Flaten

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A STUDY ON CHLOROSIS OF PINUS RESINOSA IN A FOREST NURSERY, WITH SPECIAL REFERENCE TO SOME MINERAL DEFICIENCIES.

by

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NURSERY OBSERVATIONS AND GENERAL INFORMATION

In May 1937, many 2-0 red pine seedlings were planted in the University of Michigan Forest Nursery near Packard St. Most of the stock was obtained from the School's nursery at Stinchfield which is located about 20 miles west of Ann Arbor, while the remainder was secured from the Higgins Lake Nursery. Transplanting was done by the 1937 seeding and planting class under the direction of Professor L. J. Young.

A great deal of work was done on the plantations that spring, so the largest and most vigorous of the 2-0 seedlings from the Stinchfield Nursery were selected for the plantations. Most of these smaller and less vigorous seedlings were planted at the Packard St. Nursery in the beds designated as A, B, C, D, E, F, G, and H. (see map). The remainder of the Stinchfield stock and all that from the Higgins Lake Nursery were planted in the beds designated as J, K, and L.

During the summer, a "peculiar" condition developed in the beds north of the road. Most of the beds became spotted with stunted yellow plants, many having leaftips of a purplish-brown color. In some places, large numbers of the plants died leaving thin and bare areas. Despite several fertilizer treatments, the condition has persisted up to the present time. This spring (1939) at least 25% of the stock was totally unfit for field planting due to chlorosis and inadequate root and top development.

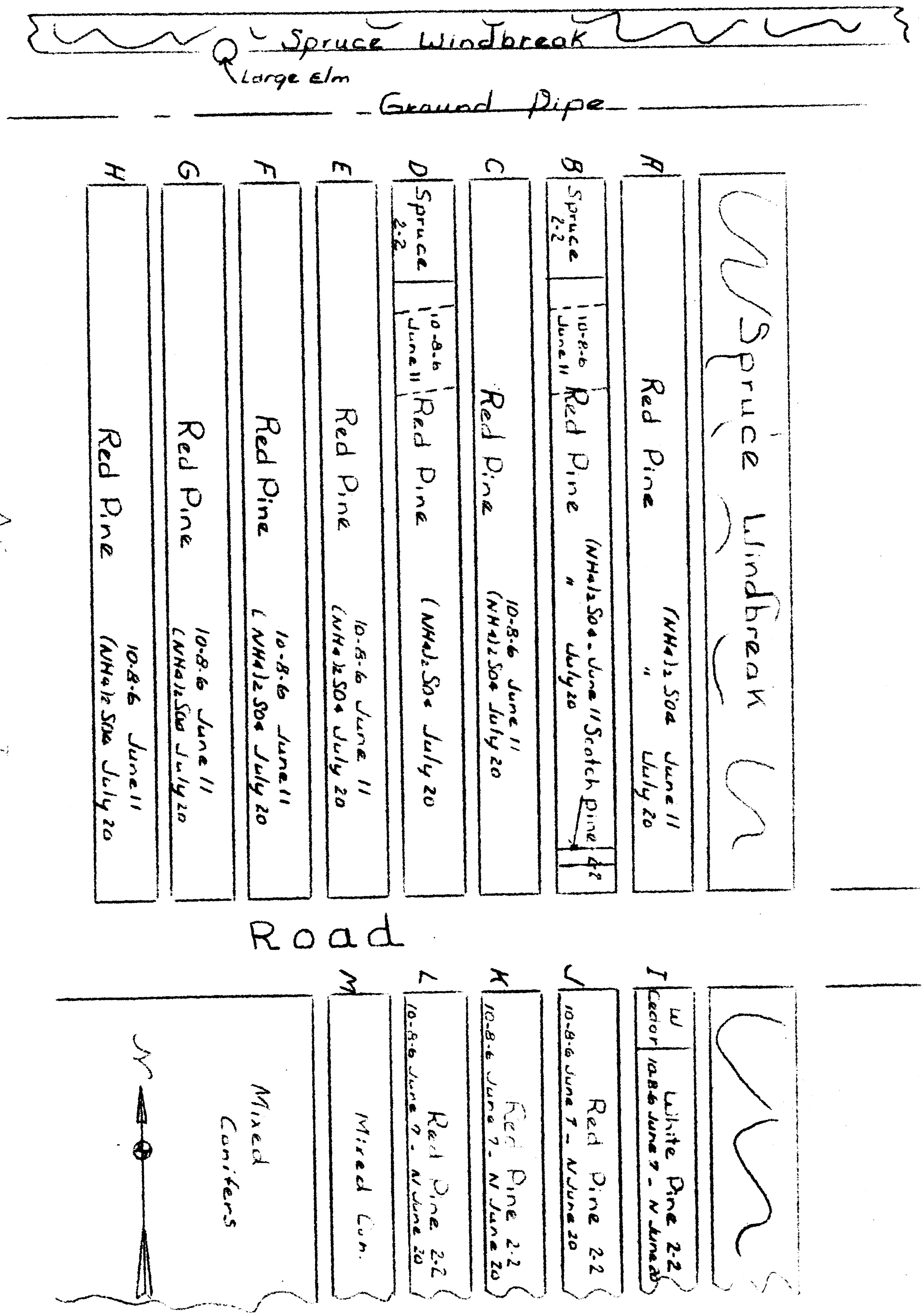

Spruce Windbreak
Large Elm
Ground Pipe
Map I
A
B
C
D
E
F
G
H
Spruce Windbreak
Red Pine
(NH4)2 SO4 June 11
" July 20
Spruce 2-2
10-8-6 June 11
(NH4)2 SO4 June 11
" July 20
Scotch Pine 2-2
10-8-6 June 11
(NH4)2 SO4 July 20
(NH4)2 SO4 July 20
10-8-6 June 11
(NH4)2 SO4 July 20
10-8-6 June 11
(NH4)2 SO4 July 20
10-8-6 June 11
(NH4)2 SO4 July 20
10-8-6 June 11
(NH4)2 SO4 July 20
Road
I
J
K
L
M
W Cedar
White Pine 2-2
10-8-6 June 7 - N June 20
Red Pine 2-2
10-8-6 June 7 - N June 20
Red Pine 2-2
10-8-6 June 7 - N June 20
Red Pine 2-2
10-8-6 June 7 - N June 20
Mixed Con.
Mixed Conifers
N

PLATE I

(Views looking northward along beds A, B, and C.)

