Larix laricina (Du Roi) K. Koch Tamarack

Pinaceae Pine family

William F. Johnston

Tamarack *(Larix laricina)*, also called eastern, American, or Alaska larch, and hackmatack, is a small- to medium-sized deciduous conifer extending from the Atlantic to central Alaska. One of the largest tamaracks recorded is in Maine and measures about 94 cm (36.9 in) in d.b.h. and 29 m (95 ft) in height. The heavy, durable wood is used principally for pulpwood, but also for posts, poles, rough lumber, and fuelwood. Wildlife use the tree for food and nesting; it is also esthetically appealing and has significant potential as an ornamental.

Habitat

Native Range

Tamarack (fig. 1) has one of the widest ranges of all North American conifers. Its main range extends from Newfoundland and Labrador west along the northern limit of trees, and across the Continental Divide in northern Yukon Territory (52); then south in the Mackenzie River drainage to northeastern British Columbia and central Alberta; and east to southern Manitoba, southern Minnesota, southern Wisconsin, extreme northeastern Illinois, northern Indiana, northern Ohio, northern Pennsylvania, northern New Jersey, northern Connecticut, and Maine. It also grows locally in the mountains of northern West Virginia and adjacent western Maryland. A major disjunct area of tamarack is found in interior Alaska, in the Yukon and Kuskokwim River basins between the Brooks Range on the north and the Alaska Range on the south; three minor areas are near the Alaska-Yukon border.

Climate

Because of its wide distribution, tamarack grows under extremely varied climatic conditions. Average January temperatures range from -30" to -1" C (-22" to 30" F) and those of July from 13" to 24" C (55" to 75" F). The lowest recorded temperatures range from -29" to -62" C (-20" to -79" F); the highest, from 29" to 43" C (85" to 110" F).

Annual precipitation within the range of tamarack is also extremely variable. It ranges from 180 mm (7 in) at Fort Yukon, AK, to 1400 mm (55 in) in eastern Canada. Of this, 75 to 355 mm (3 to 14 in) is in June, July, and August. Snowfall has a similarly wide variation, from about 100 cm (40 in) in the District of Mackenzie in northwestern Canada to 510 cm (200 in) near the Atlantic coast in Labrador and Quebec.

The average frost-free period for tamarack ranges from probably less than 75 days over much of its range to 120 days in interior Alaska and 180 days along its southern limits. The generally shorter growing season in the northern latitudes is counterbalanced by longer periods of daylight *(12)*.

Soils and Topography

Tamarack can tolerate a wide range of soil conditions but grows most commonly on wet to moist organic soils (Histosols) such as sphagnum peat and woody peat. The latter is usually better decomposed, has more nitrogen and mineral nutrients, and is less acid than sphagnum peat. Tamarack grows fairly well on extremely dry soils where these are shallow over bedrock or where the water table is low, but it can die from drought on such sites. The tree is found on mineral soils, especially Inceptisols and Entisols, that range from heavy clay to coarse sand; thus texture does not seem to be limiting. Although tamarack can grow well on calcareous soils, it is not abundant on the limestone areas of eastern Ontario (27) and is rare on those of the Gaspé Peninsula and Anticosti Island in Canada.

Because it can withstand high soil moisture, high acidity, and low soil temperature, tamarack is more abundant on peatlands than trees characteristic of surrounding uplands. It grows best, however, on more favorable sites such as moist but well-drained loamy soils along streams, lakes, and swamps; seep areas; and mineral soils with a shallow surface layer of organic matter (12). In Alaska tamarack grows well on upland sites having wind-deposited loess soils (50).

Tamarack is a characteristic tree of peatlands, especially in the southern limits of its range. It is found on the full range of peatlands from rich swamp (forested rich fen) to raised bog but is most characteristic of poor swamps where the soil water is weakly enriched with mineral nutrients *(17)*. Farther north tamarack is still common on peatlands (38); in Alaska it occurs especially on bogs underlain by permafrost (perennially frozen soils) (50).

Tamarack often grows on much drier sites in the northern part of its range. Scattered individuals and

