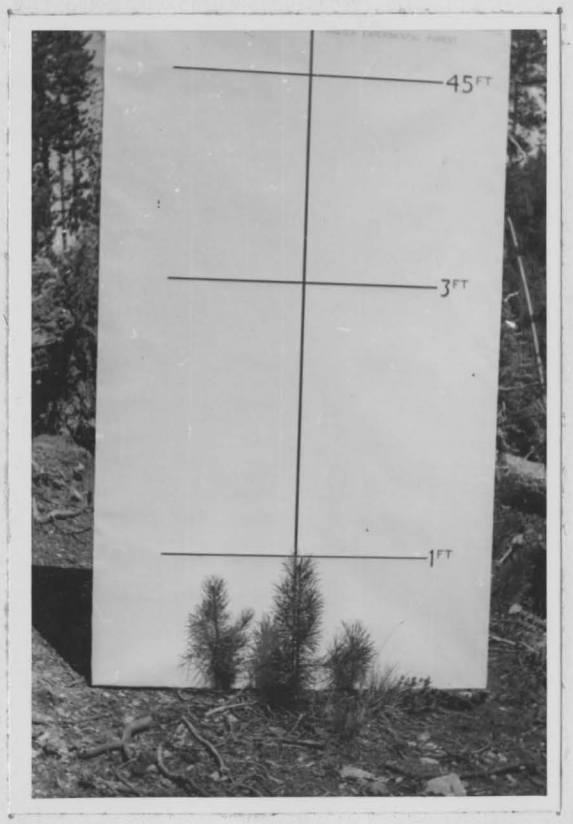


Fig. 16 --Subsequent Reproduction under 1 foot tall on Commercial Clear Cut Plot.

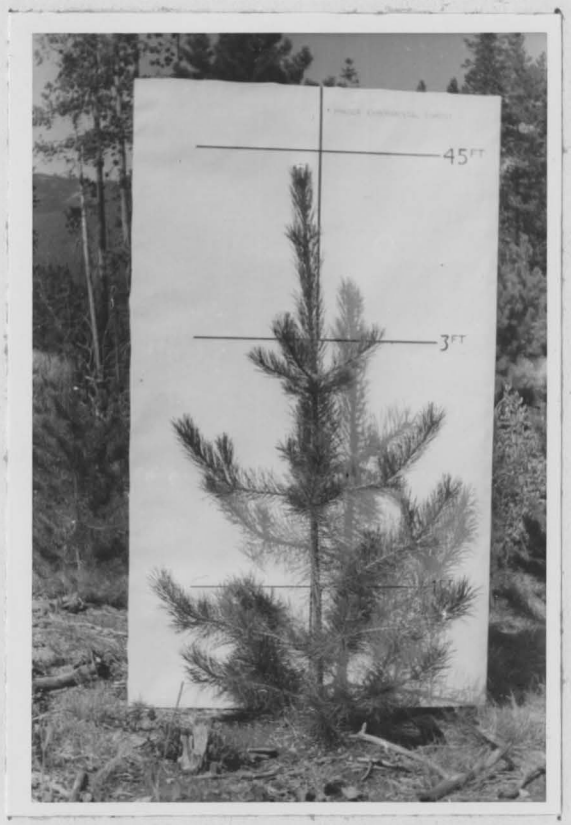


Fig. 17 --Subsequent Reproduction under 4.5 feet tall with 18 inch tip growth during the past year.

Fig. 18 --Advanced Reproduction on Commercial Clear Cut Plot showing vigorous growth.

Fig. 19 --Exposed mineral soil at base of windthrown tree furnishing excellent seedbed for lodgepole pine reproduction.

pine seedlings were in abundance around the bases of the fallen trees where the soil had been disturbed and exposed. An example of this is shown in Figure 19. Many one or two-year old seedlings of lodgepole pine, Engelmann spruce, and alpine fir were found growing on logs in an advanced stage of decomposition. These logs were always located in a creek bottom or damp area. The probability pf survival of any of these seedlings is extremely small as their roots have little chance of reaching mineral soil before the log has dried out or the nutrient supply is exhausted.

