Effects of Peat Additions and Seedling Density Upon Development and Chemical Composition of Douglas-Fir (*Pseudotsuga menziesii*) Nursery Stock

CHEN HSIEN-FANG

INTRODUCTION

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is a predominant species in the coniferous forests of the Pacific Northwest of the United States and Canada. Millions of seedlings of this species are produced in nurseries annually to plant cutover and denuded lands. In recent years, foresters of this region recongnize that quality of planting stock is one of the most important variable in plantation success and attempt to raise stock quality in order to obtain satisfactory survival and growth in the field. The economic importance of quality of planting stock produced from a nursery has also been pointed out by wilde (21). The fate of the multi-million dollar enterprise embodying the cost of reforested land, plantation, fire protecion and silvicultural management is strongly dependent upon quality of stock. This report is to present the results of experiments on the effects of peat additions and density of seedlings in seedbeds upon the growth, root development, and quality of Douglas-fir nursery stock.

---

* The writer wishes to express his sincere appreciation to Dr. Stanley P. Gessel, professor of forest soils, University of Washington, under whose direction this study was conducted. The writer is grateful to Dr. Richard B. Wallker, professor of plant physiology, University of Washington, for his invaluable advices for the leaf tissue analytical technique. This study was in coopperation with Dr. J W. Duffield, Forest Industries Tree Nursery at Nisqually, and Dr. E. C. Steinbrenner, Weyerhaeuser Timber Company. Their great help during the study are acknowledged with thanks by the writer.

MATERIAL AND METHODS

1. Nursery culture technique.

This experiment was carried out in the Forest Industries Tree Nursery, at Nisqually, Washington. Two seed beds, 250 feet by 4 feet, were used for planting; one bed was used for peat treatment, and the other one for the control. The bed used for peat treatment was divided into three plots with a five-foot buffer strip between treatments. Peat was applied to the bed at the rate of five, ten, and twenty cubic yards per plot. These are called the light, medium, and heavy peat treatments. Each peat treatment was subdivided into four sub-plots to which the densities of ten, twenty, thirty, and forty seedlings per square foot were randomly assigned.

The peat used was sedge peat taken from Black Lake, Thurston County, Washington. The characteristics of this peat are given in Table I. The peat was applied to the seedbed on May 15, 1955 and was incorporated to a depth of nine inches in the soil before sowing. Side boards of 1″×6″×10″ cedar were installed on bed to prevent sloughing. After incorporation of the peat, the bed was rolled to firm the soil.

Table I

The characteristics of the peat used

moisture content	pH	Ash	Organic matter	N	PO_4	Ca	Mg	K
%		%	%	%	%	m. e.*	m. e.	m. e.
53.0	5.08	25.7	75.2	1.94	0.14	85.0	29.8	0.94

Good quality V-413 K Douglas-fir seed with a germination of eighty percent was used for this experiment. The number of seeds per square foot was computed by the following formula:

---

* Millligram equivalents per 100 grams oven dry peat.

$$\text{Number of seeds} = \frac{\text{area} \times \text{density}}{\text{survival factor}^{**} \times \text{germination}\,\%}$$

The seeds were planted one-half inch deep with a planting board and covered by hand. The control bed received no peat and was drilled at the rate of fifty seedlings per square foot. The beds were irrigated by the ordinary overhead sprinklers.

The seedlings were partly harvested on October 27, 1955 just before the end of the growing season. They were sampled for measurement and then separated into shoots and roots and were dried to constant weight in a ventilated oven at 70°C. The dry weight of shoots and roots of the seedlings at various densities in each treatment were separately recorded. Leaf tissue for chemical analysis included the green, succulent youngest stems, but excluded the brownish, heavily lignified stems and branches. After oven drying, the tissue was ground in a Wiley mill through a 40 mesh screen and stored for analysis. Many seedlings were left in the nursery beds for later observation and field study.