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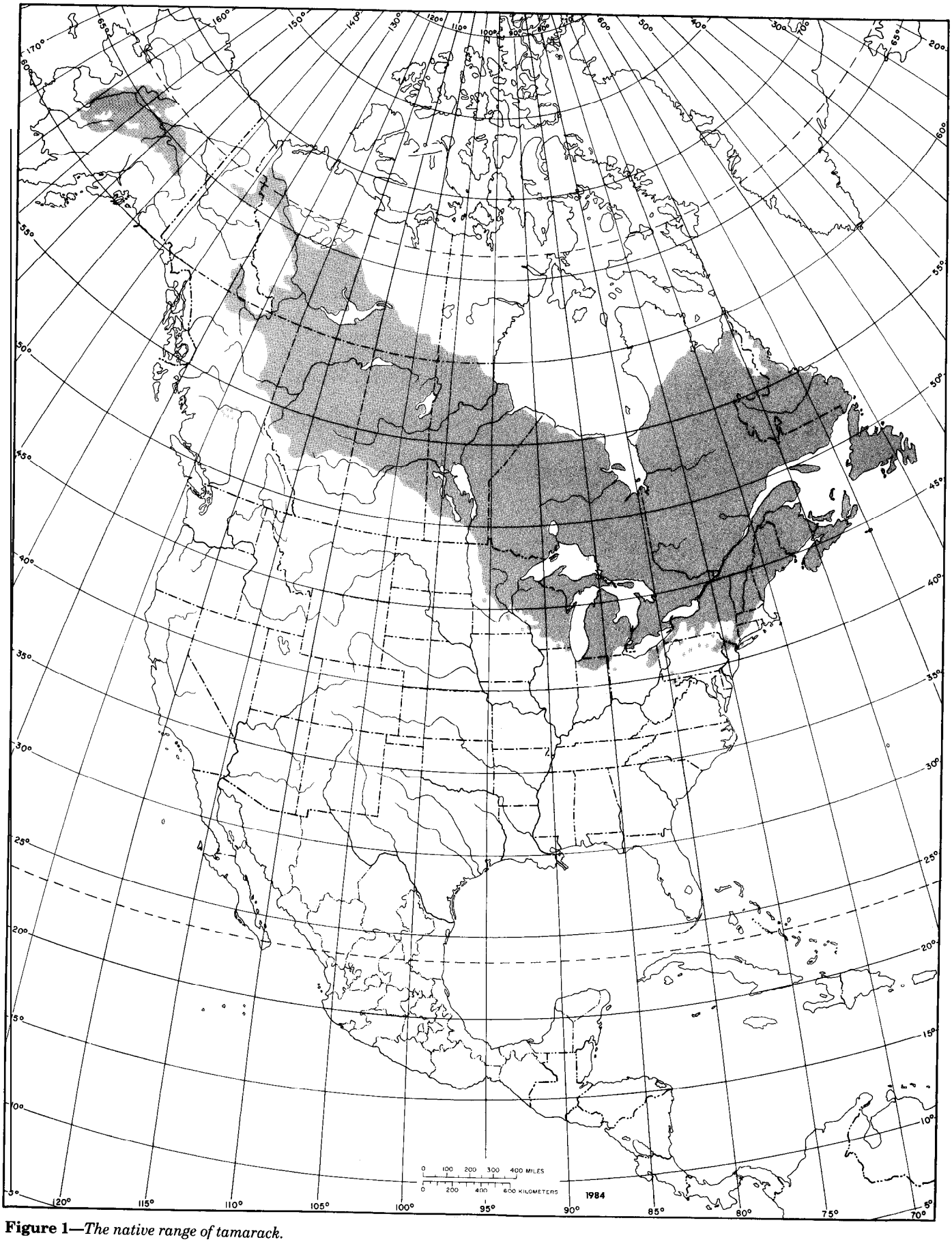

Figure 1—*The native range of tamarack.*

sometimes stands are found on swamp margins, on the banks of streams and lakes, and on low ridges and benches and other upland sites. In the Hudson Bay lowlands, tamarack grows on both extensive fens *(11)* and beach ridges (38). In British Columbia it is often an upland tree, growing on the cool moist north slopes of mountains as well as in valley swamps.

Tamarack grows on sites with about the same elevation throughout most of its range. In eastern North America, however, the tree grows between sea level and 1220 m (4,000 ft); in the Canadian Rockies and Alaska it grows between about 180 and 520 m (600 and 1,700 ft) *(12).*

Associated Forest Cover

Tamarack forms extensive pure stands in the boreal region of Canada and in northern Minnesota. In the rest of its United States range and in the Maritime Provinces tamarack is found locally in both pure and mixed stands. It is a major component in the forest cover types Tamarack (Society of American Foresters Type 38) and Black Spruce-Tamarack (Type 13) and is a minor component in the following types *(11):*

	Jack Pine
5	Balsam Fir
12	Black Spruce
33	Red Spruce-Balsam Fir
37	Northern White-Cedar
39	Black Ash-American Elm-Red Maple
107	White Spruce
203	Balsam Poplar
204	Black Spruce
253	Black Spruce-White Spruce
254	Black Spruce–Paper Birch