Lodgepole pine seedlings are favored by shading during the first or two three years after germination but the shading must not furnish too severe competition for moisture. It was noted that reproduction occurred more abundantly underneath logs which cleared the ground by two inches or more and furnished shading. This may be partially due to conserving of the soil moisture by the shading. Lodgepole pine reproduction comes in abundantly in areas with a ground cover of huckleberry (Vaccinium) where the seedlings extend above the height of the huckleberry within two or three years after their start. It does not become established under a ground cover of buffalo berry (Shepherdia canadensis (L.) Nutt.) since it cannot grow through the cover of buffalo berry before becoming intolerant to shading. On open knolls where the

area was exposed to direct sunlight and a layer of duff was present reproduction did not occur. This is due to the combined factors of drying of site by exposure to the sun's rays and mechanical prevention of seed reaching the mineral soil.

The response of lodgepole pine seedlings to release by opening the canopy and site is first observed in the vigor and density of needles. Reproduction under the virgin stand has thin, spindly, crooked stems with only a few needles present at the tip of the stem in bunches or tufts. Figures 20 and 21 illustrate release of advanced seedlings on the commercial clear cut treatment plots. The needle vigor, density, and renewal of growth at the tip is easily discerned.

Lodgepole pine seedlings outgrow their tolerant associates, Engelmann spruce and alpine fir, on removal of the overhead canopy. A comparison of the photographs in Figures 17 and 18 with those in Figures 22, 23, 24 and Figures 25, 26, 27 shows the more rapid growth of the lodgepole pine seedlings.

The growth of lodgepole pine seedlings on the reserved volume plots is less than on plots with all merchantable volume removed. The growth rate is, however, still adequate and will probably surpass that of the seedlings on the heavily cut area within a few years as the fewer seedlings present will not stagnate. The

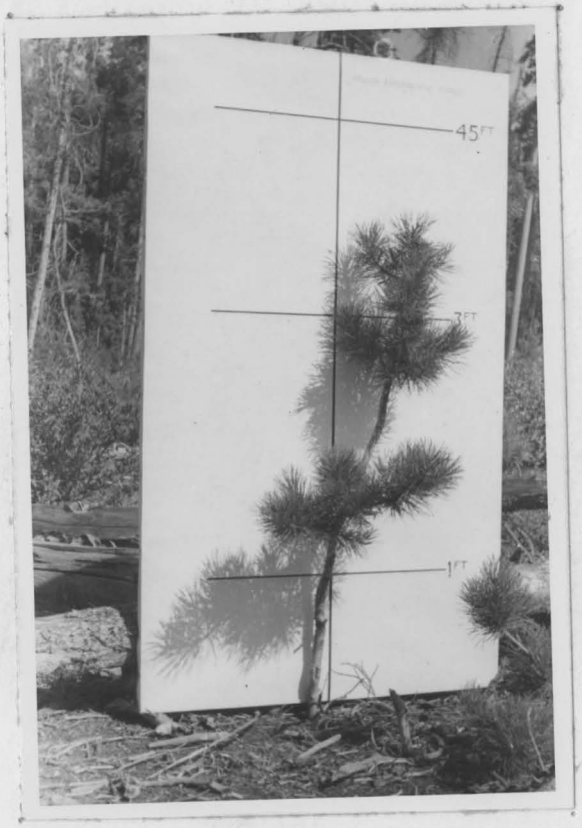


Fig. 20 --Advanced Reproduction on Commercial Clear Cut Plot illustrating needle vigor when released.

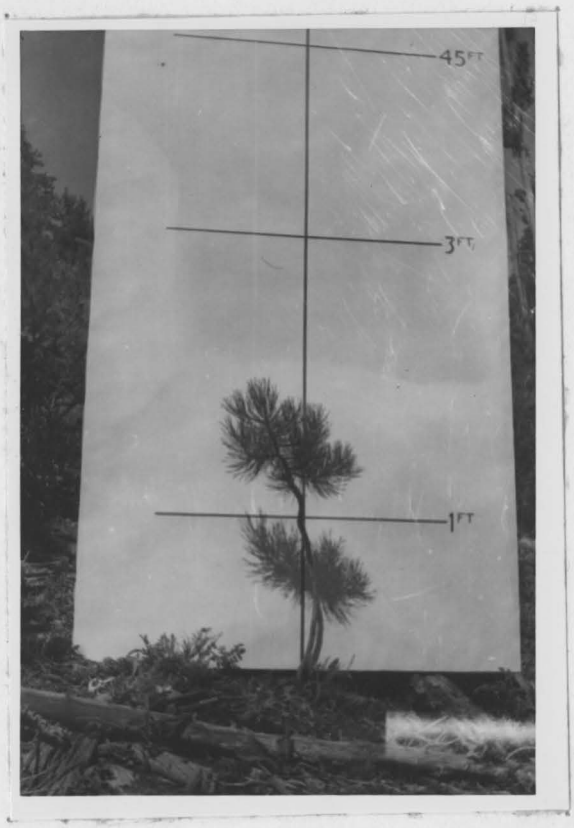


Fig. 21 --Advanced Reproduction on Reserve volume plot illustrating growth when released.