2. Analytical methods.

The soil and peat samples were analyzed following procedures recommended by the Forest Soils Committee of the Douglas-fir Region (19). Soil reaction was measured by the glass electrode with a soil-water ratio of 1:1 and peat-water ratio of 1:2.5. Soil texture was determined by Bouyoucos hydrometer method. Organic matter of soil and peat was determined by the potassium dichromate method. The total nitrogen of the soil was determined by macro-Kjeldahl method modified from Winkler (cited from Piper (16)); the ammonia was distilled into boric acid solution and then titrated with standard sulfuric acid solution. Available phosphorus in the soil was extracted with sodium bicarbonate

---

** Survival factor allowS for mortality between germination and harvest of seedlings. In this case it was 0.90.

(14), and then estimated by comparing with phosphate standards on a colorimeter. Cation exchange capacity was determined by a method modified from Peech et al. (15); the adsorbed ammonia in the filtrate was distilled into boric acid solution and titrated with standard sulfuric acid solution.

Ash content of peat and leaf tissues were determined with a two grams of sample. The sample was heated in the muffle furnace at 300° C. overnight, then raised to 500° C. and heated until the ash was light gray. The samples of peat and leaf tissues for calcium, potassium, magnesium, and phosphate determination were prepared by a dry ashing method using ordinary laboratory procedures. Calcium was precipitated as calcium oxalate, and the oxalate titrated with standard permanganate in hot sulfuric acid solution(11); potassium was precipitated as the cobaltinitrite and titrated with permanganate (12). Magnesium and phosphate were determined by a modification of the molybdivanadate method of Murray and Ashley(13)* Magnesium was precipitated as magnesium ammonium phosphate and then estimated by comparing with phosphate standards on a colorimeter; for phosphate the ash solution was used directly. Nitrogen was determined by a micro-Kjeldahl modified from Ballentine and Gregg (2); the ammonia was distilled into potassium biiodate solution, potassium iodide was added, and the titration made with standard thiosulfate.

Reducing sugars, sucrose, and starch were determined by the methods of Hassid (6 & 7), and Hassid et al. (8). The methods involve the reduction of alkaline ferricyanide and titration of the reduced ferricyanide with ceric sulfate using Setopaline C for the indicator. Sucrose was hydrolysed with pure invertase and starch was hydrolysed with dilute fresh saliva in a water bath at 37° to 40° C. for two hours.

---

* The modification was suggested by C. M. Johnson and E. Epstein, Depastment of Plant Nutrition, University of California, Berkeley. Ten ml. of the following combined reagent is used in 100 ml. of the reactant mixture: dissolve 46 ml. conc. sulfuric acid, 10 ml. conc. nitric acid, 0.83 gram ammonium vanadate, and 17 grams ammonium molybdate in 500 ml. of distilled water, then make to 1,000 ml.

RESULTS AND DISCUSSION

1. The effect of peat on nursery soil improvement.

The soil physical and chemical properties were modified after treated with peat. Table II shows the soil reaction, air dry moisture content, texture, organic matter and chemical composition of the soil with peat treatments as compared to the control.

The soil improving effect of peat in this experiment generally agrees with results obtained by previous workers. The acidity, texture, air dry moisture content, organic matter and cation exchange capacity of the soils were increased by peat additions. Such improvement varied with the different amount of peat

Table II

The physical and chemical properties of the seedbed soils

Treatment	Air dry moisture content %	Texture Name	Texture sand %	Texture silt %	Texture Clay %	Organic matter %	N %	PO_4 %	Cation exchange capacity m. e.*	pH
No peat	2.15	Loam	51.8	36.1	12.1	5.7	0.099	0.0178	9.55	5.83
Light peat	2.25	Sand loam	54.9	34.2	10.9	5.8	0.117	0.0157	10.61	5.75
Medium peat	2.88	Loam	42.9	43.6	13.6	13.2	0.225	0.0177	19.28	5.58
Heavy peat	3.41	Loam	43.7	44.2	12.1	16.8	0.303	0.0146	25.45	5.60

added. Doughty(4) pointed out that peat had a power of phosphate fixation. This fact is confirmed by the results in this experiment, as the available phosphate levels in the peat treatments were lower than that of the control soil. Nevertheless, the available phosphate amount on the peat treated soils was still high and sufficient for normal tree seedlings growth.