Black spruce *(Picea mariana)* is usually tamarack's main associate in mixed stands on all sites. The other most common associates include balsam fir *(Abies balsamea),* white spruce *(Picea glauca),* and quaking aspen *(Populus tremuloides)* in the boreal region, and northern white-cedar *(Thuja occidentalis),* balsam fir, black ash *(Fraxinus nigra),* and red maple *(Acer rubrum)* on the better organic-soil (swamp) sites in the northern forest region *(11).* In Alaska, quaking aspen and tamarack are almost never found together *(50).* Additional common associates are American elm *(Ulmus americana),* balsam poplar *(Populus balsamifera),* jack pine *(Pinus banksiana),* paper birch *(Betula papyrifera),* Kenai birch *(B. papyrifera* var. *kenaica),* and yellow birch *(B. alleghaniensis).*

Tamarack stands cast light shade and so usually have a dense undergrowth of shrubs and herbs. Because the tree has an extensive range, a great variety of shrubs is associated with it. Dominant tall shrubs include dwarf (resin) and low (swamp) birch *(Betula glandulosa* and *B. pumila),* willows *(Salix* spp.), speckled alder *(Alnus rugosa),* and red-osier dogwood *(Cornus stolonifera);* low shrubs include Labrador-tea *(Ledum groenlandicum),* bog-rosemary *(Andromeda glaucophylla),* leatherleaf *(Chamaedaphne calyculata),* and small cranberry *(Vaccinium oxycoccos)* (see 12 for a more complete list). Characteristically the herbaceous cover includes sedges *(Carex* spp.), cottongrass *(Eriophorum* spp.), false Solomonseal *(Smilacina trifolia),* marsh cinquefoil *(Potentilla palustris),* marsh-marigold *(Caltha palustris),* and bogbean *(Menyanthes trifoliata).* Ground cover is usually composed of sphagnum moss *(Sphagnum* spp.) and other mosses *(11).*

Life History

Reproduction and Early Growth

Flowering and Fruiting-Tamarack is monoecious; male and female flowers are small, solitary, and appear with the needles. Male flowers are yellow, globose, and are borne mainly on 1- or 2-year-old branchlets. Female flowers are reddish, subglobose, and are borne most commonly on 2- to 4-year-old branchlets, but also on branchlets 5 to 10 or more years old, or on l-year-old twigs of young trees. Cones usually are produced on young growth of vigorous trees. On open-grown trees, cones are borne on all parts of the crown. Ripe cones are brown, oblong-ovoid, and 13 to 19 mm (0.50 to 0.75 in) long.

General dates for tamarack flowering in Ontario and the Lake States are April to May *(36),* especially from late April to early May *(1,12).* In interior Alaska tamarack generally flowers from mid- to late May *(50).* General dates for cone ripening in Ontario and the Lake States are August to September.

Seed Production and Dissemination-Isolated trees on peatlands and trees in upland plantations begin to bear viable seed at 12 to 15 years of age or even less. In eastern Ontario viable seed has been collected from vigorous plantations as young as 4 years (27). Seed production in large quantities generally begins at about 40 years, the optimum age being about 75 years. Tamaracks on peatland in Saskatchewan and Manitoba do not bear cones in quantity, however, until they are about 50 years old *(12).*

Vigorous, open-grown trees 50 to 150 years old produce the best cone crops; a single tree may bear as many as 20,000 cones containing more than 300,000 full seeds in a good year. Seed production in

stands is generally confined to dominant and codominant trees. Open-grown mature stands 80 years old may produce 3,700,000 to 6,200,000 full seeds per hectare (1,500,000 to 2,500,000/acre) in a good year, while closed stands the same age may produce 1,200,000 to 3,000,000 seeds per hectare (500,000 to 1,200,000/acre).

Tamarack bears good seed crops at intervals of 3 to 6 years, with some seed produced in intervening years. In Minnesota cones from mature trees averaged 26 seeds, 67 percent of which were full; cones from young trees averaged 39 seeds and 85 percent were full.

General dates for tamarack seed dispersal in Ontario, the Lake States, and interior Alaska are September to spring *(36,50)*. A l-year study in northeastern Minnesota revealed that 65 percent of the crop fell from September 1 to September 20, 25 percent from September 20 to October 10, and nearly all of the remaining 10 percent before October 31. Empty cones remain on the trees from 2 to 5 years *(12)*.

Tamarack seeds are 3 mm (0.12 in) long and have light chestnut-brown wings 6 mm (0.25 in) long; cleaned seeds average about 550 000 to 710 000/kg (250,000 to 320,000/lb) *(18,36)*. Although the seeds are small, few fall at a distance greater than twice the tree height. However, tamarack can reproduce well as far as 60 m (200 ft) from seed-bearing trees if favorable seedbeds are present (22).

