



United States
Department of
Agriculture

Forest Service

Northeastern Forest
Experiment Station

Research Paper NE-700



Effects of Fertilization on the Growth and Development of a Japanese Larch Plantation in West Virginia

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Abstract

The effects of fertilization on the growth and development of a Japanese larch plantation in central West Virginia were evaluated after 9 years. After mechanical site preparation of the entire study area (22.1 acres) in the fall of 1983, larch were planted in the spring of 1984. Beginning in April 1987, ammonium sulfate was applied aerially three times each year at an annual rate of 150 pounds per acre to 43 plots. Six control plots were established and excluded from treatment. Larch trees grew better on the unfertilized plots. Mean height for all trees after 9 years was 18.6 feet on the unfertilized plots compared to 15.8 feet on the fertilized plots. Average diameter at breast height (d.b.h.) for the unfertilized and fertilized plots was 1.9 and 1.6 inches, respectively. Foliar and soil chemical analyses were used to examine this apparent anomaly. Japanese larch demonstrated an ability to grow well on a very nutrient-deficient site and was not damaged by deer browsing.

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Manuscript received for publication 7 February 1995

Cover Photo

A 25-foot-tall Japanese larch growing on the study area.

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August 1995

Introduction

Forests in the central hardwood region contain many acres where site quality is too low to grow quality hardwoods. If an eastern white pine (*Pinus strobus* L.) seed source exists, white pine often becomes established and grows well. For example, areas in the southern Appalachians with an oak site index of 57 have a white pine index of 67 (Doolittle 1958). When white pine has been planted on cutover land, the slow growth of white pine during the early stages of development usually requires at least one and possibly two releases from competing hardwood vegetation to ensure establishment of a satisfactory number of pine (Wendel 1971). Also, in many areas severe browsing by white-tailed deer (*Odocoileus virginianus*) interferes with establishment of white pine seedlings.

As an alternative to white pine, Japanese larch (*Larix leptolepis* (Sieb and Zucc.)) was planted on poor-quality hardwood sites in Pennsylvania (Shipman 1973, 1979). Japanese larch had relatively rapid growth on these poor sites and had the ability to recover from deer browsing with little effect on growth. It also has been used successfully to revegetate surface mine spoil banks (Hart and Byrnes 1960). Japanese larch of good provenances is generally considered one of the fastest growing conifers planted in northeastern North America (MacGillivray 1969; Cook 1971). Results from a study in Newfoundland indicated that Japanese larch outgrew tamarack (*L. laricina* (Du Roi) K. Koch.) and European larch (*L. decidua* Mill.) on the most productive sites (Hall 1983). After evaluating yield data from a 25-year-old provenance trial in the Maritime Region of eastern Canada, Fowler and others (1988) concluded that Japanese larch, when managed on short rotations, is capable of producing two or three times more wood than other conifer species commonly planted in the area. These authors pointed out that Japanese larch is genetically highly variable in terms of volume growth. Trees of the best provenances produced three times as much wood as trees of the poorest provenance.

The objective of the West Virginia study was to evaluate the effects of fertilization on the growth and development of a 9-year-old Japanese larch plantation and to determine the suitability of using this species for planting on lower quality sites in the central Appalachian region.

Study Area

The study area (22.1 acres) located (39° 9' N 79° 49' W) near Parsons, West Virginia, has a southern aspect and an average slope of 25 percent. Average elevation is 2,600 feet. Predominant soil is Calvin channery silt loam (loamy-skeletal, mixed, mesic Typic Dystrachrept) underlain with fractured sandstone and shale of the Hampshire formation (Losche and Beverage 1967). Annual precipitation for the 9-year period averaged 64 inches, 31 inches during the growing season and 33 inches during the dormant season. The average length of the frost-free season during the study was 146 days. The

approximate site index is 65 for northern red oak (*Quercus rubra* L.). Deer populations around the study area between 1984 to 1990 were estimated at about 40 per square mile, based on annual buck kill (Pers. commun., Walter Lesser, West Virginia DNR, 1994).