The light peat treated soil was the best for seedling growth in this experiment. The seedlings grown on this soil yielded the greater height

* m. e. per 100 grams oven dry soil.

growth and diameter of stem than those of the control. However, The difference in the physical and chemical properties of these two soils was not significant except a little higher nitrogen content for the light peat soil. Medium and heavy peat treated soils had greater nitrogen contents, organic matter, and cation exchange capacity than the control. However, such increase did not effectively promote the height growth and root development as compared with the control. It might be that there was a limitati on of a certain element to balance the nutrient in these soils.

2. The effects of peat additions and seedling density on growth and root development of the seedlings.

Table III shows the height growth, diameter of stem, number of later branches, root length, and dry weights of the Douglas-fir seedlings.

Andrews (1) grew loblolly pine seedlings in the nursery soils treated separately with peat, commercial fertilizer (4-8-4) plus peat, and cottonseed meal plus peat treatments. When the seedlings aged about four and one-half months, he found that the height growth, root development and dry weights in various treatments were significantly higher than that of the control. However, no great differences were found for the yields of the seedlings with peat, and peat plus fertilizer or cottonseed meal treatments. Wilde et al. (20) supplied different kinds of peat for the growth of red pine plantation on outwash sandy soil. After about three and one-half years treatment, they found that the average height growth increased 8.7 percent for the trees grown with two quarts of slightly acid sedge peat per tree placed in the planting hole, 3.4, 12.2, and 4.2 percent for with one quart, two quarts, and four quarts of strongly acid sedge peat per hole. However, the trees were depressed in height growth when alkaline sedge peat was mixed with the soil.

Muntz(12) grew longleaf and slash pine in central Louisiana at densities of ten, twenty, thirty, forty, and fifty seedlings per square foot. In the first growing season, he found that the height increased slightly as the density

Table III

The Yields of the Douglas-fir per average seedling

Treatment	Density Trees/ft^2	Height growth (Cm.)	number of lateral branches	Diameter of stem (mm.)	Root length (Cm.)	Dry weights Shoots (gm.)	Dry weights Roots (gm.)	Shoot-Root Ratio
No peat	50	9.9	2.3	1.2	27.1	0.189	0.081	2.3
Light peat	10	10.0	3.6	1.6	30.9	0.298	0.136	2.2
Light peat	20	10.3	3.4	1.5	27.0	0.299	0.110	2.7
Light peat	30	11.5	3.5	1.5	28.0	0.309	0.108	2.9
Light	40	10.4	3.3	1.4	27.0	0.242	0.101	2.4
Medium peat	10	8.6	2.9	1.4	27.3	0.244	0.120	2.0
Medium peat	20	8.5	2.2	1.3	27.8	0.198	0.085	2.3
Medium peat	30	9.9	3.0	1.3	28.0	0.198	0.085	2.3
Medium peat	40	8.7	2.1	1.2	29.0	0.188	0.082	2.3
Heavy peat	10	9.5	3.0	1.5	29.6	0.258	0.111	2.3
Heavy peat	20	8.6	2.3	1.3	27.6	0.194	0.089	2.2
Heavy peat	30	10.1	2.9	1.3	29.3	0.226	0.090	2.5
Heavy peat	40	9.1	2.2	1.2	26.4	0.197	0.090	2.2

increased to about thirty seedlings per square foot for both species, at which point the maximum height growth was attained. Each additional increase in density produced a corresponding decrease in height. The stem diameter of both species was greater at a density of ten than at fifty. The toproot length and root extent for both species decreased, as the density increased. Stefansson (18) sowed Scots pine seeds in nursery soil at densities 100, 200, 300, and 400 seeds per meter of seed drill 2.5 cm. wide. At an age of one year and four months, he found that the weight of seedlings for 100 seeds per meter about 2, 3, and 4 times higher than those at 200, 300, and 400 seeds per meter.

The growth and root development of Douglas-fir seedlings in this experiment did not agree in some points with the results obtained by previous workers using other species. Seedlings at all peat treatments showed an increase in dry weight but only slight increases or reductions in height growth. In general, the seedlings with the light peat treatment developed better than those with other treatments. The seedlings grown on the light peat treated soil had large diameter of stem, greater height growth, greater dry yields, and more extensive root development. The difference in growth and root development for the medium and heavy peat treatments was not significant. Seedling density also played a part in the growth of plants, as greater diameter of stem and higher dry weights per average seedling occurred at lower densities. However, density did not affect height growth and primary root length very much.