Seedling Development-Up to half the tamarack seeds that fall may be destroyed by rodents. As a result of this loss plus that by fungi or bacteria, only 4 to 5 percent of the seed may germinate *(12)*. In nurseries, erratic and often poor germination has been a major difficulty in producing tamarack stock (27); germination can even be poor in a greenhouse (24). Recleaning the seed can substantially reduce the high percentage of empty or improperly developed seed found in many seed lots *(18)*. Experience in Ontario shows that under optimum conditions, seed collected from vigorous stands in a good seed year has 75 to 90 percent germination (27).

Tamarack seed remains viable for 4 years or more when stored in sealed containers at 2 to 5 percent moisture content and –8° to –6° C (18° to 22° F). Internal dormancy apparently ranges from none to mild. Under forest conditions any existing dormancy is broken while the seed lies on the ground during the first winter; thus fall sowing is generally recommended. However, spring-sown seed may germinate well without any cold stratification *(18,36)*.

Germination is epigeal, the cotyledons rising above the ground. It normally begins from late May to mid-June and reaches a peak at surface temperatures of 18° to 21" C (65" to 70" F). In laboratory experiments germination has occurred at temperatures as low as 12" C (54" F) (4) and the rate may increase with temperature up to about 24" C (75" F). Under deep shade germination occurred at 13" C (55" F). Alternating day and night temperatures of 30" and 20° C (86° and 68° F), respectively, are recommended for germination tests (36).

The best seedbed is warm, moist mineral or organic soil with no brush but a light cover of grass or other herbaceous vegetation. Hummocks of slow-growing sphagnum moss often make a good seedbed, but some sphagnum mosses may offer too much competition. In Minnesota germination beneath tamarack stands was best on fine-textured mosses (primarily ***Mnium, Drepanocladus,*** and ***Helodium)*** (12). Findings from clearcut peatlands in Minnesota show that slash-burned seedbeds favor tamarack reproduction, whereas slash hinders it (22). On uplands, tamarack apparently reproduces well on rock-raked areas after natural seeding.

For best growth tamarack seedlings need abundant light and a constant but suitable water level. In Canadian studies, full light produced the tallest seedlings and heaviest root weights (26). Under drought conditions, leader length and stem diameter were significantly reduced by soil moisture tensions of 15.2 bar (15 atm), but tensions of 1.0 and 6.1 bar (1 and 6 atm) had little effect *(14)*. Seedlings under fully stocked stands usually grow 2 to 3 cm (1 in) the first year and do not survive beyond the sixth year. With little or no cover they may be as tall as 18 to 23 cm (7 to 9 in) the first year and 46 to 64 cm (18 to 25 in) the third year. From then on, growth is generally even more rapid if light is adequate and drainage is good *(12)*.

Buds begin to swell 2 or 3 weeks before opening; in northeastern Minnesota this occurs from early to late April. Needles begin to emerge from about mid-April to mid-May in Minnesota, Michigan's Upper Peninsula, and Saskatchewan. On the short shoots, needles elongate rapidly and the annual stem increment-only about 1 mm (0.04 in)-is completed shortly after budbreak. On the long shoots, basal needles reach full length by mid- to late June in northern Wisconsin, whereas stem needles mature along the stem as it grows; stem elongation is completed by the end of July *(5)*. Needles begin to turn yellow in early September in Michigan's Upper Peninsula and reach maximum color in early October in Michigan and northeastern Minnesota. Tamarack loses its needles in these same areas from about mid-September to mid-October *(1,12)*.

Height growth apparently does not begin until the first needles are fully developed. In Michigan's Upper Peninsula height growth begins in late May and continues until mid-August ***(12).*** Diameter growth begins from early April to early June and ceases from late July to early August in northeastern Minnesota *(1).*

Because they are small, tamarack seedlings are easily killed during the first 6 or 8 weeks after germination. Early losses are primarily caused by damping-off; in the second and third years drought, drowning, and inadequate light sometimes cause appreciable loss. One-year-old seedlings grown in full light can survive desiccation of the upper 2 to 3 cm (1 in) of organic soils to as low as 45 to 65 percent by weight, whereas forest-grown seedlings 1 to 3 years old are fairly intolerant of drought (or flooding) *(12).*

Vegetative Reproduction-Layering is ap-parently the dominant reproductive mode for tamarack along the northern limit of trees in Canada and Alaska *(10,50),* whereas farther south it is uncommon but may occur when branches are covered by fast-growing sphagnum moss or drifting sand. Roots are also known to produce shoots *(12),* and experience in Ontario shows that tamarack can be easily propagated from softwood cuttings taken in early July from young trees (probably less than 5 to *7* years old) (27).

