SEEDLING QUALITY — SOIL FERTILITY RELATIONSHIPS OF WHITE SPRUCE, AND RED AND WHITE PINE IN NURSERIES¹

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ABSTRACT

An index based on combined morphological features of seedlings was used to relate seedling quality to different levels of nursery soil fertility as determined by soil and seedling analyses. Nutrient content on a per seedling basis was closely related to seedling quality.

INTRODUCTION

The forest tree nurseryman is obligated to turn out planting stock in quantity that will exhibit high rates of survival and growth in the often-rigorous field environment. Proper nursery soil management practices are necessary to meet this obligation. Periodic soil and seedling analyses are prerequisites for good soil management.

This paper discusses the relationship of soil fertility levels as determined by soil and seedling analyses to the quality of 2-0 white spruce, red pine and white pine seedlings grown at four northeastern United States nurseries.

MATERIALS AND METHODS

The four nurseries in which the soil and seedlings were sampled are located at Essex Junction, Vermont; and Saratoga, Lowville and Oak Orchard, New York. All four nurseries were subject to essentially the same gross environmental influences. The soils of the nurseries are generally of similar coarse texture and glaciofluvial origin, but vary in depth to difficultly pervious strata: Essex Junction nursery soil is of the Adams series; Saratoga nursery soil is in the Merrimac series; Lowville nursery soil includes Duane and Colton series; and Oak Orchard nursery soil includes Ottawa and Berrien series. The surface six inches of the soils from the four nurseries are sandy in texture with a silt-plus-clay content ranging from approximately 5.5 to 20 per cent and organic matter content of approximately 2.5 to 7.5 per cent, though in most cases the organic matter does not exceed 6.0 per cent. The soil reaction ranged mainly between pH 4.4 and 5.7, but there were a few cases above and below this range (Table 1).

Samples of soil and 2-0 white spruce, and white and red pine seedlings were obtained from three 36 x 6 inch plots within each species in each nursery laid out in seedbeds with the long axis of the plots at right angles to that of the seedbed rows. Thus, six inch buffer strips were left on both edges of the

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TABLE 1
RELATIONSHIP OF SEEDLING QUALITY INDICES OF 2-0 WHITE SPRUCE, WHITE
PINE AND RED PINE IN FOUR NORTHEASTERN U.S. NURSERIES TO ANALYSIS OF
SURFACE 6 INCHES OF SOIL SUPPORTING THESE SEEDLINGS

Quality Seedling Quality Index	Soil Analysis							
	Silt plus Clay	Organic Matter	Reaction	Total Available		Exchangeable		
				N	P	K	Ca	Mg
				p.ct.	pounds per acre			
2 - 0 WHITE SPRUCE								
0.46	11.1	2.8	4.2	0.05	226	32	149	20
0.25	11.0	2.7	4.4	0.08	243	44	176	20
0.20	9.8	3.4	4.4	0.06	192	35	100	20
0.15	11.1	5.8	4.4	0.23	226	139	1078	54
0.14	9.8	5.8	4.5	0.15	240	133	1143	76
0.11	13.9	6.4	4.4	0.20	184	119	873	49
0.070	10.2	3.3	5.3	0.09	95	144	1931	22
0.065	12.2	4.1	5.4	0.11	67	190	2301	92
0.061	5.4	2.2	5.7	0.06	50	82	3286	97
0.056	5.4	2.6	6.2	0.08	52	85	2281	80
0.046	16.8	4.7	5.3	0.16	126	246	2950	43
0.038	5.3	2.5	6.2	0.09	39	69	2922	118
2 - 0 WHITE PINE								
.27	11.4	3.1	4.3	0.05	151	40	123	18
.22	12.6	3.1	4.4	0.06	201	59	256	40
.19	11.4	3.0	4.3	0.06	186	28	149	19
.15	11.2	3.2	4.8	0.10	111	91	844	19
.13	10.8	3.4	4.9	0.11	123	92	643	19
.12	11.8	4.3	4.9	0.10	272	87	1289	52
.11	14.8	4.4	4.9	0.11	238	109	1514	57
.11	7.2	2.7	4.9	0.06	81	54	572	20
.082	12.8	3.8	5.0	0.11	247	108	1644	82
.057	8.3	3.6	5.7	0.12	74	95	3784	114
.054	11.3	4.4	5.7	0.15	74	116	3430	103
.042	13.4	5.4	6.2	0.15	50	142	4682	220
2 - 0 RED PINE								
.31	9.6	3.2	4.3	0.06	254	44	235	39
.19	11.7	3.1	4.4	0.07	199	70	228	21
.16	16.8	3.5	4.8	0.07	253	68	701	39
.11	15.4	4.6	5.2	0.10	59	194	1623	23
.083	12.4	4.2	5.6	.09	83	197	1954	92
.067	19.2	6.3	5.7	.18	47	77	3013	134
.056	18.1	6.4	5.7	.22	58	73	4630	120
.054	12.7	5.7	4.4	.11	190	166	485	18
.049	13.6	4.4	5.3	.14	117	224	2666	84
.047	9.7	5.2	4.4	.13	126	136	485	15
.046	11.7	4.8	4.4	.15	123	133	514	17
.038	19.2	7.4	5.6	.22	43	83	3396	178

