FACTORS AFFECTING THE ESTABLISHMENT OF FOREST PLANTATIONS ON THE KELLOGG REFORESTATION TRACT

THESIS FOR DEGREE OF M. S.

BERNARD M. KIRK

1937

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Submitted to the Faculty of the
Michigan State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of
Master of Science in Forestry

by

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May, 1937

THESIS

The writer wishes to acknowledge his indebtedness to Professor R. H. Westveld, formerly of the Forestry Department of Michigan State College of Agriculture and Applied Science, who collected the data on survival prior to 1936 and suggested the problem, and to Professor M. E. Deters of the Forestry Department of Michigan State College for suggestions and assistance received during this investigation.

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INTRODUCTION

Forest planting in the United States has been only moderately successful. U. S. Forest Service data (18) show that only 61 percent of its plantations, totaling 137,830 acres, may be classed as satisfactorily stocked (250 trees or over per acre). There are not many accurate available records indicating the degree of success achieved by other planting agencies. It seems probable, however, that other agencies on the average have not been more successful than the Forest Service. Many cases are known where areas have been planted two or three times without obtaining satisfactory stands of trees.

In the past, much attention was directed toward accomplishing the planting at the lowest possible expense. In fact, low initial planting cost often has been considered the most important criterion of success. Greater consideration undoubtedly has been given to devising methods of increasing the areas planted per man day than to methods of achieving satisfactory establishment of the trees planted.

Forest planting can be done cheaply only when it is done successfully. As a whole, the cost of the planting program is necessarily high, varying from a minimum of about $3.00 per acre in a few cases up to a maximum of perhaps $25.00 an acre. Since large areas exist which will require planting in the near future, it is important that adequate planting technique be known. Land owners obviously want reasonable assurance that reforestation measures can

be undertaken successfully. Repeated failures in forest planting certainly will discourage reforestation, no matter how necessary it may be.

Although increasing attention has been given during recent years to securing better results with forest plantings, the range of conditions under which plantings are made is so great that most results have only general application. Limiting factors are different from one locality to another. It is necessary, therefore, to determine the role and importance of each factor for a given set of conditions or for a locality or region in which conditions are essentially uniform. With such information, applicable to a given locality, it should be possible to give reasonably sound recommendations to guide forest plantings.

The Kellogg Reforestation Tract owned and managed by the Department of Forestry, Michigan State College provided an excellent opportunity to study the factors which affect establishment of forest plantations. The tract is typical of much sub-marginal, depleted and eroded farmland in southern Michigan and results should be generally applicable to this region so much in need of an extensive reforestation program. This study was begun in the fall of 1935 and continued through the fall of 1936. Records of the Department of Forestry were available from the time reforestation was begun in the fall of 1931. Data are given, therefore, for a five year period, from the fall of 1931 to the fall of 1936. The object of the study was to determine the important or limiting factors affecting establishment of forest plantations

at the Kellogg Reforestation Tract and to establish a basis for improved planting practices.

PREVIOUS INVESTIGATIONS

A considerable amount of work has been done in connection with reforestation problems and most of the factors and principles relating to the problems are generally recognized by foresters.

Among the various agencies, the United States Forest Service, the forest schools and state forestry departments have contributed most to the knowledge. The variability of the results merely serves to stress, however, that a complex of inter-related factors must be considered. Furthermore, the effect of any single factor must be evaluated in terms of local conditions.

Climatic or weather effects are recognized as important factors in establishment of forest plantations. Bates (4) states that several species of the Central Rocky Mountain region are controlled in their natural distribution almost wholly by the degree of insolation of the site, the resulting temperature and the closely related surface moisture conditions. The south slopes normally have the highest temperatures and evaporation rates, while the north slopes have the lowest.

Baker (1) found that temperatures of 120 - 130°F within the cells caused coagulation of the protoplasm, and even below this temperature the catabolic processes were more rapid than the anabolic. The cambium, being insulated by the protective layer of bark, remained 15 - 20°F below the external layers.

Severe damage to red and white pine plantations in New York is reported by Belyea (6) as due to continued dry winter winds. Damage was more severe on red than on white pine. Stone (16) describes sun scorch of both planted and wild pine. During extremely dry years, the foliage of this and other conifers was killed due to drought effects.

Baker and Korstian (2) working in the Inter-mountain region brush lands found first year losses due principally to drought. Losses were especially heavy when droughts came early in the season, before the roots were well established. After the first year, competition of brush was more important. Evaporation had little significance, except as it affected drought the first year.

Exposure of roots to drying for forty minutes was found by Haasis (9) and Ziegler (20) to result in decreased vigor and much lower survival.

Using three methods of planting, Carter (7) found failure to remove sod resulted in increased losses of 13 - 21 per cent during the first year.

Pickering (14) mentions that competition effects with sod caused losses of apple trees. Competition for moisture was the critical factor.

Furrowing to reduce competition is credited by Hilton (12) as being responsible for increased survival of forest plantations in sand soils of Michigan.

Young (18) found 2 - 0 stock of white and Norway pine in southern Michigan suffered 43 percent greater losses after two years than 2 - 2 stock unless competition of other plants was removed by cultivation. Heavy losses were attributed to

careless planting.

In a study of Yale Forest School's plantations, Hawley (11) found that red pine gave slightly higher survival than white pine.

Kittredge (13) studied the causes of failure of forest plantations from a large amount of data. He lists fire, animals, insects, fungous diseases, weather, poor stock, careless planting, and competition with other vegetation as the principal causes of failure. However, no one cause appeared to make planting in the Lake States inadvisable.

He concluded that a drought of over 10 days at the time of planting, or during the first season caused heavy losses. Temperatures of over 90°F, besides their drying effect often resulted in such extremely high surface soil temperatures that the stem was girdled at the ground level. Late frost caused damage to the growing tips, especially of Norway and white pine.

Snowshoe rabbits have caused excessive losses, in Minnesota especially, and are one of the most serious enemies of plantations. Deer, porcupines, mice and squirrels also cause damage.

Insects were found by Kittredge to be responsible for the killing of relatively few trees. Jack pine was most frequently attacked. White pine showed extensive weeviling. Red pine was the least susceptible to insect attacks. Fungi, with the exception of white pine blister rust, appeared not to be dangerous.

Poor quality stock and careless planting were among the

most serious causes of loss. Exposure of roots for one hour before planting caused heavy losses. Trees with the soil not well packed around the roots showed excessive losses.

Underplanting gave favorable results apparently because of protection from excessive insolation. Where moisture became limited, however, mortality of underplanted trees was very nigh.

Rudolf (15) summarizes the matter of forest plantations under 12 points. These include: species and site selection, underplanting, quality of planting stock, climate, protection from animals, ground preparation, methods of planting. He emphasizes the fact that forest planting must depend on a thorough knowledge of the local conditions.

DESCRIPTION OF KELLOGG REFORESTATION TRACT

The Kellogg Reforestation Tract is located about 9 miles northwest of Battle Creek, Michigan. It has been cleared and under cultivation for at least thirty years, but was abandoned about ten years ago. It lay idle until coming into possession of the Forestry Department of Michigan State College in 1931.

The tract is made up of about two hundred eighty acres along both sides of Augusta Creek. There are three land types nearly equal in area. The first consists of fairly level valley lands occurring along the creek. The second consists of the slopes along the sides of the valley. These average about two hundred yards long with five to thirty percent slopes throughout. Above these are the nearly level ridge and hill tops. The topography is typically rough and morainic.

The soils are variable. In the poorly drained bottom land near the creek, the soil has a high organic content and probably is classified as Maumee silt loam. The better drained level lowland is classified as Newton loam. Both of these soil types are heavy and fertile.

The slopes consist of badly eroded Rodman gravelly sandy loam. This is a greyish brown sandy loam underlain by cobbles, and in its present eroded condition is of low fertility.

The more level upland areas are Bellefontaine sandy loam, underlain by a thick sand layer. Drainage is rapid and erosion has been serious even on the gentle upland slopes.

June grass (Poa pratensis L.) characterizes the more fertile lowland areas. The sod is thick and continuous. On the eroded slopes, the sod is much lighter and other grasses and

weeds are mixed with the bluegrass. The level uplands have conditions similar to the slopes. Adjacent woodlots are predominantly red oak on upland, with tamarack and willow on the lowland.

THE FOREST PLANTATIONS

Forest plantations were first made on the tract in the fall of 1931, using red pine and white pine. Planting has continued each year to the present. Table I lists the plantations with which this study is concerned. Although a large number of species has been planted, only white pine and Norway pine have been planted each year and under enough different conditions to furnish a basis for analysis of survival data. In addition to these two species a limited amount of data are considered for Norway spruce.

TABLE I. DESCRIPTION OF PLANTATIONS STUDIED

Year	Planting season	Age class of stock	Area in acres	Survival to date
		Red Pine		
1931	fall	3 - 0	3.2	60%
1932	spring	2 - 0 3 - 0	25.9	85% 65%
1933	spring	2 - 0	12.4	16
1934	spring	3 - 0	15.6*	0
1935	spring	2 - 0 2 - 2	31.5*	18 75
1936	spring	2 - 0	6	51
		White Pine		
1931	fall	varied	6.4	10%
1932	spring	3 - 0	18.7	28%
1933	spring	varied	24.5*	10%
1935	spring	3 - 0 & 2 - 2	24.5*	8%
		Norway Spruce		
1932	spring	2 - 0 & 2 - 3	13	2 - 3%
1933	spring	3 - 0	2.5*	•

*Replacements

It can be seen that from the standpoint of tree survivals the results are quite unsatisfactory. Best results were obtained with plantations set out in 1932. Red pine planted this year has from 60 - 85% of the trees alive, while white pine also of this year has 28% yet alive, highest survival for that species on the Kellogg Tract. The only failures in plantations made in 1932 are in those of Norway spruce, of which less than 5% has survived.

Plantations of both red and white pine set out in 1933 have been failures. Only 16% of the red pine and 10% of the white pine is now alive. Similarly, the plantations set out in 1935 have been failures. Except for a relatively small number of 4 year red pine transplants, losses in 1935 plantations are 82 and 92% for red and white pine respectively.

So far, the red pine plantations of 1936 have proven satisfactory. Losses during their first year, characterized by severe droughts, were lower than those of the 1935 plantations.

An important part of this study is to determine the causes of such wide differences in survivals among these four series of plantations.

METHODS OF STUDY

Permanent sample plots containing twenty-five trees each were staked out at the time of planting. Survival counts have been made twice each year. Thus there is a history of the losses on each plot dating from the time of planting to October, 1936.

In the fall of 1936, data were taken on the soil, aspect, slope, planting method, and intensity of competition on each plot.

Soils were separated into two groups, heavy and light. The heavy soils are those having the physical characteristics of loam or heavier soils, in contrast to the predominantly sandy, unfriable soils. The lowlands are typically heavy, and the uplands typically light.

Aspect data are combined into two groups: North and South. The former includes the N.W., N. and N.E. slopes; the latter includes the S.E., S. and S.W. slopes.

Slope classes are from 0 - 7%, and over 7%.

Preparation of site includes furrowed and non-furrowed areas. In the latter case, no more sod was removed than that necessary to dig the planting hole. Therefore, it is described as having no preparation. Several areas were treated both ways. Survival records on these provide additional material.

Intensity of competition is included in two classes, light and heavy.

Plots were separated first on the basis of species and then year of planting. Each factor was analyzed independently by grouping together all plots similar in respect to that factor.

For purposes of comparison, the results were computed in four ways. (1) The total mortality percent for the period, (2) The annual mortality percent, based on the number alive in the spring of each year, (3) The deviation of the annual mortality percent from the average annual mortality percent, and (4) This deviation expressed as a percent of the average mortality percent. This last analysis serves as a basis for comparing the effects of the various factors.

The losses of Norway spruce were so nearly complete that no effort was made to summarize the data for that species.

It will be noted that occasionally in tables V and VII the deviations from average for the both conditions of a factor will be either above or below average. Since the annual mortality figures are calculated on the basis of the number of trees alive at the beginning of the year, the losses of each year will affect the percentage losses of the following years.

Plantations of several ages of white pine stock were made. These provide comparable data on the survivals of 3 - 0, 2 - 1, and 2 - 2 stock.

First year survivals of 28 red pine trees for each of ten different crews serve to bring out some of the results of good and poor planting.

Studies were made of the root systems of dead trees. Many could be pulled up easily even after two years growth. Pulled trees were taken to the laboratory for study.

Losses of the two species of pine were compared. These are presented by mortality percent, and by total loss, through 1936 in tabular and graphic form. Some data for Norway spruce are included also.

It is necessary to include weather as a factor of primary importance. Monthly totals for each growing season, together with the averages and annual totals were available. These data are from a station three miles from the area. Mean annual averages based upon long time records were taken from the Battle Creek records. This station is approximately 10 miles from the tract. Rains of two tenths inches or less are considered as not significantly effective for vegetative growth.

Drought effects were measured in the following three ways:

(1) The total number of days in 10 days drought periods during the growing season.

(2) The longest drought period during the growing season.

(3) The average length of drought. Maximum temperatures are used also in estimating severity of drought.

Frost heaving resulting from alternate freezing and thawing of the soil caused losses among fall planted trees. Comparisons are made of losses among three classes of white pine stock for degree of site preparation, between mulched and non-mulched areas and according to planting method used.

