"NATURAL REPRODUCTION ON THE CLOQUET FOREST"

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NATURE OF STUDY

The region under consideration is in Carlton County on what is known as the Fondulac Indian Reservation. No study has been made in any detailed fashion that would give any information as to the geology and nature of the vegetation in this district, so that aside from the comparatively very small regions studied in three months no attempt will be made to generalize the topography and nature of the formation of the whole region from two thousand acres studied in the Experiment Station tract. From the Minnesota geological survey, 1896 to 1898, and from observations a year ago in this region, and from lumber reports, maps and all other available information, the region might be classed as the Great Lake Caniferous Formation, to separate it from the mixed conifers and hardwood formation farther south, and the hardwood and prairie formation still farther south and west.

The manner and method of study of the vegetation and the factors which determine the vegetation was that outlined by Doctor Clement in his "Research Method in Ecology." As this paper may throw some

light on ecological conditions found in this region of Minnesota, a brief account of the methods used will be given to make clear the kind of work started to those not closely familiar with this kind of work. This will be found on page .

In some work special lists have been made to give the relative importance of a species in each plot or quadrat studied. To those not familiar with the region, a map of each quadrat with each species located just as it is found, with different colored inks, gives a picture of the kind of vegetation that a list of names would never convey. As these are all supplemented by five by seven photographs a good idea of the vegetation may be obtained from a study of these.

Just as subdivisions are made of land according to the size of the units so likewise in vegetation different terms are applied to larger or smaller groupings of plants. The term formation is taken to mean an area of vegetation which is characterized by one or more prominent or controlling species. These are sometimes called facies, and so for example I have charac-

terized the northeastern part of Minnesota as the Great Lake Coniferous Formation, the prominent or controlling species being the cone bearing trees, Pines, Spruces, Fir , Tamarack and Cedars.

Somewhat as a county within a state, so each formation is made up of smaller areas or associations, the term consocies is sometimes applied to this smaller area. These are major parts of the formation and are made up generally of species which are not uniformly distributed, but which are always grouped together,, for example the Norway White Pine type very familiar in this region. In some places the White Pine will predominate, and in others the Norway, yet the two taken together would be called a consocies or Association.

A Society is an area controlled or characterized by some one principal species, as a Jack Pine Society, or Popple Society.

Communities are smaller groups of secondary species as Hazel in a Popple Society.

METHODS

The factors which determine vegetation as summarized in "RESEARCH METHODS" by Doctor Clements, are water content, humidity, light, temperature, soil wind, precipitation, pressure, altitude, exposure, slope, surface cover, and animals; among these water content, light, temperature and soil are the most important.

WATER - Water content in the region studied as in most others, must be considered the most important factor. In determining the water content of the soil, the first thing generally sought is the amount of water in the soil. For this purpose it is necessary to get an average sample of soil so that the results can be applied to the location from which it is taken, and also from other spots or areas which have the same soil and condition.

To get an average sample it is best to get an average of a large number of samples which have been taken over the area, as some factor of no importance

in the area as a whole may influence the few inches from which the soil sample is taken. The next thing is to take the samples at the same depth so that the water content of the soil at various depths may be known. This is important in determining the amount of water present either at the surface of germination of seed or at different levels for transplants or seedlings after germination. This is also important upon the root system of trees, the kind of weeds which will be likely to come in and many other like questions which will present themselves in this sivicultural work. The last requisite is that the samples must be taken over quite a long period of time and thruout the length of time that the plants will be affected by water in a growing season. Very often as in the region considered this year enough moisture may be present to cause a great deal of seed to germinate and an observer going thru would surmise that any tree would thrive in this location, but the water is also unevenly distributed so that at some future time there would not be enough water to keep the plants alive.

These observations should extend over a series of years and the average of these would give a very good idea as to the results to expect from a crop of trees in the future, where the water content was one of the factors to be taken into account. The extremes are also of great importance, the same as frosts with some fruit trees. They may do well for several years, but when the extremes come, these will determine the final outcome of whatever is under consideration for this work.

The most useful thing for taking soil samples is a geotome which is a hollow cylinder or tube sharpened at one end, with a handle on the other end to push it down into the soil, and a plunger to push the core of earth that has been cut by pushing the tube down into the soil. A ½ or ¾ inch diameter geotome gives the best results. These do not pack the soil too firmly and yet hold bog mud and like soil better than one of larger bore. The length may vary with the depth of the soil samples required. The outside of the tube

is graduated into inches or decimeters so that it is very easy to get the right depth of samples required.

After the sample has been taken the core is pushed down into something to be weighed. An aluminum soil-can being the receptacle most used, The most convenient size being about the size of a water tumbler. Several samples are generally taken at the same depth near each other, and all of these put in a can the weight of which is known. If the soil is to be carried any distance an air tight lid is screwed on the can and the sample may be carried to a scales or left for several days without losing weight. The can with the soil in it is then weighed; sometimes, if delicate enough, scales are available to the miligram, otherwise, in field work to a centigram which is close enough for all practical work. The soil is next heated at a moderate temperature, high enough to cause the water to evaporate in a few days, and yet not hot enough to cause any humus or organic matter to volatilize.

Many devices have been used to heat soil

Plate I

Plate I.

This illustrates the oven used in trying out soil samples. Two shelves would hold about fifteen cans, a lantern was put in one of these lard cans and the other one inverted over it. The samples would ordinarily dry out in thirty-six hours.

samples; an oven not too hot serves the purpose well.

In my work two five gallon lard cans one with shelves upon which to place the soil cans and a kerosene lamp, inside, and the other lard can inverted over it made a very good oven in which a dozen cans can easily be heated. After all the water had been driven off from a sample it was again weighed and the percent of water driven off, or what is known as the water content, was computed on the dry weight of the soil.

A record is kept for the season and from year to year of the water content for each depth of soil on each similar location or quadrat in each society of vegetation, and in this way the amount of water available at different times of the year at different depths can be estimated, and the extremes which will effect the trees determined.

A little thought on this will show the necessity of a continuous record and the work this year will be only a beginning in that line.

Aside from the actual water in the soil

to one not closely familiar with the country or location, and the vegetation associated with the water content in different soils in different locations, a thing of more importance would be the amount of water available in the soil for different trees or plants. Soils vary greatly in their ability to hold water as much a sponge differs from a rock. In sand nearly all the water is available for plant use;, about one-fourth of one per cent being all that is not available, according to Hedgecock, for plants used to living in ordinary, medium saturated soils, and called mesophytes. In clay about six to seven per-cent is withheld, and in saline soils about ten per cent.

To many the importance of the available water seems to outweigh the water content, and until one is familiar with the amount of water available in a certain soil for certain plants or types of vegetation, it is of the utmost importance, but after the amount of water available has been worked out for different species in different kinds of soils until

they become too large to get any reliable results, its usefulness stops.

If the amount of water in the soil is daily recorded for different depths for a growing season, and a certain species does well, and then as the water content drops, finally dies over an area, the results in the writer's estimation are much better than the available water computed by disturbing the roots and based upon individual plants which may be influenced by other factors.

This is not intended to mean that the available water determinations are not of great importance in grain and herbaceous vegetation where the material is of a size easy to manipulate and the results are very accurate; but is meant to be interpreted as believing that above the age of theseedling three or four years old the available water is determined with great difficulty and cannot give as reliable results as where the water content is recorded for the growing season and a texture of thesoil known.

To show how difficult this matter of de-

termining the available water for any but one and two year old seedlings, I will cite a few of my own experiences.

In order to get any idea of the available water, the plants must be selected from representative areas for each species, and each location, or different kinds of soil. For my work I used lard cans, large tin wash tubs, left at lumber camps, kettles and the like, large enough to hold all the roots and give as near natural conditions as possible. To dig a six to ten year old Norway White Pine or Spruce out of sand and transfer it to a receptacle so that the soil will not be cracked around it is no easy task in itself. Several trees are generally dug up before this is accomplished. Prof. Clements advocates putting tin or thin iron plates on each side and below the plant until it wilts. This may be all right in some locations where it never rains while the determinations are going on, but where this work was carried on the only way possible was to put them in cans etc., where the run-off and seepage would not effect them, and where they could be

shielded from the rain. This would work if enough men were working and the plants near enough to the base station. But to get the most accurate results the plants should be left in their own habitat. This necessitates the building of shade tents over the plant to keep out rain. These shades must be removed when it is not raining and replaced when rain falls. In several situations a study of this kind is an impossibility when rain storms come up quickly and only one man working at this.

To obviate these difficulties I transfer all plants and tubs and cans to a tent near mine and when rain threatened I hauled them in, and then put them out when the danger was over, trying as near as possible to put them in about the same shade condition they were originally in. No one who has never tried this will appreciate the length of time it takes a young tree with enough soil to embrace all its roots to die: another thing with conifers is that it is hard to tell from their appearance just when the plant has obtained all the water it can.

These are the reasons which have caused

me to believe that a continuous record of water content for various locations and a thorough knowledge of the physical condition of the soil will be most reliable for tree work.

HUMIDITY - By humidity is meant the amount of water in the air. This has a large influence upon the evaporation of water from the soil and likewise the amount of water given off by plants. If there is a great deal of water in the air the ability of the air to take up more water in the form of vapor is lessened and consequently the loss from the ground and the plant is small; on the other hand if the air is dry it will readily draw water from the soil and plants.

Plants lose water thru pores in their leaves. This loss is regulated to a greater or less extent by the leaves, but if the loss of water be greater than the amount taken by the plant from the soil, the leaves will wilt, and shrivel up and often die.

In order to determine the humidity of the air an instrument called a psychrometer is used.

This is an arrangement of two thermometers with a cloth wrapped around the bulb of one while the other is left free from covering. The cloth about the bulb of one is thoroly moistened and then the thermometers are rapidly whirled. If there is not much moisture in the air the water on the cloth will rapidly evaporate and consequently cool the bulb it surrounds. The cooling will take place only so fast as the water is evaporated and when this point has been determined the lowest point reached on the wet thermometer is compared with the temperature in the dry thermometer and the difference between them noted. This difference is then found in a table giving the humidity or amount of water in the air for all differences and all temperatures, and thus the humidity of the air is determined.

The humidity of the air plays an important part in determining the success of introduced trees which lose a large amount of water when they are moved to a dry situation where the amount of water in the soil is much less than they have been accus-

tomed to. The extremes of humidity are also of great importance, as a few days of very dry weather will sometimes kill plants which otherwise would survive.

In the work this year the humidity at the Station was determined three times a day for several months. The results in tabulated form will be found on Page_____.

TEMPERATURE - Temperature is a very important factor in the growth of forestry trees and this factor becomes more and more important the further north the trees grow. A long period, when the ground is frozen, corresponds to desert conditions, as no water is available. This causes the trees to adapt themselves to these conditions. The broad leaf trees gradually give way to narrow leaf trees or needle leaf trees, which have their leaves ready to work the first minute the ground thaws, and do not have to lose from three weeks to a month in budding and making leaves. In the fall with their deep roots they can get in a month or more of work when the leaves of the hard woods are killed

by the first hard frost. The rate of growth corresponds to the amount of food the tree can make. Roots cannot function properly when the temperature is below eight degrees C., or approximately this low. In many of the swamps the rate of growth is exceedingly slow, Tamarack, and Black Spruce taking twenty-five to thirty years to grow a half inch. The same condition of affairs is found on the tops of mountains where the roots cannot take up enough water even with snow banks around them, so that they may be a hundred years old and yet be only an inch in diameter.

In some of the swamps, ice is found around the roots of trees until the middle of July; this, of course, cut down the ability of the tree to make food, as the surface water was nearly ice cold and slowly seeped thru the ground.

According to Zon (Light in Relation to Tree Growth) "the higher the temperature the less light required, and the lower the temperature the more the light required." This, I think, may have a great deal of bearing upon the intolerance of a Tamarack and Black

Spruce in these locations. Enough work has not been done to warrant any direct statement on this theory, but the fact that the Tamarack is so much more intolerant in these cold swamps than in situations where there is not so much water but warmer soil seems to strengthen this idea. Spruces in situations where warmer conditions prevail are supposed to be among the most tolerant trees, having branches which persist from the ground up. This contrasts strongly with the dead branches found on two-thirds of the trunks of the more isolated Spruces in cold swamps where more light and water. More work on this problem will bring out many interesting facts.

HUMIDITY

Date	7 A. M.			1 P. M.			6 P. M.		
	Dry C.F.	Wet C.F	%	Dry C.F.	Wet C.F.	%	Dry C.F.	Wet C.F.	%
6/16	18-64	16-61	84	25-77	20-68	63	(Rain)		
6/17	25-78	19-66	51	23-73	19-67	73	22-73	17-62	53
6/18	25-77	17-62	42	28-84	18-64	27	21-70	17-62	64
6/19	22-72	18-64	65	31-88	21-70	40	31-88	20-69	43
6/20	21-70	18-64	72	23-73	18-64	61	16-61	14-57	78
6/21	21-70	17-63	68	31-88	21-70	67	25-77	20-69	67
6/22	23-73	19-66	69	26-78	21-70	67	16-62	10-51	45
6/23	10-51	10-50	94	15-59	13-55	78	10-51	9-49	87
6/24	10-50	9-48	87	23-73	18-64	61	23-73	21-66	69
6/25	(Rain)			23-73	21-71	91	17-63	16-62	95
6/26	(Rain)			21-70	18-64	72	21-70	17-63	68
6/27	11-52	9-48	75	13-56	10-51	70	12-53	10-50	81
6/28	12-54	9-49	70	18-64	13-55	56	11-52	9-48	75
6/29	(Rain)			16-61	14-58	84	13-55	12-53	88
6/30	26-78	21-71	71	24-75	19-66	54	28-84	22-72	56
7/1	28-84	22-72	56	34-93	24-76	43	27-80	20-68	54
7/3	19-67	17-62	75	30-86	20-68	50	24-75	20-68	68
7/4	20-70	20-68	90	(Rain)			(Rain)		

HUMIDITY (continued)

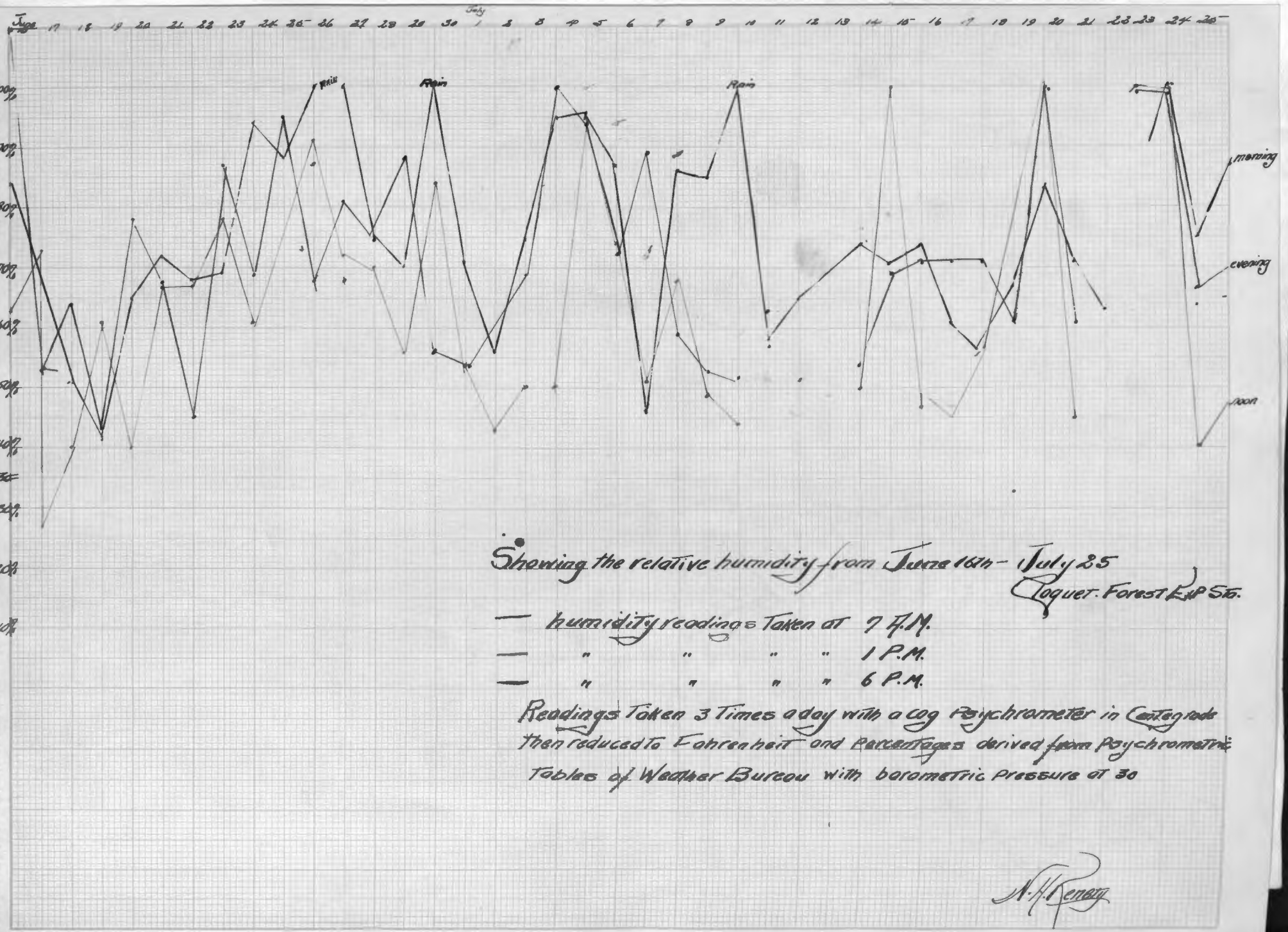
Date	7 A. M.			1 P. M.			6 P. M.		
	Dry C.F.	Wet C.F	%	Dry C.F	Wet C.F	%	Dry C.F.	Wet C.F.	%
7/5	23-73	22-71	91	25-77	21-70	74	16-62	15-61	94
7/6	11-52	10-50	87	24-76	18-64	51	24-75	19-66	62
7/7	17-63	11-52	46	20-70	17-63	68	16-62	15-59	84
7/8	23-73	21-70	86	32-90	24-75	49	29-84	23-73	59
7/9	20-68	18-65	85	- - -			- - - -		
7/10	(Rain)			27-80	18-65	44	23-73	16-62	53
7/11	16-61	12-53	58	19-66	14-57	57	16-61	12-54	63
7/12	16-61	13-55	65	- - - -			21-70	15-59	51
7/14	17-62	14-57	74	23-73	16-61	50	20-68	14-58	54
7/15	19-66	15-59	71	(Rain)			17-63	14-57	69
7/16	17-62	14-57	74	18-64	12-53	47	13-56	11-51	71
7/17	14-57	10-50	61	- - - -			14-57	11-52	71
7/18	15-59	12-53	67	19-66	14-57	57	14-57	11-52	71
7/19	14-58	13-55	83	27-80	16-61	33	18-65	14-57	61
7/20	17-62	13-56	71	(Rain)			(Rain)		
7/21	15-60	12-53	71	22-72	15-59	45	15-59	11-52	61
7/23	(Rain)			(Rain)			(Rain)		

HUMIDITY (continued)

Date	7 A. M.			1 P. M.			6 P. M.		
	Dry C.F.	Wet C.F.	%	Dry C.F.	Wet C.F.	%	Dry C.F.	Wet C.F.	%
7/24	11-52	9-48	75	(Rain)			(Rain)		
7/25	11-52	10-50	87	19-66	12-52	40	15-59	12-53	67
7/26	18-64	13-56	60	- - - -			- - - -		
7/27	19-67	15-59	62	27-80	19-66	47	(Rain)		
7/28	(Rain)			(Rain)			(Rain)		
7/29	"			"			"		
7/30	"			"			24-74	20-68	50
8/2	17-63	14-58	74	21-69	15-59	55	20-68	16-61	67
8/3	17-63	15-59	79	19-66	16-61	75	(Rain)		
8/4	(Rain)			21-69	18-64	76	20-66	16-61	67
8/5	16-61	15-59	89	- - - -			22-71	18-64	81

The average humidity for the whole period covered by this table is as follows: for the morning 74.27 per cent; for noon, 62.38 per cent; and for the evening 70.17 per cent.