seedbeds to reduce edge-effect variation. The plots for each species were randomly selected in rows of as nearly uniform stocking and seedling size as possible at the four nurseries.

Seedling density was determined, and fifty seedlings in a strip parallel to the long axis and within each plot were clipped at the ground line for height and diameter measurements. Some twenty intact seedling in their respective nursery soils were transferred to the laboratory for analysis including fresh and dry weights of tops and roots, top-root ratio, and contents of nitrogen, phosphorus, potassium, calcium and magnesium (Wilde and Voigt, 1955).

Samples of the surface six inches of soil were obtained from each plot and transferred to the laboratory for analysis including texture, organic matter content, reaction, and levels of nitrogen, phosphorus, potassium, calcium and magnesium (Wilde and Voigt, 1955).

The seedling quality index was based upon certain morphological characteristics of the stock. The method of determining the index was according to Dickson *et al.* (1960) as follows:

$$\text{Quality Index} = \frac{\text{Dry Seedling Weight (gms.)}}{\text{Height (cm.) / Diameter (mm.) Quotient} + \text{Top (gms.) / Root (gms.) Ratio}}$$

In this index the dry seedling weight is heavily weighted, but the height-diameter quotient and top-root ratio are also considered. Thus, the quality index is lowered accordingly if the seedlings are spindly or unbalanced.

STOCK QUALITY RELATED TO SOIL AND SEEDLING ANALYSES

Seedling quality according to the index ranged (good to poor) from 0.460 to 0.038 for white spruce, 0.266 to 0.041 for white pine, and 0.310 to 0.038 for red pine, respectively.

The nutrient levels of the soils varied considerably between plots and differed from the suggested standards of fertility for soils supporting white spruce, and red and white pine. Except for the available phosphorus contents, the soil fertility levels in many cases were considerably below the suggested standards of approximately 0.12 per cent total nitrogen, 30 pounds per acre available phosphorus, 200 pounds per acre exchangeable potassium, 1,000 pounds per acre exchangeable calcium, and 250 pounds per acre exchangeable magnesium (Wilde, 1958). There was a lack of correlation between the results of soil analysis and the seedling quality indices (Table 1). This lack of correlation probably was due in part to the deficiencies of several of the nutrient elements in the soils and the effect of their interactions, and also to the variation in densities of stocking.

The factors of seedling production vary considerably between plots and differ from suggested levels of seedling density and dry weight production for 2-0 white spruce, and red and white pine (Table 2). The stocking densities varied from 12 2-0 white spruce to 205 2-0 red pine seedlings per square foot and the white pine seedlings fell within this range. The suggested level of stocking for these species is approximately 50 seedlings per square foot since a higher level would tend to produce spindly stock and a lower level may not be justified economically (Stoeckler and Jones, 1957). Dry weight production varied from a low of 22 grams per square foot for white spruce to 255 grams per square foot for red pine, while the suggested level for all three

species is approximately 100 grams per square foot (Lunt, 1938). Since a soil is capable of only a certain level of organic matter production, an inverse relationship is indicated between seedling quality and stocking density.

The results of analysis of the seedlings for their level of nutrients indicate a similar lack of correlation with quality when the nutrients in the seedlings are expressed on a per cent concentration or uptake in pounds per unit area of seedbed. This lack of correlation may be due to reasons similar to those expressed above concerning the results of soil analyses: several nutrient deficiencies in the soil plus variations in density of stocking. The concentrations of nutrients of the seedlings range as follows: 2-0 white spruce, nitrogen 0.87-1.75 per cent, phosphorus 0.09-0.13 per cent, potassium 0.14-0.42 per cent, calcium 0.42-0.66 per cent, magnesium 0.09-0.16 per cent; 2-0 white pine, nitrogen 1.21-2.14 per cent, phosphorus 0.10-0.14 per cent, potassium 0.21-0.51 per cent, calcium 0.17-0.61 per cent, magnesium 0.07-0.13 per cent; and 2-0 red pine, nitrogen 0.82-1.81 per cent, phosphorus 0.09-0.13 per cent, potassium 0.17-0.56 per cent, calcium 0.16-0.37 per cent, magnesium 0.08-0.16 per cent.