Sapling and Pole Stages to Maturity

Growth and Yield-Average height of mature trees is 15 to 23 m (50 to 75 ft), but occasional individuals may grow 30 to 35 m (100 to 115 ft) tall. Mature trees are usually 36 to 51 cm (14 to 20 in) in d.b.h., but a few reach 91 to 102 cm (36 to 40 in). Trees 18 to 24 m (60 to 80 ft) tall and 51 to 61 cm (20 to 24 in) in d.b.h. were once common in the Lake States. In interior Alaska mature tamaracks often are only 3 m (10 ft) tall and 8 cm (3 in) in d.b.h. (12); on good sites, however, they sometimes reach heights of 24 to 27 m (80 to 90 ft) and diameters of 30 to 38 cm (12 to 15 in) *(50).* Maximum age is generally 150 to 180 years, but trees 230 to 240 years old and one 335-year-old individual have been found.

The growth rate of tamarack apparently depends on both the nutrient status and moisture-aeration conditions of the site. In Minnesota, tamarack site index is positively correlated to nutrient supply and foliar nutrient concentrations (especially nitrogen and phosphorus) but negatively correlated to amount of standing water (43). On water-covered stagnant peatlands, the tree grows slowly and may be only 2 m (6 ft) tall in 55 years. In northern Ontario it grows well on 91 cm (36 in) or more of peat if the zone of continuous saturation is at a depth of 46 cm (18 in) or more ***(12);*** drainage of tamarack-speckled alder swamps in the clay belt would probably increase site index (at 100 years) by about 5 m (16 ft) (39).

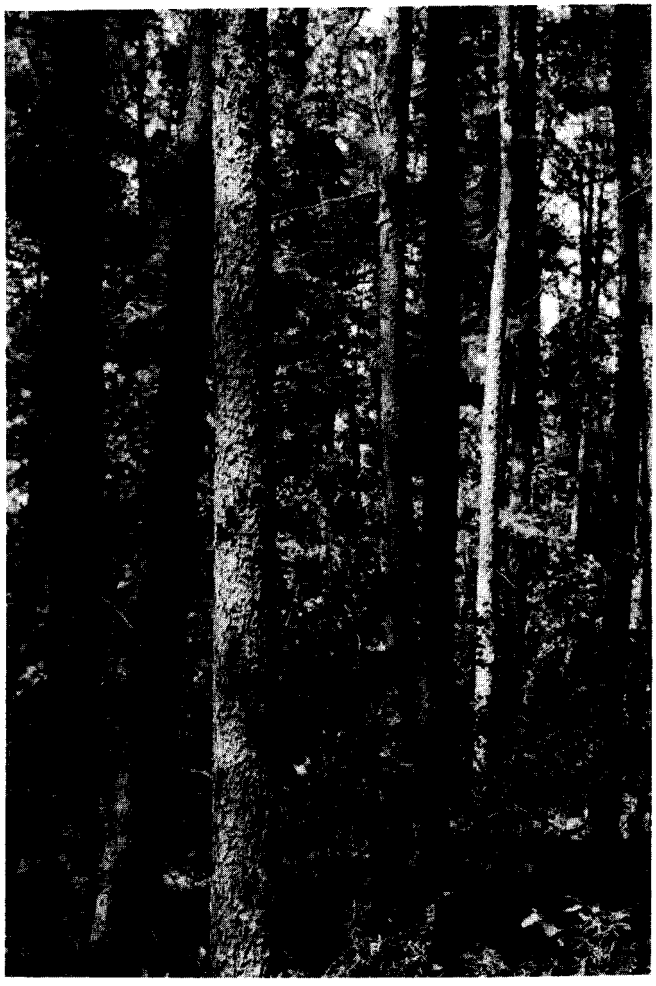

Figure *2-A poletimber stand of tamarack on a good peatland site in northern Minnesota.*

With abundant light, tamarack is one of the fastest growing conifers on uplands in the boreal (including Alaska) and northern forest regions; on peatlands it outgrows any other native conifer *(6,12,50).* In Alberta, good-site tamarack averages almost 0.5 m (1.5 ft) in annual height growth for 20 to 30 years, but growth apparently drops sharply when the crowns close, or after the age of 40 to 50 years.

Information on growth of natural tamarack stands is apparently available only from northern Minnesota (fig. 2). Limited data indicate that annual growth of poletimber stands (presumably on peatland

sites) is from 1.9 to 2.5 m^3/ha (0.3 to 0.4 cord/acre). In 70- to 100-year-old stands, annual periodic growth averaged 3.8 m^3/ha (0.6 cord/acre) on well-stocked plots with a basal area of 21 m^2/ha (93 $ft^2/acre$) and 1.9 m^3/ha (0.3 cord/acre) on poorly stocked plots with 8 m^2/ha (35 $ft^2/acre$) *(12).*

