INSTITUTE OF
PAPER CHEMISTRY
Appleton Wisconsin

GENETIC INPROVEMENT OF LARCH
Project 3409

Report Eight
A Progress Report
to
MEMBERS OF GROUP PROJECT 3409

February 15, 1988

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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Scott Paper Company

The Mead Corporation

Thilmany Pulp & Paper Company

Consolidated Papers, Inc.

Wisconsin Department of Natural Resources

Michigan Department of Natural Resources

TABLE OF CONTENTS

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

GENETIC IMPROVEMENT OF LARCH

SUMMARY

Five Sudeten origin larch clones from a tree improvement group in West Germany were added to the larch project in 1987. Seed from two of these clones is being tested in field trials, and these are among the best sources identified to date.

1589 Grafts were made in 1987 with an overall success rate of 67%. Graft mortality was due about equally to rootstock and scion failure.

The Greenville Larch Arboretum is well established. Extra grafts lined-out from previous years were moved with a commercial tree spade to replace mortality within the arboretum.

No larch flowers were available for controlled pollination work. A flower stimulation experiment employing gibberellic acid and/or strangulation techniques to induce flowering was undertaken.

Forty-one pounds of European larch seed was purchased. The majority was used by cooperators.

A fungus disease on larch caused by *Meria laricis* was found in the Hayward State Nursery, at Hayward. The Wisconsin Department of Agriculture ordered the stock destroyed. A cooperative effort involving Wisconsin DNR and USFS pathologists will undertake a survey of Wisconsin to determine prevalence of the disease. *Meria laricis* is a common nursery problem in western larch and

has been reported in Europe on larch since 1895. All reports indicate it is a nursery disease of little consequence.

The Michigan DNR larch seed orchard was completed this year and previously planted grafts are doing well. The Wisconsin DNR orchard injured by frost in 1986 has recovered well. The Mead Paper orchard is growing vigorously but has been damaged by deer browse. A hybrid larch orchard will be planted by Scott Paper in Maine this spring.

Several replicated field trials were measured, including two large seed source tests on Mead Paper land near Escanaba, MI. Significant growth differences were detected, with hybrid and Sudeten larch ranking among the best provenances. A frost damaged trial on Consolidated Papers land near Argonne, Wisconsin recovered well, with two Sudeten larch sources doing best. A hybrid larch source is the best of 8 sources in Scott Paper's trial near Fairfield, Maine, and average 16.9 feet after 6 years. Hybrid larch seedlings planted on a chemical site preparation trial on Consolidated Papers land near Loretta, Wisconsin, recovered well from 1986 frost injury and are showing no detectable reduction in growth from the herbicide treatments, but also no increase in height from the treatments.

A tamarack pulping study was undertaken in cooperation with the Institute's Pulping Sciences Group. Mature tamarack with an average age of 69 were compared to 26-year-old plantation grown tamarack. Both chip sources were cooked to kappa 30 and 50 and tested under conditions comparable to those used to evaluate red pine, jack pine, European, Japanese, and hybrid larch in earlier studies. Chemical requirements for bleaching to an 88 G.E. brightness were similar to jack pine and other *Larix* spp.

Mature larch wood pulps refined with slightly greater difficulty than young tamarack. Both tamarack sources required more beating energy than jack pine or European larch but were similar to hybrid larch.

Pulp strength properties of the tamarack sources were similar. Both had good tearing strength but when refined to improve breaking length, tear strength decreased and at a breaking length of 9 km had 15% lower tear, 5% greater burst, and equal TEA when compared to jack pine and European larch.

Plans for 1988/89 include the planting of 10,000 hybrid larch seedlings, establishment of 2 replicated trials testing new seed sources, planting a hybrid larch seed orchard, continued evaluation of plantations, development of plantation guidelines, continuation of grafting for seed orchards, acquisition of known origin seed, and if flowering permits, make controlled pollinations with European larch clones. Work beyond the coming year will depend in large part on the effects of the IPC move to Atlanta, Georgia. The level of support and type of facility needed to continue the larch work needs to be determined.

INTRODUCTION

The rapid growth (greater than any northern conifer and perhaps competitive with southern conifers), wide range of site requirements, good wood and pulp properties, and the ability to recover from both animal and climatic injury are sufficient reasons to continue examining and defining the niche larch can occupy in reforestation programs. Unfortunately, negative aspects (and what species are without them?) are receiving more attention in some quarters than positive attributes.

At the risk of climbing too high onto the soap box, a perspective needs to be placed on the process for evaluating tree species, and in this case *Larix*. One of the bases for considering *Larix* was a recognized need to expand the number and nature of conifer species available to foresters for planting. In addition, it was recognized that both insect and disease problems were having or potentially could have an effect on the conifer fiber resource. *Larix* offered the greatest potential for increasing species diversity.

The evaluation process has shown that larch is a highly productive, rapid grower and can provide superior raw material, but it has also shown that larch is sensitive to frost and that seedlot germination rates can vary. In the balance, neither frost nor low germination rates are sufficient reasons to dismiss larch as a reforestation option. Solutions to both problems are available; only the will to apply the solutions is absent.

The tamarack pulping results included in this report support the contention that tamarack can be a useful option. Given the frost susceptibility of exotic larches on some sites, tamarack would appear to be a ready solution.

The inclusion of tamarack in the larch project would appear timely. Hybridization work with tamarack may further enhance its reforestation potential. The clones in the Project 3409 larch arboretum are near flowering age and provide a ready starting point for tamarack work, as are the selection, propagation, and testing expertise.

The decision to move The Institute of Paper Chemistry to Atlanta, Georgia, by 1991 should have little negative impact on the larch program, provided that current and future cooperators have sufficient interest and commitment. The Institute is interested in maintaining a tree improvement presence in the North Central States and is investigating its options. The pending move, ways to secure adequate funding for tree improvement, and potential impacts on the larch program will be discussed at the annual meeting.

SELECTION AND PROPAGATION

SELECTION

Five European larch selections from the Institute for Forest Plant Research in Hann Munden, West Germany were added to Project 3409 in 1987. One of the selections, LD-1-87, is the parent of the good performing Sudeten seedlot, XLD-3-79. The other four, also of Sudeten origin, are from seed orchards in West Germany.

GRAFTING

The 1987 grafting work emphasized European larch for seed orchards and arboretum replacements. A total of 1589 grafts were made of which 1285 were European larch, 233 were Japanese larch, and 71 were tamarack. Grafting success for European larch averaged 66% and ranged from a low of 36% to a high of 98%. Failure was due equally to rootstock death and poor scion condition. Grafting success with Japanese larch averaged 84%, with failures due almost entirely to rootstock death.

Bareroot rootstock were potted 2-3 weeks prior to grafting. Stock that flushed slowly or had dead tops were discarded. Although grafts were made on apparently vigorous stock, approximately half of the failures were due to rootstock death. The rootstock was acquired from outside sources, and appeared of questionable vigor when stored in the fall of 1986. Despite the losses, the 66% overall European larch success rate is acceptable and could be improved considerably with good vigor rootstock.

Completed grafts were held in the greenhouse until danger of frost was past, then moved to the lath yard and held under 50% shade until late summer.

They remained outside until needle drop and were then moved to an unheated but insulated room in the nursery pole barn for winter storage.

GREENVILLE ARBORETUM

Our larch arboretum continues to do well (Fig. 1). Several clones have inadequate representation, and replacements will be planted this spring. Extra grafts left over from previous years were routinely planted at close spacings in a vacant nursery compartment for use as scion sources and in flowering research. A commercial tree spade was hired to move 30 of these grafts ranging in size from 4-12 feet into the appropriate location within the arboretum as replacements. The cost was less than $200 and there was little loss in age and growth within arboretum blocks.

Figure 1. European and Japanese larch clones in the Greenville arboretum.

Despite an abnormally dry spring which necessitated carrying water to newly planted grafts, growth on established grafts was very good and many 2-year-old grafts doubled their height. Stakes used to support new grafts were removed from the majority of 2- and 3-year-old grafts.

Flowering was very sporadic and light, and controlled pollination work could not be done. However, a flower stimulation experiment was done and is described in the following section. Six- and eight-year-old grafts have heights of 12-20 feet and full crowns. It is apparent from the width of crowns at the 12-foot spacing within the arboretum that the 30-foot spacing used in seed orchards was an appropriate choice.

FLOWER STIMULATION TREATMENTS

Although larch flowers at an early age, extent and frequency of flowering is variable, just as in other tree species. Both tree breeders and seed orchard managers have sought methods to stimulate flowering in a predictable manner.

A method tried with a wide range of conifer species is an application of plant hormones, particularly the gibberellins. A paper by Bonnet-Masimbert[1] reported significant increases in both male and female flowers of _Larix leptolepis_ and _L. decidua_ following treatment with gibberellic acid alone or in combination with girdling.

Our aspen project routinely employs strangulation treatments (similar to girdling) to induce flowering on both male and female trees. An experiment with the gibberellic acid spray described by Bonnet-Masimbert (400 milligrams per liter) and strangulation as used in aspen was conducted last spring. Four

European larch clones and one Japanese larch clone were treated. Treatments consisted of strangulation alone, $GA_{4/7}$ spray alone, strangulation and $GA_{4/7}$ spray, and control (no treatment). Spray treatments were applied on May 29 and June 26, 1987. Strangulation treatments were applied May 29 and removed on August 7, 1987.

Results will be evaluated the spring of 1988, and also applied to a different set of clones.

SEED ACQUISITION

Large quantities of European larch seed were again sought this past year. A total of 41 pounds from nine European provenances were acquired along with one pound of tamarack seed from Scott Paper Co., and one half pound from four half-sib Sudeten seedlots from clones in seed orchards. In addition, one or two Siberian larch seed sources will be acquired before spring, along with European larch seed from Danish seed orchards, and hybrid larch seed from West German seed orchards.

Cooperators frequently voice concern about the low germination and cost of larch seed. Larix species, as reported in the Seeds of Woody Plants in the United States,[2] have relatively low germination rates; *Larix decidua* averages 36%, *L. leptolepis* 43%, and *L. laricina* 47%. The majority of *L. decidua* seed acquired by us had germination rates above 30%. Seed cost (for relatively small quantities ordered) was frequently in the range of $150-250 per pound. Contrasted with red pine at $80/lb, larch does appear expensive. Seed cost per thousand seedlings is about $2.00 for red pine and $6-8 for Larix, a not unreasonable cost to pass on to the buyer.

Seed acquisitions have mainly been for cooperator use in production of seedlings for operational size plantings. A portion of the seed acquired in 1985 was used by IPC to contract grow 10,000 bareroot hybrid larch seedlings that will be available this spring. These seedlings were grown from seed produced in a West German clonal seed orchard.

Seed from documented origins will continue to be sought. Growers are encouraged to use seed regardless of germination to further evaluation of known larch sources under a variety of site and climatic conditions. It is incongruous to select seedlots on the basis of germination rather than on genetic quality or adaptability. Certainly seed cleaning and sowing procedures are available or could be developed to increase efficiency of seedling production.

LARCH DISEASES

Mycosphaerella laricina

A potentially serious disease problem of European larch is the needle cast caused by *Mycosphaerella laricina*. Seed source screening trials are being conducted by the USFS in Iowa and Wisconsin. It was first noted on the Yellow River State Forest in Northeast Iowa in the mid-1970s and was reported by Palmer *et al.*[3] We visited the area in 1980 to select parent trees. French and Austrian seed sources were infected, and suffered some mortality. Adjacent plantings of Polish larch, hybrid larch, and Japanese larch were unaffected. Infection of tamarack occurred only on seedlings newly planted in the area for test purposes.

Disease symptoms appear about mid-June and continue as late as October. Areas on individual needles become yellow, then tinged with brown. Premature defoliation occurs, but many trees retain foliage in the upper crown. Shoots losing needles early in the season may flush again but needles also become infected.

The larch project provided eight of the 21 sources of larch seed used in the U.S. Forest Service screening trials in Iowa and Wisconsin. Three of our sources, XLL-5-79, XLD-4-83, and XLD-14-83, were highly resistant. Two hybrid larch sources were intermediate in resistance. U.S. Forest Service sources of western larch were highly susceptible. Variability in susceptibility occurred in European larch sources from Czechoslovakia.

In summary, considerable variation has been observed in resistance among species, seed sources, and individual trees within seed sources. Adequate control may be attained through selection of resistant material. Pathologists will continue to monitor existing tests and plantations, but will not be establishing additional trials. Our early awareness of this potential problem enabled us to avoid the most susceptible seed sources and concentrate on the more resistant.

Meria laricis

During routine inspection of the Wisconsin State Nursery at Hayward, Wisconsin, last spring, a slight needle discoloration was noted in a 2-0 European larch seedbed. Though first believed to be *Mycosphaerella laricina*, subsequent identification showed it to be *Meria laricis*, a previously unreported disease in Wisconsin. Being the first reported incidence in Wisconsin, the Wisconsin Department of Agriculture issued a hold order on the nursery stock, and later ordered it destroyed.

Meria laricis is a fungus disease commonly associated with western larch. It causes needle discoloration and needle casting at later stages of infection. M. laricis is generally a nursery disease, is not known to cause significant mortality in natural stands of western larch, and is not considered a serious forest pest.[4] Because this was the first report of M. laricis in Wisconsin, the procedures outlined in the Agriculture, Trade, and Consumer Protection regulations required the destruction of the stock and monitoring for recurrence of the disease.