Expression of nutrient uptake on a per seedling basis results in linear trends in the relationships between nitrogen, phosphorus, calcium and magnesium contents, and the quality indices (Table 2). Since larger seedlings, unless abnormally developed, are of higher quality, the seedling quality index reflects dry matter production. The nutrient uptake on a per seedling basis is related to dry matter production. Thus, the contents of nutrients per seedling are closely, but not completely, related to the quality index. Since the index includes the modifiers of height-diameter quotient and top-root ratio, several instances occur in Table 2 where nutrient contents do not correlate with the appropriate indices.

CONCLUSION

Seedling quality is affected by the two environmental factors of nursery soil fertility level and density of stocking. It is possible to maintain high quality stock supported by soils of relatively poor fertility by maintaining low seedling density. However, sustained economic production of stock can only be maintained by controlling stocking density and soil fertility levels.

At a given stocking density, the quality index, when further refined, should provide an indication of weaknesses in the soil management program which would then need detailed investigation through soil and stock analyses.

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TABLE 2
RELATIONSHIP OF SEEDLING PRODUCTION AND ANALYSIS TO SEEDLING QUALITY
INDICES OF 2-0 WHITE SPRUCE, WHITE PINE AND RED PINE IN
FOUR NORTHEASTERN U.S. NURSERIES

Quality Seedling Quality Index	Seedling Density No./sq. ft.	Seedling Dry-Wt. Production g./sq. ft.	Reaction pH	Seedling Analysis				
				N	P	K	Ca	Mg
2-0 WHITE SPRUCE								
.46	12	32.5	5.4	47.5	3.5	6.2	14.1	2.7
.25	26	40.0	5.3	26.6	1.7	3.5	6.5	1.5
.20	26	32.0	5.5	20.8	1.5	2.7	5.4	1.1
.15	56	50.4	4.7	14.8	1.0	1.6	4.0	0.8
.14	62	58.3	4.8	14.9	1.0	2.3	4.7	1.0
.11	63	53.5	4.7	14.7	0.8	2.7	4.2	0.8
.070	94	51.7	4.8	5.7	0.5	2.2	3.3	0.7
.065	135	79.6	4.7	6.0	0.6	2.5	3.4	0.9
.061	105	38.8	5.1	5.2	0.3	0.5	2.0	0.5
.056	63	22.7	4.9	5.3	0.4	0.5	2.4	0.5
.046	118	59.0	4.8	4.3	0.6	2.4	2.5	0.7
.038	189	25.7	5.1	3.6	0.2	0.4	1.3	0.3
2-0 WHITE PINE								
.27	39	54.2	4.5	17.5	1.8	3.3	2.4	1.2
.22	44	66.9	4.5	25.8	1.8	3.5	2.7	1.1
.19	91	128.3	4.5	25.9	2.0	3.7	2.4	1.3
.15	95	64.6	4.3	9.2	0.7	3.3	2.2	0.6
.13	73	62.8	4.3	10.4	1.0	4.4	2.0	1.0
.12	91	67.3	4.4	11.0	0.9	1.8	2.5	0.5
.11	137	100.0	4.4	11.1	0.8	3.4	3.1	0.9
.11	59	29.5	4.4	7.1	0.5	2.2	1.6	0.4
.082	71	34.8	4.3	7.1	0.5	1.1	1.3	0.6
.057	78	24.2	4.7	5.7	0.4	0.6	1.9	0.4
.054	93	26.0	4.7	5.1	0.4	0.7	1.2	0.4
.042	120	30.0	4.6	5.3	0.3	0.6	1.2	0.3
2-0 RED PINE								
.31	37	119.9	4.2	40.8	3.6	10.7	4.9	2.9
.19	164	254.2	4.1	12.7	1.4	3.2	2.2	1.4
.16	172	196.1	4.3	15.0	1.4	4.3	1.9	1.0
.11	102	50.0	4.2	6.4	0.5	2.1	1.0	0.5
.083	75	30.0	4.2	5.3	0.4	2.0	0.7	0.4
.067	205	45.1	4.7	4.0	0.2	0.4	0.6	0.2
.056	201	40.2	4.7	3.4	0.2	0.3	0.5	0.2
.054	177	58.4	4.3	5.8	0.4	1.0	0.8	0.4
.049	97	22.3	4.2	3.0	0.3	1.3	0.4	0.2
.047	185	64.7	4.4	6.3	0.3	1.1	0.7	0.5
.046	182	54.6	4.3	5.3	0.2	0.6	0.5	0.2
.038	189	32.1	4.7	2.6	0.2	0.6	0.7	0.3