No yield tables are known for tamarack. Characteristics of a few 80- to 130-year-old stands on medium- to poor-peatland sites in northern Minnesota generally ranged as follows: average height, 12.2 to 15.5 m (40 to 51 ft); average d.b.h., 13.0 to 14.7 cm (5.1 to 5.8 in); number of trees, 1,370 to 1,740/ha (555 to 705/acre); and basal area, 19 to 23 m^2/ha (83 to 102 $ft^2/acre$) *(41).*

No doubt because of its potential for rapid juvenile growth, tamarack has been used in several planting tests on different sites in the Lake States *(25,32,33)* and eastern Canada *(15,28)*. Trees *grew* slowly on peatland, but on other sites height averaged from 3.2 to 4.4 m (10.5 to 14.4 ft) in 8- to lo-year-old plantations where competing vegetation was initially controlled. Survival was more variable, being very poor on shallow soils over limestone.

Growth rate (particularly diameter) declines after 12 to 15 years if tamarack is planted at close spacings such as 1.5 by 1.5 m (5 by 5 ft), but it should be unimpeded for the first 25 years at wider spacings up to 2.4 by 2.4 m (8 by 8 ft). In a good plantation in eastern Ontario, height at 25 years averaged 14.9 m (49 ft), d.b.h. 17.3 cm (6.8 in), and volume 202 m^3/ha (32 cords/acre). Depending on site, final harvests of 189 to 252 m^3/ha (30 to 40 cords/acre) are possible at 25 years in well-managed tamarack plantations (27). Intensively cultured plantations can produce two to three times more biomass than conventionally tended stands *(51).*

In stands tamarack is characteristically a straight, slender tree with a narrow, pyramidal crown that occupies one-third to one-half the bole length (fig. 3). Trees whose tops have died back after heavy defoliation by the larch sawfly *(Pristiphora erichsonii)* or after prolonged flooding typically produce numerous adventitious shoots. Although these shoots no doubt help tamarack survive defoliation or flooding, they also apparently support high sawfly populations *(12).*

Rooting Habit-Tamarack typically has a shallow, spreading root system. On favorable sites roots may spread over an area greater in radius than the tree height but are only 30 to 61 cm (12 to 24 in) deep. Trees on sandy upland have a platelike rooting habit; few roots reach below a 30-cm (12-in) depth and taproots are rare. On wet sites tamarack roots are usually stringy with no branches on the terminal 15 cm (6 in). Peatland tamaracks, in particular, have

Figure *3-A mature tamarack (seed tree) surrounded by saplings on a Minnesota peatland.*

wide root systems and do not form taproots. As the moss layer deepens, new roots develop on the stem above the original root collar, and growth of old roots nearly ceases. On drier sites roots of larger trees bend sharply from the trunks, forming knees (12).

Reaction to Competition-Tamarack is very intolerant of shade. Although it can tolerate some shade during the first several years *(21,50)*, it must become dominant to survive, and when mixed with other species, it must be in the overstory. On good swamp sites in Michigan, for example, tamarack is a dominant tree in the overstory of some mixed conifer stands, but it is practically never found in the understory (2). The tree is a good self-pruner, and boles of 25- to 30-year-old trees may be clear for one-half or two-thirds their length.

Tamarack is a pioneer tree, especially on open unburned bogs and burned organic soil ***(11).*** It is generally the first forest tree to invade filled-lake bogs. In the Lake States tamarack may first appear in the sedge mat, sphagnum moss, or not until the bog shrub stage; farther north it is the pioneer tree in the bog shrub stage (12). Tamarack is fairly well adapted to reproduce successfully on burns *(35)*, so it is one of the usual pioneers on most sites in the boreal forest immediately after fire. The tree commonly forms stands on abandoned farmland in eastern Ontario (27) and reproduces well on sites in Alaska that were cleared and then abandoned (50).

Because tamarack is very intolerant, it does not become established in its own shade. Consequently, the more tolerant black spruce eventually succeeds tamarack on poor (bog) sites, whereas northern white-cedar, balsam fir, and swamp hardwoods succeed tamarack on good (swamp) sites (12). Recurring sawfly outbreaks throughout the range of tamarack have probably speeded the usual succession to black spruce or other associates ***(11).***

Various tests on planting and natural reproduction indicate that competing vegetation hinders tamarack establishment. A year's delay in planting furrows on a wet lowland resulted in significantly lower first-year survival, apparently because of the rapid resurgence of grass and other herbaceous vegetation (24). On brushy peatland, 7-year survival and height were both much lower where tamarack was planted on unsprayed rather than on herbicide-sprayed areas (33). Six years after broadcast burning and natural seeding on peatland, tamaracks overtopped by surrounding vegetation were only about half as tall as those generally not overtopped ***(21).*** Tamarack does not grow well where sugar maple *(Acer saccharum)* reproduction is present; this seems at least partly due to the maple's root exudate (44).

