SOIL FACTORS AND THE GROWTH OF JAPANESE AND EUROPEAN LARCH

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We have planted larches on a wide variety of soils in Northeastern United States but still have little exact knowledge about heir requirements or responses Their rapid early growth relative to other species, together with frequent establishment failures unrelated to site perhaps obscures the practitioners judgment of site influences, apart from the obvious consequences of frost We have not yet begun to exploit the store of information that is embodied in the performance of older plantations, and available to anyone who will but measure their growth and accurately appraise the soil.

Rather than attempt a survey of a substantial European literature on larch sites, I would like to concentrate attention on three functional properties or groups of soil properties that must influence larch as well as other species. These are (1) storage capacity for plant-available water, (2) nutrient supply, and (3) aeration Though no one would claim that our knowledge of any of these is satisfactory, yet each can be estimated to a useful degrees. Moreover, each often is linked with standard soil survey units so that some meaningful interpretations can be made wherever modern surveys exist

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STORAGE CAPACITY FOR PLANT-AVAILABLE WATER

First among these properties is available moisture storage capacity--that is, the number of inches of water retained within the rooting profile and available for plant uptake. Table 1 exemplifies the magnitude of differences among soils of various textural classes. If one would multiply such values by the rooting depths observed in the field, however; he may not ignore dilution by coarse fragments, "rocks and gravel", that compose 20 to 80% of many soils on which larch is planted. Furthermore, one must somehow take account of the increases in profile storage often caused by slowly permeable layers or textural discontinuities within the rooting zone.

Table 1.--Average Available Moisture Storage in Soil Classes

Soil texture		Inches of moisture storage per foot of soil depth	
Very coarse	Coarse sand, loamy sand	0.50	0.50
Moderately coarse	Loamy fine sands, sandy loams, very gravelly loams	0.50 to 1.25 1.25 to 1.50	0.75 1.37
Medium	Loam and silt loam	1.75 to 2.25	2.00
Fine	Clay or silty clay loam	1.80 to 2.00	1.90

Soil moisture storage is meaningful only in relation to evapo-transpiration on the one hand, and rainfall patterns on the other, A very simple view of these relationships would be thus:

In closed canopies the potential for evapo-transpiration (E-T) is, of course, set by the transfer of energy by direct radiation and, to a lesser extent, from ai~~r t~~o the foliage- It is important to realize that, at least as a first approxi mation, potential loss from closed canopies is established by atmospheric variables and not by the plant. There is no reason to expect that larch species differ from each other despite various assertions, nor, for that matter, from other conifers or hardwoods in closed canopies. Hence, "potential E-T" is as applicable to larch as to many other vegetations. Actual transpiration rates depart from potential, of course, to the extent that available soil moisture supplies or absorption by roots limit uptake. A substantial literature on moisture stress demonstrates that any sustained reduction in transpiration entails reduction in photosynthesis and elongation, and these may nearly cease when stress is severe

Potential E-T i our climate ranges between about 1 and 1-1/2 inches of water per week during bright weather. Hence, if a stand in full leaf is to withstand a rainless period of two weeks without appreciable reduction in growth, it must have access to nearly 3 inches of stored soil moisture. A soil of lesser capacity cannot sustain unimpaired growth through such a period. Whether a soil of adequate capacity actually contains sufficient water at the beginning of the two weeks obviously depends on previous history of depletion and rainfall. If potential evapotranspiration can be estimated and rainfall is known, a simple balance sheet can be kept for soils of different storage capacities. Figure 1, from a summary now in progress by Drs. Dethier and Pack of Cornell, is such an idealized balance sheet, calculated from actual weather records at Albany and the Thornwaite equation for E-T, The plotted points are end-of-the-week status reports, rather than weekly means, for successive seven-day periods beginning on March 1. As many of you will

Figure 1. CALCULATED MOISTURE DEPLETION ON TWO SOILS IN A WET YEAR (1938) AND A DRY YEAR (1964) AT ALBANY, NEW YORK (Unpublished data of B. E. Dethier and A. B. Pack)