Figures in this plate show the conditions as they existed in the spring of 1939 upon removal of the best stock for field plantings. Note in fig. 1, bed A which has a good growth strip on the side nearest the spruce windbreak. Other figures show the beds from different points of view.

PLATE I

Fig. 1

Fig. 2

Fig. 3

PLATE II

(Figures 1 and 2 are views looking south and southeast along the beds.)

Fig. 3 gives a general idea of the appearance of the stock as removed from the beds. Notice particularly the healthy tops and roots of the three plants on the right as compared with the tops and roots of the chlorotic plants on the left.

PLATE II

Fig. 1

Fig. 2

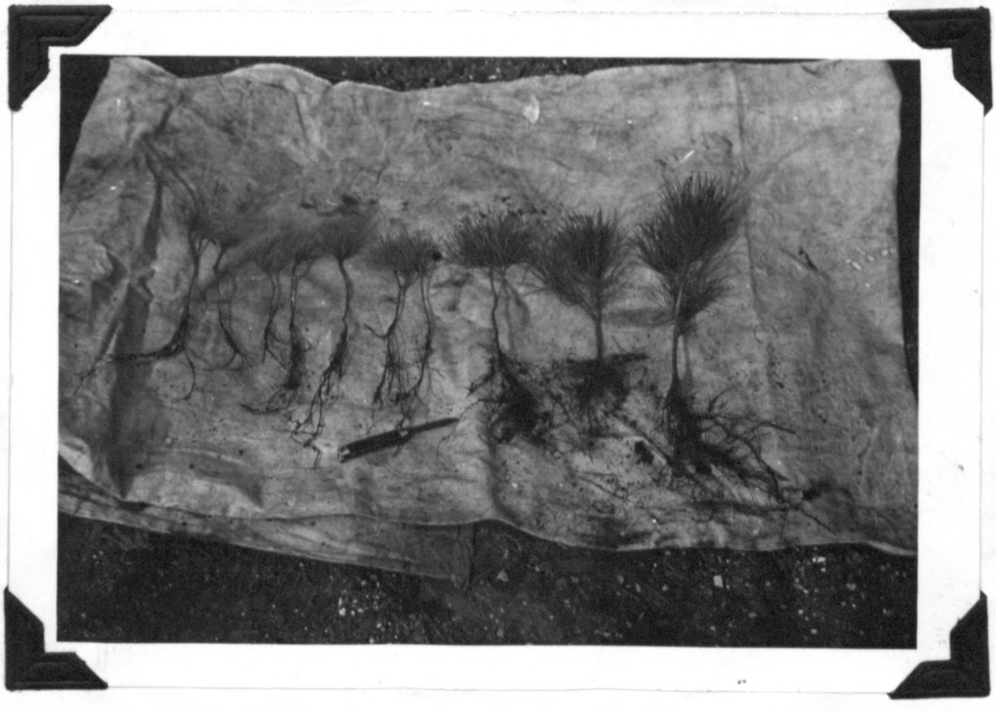


Fig. 3

PLATE III

Plate III shows red pine 2-2 stock as removed from the transplant beds in the spring of 1939. The healthy plants on the left show excellent root systems. Chlorotic plants on the right are poorly branched and have few short roots.