The intolerance of tamarack dictates the use of even-aged management, with some adaptation of clearcutting or seed-tree cutting generally considered the best silvicultural system, because tamarack seeds apparently germinate better, in the open and the seedlings require practically full light to survive and grow well. Tamarack is also usually windfirm enough for the seed-tree system to succeed (fig. 3). Satisfactory reestablishment of tamarack, however, often requires some kind of site preparation, such as slash disposal and herbicide spraying (22).

For successful tamarack plantations, the planting stock's roots and shoots must be well balanced and dormant; probably the best stock is begun in a greenhouse and transplanted for 1 year. Competition must also be controlled, the first 2 years after planting being critical. Because tamarack is very intolerant, the trees should be planted at wide spacings such as 2.4 by 2.4 m (8 by 8 ft) (27).

Damaging Agents-Because its bark is thin, tamarack is highly susceptible to fire damage, except perhaps in older, upland stands; and because its roots are shallow, it is usually killed on peatlands by all but very light burns. However, the habitat of tamarack-specially south of the boreal forest-is normally wet enough to protect the tree from fire (6). In the boreal forest the tamarack type apparently has a high surface-fire hazard in spring but a low crown-fire hazard in pure stands (35).

Abnormally high water levels often kill tamarack stands, and those that survive under such conditions usually grow very slowly Other effects of high water include dieback and the development of adventitious roots and shoots (8). Wetland road crossings and beaver damming are the primary causes of flooding. Road-caused flooding has killed tamarack or reduced its growth on thousands of hectares in northern Minnesota *(40)*; natural gas and petroleum pipelines will probably have similar effects unless cross drainage is provided (3).

Strong winds can uproot large tamarack trees growing in swamps or other wet sites where rooting is shallow. Compared with black spruce, however, tamarack seems to be fairly windfirm.

The larch sawfly is the most destructive insect enemy of tamarack. Epidemics occur periodically across Canada and the northern United States and have caused tremendous losses of merchantable tamarack throughout most of the tree's range. Indications are that radial increment declines markedly after 4 to 6 years of outbreak and trees die after 6 to 9 years of moderate to heavy defoliation (9). In southeastern Manitoba and northern Minnesota, however, imported parasites of the sawfly (especially

Olesicampe benefactor) have become established and should reduce the frequency and duration of future outbreaks (42).

The larch casebearer *(Coleophora laricella)* is also a serious defoliator of tamarack. A native of Europe, it is now widely distributed in eastern North America westward to southeastern Manitoba and the Lake States. The larch casebearer attacks tamarack of all ages, and several severe outbreaks have caused extensive mortality in some areas (49). Outbreak severity has lessened in recent years, however, probably because imported parasites of the casebearer have also become widely established (34).

Only a few other insects and related organisms (such as mites) that feed on tamarack are known to sometimes cause serious injury During an outbreak the spruce budworm *(Choristoneura fumiferana)* can severely damage tamarack where it grows along with balsam fir and white spruce-the preferred hosts. The larch bud moth *(Zeiraphera improbana)* has had occasional short epidemics, and the spruce spider mite *(Oligonychus ununguis)* is occasionally found in large numbers on tamarack. The larch shoot moth *(Argyresthia laricella)* is widely distributed but serious injury is unusual. One of the most common bark beetles attacking tamarack is the eastern larch beetle *(Dendroctonus simplex),* but it feeds mainly on weakened, dying, or dead trees. Warren's collar weevil *(Hylobius warreni),* common in Canada, has killed pole-sized tamarack in Michigan's Upper Peninsula *(34,49).*

Several insects feed on tamarack cones and seeds, but little is known about their importance. Those that feed inside cones include the spruce coneworm *(Dioryctria reniculelloides)* and a seed chalcid *(Megastigmus laricis).* Two defoliators that sometimes feed on tender young cones during epidemics are the spruce budworm and the larch bud moth *(16,34).* Cones were still being produced after 3 to 4 years' defoliation by the larch sawfly in Canada and after 8 years of attack in northern Minnesota *(12).*

Tamarack is host to many pathogens, but none causes disease serious enough to have an economic impact on its culture. The only common foliage diseases are rusts, such as the leaf rust of poplar *(Populus* spp.) and larch *(Larix* spp.) in eastern and central North America. However, this rust, caused by the fungus *Melampsora medusae,* and other rusts do little damage to tamarack *(19,37). The* needle-cast fungus *Hypodermella laricis* has attacked tamarack in Ontario and has the potential for local damage.

Tamarack is essentially free of stem diseases. Eastern dwarf mistletoe *(Arceuthobium pusillum)* is occasionally found on the tree *(29),* but its witches' brooms are small on tamarack and occur only where the tree is growing in mixture with infected black spruce (19).