Wisconsin DNR pathologists undertook a survey of Wisconsin plantations this summer to determine prevalence of M. laricis. It was subsequently found on natural regeneration of European larch adjacent to a windbreak of 20-year-old European larch, and on four 30-40 year old trees on three private properties. This suggests that M. laricis has been present in the state but not detected and reported previously.

A meeting of Wisconsin DNR Forestry personnel, Wisconsin Department of Agriculture personnel, U.S. Forest Service and Wisconsin DNR pathologists, IPC, and Consolidated Papers personnel was held on December 8, 1987 at the WDNR Headquarters in Black River Falls, Wisconsin, to discuss the implications of the disease.

To assess the potential for damage on European larch, a literature search was conducted. Two pertinent articles by Batko[5] and Peace and Holme[6] dealing with the disease in Europe were located. M. laricis has been present in Europe since at least 1895, and has been of no consequence in larch plantations and natural stands. As with western larch, the injury of significance has been in nursery beds. Infected stock inadvertently moved into the field recovered rapidly and displayed no further disease symptoms on several occasions.

To address the Wisconsin Department of Agriculture concerns, the Wisconsin DNR Insect and Disease Unit will coordinate a field survey during June and July, 1988 to collect needle tissue for culturing and determination of *M. laricis* presence. In addition, IPC will provide WDNR and State and Private Forestry with seedlots to determine if the disease might have been seed borne. IPC will also assist in field collections of needle tissue.

SEED ORCHARDS

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

The last grafts needed to complete the European larch seed orchard at the Southern Michigan Nursery were planted in July. The previously planted portion of the orchard is well established (Fig. 2). The orchard has 20 European larch clones selected from areas in Poland and Czechoslovakia or from U.S. plantations derived from similar seed sources.

Figure 2. Rich Mergener, Michigan DNR Tree Improvement Specialist next to a two-year-old European larch graft in the MDNR larch seed orchard near Howell, Michigan. The orchard was completed last spring and the first grafts planted are well established.

The 400 grafts (20 ramets from each of 20 clones) are at a 30 x 30 foot spacing. First seed production is expected at age 10, but significant seed production will not occur until age 15-18. Plans for the orchard include routine maintenance such as mowing, fertilizing, rodent protection, and insect control as required.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

The WDNR European larch orchard was one of the first planted. Only half of the 400 grafts have been planted. Because of frost injury in the spring of 1986, planting of the remaining half was delayed until frost damage could be assessed.

Recovery from the 1986 frost injury was very good (Fig. 3). Most grafts grew up to 2 feet this summer, and 3 foot leaders were not uncommon. A number of grafts are 7-8 feet in height. No spring frost injury occurred in 1987. Replacements of dead or weak grafts were made in September. A decision on whether or not to locate the remaining half of the orchard at a more northerly site within the state is pending.

MEAD PAPER

The European larch seed orchard planted by Mead Paper in May, 1986, near Escanaba, Michigan, is the most northern orchard. The potential for frost injury is limited by the proximity of Lake Michigan. Three hundred seventy-nine grafts have been planted since 1986. Although first year growth was good, deer browsed most grafts. Recovery may be negated by repeat browsing. The deer population appears to be higher than normal and is also affecting other conifer plantings and hardwood regeneration.

Consideration is being given to moving the present orchard or establishing a second orchard in Ohio. A chemical deer repellent is also being tested.

Figure 3. Wisconsin DNR European larch seed orchard near Summit Lake, Wisconsin. Recovery from a damaging spring frost in 1986 was good. The 3-year-old graft shown recovered from the frost and grew over 3 feet in height this year.

SEED ORCHARD PLANS

The first larch orchard planted as part of Project 3409 was for Consolidated Papers. Unfortunately, the site was more frost prone than expected, and the orchard was lost the year after planting. Alternative sites are being considered.

Grafts from four Japanese larch clones and ten European larch clones will be delivered and planted this spring for our first hybrid orchard (Scott Paper Co., Fairfield, Maine). Orchard design is similar to one observed in

Denmark by Dean Einspahr. Seed from the Scott orchard mainly will be collected from Japanese larch clones. European larch clones will function as pollinators, but European larch seed could also be collected. A small proportion of that seed would be hybrid, and the remainder would be high quality European larch seed.

REPLICATED FIELD TRIALS

CONSOLIDATED PAPERS, INC., LARCH TRIAL V

Larch Trial V is a four replication, randomized block design testing eight larch seed sources. It was planted in August, 1981, with container grown seedlings. The trial is on an old field near Argonne, Wisconsin, and is considered a medium-quality hardwood site. Two Japanese larch sources were replaced in 1983 with European larch sources after mortality from repeated frost damage. Heavy competition from quack grass during establishment slowed growth of all sources.

The spring 1986 frost injury discussed in our last report[7] did not occur in 1987. The trial was observed on May 3, 1987; all trees had flushed, including the tamarack source. The trial was observed again on July 25 and no frost injury was apparent. General growth was excellent, and numerous 3 foot leaders were noted. However, a porcupine had damaged or killed several good trees in seed source XLD-3-79.

The trial was measured last fall. A half sib Sudeten seed source (XLD-3-79) from a Bruntal, Czechoslovakia clone continues to be the best performing material (Table 1). This source grew an average of 3.5 feet this past year, despite rather severe frost injury in 1986 that damaged 50-75% of all needles and shoots. Figure 4 shows several of the better individuals from seed source XLD-3-79.

A half sib Sudeten seed source collected from a clone from Krnov, Czechoslovakia, also recovered from the 1986 frost damage and averaged 2.9 feet of height growth this past growing season.

Table 1. Growth and survival of Consolidated Papers, Inc. Larch Trial V.

Seed Source*	1985 Av. Ht., feet	1985 Survival, %	1986 Av. Ht., feet	1986 Survival %	1987 Av. Ht., feet	1987 Av. Ht. Growth, feet	1987 Survival, %
XLD-3-79	6.3	84	7.6^{w}	84^{x}	11.1^{x}	3.6^{x}	84^{x}
XLD-5-79	5.0	94	6.4^{wx}	88^{x}	9.3^{y}	2.9^{xy}	88^{x}
XLD-6-79	3.6	64	4.0^{y}	61^{y}	6.3^{z}	2.3^{y}	56^{y}
XLL-1-79	1.6	46	1.0^{z}	19^{z}	2.2	1.2^{z}	5^{z}
XLD-LL-1-79	3.6	94	3.8^{y}	86^{x}	5.4^{z}	2.2^{yz}	75^{xy}
XLTK-5-80	4.7	91	5.2^{xy}	89^{x}	6.5^{z}	1.3^{z}	84^{x}
**XLD-1-81	3.6	96	4.0	96	6.0	2.0	83
**XLD-5-82	1.1	61	1.1	36	1.6	0.5	10

*See Appendix for description of seed course code.

**Planted in 1983 as replacements for Japanese larch sources with high mortality. Growth and survival data were not included in Analysis of variance. Other seed sources were planted in August, 1981.

^{wxyz}Duncan's New Multiple range test was calculated when "F" test values for treatments were significant. Values within a column followed by a common superscript letter are not significantly different at the 5% level.

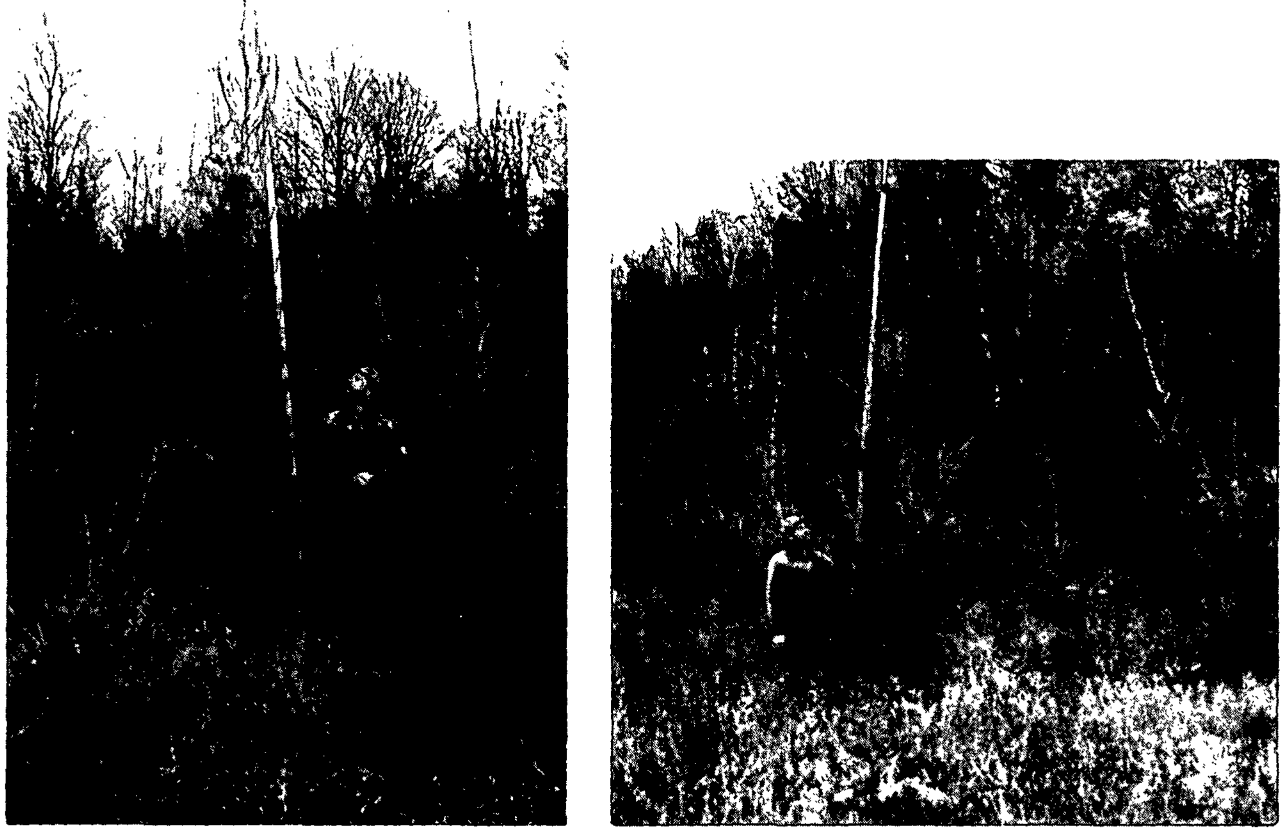

Figure 4. Consolidated Papers' Larch Trial V near Argonne, Wisconsin. The Sudeten larch seed source XLD-3-79 grew an average of 3.5 feet this year, recovering well from 1986 frost injury.

The growth of the hybrid seed source XLD-LL-1-79 recorded in Table 1 reflects considerable variation between individual trees. Heights ranged from less than one foot to 12 feet. The variation reflects light frost injury in 1985, slow recovery during 1985, and severe frost injury in 1986.

MEAD PAPER REPLICATED LARCH TRIALS XI AND XII (SAWYER FARM AND VIRGIL WRIGHT)

Two trials were planted by Mead personnel in May, 1986. Trial XI was near Escanaba, Michigan (Sawyer Farm) and Trial XII was near Cooks, Michigan

(Virgil Wright), approximately 35 miles east of Escanaba. Test seedlings were grown in containers by Mead in their greenhouses.

The Sawyer Farm (Trial XI) old-field site was prepared by spraying during the summer of 1985 with 2-1/2 quarts of Roundup and disking in late fall. The area was resprayed with 2 quarts of Roundup in early May, 1986, just prior to planting. Survival after two growing seasons was good (Table 2), indicating the site preparation was successful.

The Virgil Wright planting (Trial XII) is on an old field. All but one of the seed sources planted at the Sawyer Farm (Trial XI) were planted in this trial. Due to a combination of circumstances, growth was considerably less than that in Trial XI (Tables 1 and 2). Trial XI was planted first using the best and most uniform stock, leaving a somewhat "mixed bag" of material for Trial XII. In several instances, sufficient numbers of seedlings were not available to complete three replications.

The site was sprayed in fall 1985 with Roundup at the rate of 2 quarts/acre, then disked, and furrowed with a TTS disk trencher in spring 1986. Furrows were banded with Oust at 3 ounces per acre at the time of trenching.

Seedlings were hand planted in furrows in spring 1986. There was good soil moisture at the time of planting, but the following June and July were quite dry. Observations indicated that seedlings had good color and grew normally until August when heavy rains caused erosion into the trenches. Following the heavy rains, the seedlings developed a purple, chlorotic, and stunted appearance. Herbicide injury from Oust was suspected. Mead foresters concluded that the heavy rains eroded the sides and tops of the furrows depositing damaging levels of Oust in the bottom of the furrows, thereby causing the

Table 2. Second year growth and survival of Mead Paper's Sawyer Farm and Virgil Wright replicated larch Trials XI and XII.