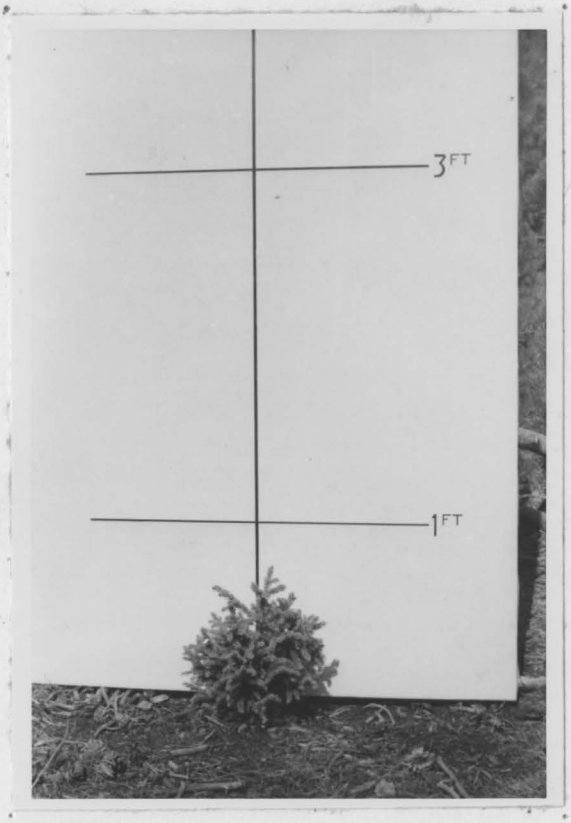


Fig. 22 --Engelmann Spruce Subsequent Reproduction under 1 foot tall.

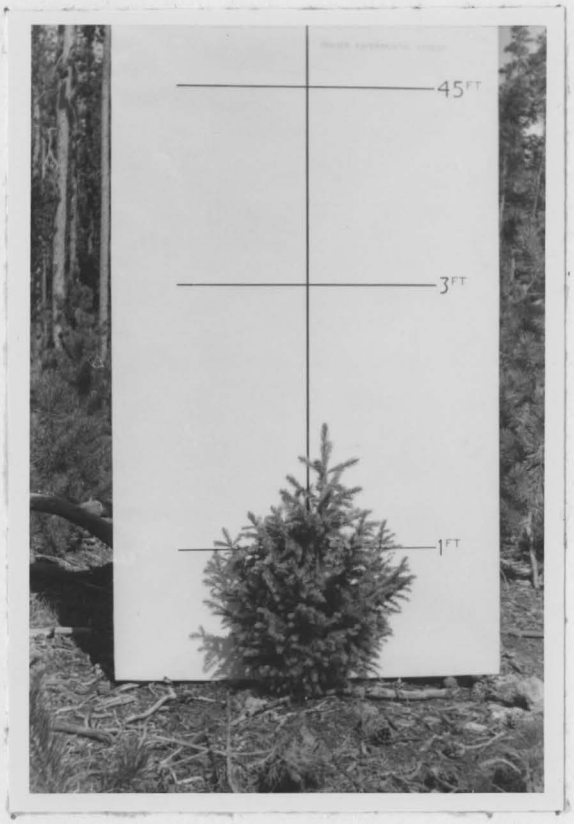


Fig. 23 --Engelmann Spruce Advanced Reproduction under 3 feet tall.