PLATE III

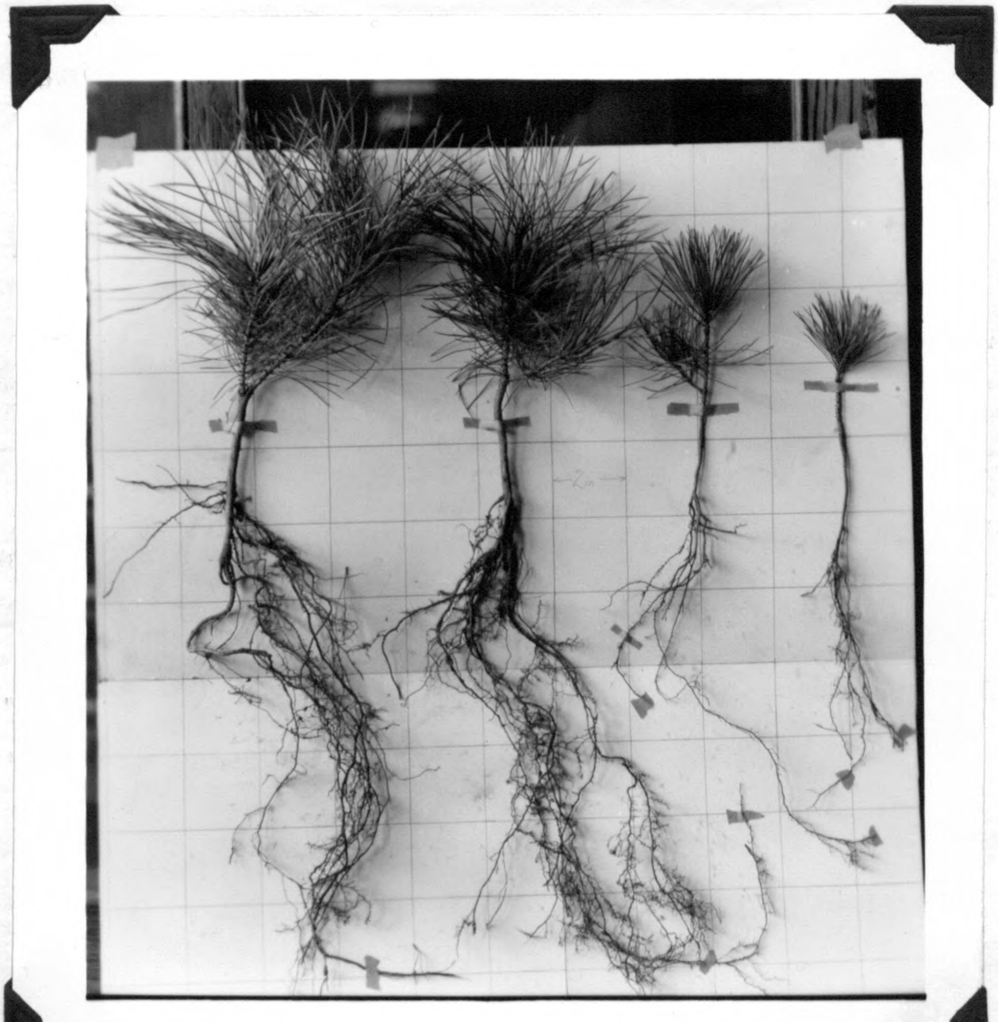
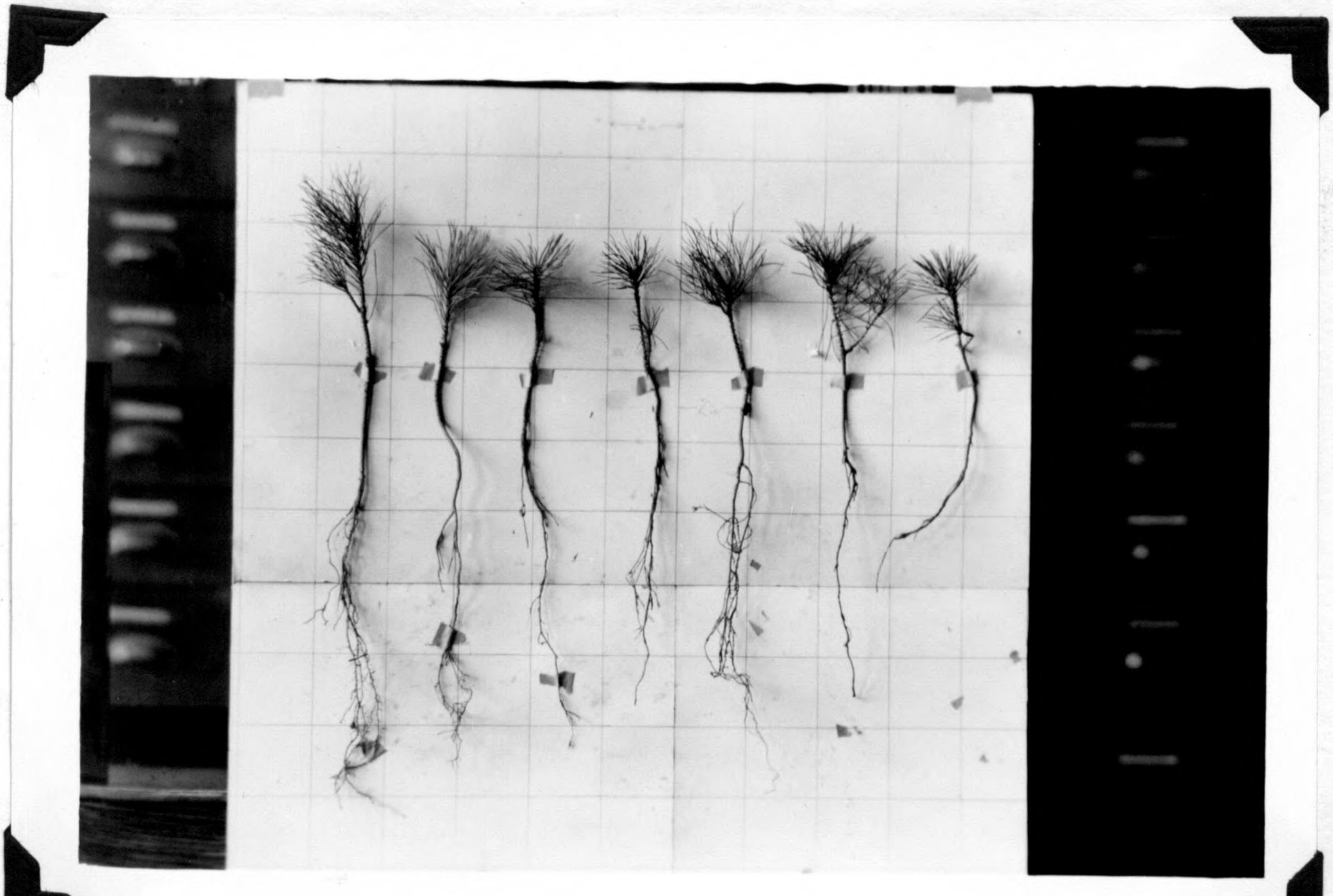


PLATE IV

Appearance of the dead plants upon removal from the nursery beds.

PLATE IV



EXPERIMENTAL

GENERAL

Experimental work dealt primarily with deficiencies of the principal mineral nutrients. viz., potassium, nitrogen, and phosphorous. Work was conducted by means of chemical and pot tests, and supplemented by nursery records and general observations of plants and nursery conditions.

A total of fifteen soil samples was tested by means of the Spurway method for determining the content of available and reserve mineral elements in the soil. This was supplemented in the case of phophorous, by the Bray test which is used extensively in Illinois.

As a check on the chemical tests, a series of pot experiments were set up in the greenhouse. These contained soils and plants from the chlorotic beds to which various combinations of N, P, and K were added in an effort to get a growth stimulus which would indicate the need for fertilization. Only a fair amount of success was obtained from these experiments due to the death of a large number of the plants. Then too, a great deal of difficulty was encountered in getting the plants to break their dormancy. Plants taken in during the months of October, November, December, and January failed to break dormancy, although subjected to periods of low temperatures, and treatments with ethylene chlorhydrin. Electric lights were used, but even this treatment failed to bring about satisfactory results.

Healthy plants taken in during February and the early part of March broke their dormancy after a four to five week period during which the lights were kept on for 12 hour periods every day. This however, left a rather short growing period, so growth was not felt to be altogether significant at this writing.

A number of pH tests were made in the field and laboratory by means of the soiltex, Morgan, and potentiometer tests.

Many plants were carefully examined in an effort to determine the extent of root rot and if possible, the presence of mycorrhizae.