Seed Source*	Trial XI (Sawyer Farm) Av. Ht., feet	Trial XI (Sawyer Farm) Survival, %	Trial XII (Virgil Wright) Av. Ht., feet	Trial XII (Virgil Wright) Survival, %	Origin
XLD-LL-6-84	3.0[a]	98	1.3**	88	West German hybrid larch seed orchard
XLD-2-84	2.8[ab]	96	1.5	91	Spisska Nova Ves, Czech. (Tatra)
XLD-2-81	2.6[bc]	97	1.6	88	West German seed orchard
XLD-7-82	2.6[bc]	94	1.5	90	Prudnik, Poland (Sudeten)
XLD-LL-1-79	2.6[bc]	90	0.9	76	West German hybrid larch seed orchard
XLD-LL-2-83	2.6[bc]	96	1.1**	78	New York hybrid larch seed orchard
XLL-LD-12-84	2.6[bc]	97	1.0	91	Danish hybrid larch seed orchard
XLD-4-84	2.4[bcd]	95	1.5	88	West German seed orchard (Sudeten)
XLD-4-81	2.4[bcd]	94	1.9	92	West German seed orchard (Alpen)
XLD-5-82	2.4[bcd]	92	1.5	93	West German seed orchard (Sudeten)
XLD-9-82	2.3[cd]	99	1.5	95	Bardo, Poland (Sudeten)
XLD-3-84	2.3[cd]	93	1.9	94	Podolinec, Czech. (Tatra)
XLD-2-82	2.3[cd]	95	1.0**	92	West German seed orchard (Sudeten)
XLD-6-82	2.3[cd]	98	1.7	93	Austria seed orchard (Alpen)
XLD-3-81	2.3[cd]	95	1.1**	72	West German seed orchard
XLD-4-82	2.3[cd]	94	0.9	81	West German seed orchard
XLD-1-82	2.2[cd]	88	1.1	84	West German seed orchard
XLD-8-82	2.2[cd]	93	0.8**	75	Bystrzyca Klodzka, Poland (Sudeten)
XLD-1-84	2.1[d]	94	2.0	90	Podolinec, Czech. (Tatra)
XL7K-5-80	2.0[d]	94	1.3	89	Watersmeet, Michigan - Tamarack
XLD-12-81	2.0[d]	93	1.1	98	Poland (Sudeten)
XLD-5-84	2.0[d]	91	2.2	90	Litovel-Usov, Czech. (Tatra)
XLD-1-85	2.0[d]	93	Not planted		Saris/Podolinec, Czech. (Tatra)
XLD-5-85	Not planted		0.4***	50***	Gdansk, Poland
XLD-LL-3-85	Not planted		0.5***	81***	West German hybrid larch seed orchard

[abcd]Duncan's New Multiple Range Test was calculated when "F" test values for treatment were significant. Values within a column followed by a common superscript letter are not significantly different at the 5% level.

*See Appendix for description of seed source code.

**Average of 2 replications.

***Average of 1 replication.

injury. Observations this past year did not show the same chlorotic/purpling symptoms, but height growth was reduced. Replacements were made for a number of seed sources, and survival figures given (Table 2) reflect them.

Of the two trials, Trial XI will provide more useful information. An analysis of variance showed highly significant differences between seed sources in terms of height growth; no significant differences were found for survival. The best performing seed source, XLD-LL-6-84, was from a hybrid seed orchard in West Germany. The seed was collected from a single European larch clone pollinated by Japanese larch clones selected from natural stands whose superiority was proven in international provenance trials.

Although future performance cannot be predicted, the considerable variation among sources and the relative ranking of both hybrid and Sudeten sources are of interest. Trial XI, with its good survival, should provide important growth information over the next several years. Trial XII must be interpreted carefully because of variation in stock quality and herbicide damage.

SCOTT PAPER CO. REPLICATED LARCH TRIAL VII

The Scott Paper replicated Trial VII was planted in 1982 with bare-root stock near Unity, Maine. Seedlings tested include four sources of European larch, two sources of Japanese larch, and one source each of hybrid larch and tamarack. Three of these are also in Consolidated Papers Trial V (Table 1).

Thus far, hybrid larch source XLD-LL-1-79 has the best survival, height growth, and annual growth (Table 3). European larch source XLD-3-79 ranks among the best materials; this seed source is consistently among the best. It appears to have broad adaptability.

Table 3. Scott Paper Company - growth and survival of Larch Trial VII.

Seed Source[a]	1985		1986			1987		
	Av. Ht., feet	Survival, %	Av. Ht., feet	Survival, %	Annual Growth, feet	Av. Ht., feet	Survival, %	Annual Growth, feet
XLD-1-79	5.1	88	7.9	88	2.7	11.0^{xyz}	86	3.1^{xy}
XLD-2-79	5.6	63	7.8	58	2.8	11.0^{xyz}	55	3.2^{xy}
XLD-3-79	6.5	86	10.2	85	3.7	13.7^{x}	84	3.6^{wx}
XLD-6-79	6.1	70	7.8	64	2.8	10.4^{yz}	64	2.7^{y}
XLL-2-79	6.0	65	8.6	59	2.6	11.4^{xy}	59	3.0^{xy}
XLL-3-79	6.7	71	9.7	63	3.0	12.2^{xy}	63	2.7^{y}
XLD-LL-1-79	8.5	95	12.8	92	4.3	16.9^{x}	92	4.1^{w}
Tamarack	4.1	52	6.3	52	2.2	8.2^{z}	53	2.0^{z}

[a] See appendix for seed source code description.

[wxyz] Duncan's New Multiple Range Test was calculated when "F" test values for treatments were significant. Values within a column followed by a common superscript are not significantly different at the 5% level.

Annual height growth for all materials, with the exception of tamarack and one European source exceeded 2.5 feet, with the hybrid averaging over 4 feet and the best European larch averaging over 3 feet. A number of individual hybrids exceed 20 feet at age 6.

A pocket of mortality was noted in one replication in 1986. University of Maine pathologists examined the trees and suggested that a high water table, apparent at time of inspection, may have caused the problem. Root samples were taken and several weakly saprophytic fungi were cultured. Comments were that it was unlikely these fungi caused the mortality. Observation of the area this past year revealed that mortality had not spread beyond the area of high water noted in 1986.

RIPCO TEST AREA - LARCH REPLICATED MISCELLANEOUS PLANTING

Frequently, small numbers of seedlings from various seed sources remain after stock for replicated trials has been dispersed. Rather than discarding or pooling excess seedlings, they are planted in random positions in an area on the Ripco Test Area near Sugar Camp, Wisconsin. Unequal and relatively small numbers of seedlings are planted in four tree blocks at 8 x 8 foot spacing. Although the information acquired is not as useful as that from replicated trials where larger numbers of trees with more uniform quality are planted, the growth and survival information is still a useful indication of performance (Fig. 5). Table 4 presents information from 25 larch sources planted in 1985 and 1986.

Figure 5. Ripco replicated miscellaneous larch planting near Sugar Camp, Wisconsin. Individuals from two of the best seed sources are shown after 3 years of growth. The seedling on the left is a hybrid from seed source XLD-LL-1-79 and the one on the right is from the European larch seed source XLD-11-81.

The planting was an old field with no advance site preparation. Seedlings were planted into scalped areas of approximately 24-inch diameter. The 1985 planting was sprayed preemergent with Oust at a 3 oz/acre rate in a 4 foot diameter circle around half of the trees.

Table 4. Ripco Test Area replicated miscellaneous larch seed source growth and survival.

Seed Source Planted 1985*	2nd Year Av. Ht., feet	2nd Year Survival, %	3rd Year Av. Ht., feet	3rd Year Survival, %
XLD-LL-1-79 (52)	2.5	90	4.5	85
XLL-LD-2-79 (48)	1.5	40	2.1	29
XLL-1-79 (12)	1.6	42	2.8	33
XLL-5-79 (48)	1.3	54	2.1	48
XLL-6-79 (48)	1.5	40	3.2	29
XLD-6-79 (12)	2.2	92	4.1	83
XLD-9-79 (48)	2.0	88	3.3	85
XLD-11-81 (12)	2.7	83	4.1	75
XLD-12-81 (4)	1.7	100	1.8	100
XLD-5-82 (48)	2.2	96	3.4	90
XLD-6-82 (36)	2.1	97	3.1	89
XLD-LL-2-83 (48)	1.4	58	2.9	50

Seed Source Planted 1986	1st Year Av. Ht., feet	1st Year Survival, %	2nd Year Av. Ht., feet	2nd Year Survival, %
XLD-3-79 (24)	1.0	75	1.9	75
XLD-9-79 (24)	1.4	75	1.8	67
XLD-1-81 (24)	2.3	88	2.6	88
XLD-7-82 (24)	1.0	63	1.9	50
XLD-9-82 (24)	0.7	38	1.2	17
XLTK-29-82 (24)	1.2	75	2.1	75
XLD-LL-1-83 (28)	0.8	82	1.3	64
XLD-1-84 (24)	1.0	46	1.5	46
XLD-2-84 (24)	0.9	42	1.3	42
XLD-5-84 (24)	0.9	92	1.6	79
XLD-LL-6-84 (16)	1.2	100	1.6	94
XLD-9-84 (16)	1.1	75	1.5	69
XLD-10-84 (32)	1.3	81	1.9	78
XLD-15-84 (24)	1.0	8	1.1	4

*See Appendix for description of seedlot code. Number in parentheses indicates number of seedlings planted.

Frost injury occurred in spring of 1986, severely damaging a number of sources. Variation in survival (Table 4) primarily reflects the effects of frost damage. All sources were damaged and the ones with good survival recovered well. The 1986 planting was not affected by frost, as it was being planted when the freeze occurred. Low survival of several entries in it is due to poor stock quality and vegetative competition.

DEMONSTRATION PLANTING

CHAMPION INTERNATIONAL - FAITHORN JAPANESE LARCH PLANTING

Part of the Kimberly-Clark lands acquired by Champion International included the Faithorn Experimental Forest. Although not a member of the larch project, Champion International allowed IPC personnel to measure a 22-year-old Japanese larch planting established by Kimberly-Clark. The planting is near Hermansville, Michigan, in Menominee County.

The planting was of interest because it was Japanese larch in a northern location. Height was measured in three randomly selected rows and overall survival was estimated. The spacing was very tight at 6 x 6 feet. Average growth was 36 feet in height and 4.8 inches dbh; survival was 83%. Heights were fairly uniform, but diameters varied considerably, reflecting the tight spacing. Figure 6 illustrates the size of the trees in the plantation.

The good survival and growth (given the tight spacing) indicate there may be northern locations suitable for Japanese larch. This particular plantation is located on the top and sides of a hill which most likely contributed to lessened frost incidence. Another speculative factor may be a lack of late spring frosts during the establishment years. Results reinforce the recommendations that larch should be planted on slopes with good air drainage and avoiding frost pockets.

Figure 6. A 22-year-old plantation of Japanese larch in Menominee County, Michigan, on Champion International lands. Heights averaged 36 feet and diameters averaged 4.8 inches, reflecting the effects of a tight 6 x 6 foot spacing.

HERBICIDES AND LARCH

LORETTA CHEMICAL SITE PREPARATION TRIAL - CONSOLIDATED PAPERS

Soils and vegetation control are described on pages 46-50 of Progress Report Seven. The chemicals, levels, and application dates are reproduced below (Table 5). General observations of the vegetation this summer indicated that all plots had ground cover composed primarily of forbs and scattered grasses. The Garlon 4 plot was still covered with grasses and differed markedly from the others. The extensive cover of climbing false buckwheat and bull thistle noted on the Oust plots in 1986 was considerably reduced this year.

Table 5. Loretta chemical site preparation trial treatments.

Treatment	Rate	Application Method	Treatment Date
Velpar liquid	3 qts/acre	Broadcast	May 22, 1985
Velpar liquid	3 qts/acre	Solid stream	May 23, 1985
Oust-preemergent	3 oz/acre	Broadcast	May 7, 1985
Oust-postemergent	3 oz/acre	Broadcast	May 22, 1985
Arsenal	3/4 lb/acre	Broadcast	Aug. 5, 1985
Arsenal	1 lb/acre	Broadcast	Aug. 5, 1985
Garlon 4	4 qts/acre	Broadcast	May 23, 1985
Control	No treatment		

Seedlings planted one year after treatment were measured this past fall (Table 6). The bareroot hybrid larch grew an average of 1.5 to 2 feet on all plots (Fig. 7). The variation in growth and survival within treatments was large and resulted in a nonsignificant "F" test when an analysis of variance was

Table 6. Loretta site preparation herbicide trial 2 year seedling growth and survival.

Treatment	Bareroot Larch: First Year Av. Ht., feet	Bareroot Larch: Second Year Av. Ht., feet	Bareroot Larch: First Year Survival, %	Bareroot Larch: Second Year Survival, %	Container Red Pine: First Year Av. Ht., feet	Container Red Pine: Second Year Av. Ht., feet	Container Red Pine: First Year Survival, %	Container Red Pine: Second Y[illegible] Surviva[illegible] %
Velpar L	1.6	3.7	100	97	0.5	1.1	53	47
Velpar L	1.3	2.7	87	63	0.5	0.9	40	60*
Oust pre	1.4	3.2	97	97	0.5	0.8	60	60
Oust post	1.8	4.1	100	97	0.5	1.2	60	53
Arsenal	1.3	2.8	97	93	0.6	0.9	80	73
Arsenal	1.4	3.1	80	77	0.4	1.0	67	73*
Garlon 4	1.6	3.0	83	80	0.7	1.0	33	53*
Control	1.3	2.5	79	70	0.5	0.9	47	60*

Treatment	Hybrid Aspen: First Year Av. Ht., feet	Hybrid Aspen: Second Year Av. Ht., feet	Hybrid Aspen: First Year Survival, %	Hybrid Aspen: Second Year Survival, %
Velpar L	1.8	3.4	73	73
Velpar L	1.8	3.0	93	80
Oust pre	1.7	4.0	100	73
Oust post	1.4	2.7	73	67
Arsenal	1.5	1.7	60	20
Arsenal	1.4	3.0	70	60
Garlon 4	1.8	3.0	40	40
Control	1.4	2.4	87	40

*Increase in survival reflects ability to find seedlings not found in first year.

run on the data. However, the herbicide sensitive species, larch and aspen, have been uninjured by the treatments with the possible exception of the aspen/garlon treatment. Results also indicate that growth has not been negatively affected.