EFFECTS OF THE IMPORTANT FACTORS

Rainfall

Wide variations in rainfall occurred during the growing seasons between 1931 and 1937 (tableVI). Precipitation from April 1 to September 30 during 1934 was 6½ inches below average, and for July 1936 was 75 percent below average. Examinations of daily precipitation records (figures 3 - 7) show the occur-

Annual Mortality Percent of 1 and 2 year Plantations for the Period 1932 - 1936

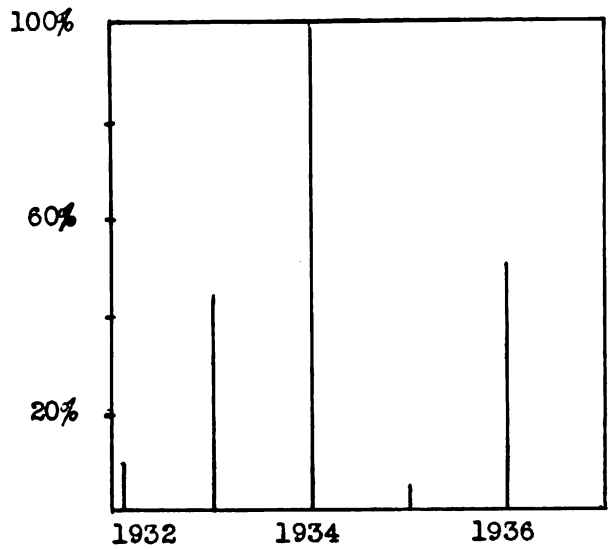


Fig. 1. 1 year-old plantations

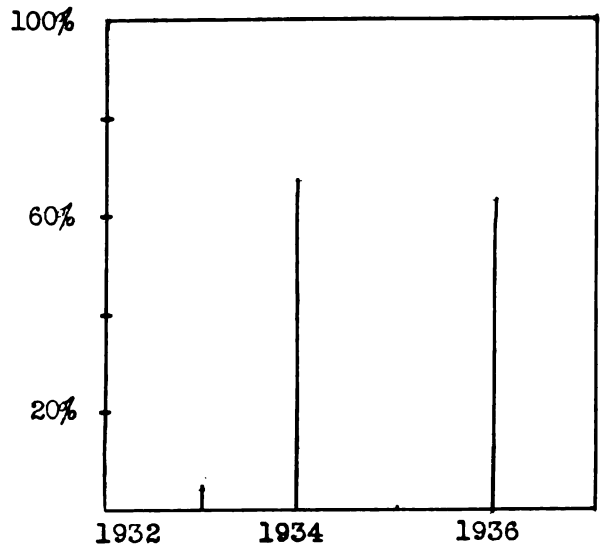


Fig. 2. 2 year-old plantations

rence of these and other drought periods. Figure 8 compares the growing seasons from 1932-1936 with respect to droughts on the basis of the average length of dry period, the longest dry period, and the total length of all dry periods during any one year. The years of 1932 and 1935 appear to be quite favorable. 1934 and 1936 show very severe conditions. From the standpoint of the longest drought period 1936 was outstanding. There occurred an interval of 40 days without a significant amount of rain. This period extended from July 4 to August 12, and was

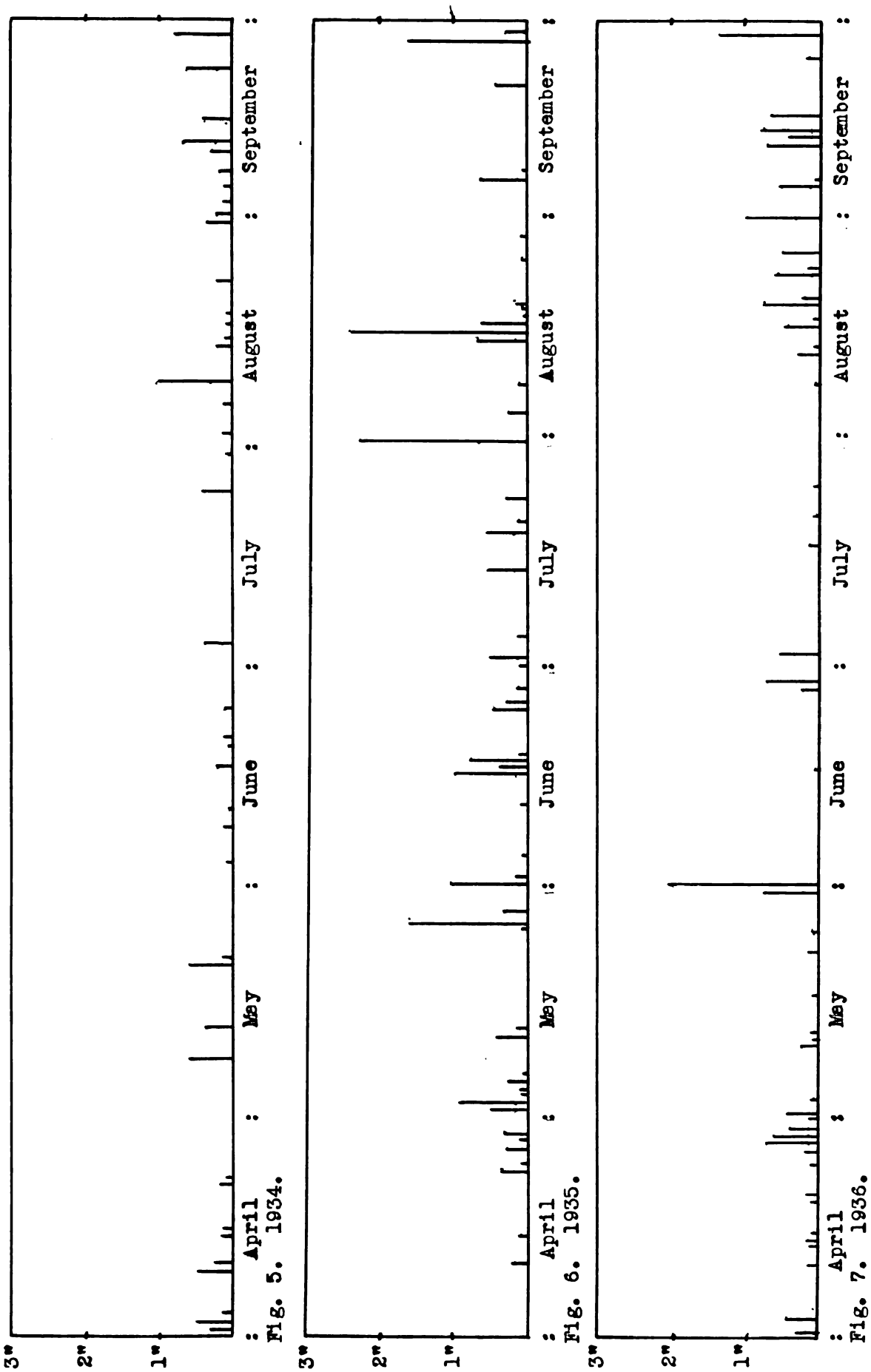


Fig. 5. 1934.

Fig. 6. 1935.

Fig. 7. 1936.

accompanied by 8 days with temperatures of over 100°F. In 1934, a drought of 20 days occurred, extending from May 11 to May 30. It ended with2.6" of rain. This was followed by a period of 26 days without rain. Figures 1 and 2, (preceding page) giving mortality percents for each year show that such extremely long dry periods as that of 1936, and

Daily Precipitation During the Growing Season (April 1 - Sept. 30) for the period 1932 - 1936.

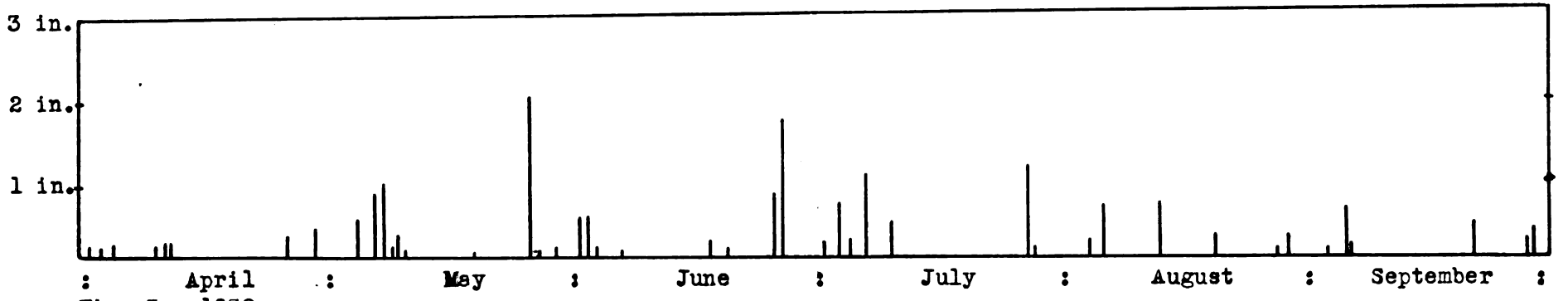


Fig. 3. 1932.

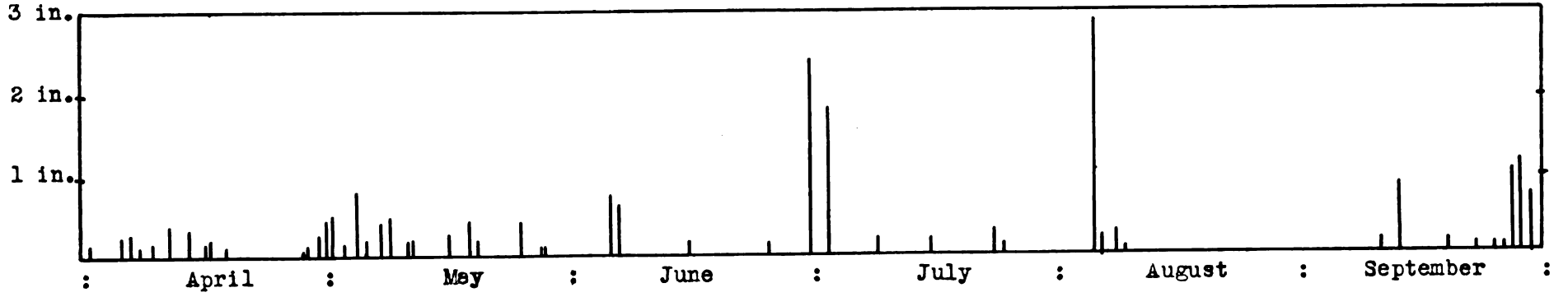


Fig. 4. 1933.

early periods as that of 1934 are most serious. Losses were considerably lower during 1933 although there was a 34 day drought period which lasted from August 9 to September 12, and the plantations in 1933 were one year younger than in 1934.

It is apparent that very long droughts accompanied by high temperatures occurring in the middle of the summer, or shorter periods of drought early in the season result in greater loss than do August and September droughts. This is in agreement with Baker and Korstians (2) findings.

Insofar as average precipitation is concerned, however, drought should not prove a limiting factor in southern Michigan during normal years. In fact, average precipitation data show that conditions should prove distinctly favorable.

Frost Heaving

Frost heaving proved to be a significant factor on the Kellogg Tract. The extent of this damage under various conditions is presented in Table III (next page).

Losses from this cause on fall-planted areas amounted to from 5 to 65 percent during the winter of 1931-1932. During the winter of 1936-37, damage in new plantations was also severe. Extensive heaving resulted and although heaved trees were reset in early spring 1937, some losses are to be expected. Some damage also was apparent during this season on plantations set out in 1935 and earlier.

Damage in 1931-1932 to 2 - 2 stock was 48% less than to 3 - 0, and 11% less than to 2 - 1 stock. Losses of 2 - 0 red pine were greater than with older stock. Trees planted in furrows suffered 23% greater losses than those set in the sod. Mulching with straw reduced heaving damage from 15 to 33%.

TABLE III. MORTALITY DUE TO FROST HEAVING

White Pine

By class of stock

3 - 0	60%
2 - 1	23%
2 - 2	12%

Basis 200 trees each

By Method of Site Preparation

Red Pine

	Unmulched	Mulched
Furrowed	43%	10%
Spot	20%	5%

100 trees in each group

By Method of Planting

3 - 0 White Pine

Shovel (hole)	65%
Shovel (slit)	55%

100 trees in each group

Trees planted in shovel holes had 10% lower losses than those planted in shovel slits.

The results show that the damage by frost heaving is lessened by protection against rapid temperature changes and by having the trees well set in the soil. Planting on north slopes, mulching, leaving protective sod, using well developed plants and distributing the roots carefully reduce losses. West and south facing slopes showed greatest frost heaving damage.

Mortality by years after planting

Tables II and III show the annual mortality percents for red and white pine. Annual losses, based on the number of trees alive each spring, show red pine set out in 1932 suffered 10% mortality the first year after planting, 4% the second (1933), 9% the third (1934), and none the fourth and fifth years. White pine for the same period had losses of 15%, 15%, 48% 3%, and 27%.

Red pine plantations set out in 1933 had 43% losses during the first year, 67% the second (1934) none the third, (1935) and 11% the fourth (1936). For the same period, white pine suffered 47%, 66%0%, and 39% mortality percents.

Plantings made in 1935 had losses of 4% and 27% for red and white pine respectively during the first year (1935), and 64% and 93% respectively during the second year (1936).

The 1932 series of Red pine plantations had become so well established after the third year that no further losses occurred, even during the severe 1936 season. In the case of white pine,

TABLE II. MONTHLY RAINFALL DURING THE PERIOD

APRIL 1 TO SEPTEMBER 30

FOR THE YEARS 1932 - 1936

Total in inches

	Average	1932	1933	1934	1935	1936
April	2.88	1.40	3.19	2.72	1.55	3.11
May	3.71	5.03	4.62	1.78	4.66	0.99
June	3.56	3.98	4.15	0.94	4.86	3.76
July	2.78	4.11	2.61	0.92	2.72	0.78
August	2.96	2.58	3.59	2.20	7.42	3.04
September	3.51	2.16	4.55	4.33	3.11	6.06
Total	19.40	19.26	22.72	12.89	24.32	20.74
Yearly Total	33.39	37.37	38.91	24.07	39.71	30.00

however, the high losses, 27 percent, during 1936 show the plantations were not established even by the fifth year. This was the case in the 1933 plantings of both species. Losses continued to occur throughout the whole four year period.

