FOREST RESEARCH REPORT

NOVA SCOTIA DEPARTMENT OF LANDS AND FORESTS
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THE POTENTIAL FOR LARCH IN NOVA SCOTIA - A LITERATURE REVIEW -

INTRODUCTION

Larches (*Larix spp.*) are known for their rapid juvenile growth and adaptation to marginal sites, especially those that are excessively moist. In fact, available information from scattered trials within the region indicates that by planting larch, forest productivity could be increased by up to 50% and rotations reduced to 30 years or less. These traits make larch a potentially valuable reforestation species. However, before detailed reforestation prescriptions can be developed for this species, existing information needs to be summarized and gaps in current knowledge identified. Therefore, a review of the literature was undertaken on the silvics, growth characteristics and wood properties of tamarack (*Larix larcinia* (DuRoi) K. Koch) and 5 promising exotic larches.

SILVICS

Tamarack can be found in every Canadian province and territory, the northeastern and Great Lakes regions of the United States, and in Alaska. Tamarack is adapted to a broad range of temperature, precipitation, photo period, and soils (Coles, 1983). Ranging in height from 9-21 m and from 30-60 cm in diameter, tamarack is often found on cold, wet, poorly drained sites, but grows best on moist, rich, well-drained, friable soils. In Nova Scotia, tamarack can be found in pure stands, but, more often as a minor component of a wide variety of stand types originating primarily from clearcuts, areas burned by wildfires, and old field or pasture sites. It is not considered self-pruning, but will develop a branch free trunk in well stocked stands. The root system is shallow, but wide-spreading, and provides moderate windfirmness (Hosie, 1975).

European larch (*Larix decidua* Mill.) is indigenous to the Alps, Czechoslovakia, southwestern Poland, and isolated locations in the Carpathian Mountains. The species is now found throughout northern Europe, including Scandinavia. In Britain it has been cultivated since the 17th century and reaches heights of 30-45 metres and diameters of 60-150 cm. European larch requires moderately rich soils, with the best growth occurring on light loams with a generous, but not excessive water supply. This species will grow on rich, shallow peat, but not on deep peat. Heavy clays, dry sands and highly calcereous soils are not preferred.

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This species is light-demanding, can withstand cold winters, requires a free circulation of air, but is susceptible to damage by strong winds and late-spring frosts (Dallimore and Jackson, 1966).

Japanese larch [*Larix leptolepis* (Sieb. and Zucc.) Gord.; also called *L. kaempferi* Sarg. and *L. japonica* Carr.] is endemic to a small region in Central Honshu, Japan, where it occurs on the slopes of volcanic mountains. Capable of reaching heights of 18-30 m and diameters of 60-120 cm; this species will grow well under a wide variety of soil and site conditions, provided that the soil is reasonably fertile. Japanese larch withstands considerable exposure, grows well at high elevations, but is susceptible to drought (Dallimore and Jackson, 1966). It is also quite hardy, very fast growing, and less subject to disease than European larch (Clinton-Baker, 1909).

Siberian larch (*Larix sibirica* Ledeb.) is widely found throughout northeastern Russia and western Siberia. In Finland and Sweden, it has been planted for timber and was introduced to Britain in the early 1800's. The tree attains heights of 24-30 m and diameters ranging up to 120 cm. Siberian larch is adapted to short sunny summers and long, cold winters. The very early breaking of the leaf-buds and the crippling effect of spring frost on the young shoots has restricted the use of this species in reforestation programs outside its natural range. In Britain, Siberian larch suffers so much from spring frost that it is not likely to prove a success and no specimens larger than nursery plants are known (Clinton-Baker, 1909).

Another species deserving mention is **Dahurian larch** (*Larix gmelini* Rupr. Litvin.). This variable tree grows to 18-24 m or sometimes 30 m high, but in some places is reduced to a low-growing bush. The species occurs in Siberia, Korea, and Manchuria with several geographic varieties. It is abundant in swamps, grows under very cold conditions and is subject to injury by late spring frosts. Its susceptibility to frost injury has limited the planting of this species.