Second Ye
Survival,
%

47
60*
60
53
73
73*
53*
60*

Figure 7. Two-year-old hybrid larch seedlings averaged 3 feet in height on a chemical site preparation trial on Consolidated Paper's land near Loretta, Wisconsin. Individual seedlings on the trial were over 6 feet in height.

The hybrid larch had minor frost injury the spring of 1986 but recovered well in 1987. This trial is at the top of a slope with air drainage in three directions which most likely contributed to lessened injury during the widespread frost incidence in 1986. The trial will be observed again this coming year and measured in the fall.

KRAFT PULP CHARACTERISTICS OF YOUNG PLANTATION-GROWN TAMARACK AND MATURE TAMARACK, AND COMPARISONS WITH JACK PINE, RED PINE, AND EUROPEAN, JAPANESE, AND HYBRID LARCH

SUMMARY

Kappa 50 and kappa 30 pulps were prepared from bark-free chips of 26-year-old (young wood) and 69-year-old (mature wood) tamarack. The resulting pulps were evaluated for strength and compared with earlier evaluated jack and red pine and pulps from European, Japanese, and hybrid larch.* Of particular interest was the usefulness of young wood from tamarack as a conifer fiber source. The tamarack young wood pulped at the same rate as the mature wood, and both sources pulped with greater ease than the jack pine control chips and wood from the above three sources of larch. Pulp yields for plantation grown tamarack (young wood) were comparable to tamarack mature wood and to jack pine mature wood but were 4 to 5% lower than European and hybrid larch and red pine.

Both the young wood and mature wood pulps bleached to an 88 G.E. brightness with relative ease using a C_DEHDED bleaching sequence. The tamarack bleaching chemical requirements were very similar to the requirements of the earlier evaluated jack pine control pulps and the young *Larix* species pulps. When the tamarack results are compared with the bleaching results for the mature red pine, tamarack pulps had about 1.0% higher chlorine consumption in the chlorination stage and very similar requirements in all other stages. Brightness levels were comparable (88.4 *vs.* 89.2) and the tamarack pulps appeared to be less degraded based upon Cuene viscosity data.

*Tamarack has been used to designate eastern larch data, and the terms *Larix* and larch are used to describe European, Japanese, and hybrid larch data.

The mature wood pulps refined with slightly greater difficulty, particularly the kappa 50 pulps, than the tamarack young wood pulps. Both sources of pulp refined with greater difficulty (required more beating energy) than the jack pine, European larch, and red pine pulps but were very similar to hybrid larch in refining requirements.

Regarding strength properties, pulps from plantation grown tamarack (young wood) did not differ from the strength properties of tamarack mature wood pulps. Both sources of pulp had good tearing strength, but when the pulps were refined to improve breaking length, tearing strength decreased and at a breaking length of 9 km they had an estimated 15% lower tear, 5% greater burst, and equal tensile energy absorption, when compared with earlier evaluated pulps from the jack pine mature pulpwood bolts and 18-year-old European larch plantation grown trees.

INTRODUCTION

There is an urgent need for a conifer fiber source that will grow well on poorly drained, frost-prone sites in the Lake States region. The use of tamarack, i.e., eastern larch, (*Larix laricina* "Du Roi" K. Koch) and tamarack hybrids appear to have considerable promise on these sites and on better drained upland sites. Mature tamarack has a slightly longer fiber length (3.6 mm), similar fiber width (25-35 μm), and higher specific gravity (0.49) than white spruce.[8] The young tamarack used in this study had wood properties not greatly different from mature tamarack. Considerable bias exists against the utilization of *Larix* species for pulpwood. This bias resulted from experience gained in attempts to utilize slow-growing mature (50 to 150 year old) pulpwood-sized trees. Tamarack fiber properties seem to be appropriate for papermaking but the high extractive levels present in the heartwood of mature Larix species appear to be an important drawback.* High extractives reduce pulp yield and can cause pitch and pulp color problems.

IPC results with younger (18 to 24 year old) European, Japanese, and hybrid larch and Canadian results with young tamarack[9] suggest reduced extractive levels and improved paper properties will be obtained if rapid-growing younger-aged tamarack are utilized. These results are anticipated because of lower levels of heartwood, lower extractive levels in the heartwood, and higher levels of juvenile wood.

The research described in this report was undertaken because the Institute's pulping and forest genetics groups felt there was a need for basic pure-species pulping data for a number of Lake States conifers (red pine, jack pine, tamarack, etc.). Additionally, there was a need to verify the suitability of 20- to 30-year-old tamarack for use in papermaking before undertaking large-scale plantings or a major genetic improvement program involving tamarack.

The purpose of the research was to (1) provide basic wood and fiber property data for young and mature tamarack, (2) provide basic kraft pulping data for young and mature tamarack, (3) examine the wood extractive levels and the pulp bleach requirements of the two sources of tamarack, and (4) compare the tamarack results with the earlier pulped red pine, jack pine, and larch species. This report summarizes the results of the kraft pulping of plantation grown and mature tamarack growing in northern Wisconsin. Throughout the report plantation grown is described as young wood and most of the comparisons that follow are between young wood and mature wood.

*Arabinogalactan appears to be the major water soluble extractive in mature heartwood that causes pulping difficulties.

MATERIALS AND METHODS

WOOD PROPERTIES

The trees selected for this study consisted of three 26-year-old pulpwood-sized trees from a plantation in northern Wisconsin (Oneida County) and three 69-year-old, well-formed, dominant/codominant trees growing in a nearby unmanaged stand. The plantation trees were growing on a well-drained sandy site and the unmanaged stand was located on a low, poorly-drained soil typical of the sites presently supporting tamarack stands in north central Wisconsin.

The size of the experimental trees, along with information on wood specific gravity, percent bark, heartwood, and compression wood are summarized in Table 7. As can be noted from the data plantation tamarack on a well-drained site grew considerably faster than the mature tamarack in a low, poorly drained site typical of where most tamarack are found; another indication that tamarack can occupy upland sites. After collection, the trees were sampled by taking disks at the base, 4-1/2 ft (1.37 m), and every 6 ft (1.83 m) to a 4-inch (10.2 cm) top inside diameter. The bolts were then manually debarked and chipped. Chips were screened and those passing the one-inch (25.4 mm) screen and retained on the 1/2- and 1/4-inch (12.7 and 6.4 mm) screens were the fractions pulped. Oversize reject chips were rechipped and rescreened once prior to discarding the rejects and fines. The accepted chips were air dried prior to pulping.

Pulps were evaluated for their usefulness as bag papers by kraft cooking to a kappa number of approximately 50 and for use as part of a furnish of bleachable-grade pulps by cooking to a kappa 30. The pulping conditions used were the same as for earlier studies conducted by Project 3409 on red pine,

Table 7. Tamarack tree size and wood quality.

Tree No.	Type of Material	Age, years	DBH, inches	Total Height, feet	Whole Tree sp.gr.	Age-15 Fiber Length, mm	Bark, %	Heartwood, %	Compression Wood, %
I	Mature	71	10.0	67	0.464	2.1	7.4	49.4	6.5
II	Mature	72	9.9	72	0.453	2.6	9.8	49.9	6.4
III	Mature	63	9.7	74	0.498	2.5	7.9	52.5	6.2
	Av.	69	9.9	71	0.472	2.4	8.4	50.6	6.4
IV	Young	26	7.0	50	0.423	2.5	11.8	39.8	11.4
V	Young	26	7.0	50	0.411	2.2	10.6	37.6	9.4
VI	Young	26	7.9	50	0.397	2.8	9.4	26.8	7.4
	Av.	26	7.3	50	0.410	2.5	10.6	34.7	9.4

European larch, Japanese larch, and European x Japanese hybrid larch pulpwood-sized thinnings. Fifty-five-year-old jack pine wood was also included in the earlier studies as a source of control pulp.

The data on percent bark are the weighted average values and were estimated from disk samples by removing the bark and comparing wood and bark oven-dry weights. Tree specific gravity is the dry weight divided by green volume, with the green volume being determined by a maximum-moisture, water-displacement procedure using disks located at six-foot intervals up the tree to a four-inch top diameter. Compression wood and heartwood levels were determined using disk samples taken at six-foot intervals. Moist disks were examined using a light box to help distinguish heartwood and compression wood areas. The levels presented are weighted average whole-tree values to a four-inch top diameter for both the thinnings and the mature wood samples.

Fiber measurements were made on representative unbeaten mature wood and young wood pulps and on breast high (4-1/2 ft) disk samples. Appropriate annual ring samples were taken from each of the six trees used in the study and fiber length/age curves prepared for each tree. Six hundred plus intact fibers were measured for each sample. Fiber length data were generated for annual rings 5, 15, 25, 42, and 63 to 72 for the mature trees. Fiber length values were determined for annual rings 5, 15, 20, and 26 for the young wood trees. Duplicate pulp samples were measured for the kappa 30 young wood, kappa 50 young wood, kappa 30 mature wood, and 50 mature wood pulps using the Kjanni automatic fiber length measuring procedure.

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CHEMICAL DETERMINATIONS

Chemical determinations were made on representative air-dried chip samples that were prepared for analysis in a Wiley mill. The finely ground wood samples were considered to be representative of the entire bark-free bole to a 4-inch top for the three trees that make up each sample. Determinations included lignin using the Tappi Journal method,[10] alcohol-benzene extractives (TAPPI Method T 204 os-76), and hot water extractives (TAPPI Method T 207 os-75).

PULPING AND BLEACHING CONDITIONS

The chips from the three trees representing each of the two sources of tamarack wood (young wood and mature wood) were thoroughly mixed and air dried prior to pulping. Pulping runs were carried out in an M&K digester using the cooking conditions given in Table 8 to obtain pulps with kappa numbers of approximately 30 and 50. The cooking liquors were prepared from solutions of sodium hydroxide and sodium sulfide of known concentration and density, together with the appropriate amount of dilution water. A microcomputer was used to control the system and acquire temperature, H-factor, and conductivity data. Spent liquor samples were taken to determine the residual alkali. Kappa number, yield, viscosity, and brightness were measured on the pulps produced.

Table 8. Pulping conditions.

Wood charge, kg o.d.	4.0
Water-to-wood ratio, cm^2/g	4.0
Effective alkali, % o.d. wood	16.0
Sulfidity, %	25.0
Ramp rate, °C/min	1.8
Pulping temperature, °C	172.0
H-factors	1000-1700

The chips were fiberized in a Williams disintegrator, and the pulp was screened through a 0.009-inch (0.15 mm) cut screen plate in a small Valley flat screen. The rejects were oven dried, weighed, and discarded. The accepted fiber was then used to determine the physical properties of the pulps using TAPPI methods after beating in a PFI mill at a 10% consistency. Handsheets were prepared from the kappa 30 and kappa 50 pulps after beating in the PFI mill to CSF freeness intervals that varied from 340 to 730 (see table on handsheet strength properties). Handsheets were evaluated for burst, tear, tensile, zero-span tensile, tensile energy absorption (TEA), stretch, porosity, scattering coefficient, and adsorption coefficient. The strength properties of tear, burst, tensile, and TEA are discussed in detail in this report.

Two 50 gram samples of the kappa 30 pulps were bleached using a C_DEHDED sequence. Chlorination was carried out in a stirred tank reactor. The E, H, and D stages were carried out in plastic bags immersed in a constant temperature bath. Kappa number was measured after the E1 stage. Cuene viscosity, G.E. brightness, and pH were measured on pulps at several of the bleaching stages, and this information, along with chemical requirements, was used to compare pulp sources.

RESULTS AND DISCUSSION

WOOD PROPERTIES

The two sources of tamarack were from northern Wisconsin. All trees were straight dominant and codominant trees. Despite the straightness, the young wood had greater levels of compression wood. Additionally, the young wood had higher amounts of juvenile wood, lower levels of heartwood (35 vs. 51%), and lower specific gravity (0.41 vs. 0.47). The wood quality differences between wood sources were much as anticipated with the exception that the differences in heartwood levels were less than anticipated.

The chemical properties of wood (lignin, extractives, etc.) are important in the evaluation of wood species for pulping because of the influence they have on pulp yield, pitch properties, pulping chemical requirements, and pulp bleaching chemical requirements. Lignin levels were similar for young wood and mature wood, and both sources had levels that were lower than jack pine and Larix species (Table 9). The level of extractives, both alcohol-benzene and hot water, in the young wood were about twice as high as anticipated in view of the earlier results obtained with plantation grown European and hybrid larch.

No problems were encountered in chipping the two wood sources. After chipping, the material was screened and the rejects (chips retained on the one-inch screen) were rechipped once. The rejects shown are the chips retained on the one-inch screen after one rechipping. Prior to pulping, the chips were air dried. Moisture contents were taken after chipping and prior to air drying. The chip size distribution (Table 10) for the two sources of wood were very similar and, as might be expected because of the higher levels of heartwood and lower juvenile wood, the mature wood chips were a little lower in moisture content.

Table 9. Chemical properties of wood.

Type of Material	Lignin, %	Extractives, %	
		Alcohol-Benzene	Hot Water
Mature tamarack	25.6	3.9	10.0
Young tamarack	26.5	4.2	9.3
23-Year-old hybrid larch	27.9	2.5	4.2
18-Year-old European larch	27.6	1.8	3.9
Jack pine control (55 yr)	27.4	3.5	2.3

Table 10. Characteristics of chips prepared for pulping.