SOIL TESTS

Fifteen soil tests were made of soils taken from various places in the nursery beds. Results, as shown in the tables following, indicate a definite deficiency in nitrates and potassium.

Nitrification was found to be normal as tests indicated the presence of: ammonia, 8 parts per million; nitrites, a trace to 4 parts per million; and nitrates, 8 to 20 parts per million.

Potassium was present in very small amounts, or less than 24 lbs. per acre. Reserve tests also showed a low soil content of this element.

Phosphorous gave low tests by the Spurway method. However, this element was not felt to be a limiting factor because the reserve and Bray tests gave medium to high reactions which is sufficient for conifers.

Magnesium gave satisfactory tests in all cases. Iron however, seemed satisfactory in the available form but did not in all cases give satisfactory results in the reserve form.

Other minerals such as sodium, and aluminum which are toxic if present in excess, gave satisfactory tests. Calcium tested 600 parts per million or 1200 lbs. per acre, which is considered high.

EXPLANATION OF THE TERMS USED IN THE SOIL TEST TABLES.

Ppm ---- Parts per million in the soil extract.

L A/6 -- Lbs. per acre in the top 6 inches, by volume.

Spur. -- Spurway test method.

Bray --- Bray test method.

M. ----- Morgan test for pH.

S. ----- Results were satisfactory.

Blank -- Indicates no color reaction in the test. This does not mean that the element tested for was not present, but that it was present in too small amounts to give a reaction by the test used.

TABLE I

	Available								
	Sample 1			Sample 2			Sample 3		
	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks
Nitrates	8	16	low	8	16	low	8	16	low
Phos. (Spur.)	2	4	low	-	-	trace	2	4	low
Phos. (Bray)	Med.	-	S.	Med.	-	~~trace~~ S.	Med.	-	S.
Potassium	0	-24	low	0	-24	low	0	-24	low
Calcium	600	1200	high	600	1200	high	600	1200	high
Magnesium	4	8	S.	20	40	S.	20	40	S.
Ammonia	8	16	S.	8	16	S.	8	16	S.
Nitrites	-	-	-	-	-	-	-	-	-
Iron	40	80	S.	40	80	S.	40	80	S.
Aluminum	Blank	-	S.	Blank	-	S.	Blank	-	S.
Manganese	Blank	-	S.	Blank	-	S.	Blank	-	S.
Sulphates	Blank	-	S.	Blank	-	S.	Blank	-	S.
Chlorides	Blank	-	S.	Blank	-	S.	Blank	-	S.
Sodium	Blank	-	S.	Blank	-	S.	Blank	-	S.
pH	Sp.-7.0; M.-7.2			Sp.-7.0; M.-7.4			M.-7.4		
	Reserve								
Potassium	Blank	-	low	Blank	-	low	Blank	-	low
Iron	40	80	S.	40	80	S.	40	80	S.
Manganese	Blank	-	-	Blank	-	-	Blank	-	-
Phos.	4	8	low	4	8	low	4	8	low

Tests made Mar. 25, 1939

TABLE II

	Sample 4			Sample 5			Sample 6		
	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks
Available									
Nitrates	8	16	low	8	16	low	8	16	low
Phos. (Spur.)	-	-	trace	-	-	trace	-	-	trace
Phos. (Bray)	Medi	-	S	Med.	-	S	Med.	-	S.
Potassium	0	-24	low	0	-24	low	0	-24	low
Calcium	600	1200	high	600	1200	high	600	1200	high
Magnesium	20	40	S.	20	40	S.	20	40	S.
Ammonia	8	16	S.	8	16	S.	8	16	S.
Nitrites	-	-	-	-	-	trace	-	-	-
Iron	40	80	S.	40	80	S.	40	80	S.
Aluminum	Blank	-	S.	Blank	-	S.	Blank	-	S.
Manganese	Blank	-	S.	Blank	-	S.	Blank	-	S.
Sulphates	Blank	-	S.	Blank	-	S.	Blank	-	S.
Chlorides	Blank	-	S.	Blank	-	S.	Blank	-	S.
Sodium	Blank	-	S.	Blank	-	S.	Blank	-	S.
pH	-	-	-	-	-	-	Sp.-	7.0	-
Reserve									
Potassium	Blank	-	low	Blank	-	low	Blank	-	low
Iron	Trace	-	-	Trace	-	-	Trace	-	-
Manganese	Trace	-	-	Trace	-	-	Blank	-	-
Phosphorous	10	20	Med.	10	20	Med.	10	20	Med.

Tests made Mar. 25, 1939

TABLE III

	Sample 7			Sample 8			Sample 9		
	Available								
	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks
Nitrates	20	40	low	-8	-16	low	-8	-16	low
Phos. (Spur.)	-2	-4	low	-2	-4	low	-2	-4	low
Phos. (Bray)	Med.	-	S.	high	-	S.	Med.	-	S.
Potassium	0	-24	low	0	-24	low	0	-24	low
Calcium	600	1200	high	600	1200	high	600	1200	high
Magnesium	20	40	S.	20	40	S.	20	40	S.
Ammonia	8	16	S.	8	16	S.	8	16	S.
Nitrites	-4	-8	S.	-4	-8	S.	-4	-8	S.
Iron	40	80	S.	40	80	S.	40	80	S.
Aluminum	Blank	-	S.	Blank	-	S.	Blank	-	S.
Manganese	-4	-8	S.	-4	-8	S.	-4	-8	S.
Sulphates	Blank	-	S.	Blank	-	S.	Blank	-	S.
Chlorides	Blank	-	S.	Blank	-	S.	Blank	-	S.
Sodium	-	-	-	-	-	-	-	-	-
pH	-	-	-	-	-	-	-	-	-
	Reserve								
Potassium	-20	-40	low	-20	-40	low	-20	-40	low
Iron	Blank	-	-	Blank	-	-	Blank	-	-
Manganese	Blank	-	-	Trace	-	-	Trace	-	-
Phosphorous	-10	-40	Med.	-2½	-20	Med.	~~4~~ ½	~~8~~ 4	low