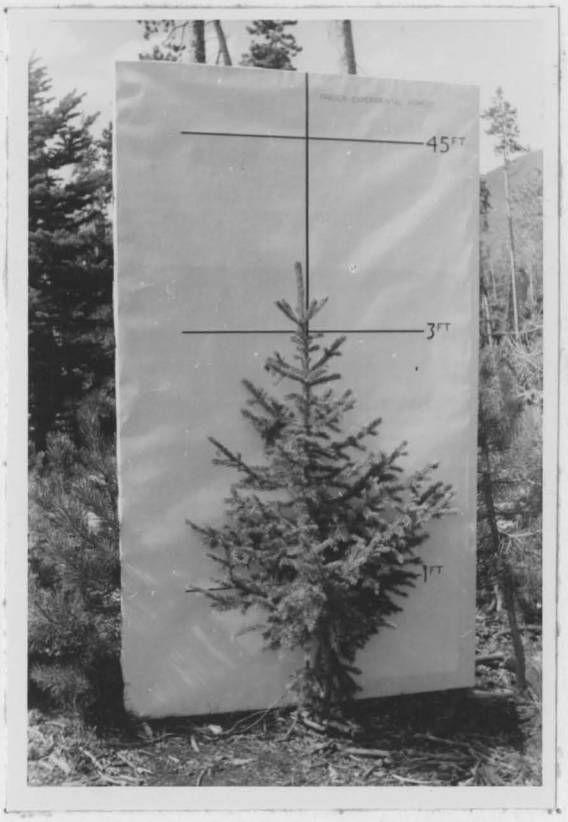


Fig. 24 --Engelmann Spruce Advanced Reproduction under 4.5 feet tall.

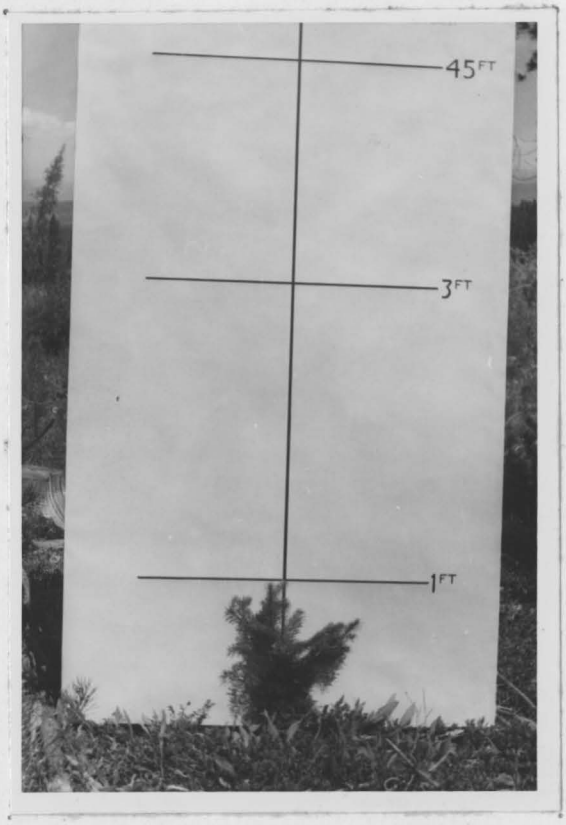


Fig. 25 --Alpine Fir Subsequent Reproduction under 1 foot tall.

Fig. 26 --Alpine Fir Advanced Reproduction under 3 feet tall.

Fig. 27 --Alpine Fir Advanced Reproduction under 4.5 feet tall.

lesser growth is illustrated in Figures 28 and 29 by photographs taken on reserved volume plots.

Plots with lopped and scattered slash are illustrated in Figures 30 and 31. These photographs were taken seven years after logging and show that an excessive accumulation of slash does not occur. The flash fuels have practically all decomposed with only the larger material remaining. Where heavy accumulations of slash were not adequately scattered, aspen reproduction appeared in considerable numbers.

Disease and porcupine damage did not have a limiting effect on the lodgepole pine reproduction. Some shoestring root rot (Armillaria mellea (Nahl.)Quel.) was observed to kill seedlings, primarily on the plots where the cutting method removed the greater amount of volume. On no plot could the loss be considered severe. Porcupine damage was negligible to the seedlings, however, mature trees in the stand indicate past porcupine damage as shown in Figure 32.