Wood Sample	Percent of Chips on Each Screen[a]				Moisture Content,[c] %
	On 1/4-Inch	On 1/2-Inch	Fines	Rejects[b]	
Young tamarack	24.7	67.7	4.3	3.4	48
Mature tamarack	28.7	61.5	6.2	3.6	41

[a]Based upon oven dry weight measurements.
[b]Rejects from first screening were rechipped once and rescreened.
[c]Moisture content of On 1/4 and On 1/2-inch chips, determined on a fresh weight basis.

PULPING CHARACTERISTICS

The pulping times required to produce kappa 50 (bag paper) and kappa 30 (bleachable grade) pulps were established and then used to obtain pulps that could be used in strength comparisons. Table 11 summarizes the results of varying pulping conditions on kappa number and pulp yield. Pulping time has been replaced by the generally more useful H-factor.[11] Differences between the two sources of chips were further clarified by plotting kappa number vs. H-factor, as illustrated in Fig. 8.

Table 11. Pulping conditions, kappa number, Cuene viscosity, and pulp yield.

Material	H-Factor	Kappa Number	Cuene Viscosity	Unscreened Yield, % o.d. wood	Screened[a] Rejects, % o.d. wood
Young tamarack	1000	53.4	48.4	45.7	0.1
	1080	50.1	48.4	46.1	0.1
	1700	31.5	34.5	44.0	0.1
Mature wood	1005	49.7	43.8	45.9	0.1
	1650	30.2	35.2	42.9	0.1

[a]Pulps were run through a refiner at 1/12,000-inch gap prior to screening.

As can be seen from the regression line in Fig. 8, there appear to be only minor differences in the pulping rates for the two sources of wood. The overall rate of pulping for tamarack, as will be commented on later, was more rapid than for the earlier evaluated sources of larch and jack pine, but not as rapid as red pine.

Obtaining the maximum yield of pulp from each oven dry pound of wood is extremely important. Figure 9 illustrates the lack of differences that existed between the two sources of wood when they were evaluated at comparable kappa numbers. The degree of polymerization of the pulps, as measured by Cuene viscosity, were about 3 units higher for the kappa 50 young wood pulp, and this indicates a lower level of cellulose degradation during pulping. However at kappa

30, the mature wood pulps had a slight viscosity advantage. Levels of screen rejects were not influenced by wood source. Rejects were only 0.1%, even for the pulps cooked to the higher kappa numbers (49 to 53). However, the procedure used, which involved passing the pulp through a refiner with a 1/12,000-inch gap prior to screening rejects, probably reduced any differences that existed between pulps before refining.

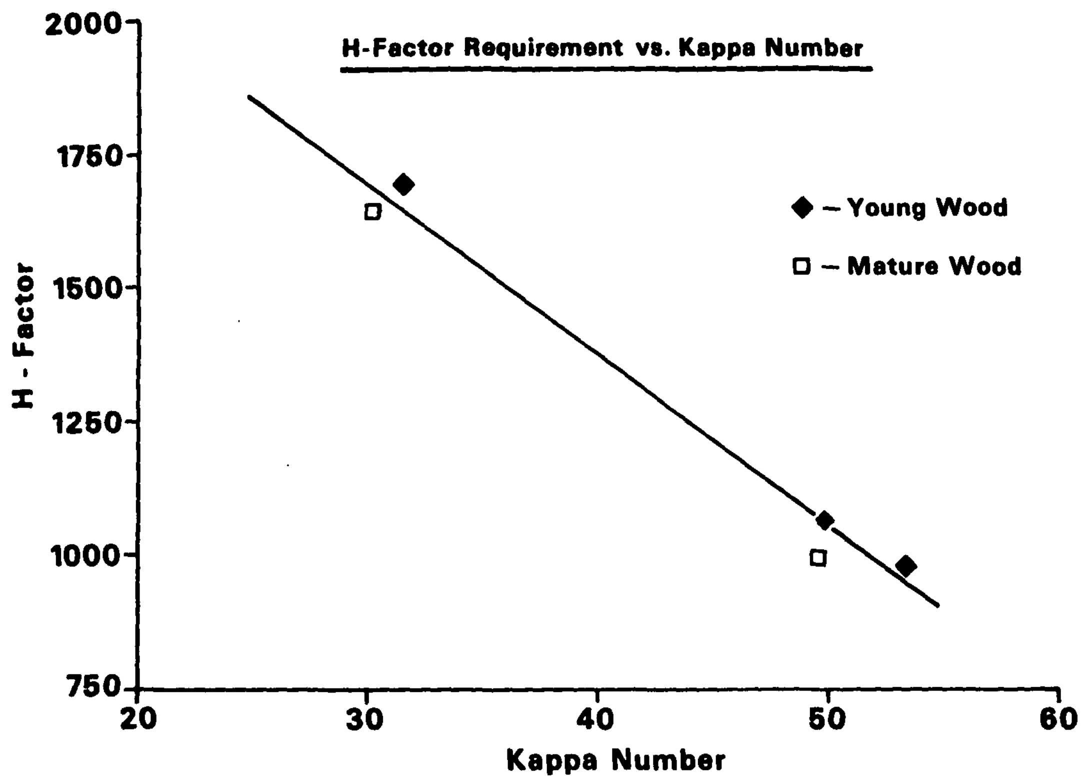

Figure 8. H-factor requirement vs. kappa number for tamarack. The regression line is based on the equation kappa no. = 82.93 + (-0.031 • H factor), R = 0.99.

PULP BLEACHING RESULTS

Mature wood kappa 30.2 and young wood kappa 31.5 pulps were bleached using the C_DEHDED bleaching sequence. Duplicate samples of each pulp source were evaluated. The chlorination stage involved substitution of 15% of the estimated chlorine requirements with chlorine dioxide. The starting chlorine requirements were determined from the formula % Cl_2 = 0.22 x kappa number. Chemical requirements, pulp viscosity, and pulp brightness were used to evaluate the bleached pulps (Table 12).

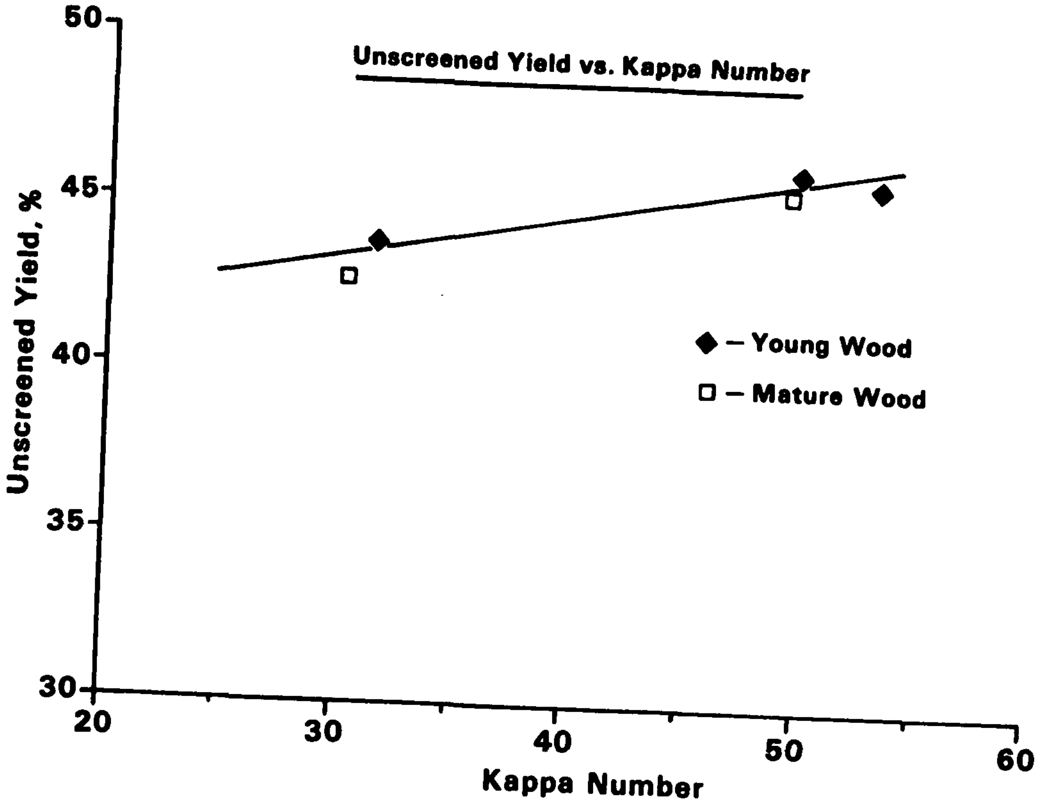

Figure 9. Unscreened yield vs. kappa number for tamarack. The regression line is based on the equation unscreened yield = 39.8 + (0.119 · kappa no.), R = 0.95.

The young wood pulps had a little higher starting kappa number (1.3 units) and as a result had about 0.3% greater starting chlorine level. The young wood tamarack consumed a little higher chlorine in the chlorination stage than the mature wood pulp. Chlorine consumption in the hypo-stage was identical for the pulp sources. Chlorine dioxide consumption was less for the young wood pulps in the dioxide stage (D1) and the same in the D2 stage. The Cuene viscosity, which is a measure of the degree of polymerization of the pulps and reflects pulp degradation, was similar for young and mature wood pulps. The

Table 12. Tamarack bleaching results.

Bleaching Stage	Pulp Source: Young Wood[a]	Pulp Source: Mature Wood[a]
C_D Chlorination: % Cl_2 = 0.22 x kappa no., 15% substitution of Cl_2 by ClO_2		
Cl_2 consumed, %[b]	6.9	6.6
Exit pH	1.52	1.51
E_1 Extraction: % NaOH = Cl_2 • 0.55, 60 min reaction time, 60°C, 10% consistency		
CE kappa no.	6.2	6.4
CE viscosity	33.0	29.4
Exit pH	12.2	12.6
H Hypo-Stage: 1.0% active Cl_2 as NaOCl, 0.4% NaOH, 60 min, 35°C, 10% consistency		
Residual NaOCl, %[b]	0.05	0.05
Exit pH	10.6	10.4
D_1 Dioxide-Stage: 0.8% ClO_2, 0.4% NaOH, 180 min, 70°C, 10% consistency		
Exit pH	2.5	2.4
Residual ClO_2, %[b]	0.22	0
CEHD viscosity	28.9	28.2
G.E. brightness, %	83.8	83.2
E_2 Extraction: 0.4% NaOH, 60 min, 60°C, 10% consistency		
Exit pH	11.8	11.8
D_2 Dioxide: 0.4% ClO_2, 0.07% NaOH, 180 min, 70°C, 10% consistency		
Exit pH	3.5	3.5
Residual ClO_2, %[b]	0.14	0.14
Final viscosity	27.1	25.2
G.E. brightness, %	88.2	88.6

[a]Average values of duplicate samples.
[b]% based on o.d. pulp.

final brightness levels were essentially the same for the two sources of pulp (88.2 vs. 88.6).

Both tamarack pulps bleached without difficulty and had very similar bleaching chemical requirements when compared with bleached jack pine control pulps and 18-year-old European and 23-year-old hybrid larch pulps, when a CEDED bleaching sequence was used (Project 3409, Progress Report One, p. 56). Jack pine 55-year-old control pulps, for example, consumed 7.0% Cl_2 in the chlorination stage, 1.2% ClO_2 in the D1 stage, 0.4% ClO_2 in the D2-stage, and achieved a 90.3 G.E. brightness. It should be noted, however, the bleaching results from the two studies are not strictly comparable because hypochlorite stage was added to the sequence for the tamarack study.

Unpublished data are also available on the C_DEHDED bleaching of the red pine pulps that were evaluated in Project 3409, Progress Report Seven, 1987. When the tamarack bleaching results are compared with bleaching results for mature red pine, the tamarack pulps had about 1.0% higher chlorine consumption in the chlorination stage and very similar chemical requirements in all other bleaching stages. The bleached tamarack pulps were 4 to 7 units higher in Cuene viscosity (degraded less) and had very similar G.E. brightness (88.4 vs. 89.2). Bleaching does not appear to be a problem for the kappa 30 kraft tamarack pulps evaluated in this study.

PULP STRENGTH

The strength properties of the pulps obtained from plantation grown tamarack (young wood) and mature wood are summarized in Table 13. Conifer pulps are refined to improve formation, increase bonding, and improve tensile strength

Table 13. Physical properties of unbleached kappa 50 and kappa 30 tamarack pulps.

Wood Type	No. of Revs.	CSF, mL	Sheet Density, kg/m³	Burst Index, kPa·m²/g	Tear Index, mN·m²/g	Breaking Length, km	Tensile[a] Index, N·m/g	TEA, J/m²
				Kappa 50 Pulps				
Young	0	705	559	4.1	15.1	5.7	56	55.4
	2500	660	701	6.7	11.5	8.3	82	104.3
	4000	600	725	7.2	10.7	9.0	89	115.2
	5400	515	738	7.6	10.0	9.1	90	105.9
	6300	460	757	7.9	10.6	9.2	91	110.5
	8000	355	780	7.9	9.6	9.3	92	127.7
Mature	0	730	530	3.3	20.8	4.9	49	50.7
	2400	665	632	5.9	15.0	7.8	77	81.2
	3500	600	657	6.2	13.3	8.1	80	86.5
	4500	520	684	6.9	12.9	8.2	81	105.1
	5750	430	706	7.2	12.0	9.4	93	108.6
	7000	340	718	7.4	10.9	8.9	88	122.6
				Kappa 30 Pulps				
Young	0	680	633	4.5	15.6	6.3	63	74.3
	600	640	700	5.9	13.0	7.8	78	93.6
	1400	605	718	6.6	11.9	9.0	89	96.6
	2800	520	764	7.3	10.2	8.4	82	98.6
	3900	450	771	7.7	10.8	8.9	88	108.4
	5200	370	777	7.8	10.3	9.5	94	120.2
Mature	0	725	559	3.3	20.4	5.5	50	47.6
	1500	650	653	5.9	15.0	7.8	78	79.7
	2500	585	693	6.9	13.8	8.6	85	93.6
	3400	520	699	6.8	13.6	9.4	93	110.2
	4000	455	708	7.3	12.5	9.3	92	110.6
	5000	365	726	7.4	12.3	8.6	85	104.1

[a]Tensile index = breaking length in km x 9.8.