The area was farmed until 1930. After farming ended, natural revegetation by poor-quality hardwoods proceeded until November 1983. A vegetation survey taken in October 1983 indicated that 39 percent of the pretreatment surface area was classed as "open"—not shaded by other vegetation. Approximately 3 acres were still in old fields dominated by a variety of grasses, for example, *Panicum* spp. and tall redtop (*Triodia flora* L.); widely scattered mountain laurel (*Kalmia latifolia* L.); clumps of blueberries (*Vaccinium* spp. L.); and small hardwoods. The remaining area was forested. Common species were red maple (*Acer rubrum* L.), sassafras (*Sassafras albidum* (Nutt.) Nees), flowering dogwood (*Cornus florida* L.), blackgum (*Nyssa sylvatica* Marsh.), sourwood (*Oxydendron arboreum* (L.) DC), and hickory (*Carya* spp. Nutt.).

Methods

Most trees larger than 6 inches d.b.h. were cut on the study area in the fall of 1983. The area was prepared for planting in November 1983 with a mechanical site-preparation treatment consisting of root-raking and windrowing slash on the contour using a D7F tractor equipped with a root rake (Kochenderfer and Helvey 1989). The treated area (22.1 acres) was planted in April 1984 with 2-0 Japanese larch at approximately a 6- by 6-foot spacing. Planting stock was obtained from the New York State Nursery at Saratoga Springs, New York. Aerial views of the study area taken in 1984 and 1993 show a 3.5-acre untreated buffer zone along the stream and the development of the larch plantation (Figs. 1 and 2).

A 100- by 100-foot grid of 93 permanent sampling points marked with 0.5-inch reinforcing rod was systematically established on the treated area. In May 1984, 0.01-acre plots were established around alternate sampling points (43 plots). All larch on these plots was permanently marked and the trees numbered. In addition to survival status, total height to the nearest one-tenth of a foot, d.b.h., and condition class were recorded for each larch. Four condition classes were used to describe the larch trees:

1. Good vigor—dominant or codominant trees with at least one-half of the crown above competing vegetation.
2. Medium vigor—intermediate trees with less than one-half of the crown above competing vegetation.
3. Poor vigor—trees with crowns shorter than surrounding vegetation or trees completely overtopped by competing vegetation.
4. Dead trees.

Trees were measured in May 1984, September 1985, October 1986, and April 1993.