The 1935 series of plantations had a less favorable opportunity than the 1932 to become established quickly. The first year, 1933, was only fair in regard to precipitation, and the second, 1934, was very dry. Conditions for the 1935 plantations are somewhat similar to those for 1933 - a favorable year followed by an unfavorable year. These data show that red pine became established in three or four years when conditions were not severe during the first two years. White pine failed to become established during this period.

When conditions during the first two years were severe, both red and white pine failed to become established within three years. Heavy losses, 11 and 49 percent occurred during the fourth year in this case.

Thus it is apparent that establishment of red pine may take place within three years if conditions during the first two years are favorable. Severe conditions in regard to drought during the first two years not only cause much heavier losses during the season in which they occur but also prolong the period necessary for establishment and result in higher losses during the ensuing years.

SOIL

Tables II for red pine and III for white pine show slight mortality differences for the conditions of soil. These differences are more clearly shown by the percentage deviations from

Table IV. Mortality Percent of Red Pine Under Different Site Conditions

Site Condition	No. of Trees	Percent of Trees Dying Each Year Based on Original Number Year After Planting						Percent of Trees Dying Each Year Based on Number Alive in Spring of Each Year Year After Planting				
		1st	2nd	3rd	4th	5th	Total	1st	2nd	3rd	4th	5th
1932 Planting												
Soil												
Heavy	473	12	4	7	0	0	23	12	5	9	0	0
Light		2	2	13	0	0	17	2	2	14	0	0
Exposure												
North	74	11	0	1	0	0	12	11	0	1	0	0
South	484	10	5	9	0	0	24	10	6	11	0	0
Slope												
0-7%	316	9	4	7	0	0	20	9	4	8	0	0
Over 7%	302	11	4	9	0	0	24	11	4	11	0	0
Preparation												
None	115	12	5	12	0	0	29	12	6	14	0	0
Furrowed	503	9	3	7	0	0	19	9	3	8	0	0
Competition												
Light	346	7	3	7	0	0	17	7	3	8	0	0
Heavy	272	14	5	9	0	0	28	14	6	11	0	0
Average		10	4	8	0	0	21	10	4	9	0	0
1933 Planting												
Soil												
Heavy	50	44	50	0	0		94	44	89	0	0	
Light	275	43	36	0	2		81	43	63	0	10	
Exposure												
North	175	38	35	0	3		76	38	56	0	11	
South	150	49	40	0	0		89	49	78	0	0	
Slope												
0-7%	25	44	28	0	0		72	44	50	0	0	
Over 7%	300	43	39	0	2		84	43	68	0	11	
Preparation												
None	325	43	38	0	2		83	43	67	0	11	
Furrowed												
Competition												
Light	275	44	36	0	1		81	44	64	0	5	
Heavy	50	42	50	0	6		98	42	86	0	75	
Average	325	43	38	0	2		83	43	67	0	11	
1935 Planting												
Soil												
Heavy	112	3	47				50	3	48			
Light	288	4	66				70	4	69			
Exposure												
North	241	5	58				63	5	61			
South	152	3	66				69	3	69			
Slope												
0-7%	79	2	22				24	2	22			
Over 7%	320	4	70				74	4	73			
Preparation												
None	300	4	72				76	4	75			
Furrowed	99	5	26				31	5	27			
Competition												
Light	278	5	62				67	5	65			
Heavy	121	2	56				58	2	57			
Average	399	4	61				65	4	64			

Table V. Deviation From Average Mortality
Red Pine

Site Condition	Actual Deviation From Average Mortality * Year After Planting						Actual Deviation Expressed As A Percent Of The Average Mortality Year After Planting				
	1st	2nd	3rd	4th	5th	Total	1st	2nd	3rd	4th	5th
1932 Planting											
Soil											
Heavy	+4	+3	0	0	0	+7	+40	+75	0	0	0
Light	-3	-2	0	0	0	-5	-30	-50	0	0	0
Exposure											
North	+2	+1	0	0	0	+3	+20	+25	0	0	0
South	-8	-2	+5	0	0	-5	-80	-50	+55	0	0
Slope											
0-7%	-1	0	-1	0	0	-2	-10	0	-12	0	0
Over 7%	+1	0	+1	0	0	+2	+10	0	+12	0	0
Preparation											
None	+2	+2	+4	0	0	+8	+20	+50	+50	0	0
Furrowed	-1	-1	-1	0	0	-3	-10	-25	-12	0	0
Competition											
Light	-3	-1	-1	0	0	-5	-30	-25	-12	0	0
Heavy	+4	+2	+1	0	0	+7	+40	+50	+12	0	0
1933 Planting											
Soil											
Heavy	+1	+22	0	-11		+12	+2	+33	0	-100	
Light	0	-4	0	-1		-5	0	-6	0	-9	
Exposure											
North	-5	-11	0	0		-16	-12	-16	0	0	
South	+6	+11	0	-11		+6	+14	+16	0	-100	
Slope											
0-7%	+1	-17	0	-11		-27	+2	-25	0	-100	
Over 7%	0	+1	0	0		+1	0	+1	0	0	
Preparation											
None											
Furrowed											
Competition											
Light	+1	-3	0	-6		-8	+2	-41	0	-55	
Heavy	-1	+19	0	+64		+82	-2	+28	0	+582	
1935 Planting											
Soil											
Heavy	-1	-16				-17	-25	-25			
Light	0	+5				+5	0	+8			
Exposure											
North	+1	-3				-2	+25	-5			
South	-1	+5				+4	-25	+8			
Slope											
0-7%	-2	-42				-44	-50	-66			
Over 7%	0	+9				+9	0	+14			
Preparation											
None	0	+11				+11	0	+17			
Furrowed	+1	-37				-36	+25	-58			
Competition											
Light	+1	+1				+2	+25	+2			
Heavy	-2	-7				-9	-50	-11			

* Percent of mortality each year based on number alive in spring of each year.

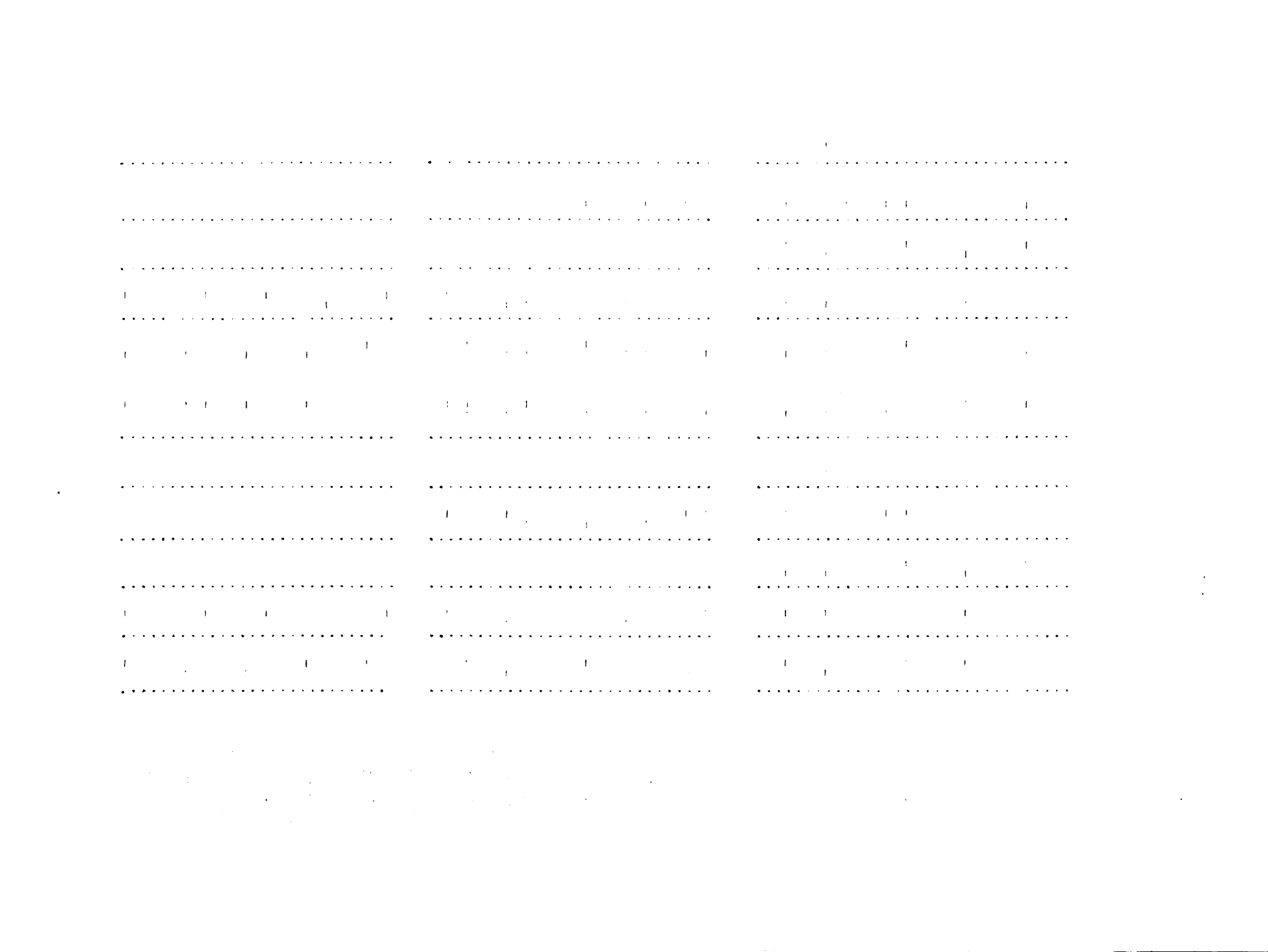
Table VI. Mortality Percent of White Pine Under Different Site Conditions

Site Condition	No. of Trees	Percent of Trees Dying Each Year Based on Original Number Year After Planting						Based on Number Alive in Spring of Each Year Year After Planting				
		1st	2nd	3rd	4th	5th	Total	1st	2nd	3rd	4th	5th
1932 Planting												
Soil												
Heavy	200	10	12	35	1	12	70	10	13	45	2	28
Light	320	19	11	35	1	10	76	19	14	50	3	29
Exposure												
North	240	10	8	30	2	8	58	10	9	37	4	40
South	140	16	14	39	7	12	88	16	17	56	23	50
Slope												
0-7%	395	15	11	33	1	13	73	15	13	45	2	32
Over 7%	125	17	12	41	0	2	72	17	14	58	0	7
Preparation												
None	435	18	12	38	0	12	80	18	14	54	0	38
Furrowed	85	24	6	20	4	7	61	24	8	29	8	15
Competition												
Light	280	12	8	35	1	12	68	12	9	44	2	27
Heavy	240	19	15	35	1	8	78	19	19	53	3	27
Average		16	11	35	1	10	73	16	13	48	3	27
1933 Planting												
Soil												
Heavy	175	36	38	0	9		83	36	59	0	35	
Light	175	57	31	0	4		92	57	72	0	33	
Exposure												
North	50	34	48	0	2		84	34	73	0	6	
South	175	53	25	0	10		88	53	53	0	77	
Slope												
0-7%	175	45	43	0	3		91	45	78	0	2	
Over 7%	175	48	36	0	10		94	48	69	0	62	
Preparation												
None	225	59	37	0	0		96	59	90	0	0	
Furrowed	125	25	30	0	16		71	25	40	0	36	
Competition												
Light	100	45	36	0	6		87	45	66	0	32	
Heavy	250	47	34	0	7		88	47	64	0	37	
Average	350	47	35	0	7		88	47	66	0	39	
1935 Planting												
Soil												
Heavy	228	32	61				93	32	90			
Light	336	26	71				97	26	96			
Exposure												
North	123	38	51				89	38	82			
South	231	22	74				96	22	96			
Slope												
0-7%	354	33	59				92	33	88			
Over 7%	210	17	80				97	17	96			
Preparation												
None	495	28	64				92	28	89			
Furrowed	69	17	83				100	17	100			
Competition												
Light	205	29	68				97	29	96			
Heavy	359	26	66				92	26	90			
Average	564	27	67				94	27	93			

Table VII. Deviation From Average Mortality
White Pine

Site Condition	1932 Planting: Actual Deviation From Average Mortality * Year After Planting						Actual Deviation Expressed As A Percent Of The Average Mortality Year After Planting				
	1st	2nd	3rd	4th	5th	Total	1st	2nd	3rd	4th	5th
Soil											
Heavy	-6	0	-3	-1	+1	-9	-37	0	-6	-33	+4
Light	+3	+1	+2	0	+2	+8	+19	+8	+4	0	+7
Exposure											
North	-6	-4	-11	+1	+13	-7	-37	-31	-23	+33	+46
South	0	+4	+8	+20	+23	+55	0	+31	+17	+667	+85
Slope											
0-7%	-1	0	-3	-1	+5	0	-6	0	-6	-33	+18
Over 7%	+1	+1	+10	-3	-20	-11	+6	+8	+21	-100	-74
Preparation											
None	+2	+1	+6	-3	+11	+17	+12	+8	+12	-100	+41
Furrowed	-14	-5	-19	+5	-12	-45	-88	-38	-40	+167	-44
Competition											
Light	-4	-4	-4	-1	0	-13	-25	-31	-8	-33	0
Heavy	+3	+6	+5	0	0	+14	+19	+46	+10	0	0
Soil	1933 Planting										
Heavy	-11	-7	0	-4		-22	-23	-11	0	-10	
Light	+10	+6	0	-6		+10	+21	+9	0	-15	
Exposure											
North	-13	+7	0	-33		-42	-28	+11	0	-85	
South	-16	-13	0	+38		+9	-34	-20	0	+98	
Slope											
0-7%	-2	+12	0	-37		-27	-4	+18	0	-95	
Over 7%	+1	+3	0	+23		+26	+2	+4	0	+59	
Preparation											
None	+12	+24	0	-39		-3	+26	+36	0	-100	
Furrowed	-22	-26	0	-3		-51	-47	-39	0	-8	
Competition											
Light	-2	0	0	-7		-9	-4	0	0	-18	
Heavy	0	-2	0	-2		-4	0	-3	0	-5	
Soil	1935 Planting										
Heavy	+5	-3				+2	+18	-3			
Light	-1	+3				+2	-4	+3			
Exposure											
North	+11	-11				0	+41	-12			
South	-5	+3				-2	-18	+3			
Slope											
0-7%	+6	-5				+1	+22	-5			
Over 7%	-10	+3				-7	-37	+3			
Preparation											
None	+1	-4				-3	+4	-4			
Furrowed	-10	+7				-3	-37	+8			
Competition											
Light	+2	+3				+5	+7	+3			
Heavy	-1	-3				-4	-4	-3			

* Percent of mortality each year based on number alive in spring of each year.



the average mortality (table III and V) and by figures 30 and 31 for cumulative losses on heavy and light soils.