The root- and butt-rot fungi reported on tamarack include Armillaria (or shoestring) root rot *(Armillaria mellea), Scytinostroma galactinum,* red-brown butt rot *(Phaeolus schweinitzii),* and the false velvet top fungus *(Inonotus tomentosus) (19,47).* They are not aggressive killers on tamarack; however, flood-damaged trees are particularly susceptible to attack by fungi such as Armillaria root rot *(8),* and pole-sized trees have been killed by the false velvet top fungus.

The principal heart-rot fungi of tamarack are brown trunk rot *(Fomitopsis officinalis)* and red ring rot *(Phellinus pini). Climacocystis borealis* causes a white mottled rot of tamarack in Canada *(19).*

Snowshoe hares kill many tamarack seedlings in some areas of the Lake States, Alberta, and Alaska (50). White-tailed deer and moose apparently browse seedlings or saplings to a lesser extent. Porcupines commonly feed on the inner bark and deform the stem or kill the tree. Many tamarack stands have been damaged by this pest in the Lake States, Maine, and eastern Canada (27). It can be especially damaging in plantations (48). Red squirrels often cut cone-bearing branchlets, and birds such as the red crossbill occasionally eat the seeds *(12).*

Special Uses

The principal commercial use of tamarack in the United States is for making pulp products, especially the transparent paper in window envelopes. Because of its rot resistance, tamarack is also used for posts, poles, mine timbers, and railroad ties. Other wood products include rough lumber, fuelwood, boxes, crates, and pails (23). In interior Alaska young tamarack stems are used for dogsled runners, boat ribs, and fishtraps (4); in northern Alberta the branches are used to make duck and goose decoys (50). Historically, knees from larger trees were used in wooden ship construction and Indians used the fine roots to sew birch bark, the wood for arrow shafts, and the bark for medicine (48).

Tamarack has certain wildlife values. Porcupines feed on the inner bark, snowshoe hares browse on seedlings, and red squirrels eat the seeds. Birds common in tamarack stands during the summer include the white-throated sparrow, song sparrow, veery, common yellowthroat, and Nashville warbler (7). The American osprey, a sensitive species, often nests in lowland types such as tamarack; and the great gray owl, a rare winter visitor in the northern Lake States, apparently nests there only in the tamarack peatlands of northern Minnesota.

Tamarack is esthetically appealing, especially in early autumn when its needles turn yellow. Although the tree has been infrequently planted for ornamental purposes *(30)*, it has significant potential+ven in Alaska *(50)*—because of its rapid growth and fall color. Tamarack is particularly valuable in suburban areas but is not suitable as a shade tree on city streets *(18)*.

Tamarack has limited value as a watershed protector because it usually grows on gently sloping terrain, and management of the type probably has little or no effect on water yield or quality because harvesting is generally on a small scale.

Genetics

Population Differences and Races

Tamarack shows much genetic variation. Growth responses to photoperiod were found to differ between northern seed sources and a southern source (45). Differences in germination patterns due to photoperiod and length of cold stratification have been shown between seed from interior Alaska and seed from southern sources (4).

Growth responses would seem to indicate that photoperiodic ecotypes exist in tamarack (45). The species is considered to have a clinal pattern of variation, however, and no races or ecotypes are presently recognized. For example, tamarack's gene pool in Wisconsin is highly variable but unsegmented, with a clinal pattern of variation evident among the State's major geographic subdivisions *(31)*.

Tamarack seed sources differed significantly in survival, height, and d.b.h. 10 years after planting in north-central Wisconsin. The following sources grew best on a high-yield site and are recommended for north-central Wisconsin (32): Somerset County, ME; Eau Claire, La Crosse, and Oneida Counties, WI; and Annapolis County, NS.

Tamarack in Alaska was once named as a separate species *(Larix alaskensis)* and later reduced to a variety *(L. laricina* var. *alaskensis)*, but the Alaska variety is no longer accepted (46).

Hybrids

Little information is available on intraspecific hybridization in tamarack, but careful selection and breeding may result in substantial genetic improvement. Similarly, although tamarack has been little used in interspecific hybridization, it has been crossed with two other species of the Section *Pauciseriales*—Japanese larch *(Larix leptolepis)* and European larch *(L. decidua)*. Progenies with hybrid vigor are often produced, but seed yield is very low *(13)*. The tamarack-Japanese larch hybrid is especially promising because it combines rapid growth with adaptability to shorter growing seasons (20). Although crosses between tamarack and the remaining species of the Section-Dahurian larch *(L. gmelini)* and Siberian larch *(L. sibirica)-seem* feasible *(30)*, apparently none has yet been produced.

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