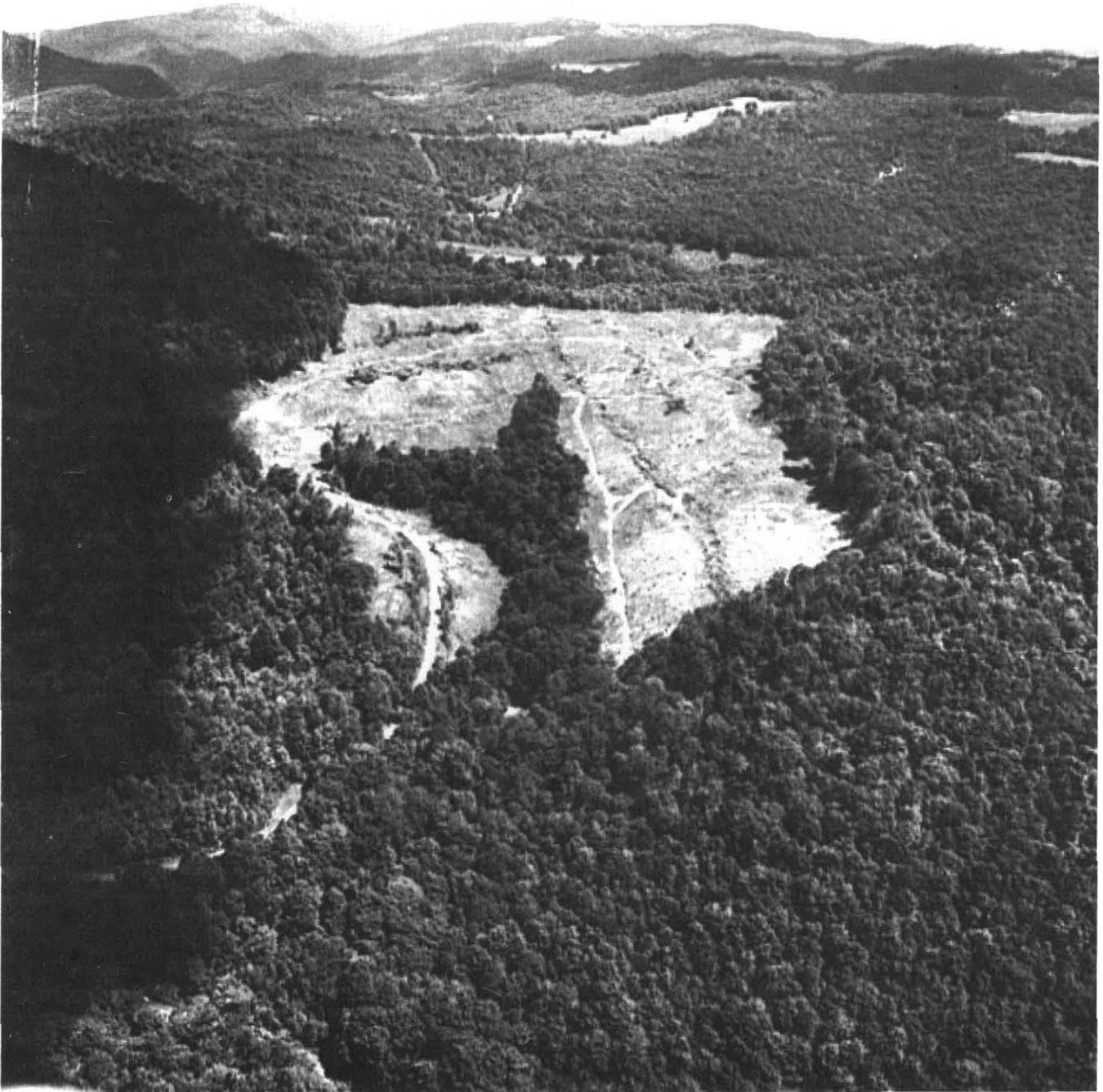


Figure 1.—Aerial view of the study area, summer 1984.

Beginning in April 1987, the larch plantation was included in an artificial acidification study (Adams and others 1993). Granular ammonium sulfate fertilizer (21-0-0-24, relative proportions of N (nitrogen), P (phosphorus), K (potassium), and S (sulfur)) was applied by helicopter three times each year to the 43 (0.01-acre) plots. Fertilizer was applied annually in March, July, and November. To mimic seasonal ambient deposition, 30 pounds per acre of fertilizer were applied in March and November and 90 pounds per acre in July for a total annual application rate of 150 pounds per acre. The application of 31.5 pounds per acre per year of N is twice

the ambient rate of N falling on the site but very low when compared to the 150 pounds per acre per year often applied to field crops.

Larch was permanently marked and numbered on six 40- by 50-foot control plots (0.0459-acre) that were established on the study area. Buffers were established around these plots, and they were excluded from the fertilizer treatments. The same measurements were made on the unfertilized plots that were made on the 0.01-acre fertilized plots. Measurements were recorded on the unfertilized plots in November 1986 and April 1993.