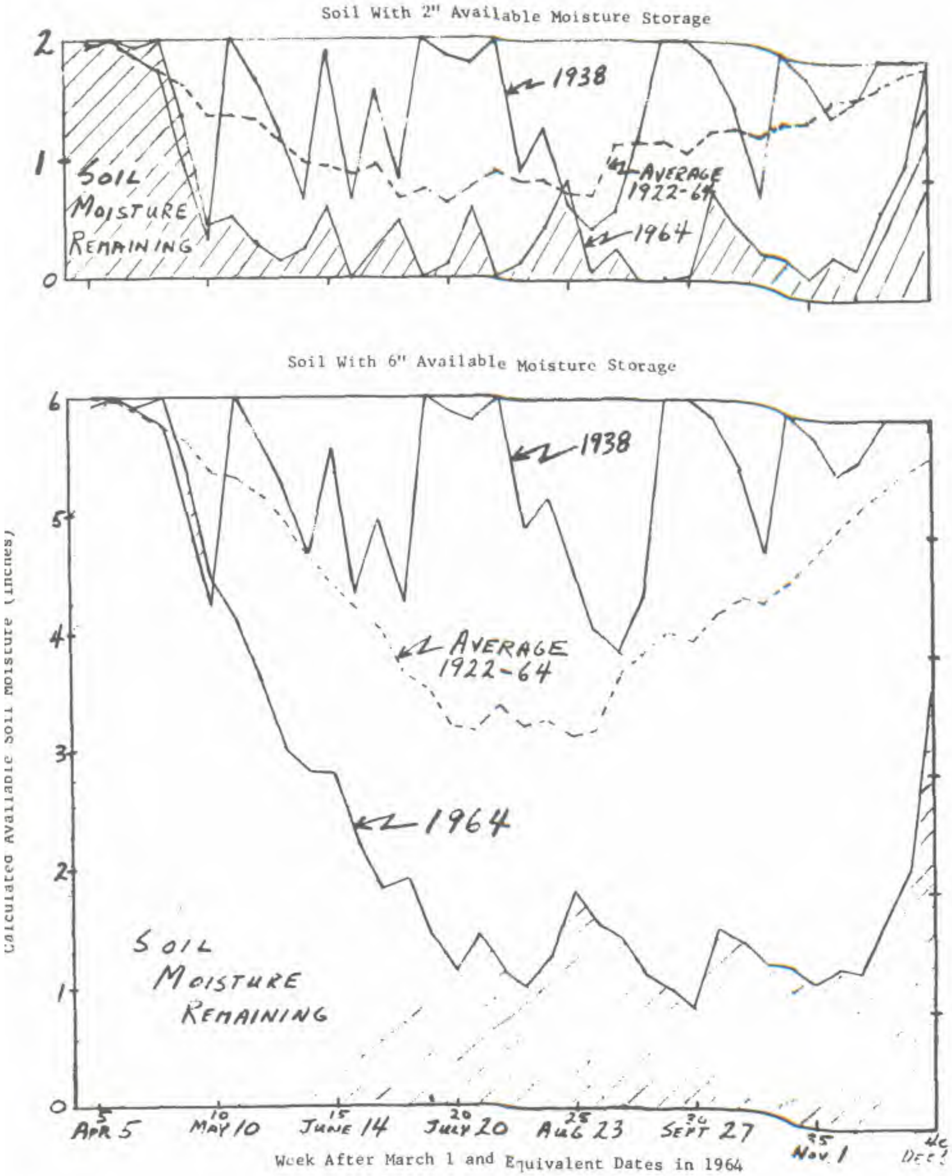
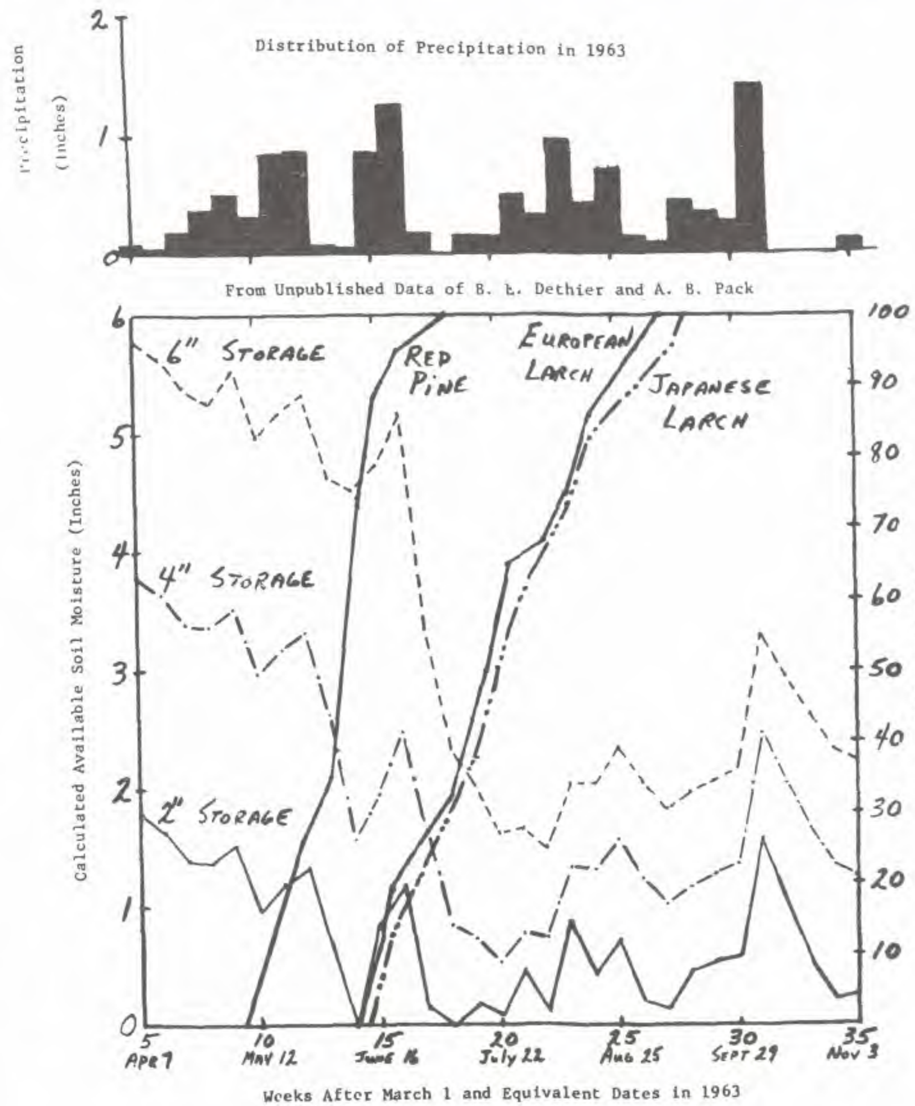