(breaking length). Such refining increases sheet density, breaking length, and bursting strength and decreases tearing strength.

One extremely useful way of comparing two pulps is at a constant sheet density. When this is done, the same level of bonding is involved in making the evaluation. When such a comparison was made using the tear factor data generated, the kappa 30 tear values were higher but were not significantly better than the kappa 50 pulps.*

As a result, the kappa 30 and 50 data were combined for comparisons between mature and young wood pulp sources. Differences between the two pulp sources in the sheet density range of 600 to 800 were not statistically significant (Fig. 10). "Mature/young" differences were greater at the low sheet densities (unbeaten pulps). The tear index values for both the young and mature wood pulps were typical of good quality conifer pulps, were greater than the pulps from the earlier evaluated red pine thinnings, and were very similar to pulps from red pine mature wood (Progress Report Seven, p. 62). Pulps from both the tamarack young wood and mature wood can be expected to perform satisfactorily where high tear strength is required.

Tensile strength (breaking length) normally increases as the level of refining and sheet density increases. The tamarack pulps behaved as expected with refining. When the kappa 30 and 50 tensile strength (breaking length) data were evaluated at comparable sheet densities, there were no significant differences for either the young wood or the mature wood. This again allowed

*The standard error of estimates of the regression lines were used to determine when significant differences existed between pulps. Differences were considered significant when the t_{05} s_y values for the regression lines did not overlap.

combining the kappa 30 and 50 data prior to comparing the tensile strength of the mature and young wood pulps.

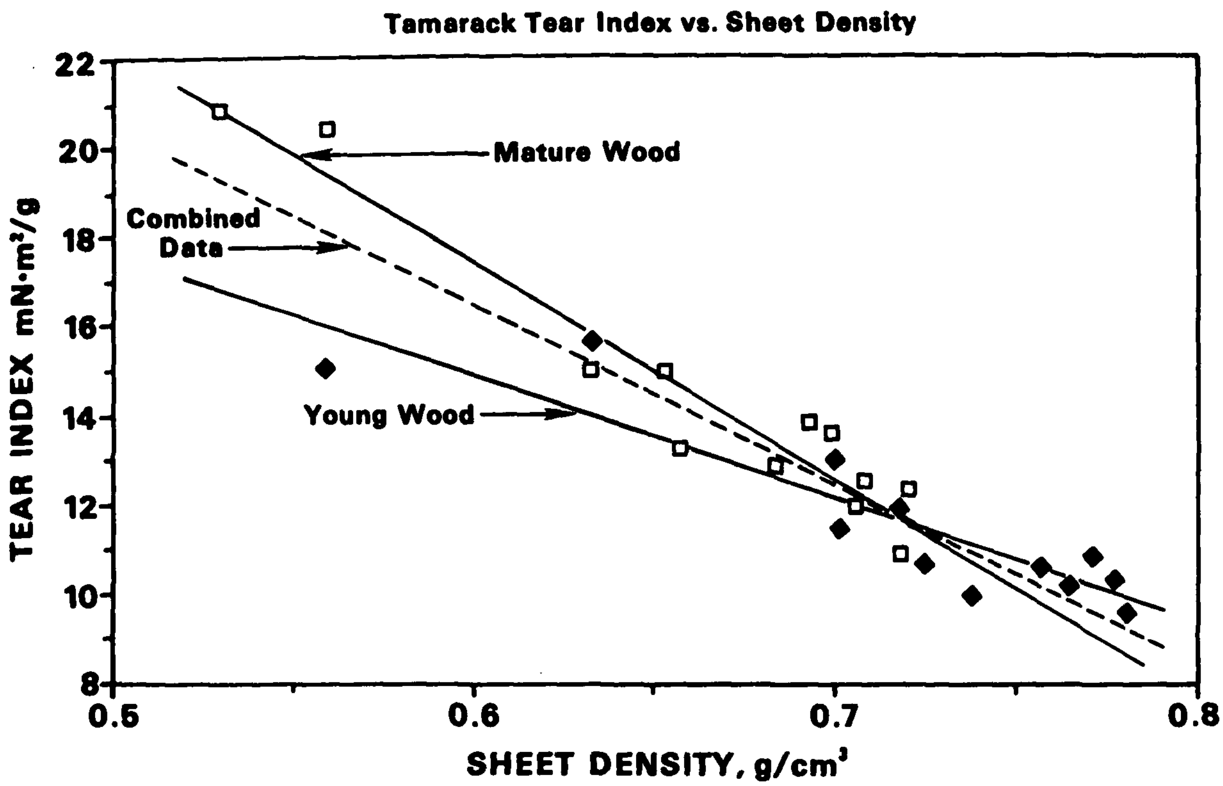

Figure 10. Tear index for young and mature tamarack wood did not differ significantly. The combined data regression equation is tear index = 40.4 - 39.63x, R = 0.93.

When the kappa 30 and kappa 50 tensile strength data were combined, and an appropriate regression analysis applied (Fig. 11), the mature wood pulps had 7 to 12% higher breaking length at sheet densities of 650 to 750 kg/m^3. When, however, the differences were compared using the standard error of estimate for the pulp sources, the differences were not statistically significant (95% probability level). It should also be noted, as will be illustrated later, the tensile strength (breaking length) values of the tamarack pulps were lower than normal when compared to the earlier evaluated conifer pulps. This was not entirely unexpected because when tear values are higher than normal, tensile and burst values are usually lower than normal.

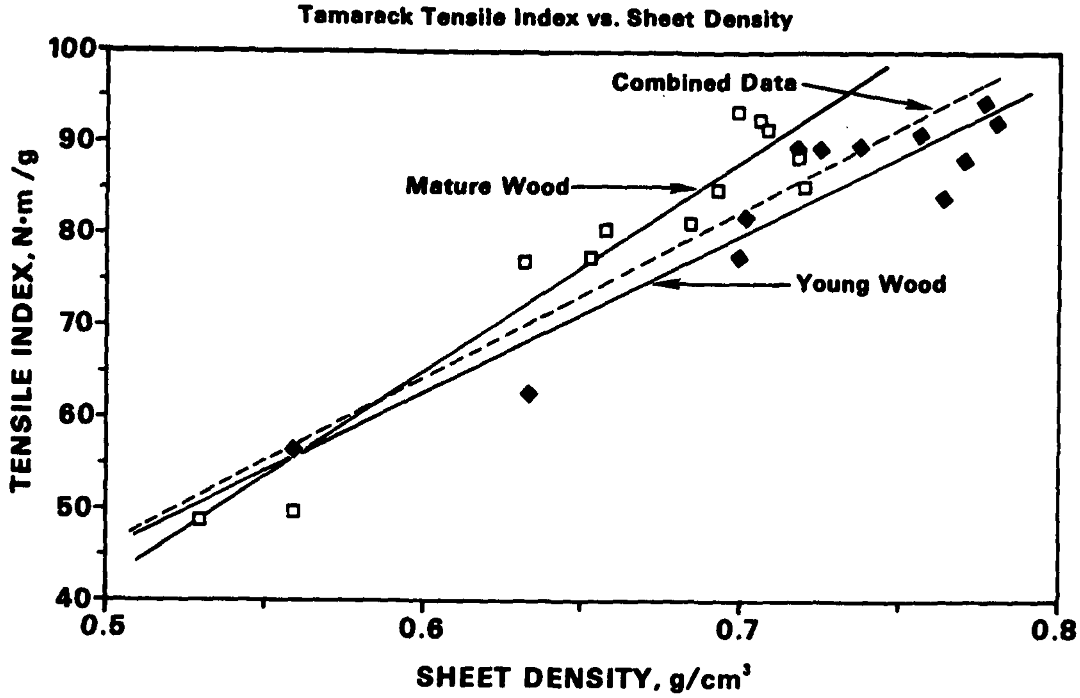

Figure 11. Tensile index (breaking length) for the two sources of tamarack wood did not differ significantly. The regression equation for the combined data is tensile index = 42.01 + 178.26 x, R = 0.91.

Bursting strength usually reacts to refining in a manner similar to tensile strength, i.e., increases as refining and sheet density increase. When, as with tear and tensile strength, the kappa 30 and 50 data were evaluated, the differences were not significant (Fig. 12). As expected, the tamarack young wood pulps produced handsheets of higher sheet density. When, however, burst is evaluated at comparable sheet densities, the mature wood pulps have burst values that are 10 to 12% greater at sheet densities of 700 to 750. These differences, however, are confined to a very narrow sheet density range and the overall differences between sources of wood are not statistically significant.

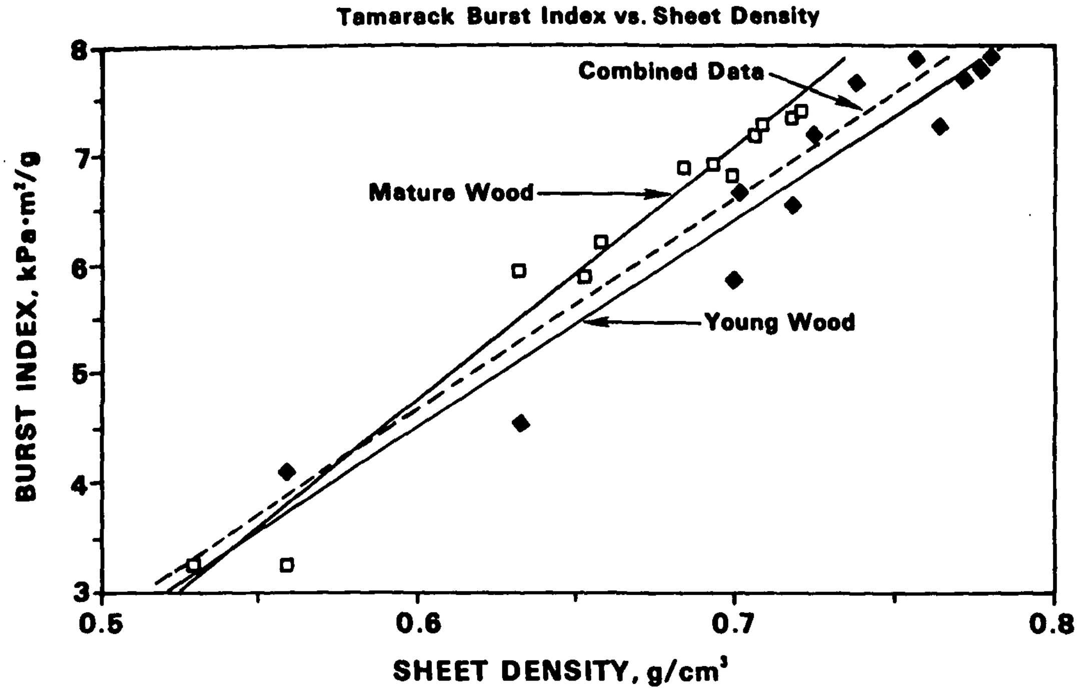

Figure 12. Burst index differences between young wood and mature wood were not statistically significant. The regression equation for the combined data is burst index = 6.72 + 19.102 x, R = 0.95.

Tensile energy absorption (TEA), which is a measure of the ability of paper to absorb energy prior to tensile failure, is an important property of multiwall sacks, packaging, and wrapping papers. Comparisons made regarding the influence of kappa number on TEA demonstrated there were no differences between kappa 30 and 50 pulps for either wood sources. When the TEA for the two types of pulps were compared at the same sheet density, the source of wood (mature vs. young wood) had only a minor influence on TEA values. Mature wood pulps were about 6 to 10% greater in TEA at a sheet density of 700 to 750 and were the same at a sheet density of 600 (Fig. 13). When evaluated using the standard error of estimate for regressions, the differences were not significantly different.