These readings were all taken in Centigrade, and transposed to Fahrenheit, and the humidity



Showing the relative humidity from June 16th – July 25

Coquet. Forest Exp Sta.

— humidity readings Taken at 7 A.M.
— " " " " 1 P.M.
— " " " " 6 P.M.

Readings Taken 3 Times a day with a Cog Psychrometer in Centegrade then reduced to Fahrenheit and Percentages derived from Psychrometric Tables of Weather Bureau with barometric pressure at 30

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obtained from the psychrometric tables of the United States Weather Bureau.

These humidities have been plotted in different colored inks. The humidity in the morning follows about the same curve as the noon humidity while the evening humidity seems to bear no direct relation to the other two.

Date	Depth in Cm.	WATER			
		Wet wt. can and soil	Dry wt. can and soil	Wt. of can	Percent
6/19	10	124	119.5	70.3	.084
	20	141.4	135.2	70.7	.088
	30	147.5	141.	72	.086
6/20	10	143.	133.5	70.2	.13
	20	135.3	130.8	70.3	.069
	30	154.4	146.3	72	.99
6/21	10	150.2	140.	70.7	.126
	20	179.2	169.2	74.1	.095
	30	164.7	158.8	70.5	.062
6/22	10	146.5	141.2	67.5	.067
	20	163.	155.8	70	.077
	30	137.1	131.5	65.2	.078

WATER (continued)

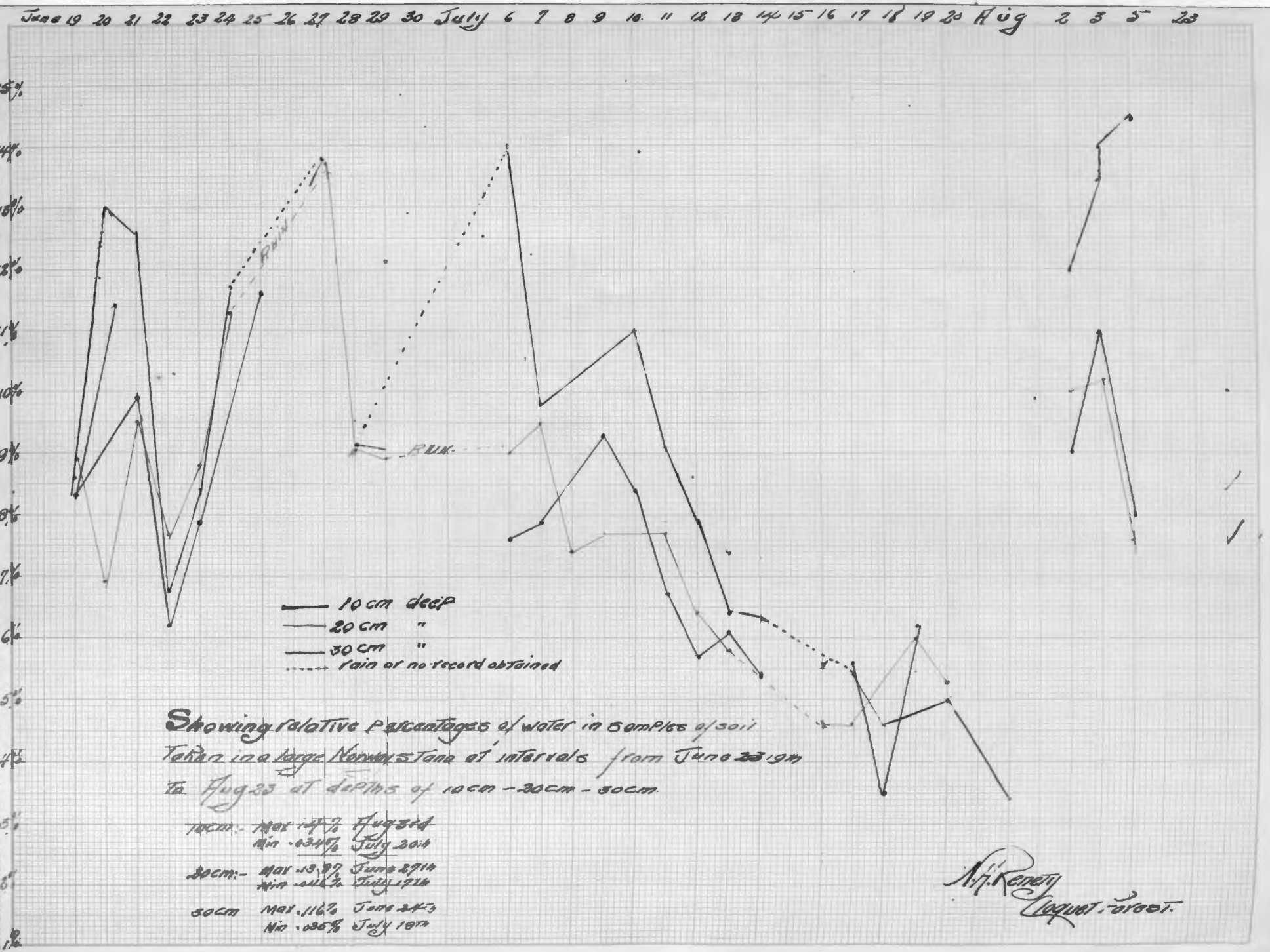
Date	Depth	Wet wt. can and soil	Dry wt. can and soil	Wt. of Can	Percent.
6/23	10	152.7	146.0	73.3	.884
	20	175	167.5	78.6	.088
	30	168.2			
6/24	10	123.5	117.5	72.7	.117
	20	131.8	124.8	70.2	.113
	30	129.	122.6	74.1	.116
6/27	10	136.5	128.5	78.6	.138
	20	117.2	110.	65.2	.138
	30	149.	142.5	70	.09
6/28	20	127.7	122.8	73.3	.09
6/29	20	134.9	128.7	65.2	.089
7/1	10	127.4-	113.5	73.2-	.117-
7/6	10	123.5	116.3	72.7	.14
	20	133.	127.2	67.5	.09
	30	134.5	129.2	65.2	.076
7/7	10	134.3	128.	78.6	.98
	20	135	128.8	70.2	.95

WATER (continued)

Date	Depth in Cm.	Wet wt can and soil	Dry wt. can and soil	Wt. of can	Percent
	30	145.5	139.5	70	.79
7/8	30	136.2	130.	70	.93
7/10	10	110.5	105.7	70.7	.11
	20	134.5	129.5	67.5	.074
	30	142.7	136.9	74.1	.084
7/11	10	128.5	123.4	72.7	.091
	20	141.4	136.	72	.077
	30	147.5	142.3	70.2	.067
7/12	10	121.4	117.5	70.7	.079
	20	132.7	128.5	67.5	.064
	30	130.8	127.	65.2	.057
7/13	10	121.5	118.8	73.3	.064
	30	139.	135.3	78.6	.061
7/14	10	116.3	113.2	67.5	.063
	20	138.6	134.7	72	.058
	30	142.7	138.5	65.2	.054
7/17	10	118	115.4	70.7	.054
	20	144.8	141.5	73.3	.046

WATER (continued)

Date	Depth in Cm.	Wet wt. can and soil	Dry wt. can and soil	Wt. of can	Percent
	30	128.3	124.7	65.2	.056
7/18	10	118.7	116.3	67.5	.046
	30	139.5 n	137.2	74.1	.035
7/19	10	120.8	118.2	70.7	.051
	20	147.2	142.7	72.7	.060
	30	125.9	122.4	70.2	.062
7/20	10	120.7	119.3	67.5	.03
	20	140	136.1	65.2	.53
	30	154	139.3		
8/2	10	124.5	117.	65.2	.12
	20	145	137.4	70.2	.10
	30	144.6	138.	70.5	.09
8/3	10	106.7	101.5	70.7	.14
	20	139.8	133.	72.7	.10
	30	137.5	132.5	70	.11
8/5	10	116.7	107.2	65.2	.165
	20	142.5	137	70.2	.076
	30	151.8	145.3	70.3	.080



Showing relative Percentages of water in Samples of soil
Taken in a large Nonesuch Tank at intervals from June 23 19th
to Aug 23 at depths of 10cm – 20cm – 30cm.

10cm:- Max 14.1% Aug 3rd
Min .634% July 20th

20cm:- Max 13.9% June 27th
Min .618% July 19th

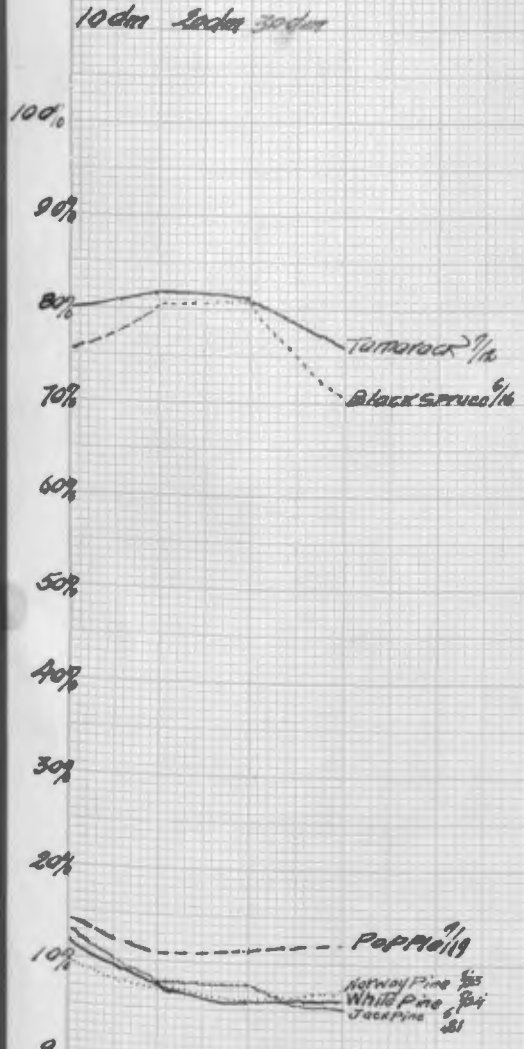
30cm Max. 11.6% June 24th
Min .036% July 18th

N. F. Kenety
August 1907.

The above water determinations were taken under a stand of Norway Pine, near camp, so that they might be compared with other situations. The stand contains no under growth of any kind; what there was consisted of pyrola, diervilla, grass, and cynoglossom, strawberry, kunistera, etc. The samples were taken at various places in the stand, three samples being taken for each depth, and these put into a can and the water content of this sample taken as the water content for that depth for each day.

COMPARATIVE WATER CONTENT OF THE DIFFERENT SITUATIONS

Species	Date	Depth	Percent
Black Spruce	6/16	30 cm.	71
" "	"	10	76.5
" "	"	20	80
Jack Pine	6/21	10	12.8
" "	"	20	8.8
" "	"	30	5.7



Showing Percentage of water in soil of forest situations at depths of 10-30-30 dm.

Cloquet Forest

W. H. Kenety

Species	Date	Depth	Percent
Tamarack	7/12	10	80
"	"	20	80
"	"	30	76
Poplar	7/19	10	14
"	"	20	11
"	"	30	11.8
White Pine	8/24	10	12
"	"	20	7.9
"	"	30	6.2

These samples of soil for the water content were taken from quadrats which were plotted. The vegetation for each of these quadrats may be found by referring to the charts.

SOIL TEMPERATURES

The following temperatures were taken in the same plot in which the water readings were taken at camp, and will serve as a sort of a standard to compare the temperatures of other situations with.

Date	1½ M.	Surf.	Depth 1 dm.	2 dm.	3 dm.
6/19	30.2	30.1	22	18.2	18.
6/20	23.2	24	19.5	17.1	17
6/21	32	33.2	21.8	17.6	17.5
6/22	26.4	26.8	20	17.8	16.8
6/23	14.4	18.	16.4	15.8	15.4
6/24	15.6	18	16.8	15.2	14.6
6/26	20	22	16.8	15.9	15.6
6/27	12.8	15	14.9	14.7	14.4
6/28	11.6	12.4	15	14.9	13.6
6/29	13.6	14.8	14.8	13.3	13
6/30	28	27.4	19.2	15.3	14.8
7/1	34	33.2	33.2	18.2	16.8
7/6	25.2	25.4	19.	17.1	16.4
7/7	22	23	18.8	17	16.4
7/8	30.8	32	21.5	19.2	17.4
7/10	25.4	23.6	19.8	17.3	16.8
7/11	16.6	18.8	17.6	16.8	16.2
7/12	20.8	22	18	16.4	15.8
7/13	20.4	21.2	18.2	16.2	15.8

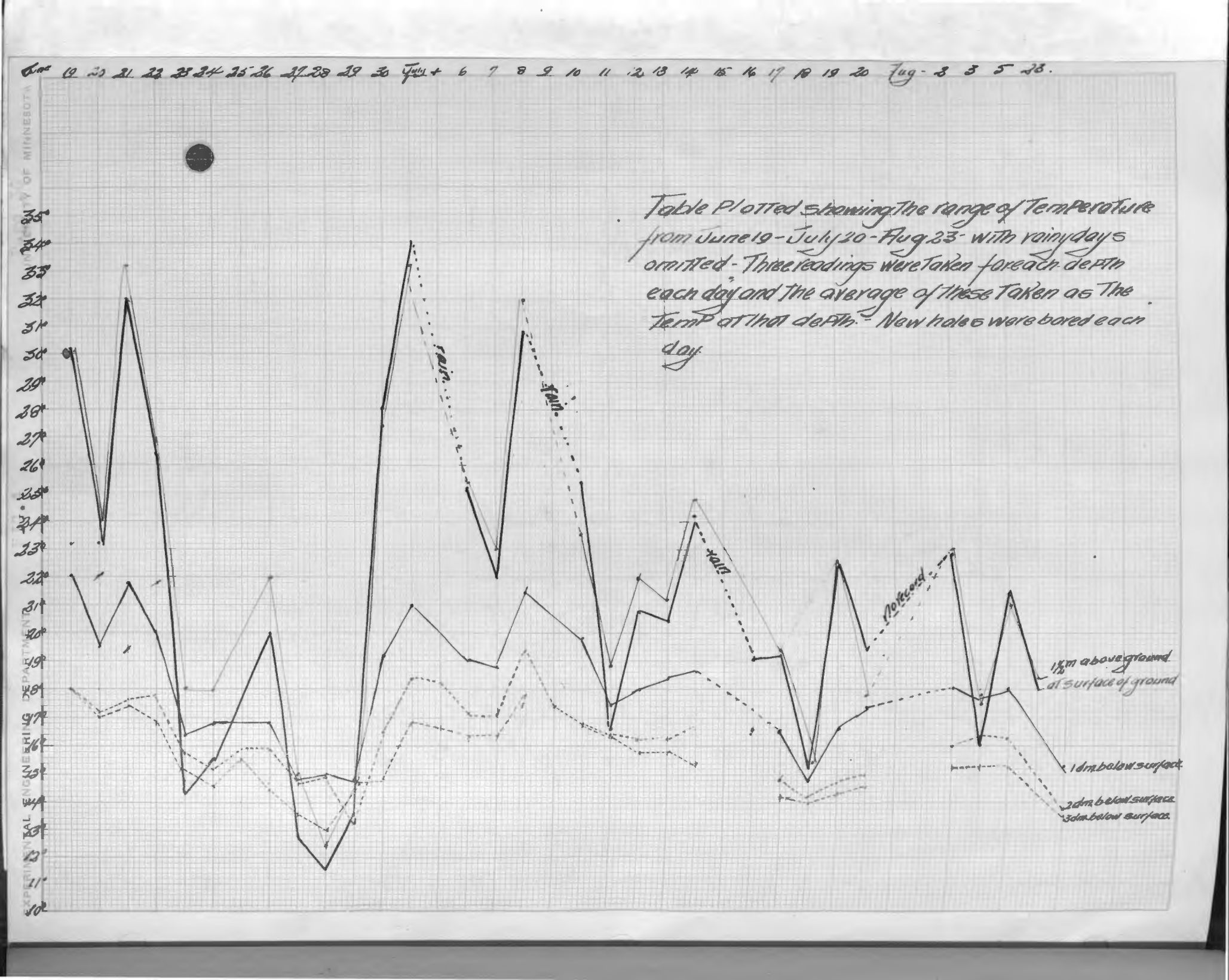
Date	1½ M.	Surf.	Depth. 1 dm.	2 dm.	3 dm.
7/14	24.2	24.8	18.6	16.2	15.4
7/17	19	19.2	16.6	14.8	14.2
7/18	14.6	15.2	14.8	14.2	14.2
7/19	22.4	22.4	16.7	14.7	14.3
7/20	19.4	17.8	17.4	15.	14.6
8/2	22.8	23	18	15	15.2
8/3	16	17.4	17.6	16.2	15.2
8/5	21.4	21	18	16.2	15.2
8/23	18	18.4	15.3	13.8	13.6

LIGHT

July 17 - Norway Quadrat, light value .15 Same Plot Solidago Society light value .16.

July 18 - Spruce Balsam Type, mature shrubs, Acerspicatum - Cornus stolonifera - Cornus canadensis - Floor cover, Coptis, Clyntonia unifolium - Pyrola, light value .033.

July 18 - Popple stand, crowns touching, undergrowth, Hazel, Wild Saraaparilla, Solomon seal, Epilobium, Honeysuckle, Wild ginger, Clyntonia, Ferns


June 19 20 21 22 23 24 25 26 27 28 29 30 July 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 Aug. 2 3 5 28.
Table Plotted showing the range of Temperature from June 19 - July 20 - Aug. 23 - with rainy days omitted - Three readings were taken for each depth each day and the average of these taken as the Temp at that depth. - New holes were bored each day
rain
rain
hail
Notecard
1½m above ground
at surface of ground
1dm below surface
2dm below surface
3dm below surface
EXPERIMENTAL ENGINEERING DEPARTMENT UNIVERSITY OF MINNESOTA

The following temperatures were taken at one and one-half meters above ground on the surface 1 dm., 2 dm., and 3 dm. below the surface, for all quadrats studied. The temperatures ran as follows:

Site	Date	1½ M.	Surf.	1 dm.	2 dm.	3 dm.
Tamarack	7/12	21	18.8	13.8	12.4	11.8
"	8/22	27	27.6	13	12	11.3
Popple	7/19	19.2	18.6	11.8	11.6	11.2
White Pine	8/24	16.8	16.8	13.2	13.2	13
Swamp	7/1	32.2	28.2	14.6	12.2	11.8
"	8/12	27	27.6	13	12.2	11.2

Plate ~

Plate 2

This is a method used in getting temperatures in a swamp where the surface sphagnum moss and full of water. If a hole is dug and a thermometer placed in the bottom, the surface water runs in and the exact temperature cannot be obtained. By using a post hole digger of this type the soil at any depth may be obtained down to 4 or 5 feet, and the temperature derived as illustrated.

Plate 3

This illustrates the very shallow root system of the spruce in swamp locations the roots being very shallow on account of the low temperature below the surface . More food can be obtained if these roots penetrate further into the mineral soil, but on account of the ice which often remains until August the soil is so cold that they cannot function.