Figure 2. CALCULATED MOISTURE DEPLETION ON 3 SOILS WITH 2, 4 and 6" AVAILABLE MOISTURE STORAGE CAPACITY, AT ALBANY, NEW YORK, IN 1963 *



* E-T Estimated by Thornthwaite Formula. Height Growth Curves Are Those of Cook (1941) From Stephentown in 1940

know, the banking rules in such a game do not allow depletion by E-T to exceed the amount remaining in storage, nor additions to rise above storage capacity, no matter how heavy rainfall may be. Moreover, a sliding factor enters into loss rates so that calculated daily depletion is lessened as the remaining moisture supply diminishes.Hence, soils of different storage capacities do not necessarily fluctuate alike over week-long periods.

The 2" and 6" storage capacities treated in Figure 1 represent what one might find, respectively, in a shallow soil, perhaps a foot and a half of well-drained channery silt loam over bedrock, and in a corresponding soil four and a half feet deep Or, the six-inch storage might be provided by intensive root development in twelve feet of coarse sand (European larch is known to root deeper than 16 feet in snds at the Pack Forest). In any cases figure 1 demonstrates that soil moisture was abundant through almost the entire season in both deep and shallow soil during the "wet year" of 1938. Maximum depletion of the deeper soil scarcely exceeded 3576 of its capacity. In 1964, however, the soil with only 2" storage capacity was brought near the wilting point by early June and hovered near this minimum until late September. The activity of any vegetation could have been only intermittent at best; depending entirely on the effectiveness of occasional showers Even on the soil with 6" storage, available moisture was depleted below 2070 of capacity by mid-July, while it is likely that larch or other vegetation would have experienced sore degree of stress thereafter, wilting point was not reached throughout the profile.