The losses were consistently higheron heavy soils , from 2 per cent to 75 per cent above agerage for the 1932 and 1933 red pine plantations, and lower, 6 percent to 37 percent below average, for white pine. Red pine on heavy soils showed total losses from 7 to 12 per cent above average. White pine on heavy soils had losses from 9 to 22 per cent below average. Results of the 1936 losses in two-year-old plantations, on which losses on light soils were heavier for both species, indicate that droughts are more severe on sand soils. This effect is most apparent during the first two or three years, before the plantations become well established.

The fact that red pine is better adapted to light soils and white pine to heavy soils is borne out by observations of natural stands. Red pine occurs naturally more frequently on lighter soils than does white pine whereas white pine prefers the heavier to the lighter soils.

ASPECT

Both species show total losses on north slopes 4 to 30 per cent lower than on south slopes, figures 9, 32, 20 and 33. This is more apparent during severe years like 1934 and 1936 when losses were much lower on north slopes. During good years like 1932 and 1935 losses are about the same or even lower on the south slope. During 1934 three-year-old white pine losses on the north slopes were 31 per cent below average. Similar effects are shown for 1936 especially in white pine and newly established red pine.

Drought Periods During the Years 1932-36

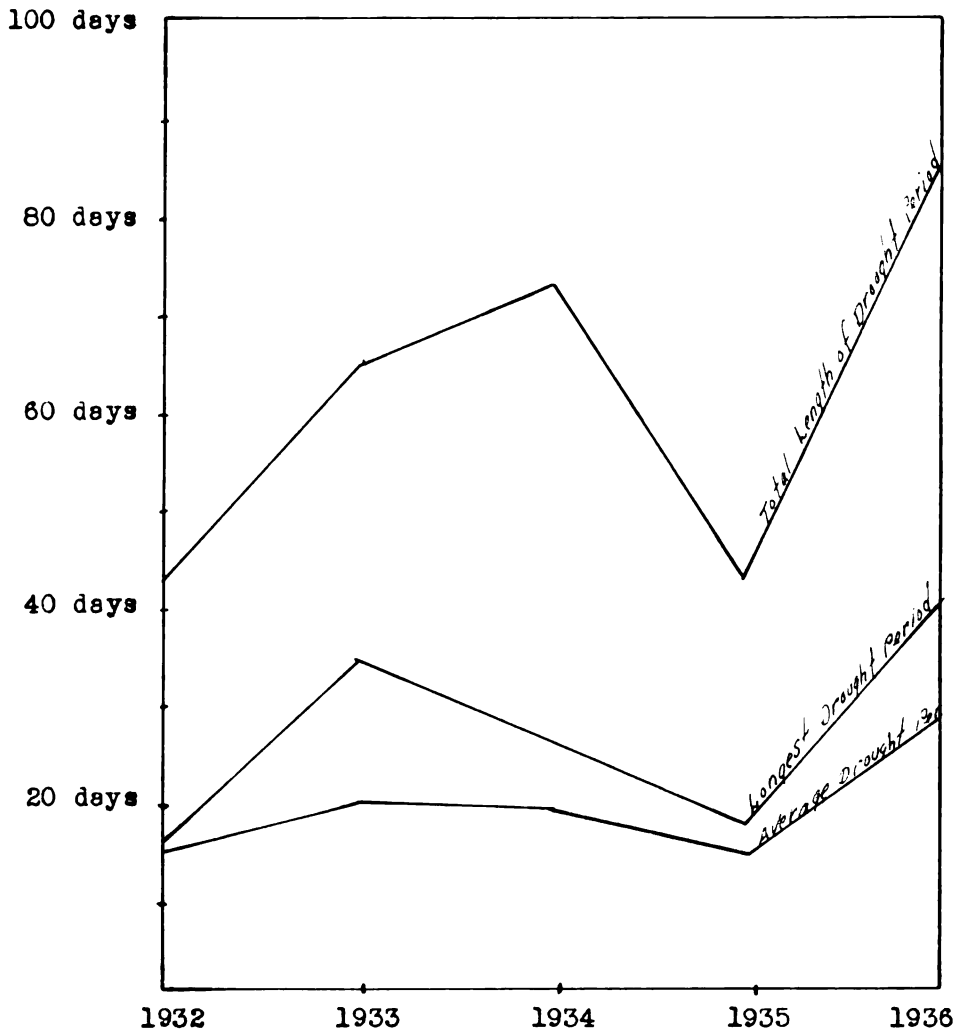


Fig. 8.

Mortality Percent of Red Pine Under
Different Site Conditions

Soil

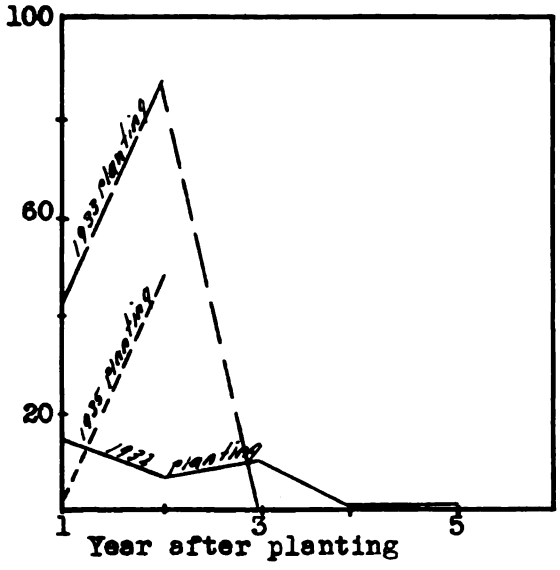


Fig. 9. Heavy Soil

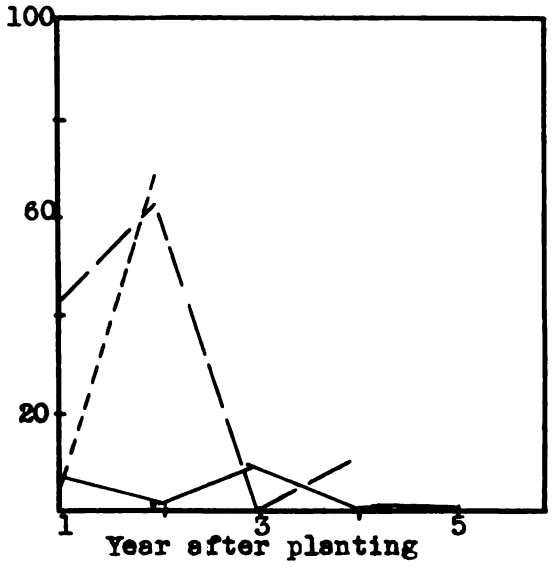


Fig. 10. Light Soil

Aspect

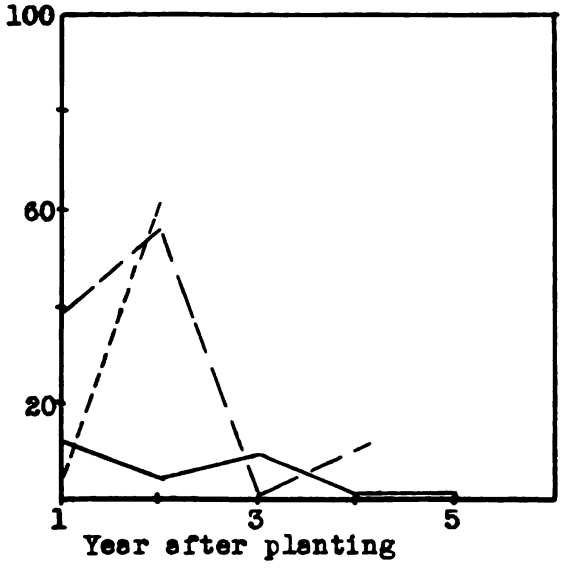


Fig. 11. North aspect

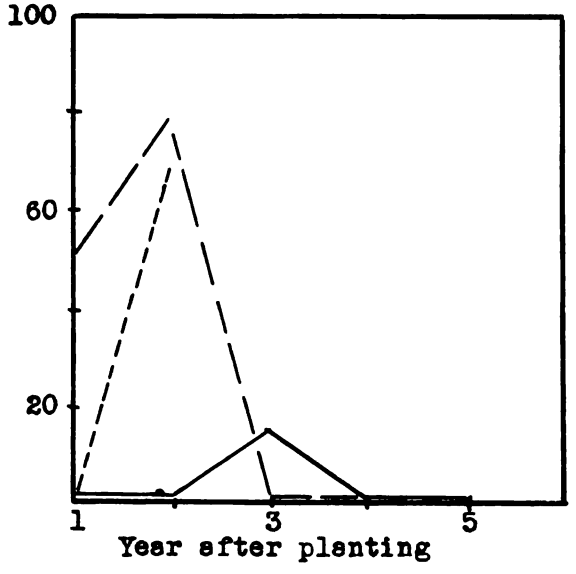


Fig. 12. South Aspect

Mortality Percent of Red Pine Under
Different Site Conditions (cont)

Slope

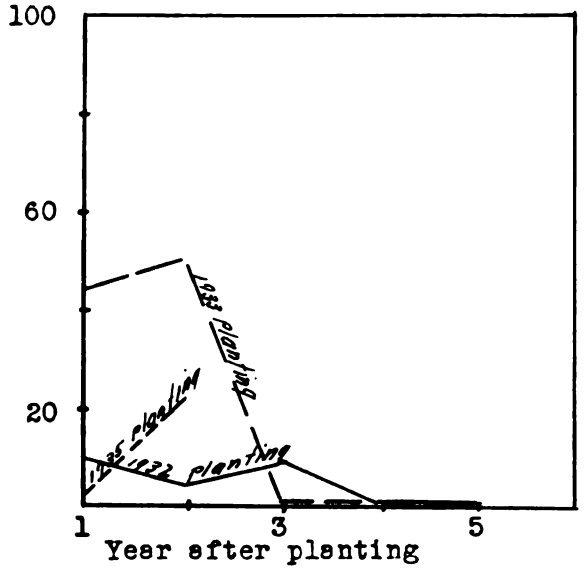


Fig. 13. 0 - 7% slope

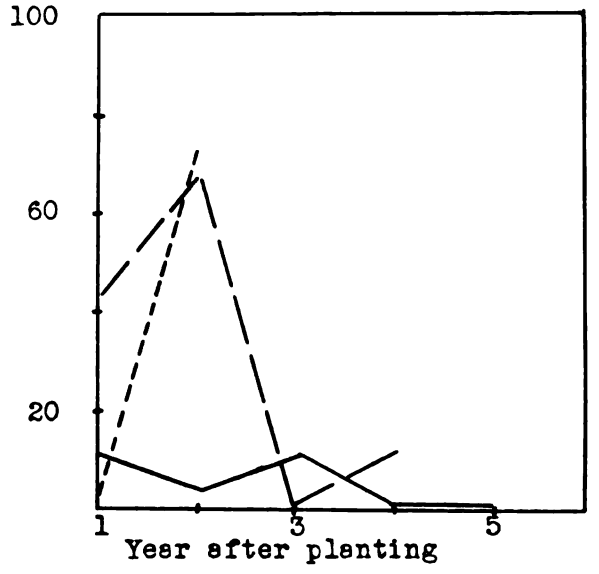


Fig. 14. Over 7% slope

Site Preparation

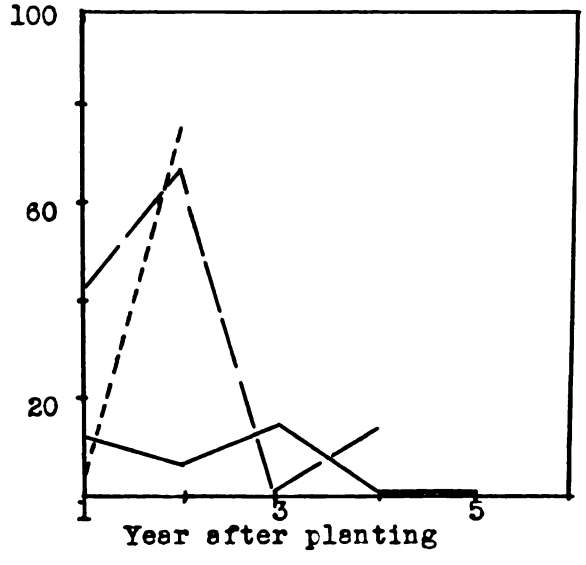


Fig. 15. No preparation

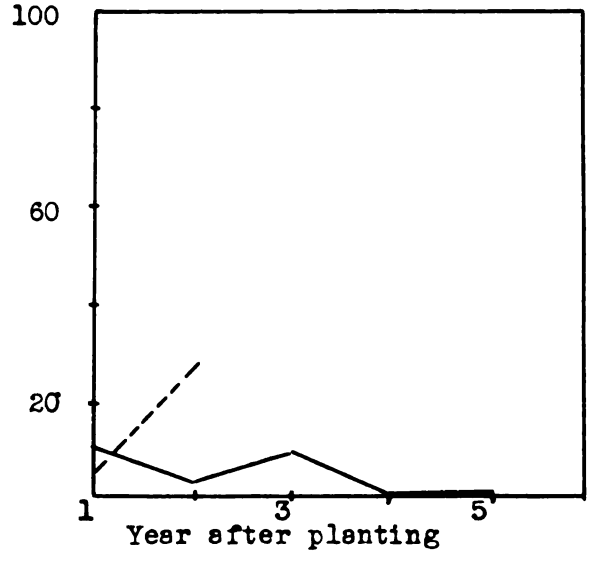


Fig. 16. Furrowed (none in 1933)