Dunkeld larch (*Larix eurolepis* Henry) is a hybrid between European and Japanese larch, which first appeared as open-pollinated offspring near Dunkeld, Scotland. The tree grows vigorously to 18 m or more in height. Under cultivation, this larch will often outperform both parents, and appears to be free from attack by aphids and fungi which are so destructive to European larch (Dallimore and Jackson, 1966).

REFORESTATION

NURSERY PRODUCTION

North American nurseries have traditionally obtained seed of exotic larches from stands in Europe and Asia. It has been suggested that better quality seed could eventually be obtained from locally established seed orchards or seed production areas (Campbell, 1983). Other problems related to seed supply include (i) chronic shortfalls of tamarack seed for the past decade in eastern North America and (ii) extreme vulnerability of tamarack and several exotics to cone and seed insects (Schopmeyer, 1974). Measures available to conserve larch seed include greenhouse seeding and/or vegetative propagation.

In tree nurseries, larch does best in fertile soils characterized by soil nutrient levels of 300 ppm phosphorous, 117 ppm potassium, 450 ppm calcium, and 60 ppm magnesium (Campbell, 1983). Soil pH in excess of 6.5 causes larch to become chlorotic and stunted (Campbell, 1983). Schopmeyer (1974) reports that larch have very few enemies in the nursery with only occasional damage from fungal agents.

Larch seedlings are not tolerant to competition from common weeds and grasses, hence the nursery beds must be kept as free of competition as possible. Pre-emergent herbicides and mineral spirits are recommended (Campbell, 1983).

Unlike other conifers, larch continues height growth throughout the summer. Both tamarack and exotic larches normally harden-off well, although Japanese larch will usually undergo frost-kill to some degree, but will rebud and grow out of its damaged condition exhibiting strong apical dominance. Because of the deciduous nature of *Larix* species, the elongation of 'long' shoots (terminal growth) is delayed until after 'short' shoots (needles) have been formed. Most conifers have attained their year's height growth by mid-July, while the larches continue to grow into September.

Larch is generally shipped for planting as 2 year old-field grown bareroot stock, or as 1 year old greenhouse grown container stock.

PLANTATION ESTABLISHMENT

Site Selection

Japanese and European larch are upland species not adapted to the wet sites commonly occupied by tamarack. On well drained sites classified as loamy sands, loams, and silt loams, these two species have consistently outgrown white and Norway spruce and red, white and jack pine (Einspahr *et al*, 1984; Vallee, 1983; Popovich and Houle, 1970; Hall, 1982). Larch does not require rich sites. In fact, high productivity can be expected on sites of medium fertility. Popovich and Houle (1970) reported a total annual production of 12.1 m^3/ha for a European larch plantation located near Drummondville, Quebec on a sandy, well drained orthic podzol. On a wetter soil classified as a gleyed podzol in the same plantation, growth was only 5.6 m^3/ha/year.

Sites to be avoided when planting either European or Japanese larch are frost pockets, peat soils, climatically exposed sites at high elevations and near the ocean, heavy clay or dry sandy soils, and those that are imperfectly or poorly drained. However, Japanese larch can withstand moderate exposure.

Successful planting of Siberian larch outside its natural range has generally been restricted to areas with short summers and long cold winters. It grows well on a variety of sites but is very susceptible to spring frosts.

Dehayes *et al* (1980) concluded that exotic larches can be expected to perform best on deep, moist, well-drained soils, but even on dry sandy soils, growth can be excellent. Exotic larches will not tolerate poorly drained sites or soils with impervious subsoil pans. Larches also require full sunlight and a free circulation of air such as available on mountain sides. Although larch can withstand windstorms better than most conifers, plantations located on severely exposed sites are rarely successful.

Stock Type

Vallee (1983) reports that it is better to use large bareroot stock when planting cutovers, particularly hardwood cutovers. Since larch does not tolerate "over the top" application of herbicides and because manual weed control is expensive; large bareroot seedlings are favoured due to their greater ability to outgrow weed competition. Campbell (1983) reports that large, 2 year old bareroot transplants are well suited for cutover planting and may reduce the need for extensive site preparation.

Spacing

In Great Britain, where large acreages have been planted to larch, maximum plantation spacing for European larch is 1.7 m by 2.1 m. Closer spacings of 0.9 by 1.4 m require thinning at 12-15 years. Japanese larch is not recommended for planting at less than 1.7 by 2.1 m because of rapid juvenile growth.