Plate 3.

(cont.p.35)
Astor, Grass, Young Popple, light value .5.

July 21 - Quadrat and Popple Thicket, below both Popple and Under growth, composed of Hazel, Alder and Pin Cherry, light value .001.

July 28 - Crown of Norway, 18 inches in diameter, fairly open, light value .15,

July 28 - Same situation as above, light value .25.

July 28 - Same plot, under Jack Pine, light value .15.

July 28 - Clump of Young Norway and Young Jack, not in very good condition, under the shade of 6 to 10 inch Jacks, light value .15.

July 28 - Young Norway very thick, only Jack over head, light value .20.

July 28 - Same Plot, shade of Jack, light value .15.

August 9 - Norway Shade tree light value .18.

August 9 - White Pine, light value .15.

August 9 - In Tamarack swamp in quadrat mapped, light value .6.

In same swamp, August 9, light value .6

In same Tamarack Swamp, August 9, light value .6.

Norway and White clump 18 to 20 years old, light value .10, shade of older Norway some White Pine, most all Young Norway dead, light value .10.

Young Jack 20 years old, antennaria and wintergreen, thinly scattered underneath, light value .15.

Jack stand very thick, no reproduction, light value .13.

Under White Spruce on edge of swamp, large percent of Tamarack, ground cover, alder, maple, dogwood, fern, ground floor, wild licorice, potentilla, dwarf dogwood, wild sarsaparilla, pyrolla, clyntonia, sedge, light value .026.

Under Young Ash, 20 feet high, Tamarack swamp, Coptis, moss, wild saraaparilla, light value .03.

Shade of Acer spicatum, Tamarack swamp, underneath, very dense clump of Maple, lower leaves large in comparison with upeer, undergrowth ferns, coptis, borage, galium, triantalis, young balsam, light value .011.

White Pine Quadrat, light value .075.

White Pine Quadrat, light value .066.

Jack Pine Quadrat, alder Jack Pine, light value .075.

Jack Pine Denuded quadrat, light value .12.

Same Jack Pine denuded quadrat, light value .10.

Depp shade Jack Pine quadrat light value .06.

Medium Light Spot in Jack Quadrat, light value .10.

Under fern shade in above Jack Quadrat, light value .66.

Under sweet fern, in the open, in stand of burned, dead Jack Pine, light value .038.

Under sweet fern, in the open, light .04

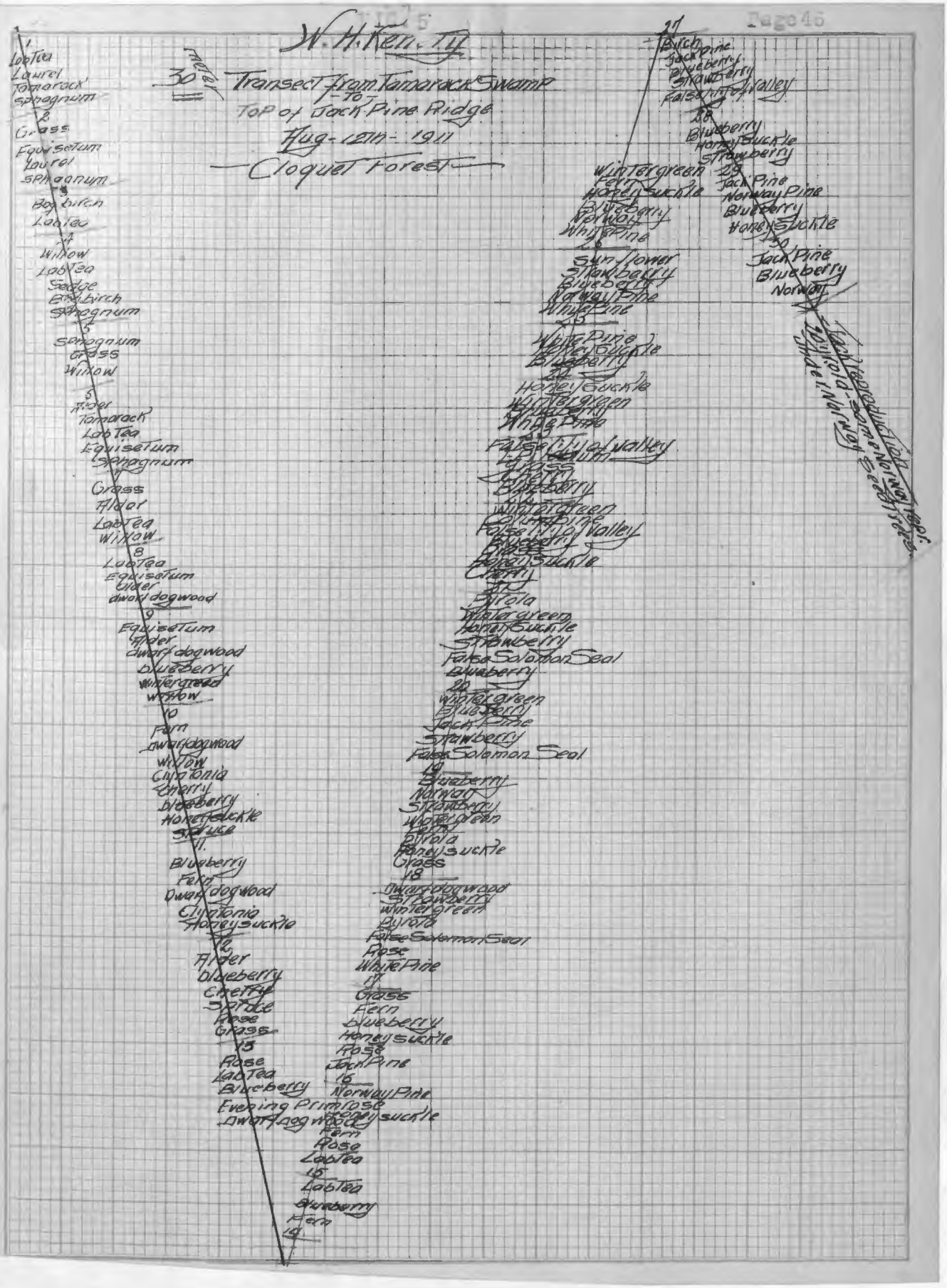
W. H. Keith

30 Chains

Transect From Tamarack Swamp To Top of Jack Pine Ridge

Aug-12th-1911

—Cloquet Forest—



30 METER TRANSECT FROM TAMARACK SWAMP TO TOP OF JACK PINE RIDGE.

August 12th, the transect was run from a Tamarack Swamp to a typical growth of Jack Pine, up an incline of about ten percent grade, to get the changes in vegetation brought about by the different ecological factors resulting from the difference in location.

The vegetation was taken at every meter for thirty meters, or about one hundred feet. About thirty feet were in the swamp, thirty feet up the slope and the remainder on the bench above. A glance at the accompanying transect plotted for each meter will show the different species found along the line. The number of each species was not tabulated as a transect varies so greatly if a narrow strip be taken, but all species within a half meter on each side of the tape making a belt one meter wide, were put down. The temperature was taken at every five meters and in this way an idea of the difference in temperature along the way was found and this correlated with the vegetation. Likewise,

water content was determined for each five meters to a depth of three dm. and this also correlated with the vegetation. Finally the light content was determined, and the three determinative factors compared with the vegetation.

Of course, the greatest difference in percentage would not show that the one showing the greatest difference was necessarily the factor which affected the vegetation alone.

The differences in temperature, water and light are arranged in the following table:

TEMPERATURE, WATER AND LIGHT READINGS OF TRANSECT.

M.	Temperature			Water			Light
	1 dm.	2 dm.	3 dm.	1 dm.	2 dm.	3 dm.	
				Average of three			
1	16.2	14.8	14.6		9.3		.4
3							.3
4							.15
5	15.8	14.8	14.6		8.4		.15
7							.4
8							.2
9							.3
10	16	14.4	14.2		12.2		.3
15	14.8	13.4	13.2				.15
20	13.4	12.2	12				.12
25	12	11.8	11.5		30.4		.3
30	13	H_2O	H_2O		100		.2

The vegetation for each meter may be found by consulting the plotted transect, and compared with these readings.

RE-PRODUCTION

One of the most important things to consider where re-production is sought by seeds is viable seed, that is, the seed whether it be sown by hand or dropped from a tree, must be able to germinate if it has the optimum of conditions. If it will not germinate any effort to bring about the optimum of conditions is time wasted. At the Cloquet Station a good deal of the seed sown was imported and so thegermination percent of the seed from native trees could not be determined in three months, as the seed would have to be gathered the year before.

In considering the trees found on the Cloquet Forest five, and possibly six trees on the outside may be classed as commercial trees. At the present time two of these are of little importance. Trees in order of commercial importance are White Pine, Norway Pine, Tamarack, Cedar, Jack Pine, and Black Spruce.

These conifers under good conditions principal of which are proper amounts of light, moisture

and heat, when they become mature, produce seed of a fairly high percentage of germination.

As is well known these trees have periodic seed years, at which time a large amount of seed is produced, and a small amount during the intervening years; so that the optimum conditions may be present and yet be an "off year", the re-production which will take place will be small, and perhaps lead to the erroneous belief that something is the matter with the seed.

The factors which will influence the germination percent of the seeds of these trees are very late frosts, or very dry years, as the summer of 1910, when the White Norway Cones on dryer situations around Lake Itasca had not fully developed their seed before the peduncles dried the cone dropped to the ground.

In Jack Pine the habit of the Jack Pine Cone to remain closed until heated and the base of the cone dried causing the scales to curve back and release the seed, often results in the seed being held for twenty years sometimes, and consequently it will become

too old to germinate well.

Another cause for poor seed is immature trees. Around Cloquet the only trees left by the lumbermen were those which were too small to pay for the trouble of cutting, and so the amount of seed produced per tree and per cone is much less than from mature trees, and the germination percent much lower as many of the seeds are poorly developed.

Fungi may destroy the seed in the cone on the tree or after the cone has dropped to the ground. I found no evidences of fungi infecting the cones on the tree, but I found large numbers of rotted cones on the ground with the seed destroyed before it germinated. This is particularly true of White and Norway Pine.

In many plants, insects may destroy the seed or ovules by laying eggs in or near the ovule and letting the larvae feed upon the young seed, but I know of no instance of it at this place in the trees discussed.

By far the greatest detriment to the germination of seed takes place after the seed has

fallen to the ground. They will often remain above the mineral soil until the power of germination has been lost, either drying up, or lying upon a litter of leaves they absorb some moisture, and swell up and freeze. A great many as stated before, absorb moisture, and are attractive lodging places for fungi, which soon renders them non-fertile.

Another cause for poor germination is the heat of a fire which may be intense enough to kill the embryos of the seed either on the tree or on the ground, but yet not bad enough to do much other damage.

The next requirement in the growing of trees from seed is that the seed must land in some favorable place for germination. This is generally called a seed bed, and means a place where the seed lodges whether it be on top of a rock or in a soil already prepared for it.

While germination plays a very important part in determining what the density of re-production would be, the seed bed is by far the most important factor in determining the establishment of a species.

A normal seed bed is one in which the conditions are best for germination and growth. It is only found in the best nurseries and seldom approximated in nature.

A seed bed may be a poor one due to a heavy layer of needles, leaves, or other vegetable material, all of which is sometimes considered under the name of "duff". This is often very thick under the Norway stands and Jack societies. This "duff" is detrimental in several ways. It may be so dense and thick that when the seed falls upon it, it is unable to obtain enough moisture to germinate at all. Again the "duff" may be moist enough to form a good breeding place for fungi, and when the seed falls upon it, it is soon attacked and rots. "Dampingoff" was quite prevalent in plots where there was a great deal of "duff", as high as forty to sixty percent dying in some plots.

The seed may fall upon moist "duff" and germinate, and yet after germinating the roots will not be able to penetrate down to the mineral soil, and so will not be able to get the necessary mineral salts

and consequently die.

Again the seed may sift down thru the "duff" andwhen it germinates the "duff" may have become packed over it in such a way that the cotyledons may not be able to push their way up and so the young trees are smothered. It was surprising to see the ability the pines had of pushing thru the "duff", some coming up several inches with seemingly little trouble. In some of the natural plots, however, where a very heavy mulch had been spread, many of them were smothered. This was much more true with Spruce than Pine.

The next consideration in the seed bed is the texture of the soil. Norway stands upon this forest where everything had been logged, but a few scattered trees, the ground was baked so hard that seed would have to be shot into theground to become covered with soil; as a result, the seed lay exposed upon the ground without germinating, and was very easily found by birds and chipmunks.

The importance of this compactness of the soil in the establishment of White Pine was well shown

by several quarter acre plots which were sown upon this hard, Norway cut over land, baked by the sun. The land had been cut the winter before and there was little under-growth, what there was, consisted mainly of blue-berry and honey-suckle. Some of the plots were dragged with a spring tooth harrow, once, twice, three times respectively. The land upon which no dragging was done had very few seedlings, due either to the fact that the birds got the seed or that it did not germinate. The ground dragged once, gave three seedlings to the square meter in the average of five quadrats taken at random, while in the two and three times dragged plots as high as twelve to fourteen were found in some meter square quadrats. Another thing which may make a poor seed bed is the absence of any mulch to retain moisture, keep the ground from baking and also to protect the seed from the birds. Of course, as stated in regard to "duff" too much of a mulch is a bad thing at some times of the year. It was necessary to remove it completely from the seed bed after the seed had germinated in order to

prevent "dampingoff", while at Itasca the reverse of weather conditions made it necessary to keep a mulch on the seed bed to prevent too great a water loss from the sandy soil. At Cloquet wherever a layer of needles prevented the soil from becoming too hard baked, the number of seedlings was greater, tho as remarked before, this may be partly due to the protection of seed from birds.

Another factor which contributes largely to the success or failure of a seed bed is the amount of moisture present for germination; for instance, some of the Jack Pine Sand land may be as mellow as the best seed bed, and have a covering sufficient to protect the seed from birds and animals, but if enough moisture is not retained to germinate and nourish the seed, theseed bed will be a failure.

At Cloquet the problem was not one of enough moisture to germinate, but the supply was not uniform enough to supply the young seedlings thruout the growing season, and they dried up and wilted. Reference to the rain fall on another page will show that

for the year 1911 the rain fall for growing months was above three inches for eahh month except April, and at that time there was usually enough moisture in the ground to prevent drying out.

It is safe to say that the uniformity of distribution of rain has a great deal to do with the establishment of a species in this region. This summer in many stands of Norway young seedlings have come up by the thousands; there is no evidences of fire for,from five to ten, twenty years, yet no two or three year old seedling could be found in these locations. The light readings averaged alight value of from fifteen hundredths to twenty hundredths. In another plot there was sort of a depression and Norway from four to eight years old were abundant. The light value was twenty hundredths, but the water content was higher, three average samples in this clump giving forty-six thousandths, forty-two thousandths and forty-five thousandths on July 17th, and a plot of young Norway reproduction at camp giving fifty-four thousandths for one dm. deep, forty-six thousandths for two dm. deep, and fifty-six

thousandths for three dm. deep on the same day, while vegetation under Jack stands on higher situations held water on the surface, but at three dm. deep the water in the Jack Pine situation was only thirty-two thousandths on July 17th.

There must have been just as good seed years as the fall of 1910. The seed bed was not touched, but the only explanation for the absence of young two, three and four year old Norway in these situations must be in the fact that the rainfall is not uniform enough to keep them growing for a couple of years until their roots get below the surface vegetation of the situation, such as vaccinium, winter-green, antennaria, etc., and do not have to compete so strenuously for water. In the situations studied, it must be admitted that the light value ran as follows: Norway plot fifteen hundredths, Norway plot sixteen hundredths, large Norway eighteen inches in diameter on the average plot fifteen hundredths and twenty-five hundredths in a less dense part of the same plot. In a young Norway a young Jack

stand in fair condition of growth fifteen hundredths, with only Jack and Norway very thick twenty hundredths, Jack Pine stands, trees about eight inches in diameter fifteen hundredths, Norway and White Pine clump ten hundredths, shade Norway and White Pine, most all the young Norway dead, ten hundredths.

This shows that at a light value twenty hundredths young Norway flourished. In many open situations young Norway were found this year, but no evidences of last year's seedlings or the year before could be found, so I believe that the seed gets plenty of moisture to germinate, may persist for one year, but thru the dry period in competition with the surface vegetation. After this it does not get much moisture and dies, and will survive only when after a couple of favorable years the roots are below the surface vegetation, and can draw upon the water below. The correctness of this view can only be determined by watching the quadrats staked out for several years, and keeping the record of rainfall and light intensities and making absolutely sure what will cause them

to die.

A good deal has been said regarding birds and squirrels, seed trees, light, etc., but in many of these situations I feel that it is the unequal distribution of rain or scarcity of rain during the first few years of a young trees existence when it has the most competition for water that accounts for the scarcity of two to five year old seedlings. After once past this stage and from two hundredths to twenty-five hundredths light values as a minimum, I think they will grow and persist.

A seed bed may be bad on account of the fungi which may be present in the soil. This is particularly true of an artificial seed bed, and in nurseries which are used repeatedly sterilization of the soil should be a good thing. "Dampingoff" was bad last year. I tried sulphuric acid after they began to dampoff. A three percent, two percent and one percent strength solution was used. The three percent killed every seedling in a plot containing several hundred. About fifteen out of over a hundred survived the two

of it. Blue-berry was one of the main weeds under dense Jack Pine - Honeysuckle under Norway - Labrador Tea under Black Spruce - Bog Burch, grass and Laborador Tea under Tamarack. Aside from the shade cast by this ground-cover which hinders materially the success of young seedlings, the young seedlings have to compete for water and mineral salts so that in the denser growths few survive. Inmany areas examined where seed trees had been left in Popple and Hazel, very few seedlings could be found.

When an area has been logged or grown up to weeds with no reproduction the policy of running a ground fire in a heavy seed year or when it has been logged and seed trees have been left, may do away with the weeds, and the young seedlings given a chance to develop with shade enough cast by the ferns and other plants which will come in immediately.

As to animals which are injurious to reproduction, squirrels, birds, and mice are the worst enemies. The chipmunks are very numerous and in the

percent, and about one-half to three-fourths lived thru the one percent. These plots were examined about two months later around September 1st, and those which had survived the sulphuric acid treatment were still alive. The solution was sprayed over the soil and mulch. In natural reproduction, many of the seedlings this year, quite far distant from others, were found attacked and killed by this disease. No remedy can be suggested for this disease, but its presence must be noted and its damages measured so as not to attribute the cause of poor reproduction to some other controllable factor.

Another factor in reproduction is weeds. A glance at some of the quadrats will show that in some situations the ground is covered by a dense mass of young shrubs; sweet fern under scattered burned Jack Pine gave light readings of four hundredths, thirty-eight thousandths, six hundredths. This shrub grew from one foot to eighteen inches high, and would shade out any seedlings. Some of the pictures of this shrub will show its density. Whole areas were a dense mat

swamps get most of the cones. Among the pines the sweet fern seeds furnish the chipmunks with food so that the birds are the worst enemies to contend with in the pine formations. Their chief harm lies in the fact that if they miss the seed when it falls to the ground they make up for it when it is brought above ground by the cotyledons. On the Pine the seed cpat remains on for a week or more after the young plant has pushed thru the ground. Elevated as the seed coats are upon the stalks and cotyledons, the birds see them before anything else, and pick the seeds. This generally takes the top of the plant with it andthe young seedling is done for.

The song sparrow, silver throat sparrow, and wood thrush are the most numerous; mice and moles did most of their damage to seedlings in the nursery.