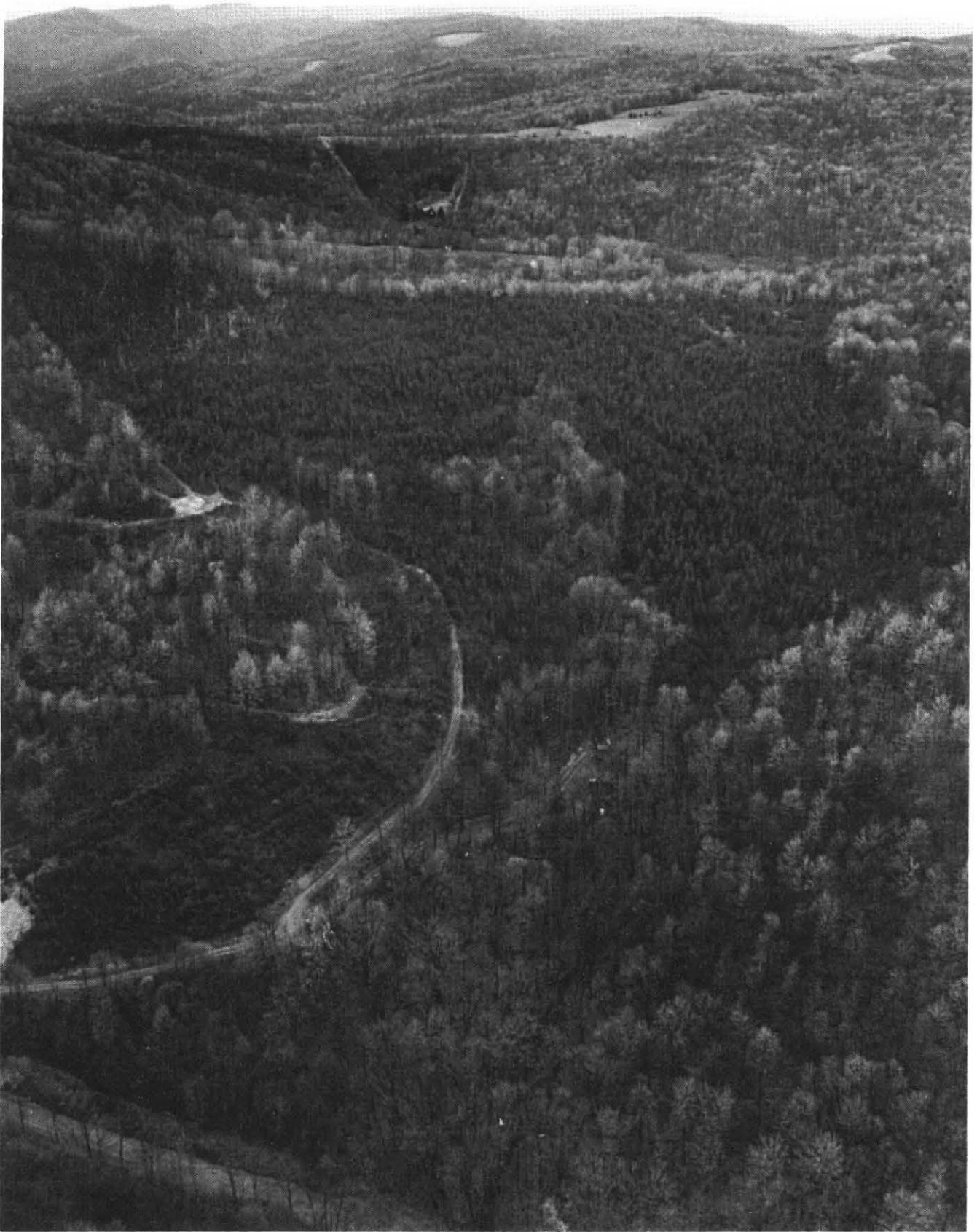


Figure 2.—Aerial view of the study area, April 1993.

In August 1993, foliar samples were collected from dominant and codominant larch trees for chemical analyses. Foliar samples were collected from current-year needles in the upper one-third of the crowns of two trees at three locations on each unfertilized plot. Samples were also collected from current-year needles in the upper one-third of the crowns of two trees at three locations on nearby fertilized plots. A total of 18 fertilized and 18 unfertilized foliar samples were collected. Tissue samples were analyzed at the Plant and Soil Analysis Laboratory at the University of Maine for total N, P, K, calcium (Ca), magnesium (Mg), aluminum (Al), Boron (B), Copper (Cu), iron (Fe), Manganese (Mn), and Zinc (Zn) content.