Weed Control

Weed control in larch plantations is complicated by its sensitivity to herbicides during active growth and its long growing season. It is one of the first species to initiate growth in the spring and the last to stop in the fall (Netzer, 1984; Vallee, 1983; Dehayes *et al*, 1980; Coles, 1983). Despite this long growing period, simazine, befenox, oxyfluorfen, pronamide and oryzalin provide adequate weed control with no damage when oversprayed in the spring on newly planted 1+0 European larch (Netzer, 1984). Other methods of curtailing competing vegetation include site preparation (mechanical or chemical) and mechanical weedings.

GROWTH AND YIELD

Larch is well known for its rapid juvenile (4-8 years) height growth. In fact, height growth ranging from 40 to 80 cm per year has been recorded (Park and Fowler, 1983; Einspahr *et al*, 1984; Reimenschneider and Nienstaedt, 1983). In New Brunswick, Park and Fowler (1983) reported total height after 8 years for Japanese larch of 3.0-4.3 m, European larch 3.2-3.4 m, and tamarack 3.8-4.1 m. Zavitkovski *et al* (1982) reported an average height of 7.6 m in Wisconsin for a 9 year old Japanese x European larch plantation. This rapid early height growth is advantageous especially on sites where competing vegetation cannot be adequately controlled. MacGillvrary (1969) showed that larches outgrew native conifers on a site in New Brunswick (Figure 1). Vallee (1983) stated that larches are the fastest growing conifers in southern Quebec (Table 1, Figure 2). His findings conclude that the spectacular growth of larch during their first twenty years could result in a rotation age of less than 30 years. A survey by Bolghari and Bertrand in 1982 (Vallee 1983) indicated that European and Japanese larches could produce from 10 to 14 m^3/ha/year on good quality sites. Vallee also stated that European and Japanese larches are able to produce 1.5 to 2.0 times more fibre than tamarack in Southern Quebec (Puttock 1983).

Only a few plantations can be identified in the literature for which data on growth and yield is available for both the exotic larches and the adjacent native conifers (Table 2). The exotic larches in these plantations outgrew the natives by a considerable margin in terms of both height and volume.

A provenance test of Japanese larch was established in 1962 at the Acadia Forest Experiment Station in New Brunswick. Park and Fowler (1983) reported that the 5 most productive provenances of Japanese larch produced 156 m^3/ha at age 19, more than double that of adjacent tamarack and European larch (Table

3). Further data from this provenance trial (pers. comm. D.P. Fowler, 1986) after 25 years from date of planting revealed the following:

Species	Height (m)	Range	Diameter (cm)	Range
Japanese larch	16.0	12.8-17.8	21.3	18.2-23.0
Tamarack	14.6	14.3-14.8	17.2	17.1-17.3
European larch	11.5	11.3-12.0	17.6	17.0-18.1

Fowler (1983) concluded that Japanese larch, if carefully planted on appropriate sites and protected (especially from porcupines), is capable of producing more wood than any other conifer species presently being planted [in the Maritimes].

In Western Prince Edward Island, a 1960 European larch plantation has been extensively studied. After 24 years, selected trees ranged from 11.2 to