Mortality Percent of Red Pine Under
Different Site Conditions (cont)

Intensity of Competition

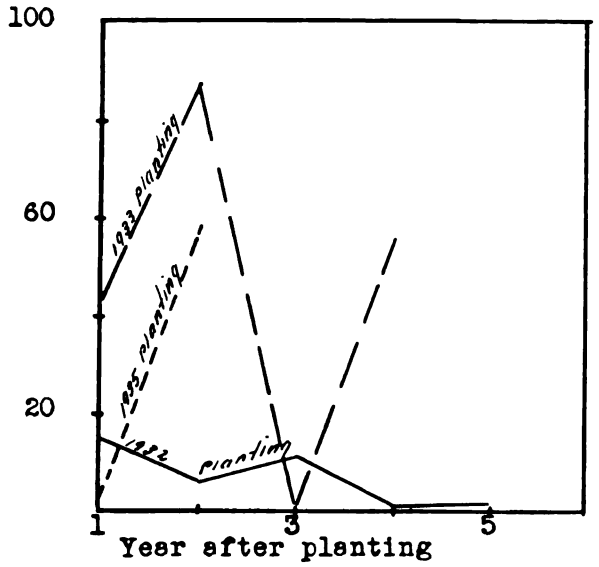


Fig. 17. Heavy Competition

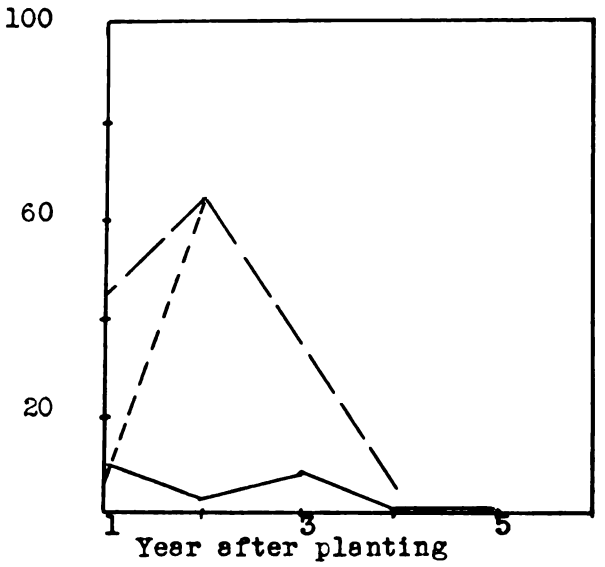


Fig. 18. Light Competition

All Conditions

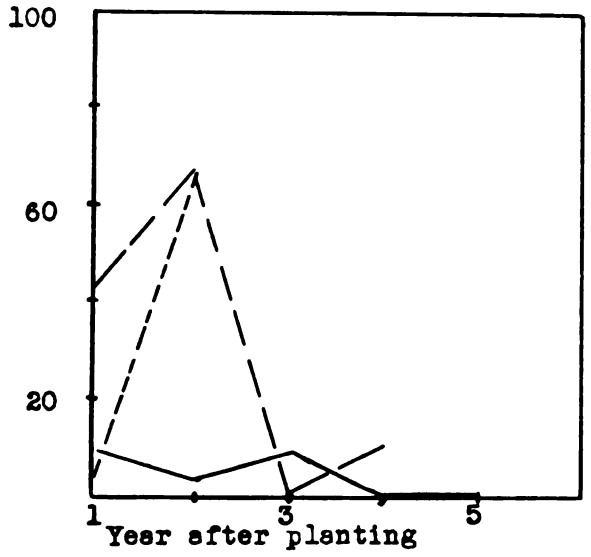


Fig. 19.

Mortality Percent of White Pine Under
Different Site Conditions

Soil

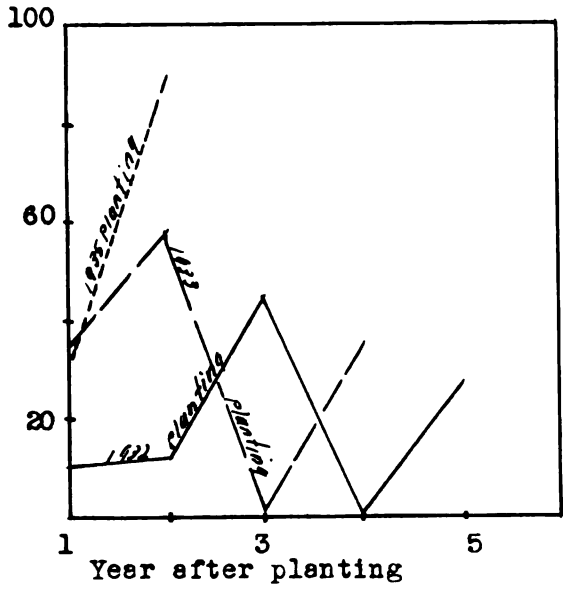


Fig. 20. Heavy Soil

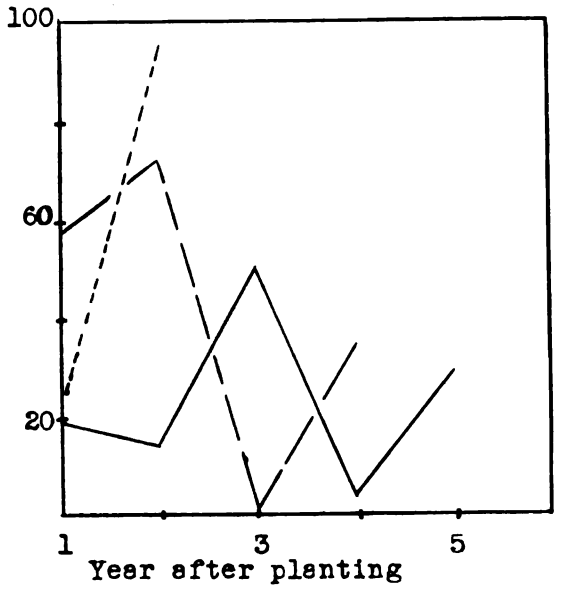


Fig. 21. Light Soil

Aspect

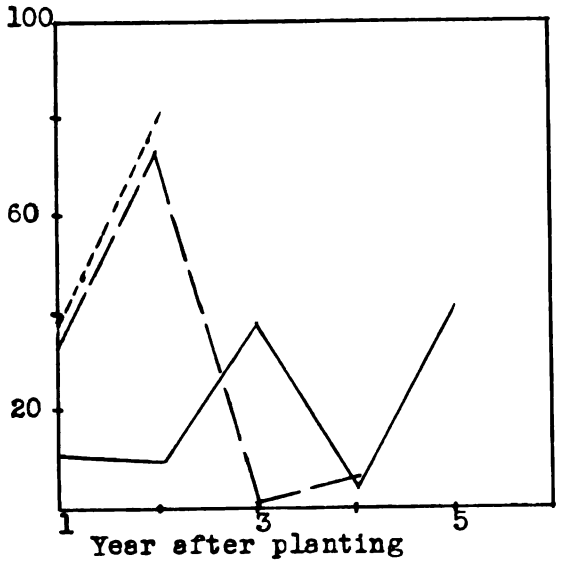


Fig. 22. North aspect

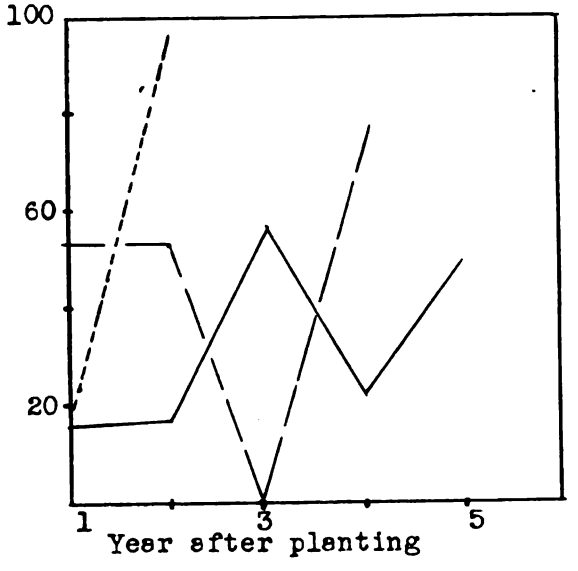


Fig. 23. South Aspect

Mortality Percent of White Pine Under
Different Site Conditions (cont)

Percent of Slope

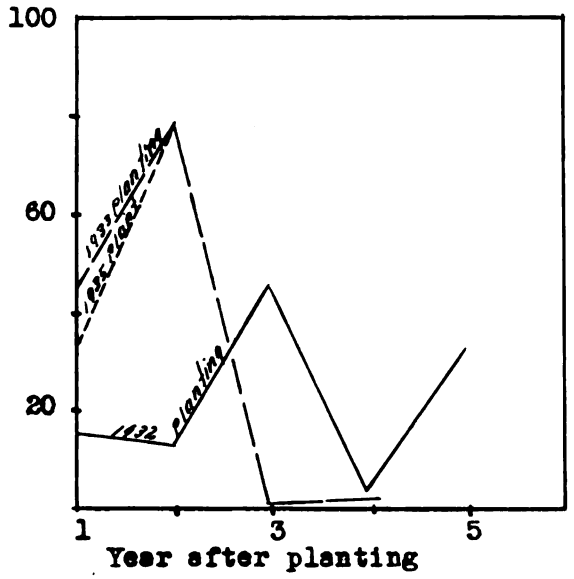


Fig. 24. 0 - 7% slope

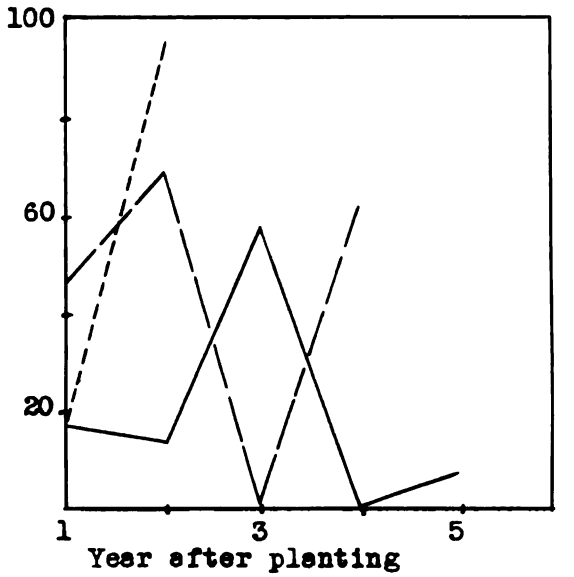


Fig. 25. Over 7% slope

Preparation of Site

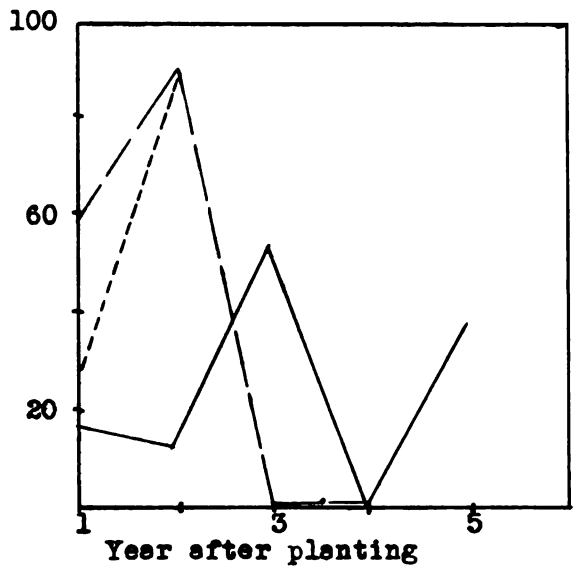


Fig. 26. No preparation

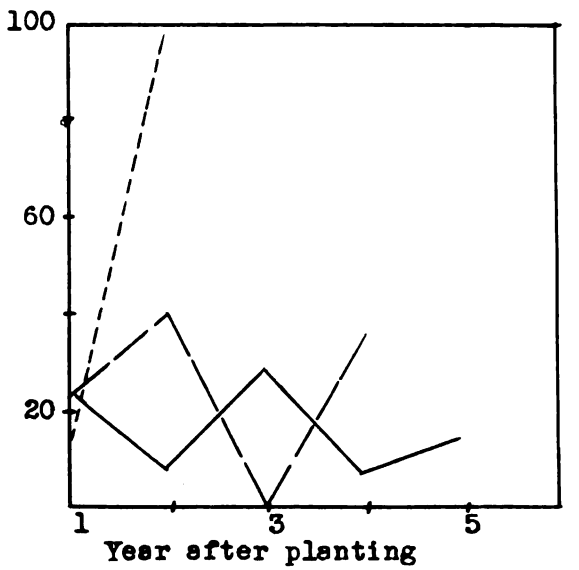


Fig. 27. Furrowed

Mortality Percent of White Pine Under
Different Site Conditions (cont)