Tests made April 1, 1939

TABLE IV

	Sample 10			Sample 11			Sample 12		
	Available								
	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks
Nitrates	-8	-16	low	-8	-16	low	20	40	low
Phos. (Spur.)	-2	-4	low	-2	-4	low	-2	-4	low
Phos. (Bray)	high	-	S.	high	-	S.	high	-	S.
Potassium	0	-24	low	0	-24	low	0	-24	low
Calcium	600	1200	high	600	1200	high	600	1200	high
Magnesium	20	40	S.	20	40	S.	20	40	S.
Ammonia	8	16	S.	8	16	S.	8	16	S.
Nitrites	Blank	-	-	Blank	-	-	Blank	-	-
Iron	40	80	S.	40	80	S.	40	80	S.
Aluminum	Blank	-	S.	Blank	-	S.	Blank	-	S.
Manganese	-4	-8	S.	-4	-8	S.	-4	-8	S.
Sulphates	Blank	-	Blank	Blank	-	-	Blank	-	-
Chlorides	Blank	-	-	Blank	-	-	Blank	-	-
Sodium	Blank	-	-	Blank	-	-	Blank	-	-
pH	-	-	-	-	-	-	-	-	-
	Reserve								
Potassium	-20	-40	low	-20	-40	low	-20	-40	low
Iron	Blank	-	-	Blank	-	-	Blank	-	-
Manganese	Blank	-	-	Blank	-	-	Trace	-	-
Phosphorous	-4	8	low	-10	-40	~~low~~ Med.	10	20	Med.

Tests made April 1, 1939

TABLE V

	Sample 13			Sample 14			Sample 15		
	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks	Ppm	LA/6	Remarks
Available									
Nitrates	-8	-16	low	-8	-16	low	-8	-16	low
Phos. (Spur.)	-2	-4	low	-2	-4	low	-2	-4	low
Phos. (Bray)	high	-	S.	high	-	S.	high	-	S.
Potassium	0	-24	S.	0	-24	S.	0	-24	S.
Calcium	600	1200	high	600	1200	high	600	1200	high
Magnesium	20	40	S.	20	40	S.	20	40	S.
Ammonia	8	16	S.	8	16	S.	8	16	S.
Nitrites	-4	-8	S.	-4	-8	S.	-4	-8	S.
Iron	40	80	S.	40	80	S.	40	80	S.
Aluminum	Blank	-	S.	Blank	-	S.	Blank	-	S.
Manganese	Blank	-	S.	Blank	-	S.	Blank	-	S.
Sulphates	Blank	-	S.	Blank	-	S.	Blank	-	S.
Chlorides	Blank	-	S.	Blank	-	S.	Blank	-	S.
Sodium	Blank	-	S.	Blank	-	S.	Blank	-	S.
pH	Spur. 7.7			Spur. 7.7			Spur. 7.7		
Reserve									
Potassium	0	-24	low	0	-24	low	0	-24	low
Iron	40	80	S.	40	80	S.	40	80	S.
Manganese	Blank	-	-	Blank	-	-	Blank	-	-
Phosphorous	10	20	Med.	10	20	Med.	10	20	Med.

Tests made May 6, 1939

POT TESTS

During the experiment, plants were removed from the nursery on Oct. 22, Oct. 29, Oct. 30, Nov. 14, Nov. 28, Nov. 30, Dec. 3, Jan. 3, Feb. 10, and Mar. 25. In all, a total of 104 pots were taken into the greenhouse, of which only 30 came through with living plants that broke dormancy early enough to be of any value in this experiment. A great many of the plants died, due perhaps to the fact that the plants were already in such a weakened condition that they could not withstand transplanting. This was particularly true of the plants removed from the beds during Oct., Nov., and Dec., as in the early part of the experiment, extremely chlorotic plants were taken in with the idea of restoring them to proper color by means of the proper nutrient treatment. It is also probable that the sudden change in temperature and increase in evaporation rate may have had a great deal to do with the death of many of the plants.

Getting the plants to break their dormancy proved to be another problem, as plants taken in as late as Hanuary continued to remain in their dormant state. Twenty-four hour treatments with ethylene chlorhydrin were tried on half the plants, but these gave no results whatsoever.

Lighting equipment was set up so that lights could be kept on the plants for 12 hour periods every day. Finally, after four to five weeks, the plants taken into the greenhouse during Feb. and Mar. began to break their period of dormancy.

Nutrient treatments consisted mainly of the additions of various combinations of ammonium sulphate, ammonium phosphate, potassium nitrate, potassium sulphate, and a full fertilizer containing N-4%, P-12%, and K_2o-4%.

The following gives some indication of the growing time, nutrients added, and growth up to the present time:

Pot No.	Treatment	Growing time days	New leaf growth inches
A_2	0	45	$1\frac{3}{4}$
40	0	52	$1\frac{1}{2}$
48	0	62	2
49	0	55	$2\frac{1}{4}$
72	0	31	$\frac{1}{2}$
74	0	34	$1\frac{1}{4}$
20	0	33	1
70	0	34	$\frac{3}{4}$
A_5	KNP-2.3 grams	40	$1\frac{1}{2}$
A_7	KNP-12. "	55	$1\frac{1}{2}$
71	KNP- 1. "	49	$\frac{3}{4}$
73	KNP- 1. "	31	$1\frac{1}{4}$
22	KNP- 1. "	30	$\frac{3}{4}$
17	KN-- 1. "	46	2
A_7	NP-- 1.9 "	27	$\frac{3}{4}$
2	N--- .7 "	62	2
A_8	K--- .34 "	70	$2\frac{1}{4}$
13	NP-- 1.9 "	58	$1\frac{3}{4}$
24	NP-- .34 "	52	$1\frac{3}{4}$

Eleven pots, each containing three healthy 2-0 seedlings from the Packard Street Nursery, were set up using two different kinds of soils. Four pots, with a total of 12 plants were set up in soil from the Stinchfield Nursery. The remaining seven were potted with soil from bed F at the Packard Street Nursery. Three of the latter pots received treatments as follows:

Pot 1 ------ 7.grams of full fertilizer.

Pot 2 ------ .7 grams of ammonium sulphate.