In March 1994, soil samples were collected at the same locations as the foliar samples. Soils were sampled from both fertilized and unfertilized sites. A total of 72 samples (36 from fertilized area and 36 from unfertilized area) was collected. In each of the fertilized and unfertilized sites, 18 samples were collected at the 15.2 cm depth and 18 samples were collected at the 30.5 cm depth. Soil samples were analyzed at the Soil Analysis Laboratory at the Ohio State University for pH, P, K, Ca, Mg, and Mn. The cation-exchange capacity (CEC) was also calculated.

Results and Discussion

Survival on Fertilized Plots

Japanese larch was tallied on 43 (0.01-acre) plots in May 1984 immediately after planting. The survey indicated that the actual number of larch planted averaged 1,088 per acre with an initial average planting spacing of 6.3 by 6.3 feet. In 1984, to be considered 100 percent stocked, it was assumed there should be at least 11 larch trees on each plot. On this basis, average stocking in 1984 was 51 percent. This indicates that planting was not uniform. In some areas, seedlings were overabundant while in others they were insufficient to meet initial stocking criteria.

Survival in 1985, after two growing seasons, was 82 percent—the average number of live trees had decreased to 893 per acre (Table 1). By 1993, nine growing seasons after planting, survival was 65.3 percent, and the number of live trees had decreased to 712 trees per acre. This

indicates (current 1993) average larch spacing of 7.8 by 7.8 feet on the fertilized portions of the study area.

If only trees in condition class 1 and 2 are considered acceptable growing stock, there were 556 trees per acre and survival was 51 percent in 1993 (Table 1). This translates into a spacing of 8.9 by 8.9 feet. If at least four trees in condition class 1 or 2 on each 0.01-acre plot are considered adequate stocking, stocking after nine growing seasons was 74.4 percent. If only trees in condition class 1 are considered acceptable growing stock, there were 372 trees per acre in 1993. This corresponds to an average spacing of 10.8 by 10.8 feet. Survival of condition class 1 trees after nine growing seasons was 65.8 percent. However, if a minimum of four trees in condition class 1 on each 0.01-acre plot is considered adequate stocking, then stocking in 1993 was 51.2 percent. Portions of the study area are still overstocked while others appear understocked.

Survival on Unfertilized Plots

The initial tally in 1986 indicated there were 987 trees per acre (Table 1). This corresponds to an average tree spacing of 6.6 by 6.6 feet. By 1993, the number of live trees had decreased to 882 trees per acre and average tree spacing increased to approximately 7 by 7 feet. Survival after six growing seasons was 89.4 percent. More trees were in condition class 1 on the unfertilized plots than on the fertilized plots. In 1986 and 1993, respectively, 45.6 and 52.2 percent of the unfertilized trees were in condition class 1 as opposed to 30.5 and 34.2 percent of the fertilized trees that were in condition class 1. This greater percentage of condition class 1 trees on the unfertilized plots is probably due to the initial uneven stocking discussed earlier. The number of trees in condition class 1 increased on the fertilized and unfertilized plots between 1986 and 1993. This is encouraging because it means that some of the condition class 2 trees were able to outgrow the rather severe hardwood competition prevalent on much of the study area and advance into condition class 1 trees. An average tree spacing of approximately 9.2 by 9.2 feet is indicated if only unfertilized condition class 1 trees are considered as potential crop trees in 1993.