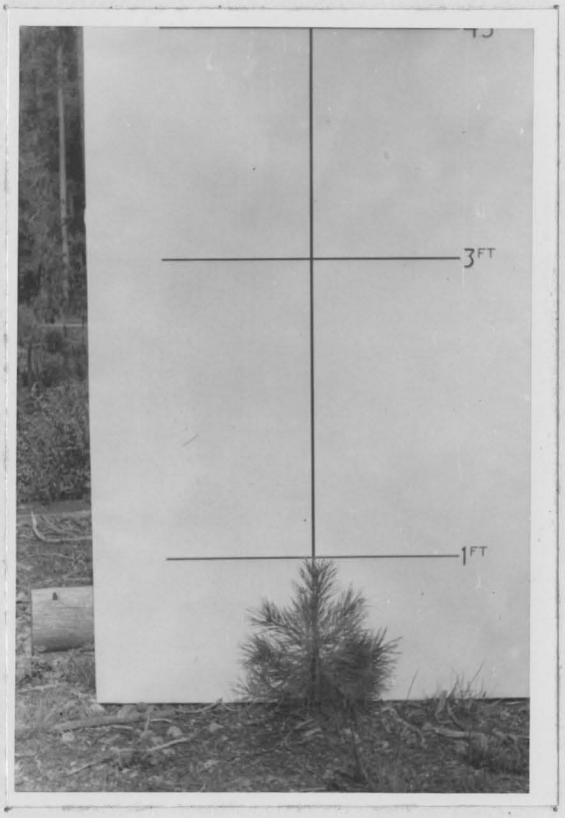


Fig. 28 --Lodgepole Pine Subsequent Reproduction under 1 foot tall on 4M.b.m. Reserve volume plot B-4.

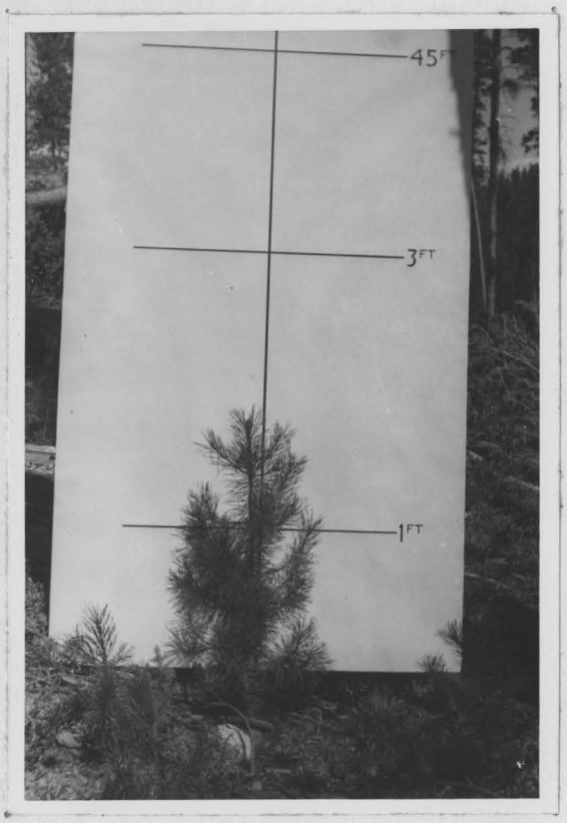


Fig. 29 --Lodgepole Pine Subsequent Reproduction under 3 feet tall on 4M.b.m. Reserve volume plot B-4.

Fig. 30 --Lopped and Scattered Slash on Commercial Clear Cut Plot C-1 seven years after logging.

Fig. 31 --Lopped and Scattered Slash on Commercial Clear Cut Plot A-5 seven years after logging.

Fig. 32 --Past porcupine damage on mature Lodgepole Pine in Virgin Plot D-2.

Chapter IV

CONCLUSIONS

Comparison of the reproduction data obtained from the experimental plots in a typical lodgepole pine stand before logging, immediately after logging, and seven years after logging under different cutting methods leads to the following conclusions.

The logging operation in a mature stand of lodgepole pine destroys an average of 43 percent of the advanced reproduction. The loss in advanced reproduction is not in proportion to the volume removed from the stand by the cutting method. Less advanced reproduction may be lost under a heavily cut stand than one in which only a portion of the merchantable timber is removed. This evidence points to the fact that about the same amount of advanced reproduction will be lost regardless of the cutting method.

Adequate restocking of a cutover lodgepole pine area occurs without a long lapse in time or the waiting for the coincidence of a good seed and moisture year. Almost complete stocking occurred seven years after logging considering the growing stock below merchantable size, the reserved trees, and the subsequent reproduction.

This indicates that practically no time is lost in establishing the growing stock for the next rotation crop.