Pot 3 ------ 1. gram of potassium nitrate.

The results from the 11 pots of 2-0 seedling stock were the same as those of the 19 containing 2-2 stock. Growth and color of the new leaves showed no correlation with the kind of soil or soil treatments.

One peculiarity observed on the old leaf growth was that in nearly every plant, the old leaf tips were dying back. This was a condition noticed on a number of the plants which had died before breaking dormancy. Though more pronounced in the potted plants, this condition was much like that observed in the nursery.

PLATE V

This plate shows the appearance of the plants at the end of a growing period of about 60 days. Close inspection of the front, which was more clearly in focus, reveals the lighter appearing new growth which was observed for color and leaf length.

Pot	Growing time days	Leaf length inches.
N	61	2
NP	60	$1\frac{3}{4}$
K	69	$2\frac{1}{4}$
O	61	2
KNP	54	$1\frac{1}{4}$
O	54	$2\frac{1}{4}$

PLATE V

POTENTIOMETER TESTS FOR PH

A number of pH tests were made by means of the Youden Hydrogen Ion Concentration Apparatus. The following are the results obtained:

Sample	First test	Second test	Third test
1	7.06	7.20	7.28
2	7.70	7.65	
3	7.78	7.65	
4	7.77	7.77	
5	7.77	7.61	
6	7.70	7.70	
7	7.99	7.90	
8	7.61	7.61	
9	7.84	7.70	
10	7.82	7.70	
11	7.87	7.87	
12	7.67	7.61	
13	7.51	7.45	
14	7.92	7.70	
15	7.51	7.32	
16	7.47	7.35	
17	7.08	7.37	
18	7.78	7.65	
19	7.78	7.78	
20	7.87	7.82	

The approximate range as can be seen from the preceding data, is between 7. and 8. No correlation between good and poor growth on the basis of hydrogen ion concentration was found.

ROOT EXAMINATIONS

Root rot was definitely present in certain spots, and especially those areas in which many of the plants had died. Upon removal of the bark from the roots, a brown discoloration was distinctly visible in the root ends. However, in many of the chlorotic plants no discoloration of the roots was at all visible.

After a little practice, one could quite easily spot trees with root rot and those lacking it. Trees that were mildly chlorotic and had no brown tips usually had no root discoloration. On the other hand, plants that had an extremely yellow color and brown tips, were almost certain to have root discolorations.

One of the peculiarities of bed B was that scotch pine at one end, and spruce at the other were growing in a healthy state despite the presence of root rot and chlorosis in the red pine transplants adjacent to them. In beds J, K, and L, just across the road, no signs of chlorosis or root rot were present.

MYCORRHIZAE

Root examinations seemed to indicate the presence of mycorrhizae on the plants in beds J, K, and L. However, some question arose as to their presence in spots of the chlorotic beds. Invariably, the healthy plants had an abundance of short roots which were swollen and had a great deal of non-suberized surface. The chlorotic plants, on the other hand, had fewer short roots, nearly all of which lacked the characteristic swollen appearance of mycorrhizal roots. Whether the condition of the chlorotic plants was actually due to the lack of mycorrhizae, or a secondary condition resulting from the general poor health of the plant was not definitely known.

In the following plates are microphotographs of a number of representative short roots of both chlorotic and healthy plants.

PLATE VI

Roots from healthy plants, showing the elongated and swollen tips which are believed to have mycorrhizae.

PLATE VI

Fig.1 (10x)

Fig.2 (10x)

PLATE VII

Short roots from chlorotic plants, showing the lack of swollen and elongated tips. The appearance is much like that described as psuedomycorrhizae by Raynor.(6) " In pine they are usually simple and unbranched, more slender and of a darker color than true mycorrhizae."

PLATE VII

Fig.1 (10x)

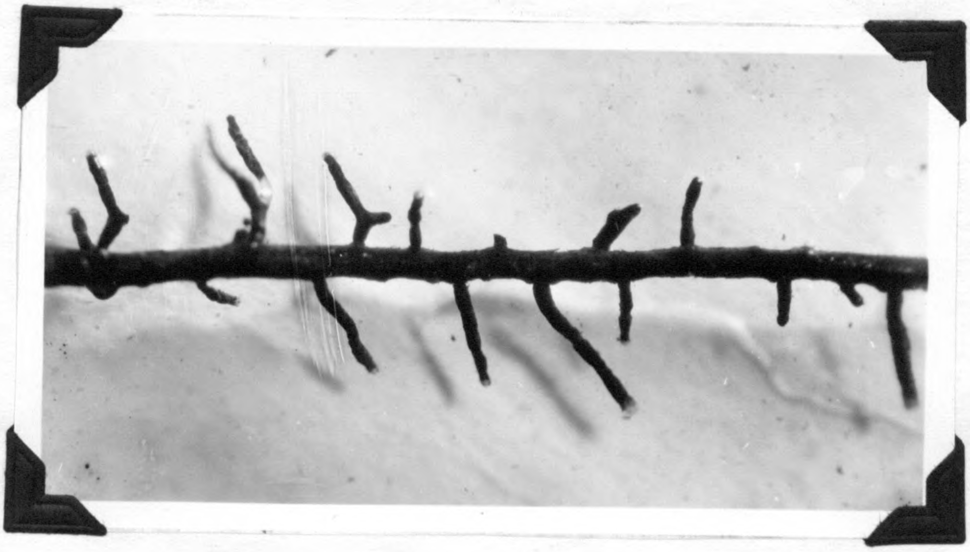


Fig.2 (10x)

Fig.3 (10x)

PLATE VIII

Fig. 1 --- Hatch, A. B. " The Physical Basis of Mycotrophy". Black Rock Forest Bull. #6 pp. 134

Fig. 2 --- Arthur, Pierson Kelley " Mycorrhizae of Mt. Alto Nursery Stock". Jour. of For. v 29, 1930 pp 37