Table 1.—Average number of trees per acre and percentage of trees, by condition class

Condition class	Pre-treatment (1986) ^a						Post-treatment (1993)			
	1985		Fertilized		Unfertilized		Fertilized		Unfertilized	
	Trees/acre	Percent	Trees/acre	Percent	Trees/acre	Percent	Trees/acre	Percent	Trees/acre	Percent
1	442	40.6	332	30.5	450	45.6	372	34.2	515	52.2
2	277	25.4	235	21.6	319	32.3	184	16.8	171	17.3
3	174	16.0	291	26.8	218	22.1	156	14.3	196	19.9
4	195	18.0	230	21.1	—	—	376	34.7	105	10.6
Total	1,088	100.0	1,088	100.0	987	100.0	1,088	100.0	987	100.0

^aFertilization began in April 1987.

Spacing Requirements

Because larch is usually regarded as one of the most intolerant conifers, wide spacing is generally recommended. Cook (1971) recommended initial spacing of up to 6 by 20 feet. Turner and Myers (1972) found that diameter growth declined between age 19 to 24 in a Japanese larch plantation in Vermont with an initial spacing of 7 by 14 feet. They attributed the growth decline to between-row crown closure and recommended close observation and prompt cultural treatments because of rapid growth. Carter (1987) also recommended wide spacing and early thinnings for larch because of its intolerance and rapid growth.

Height Growth

There were no significant differences in height of the larch trees growing on the fertilized and unfertilized plots in 1986 for any of the condition classes (Table 2). Trees in condition class 1 averaged 1.4 feet taller than those in condition class 2 and were more than twice as tall as those in condition class 3.

In 1993, after nine growing seasons, average height of the unfertilized larch trees was significantly greater (0.05 level) than that for fertilized trees in all condition classes (Table 2). For example, average height of larch trees in condition class 1 growing on the unfertilized plots averaged 22 feet versus 19.1 feet for trees growing on the

fertilized plots. Unfertilized larch trees in condition classes 1 and 2 were approximately 2 feet taller than fertilized trees growing in the same condition class.

The mean height of all larch trees after nine growing seasons was 18.6 feet on the unfertilized plots and 15.8 feet on the fertilized plots. The tallest larch tree measured was 31 feet. Growth of the Japanese larch in this study compares favorably with the height-age curve developed for the fastest growing provenance in a trial of 20 Japanese seed sources in eastern Canada (Magnussen and Park 1991). Height growth was also similar to that observed for several species of *Larix* and some larch hybrids in an 8-year-old progeny test in Wisconsin (Reimenschneider and Nienstaedt 1983).

Diameter Growth

Average diameter of unfertilized trees in condition classes 1 and 2 was significantly larger than that of fertilized trees (Table 3). Average diameter of fertilized and unfertilized trees in condition class 3 was not significantly different. As expected, most of the larch basal area occurred in the larger condition class 1 trees. Seventy-nine percent of the total basal area of the fertilized trees was in condition class 1, while 85 percent of the total basal area of the unfertilized trees was in condition class 1. Total basal area of the unfertilized trees in condition class 1 was more than 1.5 times greater than basal area of the fertilized trees.

Table 2.—Average height of larch trees, by condition class for fertilized and unfertilized trees

Condition class	Pre-treatment (1986) ^a		Post-treatment (1993)		Average 6-year height growth (1986-1993)		
	1985	Fertilized	Unfertilized	Fertilized	Unfertilized	Fertilized	Unfertilized
	-----Feet-----						
1	2.3	3.9 (0.1) ^b a ^c	4.0 (0.1)a	19.1 (0.3)b	22.0 (0.3)c	15.2	18.0
2	1.7	2.5 (0.1)a	2.6 (0.1)a	14.6 (0.4)b	16.6 (0.4)c	12.1	14.0
3	1.3	1.8 (0.1)a	1.8 (0.1)a	9.5 (0.5)b	11.2 (0.6)c	7.7	9.4

^aFertilization began in April 1987.

^bStandard error.

^cFor a given year and condition class, means followed by different letters are significantly different at $\alpha=0.05$ (analysis of variance followed by Tukey's HSD test).