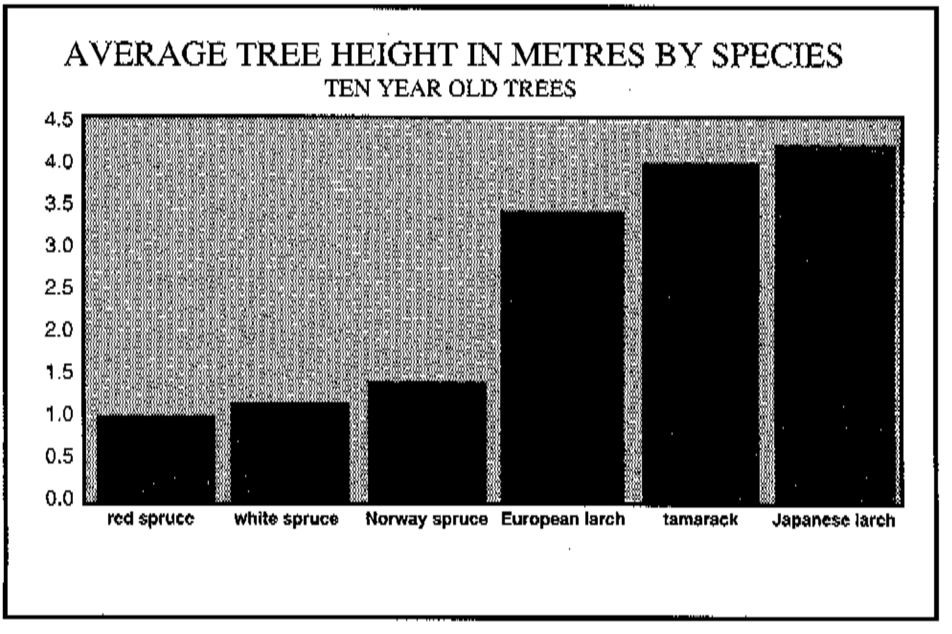

Figure 1. Average tree height for the most vigorous 10 year old provenance within each species. All tests in close proximity and on the same quality site at the Acadia Forest Experimental Station, New Brunswick. The European larch are not believed to be from the best seed sources for New Brunswick (MacGillivrary, 1969).

Table 1. Minimum, mean and maximum site indices measured in southern Quebec plantations by Bolghari and Bertrand (Vallee 1983)

Species	Number of Sample Plots	Site Index at 25 years (m)		
		Minimum	Mean	Maximum
Red pine	289	6.0	11.8	18.1
White pine	59	5.8	9.4	12.7
White spruce	249	4.4	8.9	15.1
Norway spruce	120	6.6	9.9	15.7
Tamarack	118	9.3	14.3	18.2
European and Japanese larch	70	8.4	16.2	23.7

15.0 m and 18.8 to 24.9 cm (d.b.h.). Total basal area of the stand was 32.9 m²/ha and there was a merchantable volume of 135.4 m³/ha (22.8 cords/ac) and 2220 trees/ha (900 trees/acre). Due to inadequate weed control in the early life of the plantation, the trees got off to a slow start resulting in a 5 year difference between stump and breast height age (pers. comm. B. Glen, P.E.I. Dept. of Energy and Forestry, 1986).

A European larch plantation in Maine, established in 1930, at age 51 had an average dominant/co-dominant height of 29.6 m and an average merchantable diameter of 31 cm (pers. comm. David Maass, Scott Paper Co., 1985).

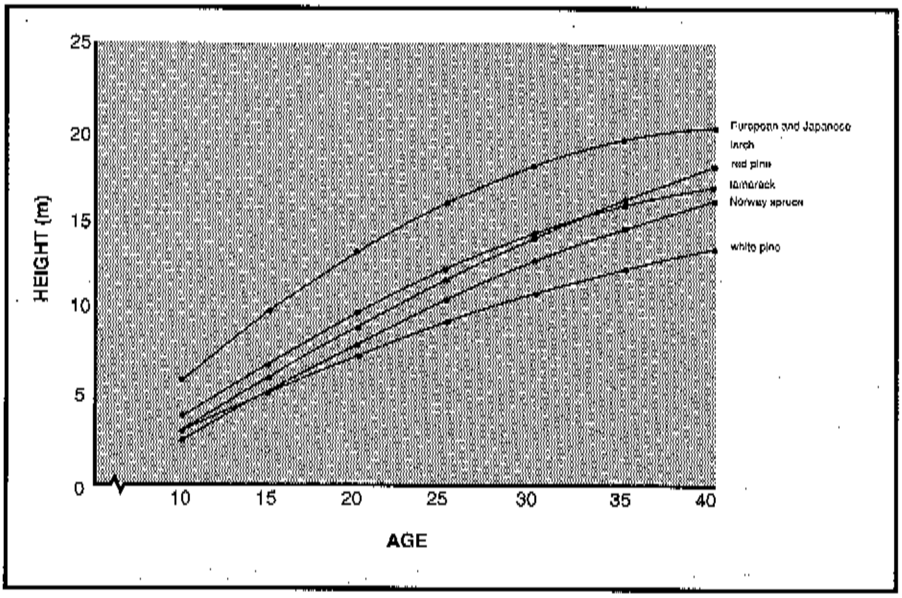

Figure 2. Mean site index curves for southern Quebec larch plantations compared to the four other best coniferous species (Vallee, 1983).