Conclusions - The foregoing must be understood and thoroly studied before any measure are taken to re-forest any area, or to advocate seed trees, planting certain species, etc., until the factors

which influence the reproduction of that species are thoroly understood. Moisture determination must show that a seed will establish itself in a location or some other species must be planted which is adapted to such a situation. Neither will it do any good to plant or sow a species where the photometer shows that in like situations under the same light value the species is not able to persist.

The rule of thumb must give way to more definite methods in studying the reproduction of a species or an area. The introduction of some new species or the establishment of a native species may in some situations be a total failure andthe assumption be that it will not thrive in such a situation because thefactors which determine its success are not known, and which possibly may be easily changed and the result be a complete success.

PRECIPITATION AND MAXIMUM AND MINIMUM TEMPERATURES.

APRIL

Rainfall

Date	Amount
4	.05
5	.75
8	.06
11	.08
12	.24
13	.19
18	.04
19	.31
27	.01
30	.02

Total- - - - - - - - - 1.75

The greatest ppt. in 24 hours .75.

Temperature

Mean maximum	52.8	Minimum	8
Mean minimum	26.6	Greatest Daily range	48
Mean	39.7	No. clear days	12.
Maximum	75		

MAY

Rainfall

Date	Amount
7	.12
10	.23
12	.02
14	.35
15	.34
16	..73
19	.98
22	.30
27	.03
30	.21

Total - - - - - - - - - - 3.31

Temperature

Maximum 92.8

Minimum 8

Mean 53.8

Mean maximum 70.8

Clear days 18

Mean minimum 36.7

Greatest daily range 58

Greatest ppt. in 24 hours, .98

Frosts 8

JUNE

Rainfall

Date	Amount
2	.065
4	.82
8	.34
10	.07
11	.51
15	.02
16	.45
25	.94
26	.17
29	.10
Total - - - - - - - - -	-4.07

Temperature

Mean maximum	71+
Mean minimum	44
Maximum	93
Minimum	32
Greatest daily range	46
Greatest ppt. in 24 hours	.94
No. clear days	16

JULY

Rainfall

Date	Amount
4	.69
5	.34
15	.11
20	.43
23	1.99
24	.04
25	.06
28	1.54
31	.94
Total - - - - - - - - - -	-6.14

Temperature

Mean maximum	79.6
Mean minimum	53
Mean	66.3
Maximum	97
Minimum	39
Greatest daily range	39
Greatest ppt. in 24 hours	1.99
No. clear days	14

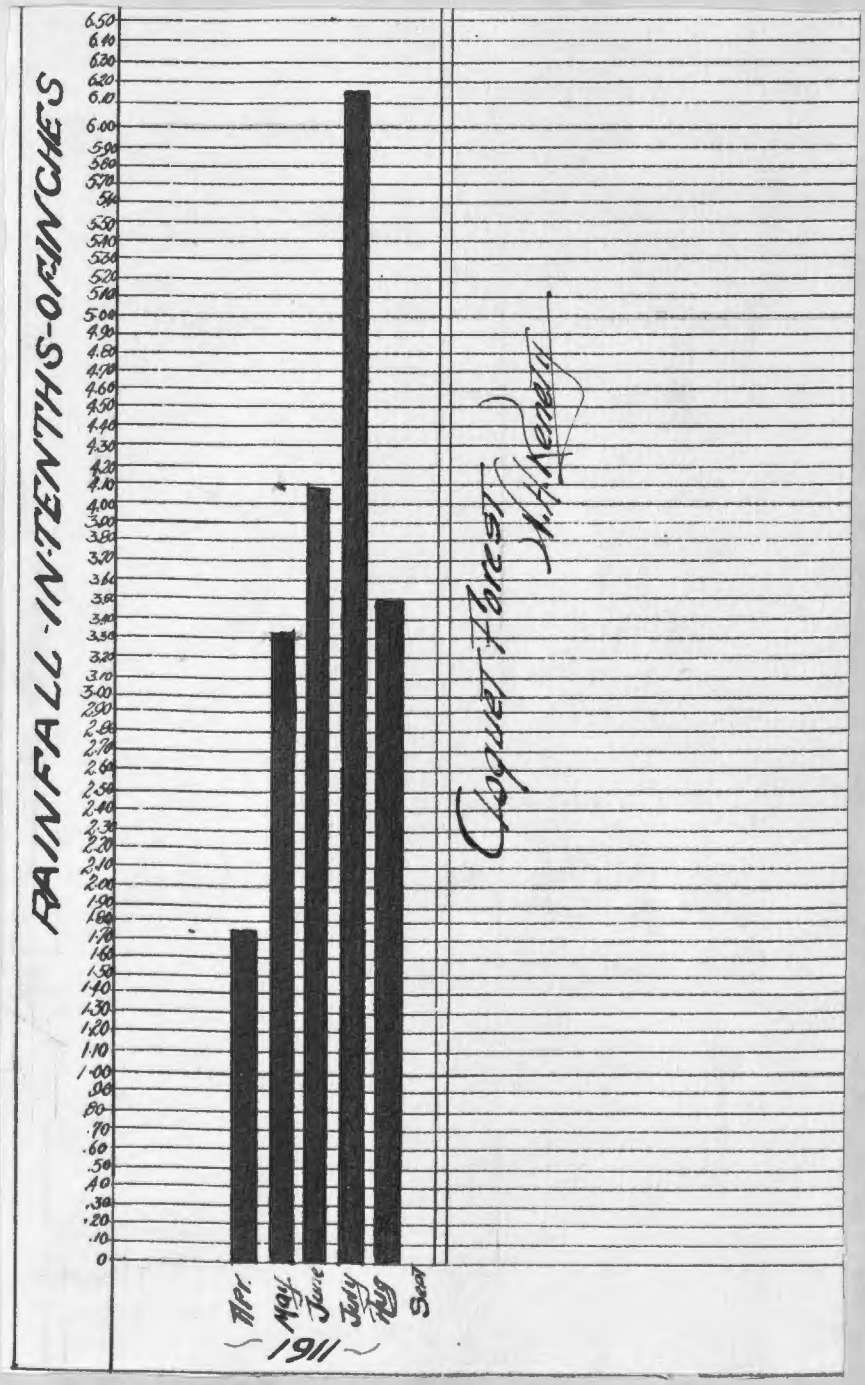
AUGUST

Rainfall

Date	Amount
1	.28
4	.06
7	.67
10	.25
15	.05
21	.90
27	.60
30	.68
Total	3.49

Temperature

Mean maximum	77.5
Mean minimum	46
Mean	61.5
Maximum	86
Minimum	39
Greatest daily range	48
Greatest ppt. in 24 hrs.	.90
No. clear days	14
No. frosts	3


RAINFALL - IN TENTHS - OF INCHES
6.50
6.40
6.30
6.20
6.10
6.00
5.90
5.80
5.70
5.60
5.50
5.40
5.30
5.20
5.10
5.00
4.90
4.80
4.70
4.60
4.50
4.40
4.30
4.20
4.10
4.00
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1.30
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
April
May
June
July
Aug
Sept
1911
Coquet Forest
M. A. Newell

Plate 4

Plate 4

This illustrates the formation of roots upon a layering branch. At the end of the branch several fruiting bodies of fungi may be seen, showing conclusively that this end was out of the ground. A good many of the roots were torn off in getting the branch out of the soil, but enough were there to show the nature and place of formation. Some of the secondary branches have already begun to push out and the method and manner by which future generation of trees may be formed by layering from one parent tree can be seen.

REPRODUCTION BY LAYERING.

While investigating a quadrat in a group of Black Spruce, several apparently young spruce seedlings were found all flourishing and in a healthy condition. Upon attempting to pull these up to my surprise I found them attached to live trees often five to ten feet distant, and in some cases to fallen trees, partly covered with vegetation, and in other cases I found a young tree with a dead end often protruding above ground.

Upon investigation in this plot and others I was not able to find a single young Spruce Seedling altho the Spruce cones were very abundant. The ground was full of pools of water in the sphagnum moss so that there was little chance of germination and establishment in that way; what young trees there were there, were all produced by layering and these would average from five, fifteen to twenty in a ten meter quadrat.

Very little literature has been published

on this kind of reproduction in the conifers. Cooper six months after these observations were made, published a paper in Botanical Gazette, Volume 52, in which he described with a picture, layering of Balsam Fir (Abies balsamea) and mentions that layering is quite common in other species, even Tamaracks, around Lake Superior.

Investigations by Prof. Cheyney, after observing the layering of Spruces at Cloquet revealed the fact that this layering was common in the swamps around Lake Itasca, and so altho further investigations must be made, it is probable that reproduction of balsam Spruce in the muskegs of northern Minnesota is not alone as has hitherto been supposed by means of seed, but largely by layering.

With the exception of Cooper's late reference Sudworth and Clements have reported layering in America, and these refer only to western firs.

In all cases of layering the growth of side branches near the ground is necessary as the branch must have some connection with the mother tree

and get its food and water from it until it can send roots of its own down from the branch into the moist substratum below. After the young ones which have gone down from the covered branch, have begnn to function the branch looses its tendency to grow at right angles to the main trunk andassumes the upright position of a young seedling. The accompanying plates will show each characteristic quite plainly.

In some cases fifty year old trees which had been wind thrown or prostrated for other reasons and whose branches were pushed down and quickly covered up by the sphagum moss gave rise to young layering trees, while the old trunk decayed away and probably in a few years no indication of the original parent of these young trees will be found.

In some cases the young trees when pulled up were found to be the old branches with the ends where once attached to a tree completely severed, and no indication of where they were derived from.

In the muskegs around every old Black Spruce the branches will nearly always be found to be

dead on the main trunk except just near the top, but around the base a group of young trees will be found which have sprung up around the old tree. When the origin of these is looked into and the moss, bog Birch and other vegetation, is removed from the base of the tree, these clusters of young trees will be found to be attached to the old tree in various stages of separation, and their own roots which have been sent down into the moist moss are furnishing water and dissolved salts which originally were supplied by the roots of the parent tree.

Whole stretches of country are made up of this muskeg formation and the importance of layering in the gradual succession of trees to the herbaceous growth is of great importance. The importance of this in the study of natural or aritifcial reforestation of swamp lands is seen, for, until this year, no mention has been made of this method of reproduction, yet to the casual observer thousands of these young trees show themselves, and the idea prevalent at this time is that they arise from seed and that the

reproduction from seed is very good. When the great stretches of Spruce Forest in northern Minnesota and the importante of the paper industry in this state which depends entirely upon Spruce for pulp wood is considered, it is apparent that this recently discovered method of reproduction is worth while, and should be studied on account of its economic importance, as well as from its ecological bearing upon the succession of vegetation. It will be an important factor in the final disappearance of swamps and muskegs and the growth of forests in their place..

Plate 5

Plate 5

This shows the first stages in the formation of the muskegs. The one time lake is slowly filling up with vegetation, sedges and rushes are seen in patches all over the surface. On the edges leather leaf, bog birch, swamp laurel are taking the place of the sedge and rushes, back of these on the further side the black spruce may be seen. its dwarfed layering specimens in advance forming a sort of picket line which will be increased by others as the vegetation slowly rises and the swamp fills up.

Plate 6

Plate 6

This shows a stage in the development of a muskeg a step further than shown in Plate 1. The water has disappeared from sight and a meadow-like growth of sedge with an occassional herb are now in possession of the tract. At the far side of the picture the spruce is seen enroaching upon the grass.

Plate 7 -

Plate 7

This shows a still further advance in the reclaiming of grass lands by Spruce and Tamarack. In the foreground the sedge and grass show up, gradually merging into leather-leaf which is a mat as may be seen in the center of the plate, with some laurel and bog birch scattered thru it, while the spruces are slowly establishing themselves in the herbaceous growth.

Plate 1.

Plate 8

This is a nearer view of the invasion of spruce into the muskegs. Note the scraggly appearance of the trees, the scarcity of foliage and the generally destitute condition they are in, due as stated before, to low temperature, and excess water oftimes acid.

Plate 9

Plate 9

A view of the invading spruces showing the characteristic method of reproduction in the muskeg swamps by layering. Notice the cluster of young spruce at the base of the older spruce.

Plate 10

Plate IO

This is a good example of the reproduction by layering. The tree held up by the axe to all appearances was a single normal tree. Upon clearing away the moss and vegetation this was found attached to the large tree on the left of the picture by a very small dead strand of wood. All of the water and mineral salts were derived from the soil by the roots of the branch itself, Note the curved appearance of the branch becoming perpendicular to the ground as soon as it began to have its own roots.

Plate II

Plate II

This shows the layering habit very well. All the trees in this illustration were at one time branches of the central tree. This was actually determined by digging and tracing them out. Any idea that they arose from the same cone is easily controverted by noticing the difference in size between the central plant and the others. The branches near the ground are kept moist and grow laterally until outside the shading of the branches above. The moss and vegetation rises very fast in these swamps, particularly in the open where the sunlight is full. Around the trees outside the shade of their branches this moss and vegetation grows much faster than below them. This causes a sort of mound to form around each tree and to rapidly rise and cover the branches just outside the place where the shade of the branches above falls. As the moss rises around the tree the lower branches and begin to root.

Plate I2

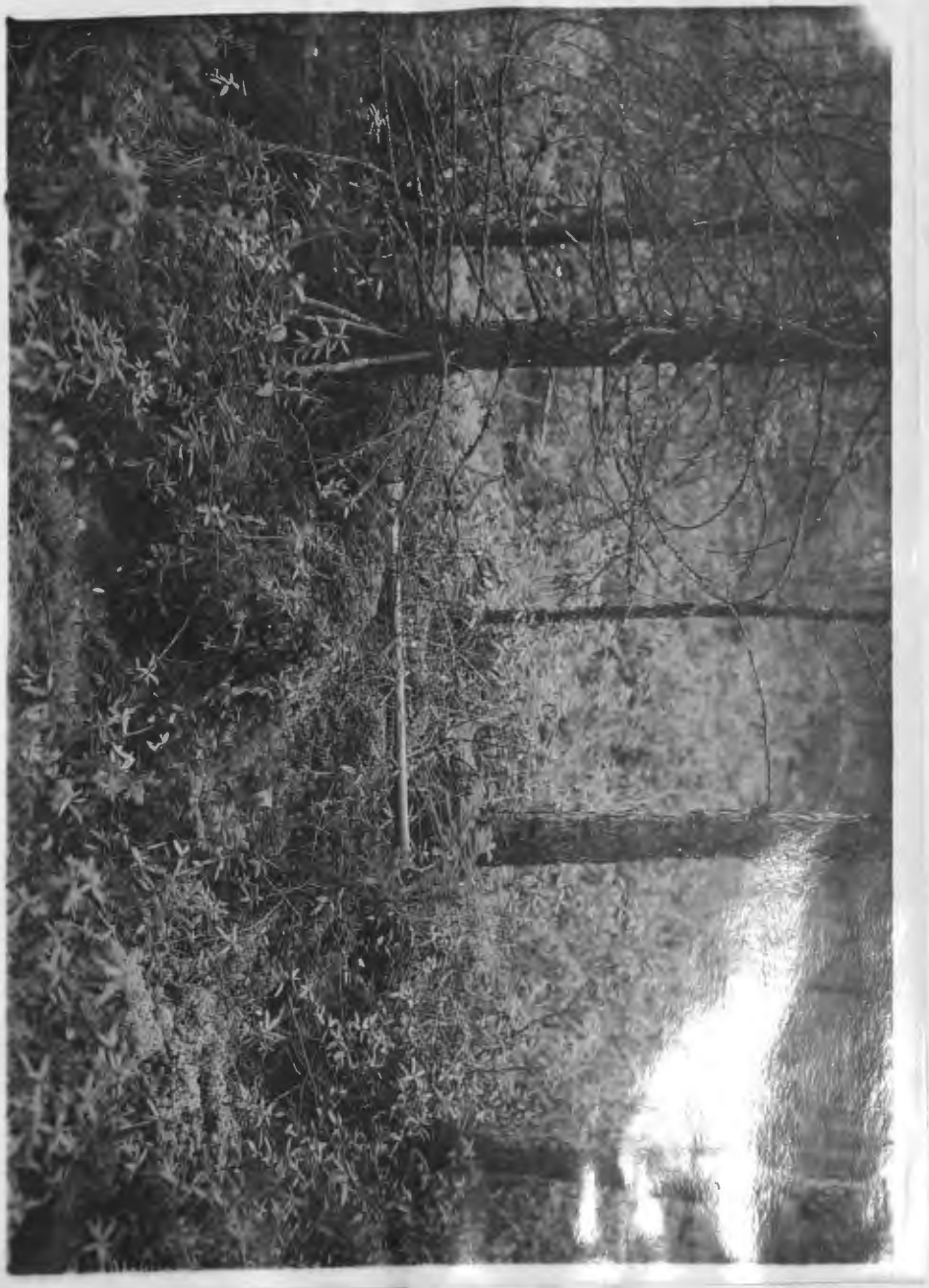


Plate I2

Note the young tree out at the end of the grub hoe. To all appearances this is a young seedling. Compare this with Plate I3

Plate 1

Plate I3

THis young tree is the same one as appeared in Plate I2 showing it to be merely a branch of another black spruce, but already starting to get its nourishment from its own roots, and growing upright instead of latarally as a branch would. Notice that the branches above are all dead.

Plate 14.

Plate I, 4

This is another illustration of the layering habit. The branches seem to grow laterally until they extend outside the shade of the branches above, after this getting full light they turn and start to go upward.

COMPARATIVE RATE OF GROWTH

All ages in the study of the different plots was determined by cutting down trees and counting actual rings at the surface of the ground.

BLACK SPRUCE - In the Black Spruce swamp plotted and charted before the age was very uniform showing that the trees must have started at about the same time. The ages of those taken, hit or miss, falling in between fifty-four and fifty-eight years of age.

They range as follows:

Age	Diameter	Heighth (Approximately)
54	2¼"	35'
56	2½	35
54	5½	40
58	4¼	35

TAMARACK - The quadrat of Tamarack was in a very wet location and one in which ice was found until the first of August, consequently the growth of the tree

was very stunted. The trees might be likened to those growing in an arctic region, no large thrifty trees being present. The swamp had a good deal of sedge and grass in it. It was in the stage of change, and will probably give way to other trees in time. The trees cut down ran as follows:

Age	Diameter	Heighth (Approximately)
63	3"	25'
53	2¾	25
33	1¾	25

MIXTURE - This quadrat 1 m. by 1 m. contained four genera. It was located at the top of a ridge which was about 10 feet above a Tamarack swamp. The comparative growth of the different genera in this small plot is interesting.

	Age	Diameter	Heighth (Appr.)
Tamarack	18	¾"	8
Norway	24	1	8
Spruce	20	1¼	9
Jack	24	2¼	20

This quadrat, as can be seen, was best adapted to Jack Pine, as far as heighth growth was concerned; but this can be explained in some measure by the fact that there was a moderately dense stand of mature White and Norway Pine over head, which made the light condition least favorable for Jack Pine and stimulated upward growth.

POPPLE - This quadrat is not typical of popple, but is a cut over section of White and Norway, neverthe less it shows a comparative growth of the hardwoods which come in the moisture places, and prevents or smothers out conifer seedlings.

	Age	Diameter
Burch	34	7"
Popple	46	9½
Cherry	48	4

The heighth of the Birch and Popple is about forty feet while the Cherry reached the heighth of about twenty feet. These trees while not as dense as the conifers in many places spread out so much that they do more harm by shading than the conifers.