On the basis of increased dry weight, the seedlings grew better in all peat treatments than the control. Higher dry yields of shoots associated with larger diameter of stem and more branches were related to greater height growth for the light peat treatment but not related with greater height growth for the medium and heavy peat treatments. On the other hand, the control plants had a moderate height growth but yielded the smaller dry weights and diameter, and least branches. It is evident that the nutrients in the control, and the medium and heavy peat soils were not in balance for this species to produce normal seedling growth. Seedlings on peat treated beds had greater dry weights of roots than the control. The seedlings grown on the light peat soil had a higher dry yield of roots than those with the medium and heavy peat treatments. However, the greater dry weight of roots for all peat treatments was not positively related to primary root length or number of secondary roots. The shoot-root ratio for the seedlings in various treatments varied greatly, the range was from 2.0 to 2.9. It is hard to judge what ratio indicates good quality of stock, as the ratio for the good growth seedlings on the light peat treated bed ranged from 2.2 to 2.9, and for the fair growth seedlings with other treatments the range was from 2.0 to 2.5.

3. Chemical composition and carbohydrates of the Douglas-fir seedlings.

Ash content, chemical composition and carbohydrates of the leaf tissue of the seedlings are shown in Table IV. Wilde et al. (21) reported that heavy application of fertilizers increased ash content of the 2-0 jack pine seedlings. Ash contents were 2.96, 3.82, and 5.10 percent for 2-0 naturally reproduced jadk pine on coarse sandy soil, moderately fertilized and heavily fertilized beds in Griffith nursery. Conversely, Sideris and Young (17) found that ash contents of the leaves of *Ananas comosus* were higher in the low nitrogen than high nitrogen cultures. In this experiment, the ash contents of the Douglas-fir seedlings were not significantly different in various treatments, but was slightly higher for the seedlings grown on the heavy peat treated

Table IV

The ash content, chemical composition, and carbohydrates of the leaves of the Dougla-fir seedlings

Treatment	Density Trecs/ft^2	Ash %	N %	PO_4 %	Ca* m.e.	Mg m.e.	K m.e.	Reducing sugars %	Sucrose %	Starch %
No peat	50	4.4	2.07	0.92	19.0	10.0	29.5	6.23	0.011	0.019
Light peat	10	4.6	2.16	0.71	19.5	9.70	30.6	7.14	0.310	0.019
Light peat	20	4.5	2.51	0.89	20.0	10.0	29.3	5.92	0.110	0.019
Light peat	30	4.4	2.46	0.82	19.5	9.70	31.4	5.68	0.042	0.010
Light peat	40	4.3	1.99	0.68	20.0	9.85	28.6	6.02	0.000	0.000
Medium peat	10	4.4	2.76	0.83	20.5	9.70	29.1	5.84	0.220	0.000
Medium peat	20	4.7	2.68	0.91	20.5	9.70	30.5	6.14	0.011	0.000
Medium peat	30	4.3	2.61	0.84	20.0	10.7	27.9	6.48	0.000	0.039
Medium peat	40	4.5	2.48	0.81	20.0	9.85	28.6	6.60	0.000	0.058
Heavy peat	10	4.8	2.78	0.89	24.0	13.3	28.4	5.97	0.000	0.000
Heavy peat	20	4.5	2.73	0.85	23.5	9.85	27.1	6.82	0.280	0.010
Heavy peat	30	4.6	2.67	0.88	23.5	9.85	28.2	6.02	0.150	0.000
Heavy peat	40	4.6	2.60	0.90	23.0	10.1	29.1	7.10	0.370	0.058

* m. e. per 100 grams oven dry tissue.

soil as compared to the control. Nitrogen and calcium contents of the needles of the seedlings were increased by peat additions, while the potassium, magnesium and phospate changed little. In agricultural plants calcium and magnesium decreased concomitantly with increase of potassium(19). For Douglas-fir, a lower calcium content in the control plants did not affect the magnesium and potassium levels. The chemical composition of the leaf tissue of the seedlings generally corresponded to the composition of vigorous growing natural Douglas-fir trees(5), except the nitrogen level was greatly higher in the nursery seedlings.