Intensity of Competition

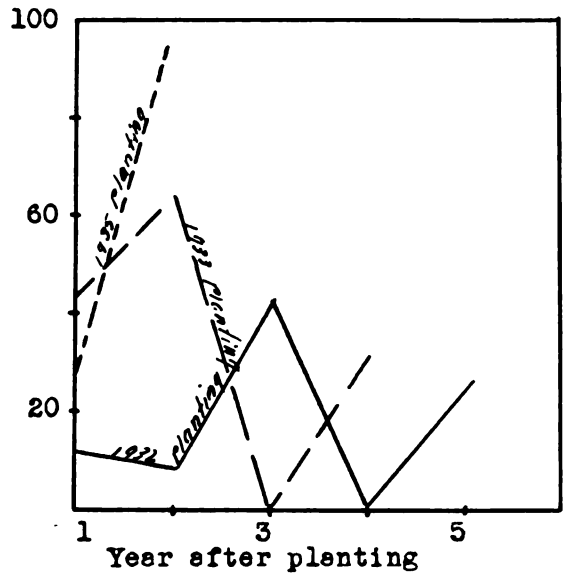


Fig. 28. Light Competition

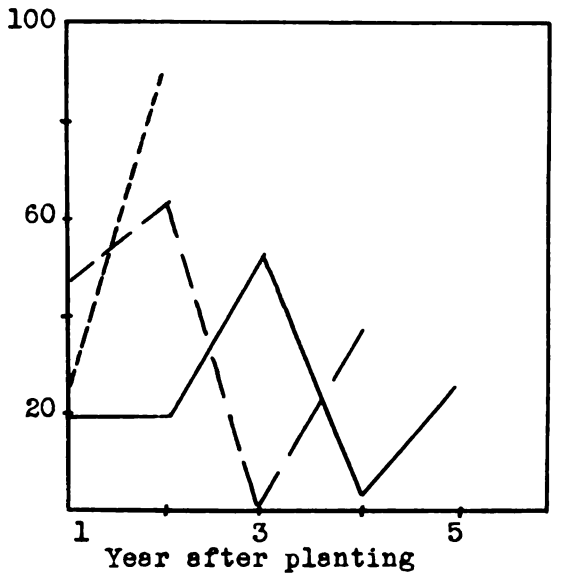


Fig. 29. Heavy Competition

All Conditions

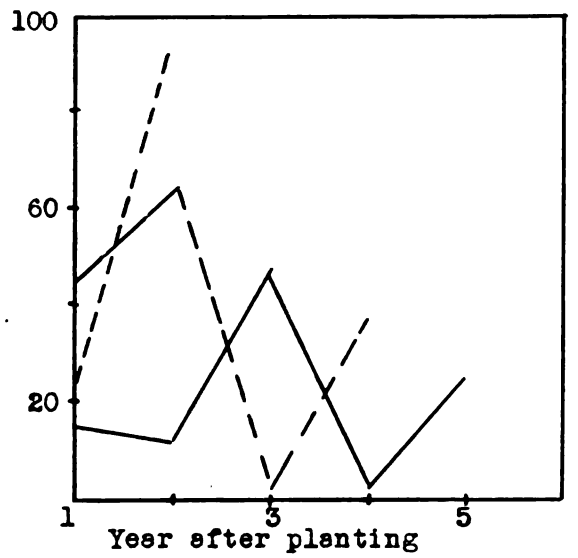


Fig. 30.

Cumulative Mortality Percent of Red and White Pine Under Different Site Conditions

Red Pine

White Pine

Soil Condition

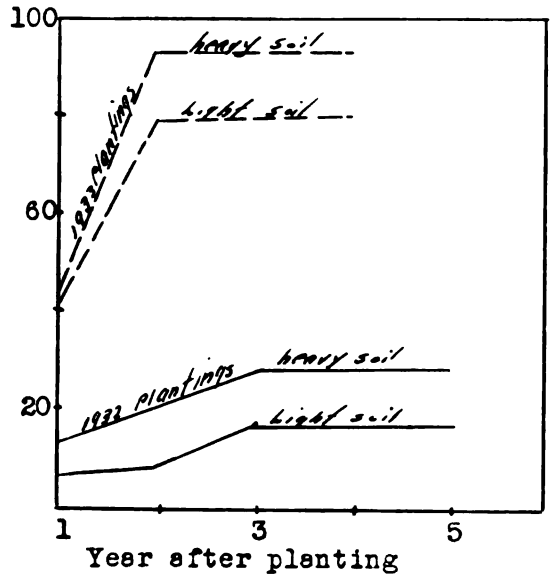


Fig. 31.

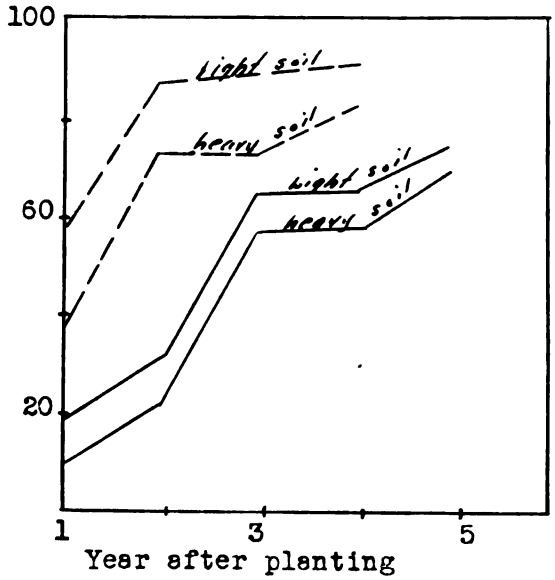


Fig. 31.

Aspect

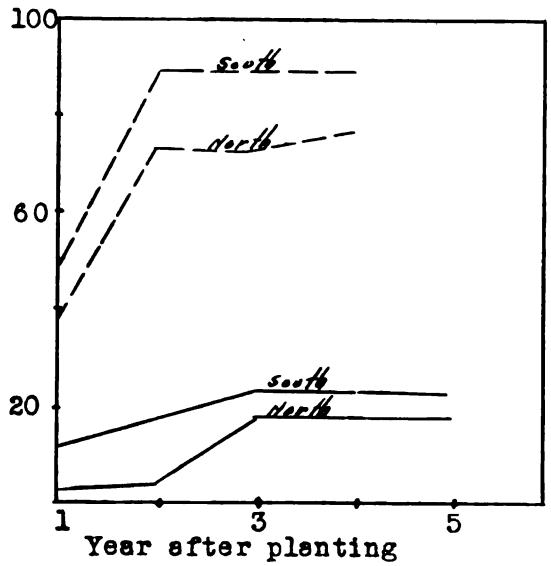


Fig. 33.

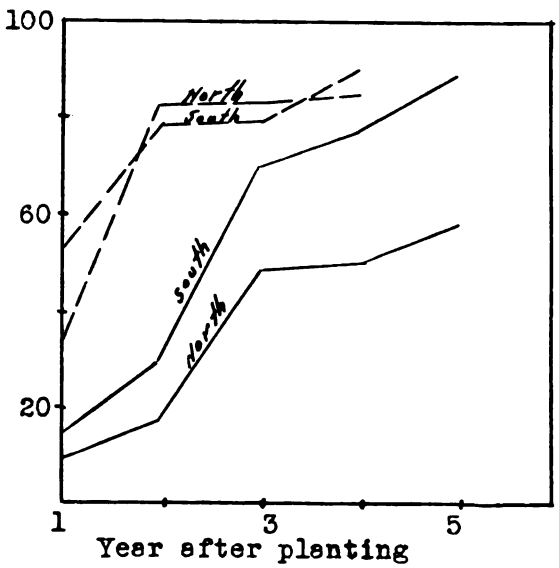


Fig. 34.

New plantations of the latter during 1936 suffered losses on north slopes 30 per cent lower than on south slopes.

SLOPE PER CENT

Slope per cent apparently had some effect upon survival. The total survivals of red pine on level areas are from 4 to 50 per cent higher than those on slopes. The main differences occur during the years of critical droughts. For instance, in in 1933 losses of newly planted red pine on both conditions of slope were almost identical, while in 1935 a very dry year, losses in these same plantations on the slopes of over 7 per cent were 18 per cent higher than losses on the more level areas. Similarly, in 1935 losses of red pine were almost the same on both conditions of slope, and in 1936 on these same plantations, the more level areas had losses 48 per cent below those on the slopes. Differences in losses are slight between the two conditions of slope in white pine plantations. The total losses vary no more than 5 per cent from each other. The losses in the 1932 plantations, during the summer of 1934, were 15 per cent lower on 0 - 7 per cent slopes than on steeper slopes. During 1936 losses were 25 per cent higher on level areas of 1932 plantings, 60 per cent lower in 1935 plantings, and 8 per cent lower in 1935 plantings. During favorable years, these differences are less or even reversed.

PREPARATION OF SITE

Preparation of the site previous to planting resulted in better survival as is shown by figures 35 and 36. In only three out of the 22 cases were the losses on furrowed areas above

Cumulative Mortality Percents of Red
And White Pine Under Different Site Conditions (cont)

Red Pine

White Pine

Percent of Slope

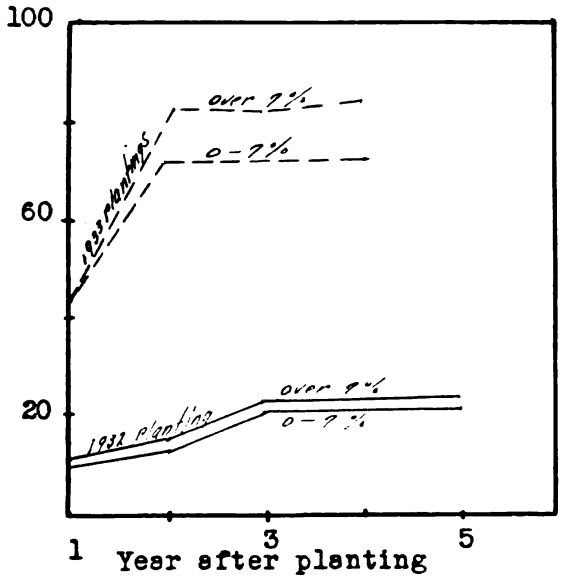


Fig. 35.

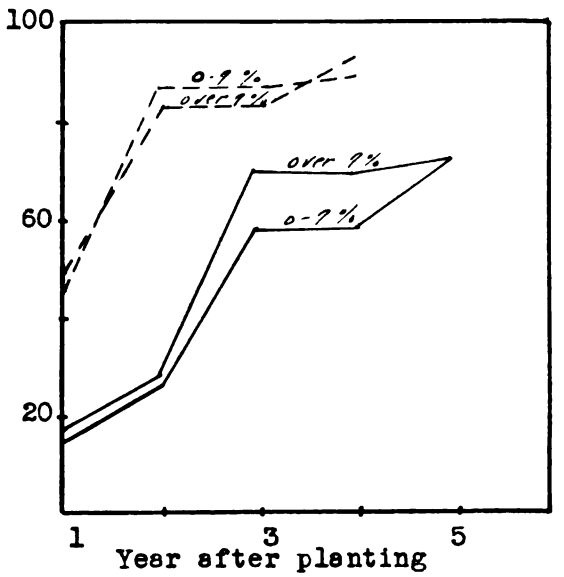


Fig. 36.

Preparation of Site

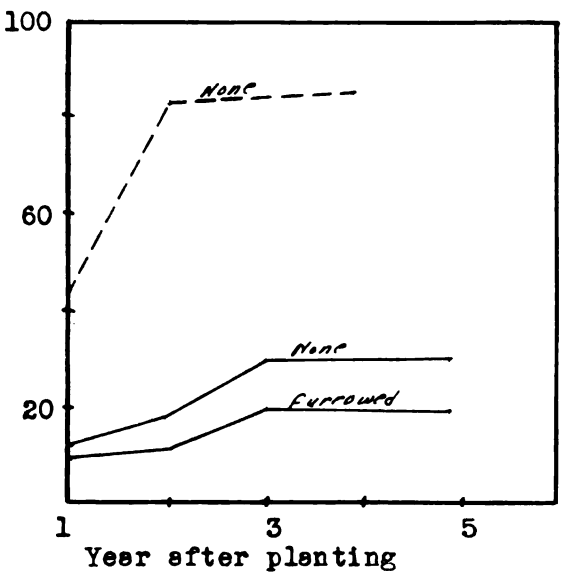


Fig. 37. (none in 1933)

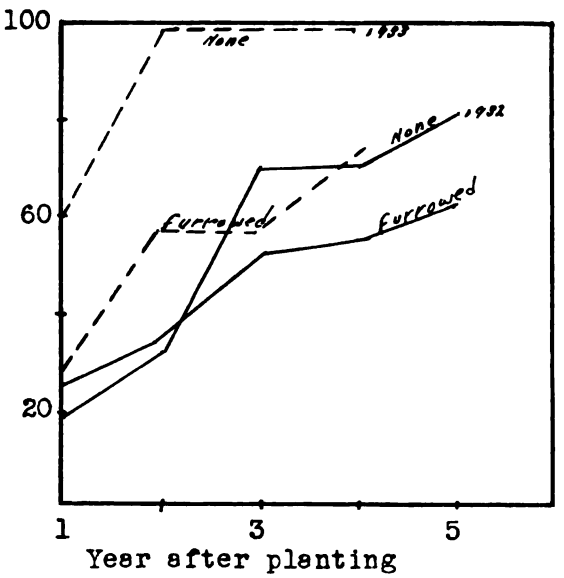


Fig. 38.

Cumulative Mortality Percents of Red and White Pine Under Different Site Conditions (cont.)

Intensity of Competition

Red Pine

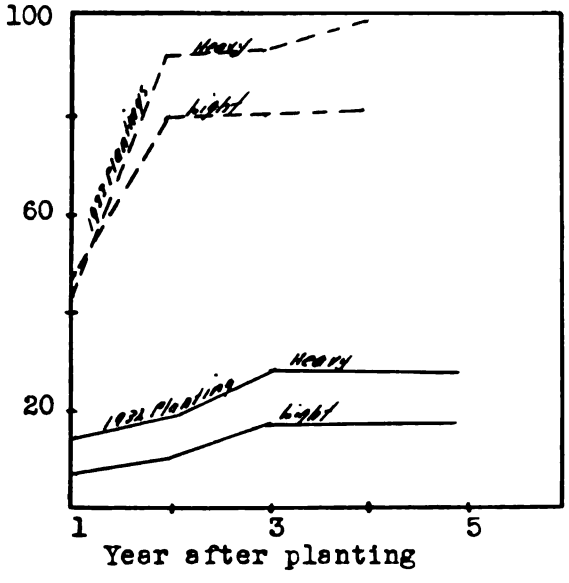


Fig. 39.