Fig. 3 --- Mitchell, Finn and Rosendahl - Black Rock Forest Papers. pp 66

PLATE VIII

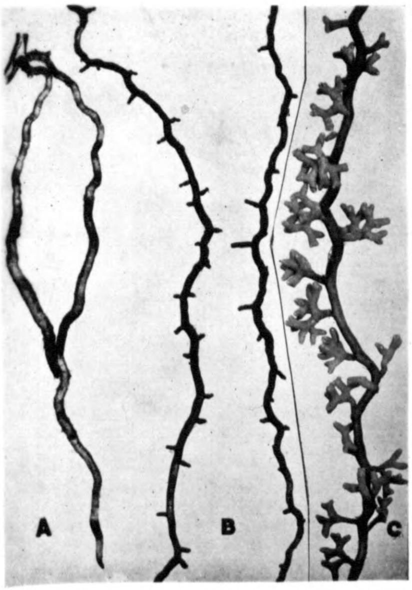


PLATE XIII. ILLUSTRATING THE RELATION BETWEEN THE ROOTING ENVIRONMENT AND SHORT-ROOT DEVELOPMENT IN SEEDLINGS RAISED IN BLACK ROCK FOREST EXPERIMENTS (X 4).

A. Long-roots lacking short-roots under conditions of high nitrogen availability (Sand culture experiments of Mitchell, 1934). B. Average development of short-roots in low nitrogen availabilities (Sand culture experiments of Mitchell, 1934). C. Short-root development in Ridge soil, Black Rock Forest, when invaded by mycorrhizal fungi. Non-suberized surface area many times as great as in B.

Fig.1

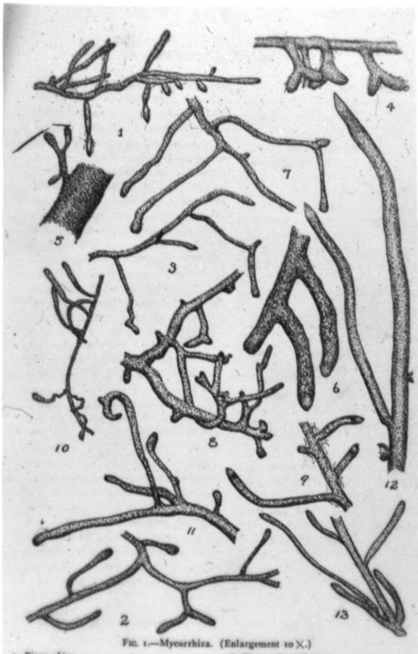


FIG. 1.—Mycorrhiza. (Enlargement 10 X.)

1. *Picea abies*
2. *Larix kæmpferi* (*sand*)
3. *Larix kæmpferi* (*clay*)
4. *Pinus rigida*
5. *Pinus echinata*
6. *Pinus strobus*
7. *Pinus sylvestris*
8. *Pinus sylvestris var.*
9. *Pinus resinosa*
10. *Quercus borealis*
11. *Juglans nigra*
12. *Fraxinus americana*
13. *Catalpa bignonioides*

Fig.2

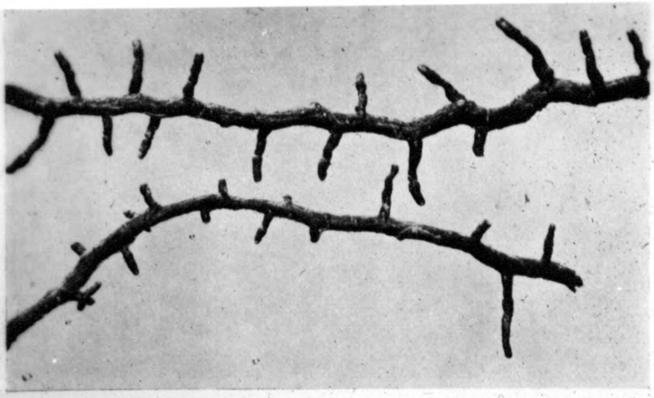


PLATE II-B.—Non-mycorrhizal short roots (that is, pseudomycorrhizae, as defined by Melin, 1917 and 1927) on mother roots of white pine seedling from region of unfertilized bed in which typical mycorrhizae were lacking; X10. The other non-mycorrhizal root type—true uninfected short roots, which possess root hairs—was infrequent in the unfertilized beds, and is not shown. (See Hatch and Doak, 1933, for distinguishing features of the various short root types).

Fig.3

DISCUSSION

SOIL TESTS FOR MINERAL DEFICIENCY

Soil tests revealed a definite deficiency in essential mineral nutrients as less than 16 and 24 pounds per acre were found for nitrates and potassium respectively.

In a recent investigation on the fertilization of Pinus resinosa, Lunt (3) finds, "Chemical analysis of nursery trees from Peoples Forest Nursery indicates that the requirements of red pine 1-0, 2-0, and 2-1 stock are respectively, for nitrates 41, 154, and 84 lbs. per acre, for P_2O_5 14, 32, and 23 lbs., and for K_2O 18, 59, and 41 lbs. Taking into consideration the density of the stand and the dry weight per unit of the stand and the dry weight per unit area, as well as the percentage composition, the total requirements for the first three years of growth were the highest for scotch pine and lowest for norway spruce."

Although the nitrate and potassium tests were low, the condition in the nursery could not be explained entirely on the basis of mineral deficiency.

In the first place, no correlation between good growth and fertility could be determined on the basis of the soil tests as these were nearly the same regardless of the growth conditions from which the soil samples were taken.

Then too, scotch pine was growing very satisfactorly in bed B although surrounded on all sides by the chlorotic red pine transplants. On the basis of Lunt's findings, the scotch pine should have shown chlorosis too, if the problem had been one of mineral deficiency, since the requirements of scotch pine are higher than those of red pine for the first three years.

Red pine of the same age in beds J, K, and L, just across the road from the chlorotic beds, gave no evidence whatsoever of chlorosis or root rot. And, though soil tests of these beds were made, they failed to show a higher fertility than soils from the chlorotic beds.

POT TESTS

Pot tests failed to show any indication of deficiencies in nitrates, potassium, or phosphorous. Healthy plants transplanted into the supposedly poor soil of bed F (poor growth area) failed to show any growth differentiation regardless of treatment or the lack of it.