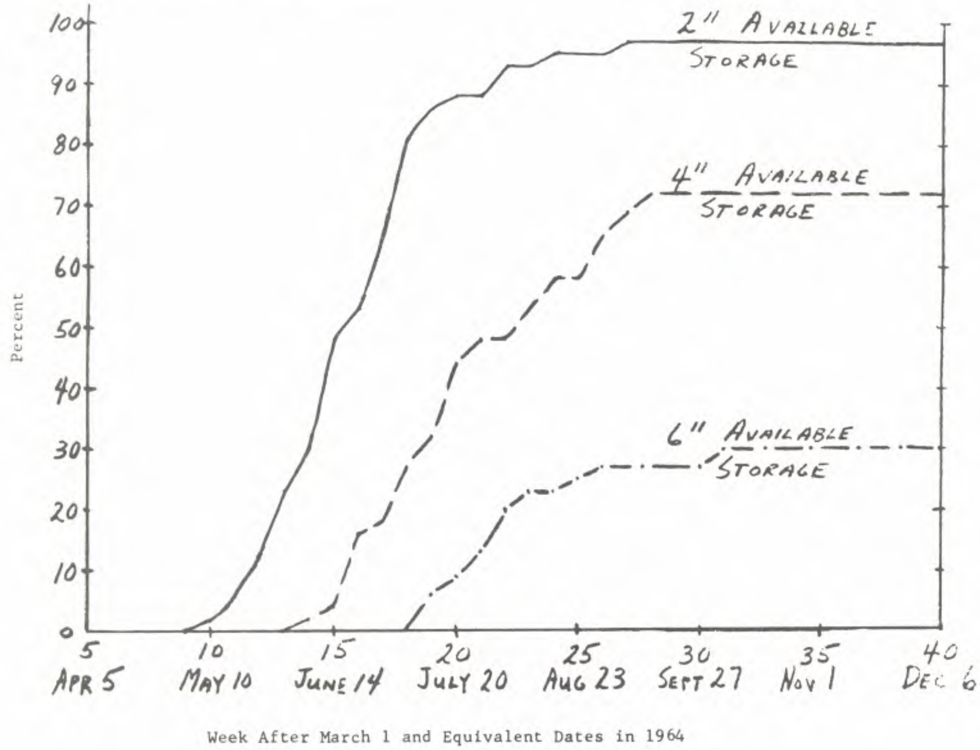
Figure 2 further emphasizes the quantitative aspects of storage capacity. Again at Albany, and during the dry year of 1963 three soils of 2, 4, and 6 inches storage, are compared. The soil of 2" storage reached wilting point by mid-June, and an essentially rainless period of 4 weeks in June and July brought the soil of 4' close to that point. Figures 1 and 2 together demonstrate that larch stands at Albany on soils of only 2 or 3 inches storage capacity must have had very limited opportunity for either synthesis or extension in the consecutive years of 1963 and 1964.