Worley (22) studied the carbohydrate changes in needles of Douglas-fir trees. The dextrose content was 1.83 percent on September 20, increased to a maximum of 5.78 percent on November 4 with no great variation until April 17 when it decreased to 4.93 percent. However, invert sugars were much higher than dextrose in his experiment, changing from 8.80 percent on September 20, to a maximum of 48.7 percent on October 20, and to 27.8 percent on April 17. A slight amount of starch remaind in the needles through the winter months. Clements (3) reported that the starch content in the needles of *Pseudotsuga mucronata* was at its maximum in September, and dropped to a minimum (practically zero) in October. This minimum was maintained until about March. The sugar content of needles increased to maximum level in winter. Reducing sugars formed the main component of sugars in the leaves of Douglas-fir nursery stock in this experiment, as the sucrose content was zero or very low. The levels of reducing sugars of the seedlings in all peat treatments varied with changes in the physiological conditions. There is no relation between reducing sugars content and peat treatment or density. Starch contents of the leaves in various treatments were zero or very small. These contents are related to seasonal changes and the results agreed with those obtained by Clements (3).

This examination of seedlings at the end of the first season of growth is the first step in a complete investigation of Douglas-fir planting stock. It is evident that a comprehensive rating of stock must be based on growth characteristics during the entire life of the seedling in the nursery followed with outplanting performance records. The complete evalution is beyond the scope of this study and must await additional work. However, it is hoped that the methods of seedlings assessment used and the results reported will serve as a reference point for this additional necessary work.

SUMMARY

Douglas-fir (*Pseudotsuga menziesii* (Mirb) Franco) seedlings were successfully grown in the Nisqually Nursery for observation on the growth, root development and the analysis of leaf tissues at densities ten, twenty, thirty, forty and fifty in various levels of the Black Lake sedge peat.

The nursery soil is generally a loam. Air dry moisture content, organic matter, nitrogen level and cation exchange capacity of the soil were increased by peat additions. However, soil phosphorus level decreased a little after the peat was incorporated with the soil.

Douglas-fir seedlings with light peat treatment had generally greater height growth, larger diameter of stem, more branches, greater dry weights and better root development than those of other treatments. The seedlings with the medium and heavy peat treatments yieled greater dry weights and diameter of stem but height growth was depressed or unaffected as compared to the control plants. Seedling density also played a part in growth and root development. Greater diameter of stem, and higher dry weight of shoots and roots were generally found for the seedlings at the lowest density.

Higher levels of nitrogen and calcium in the leaf tissues were found in soils with more peat. Potassium and magnesium contents were about the same in all seedlings. Reducing sugars were the main component of sugar in the needles of the seedlings, as the amount of sucrose was very low. The starch

levels for the control and all peat treatments were very low or zero.

LITE.RATURE CITED

1. Andrews, L. K, 1941, Effects of certain soil treatments on the development of loblolly pine nursery stock. Jour. Forestry 39: 918-921.
2. Ballentine, R., and J. R. Gregg, 1947, Micro-Kjeldahl determination of nitrogen. Analytical Chem. 19: 281-283.
3. Clements, H. F., 1938, Mechanisms of freezing resistance in the needles of *Pinus ponderosa* and *Pseudotsuga mucronata.* Research Studies of the State College of Washington. 6:3-45.
4. Doughty, J. L., 1930, The fixation of phosphate by a peat soil. Soil Sci 29:23-35.
5. Gessel, S. P., R. B. Walker, and P. G. Haddock, 1950, Preliminary report on mineral deficiencies in Douglas-fir and Western red cedar. Soil Sci. Amer. Proc. 15:364-369.
6. Hassid, W. Z., 1936, Determination of reducing sugars and sucrose in plant materials. Ind. and Eng. Chem. 8:138-140.
7. Hassid, W. Z., 1937, Determination of sugars in plants. Ind. and Eng. Chem.9 :228-229.
8. Hassid, W. Z., R. M. McCready, and R. S. Rosenfels, 1940, Determination of starch in plants. Ind. and Eng. Chem. 12:142-144.
9. Hibbard, P. L., and P. R. Stout, 1933, The estimation of potassium by titration of the cobaltinitrite with potassium permangante. Jour. Assoc. Off. Agr. Chem. 16:137-140.
10. Hoagland, D. R., 1944, Lectures on the inorganic nutrition of plants. p. 226. Chronica Botanica Co., Waltham, Mass.
11. Kolthoff, I. M., and R. B. Sandell, 1938, Textbook of quantitative inorganic analysis: The determination of calcium. MacMillan Co., pp. 576-577.