PIC. 6

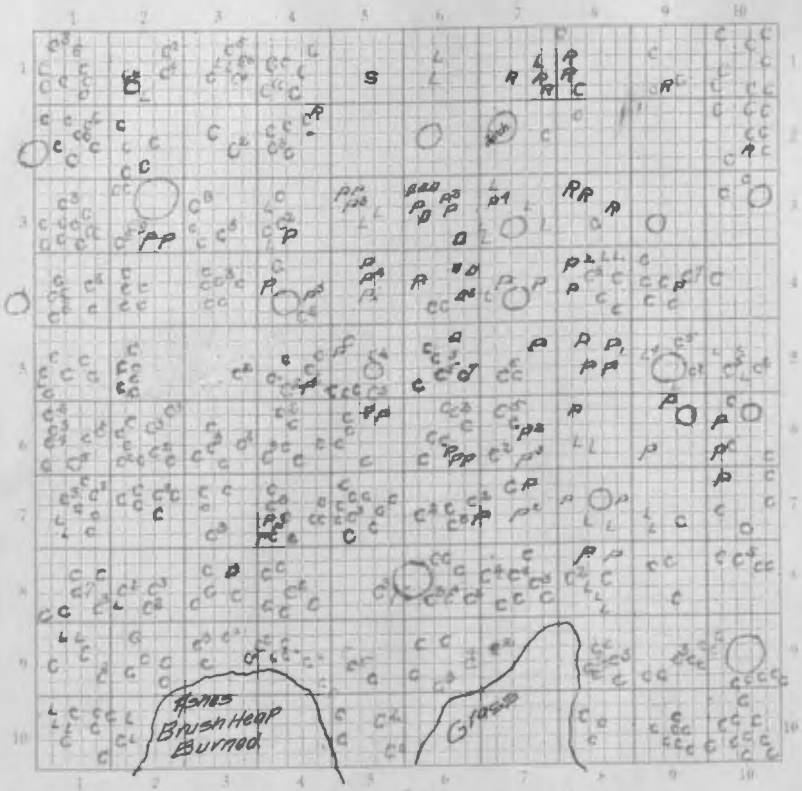
J. H. Kenelly 101

QUADRAT 11 LOCATION Cloquet Forest Near Creek DATE July 21 - '11

FORMATION Popple Thicket

CONSOCIES

SOCIETY



Scale · 1cm = 1m.

LEGEND:

O · Popple - Populus Tremuloides

C · Hazle · Corylus americana

P · Cherry · Prunus pennsylvanica

D · Dogwood · Cornus stolonifera

R · Raspberry - Rubus idaeus

L · Honeysuckle - Lonicera ciliata

Herbs - Aralia nudicalis - Clyntonia borealis - Rubus villosus - Corydalis glauca - Fragaria virginiana
Trientalis americana - Thalictrum polygenum, Vaccinium canadense - Cornus canadensis
Unifolium canadense - Vagneria racemosa - Polygonatum biflorum - Geranium bicknelli
Galium circoezons - Petasites sagittata - Apocynum androsaemifolium - Ferns Equisetum canadense

Plate 15

This is the Popple quadrat which is plotted. Note the density of the undergrowth. The light readings and vegetation will be found in the description of this quadrat. The difficulties which pine seedlings would have to compete against coming in under this vegetation can be understood from this picture.

Plate 1[illegible]

Plate 16

Plate 16

This shows a hard wood stand where the soil is more clayey and laamy. The stand consists of paper and yellow birch, hard and soft maple, a few ash and an undergrowth of hazel, alder, and yew

WHITE PINE - These ages were obtained from a newly cut over tract of Norway and White Pine on the north end of the Reserve touching the White Pine Quadrat plotted. Ground fires had swept thru the region, scarring the trees, quite badly, but not enough to kill very many of them. The heighth could not be accurately measured because no hypsometer was available, but those left standing would average around seventy to eighty feet. The age and diameter were as follows:

Age	Diameter
89	21¼"
83	14¾
75	14¾
79	15½
82	20
85	13½

Nearly every White Pine was fire scarred, some of them being burned to the center, while the Norway was comparatively unharmed, showing the better protective quality of the Norway bark.

NORWAY PINE - The ages of the Norway were gotten from the same quadrat as the White Pine so that the growth of the two species on a plot where both have grown successfully in about half in half proportion may be compared.

Age	Diameter
86	16¾"
86	17¾
85	13½
87	17¾
84	16½
85	13
87	16½
84	17¾
86	14½
85	17¼

The most striking thing about this quadrat and figures is the fact that these trees chosen at random, do not vary over three years in age, and this difference may be due to imperfect

reading of the annual rings which oftimes are hard to make out. This would bear out the idea advanced in the discussion on reproduction of Norway, where the young Norway came up this year very abundantly with a heavy rainfall, but no two, three, or four year or older seedlings could be found. The idea advanced being that two or three favorable years were necessary so that the young seedlings could get their roots below the surface vegetation, and also get far enough down so that the combined drying out of a dry year and the surface vegetation would not leave too little water for the young seedlings. After once established with a good root system far enough down in the ground, they are able to persist. The uniformity of the trees examined all being around eighty-six years of age bears out this idea that such a period must have existed at that time.

JACK PINE

Height	Diameter	Age	Whorls	
9' 6"	1 1/8	13	22	
8 4	1 5/16	13	17	
4 10	9/16	10	14	2 cones, 2' 10" from ground.
17 8	2 ¾	14	27	No cones, last year's growth, 2 feet.
17 2	1 7/8	13	24	Cone 4 whorls, 4 feet from top.
5 4	5/16	12	13	Numerous staminate cones.
5 7	3/8	12	17	
5 2	¼	12	14	
7 6	5/16	12	16	
9 8	¾	14	18	Cones 4 whorls 2 feet from top.

This table shows that competition plays a great part in the development and growth of young conifers. All these trees average within a year or so the same age, yet in heighth, they varied as much as ten or twelve feet. After once getting a start over their associates they shoot up and become leaders, so that light may play some part in this competition, per-

haps almost as much as demand for water.

That diameter growth is not proportional to the heighth growth in these young thick stands is easily shown by comparing one 17' 8" in heighth with one 17' 2" in heighth, yet the first one was 2¾ inches in diameter and the other was 1 7/8 inches in diameter. Their ages only varied one year. Another comparison may be drawn between two other Jack Pines in the same plot fourtewn and thirteen years old, the same age of the two discussed above. These were 9' 8" and 8' 4" in height, and ¾ of an inch and 1 5/16" in diameter.

In this plot some of the young Jack Pines had begun to bear cones at the age of seven years, one ten years old, having two cones 2' 10" from the ground and six whorls up. Another 9' 8" high fourteen years old had cones 2' fromthe ground.

Another thing not generally known is the fact that Jack Pines make more than one whorl of branches in a year. The general method with young Pine seedlings in order to determine their age when they are small, and it is not advisable to cut them off and im-

possible to use a borer on them, is to count the whorls from the ground up and consider that the number of whorls corresponds to the number of years that the plant has grown. In all the Jack Pines examined the ages as determined by cutting them off at the level of the ground, ranged from twelve to fourteen years and they had from thirteen to twenty-seven whorls on them. No direct relation between the age and number of whorls could be found.

PERMANENT QUADRATS (Not Plotted)

No.1

This quadrat is located where a Jack Pine was wind thrown, about 150 feet north of plot 6 A. The Norway was cut in the summer of 1910, leaving a stand of Jack Pine. The plot was taken where the lower end of the crown, about 25 feet from the top of the tree buried some of the cones in the ground two years ago. The seed in these cones have been released by the rotting of the cone scales. From one of these cone 17 seedlings had sprung.

No. 2

Fifty east of quadrat No. 1, 1 m. by 1 m. stake set at S. E. corner, no seedlings found on June 23rd, two found August 16th.

No. 3

Adjoining No. 2 on the west, stake set at S. E. corner, three seedlings found June 23rd, four found August 16th.

No. 4

On the south side of an old railroad

track, due north of Camp 8, 14 seedlings in good condition, 7 seedlings in cinders, and 7 outside.

No. 5

On south side of No. 4, 9 seedlings found, stake set at S. E. and S. W. corner.

No. 6

In Popple reproduction all large Norway and White Pine, in summer of 1910, Popple and Birch left, not lumbered. Hazel and Cherry and a few Alder made a shade too thick for any reproduction to come in. In spots where brush was burned, young Hazel coming in very thickly which will soon shade out any young Pine which might come in.

No. 7

In a stand of Jack Pine, in an old burn some of the old trees still stand, young trees averaging between 12 and 14 years of age in 20 cut down. Reproduction is so thick that many are dying off. Ten m. quadrat gave 93 alive and 134 dead.

No. 8

Norway quadrat, young trees from 1 foot to

8 feet high. 5 Jack Pine in the plot afforded shade. Number of Norway two years and younger, 15; number of Jack two years and under, 29.; number of Norway over two years and under thirteen years, 101; number of Jack over two years up to six years, 14. Location north of lodge.

INTENSIVE STUDY OF EACH SPECIES
JACK PINE

This area studied was a pure stand of Jack Pine which had been burned by a ground fire a year ago killing all the annuals which had not as yet come in except in a few cases and also killing many of the younger Jack Pine. These young Pines were examined, and on the ten meter quadrat studied and from stem analysis of trees bordering upon the quadrat it was found that trees less than twenty years old had succumbed to the heat of the ground fire, while those above that age as a general rule had survived, tho the leaves on the lower branches had been killed by the heat. This was emphasized by the large amount of needles which had fallen upon the ground after the fire had passed thru and which might have materially hindered the germination of seed which fell from the tree after the cones had been opened by the fire.

The trees were very dense, fifty-seven being found on a quadrat ten m. by ten m., tho this

included dead as well as live trees. The living crowns were about ten feet long, partly due to the density of the tree and consequent lack of side light, and also to the fire which had ran thru and killed all of these and younger branches lower than that.

Whether the death was due in the smaller trees to the killing of cambium layer at the base of the tree or to the killing of the growing points and leaves at the top of the tree is a question. The smaller trees were shorter and consequently the heat generated would effect these more than those fifteen further up. The fact that the branches on the taller trees which were on a level, with the tops of the trees killed, would substantiate this argument. On the other hand the fact that every tree in the plot of the smaller-size was killed would lead to the assumption that the death was due to the killing of the cambium by the heat on the ground, and that the bark of the younger tree was not sufficiently thick to protect the cambium.

In regard to growth the trees showed

the effect of the fire by a smaller addition of wood, probably due as much to the damage to the foliage as to the shock caused by the fire injuring the cambium.

Under Growth:

The most numerous plant on the quadrat as shown by an intensive study of two square meters in which every plant is charted was the Lady's Tobacco or Cat's paw (Antennaria campestris); tho this was not apparent at first glance at the under growth when the honey-suckle and blue-berry appeared the most numerous.

The Lady's Tobacco being a composite with parachute like apparatus for carrying its seed had the best means of migration and consequently got the first foot hold on the soil after it was swept clear by the fire. The fact that it could be reproduced by runners also tended to make the establishment of this plant a much easier matter than it would be for a plant which depended upon seed for every plant that was established.

A few Goldenrod were just appearing. Blueberry (Vaccinium canadense) was next in abundance

and arose from the under ground roots . The stems above were killed by the fire, but the fire had not materially injured those below ground. There were very few berries on the plant either due to too great shade or too young plants.

Honeysuckle (Diervilla Ciliata) was also fairly abundant tho it had not attained the height that the shrubs do which are not run over by fire. A couple of Hazel twigs had sprung up from the roots of the old Hazel bushes which were still standing after the fire altho the fire had killed them a year ago; these were about ten feet high.

Eight willow twigs were found springing from the burned remains of willows which had also attained a heighth of from five to ten feet before the fire.

Three mats of grass were found on a meter quadrat. These had just begun to establish themselves and were just producing seed.

One thing brought out by the study of this quadrat was the absence of brush in comparison with

the pine district further west in the state, and the absence of popple. One explanation is that successive ground fires which were not severe enough to kill the trees after they had attained an age of twenty or more years would, if recurring at intervals of from two to five years kill off all reproduction and leave anly such shrubs as those mentioned above which were able to reproduce and reach their full development in from one to three years, and those which being suited to the habitat had a means of migration which would enable them to establish themselves as the Lady's Tobacco mentioned above.

Reproduction:

Most cones on the lower branches had opened and shed their seed, yet not one seedling was found. The heavy fall of leaves following the death of the trees and lower branches on those notkilled by the fire left a carpet thru which the seeds could reach the mineral soil with difficulty. Another thing that should have a great deal of influence in retarding the establishment of any Jack Pine seedlings would be the

dense shade of fifty-seven trees to ten meter square.

Perhaps the most influential factor in the selection of reproduction was the song sparrow which was very plentiful and the chipmunk, several of whom viewed my examination of the quadrat from a branch within the plot.

The temperature of the Jack Pine tract corresponded quite closely with the open Norway stand upon which observations were made every day. They were as follows:

1½ M.	Surface	1 dm.	2 dm.	3 dm.
31.8	33	20.4	17.8	16.5

The water content ran as follows:

Depth	1 dm.	2 dm.	3 dm.
Percent	12.8	8.8	5.7

The accompanying charts will show graphically much better than any description, the distribution of the vegetation and the exact nature of the Jack Pine situation. In the plots studied trees would average around six to seven thousand to the acre. All these plots are permanent.

Plate 17

Plate II

This is a meter quadrat in a Jack Pine stand showing the characteristic shade vegetation. A description of this will be found quadrat plotted.

Plate 12

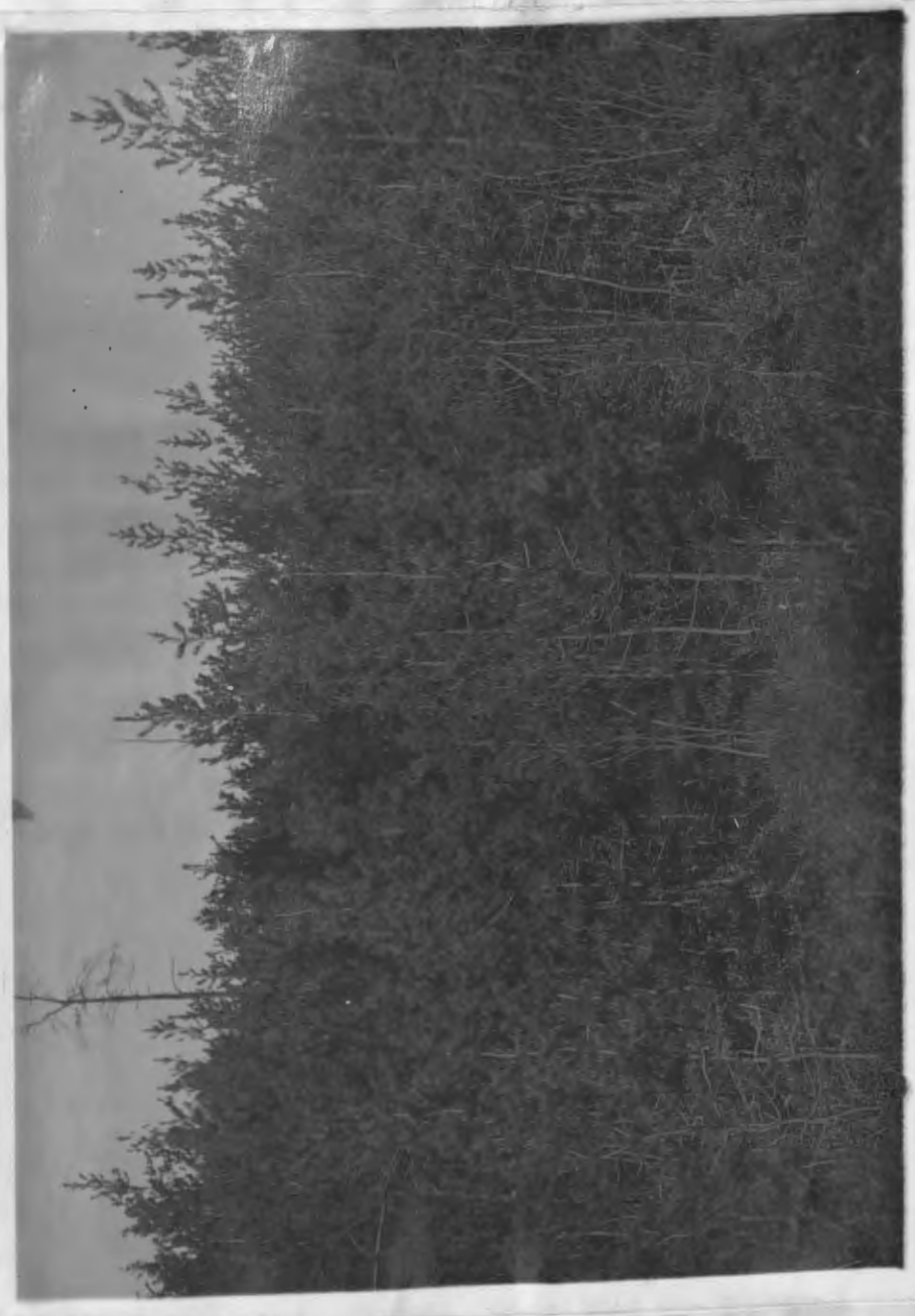


Plate 18

This shows a very dense stand of young Jack ranging between ten and twelve years of age. This shows the characteristic way by which Jack reclaims burned over areas to the exclusion of everything else. The study of the competition of Jack Pine was made in this plot, a description of which will be found on another page.

Fig. 7

W. H. Kenoyer

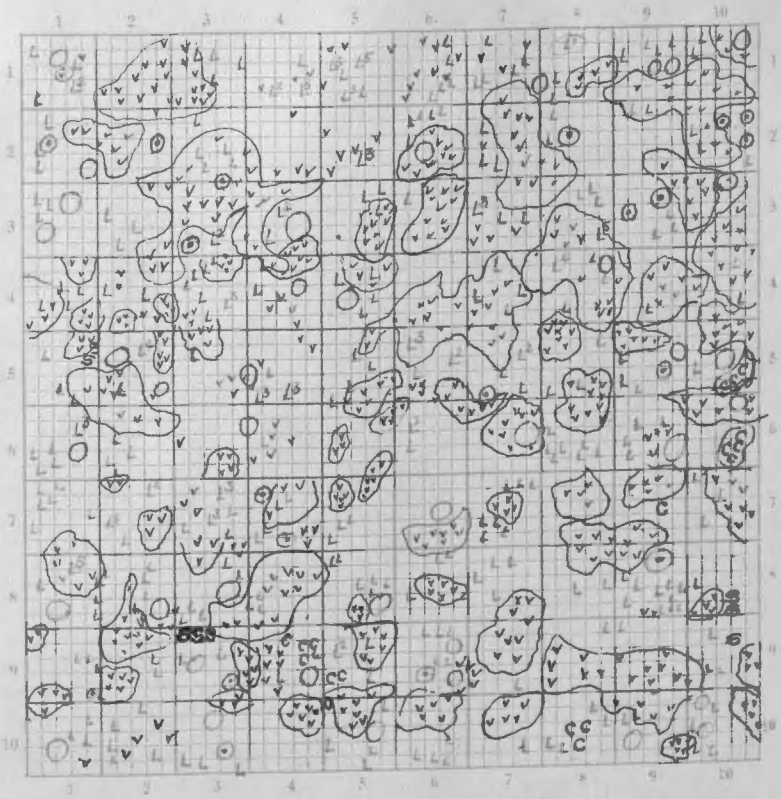
QUADRAT No 2 - 10m x 10m. LOCATION Claquet Forest. DATE June 20 - 1911

FORMATION Jack Pine.