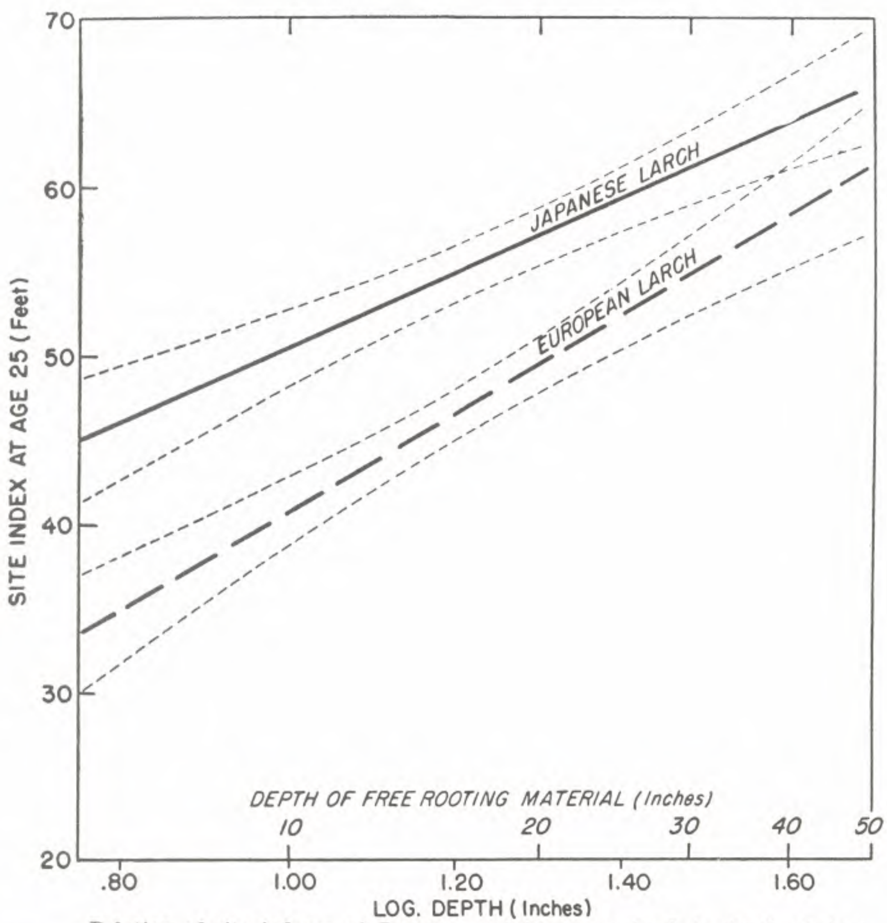
The consequences of moisture storage differences have been exemplified by transferring Dave Cooks curves for shoot elongation of larches at Steventown in 1940 to figure 2. (Our only justification for this follows Cooks opinion that, although inception of growth may depend on temperature, its course is to some degree inherent with the species within a latitude). Treating the combination as a model only, it is easy to conclude that height growth of both larches would have been materially restricted by moisture stress on both the 2" and 4" capacity soils. By contrast, the earlier elongating red pine would have complted this phase of development on the 4" soil (but not on the 2") before severe stress occurred.

Figures 1 and 2 admittedly represent extremes If we arbitrarily set 70% depletion of storage as an index of possible initial stress, figure 3 describes the frequency of such events. In soils of 2" storage this level of depletion is reached at some time-though by no means maintained--in 19 years out of 20, generally before July 1. The frequency is progressively less and the onset later in soils of increasing moisture capacity. The mere incidence of such depletion does not characterize a season (compare the 10th week values on the 2" soil in figure 1) but the frequency suggests that some degree of growth retardation is nearly an annual event on soils of low storage capacity.

While foresters and ecologists commonly characterize soils as fresh, moist, or dry, such terms are never precise and frequently are wholly inaccurate in respect to the actual moisture supply within rooting depth. Quantitative estimates of field soils are by no means simple or routine, but are essential to improved description of habitats. For example, Veen stated that in the northern Netherlands

Figure 3. FREQUENCY THAT SOIL MOISTURE IS EQUAL TO OR LESS THAN 30% OF FIELD CAPACITY AT A GIVEN DATE (Unpublished Data of B. E. Dethier and A. B. Pack)





Relation of site indexes of Japanese and European larch to depth of free rooting material, with limits of the .95 confidence intervals for the regression lines.

Figure 4.--From Aird and Stone 1955, New York.

soils should either have an available moisture storage ciy of 120 m m.(ca. 5") or more, or ground water within reach of roots, for satisfactory growth of Japanese larch.

Rooting depth, or "depth of free rooting" above a restricting layer can be taken as some measure of moisture storage capacity. height growth of both laches directly related to depth of free rooting. In our observations in New York this depth variable was itself correlated with natural soil drainage. Hence, no simple explanation of the growth relationships shown in figure 4 is warranted, although presumably moisture storage capacity is involved to a large extent.