Table 3.—1993 average d.b.h. and basal area of larch trees, by condition class for fertilized and unfertilized trees

Condition class	No. trees		No. trees/acre		Average d.b.h.		Basal area/acre		
	Fertilized	Unfertilized	Fertilized	Unfertilized	Fertilized	Unfertilized	Fertilized	Unfertilized	
	-----Inches-----							-----Ft ² -----	
1	160	142	372	515	2.1 (0.1) ^a a ^b	2.4 (0.1)b	10.1	16.8	
2	79	47	184	171	1.2 (0.1)a	1.5 (0.1)b	1.8	2.2	
3	57	50	133	182	0.9 (0.1)a	0.8 (0.1)a	0.9	0.8	

^aStandard error.

^bFor a given condition class, means followed by different letters are significantly different at $\alpha=0.05$ (analysis of variance followed by Tukey's HSD test).

Table 4.—Selected analyses of Calvin channery silt loam soil from the study site

Soil depth (cm)	pH ^b	Selected elemental analyses ^a								
		Ca	Mg	K	P	Mn	CEC			
		----- mg kg ⁻¹ -----					----- cmol kg ⁻¹ -----			
FERTILIZED ^c										
0-15.2	4.6a ^d (0.1) ^e	364a (38.1)	51.0a (1.5)	68.9a (3.0)	2.4a (0.2)	54.6a (3.9)	12.7a (0.5)			
15.2-30.5	4.6c (0.1)	456b (72.6)	55.9c (2.9)	57.6b (2.8)	1.6c (0.2)	24.2b (5.0)	12.1c (0.6)			
UNFERTILIZED										
0-15.2	4.4b (0.03)	312a (17.6)	46.2b (1.8)	79.5a (5.6)	1.9b (0.2)	58.3a (5.9)	14.7b (0.5)			
15.2-30.5	4.5c (0.03)	488b (14.4)	41.3c (1.7)	72.6c (3.5)	1.4c (0.1)	18.2b (3.0)	14.4d (0.3)			

^aExtraction was by NH₄ OAC buffered at pH 7.0.

^bExtraction was made with one part soil and two parts H₂O.

^cSelected sites were treated since 1987 with (NH₄)₂SO₄ at an annual rate of 168 kg ha⁻¹.

^dFor a given soil depth and parameter, means followed by different letters are significantly different at α=0.05 (analysis of variance followed by Tukey's HSD test).

^eStandard error.

Soil Analysis

Farming on the study site ceased in 1930 due to nutrient exhaustion (Lima et al. 1978). The soils are still depleted in nutrient content and are highly acidic (Table 4). Only Mg, K, and P showed significant differences in concentration when the fertilized and unfertilized soils were compared. The concentrations of most other elements evaluated in the study were higher at both depths on the fertilized sites, but the CEC was significantly higher in the unfertilized soil samples.

The concentration of Mn extracted from the soil samples was much greater in the surface horizons than in the lower horizons of both fertilized and unfertilized soils (Table 4). Anions, such as SO₄, associated with K or NH₄ fertilizer sources have been reported to have differential effects on the solubility and mobility of Mn or its availability to crops (Graham et al. 1988). However, the mobility of Mn from the surface to lower soil horizons was not apparent in either fertilized or unfertilized soils in this study (Table 4).

Foliar Analysis

The foliar analysis of the larch tissue shows that larch will thrive on a poor site (Table 5). Concentrations of the reported macroelements (Ca, K, P, and N) and most metals in the plant tissue are within the medium range of concentrations reported for coniferous tree species (Leaf 1973). Of the foliar elements analyzed, only the concentration of Mn was significantly higher on the fertilized sites, which may have resulted from (NH₄)₂SO₄ applications. The Mn concentration was within the medium range of concentrations reported for coniferous tree species. Iron was the only element in the low range of reported concentrations. Higher concentrations of

most metals in the plant tissue of species grown on highly acid soils are expected, but coniferous species are more tolerant of these metals than are other tree species (Leaf 1973). The larch grew rapidly on the poor site and showed a high tolerance to the available metals present in the soils.