Table 2. Mean annual increment (m.a.i.) for exotic larch and native conifers planted on adjacent sites at various locations in eastern North America.

Source[1]	Species	Age	Height (m)	Max. m.a.i. (m³/ha/yr)
1	*L. decidua*	19	16.5	12.6
	Pinus resinosa		12.0	10.6
	P. strobus		10.7	9.7
2	*L. leptolepis*	11	9.2	12.0
	Picea glauca		5.4	8.0
3	*L. decidua*	24	12.7	8.9
	P. glauca		7.8	5.6
4	*L. leptolepis*	19	13.7	11.0
	P. mariana		7.2	6.4

[1] Source: 1) Reimenschneider and Nienstaedt (1983)
2) Nova Scotia Dept. of Lands and Forests unpubl. data (1986)
3) Prince Edward Island Dept. of Energy and Forests, pers. comm. B. Glen (1986)
4) Park and Fowler (1983)

Table 3. Performance for Japanese larch, European larch, and tamarack, 19 years after planting at the Acadia Forest Experimental Station near Fredericton, New Brunswick (Park and Fowler, 1983).

	No. of Seedlots	Height (m)	Diameter (cm)	Survival (%)	Specific gravity	m^3/ha
Best 5 Provenances of Japanese larch (by volume*)	-	13.26	17.76	89.1	0.398	156.0
All Japanese larch provenances	20	12.17	16.53	82.7	0.401	120.4
European larch	3	8.65	14.32	70.7**	0.397	63.7
Tamarack	2	10.18	12.91	89.3	0.411	69.3

* Best 5 provenances - Mt. Shirane, Mt. Asama, Mt. Komaga, Hida Mts., Mt. Azusa
** Porcupines favoured European larch over Japanese larch.

TREE IMPROVEMENT AND GENETICS

European larch does not have a continuous distribution across its natural range but is broken into four distinct geographic regions: Alpen (Alps), Polen (Poland), Tatra (E. Czechoslovakia, S. Poland), and Sudetan (Czechoslovakia). Significant differences between these regions have been determined in European provenance trials. Alpen sources have been shown to be more susceptible to attack by the European larch canker. Provenance trials in North America have shown that the Sudetan provenance grows the fastest and the Alpen provenance the slowest (Rauter and Graham, 1983). Information on the best provenances for the Maritimes is limited. However, based on small unreplicated trials here and more extensive trials elsewhere in North America, it is evident that trees of southern Polish and northern Czechoslovakian provenances are among the most promising in respect to both growth and form. They are also reputed to be more resistant to larch canker than trees from more southern high elevation provenances (Fowler, 1983).

Japanese larch has a limited natural range in the central portion of the Japanese Island of Honshu where all natural stands are contained within an area of approximately 200 km^2 and between 900 m to 2500 m in elevation. The mountainous topography of this species' natural range has led to the development of distinct populations through geographic isolation. Provenance variation in Japanese larch is not considered to be geographically related, but random. The performance of a given provenance in one location does not necessarily provide an estimate of performance elsewhere (Rauter and Graham, 1983; Park and Fowler, 1983). Fowler (1983) reported that trees of the following provenances do best in Central New Brunswick: Mt. Asama, Mt. Azusa, Hida Mts., Mt. Komaga and Mt. Shirane.

Rauter and Graham (1983) report that Siberian larch does not grow or survive well in the relatively mild climate of southern Ontario, but performs relatively well in the boreal forest of northern Ontario. Siberian larch have been planted in small tests at a few locations in the Maritimes. Fowler (1983) suggests that further tests be conducted with this species, especially in northern New Brunswick and the Cape Breton Highlands.

Loo *et al* (1982) concluded from provenance research plantings in New Brunswick and Michigan that the provenance-environment interaction in Japanese larch is high for many characteristics including wood specific gravity. For this reason they concluded it is not possible to identify provenances that can be expected to have outstanding performance over a wide range of environments. Thus it will be necessary to determine the best provenance for each environment.