White Pine

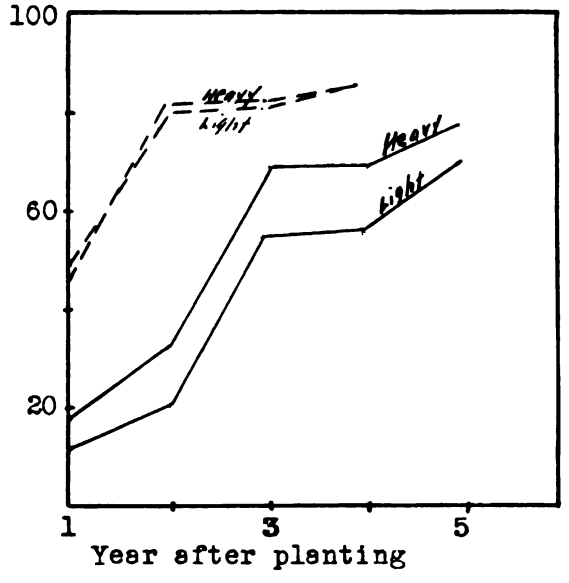


Fig. 40.

All Conditions

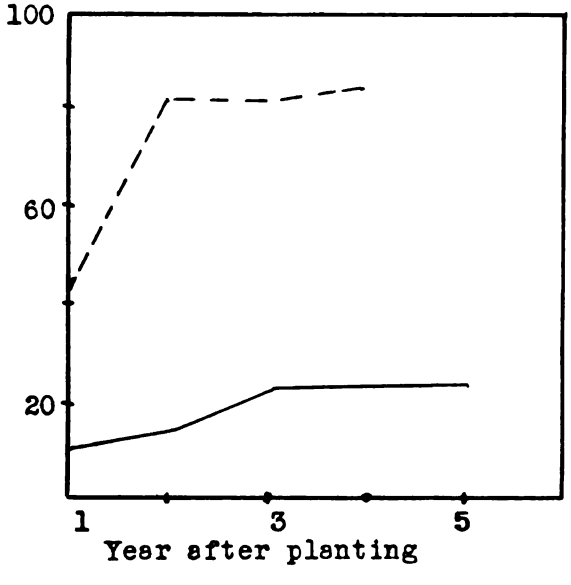


Fig. 41.

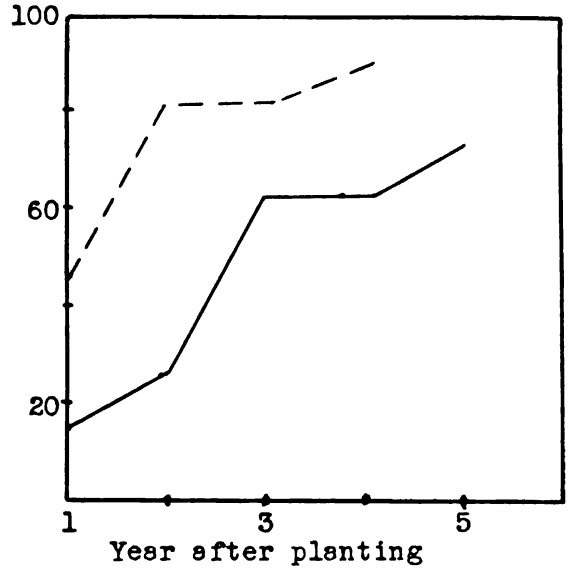


Fig. 42.

average. While losses on unfurrowed areas ranged up to 17 per cent above the average for that year, losses on furrowed areas were from 3 to 20 per cent below average.

More significant differences are brought out in figures 42 and 43 and Table VIII which compare the losses in 1932 and 1933 plantations for the entire period. Furrowed areas of red pine show losses from 9 to 26 per cent lower than on unfurrowed areas. With white pine, differences up to 27 per cent occur in favor of the furrowed areas. The main reasons for the almost complete failure of the 1933 plantations may be due to the fact that no furrowing was done before planting.

COMPETITION

The intensity of competition is shown to have some effect on the survival of plantations on the Kellogg Tract. In the 1932-1933 plantations, losses are about 10 per cent lower on acres having light competition than on those having heavy competition.

In the 1932 plantations, the differences in losses seem to occur mostly during years in which drought is not a serious factor. For example, in the case of the 1932 white pine plantations, losses during the favorable years of 1932 and 1933 are 25 to 30 per cent below average on areas of light competition, but in 1934, a year of severe drought, the losses are but 8 per cent below average.

In contrast to the better results in the earlier plantations on areas of light competition, the 1935 plantations had losses 5 to 9 percent under similar conditions.

It is logical that areas with heavy competition should

have greater losses than areas with light competition during years of favorable moisture conditions. In such years, a heavy stand of bluegrass would dry out the soil more rapidly than would the lighter growth. A condition similar to that produced by drought would soon result in the soil supporting the heavy cover, even while the less heavily vegetated area still had ample moisture. Thus there would be heavier losses on the areas with heavy vegetative cover. Moist years also tend to promote a luxuriant development of blue grass which often smothers the young trees especially if there has been no site preparation.

AGE OF PLANTING STOCK

The 2 - 2 planting stock gave 16 per cent greater survival than 3 - 0 stock and 12 per cent greater than 2 - 1 as shown in table IX and figures 46 and 48. While age of planting stock is a factor of unquestioned significance, its effects may be easily outweighed. Older, larger stock gave best results under heavy competition but even 2 - 0 stock gave excellent results where competition was controlled by furrowing.

CARE IN PLANTING

Table X gives the survival data during the first year on ten sample plots containing twenty-eight trees each, planted by different crews. Survival data vary from 57 to 89 per cent. Observations on extreme cases show almost complete losses for some crews and complete survivals for others.

Furthermore, general successes of plantations using forest school students was higher than with ordinary labor. Most dead

TABLE VIII. MORTALITY PERCENT WITH DIFFERENT METHODS OF SITE PREPARATION

3 - 0 RED PINE

Preparation	No. of trees	Mortality percent each year, based on number of trees alive in the spring of each year. Years after planting					Total Mortality %
		1st	2nd	3rd	4th	5th	
Furrowed	300	18	0	9	0	0	26
None	300	29	13	23	0	0	52
Furrowed	85	6	5	4	0	0	15
None	55	0	2	2	0	0	6
		3 - 0 WHITE PINE					
Furrowed	125	25	40	0	39	--	73
None	75	77	94	0	100	--	100
Furrowed	65	3	6	26	5	7	40
None	70	0	13	16	6	12	40

Mortality Percents of Furrowed and Un-Furrowed Plantations

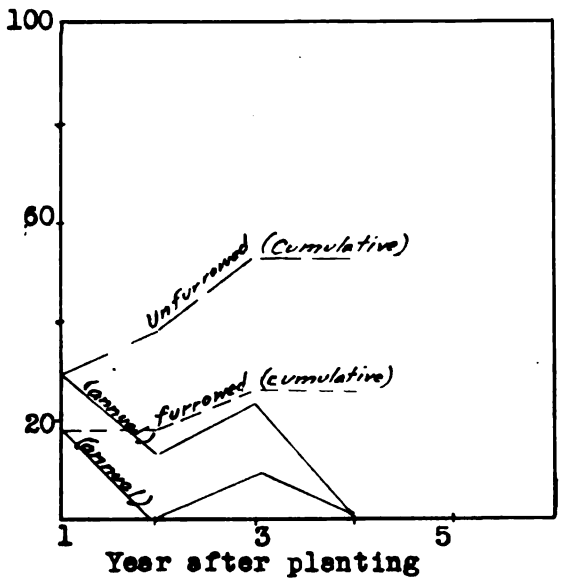


Fig. 43. Red Pine

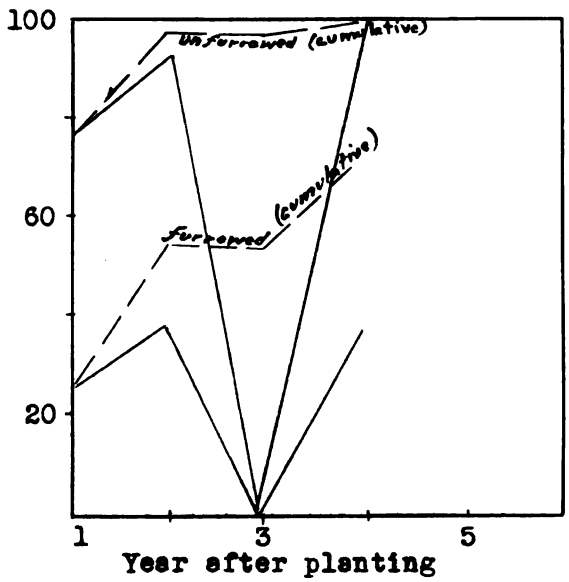


Fig. 44. White Pine

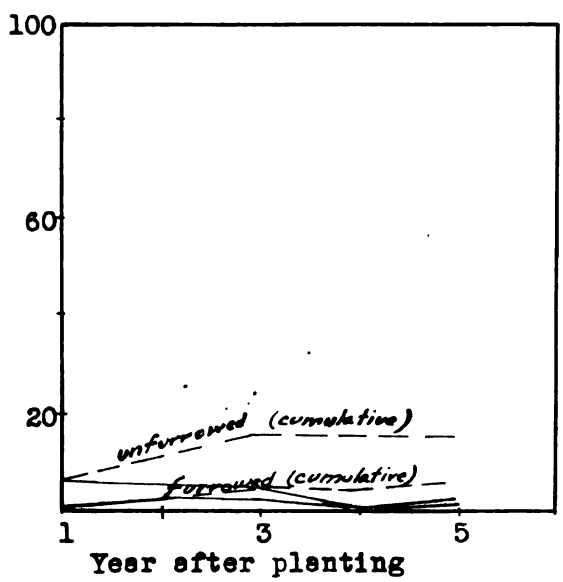


Fig. 45. Red pine (compet. light)

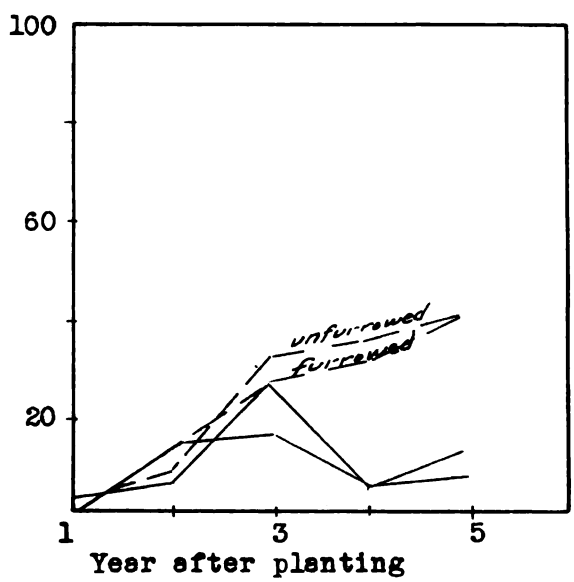


Fig. 46. White pine (compet. light)

Mortality Percents of Different Age Classes

Of White Pine Planting Stock

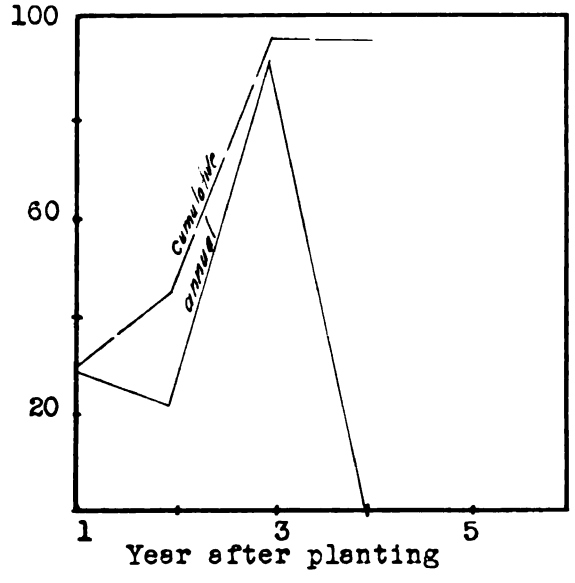


Fig. 47. 3 - 0 Stock

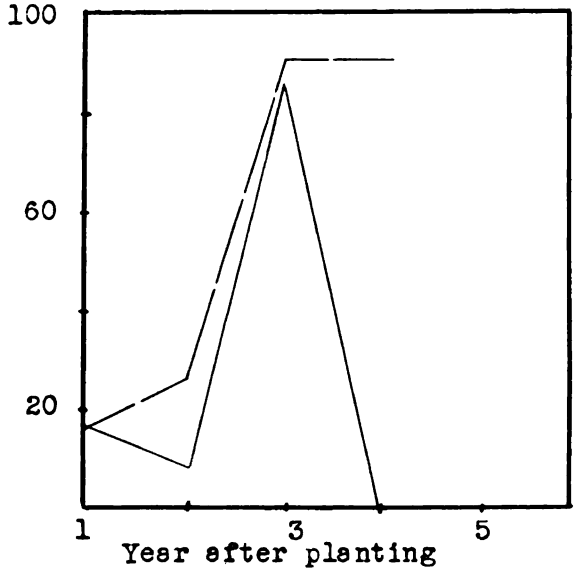


Fig. 48. 2 - 1 Stock

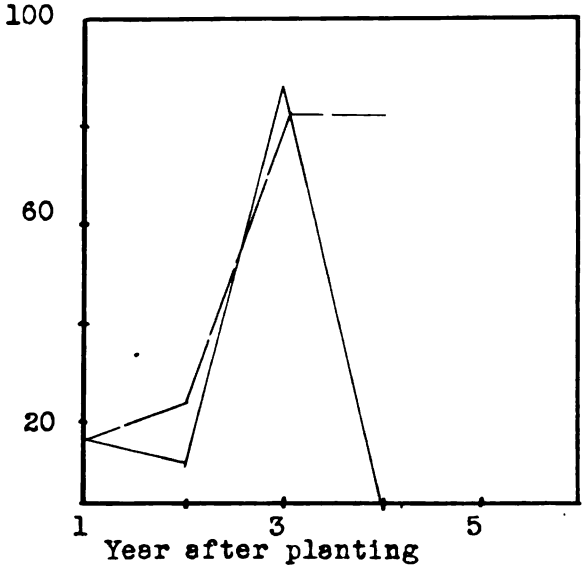


Fig. 49. 2 - 2 Stock.