NUTRIENT SUPPLY

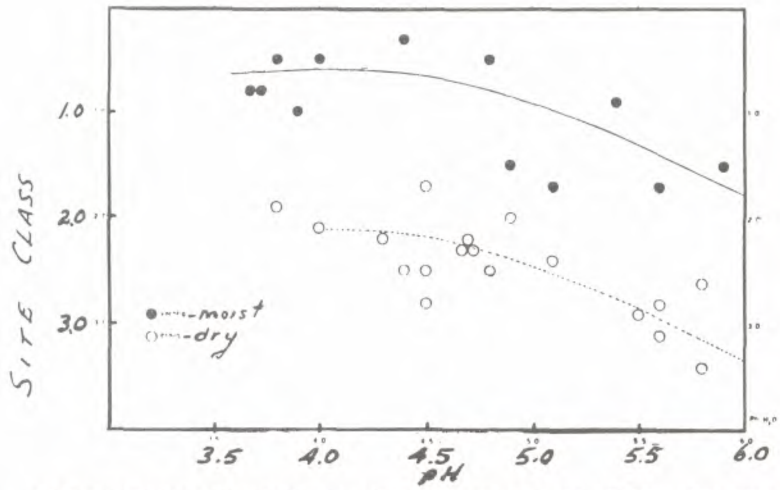
A second functional property, or group of properties, concerns nutrition. The literature on European larch suggests wide tolerance of soil chemical properties, as well as relatively low requirements for nitrogen and bases. Neverthe - less, Rennie's compilation of nutrient uptake data utilizes Wiedemann's data to indicate the following demands, per acre, upon the site for site III European larch at age 100: Ca 592 lbs.; K 191 lbs.; P 42 lbs. This species has been observed over a broad range of soil reactions, from extremely acid to calcareous. Its colonization of avalanche slopes, slips and a variety of presumably infertile soils has been taken as evidence of relatively low nitrogen needs.

The Japanese larch is likewise tolerant over a range of chemical properties. I have observed successful growth on acid peats and on raw calcareous subsoils, although the latter stand displayed evidence of magnesium deficiency. Greater attention has been given to the specific nutrient requirements of Japanese larch, as a result of the Dutch efforts to improve growth on poor sandy soils. Figure 5, from van Goor, indicates somewhat poorer growth on such soils with reactions above pH 5.5 than below; this correlation may arise from associations between pH and nitrogen availability. Figures 6 and 7 from the same author present a correlation of growth with total soil phosphate which was presumed related to available content also.

The adverse effects of high reaction, liming and nitrogen fertilization led van Goor to study nitrogen-phosphorus interactions within the plant. Increased nitrogen supply without adequate phosphorus uptake may actually depress growth of larch. This is illustrated by Holsteiner-Jogensens comparison of fertilizer effects on young Japanese larch and Norway spruce on sandy heathland in Jutland, table 2.

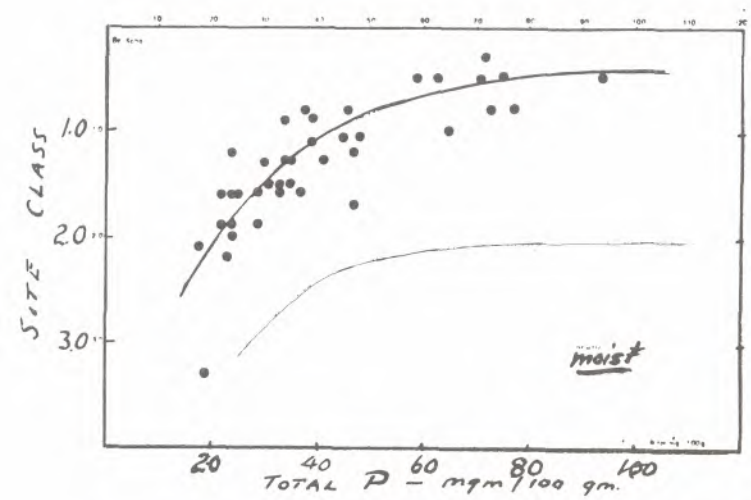
Table 2.--Terminal shoot growth and foliar phosphorus content of Japanese larch and Norway spruce in the sixth year after planting (Holsteiner-Jørgensen, 1964)