CONSOCIES

SOCIETY

Permanent Plot
Trees and Shrubs
36 live 4300
20 dead 2400
6720 to acre



Scale 1cm = 1 meter

LEGEND:

O = Live Jack Pine (Pinus divaracata
⊙ = Dead " " " "
L = Honeysuckle (Lonicera ciliata
C = Hazel - (Corylus americana
S = Willow - (Salix sp.
Ground cover = Wintergreen, Antennaria, grass -

W H Kenerly

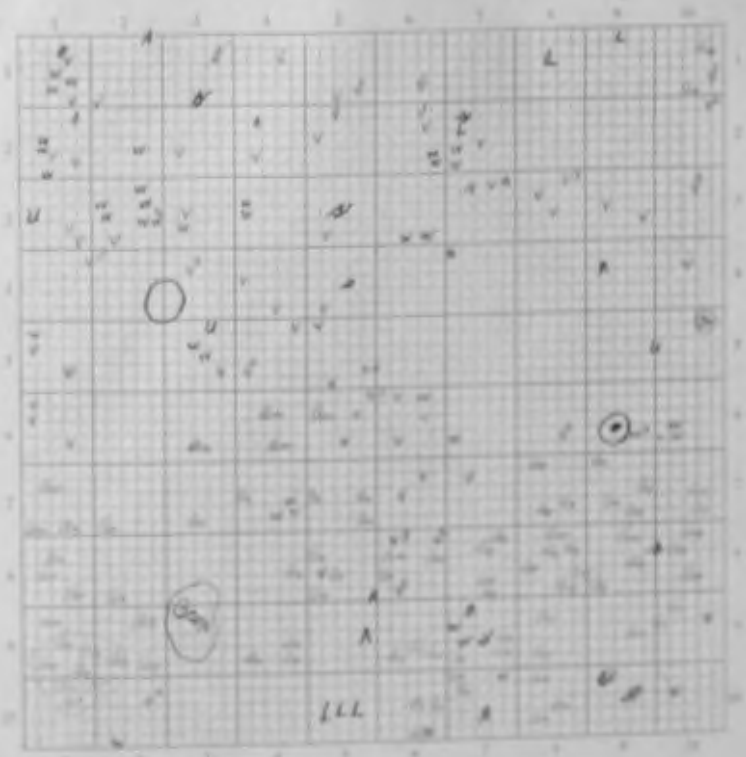
QUADRAT No3 LOCATION Cloquet Forest DATE June 23

FORMATION Jack Pine

CONSOCIES

SOCIETY

Permanent Plot



Scale - 1cm = 1dm

LEGEND:

O = Jack Pine - Pinus divaricata
(W) W = Wintergreen - Pyrola rotundifolia
(V) V = Blueberry - Vaccinium canadense
(Hn) Hn = Cats Paw - Hieracium compestris
U = False Lily of the valley Unifolium canadense
(H) H = Hazelnut canadensis
(L) L = Honeysuckle Lonicera oblata
St. Strawberry Fragaria Virginiana
Gr Grass
G Goldenrod Solidago

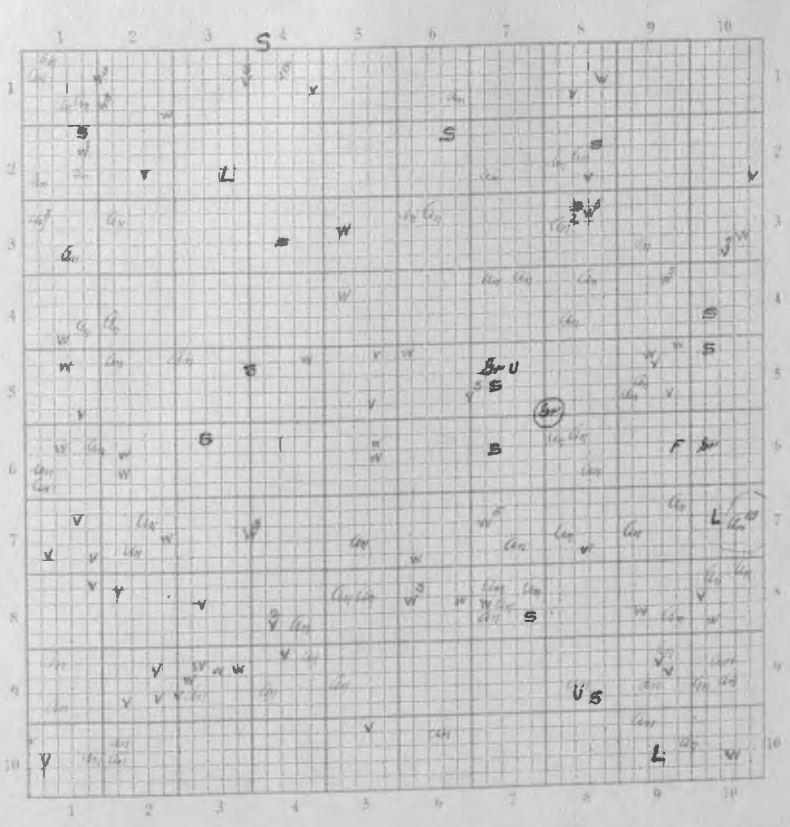
QUADRAT No 4 LOCATION Cloquet Forest DATE June-27-'11

FORMATION Jack Pine

CONSOCIES

SOCIETY

Denuded - June 27-'11



Scale - 1cm - 1dm.

LEGEND:

W = Wintergreen - Pyrola (rotundifolia) asarifolia
V = Blueberry - (Vaccinium canadensis)
Cn = Ladies Tobacco or Cats Paw (Antennaria canadensis
L = Honeysuckle (Lonicera ciliata)
S = Goldenrod - Solidago
U = False lily of the valley (Unifolium canadense
Gr = Gross
F = Strawberry (Fragaria virginiana

Plate 19.

This is a stand of scattered and burned Jack Pine. The ground is covered with a dense mat of sweet fern (myriaa). This sometimes covers hundreds of acres in a stretch. It is so dense that no other reproduction can come in under it.

Plate 1

NORWAY PINE

This stand of Norway is the finest stand of timber on the Cloquet forest and offers a fine opportunity for the study of reproduction. Last summer part of this tract was cut clear of Norway, leaving only a few seed trees in some spots to offer an opportunity to compare the results obtained by this method with those obtained by clear cutting. The stand when first observed looks very much like a pure stand of Norway, but where the Norway has been cut away and the Jack left a good percentage of Jack is shown to be mixed with Norway. This is further shown by consulting the hundred meter quadrat where 117 Jack and 134 Norway over six inches in diameter were found upon the quadrat.

It is not likely that the species will always maintain this ratio, the Jack has already begun to show the effects of the competition. Some of them are already dead and in almost every case the Norway has begun to overtop the Jack. Fifteen rep-

resentative trees were examined. The largest Jack averaged about eighty-eight years with an average diameter of fourteen inches. Norway on the other hand, had reached the age of one hundred and thirty-four in some cases, and was from twenty-one to twenty-six inches in diameter. The effect upon the Jack was evident by the fact that a fourteen inch Jack, eighty years old grew 8¼ inches the first forty-four years, and 4¾ in the last forty-four.

From the observation made upon the tract it is very reasonable to suppose that in time the Jack will in most cases be suppressed by the Norway, if nothing tends to interfere with the present stand. On the west side of the hundred meter plot the ground slopes at an angle of ten percent, which probably causes some run off. In the lower part of this draw young Norway and young Jack are coming in quite plentifully. On this side the trees on the west have been cut away, leaving no trees to shut out the afternoon sun; as a consequence the young Norway and Jack have a much better opportunity to get light. The location having both better light and water

destroyed the young growth of former years, and that the light and waterffactor is not responsible for the lack of reproduction underneath is barely possible, but no young fire killed trees are present, and the light and water hypothesis would seem to be the right one.

Under-Growth:

There is practically no underbrush in the tract, young hazel is coming up, but has been kept down by ground fires. A few Birch are growing, but are not big enough to have any effect upon the composition of the forest.

The ground cover is not what would be the natural cover if fire had not repeatedly swept thru the plot. As it is, it shows the imprint of the fire if no other indications were present, such as fire scars, etc. This is a good example of the futility of taking the vegetation found upon a tract as an indication of what the land is actually best adapted to. Here the after runners of a fire are everywhere apparent. Wintergreen, blueberry, Lady'y Tobacco, Sweet Fern, and Honeysuckle,

conditions, probably accounts for the young trees here, and not in other portions of the plot.

Thruout the plot young Norway and Jack are springing up, this being an unusual year for the distribution of rainfall. No seedlings over one year old are present except those described on the west side.

If those young Norway, so plentifully scattered over the tract, are doomed to perish for want of light and water, as must have been the case with the young trees, which must have sprung up years previous to this, is hard to say. This from a management standpoint would be a good place to try thinning out. The Jack which at best is a poor tree has about reached its period of maximum growth and is becoming suppressed by the Norway. The removal of the Jack would not only stimulate the growth of the Norway by leaving nearly twice as much water available but would let in a great deal of light for the successful continuance of the Young Norway now in a flourishing state.

All Norway and Jack are fire scarred, some burned to the center. Whether these fires have

form by far the major portion of the ground cover. Very little grass had established itself, and no open plots were present.

In one place within the plot where a campfire had been built, a natural denuded plot had been created; a transect was run thru this to see the difference between the vegetation of this year which had just come in and that on the border which had not been effected by fire for four or five years. The lately burned area had the characteristic after fire vegetation, dogbane, catspaw, while the part of the transect in the vegetation not burned showed the characteristic type of vegetation found in burns five years old, such as wintergreen, ferns, sweet fern, and blueberry. This transect has been plotted and reference to it will show this difference in the vegetation.

Three quadrats have been charted and staked out for study from year to year. These are one meter square, ten meter square and one hun-

dred meter square respectively. In the hundred meter square quadrat, 134 Norway and 117 Jack were found above six inches in diameter. All the trees in this plot have been charted with the diameter of each recordèd.

Reference to these charts will show the distribution of the trees and vegetation. The temperature and water determinations will be given with those given for the Norway as a whole.

NORWAY (2)

This stand of Norway was selected to compare if possible the growth and reproduction upon this location with the Norway stand in a dryer situation. This stand of Norway is on the edge of a depression in which willow, popple, birch, hazel, alder, etc., flourish on account of the large water content of the soil. This soil has a water content sufficiently large to support White Pine which is found in the same stand.

This area has been swept by seven large fires as is shown very clearly by very prominent fire scars on the boles of the trees.

Nothing was found which would give a clue to the number of light ground fires which had swept thru the area, not fierce enough to burn the Norway, yet severe enough to kill the under growth.

Whether the area described above as being densely grown up to Alder, Popple, Birch, etc., has been saved by the dampness of the location and the under growth beneath the Norway killed by fire or whether the much more favorable situation in the moister place has made the establishment of the growth of these species much easier can only be determined by watching the migration from year to year. At present it would seem that the dryer situation with the shade cast by the larger trees did not offer as good a habitat for the shrubs and herbs as would the adjoining situation with abundant moisture and sunshine. Young Norway are coming up in abundance as the meter quadrat will show, seven being found in a meter quadrat, andthey were found in the same abundance all around the tract. The fact that no Young Pine, except those one year old, were found, may be attributed to the

fact that the seed on account of some unknown cause did not germinate as it did last year, or else dry weather following germination had killed the young seedlings before they could get their roots deep enough in the mineral soil to get enough water to keept them alive.

The shrubs were very scanty as compared to some situations, Jack Pine for instance. This was due, as has been mentioned before, either to the continual recurrence of fires which have gotten the best of most of the perennials, or to the dense shade of the Norways, which prevented a very good growth of annuals or perennials from seed.

Under Growth:

The Hazel and Willow had begun to come in being most numerous where the Norway merged with the Popple and Birch. These had come from old roots, the remains of these shrubs being found burned around the young plant.

The ground cover was composed of very poorly developed blueberry which had not produced any fruit in contrast to that on the cut over land. Honeysuckle

Plate 20

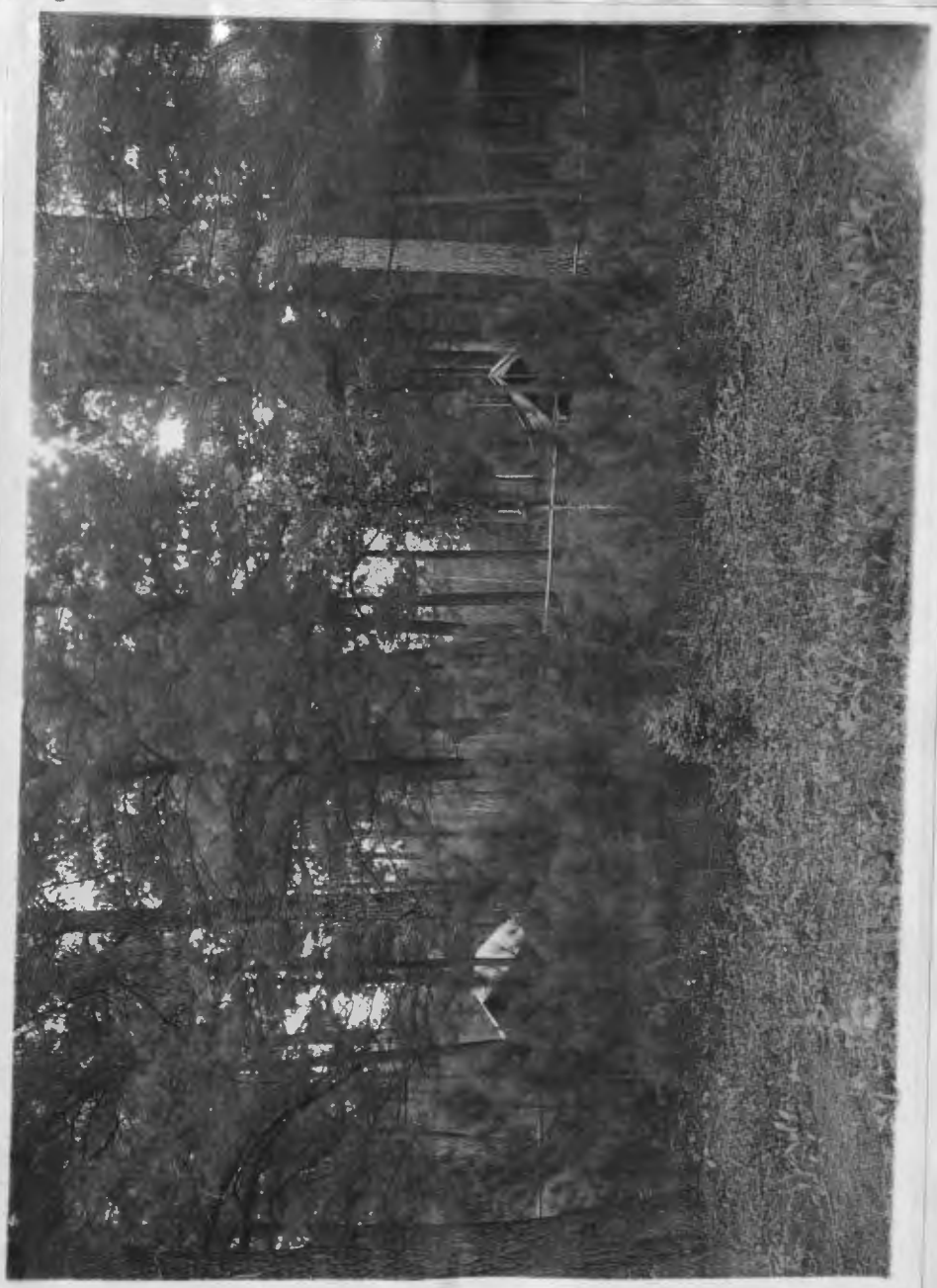


Plate 20

This is the plot of young Norway which was permanently plotted. A ten meter square quadrat containing 159 trees. Most of these are now in a healthy condition, but as they grow older competition for light will probably reduce this number to a very few.

Plate 21

Plate 22.

This is 100 m. by 100 m. quadrat, which is plotted. The water determinations, temperature readings and vegetation may be found in the description of this plot.

Plate 23

Plate 20

This is a denuded quadrat in an open Norway stand in which the vegetation was plotted and then all traces of it were removed to determine what plants would come in first and how these would compare after a couple of years with the vegetation already there.

Plate 24

Plate 24

This is another view of a terminal moraine showing the different stages or zones influenced primarily by water. At the bottom of the slope the characteristic swamp vegetation may be found, and then all the gradations from hardwoods at the bottom to Jack Pine at the top.

Plate 9

Plate 25

This is a stand of Norway about eighty or ninety years old upon a terminal moraine which extends out into a swamp.

FIG. IO

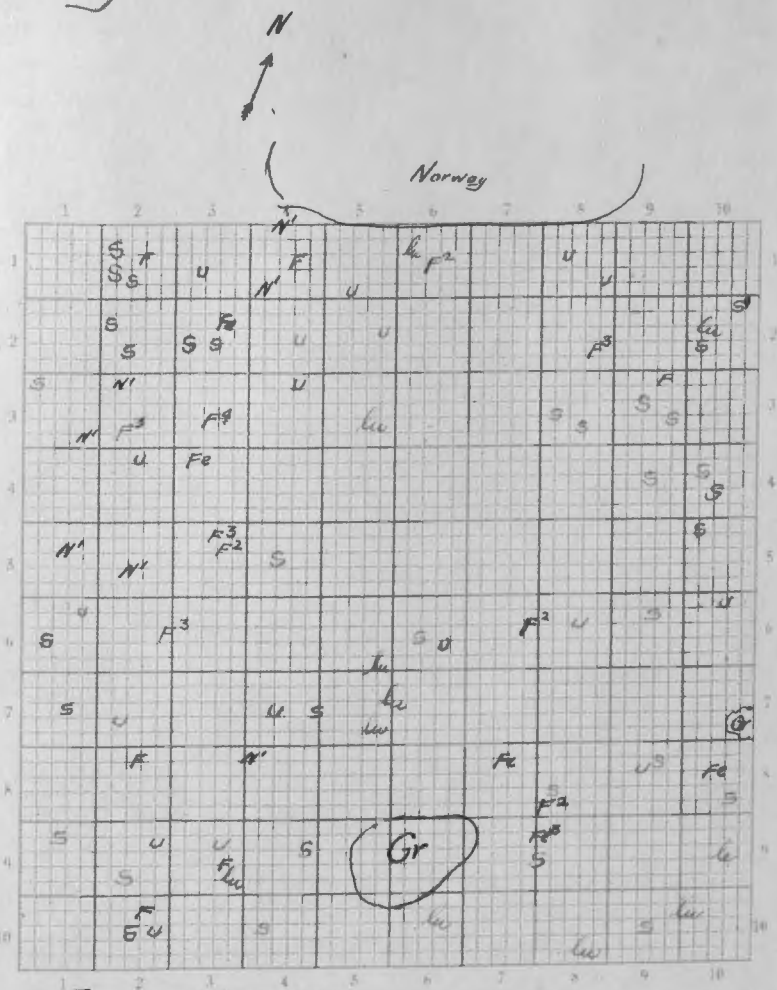
H. H. Kenety

QUADRAT - No6 LOCATION Cloquet Forest. Inside of No5. DATE June-30

FORMATION Norway Pine.