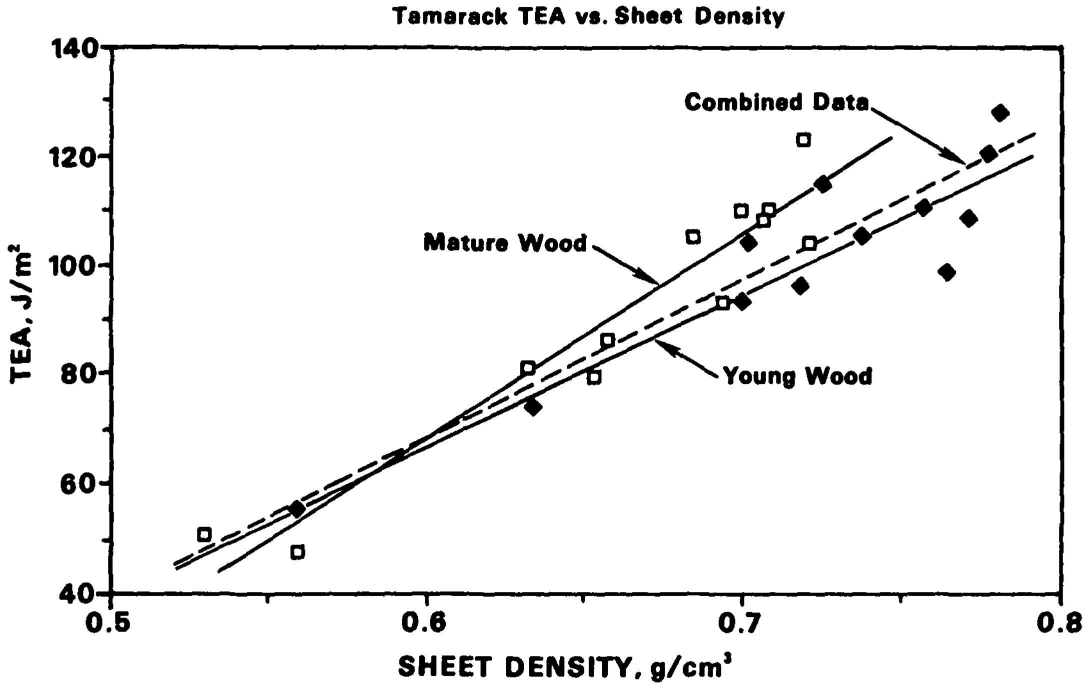

Figure 13. Tensile energy absorption (TEA) differences between the wood sources were not statistically significant. The regression equation for the combined data is TEA = 106.89 + 294.09 x, R = 0.92.

Another method of comparing the usefulness of a pulp is to plot a strength property of interest over breaking length. The reasoning in this approach is that the paper furnish being produced requires a certain minimum breaking length, and the pulp is refined to obtain the needed breaking length. By plotting various strength properties over breaking length, it is possible to determine what happens to these properties when you refine to obtain the needed tensile strength. Figure 14 is a plot of tear index over breaking length using the combined data for the two sources of pulp. Most of the mature wood tear index data fell above the regression line for the combined data. This suggests that mature wood pulps can be refined to a greater degree to obtain the needed breaking length and, at a particular level of refining and breaking length, will have a higher tear index than similarly treated tamarack young wood. Figures 15 and 16 make similar comparisons by plotting burst index and TEA data over breaking length. In these comparisons there appears to be little influence from wood source (young wood vs. mature wood) on the relationship between burst and breaking length and TEA and breaking length.

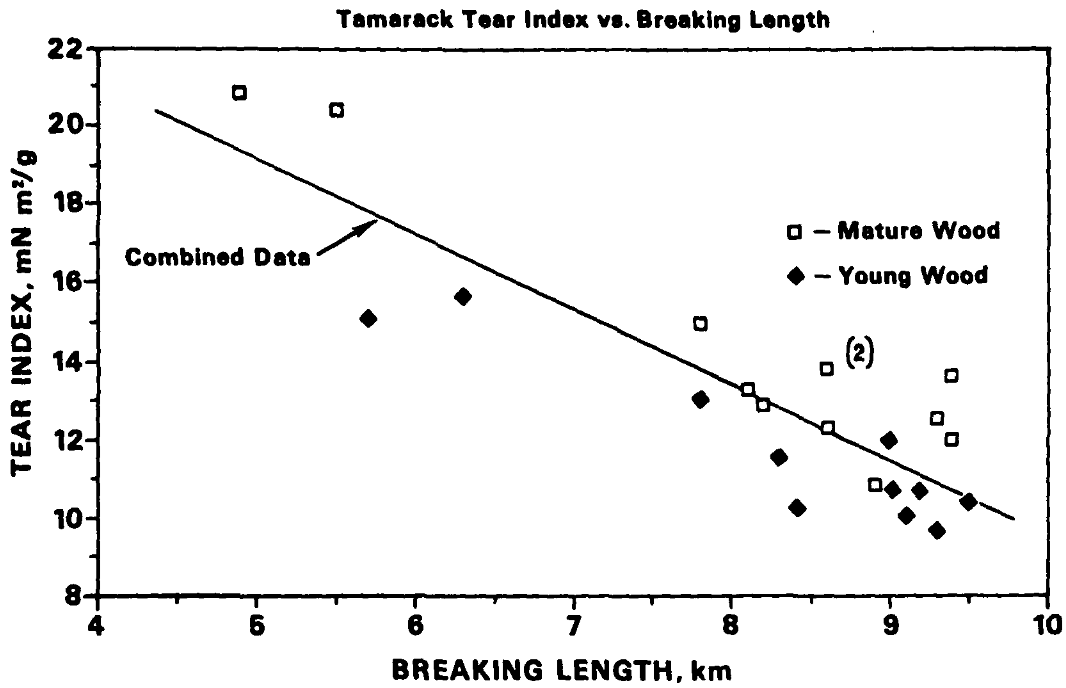

Figure 14. Refining pulps to improve breaking length (tensile strength) reduces tearing strength. Young wood pulps had lower tear than mature wood pulps when compared at equivalent breaking lengths.

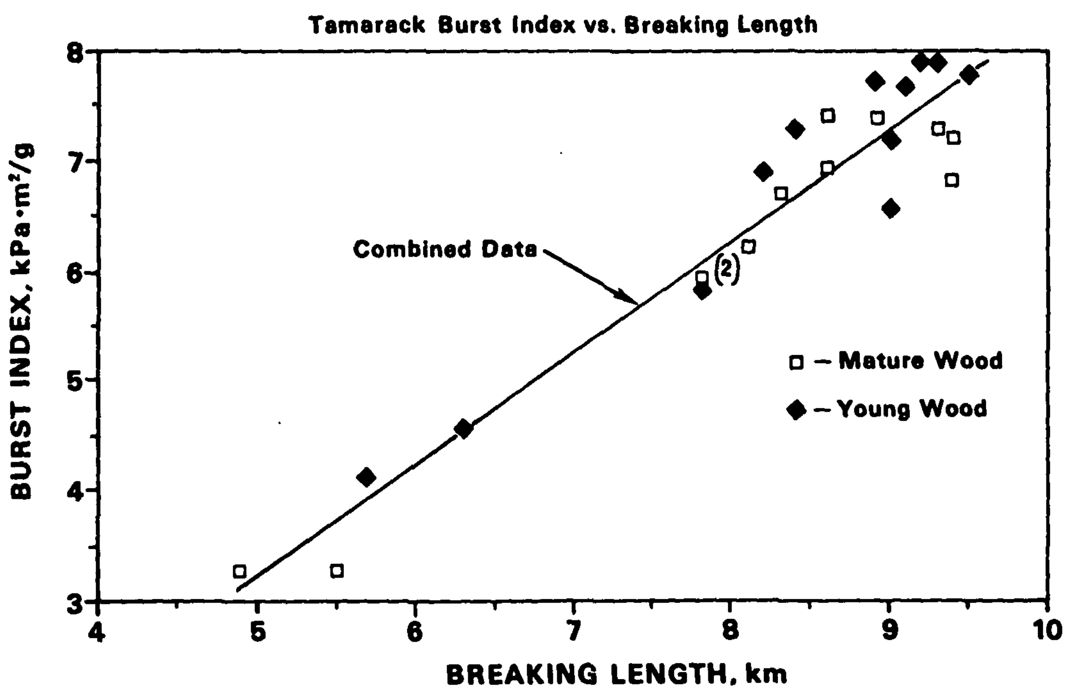

Figure 15. Burst index increased as breaking length increased with no burst differences between tamarack wood sources.

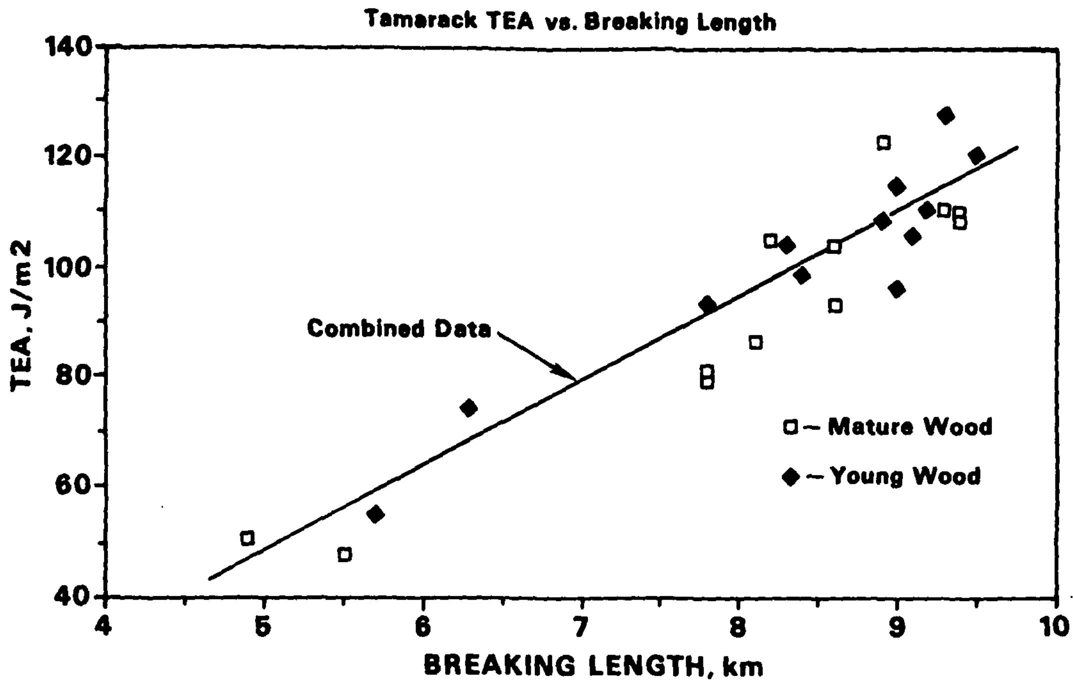

Figure 16. TEA increased as breaking length (tensile strength) increased with no TEA differences between tamarack wood sources.

REFINING CHARACTERISTICS

Breaking length (tensile strength) is an important sheet property, and as indicated in previous comments, pulps are normally refined (beaten) to improve breaking length. Pulps are usually evaluated on the degree of beating required to reach acceptable breaking length, and on the maximum attainable breaking length. Figure 17 illustrates the influence of refining on breaking length for the tamarack pulps. Regression lines of the form $y = a + b \log x$ gave the best fit of the data. The curves for the mature wood and young wood were very similar to the combined data curve given in Fig. 17. The young wood curve was displaced slightly to the right of the mature wood curve, indicating the young wood pulps required less beating and reached higher maximum breaking lengths. The differences between curves were small and not statistically significant due to large standard errors of estimate. The overall degree of beating results suggest the tamarack pulps evaluated required considerable refining and reached lower maximum breaking length values than jack pine control pulps and the 18-year-old European larch pulps (see comments in the comparison section that follows).

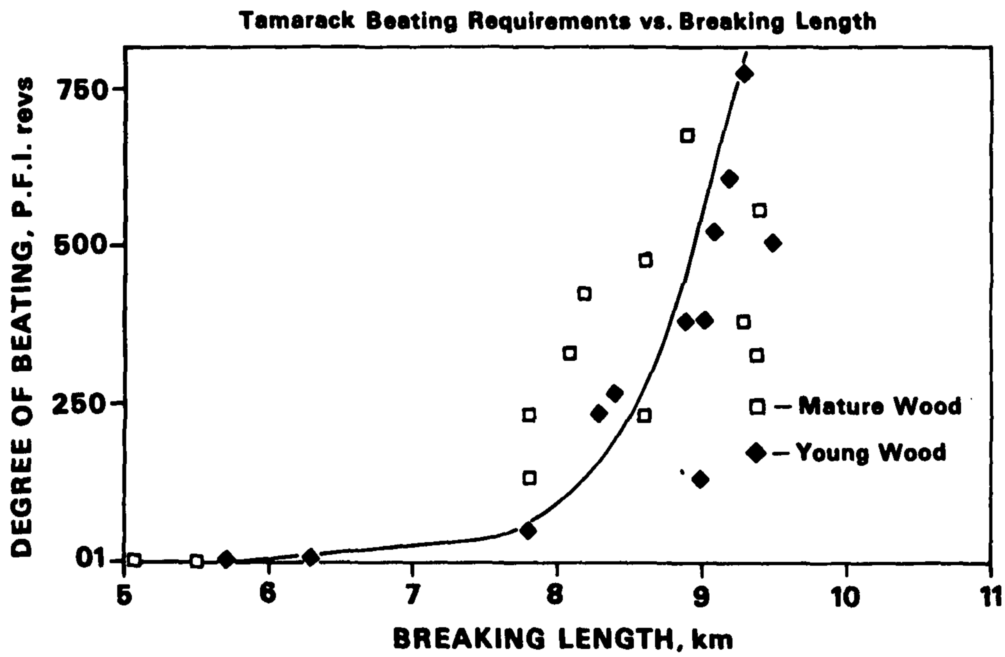

Figure 17. Tamarack beating requirements vs. breaking length. Breaking length = 5.58 + 0.54 logx, x = degree of beating; standard error of estimate = 0.46.

CONCLUSIONS

The wood from the 26-year-old tamarack had a relatively high specific gravity (0.41), high levels of juvenile wood, 35% heartwood, and produced pulp yields that were equal to the yields from mature tamarack chips. Additionally, the kappa 50 young wood pulps had Cuene viscosities 4 to 5 units higher than the mature wood pulps, while the viscosity of the kappa 30 young wood pulps were about equal to the kappa 30 mature wood pulps. Pulping rates, based upon H-factor/kappa number comparisons, were the same for the two tamarack wood sources and they pulped faster than the larch and jack pine control chips but not as rapidly as red pine.