Fertilizer treatments in the nursery during the summer of 1938, likewise failed to show appreciable results. (See the map for areas treated with ammonium sulphate and the 10-8-6- fertilizer). It is possible that in both the pot and nursery treatments insufficient amounts were used. As a check on this, varying amounts should have been added up to a point of excess, so that this unknown factor could have been eliminated.

In his nursery experiments with red pine, Lunt (3) finds that the following fertilizer ratio proved best:

N ---- 10 parts

P_2O_5 - 4 parts

K_2O -- 5 parts

Organic fertilizers such as fish meal, and tankage were found to be superior to inorganic fertilizers.

HYDROGEN ION

The pH tests varied from 7. to 8., but no correlation could be found between good and poor growth on this basis. One thing was certain however, and that was that the soil was definitely too alkaline for the best red pine growth. (No data could be found as to the best pH condition for red pine, but it is believed to be about 5.5)

What effect the high pH had on nutrient absorption, is not known.

ROOT ROT

During the summer of 1937, favorable moisture conditions for the development of root rot occurred due to heavy precipitat- and poor drainage. But, no satisfactory explanation on this basis can be offered for the presence of rot in the chlorotic beds and the lack of it in beds J, K, and L, as soil, drainage, and slope were nearly identical. There is the possibility that the Higgins Lake stock was of a superior quality and better adapted to the Packard Street Nursery conditions. However, the Stinchfield stock which was planted with that from the Higgins Lake stock in beds J, K, and L, showed no differentiation in growth.

Scotch pine and norway spruce were not affected by root rot or chlorosis although growing in the same beds as the "sick" plants. On the basis of the root rot theory, these species were either not susceptible to the root rot or they were in a more healthy condition and therefore better able to resist fungus attack.

MYCORRHIZAE

Though nothing but general observations were made concerning mycorrhizae, the findings and explanations concerning it were so novel that the writer felt they were worthwhile discussing in this report.

According to the Stahl and Hatch (2) theory, mycorrhizae vary inversely to the amounts of certain available mineral nutrients in the soil. viz., potassium, nitrogen, phosphorous, and calcium. The relationship of the fungus and plant is symbiotic, and depends upon the concentration of the nutrients within each. Since the fungus has the greater absorbing capacity, it is more capable of obtaining nutrients from the infertile soils, thereby increasing its concentration of these elements over that of the plant. As a result, the fungus supplies the nutrient elements to the plant, and the plant ~~in~~ supplies the necessary carbohydrates to the fungus.

Many writers report the absence of mycorrhizae from forest nurseries that have soils deficient in one or more of the essential plant nutrient elements. The result is a spotted and chlorotic growth condition, and unless the beds become infected, the plants die or remain chlorotic and checked for years.

Baxter (1), in a report on this nursery in 1926, brought out the fact that mycorrhizae were absent from the roots. At that time, the one year seedlings of mugho, norway, scotch, austrian, and white pine and douglas fir exhibited a stunted and rather ragged appearance. Many of the plants were brown and dying while others nearby had a good color and were in a healthy state.

In his studies on a prarie nursery at Iowa State College, McComb (4) states, "In the middle of the first growing season, many of the pine seedlings turned brown to reddish-purple in color, while certain spots in the beds retained their natural color." Examinations of the diseased seedling roots showed that little or no mycorrhizae were present.

Raynor (6) reports the following condition that was found on the Wareham Heath, Dorset, as described in a forestry report, "Germination of Maritime pine and P. radiata D. Don was good, of Corsican pine bad (that of Scots pine subsequently on the very poor and exposed parts selected for experimental purposes was invariably very bad). During the first and second years after sowing, many seedlings died outright, the survivors lingering on in a condition of more or less complete arrest, two or three inches high or less; there was no growth, the older needles turned brown, the younger becoming yellowish or reddish-green in the late summer. During the fourth and fifth years from sowing, a small percentage of the seedlings emerged from check and became green and bushy, and a still smaller percentage reacted similarly during the sixth year. In 1929 there were many blanks and puzzling inconsistencies of behavior; e.g., a small patch of seedlings suddenly beginning to grow vigorously while those a few feet away remained practically moribund."

In each of the cases mentioned, (many others could be cited) the cause was the lack of proper mycorrhizal infection. Often this lack of infection can be explained on the grounds that trees had never been grown in the region before. In other cases, a possible explanation is on the basis of toxicity.

SOIL TOXICITY

Raynor (6) believes that proper soil conditions are essential for good mycorrhizal growth, and that infertility (as regards mycorrhizae) brings about a replacement of the mycorrhizae by pseudomycorrhizae which act as mild parasites.

Melin (5) reported that a pH of 4.5 produced the best growth of mycorrhizae on trees that were typical of a raw humus type of soil. Below 3.0 and above 6.0 mycorrhizal activity was found to be greatly retarded. However, many writers report that mycorrhizae are found on forest trees regardless of the condition of acidity.

In summary to the question, Hatch (2) says, "-- except as saturation, excessive dryness or unfavorable acidities affect the abilities of mycorrhizal fungi to survive, the distribution of ectotropic mycorrhizae in nature is determined by the availabilities of nutrient elements."

SUMMARY AND CONCLUSIONS

Though soil tests failed to show any correlation between good growth and soil fertility, they did reveal a general deficiency of both potassium and nitrates.

No growth stimulus could be determined in either the pot or nursery treatments with fertilizers. However, there is the possibility that inadequate amounts were added.

Due to the high calcium carbonate content of the soil, the pH was between 7. and 8. which was considered high for red pine.

Root rot was felt to be a distinctly secondary factor despite its prevalence in the chlorotic beds.

Though little but actual observations were made concerning it, the writer felt the findings as related to mycorrhizae justified further investigations.

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QUESTIONS AS REGARDS MYCORRHIZAE

What was the condition of the Stinchfield 2-0 stock as regards mycorrhizal infection? Are the soil conditions such at Stinchfield, that mycorrhizal infection is not needed ?

Did the 2-0 stock from the Higgins Lake Nursery have adequate mycorrhizal infection ? And if it did, was the Stinchfield stock planted with it in beds L, K, and J, infected from it ?

What are the soil conditions in the Packard Street Nursery as regards Pseudomycorrhizae formation ?