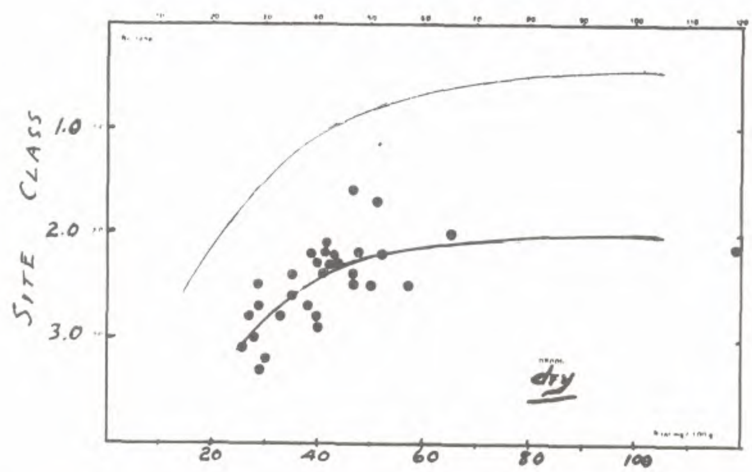
Fertilizer treatment	Species	O: Shoot length cm.	O: P %	N: Shoot length cm.	N: P %
0	Larch	28.9	.08	20.0	.03
	Spruce	6.3	.05	10.3	.05
P	Larch	42.5	.40	53.5	.43
	Spruce	10.9	.27	25.8	.26



RELATIONSHIP BETWEEN pH AND SITE CLASS ON MOIST AND DRY SOILS CONTAINING MORE THAN 45 MG/ 100 G TOTAL PHOSPHATE

Figure 5.--From van Goor 1954, Holland.





Figures 6 and 7.--Relationship between total phosphate control of the upper rooting zone and site class on sandy soils of higher (above) and lower (below) moisture holding capacity. van Goor, Holland.

On this infertile soil either N or P additions increased the growth of spruce and the combination quadrupled shoot growth. With the larch, however, nitrogen alone reduced the already low content of phosphorus in the foliage and shoot growth. Nitrogen in combination with phosphorus permitted better growth than phosphorus alone, and both responses were associated with high foliar concentrations of phosphorus.

The applicability of these results to soils of higher inherent fertility is uncertain. The possibility of similar effects with some of our soils must be considered, however, and it is evident that performance of associated conifers may not be a satisfactory indicator for Japanese larch.

There is some interest also in the report of van Goor's colleague, Veenendaal, that basal sweep or "saber foot" was much more frequent on soils of higher total phosphate content. This however, may well be a consequence of a more general association of "saber foot" with former agricultural lands and higher quality classes.

AERATION

Observations in the homelands of both species suggest that periods of poor soil aeration, resulting from impeded soil drainage and perched water-tables, are unfavorable. Analysis of such reports is always somewhat equivocal because of the uncertain meanings of the concepts and terms employed. Direct correlations between site index and soil drainage classes in New York are shown in figure 8. Such correlations do not resolve the causal factors, for as already mentioned, drainage class as well as depth to mottling are in turn correlated with rooting depth.

The dense or slowly permeable layers very commonly associated with ill-drained soils may, of themselves, restrict root development. The effect of such restriction, obviously, is shallow rooting and reduced volume of soil exploited for moisture and nutrients. Contrarily, impeding layers increase water retention within the rooting profile during periods of excess rainfall, and significant lateral flow above fragipans may continue for some time after well-drained soils have begun to dry. Hence, the effect of poor aeration per se is not readily dissociable from a variety of accompanying effects.

Just as the severity of a given drought is soil related, so also periods of excess impress a very different environment upon ill-drained soils than upon those of greater permeability. The root pruning or root damage attributed to poor aeration of the deeper soil layers during periods of saturation has been considered an entry opportunity for fungi such as *Armillaria mellea*. This is unproven but plausible, and deserves consideration when soil influences are being examined.