TABLE IX. SURVIVAL OF DIFFERENT AGE CLASSES OF WHITE PINE

Stock	% Loss by Year			Final % Survival based on original number planted
	1st	2nd	3rd	
3 - 0	72	79	9	5
2 - 1	83	91	12	9
2 - 2	88	92	16	21

trees from the larger stock had been shallowly planted and the root systems were bunched and knotted. Care in planting without doubt can be one of the major factors in the survival of forest plantations.

TABLE. X. SURVIVAL DURING FIRST YEAR
ON TEN SAMPLE PLOTS OF 28 TREES EACH
PLANTED BY DIFFERENT CREWS

	Actual Survivel	% Survivel	
Row # 1	17	61	- 8.3
2	18	64	- 5.3
3	17	61	- 8.3
4	18	64	- 5.3
5	18	64	- 5.3
6	24	86	+ 16.7
7	21	75	+ 5.7
8	25	89	+ 19.7
9	16	57	▼ 12.3
10	20	72	▼ 2.3
Average	19.6	69.3	

Mortality Percent of Different Species

Annual Mortality Percent (based on number alive in spring)

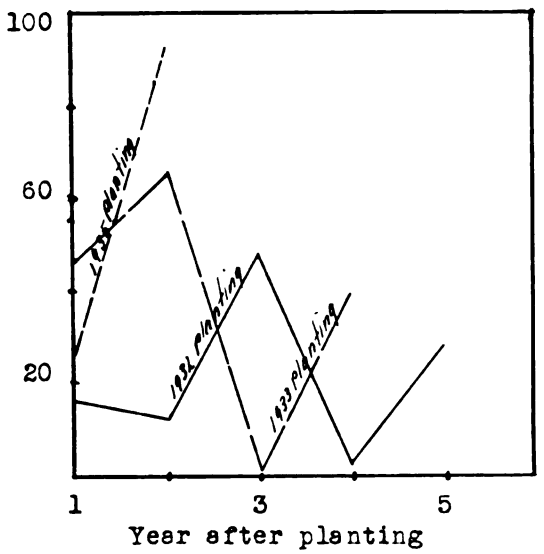


Fig. 50. White pine

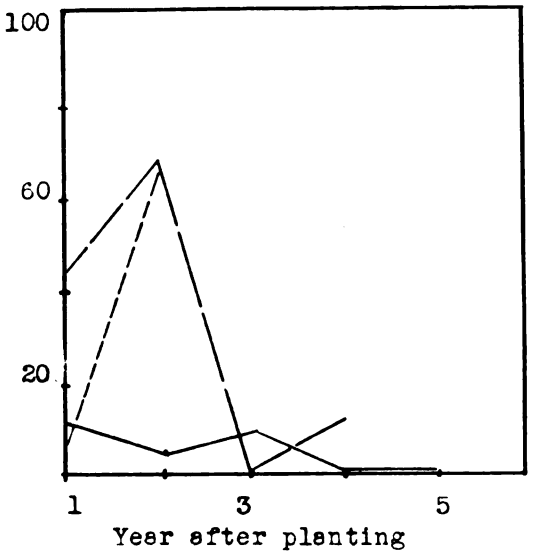


Fig. 51. Red pine

Cumulative Mortality Percent

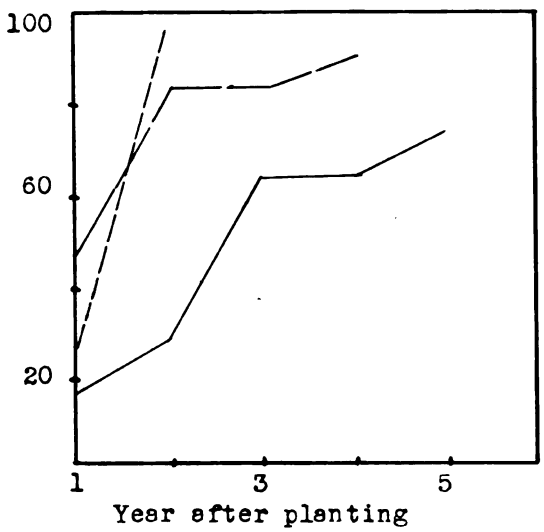


Fig. 52. White pine

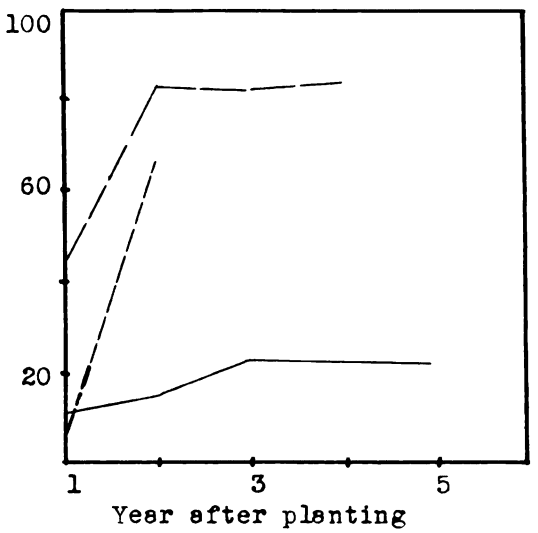


Fig. 53. Red pine

TABLE XI. MORTALITY PERCENT BY SPECIES

Species	No. of trees	Mortality Percent each year based on number of trees alive in the spring of each year					Total Mortality percent
		1932	1933	1934	1935	1936	
1932 Planting							
Red Pine	618	10	4	9	0	0	22
White Pine	520	16	13	48	3	27	73
Spruce	356	15	30	90	0	0	94
1933 Planting							
Red Pine	325		43	67	0	11	83
White Pine	350		47	66	0	39	89
1935 Planting							
Red Pine	399				4	64	65
White Pine	564				27	93	94
1936 Planting							
Red Pine	778					49	49

Mortality Percent of Different Species (cont)
Norway Spruce

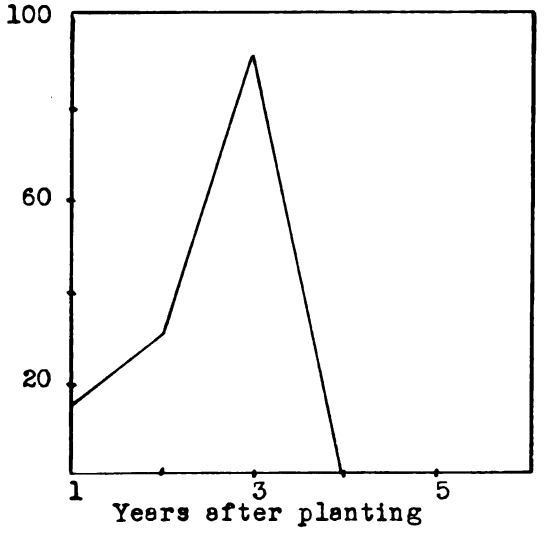


Fig. 54. Annual Mortality Per cent (based on number alive in spring)

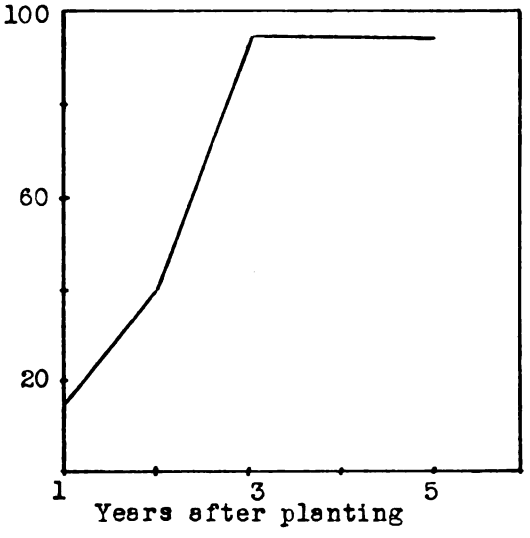


Fig. 55. Cumulative mortality percent

SPECIES

Table XI and figures 49 and 54 show the mortality per cents of the several series of plantations on the basis of species. White pine suffered losses amounting to from 73 to 94 per cent. Red pine losses are from 6 to 51 per cent below those of white pine for similar conditions. On the whole, red pine is much more satisfactory than white pine for planting under conditions similar to those prevailing at the Kellogg Reforestation Tract. Losses of Norway spruce were even greater than for white pine.

FACTORS

Insect damage was confined to that done by Tortrix pallorana, the larvae of which seriously damaged the buds and new growth of white pine, Scotch pine, ponderosa pine, pitch pine, Japanese red pine and others. Only red pine appeared immune to damage by this insect. The heavy mortality of white pine probably is due in part to this insect damage. Lowered vigor and reduced height growth no doubt lengthen the time required for the trees to become established and therefore the period during which losses occur.

Rabbits have done only minor damage to the plantations. Mice and other rodents likewise have done relatively little damage. Certainly they have not been serious factors in tree losses at the Kellogg Reforestation Tract.

SUMMARY

1. The first three years after planting were the most critical. White pine losses continued over a longer period of

years than red pine. Once established, forest plantations showed little loss from severe drought conditions such as those of 1936.

2. Droughts of over 20 days when coming early in the season, or if accompanied by extremes of temperature caused heavy losses. Early summer droughts were much more effective in causing losses of red pine and white pine than were late summer droughts. Damage is greatest when severe droughts occur in the first or second year after planting. Once established, the plantations survived severe droughts with little or no loss. In so far as rainfall is concerned average years should be favorable to the establishment of forest plantations in southern Michigan.

3. Frost heaving damage was severe on plantations set out during the fall seasons of 1931 and 1936. Mulching appears a necessary precaution for fall planting at the Kellogg Reforestation Tract and probably applies for all of southern Michigan.

4. Red pine showed slightly better survival on light soil than on heavy, whereas white pine did better on heavy soils.

5. During critical drought years losses on southerly aspects were markedly higher than on northerly aspects. Differences were less apparent in favorable years.

6. Slope had only a slight effect on establishment of plantations. As a whole, survivals were a little better on the more level areas.

7. Site preparation was of extreme importance. Where furrowing had been done, losses were considerably lower than

where no attempt was made to remove the sod near the trees. The nearly complete losses of 1933 plantations may be due to a lack of adequate site preparation, such as furrowing.

8. The losses of trees growing in competition with dense bluegrass sod have been higher than those of trees growing with less severe competition. This difference was less marked during the years of severe drought.

9. Losses of 2 - 2 white pine were lower than those of 3 - 0 and 2 - 1 on unfurrowed areas with heavy competition. Damage due to frost heaving was less with the larger stock. On furrowed areas, 2 - 0 stock of red and white pine were used with very satisfactory results.

10. Poor planting has been an important cause of losses. Careful planting is essential if high survival is to be expected especially during drought periods.

11. Red pine had better survival than did white pine. It became established more quickly than did white pine, and losses occurred for a shorter period of time.

12. White pine was subject to severe damage by Tortrix pallorana. This damage resulted in reduced vigor and growth, and thus lengthened the period necessary for this species to become established. Only red pine among the various conifers used appears immune to damage by this insect species.

13. Rabbits and mice have so far done very little damage to trees on the Kellogg Reforestation Tract.

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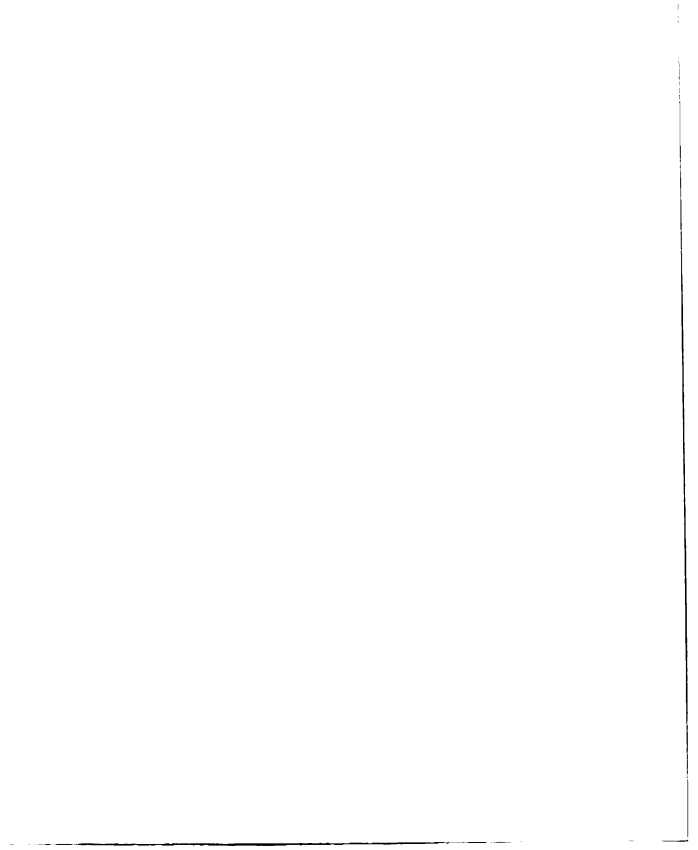

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