The greatest density and development of reproduction occurs where a heavy cutting treatment has been applied. The number of seedlings per acre is greater on a commercial clear cut area than on an area with a reserved volume of merchantable timber. The opening of the canopy by a heavy cut allows rapid growth of the intolerant lodgepole pine reproduction. To prevent stagnation and subsequent thinnings on heavily cut areas the density of reproduction may need to be regulated by lopping and scattering of slash at the time of logging.

The density and development of lodgepole pine reproduction under other partial cut treatments is held back or develops at a rate closely in proportion to the reserve stand left. Adequate reproduction can be obtained by reserving approximately one-half of the merchantable stand volume when a 2-cut silvicultural system is to be used in harvesting the stand.

Lopping and scattering of slash has an advantage over piling and burning in that it provides a better distribution of seedlings on an area and at the same time prevents the establishment of too great a number of seedlings per acre. This is in accordance with the findings of Bates, Hilton, and Krueger on the Gunnison National Forest and the Medicine Bow National Forest in 1929 (6).

The decomposition of the slash has a beneficial effect on the soil by the addition of organic matter and its shading effect tends to conserve soil moisture especially on exposed south slopes. The fire hazard created by the increased amount of slash is not severe except during the first two or three years after cutting when intensive fire protection should be the practice. It may be necessary to pile and burn excessive accumulations of the slash to reduce this fire hazard.

Timber stand improvement in the submerchantable stand does not stimulate reproduction. Stand improvement measures applied to the submerchantable stand had no advantage in density or degree of stocking over unimproved stands. This indicates that the vigor and condition of the trees producing seed have little or no effect on the quality of seed for reproduction.

This study covers only the cutting methods and treatments as applied to lodgepole pine in order to secure optimum reproduction and does not fully consider other silvicultural and economic factors. From the observations and conclusions in this study the writer recommends a 2-cut silvicultural system in a mature lodgepole pine stand, removing approximately one-half the merchantable volume of the stand in the first cut, combined with lopping and scattering of slash in order to obtain an optimum amount and spacing of reproduction. Due to the

susceptibility of lodgepole pine to windthrow it appears likely that a strip-cut modification of the 2-cut silvicultural system would be advantageous for protection of the reserve stand.

Chapter V

SUMMARY

The silvicultural management of lodgepole pine presents a problem in obtaining an optimum amount of reproduction by a cutting method which will prevent too dense a stand causing subsequent stagnation and at the same time fully stock the area after the logging operation.

A study of the influence of cutting methods on the reproduction of lodgepole pine was made at the Fraser Experimental Forest in the Arapaho National Forest in Colorado in a typical lodgepole pine stand. Four cutting methods were applied in 1940 and virgin check plots were established for a comparison of results. The cutting methods applied were : (1) Commercial Clear Cut; (2) 2M.b.m. reserved volume; (3) 4M.b.m. reserved volume; (4) 6M.b.m. reserved volume.

In addition, minor treatments of slash disposal method and timber stand improvement were applied to each plot. The minor treatments applied were: (1) Slash piled and burned; (2) Slash lopped and scattered; (3) Timber stand improvement; (4) No timber stand improvement.

Reproduction surveys were made in 1939 prior to logging of the plots; in 1941, immediately after logging; and again in 1948, seven years subsequent to logging. The surveys were made on a 14 percent sample cruise basis.

The amount of reproduction lost by the logging operation was determined as well as the number of seedlings established since the logging operation and the stocking of the plots.

The following conclusions were made from the study:

1. The logging operation in a mature lodgepole pine stand destroys an average of 43 percent of the advanced reproduction.

2. Practically no time is lost in establishing lodgepole pine reproduction after logging as the plots were adequately stocked seven years after the logging operation.

3. The density and development of lodgepole pine reproduction is in direct proportion to the amount of volume removed from the stand. The greater the amount of volume removed, the greater is the amount of reproduction established and the better is its development prior to the time it reaches the pole or sapling stage when too dense a stand causes stagnation.

4. Lopping and scattering of slash has an advantage over piling and burning in that it provides a

better distribution of seedlings on an area and at the same time prevents too great a number of seedlings per acre.

5. Adequate reproduction can be obtained by reserving approximately one-half of the merchantable stand volume when a 2-cut silvicultural system is to be used in harvesting the stand.

6. A recommended cutting method to obtain optimum reproduction in lodgepole pine is a 2-cut silvicultural system, removing approximately one-half the merchantable volume in the first cut, combined with lopping and scattering of slash.

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