Rauter and Graham (1983) conclude that the greatest potential for producing significant levels of economic improvement is through the manipulation of form. All of the larches contain large amounts of variation at the individual-tree level, which can far exceed variation at the population level. This between tree variation occurs in traits of economic importance such as wood properties and form characteristics that are under strong genetic control and possess moderate to high narrow-sense heritabilities. Hansmann and Sugden (1983), as well as Hatton (1986), concur that a tree breeding program, emphasizing fibre properties, be accorded strong consideration given the high variation among individual trees.

WOOD PROPERTIES AND PULPING

The most distinguishing characteristic of larch wood is the high content of arabinogalactans (water-soluble, highly-branched polysaccharides) in larch heartwood (Hatton, 1986). Water soluble extractives are about 3-4 times that of other coniferous species (Hansmann and Sugden, 1983). In terms of other chemical components, larch is not greatly different from other conifers (Table 4). However, the high content of water soluble extractives results in higher pulping chemical consumption, a higher ratio of dissolved solids, larger waste management problems and lower pulp yields (Coles, 1983). Among the advantages of larch for pulping are its comparatively long tracheids and its high density (Coles, 1983). Prior extraction of the water soluble material and its commercial recovery should increase pulp yields to acceptable levels. Larches also have considerably lower resin content than pine suggesting that resin-caused problems in pulping would be slight (Hansmann and Sugden, 1983).

Table 4. Physical and chemical properties of conifers in northern climes. Values are for mature trees (Einsphar, Wyckoff and Fiscus 1984).

Species	Wood Density[1]		Fibre length	Lignin	Hot-water extractives	Alcohol-benzene extractives
	g/cc	lb/cu ft	mm	Percent		
Red pine	0.39	24.3	3.4	24.8	4.8	3.5
Jack pine	0.39	24.3	3.5	28.3	3.0	4.0
Japanese larch	0.48	30.0	3.6	29.3	7.9	3.0
European larch	0.49	30.6	3.6	30.5	7.9	2.5
White pine	0.34	21.2	3.0	26.6	4.8	6.5
White spruce	0.37	23.1	3.3	29.4	2.6	2.0

[1]Wood density: g/cc = dry weight/green volume
lb/cu ft = dry weight/green volume

Mechanically pulped larch has demonstrated very poor strength and low brightness compared to black spruce (Holder, 1983; Coles, 1983). On the other hand kraft pulp from larch had a better bleached brightness, only a slightly lower yield and behaved in a similar manner during pulping and bleaching than spruce. However, the initial strength properties of larch were much lower than for the corresponding spruce kraft pulp, except for tear.

In summary, larch is not suitable for mechanical pulping until colour problems associated with larch heartwood are overcome (Hatton, 1986). However, either used alone or mixed with other species, larch is suitable for the making of kraft pulps (Hatton, 1986; Holder, 1983; Hansmann and Sugden, 1983; Coles, 1983; Isebrands, *et al* 1982). In using larch for kraft pulp, pulping conditions must be carefully selected to account for their characteristic high arabinogalactan content and above average density.

INSECTS, DISEASES AND PORCUPINES

All larch species are subject to attack by a wide variety of insects and diseases with more than two dozen significant pest problems in North America (Howse, 1983). The larch sawfly, (*Pristiphora erichsonii* Htg.) may be the most serious pest problem in managing extensive plantations of larch (Coles, 1983; Howse, 1983). Mortality of otherwise healthy trees may occur after 6 to 8 years of moderate to severe defoliation. However, sawfly infestations can be controlled with the use of insecticides or the development of parasites.

Following larch sawfly infestations, trees are susceptible to further damage and often mortality from the larch beetle (*Dendroctonus simplex* Lec.). Tree mortality due to the beetle has been building in Eastern Canada and requires that site selection for plantations of larches be made carefully to ensure vigorous trees (Coles, 1983). Possibly the second most serious defoliator of both native and exotic larches is the larch casebearer (*Coleophora laricella* Clem.). Severe attacks cause growth losses, and if prolonged, branch and tree mortality (Coles, 1983).

European larch canker (*Lachnellula willkommii* Hartig) should be considered potentially damaging until and unless research proves otherwise (Magasi, 1983). To date larch canker has been found only on native larch in the Maritimes. However, Magasi (1983) concludes that infection on non-native larch, if given adequate inoculum, will likely occur.