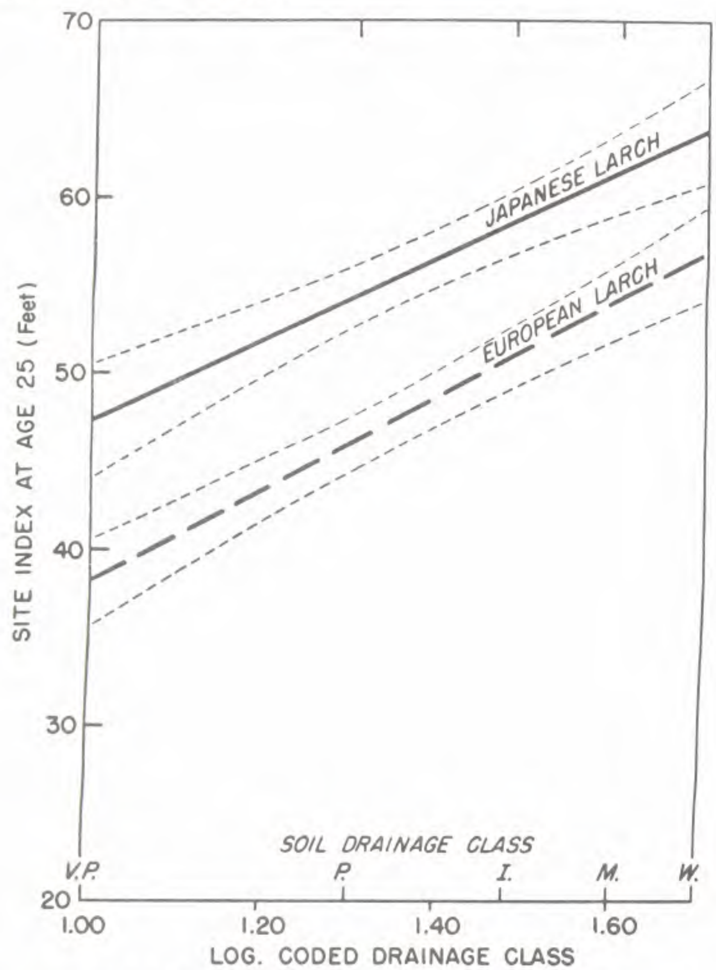
Our understanding of associations between growth rates of the two species and standard soil survey units in New York is shown in table 3. Soil series were specified in the original but, in any case, have been grouped and phased. The similarity in the response of the two species is evident, as in figures 4 and 8, but no comparisons are available on soils of low moisture storage capacity, nor on wet soils with permanent ground water.

Table 3.--The relation of mean site index[1/] at age 25 to grouped soil types

Group	Site Class	European larch SI_{25}	European larch CV-%	Japanese larch SI_{25}	Japanese larch CV-%
Excessively drained					
Shallow to rock	IV	39±3[2/]	6.9	--	--
Excessive gravel or coarse texture	III	45±4	8.5	50±5	10.8
Well drained	I	57±5	8.8	64±5	8.0
Moderately well drained	I	55±4	7.8	64±2	3.8
Imperfectly drained	II	51±5	9.0	58±4	6.3
Poorly drained					
Deeper than 15" to compact horizon	II	47±4	9.3	--	--
Less than 15" to compact horizon	III	44±5	11.9	56±4	7.1
Very poorly drained					
Deeper than 9" to gleyed horizon	III	41±1	2.4	--	--
Less than 9" to gleyed horizon	IV	36±7	18.3	46±5	10.6

1/ Aird and Stone (1955). Averages based on 3 to 11 samples for each group and species.

2/ Standard deviation of the mean. Approximately 2/3 of the observations fall within these limits.



Relation of site indexes of Japanese and European larch to soil drainage class, with limits of the .95 confidence intervals. (Abbreviations indicate, respectively, the Very Poorly, Poorly, Imperfectly, Moderately, and Well Drained classes.)

FIG. 8, from Aird and Stone, 1955, New York; cf. FIG. 4