Table 5.—Selected foliar analyses^a of plant tissue from fertilized and unfertilized Japanese larch growing on the study site

Element	Fertilized ^b		Unfertilized	
----- g kg ⁻¹ -----				
Ca	3.7 a ^c	(0.20) ^d	3.7 a	(0.20)
K	8.4 a	(0.30)	8.5 a	(0.20)
Mn	2.1 a	(0.20)	1.5 b	(0.20)
N	22.0 a	(0.30)	22.0 a	(0.40)
P	1.2 a	(0.03)	1.5 b	(0.03)
Mg	0.8 a	(0.05)	0.9 a	(0.07)
----- mg kg ⁻¹ -----				
Al	390.1 a	(28.1)	420.9 a	(26.9)
B	22.7 a	(1.0)	22.6 a	(1.1)
Cu	4.1 a	(0.1)	4.1 a	(0.1)
Fe	46.5 a	(1.5)	42.8 a	(1.1)
Zn	21.3 a	(0.4)	20.6 a	(1.0)

^aPlant tissue was analyzed by digesting samples in a hydrochloric perchloric acid mixture. Analyses were based on percent dry weight of foliar tissue collected in the late summer.

^bPlant tissue was collected from sites treated with 168 kg ha⁻¹ of (NH₄)₂SO₄ annually since 1987.

^cFor a given element, means followed by different letters are significantly different at α=0.05 (analysis of variance followed by Tukey's HSD test)

^dStandard error.

Adaptability

Robbins (1985) has discussed the risks associated with growing non-native larches. The risks include frost susceptibility, shade intolerance, diseases, insects, and animal damage. However, to date, we have not encountered any serious problems. The second year after planting, a freeze occurred on April 23 when temperatures dropped to 24° F. This caused browning of the newly emerged needles, but the larch trees did not appear to incur any permanent damage. In January 1993, heavy accumulations of snow and ice damaged a few larch trees growing adjacent to a road but other trees were not injured. Damage that might occur if heavy, wet snow accumulated on the trees in October or April when a substantial amount of foliage was on the trees is currently of some concern. Despite high deer populations in the study area during the first few years after planting, the larch suffered no damage from browsing.

A longer observation period is needed to determine if Japanese larch is adapted to the climate and growing conditions encountered at this study site. There is some evidence that Japanese larch does not perform well in West Virginia on drier sites at lower elevations. Japanese larch plantings on dry sites (<40 inches annual precipitation) at elevations near 1,000 feet in West Virginia failed, while a plantation established on a high-elevation site (3,700 feet) receiving 55 inches of annual precipitation had trees that averaged 23 feet tall and had an 80 percent survival at age 10 (Pers. commun., Bruce B. Breneman, Westvaco Corp., 1995).

Although there are areas of severe hardwood competition in some portions of this 9-year-old Japanese larch plantation, the site preparation treatment and the fairly rapid early height growth of the larch permitted it to become established and grow throughout most of the study area. Mean height of all the larch trees increased from 1.7 feet at the time of planting to 3 feet after three growing seasons. There were several condition class 1 trees between 4 to 5 feet tall at the end of the third growing season. At this time, there appears to be a satisfactory number of trees in condition class 1 to ensure adequate stocking on most of the area.

Summary

After 9 years of growth, both the height and diameter of larch trees were significantly greater on the unfertilized plots. Mean height of all larch on unfertilized plots averaged 18.6 feet versus 15.8 feet on the fertilized plots. Diameters of larch grown on unfertilized plots averaged 1.9 inches versus 1.6 inches on the fertilized plots. The heights of the larch were greater on unfertilized plots regardless of the condition class of the trees. The soils on both the fertilized and unfertilized sites were still highly acidic and nutrient deficient when evaluated after 9 years of tree growth. These early results indicate that Japanese larch would be a good choice for planting on poor sites with high deer populations in areas with similar climatic regimes. Nitrogen fertilization seems to be counterproductive and is not recommended.

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Keywords: Japanese larch, fertilization, height growth, diameter growth, central West Virginia, foliar and soil chemistry

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