12. Muntz, H. H., 1944, Effects of compost and stand density upon longleaf and slash pine nursery stock. Jour. Forestry 42:114-118.

13. Murray, W. H., Jr., and S. E. Q. Ashley, 1938, Determination of manganese, nickel, and phosphorus in iron and steel. Ind. and Eng. Chem. (Anal. Ed.) 10:1-5.

14. Olsen, S. R., C. V. Cole, F. S. Watanabe, and L. A. Dean, 1954, Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U. S.D. A. Circ. 939.

15. Peech, M., L. T. Alexander, L. A. Dean, and J. F. Reed, 1947, Methods of soil analysis for soil-fertility investigations. U.S. D. A. Circ. 757.

16. Piper, C. S., 1950, Soil and plant analysis. Interscience Publishers, Inc., N. Y.

17. Sideris, C. P., and H. Y. Young, 1946, Effects of nitrogen on growth and ash constituents of *Ananas comosus.* (L.) Merr. Plant Physiol. 21: 247-272.

18. Stefansson, E., 1948, Experiments with different nursery sowing densities. Skogen 35 (11):132-133.

19. The Forest Soils Committee of the Douglas-fir Region, 1953, Sampling procedures and methods of analysis for forest soils. Published by University of Washington, College of Forestry, Seattle.

20. Wilde, S. A., F. B. Trenk, and A. R. Albert, 1942, Effect of mineral fertilizers, peat, and compost on the growth of red pine plantations. Jour. Forestry 40:481-484.

21. Wilde, S. A., G. K. Voigt, D. P. White, and C. T. Youngberg, 1952, Characteristics of nursery stock related to its resistance against adverse environmental factors. Tech. Notes 47, The State Cons. Dept., in coop. with the Soils Dept., University of Wisconsin, Madison, Wis.

22. Worley, C. L., 1937, Carbohydrate changes within the needles of *Pinus ponderosa* and *Pseudotsuga taxifolia*. Plant Physiol. 12:755-770.

泥炭及苗木密度與道氏帝杉

苗木生長及化學成分之關係

陳 賢 芳

本試驗目的在觀察水草泥炭及苗木密度對道氏帝杉苗木生長及化學成分之影響。苗圃土壤分別施用輕量、中量、及重量水草泥炭之處理，在每種處理中又分別以每平方呎十株，二十株，三十株，四十株，或五十株之苗木密度，以培育道氏帝杉苗木。

苗圃土壤係為一種壤土。此種壤土之水分，有機物，氮素分量，及陽游子交換力，均因施用水草泥炭而增加，但有效性磷則隨泥炭之施用而降低。

由輕量泥炭處理之土壤所培育之道氏帝杉苗木，其地上部之高度，莖部直徑，側枝之數量，乾重及根系之發育等項均較由中量，重量泥灰處理及無泥炭處理之土壤所培育之苗木為高。由中量及重量泥炭處理之土壤所培育之苗木，其乾重及莖部直徑均較無泥炭處理者為大，但地上部之高度則與無泥炭處理者相若或較矮。苗木密度與道氏苗木之生長及根系之發育亦有相當之關係，一般而言，苗木密度最小之苗木，其莖部直徑及乾重比較苗木密度較密者為大。

道氏帝杉苗木葉部之氮及鈣兩元素分量，隨土壤施用泥炭而增加，但鉀鎂兩元素則無顯著之影響。糖分以還原糖類為主，因蔗糖分量甚低；澱粉則受季節之影響，含量極低幾近於零。