CONSOCIES

SOCIETY



Scale - 1 cm = 1dm

LEGEND:

S = Salix SP. Willow
U = False lily of the valley - Unifolium canadense
F. Strawberry - Fragaria virginiana
Lu = Lupine.
Fe = Fern
N' = Norway seedlings sprouted this spring
Gr = Grass

FIG. II

W. H. Kenety 1948

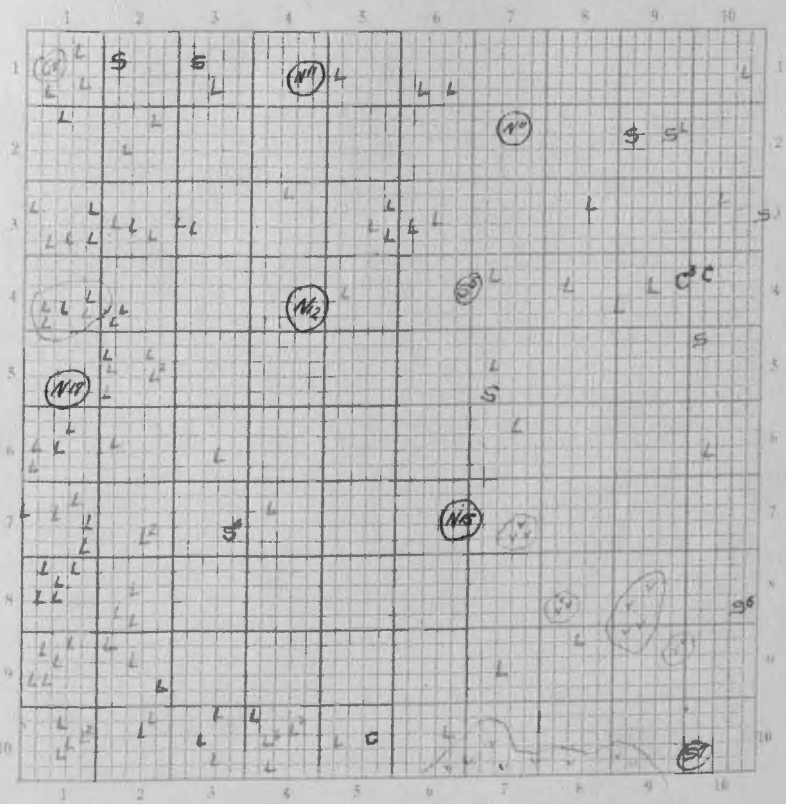
QUADRAT No 5 LOCATION Coquet Forest. East of R.R DATE ~~July~~ June 29-

FORMATION Norway Pine

CONSOCIES

SOCIETY

Trees and Shrubs



Scale - 1 cm = 1 m

LEGEND:

N = Norway Pine - P. resinosa (N11 - 11" in diam)

L = Honeysuckle - Lonicera ciliata

V = Blueberry - vaccinium Canadense

S = Willow - Salix SP

C = Hazel - Corylus americana

Groundcover - Strawberry - Ferns -

FIG. 12

W. N. Keneth

QUADRAT 8

LOCATION Coquet. Forest. South of Camp 8

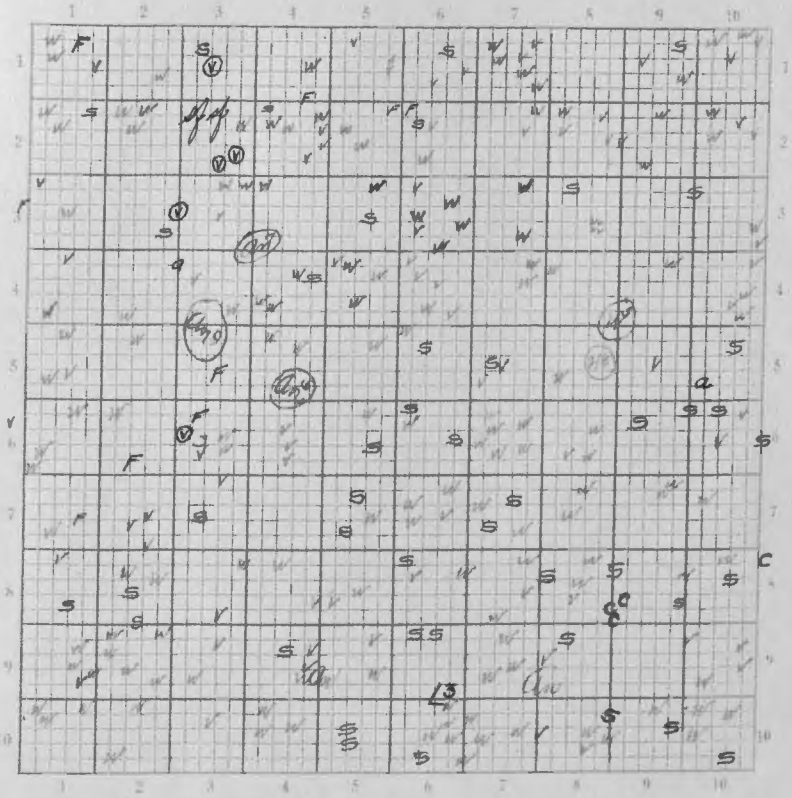
DATE July 18th. '11

FORMATION Norway Pine

Denuded - July 17 - '11

CONSOCIES

SOCIETY



Scale - 1cm = 1dm.

LEGEND:

W. Wintergreen Pyrola asarifolia

V. Blueberry Vaccinium canadensis

S = Goldenrod - Solidago - SP.

An. Ladies Tobacco Antennaria campestris

Ⓥ = Violet - Viola SP

F = Strawberry Fragaria virginiana

sf. = Sweet fern - Myrica asplenifolia

L = Honey Suckle - Lonicera ciliata

FIG. 13

N. H. Keneely 150

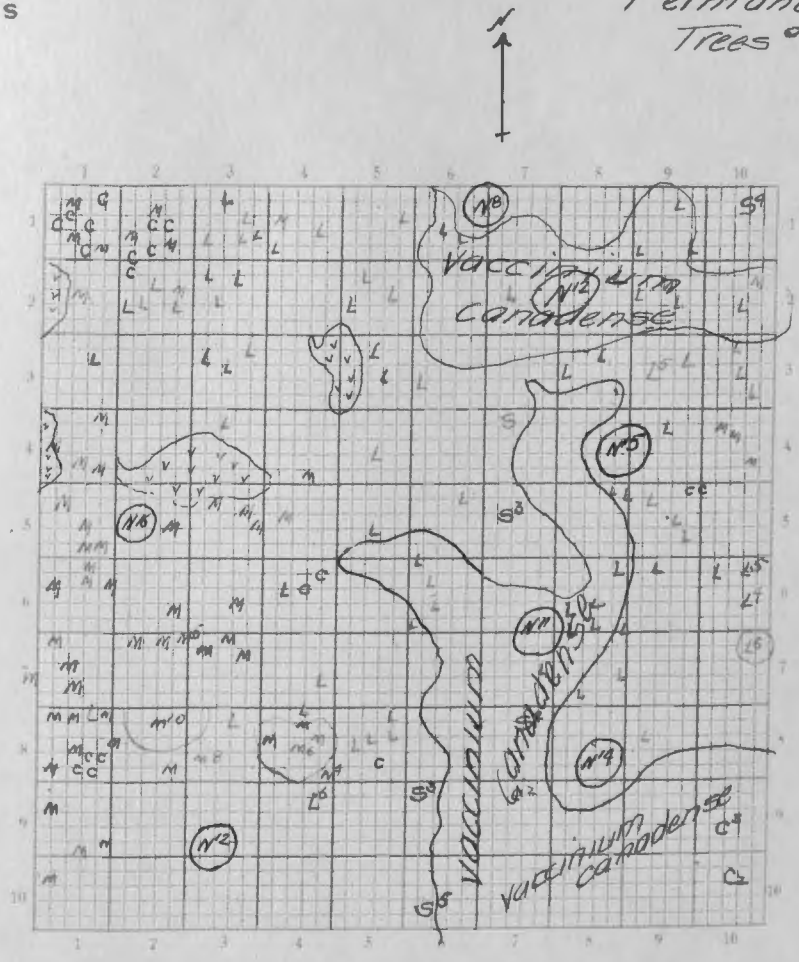
QUADRAT No. 7 LOCATION Cloquet Forest. DATE July 1st.
~~Lac~~ South of Camp 8

FORMATION Norway Pine

CONSOCIES

SOCIETY

Permanent quadrat.
Trees and Shrubs.



Scale. 1cm = 1m

LEGEND:

L = Honeysuckle Lonicera Ciliata

M = Sweet Fern = Myrica asplenifolia

C = Hazel - Corylus americana

S = Willow - Salix SP.

V = Blueberry. Vaccinium canadense

(NR) = Norway Pine - 12" in diam.

W. H. Kenety

QUADRAT 9

LOCATION Coquet Forest. Viberts claim

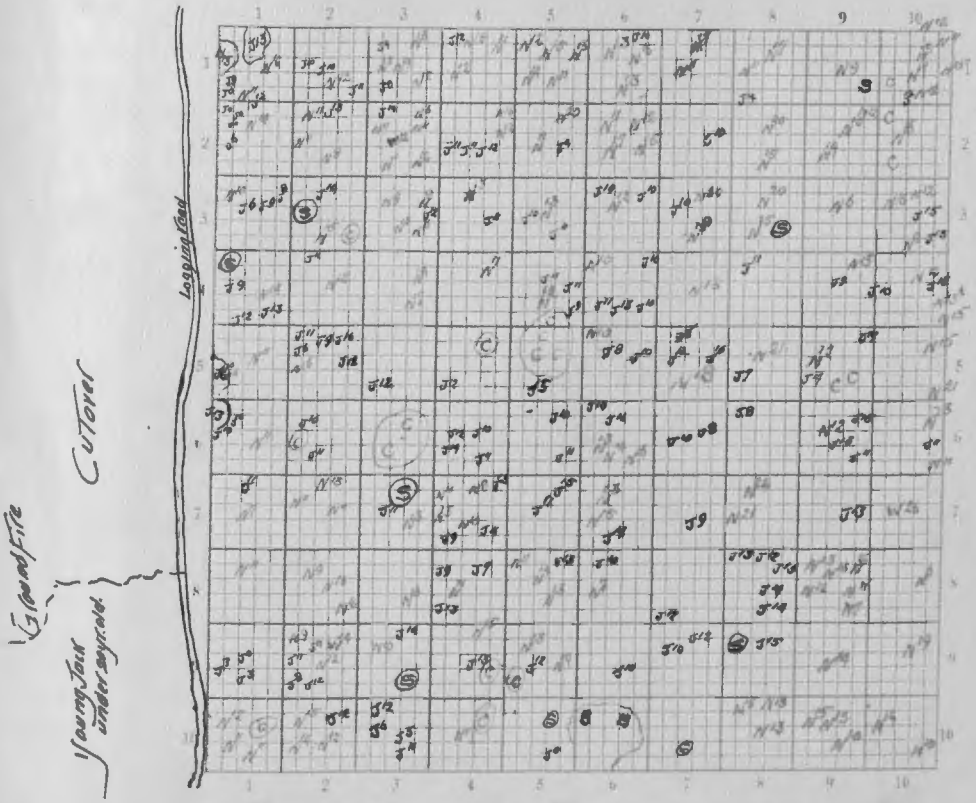
DATE July. 7.

FORMATION Norway Pine

CONSOCIES

SOCIETY

Trees and Shrubs.
134 Norway above 5"
117 Jack " 6"



Scale 1cm = 10 meters

LEGEND:

N16 = Norway Pine - 16" diam

J16 = Jack Pine - 16" diam

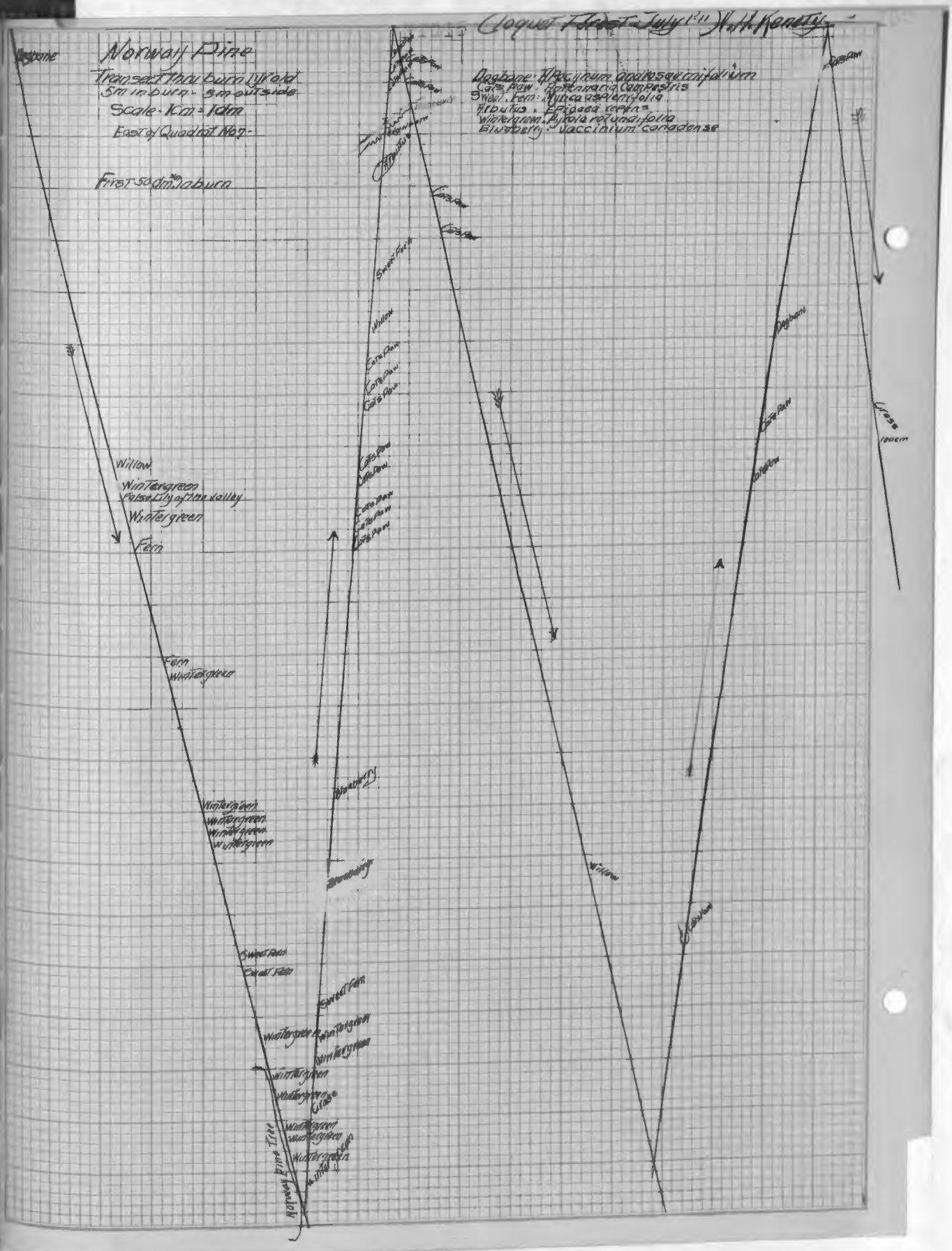
W26 = White Pine - 26" diam

(C) = Hazel clump Corylus americana

(S) = Willow clump Salix sp

B = Birch - Betula papyrifera

(S3) = Clump of 13 seedlings not 1" in diam.


Cloquet Forest July 11th Hotchkiss
Norway Pine
Transect thru burn 1/4 rod
5m in burn - 5m outside
Scale - 1cm = 10m
East of Quadrat No 7
First 50 dm in burn
Dogbane - Apocynum androsaemifolium
Cats Paw - Antennaria Campestris
Sweet Fern - Myrica asplenifolia
Arbutus - Epigaea repens
Wintergreen - Pyrola rotundifolia
Blueberry - Vaccinium canadense
Willow
Wintergreen
False Lily of the valley
Wintergreen
Fern
Fern
Wintergreen
Wintergreen
Wintergreen
Wintergreen
Wintergreen
Sweet Fern
Sweet Fern
Wintergreen
Wintergreen
Wintergreen
Wintergreen
Wintergreen
Wintergreen
Wintergreen
Norway Pine Tree
Willow
Dogbane
Cats Paw
Grass
Willow

strawberry, and lupine were the principal species with some mixture of epilobium and solidago. A good many ferns were found. No moss was present. Very little grass was found, and what was found had not formed seed. Much of it was dead. It had very likely migrated in from the adjoining grass land, and had not been able to stand the decreased amount of light. While examining the quadrat, a mole came running along. These rodents may be injurious to the young seedlings.

WHITE PINE

There is no pure stand of White Pine upon the Cloquet Forest, the nearest approach being a Norway White Pine type in the southeast corner of the reserve. This mixture is about sixty per cent White, and forty per cent Norway The ground is rolling, sloping in some places as much as 25 degrees. The ravines at the bottom of these slopes being filled with a dense thicket of Alder and Hazel with Popple as a sort of an upper story.

This particular region was fortunate in not having had any serious fires, altho some slight

ground fires had burned the vegetation in spots, and blackened the bark of the trees near the ground.

The stand was dense, the density based on a basis of ten would be about eight.

Reproduction:

Aside from the larger trees no young Norway or White reproduction over one year old was present, nor was there much brush underneath. Pine cones were strewed all over the ground, mostly White Pine cones. Some of this year's seedlings had already been cut by the squirrel and were lying upon the ground. Squirrels and chipmunks were very numerous.

The needles on the ground formed a layer about one inch thick, while the humus or top soil was from one-half to three-fourths inches thick. The soil is much more gravelly than the Jack Pine or Norway soil in the other plots studied, and contains more clay. Owing to the dense shade, the ground cover is not very thick and what there is is not very well developed.

Owing to the density of the stand the trees

are much better cleared than in some other locations, and have shorter tops. The land has never been cut over as no old stumps are to be found on the tract. A few Jack present in the stand are suppressed and dead. Some smaller Norway have also succumbed to the demand for light and are dead or on their way to die. The light value of the plot from half a dozen observations taken at different places in it ranged between seventy-five thousand and sixty-six thousand.

Young White Pine are coming up profusely. In a ten m. by ten m. quadrat seventy-six seedlings were found .

Under Growth:

The principal shrubs are Hazel, Honeysuckle and Rose bushes, and the principal herbs are Wild Sarsaparilla, Straw berry, and Aster. These shade the ground to a considerable extent, but the greatest shade is cast by the trees.

The fact that so many seedlings are present, and that no young ones over one year old

can be found is either due to the fact that this has been the most favorable year for germination, or that the young seedlings cannot stand the conditions under the dense shade.

Rate of Growth:

Part of the stand was cut last year, leaving the stumps from which some figures as to height and age were obtained. Six representative White Pine range in age from seventy-five to eighty-nine years, and in diameter from 13½ inches to 21¼ inches. Ten representative Norway were examined and the only difference in age being three years, all of them ranging around eighty-five years of age. The diameter ranged from thirteen to seventeen and three-fourths.

This quadrat has been permanently staked out and charted and may be compared with the other Norway and Jack Pine stands.