Many authors have referenced the damaging effects of porcupines on larch, especially European larch. Fowler (1983) states that porcupines are the single most damaging agent to Japanese larch plantations and have on occasion destroyed small plantations. He reports at least 50% of the Canadian Forestry Service test plantations have been essentially destroyed by this pest.

LARCH IN NOVA SCOTIA

Tamarack comprises only 1.5% (2.4 million cubic meters) of the merchantable softwood volume in the Province (N.S. Dept. of Lands and Forests, 1987). Approximately 20,000 ha of pure tamarack (80% by basal area) and 300,000 ha of mixed stands (tamarack 20% by basal area) can be found in Nova Scotia (N.S. Dept. of Lands and Forests, 1980). Tamarack grows in association with black spruce, red maple, balsam fir, white spruce, and to a lesser extent with white pine and white birch.

Data from several plots established in well stocked natural stands of tamarack by the N.S. Dept. of Lands and Forests (unpubl. data) are summarized below:

Stand	Age (BH)	Height (m)	Total Volume (m^3/ha)	Merch. Vol. (m^3/ha)	Total BA (m^2/ha)	LC (m^3/ha/yr)
1	17	9.4	110	45	25	6
2	49	16.5	240	196	33	6
3	40	17.7	265	207	38	8
4	52	16.5	307	224	42	8

BH = breast height (1.3 m)
BA = basal area
LC = land capability - potential yield at rotation age expressed in m^3/ha/yr

Tamarack usually grows faster initially in height than other native species, but preliminary data indicates that fully stocked pure stands grow slower in diameter and have a lower basal area than other native conifers (Bailey and Neily, 1986).

Tamarack has not been a major reforestation species in Nova Scotia. Only 700,000 tamarack seedlings have been outplanted in the last 10 years. One local pulp company has shipped out approximately 300,000 Japanese larch in the last 5 years. The Department of Lands and Forests and the Canadian Forestry Service have established research plantings of Japanese, European, tamarack, and hybrid larch. Another local pulp and paper company has included Siberian larch in some of their research planting trials.

The Nova Scotia Tree Improvement Working Group, with representatives from the Provincial, Federal, and local forest industries, established three test plantings in 1986 at Yarmouth; East Mines, Colchester County; and Queensville, Inverness County. Fifteen sources of tamarack (10 from Nova Scotia) and 5 sources each of Japanese, European, and Japanese x European hybrid larch were outplanted. To date, no tamarack plus trees have been selected in the Province.

In Nova Scotia, a Japanese larch provenance trial established by the Canadian Forestry Service in 1975 provides the best example of the growth potential of this species. Planted 3 m by 3 m the stand has the following characteristics after 13 growing seasons:

Diameter: 17.8 cm
Height: 10.8 m
Total basal area: 21 m^2/ha
Frequency: 840 stems/ha
Merchantable volume: 100 m^3/ha (18 cords/acre)
Site index (height (m) at 50 years): 32 (105')

SUMMARY

1) Japanese and European larch are upland species not adapted to the wet sites commonly occupied by tamarack. On well drained sites these two species will outgrow native conifers.
2) The greatest potential for producing significant levels of economic improvement in larch is through the manipulation of form. All of the larches contain large amounts of variation at the individual-tree level.
3) The most distinguishing characteristic of larch wood is the high content of water soluble extractives which are about 3-4 times that of other coniferous species. However, careful attention to pulping conditions makes larch species suitable for kraft pulping. Larch is not suitable for mechanical pulping until heartwood colour problems are solved.
4) Larch species are subject to attack by a wide variety of insects and diseases with more than two dozen significant pest problems in North America. In plantations, however, the porcupine may be the single most damaging agent.
5) In Nova Scotia exotic larch species may have the potential to outproduce native conifers by 50%. However, more research is needed before comprehensive reforestation prescriptions can be prepared.
6) The use of herbicides in larch plantations is complicated by its sensitivity to herbicides and its longer growing season. However, the rapid height growth of young plantations is advantageous on sites where competing vegetation cannot be adequately controlled.

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FOREST RESEARCH SECTION
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N.S. DEPT. OF LANDS AND FORESTS

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