Fig. 16

W. N. Keneth

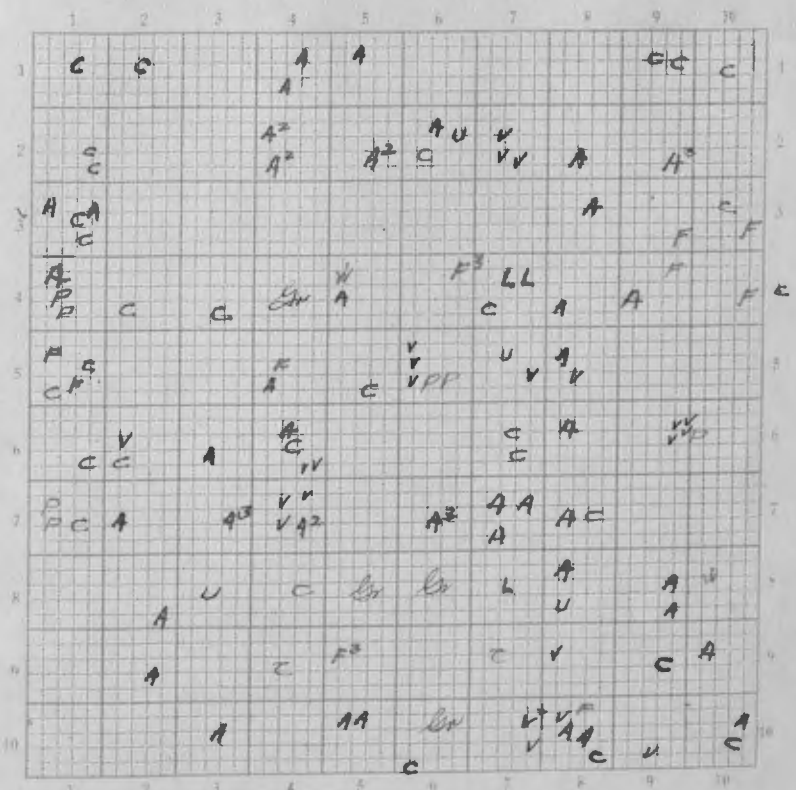
QUADRAT 13 LOCATION Nogquet Forest. DATE Aug-26-1911

FORMATION White Pine

CONSOCIES

SOCIETY

1m x 1m quadrat all vegetation inside 1sqm-quadrat.



Scale - 1 cm = 1 dm

LEGEND:

W = White Pine Seedling 1 yr. old

F. = Strawberry - (Fragaria Virginiana)

L. = Honey suckle - (Lonicera ciliata

A. = Aster. cordifolius

P. = Wild Sarsaparilla - Aralia nudicaulis

C. = Hazel - Corylus americana

U. = False Lily of the valley - (Unifolium canadense

V. Blueberry - Vaccinium canadense.

Gr. = Grass

FIG. 17

W. N. Keneth

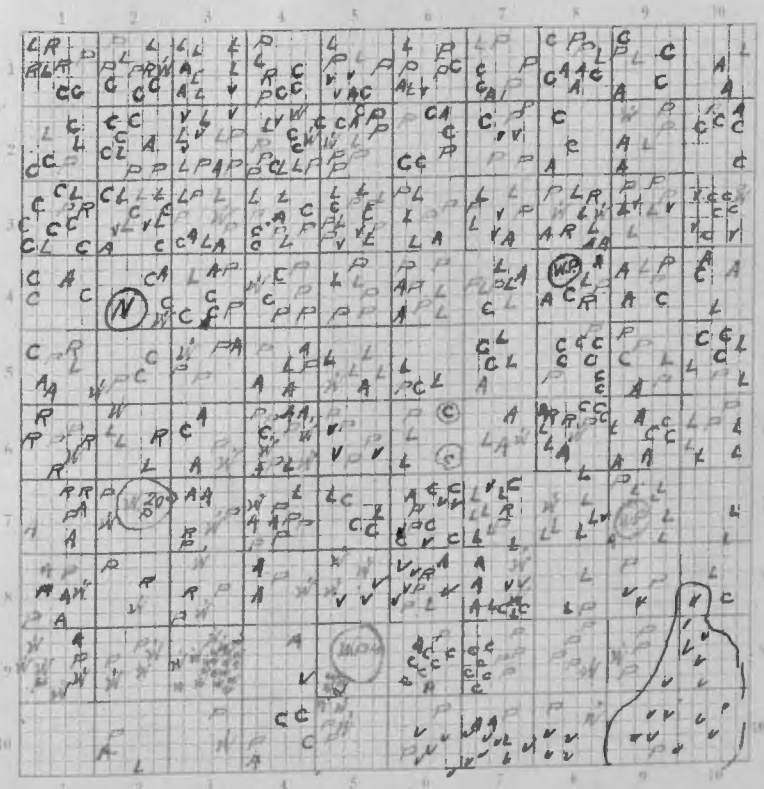
QUADRAT 14 LOCATION Coquet Forest West of East Fork Lake DATE Aug 23-11

FORMATION White Pine

CONSOCIES

SOCIETY

Trees Shrubs & Herbs large enough to shade seedlings



Scale - 1cm = 1m -

LEGEND:

(WP) or (NP) = Norway or White Pine 10" in diam

W - White Pine seedling 1 yr old

L - Honeysuckle (Lonicera ciliata

C = Hazel - Corylus americana

P = Wild Sarsaparilla Aralia nudicaulis (Panax.?)

A = Aster cordifolius

R = Rose - Rosa blando.

V = Blueberry Vaccinium canadense.

TAMARACK

The Tamarack swamp in which the accompanying quadrat was taken contained trees ranging from fifty to sixty years old, as found by cutting down five average trees from two to six inches in diameter. These trees averaged between three thousand four thousand to the acre, about one-fifth of them were dead, and some of the others were in a weakened condition.

The Tamaracks thruout this region are effected by the larch sawfly so that any studies as to suppression and death due to competition must necessarily be effected by this factor. These trees obtained a great deal of light and so the factors entering largely into competition are temperature, and available food materials.

The temperature of the swamp like many others of like nature examined, is low, so that the growing season is shorter. This probably has a good deal to do with the intolerance of the larch. As Zon states in his Forest Service Bulletin No. 92

temperature is an important factor in the ability of a tree to make food. This will be discussed further on.

In some situations such as stagnant swamps and bogs the water becomes acid, due to the decomposition of much vegetable matter from year to year, and interfers with the roots absorption of water and the salts which are in solution. As far as it was able to be determined in this swamp the acid was a negligible quantity, as there was a slow seepage to a lower level. Another factor which plays an important part in the growth of a tree, as stated before, is water. In the Tamarack situation there was a superabundance of water. Soil samples taken the 12th, of July showed the water content to be eighty percent for the first dm., eighty percent for the second dm., and seventy-six percent for the third dm. in depth.

Temperature as stated above, is very important from the standpoint of growth in all coniferous trees. This, in the writer's opinion, is the reason for the intolerance of Tamarack. Having a great supply of moisture, the Tamarack should have become a fairly

tolerant tree, but investigation showed that as late as July 15th, in patches thruout the swamp, ice still existed. This, of course, meant that the temperature around the roots of the trees was very low. On July 1st with a post hole digger and a sharp iron rod, ice was found in several places within two feet of the ground, protected by the layers of sphagnum moss, which covered the whole swamp. By July 15th the ice spots were less numerous, were much thinner and had disappeared by August 1st. The heavy rains thruout the latter part of July, no doubt, hastened the thawing of the ice. On August 12th the swamp was again examined and the temperature ranged from twenty-seven and six tenths degrees on the surface, to six and six tenths degrees Centigrade at three feet below.

Now, as was stated in the beginning, if the lower the temperature, the greater the amount of light necessary to enable the plant to make a like amount of food, the reason for the tendency of the Tamarack to get as much light as possible in these situations, is apparent. Likewise, the short seasons

in which it is possible for the Tamarack to make food due to the low temperature, make it imperative that it do the maximum amount of work possible while it can.

Reproduction:

The Tamarack in the situation studied ranged up to sixty-three years of age, and from twenty-five to thirty feet in height, and up to six inches in diameter. Some of the trees ran as follows:

Age	Diameter	Heighth
63	3"	25'
53	2¾	25
33	1¾	20 With cones
18	¾	8

The stand counting dead and live trees, averages between six thousand, seven thousand per acre, about five thousand being living trees. A small majority of the trees bear cones, which upon examination appear very normal and the seed viable. Young seedlings are very scarce. The grass and the depressions and the shade of the Labrador tree, and other shrubs upon the higher hummocks hinder the successful growth of young

sawfly, which defoliates the larch trees in July, and so shuts off the machinery for making food at about the time they are able, on account of the warming up of the soil to produce food at their maximum capacity. When the new leaves come out after the old ones have been eaten off, some of the material which should have gone to the increase in growth of the tree must be used for making new leaves. This necessarily cuts down the increment. The new leaves are less numerous and as a result the amount of food made in some cases is not enough to make up for that used in the actual life processes of the tree, and so many die. Another thing noticed in Young Tamarack is the dying back of the young terminal shoots on the ends of the twig on account of the larch sawfly laying its eggs in these places. If the pest continues most of the Tamarack seem to be doomed.

SPRUCE

When this formation was studied about one inch of water had fallen the day before as shown by the rain gage. This was taken up by the

W. H. Kenety

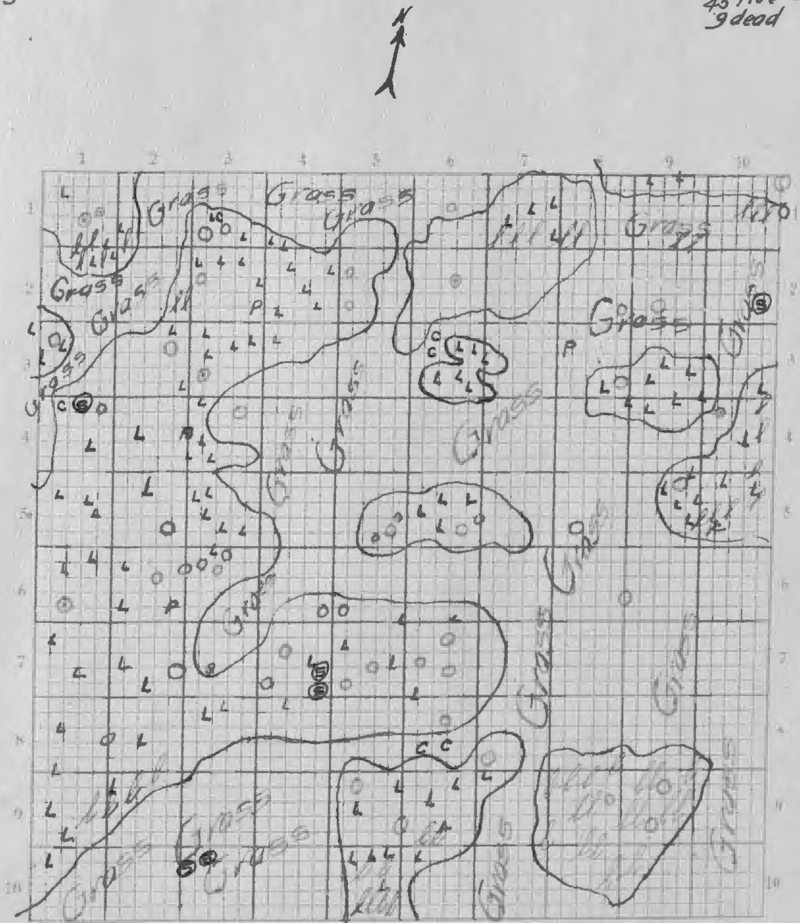
QUADRAT 12 LOCATION Cloquet Forest (South of Pasture) DATE July-13th.

FORMATION Tamorack Swamp

CONSOCIES

SOCIETY

45 live - 5400
9 dead 1080



Scale - 1cm - 1meter

LEGEND:

O = Live Tamarack - Larix americana

⊙ = Dead " " "

P. Spruce

L: Labrador Tea - ledum groenlandicum

ℒ: Laurel

Ⓢ: Willow clump Salix sp.

c: Hazel Corylus americana

Groundcover = Sphagnum moss

Plate 23

Plate 26.

This is the situation in which the Tamarack quadrat was taken. The characteristic vegetation is grass and Labrador Tea. The temperature and water content will be found in the tables describing the quadrat.

sphagnum moss, so that the samples taken at that time gave the water content as high as eighty-two percent at 2 dm. below the surface and seventy-nine percent for the first dm. of the surface.

The Black Spruce stand while not a desirable one from the lumberman's standpoint, gave some very interesting information as to reproduction and suppression. The ground cover, as stated, was sphagnum moss, which was saturated with water, so much so that pools of water were abundant. The ground was very uneven on account of the hummocks. These hummocks when measured were found to be in some places two and a half feet above the depressions. These hummocks were invariably found at the base of trees. This suggested that the shallow spreading roots of the trees afforded a sort of under framework, which prevented the moss sinking down and spreading out. Upon these hummocks more so than in other places, Labrador Tea had established itself. The roots of this herb helped to hold the moss in place. The accumulations of dead leaves together with the addition of moss from year to year

must have had much to do with the formation of the hummocks. On the top of many hummocks a sedge with very shallow fibrous roots was growing in mat like bunches.

Under Growth:

The principal herbs found were the Labrador Tea, Dwarf Birch and Blue-berry, Low Cranberry, occurred very rarely.

These herbs were found in the middle of June to be putting forth new leaves, and showing no signs of flowering, while the same species on the edge of the swamp and in a drier, warmer situation had already bloomed, and were starting to mature their fruits. Some explanation is necessary for this, and when the temperature of the soil was taken, one reason was apparent.

An average of the ten meter square quadrat was gotten by a geotome. Three borings in different places were taken for each ten cm. The average of these was then taken for each ten cm. The temperatures ranged as follows:

1½ M.	Surface	1 dm.	2 dm.	3 dm.
32.5	25	14	12	10.5

Subsequent investigations of the swamp revealed ice in many places at two and one-half to three feet below the surface, the moss making the very best packing. This would make the season at least six weeks to two months behind that of the drier, warmer situation. In connection with this the small diameter compared with the age of the trees is probably in some measure accounted for.

Another thing which may have a direct bearing upon the rate of growth as well as the establishment of Spruce in preference to other species is the acid quality of the soil. The largest tree found upon the quadrat was five and one-half inches in diameter and approximately thirty-five feet high. The diameter of four trees with their age is as follows;

Diameter	Age
2¼	54
2½	56
5½	54
4¼	58

T Three squirrel nests were found in the ten m. quadrat. This may have something to do with the lack of reproduction by seed under the Spruce.

One very peculiar thing noticed here was the layering of Black Spruce, a description of which will be given under a separate heading further on.

No animals were found upon the tract. No evidences of fire were present, altho the even age of the trees examined ranging as they did from fifty-four to fifty-eight years would give the impression that some agency must have caused the trees to start at about the same time.

The Spruce occupies this situation, not because it will thrive best there, but because it is better able to stand the cold of the short growing season than other species.

The accompanying quadrat is self explanatory, and is made very accurately for the trees and herbs found upon the ten m. square quadrat.

Fig 19

D.H. Power 171

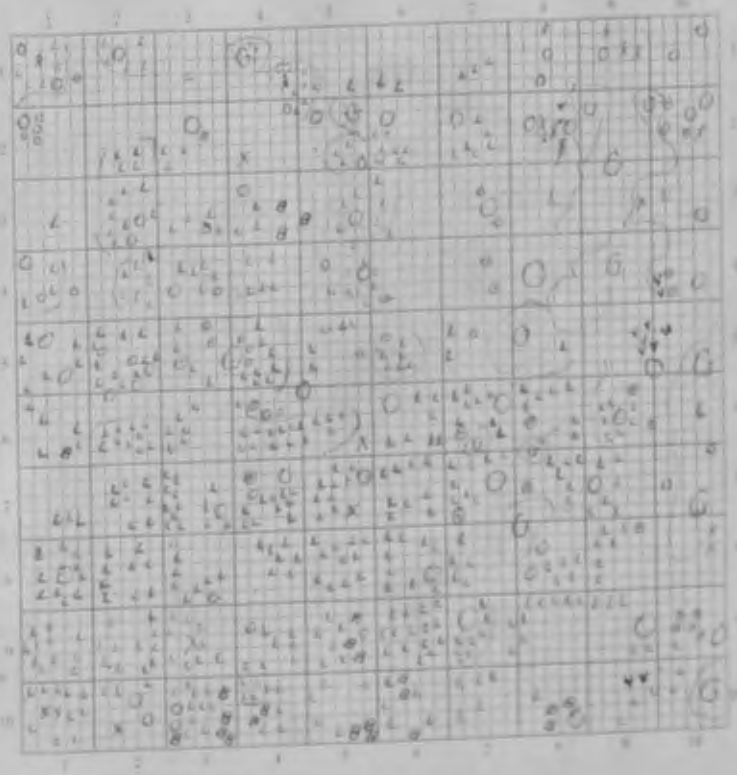
QUADRAT Not formation LOCATION Cloquet Forest DATE 6/19/11

FORMATION Spruce swamp

82 alive 9840
32 dead 3800

CONSOCIES

SOCIETY



Scale 1cm = 1meter

LEGEND:
O - Live Black Spruce (Picea mariana)
e - Dead "
X - Live Larch (Larix americana)
x - Dead "
L - Labrador tea (Ledum groenlandicum)
G - Grass (Carex)
B - Betula Pumila
V - Blueberry (Vaccinium canadense)
Ground cover - moss

Plate A7

Plate 27

This is a stand of Black Spruce showing the characteristic vegetation of Labrador Tea and Swamp Laurel. The layering habit is also manifested here. This was the situation in which the Black Spruce quadrat was taken. The vegetation will be found in the plotted chart.

Plate 28

Plate 28

This is an old railroad spur which has been dug out and makes an excellent denuded belt where migration and invasion of plants in this cut-over region may be studied easily.

SUMMARY.

I. The northeastern part of Minnesota, where this study was carried on, has been classified as belonging to the "Great Lakes" coniferous formation.

II. Water is the most important factor influencing reproduction and growth of forest trees in this region.

III. For the successful reproduction of Norway, Jack and White Pine several successive years with plenty of moisture, uniformly distributed throughout the growing season, is necessary so that the young trees may get their roots below the surface vegetation and in dry years will not starve for water on account of competition with this vegetation.

IV. Humidity readings at morning and noon followed a similar curve during the three months they were taken while those taken in the evening did not show any direct relation to the other two.

V. Ice was found in swamps until July 15th. Vegetation in these places compared to warmer situations was six weeks behind in the development.

VI. Reproduction by layering is very common in black spruce in the sphagnum swamps and plays an important part in the advance of forest trees into the swamps.

VII. Jack Pine in contrast to current opinion does not produce just one series or whorl of branches on the central bole each year. The number of whorls in most cases is greater than the number of annual rings.

VIII. At a light value of .15 or less Norway and Jack pine seedlings do not thrive well in natural sites. A light value of .20 seems to be sufficient with ordinary soil and water conditions found in natural mature stands.

Summmary

I The region studied is in the North eastern part of Minn.
It is typical of the north pine country and has been classed
as part of the great Lake coniferous Formation

II. According to the nature of the location light, water and
temperature vary in importance in their influence upon
thereproduction of the district But water is th
most importan factor

Water determinations over along period of time are more
valuable than availablewater determinations on account
of the difficulty in working with trees of any size

III. Ice is found in the swamps around the roots of trees
as late as the middle of July
This has a good deal to do with theintolerance of the
tamarack found in these situations

IV. Humidity readings for several months showed that the
moisture in the air at morning and noon was quite constant
while the humidity at evening seemed to bear no direct
relation to htat in the morning or night

V. water determinations showed that the water content ranged from 86% in black spruce toss low as 3½% in jack Pine

VI. Light readings in a large number of situations showed
that at a light value of.20 young norway andJack thrived
while ata Value ofI5 they were in apoor conditionshowing
that inthis place a light value of less than .I5 is
not sufficient to keep the se young trees a live

VII. One of the reasions for the scarvity of young Norway
seedlings where conditions are fit for them is the fact that
they need several years of abundant rainfall in order
that they may get their roots below the surface vegetation,

After once established they are able to persist

VIII Reproduction by layering is very abundant in black spruce. This has an important bearing upon the reproduction of this species and the reclamation of swamp lands by forests

IX Sweet fern covers large stretches of burned and cut over land and is so dense that it shades and crowds out ~~that such~~ any seedlings that may spring up from seed.

X Study from year to year on the burned and permanent plots will show the change in vegetation from year to year and the prevailing of the ~~sp~~ reproduction in the different situations.