The two sources of tamarack pulp (mature and young wood) bleached without difficulty to a G.E. brightness of 88 and had very similar bleaching chemical requirements. The two sources of pulp also had comparable refining requirements but developed lower than anticipated maximum breaking length.

The pulps from the plantation grown tamarack, when evaluated at higher sheet densities, had comparable tear index, slightly lower burst (10 to 12%), modestly lower breaking length (7 to 12%), and slightly lower TEA values (6 to 10%), when compared with pulps produced from tamarack mature wood. The cited strength differences between young and mature wood pulps were confined to a narrow range of sheet densities, and in no instance were the overall differences between wood sources statistically significant.

COMPARISONS WITH EARLIER EVALUATED RED PINE, JACK PINE, AND *LARIX* SPECIES

The usefulness of pulps from tamarack were evaluated further by comparing the data generated in the above described study with the yield, pulping rate, refining requirements, and paper strength information for red pine from Project 3409, Progress Report Seven and the earlier published data for mature jack pine and plantation larch.[12]

When the newly acquired tamarack pulping rate data are compared with the earlier Project 3409 pulping rate information for jack pine, red pine, and larch species (Fig. 18), it becomes evident that tamarack young wood and mature wood pulped with greater ease than jack pine and larch and less rapidly than red pine. At kappa 30, for example, H-factor values for tamarack were 7% less (1707 vs. 1832) than for age 18 European larch plantation trees. Differences are even greater when the comparison is made with jack pine and hybrid larch.

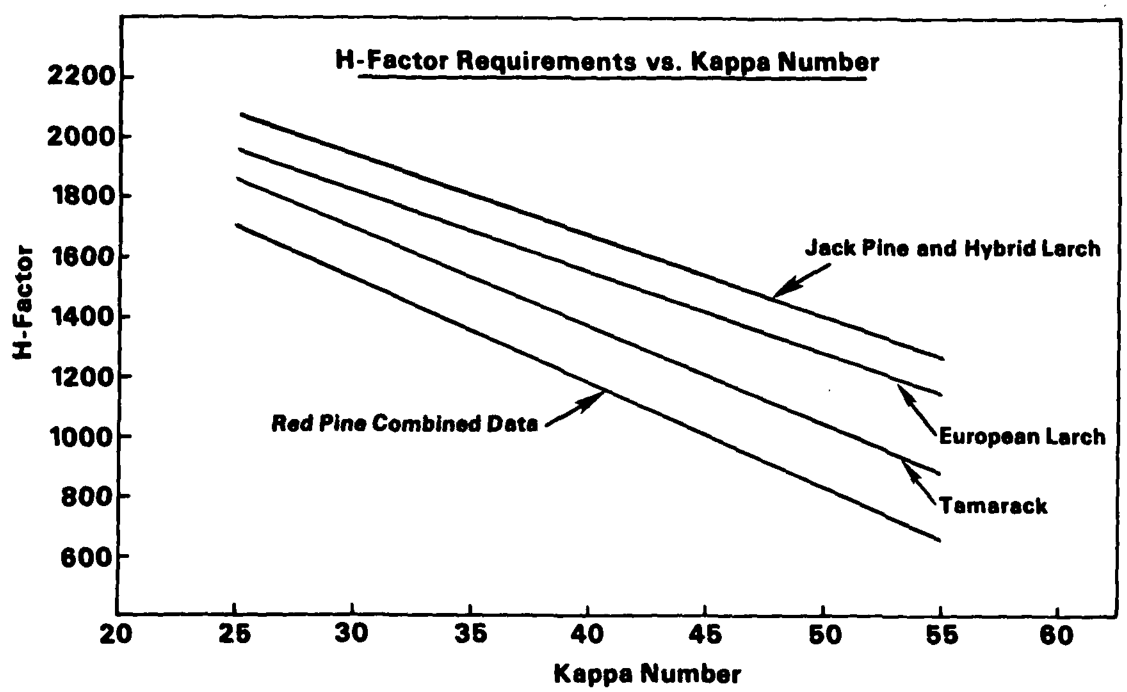

Figure 18. Comparison of H-factor requirement vs. kappa number for tamarack with similar data for red pine, European larch, jack pine, and hybrid larch.

Kraft pulp yield data available from this and earlier studies have been adjusted to kappa 35 to facilitate comparisons (Table 14). Pulp yields evaluated in this latest study were comparable to yield data from mature jack pine pulpwood bolts (44.0 vs. 44.6). This comparison suggests younger plantation grown tamarack (age 26 years) have unscreened pulp yields (44.0% at kappa 35) that are only 1% less than jack pine plantation thinnings but are less than red pine "mature wood," European larch plantation trees, and hybrid larch plantation trees by 4.0 to 5.2%.

Table 14. Summary of kraft pulp yields.

Material	Tree Age, year	Kappa 35 Unscreened Pulp Yield, %[a]	Data Source
Red pine plantation trees[b]	22	46.0	3409 Progress Report Three
Jack pine plantation trees[b]	25	45.0	3409 Progress Report Three
European larch plantation trees	18	48.0	3409 Progress Report Three
Japanese larch plantation trees	22	45.6	3409 Progress Report Three
Hybrid larch plantation trees	23	49.2	3409 Progress Report Three
Jack pine pulpwood bolts	55	44.6	3409 Progress Report Three
Red pine plantation "thinnings"	24	45.7	3409 Progress Report Seven
Red pine plantation "mature wood"	49	48.5	3409 Progress Report Seven
Tamarack plantation "thinnings"	26	44.0	3409 Progress Report Eight
Tamarack native "mature wood"	69	44.0	3409 Progress Report Eight

[a]All pulp yields were adjusted to kappa 35.
[b]Data provided by a cooperating firm.

The energy requirements for refining the tamarack pulps were compared with the requirements of earlier pulped species. The comparisons were made by determining the level of refining required to reach specific breaking length levels (plotting breaking length vs. degree of beating). The mature wood tamarack pulps refined with a little more difficulty than the young wood pulps but differences were not statistically significant. Figure 19 compares the tamarack young wood pulps (kappa 30 + kappa 50) with the kappa 50 pulps of hybrid larch, mature jack pine bolts, and 18-year-old European larch. The comparison demonstrates that pulps from plantation grown tamarack (young wood) require greater refining to reach a specific breaking length and develop a lower maximum breaking length than the jack pine and European larch pulps. Tamarack pulps do not differ greatly from hybrid larch in overall refining requirements.

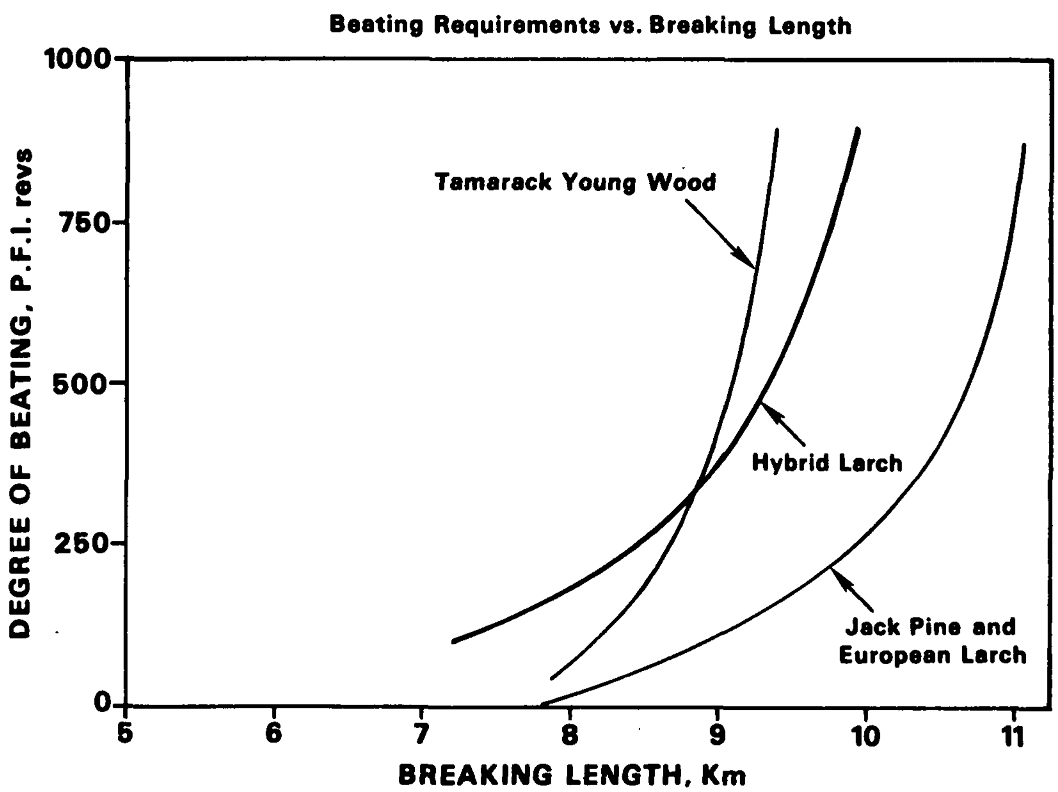

Figure 19. Beating requirements vs. breaking length comparison of tamarack young wood pulps with kappa 50 pulps of hybrid larch, jack pine, and European larch. Breaking length of tamarack young wood pulps = 5.98 + 0.497 logx, standard error of estimate = 0.32.

The tamarack young wood pulps and mature wood pulps developed adequate but significantly lower (18%) breaking length than the jack pine control and European and hybrid larch pulps when evaluated at equal sheet densities (Fig. 20). When, however, the tamarack pulps are compared with jack pine and 18-year-old European larch at equivalent breaking length, the pulp strengths are very promising. Figures 21, 22, and 23 illustrate what happens to tear, burst, and TEA when tamarack pulps are refined to obtain a satisfactory breaking length. The newly generated data were plotted with the results from the larch, red pine, and jack pine. This approach allows the comparison of the strength properties of pulps from tamarack with information from the above species at a constant breaking length. Briefly, these pulp strength comparisons demonstrate that pulps from tamarack, at breaking length 9, for example, had

1) 15% lower tear index (13.5 *vs.* 11.5),
2) 5% greater burst index (7.3 *vs.* 6.9), and
3) equal TEA (111.0 *vs.* 112.0)

when compared to pulps from 18-year-old European larch and mature jack pine pulpwood bolts. Comparisons at other breaking length levels are possible using the data in these figures.

The use of tamarack as a source of conifer pulp represents an alternative to using slow growing black spruce for poorly drained, frost-prone sites, and has produced excellent growth on upland sites. Tamarack chips cook readily and the pulps refine with only modestly greater beating requirements than jack pine and other *Larix* species. The tamarack pulps do not develop as high a maximum breaking length as most other larch pulps evaluated but when compared at equivalent breaking length have only modestly lower tear and comparable burst and TEA.

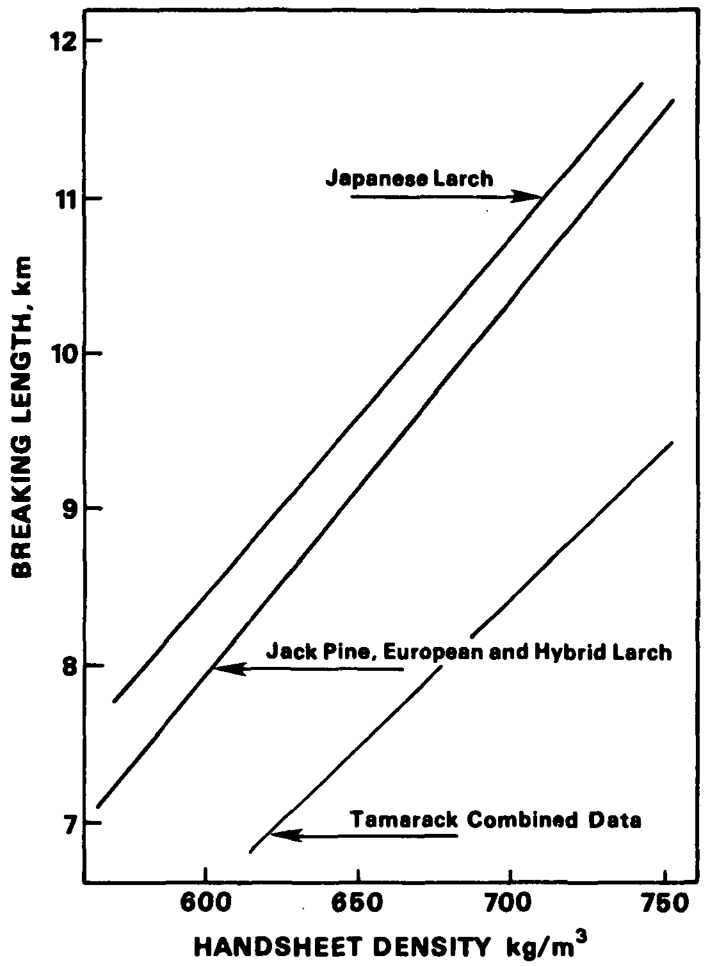

Figure 20. Breaking length vs. handsheet density. Tamarack pulps have lower breaking length values when evaluated at comparable handsheet densities.

The tamarack pulps evaluated in this study bleached readily to a G.E. 88 brightness and appeared to have only slightly higher bleaching chemical requirements than pine and larch pulps. The principal drawback to the use of tamarack appears to be the 4 to 5% lower pulp yield when compared to red pine and exotic Larix species. The wood property and pulp strength differences between mature wood and young wood were not as great as anticipated. This appears to have resulted because the growth rate and age differences between the two sources were not as great as required to produce the expected pulp strength differences.

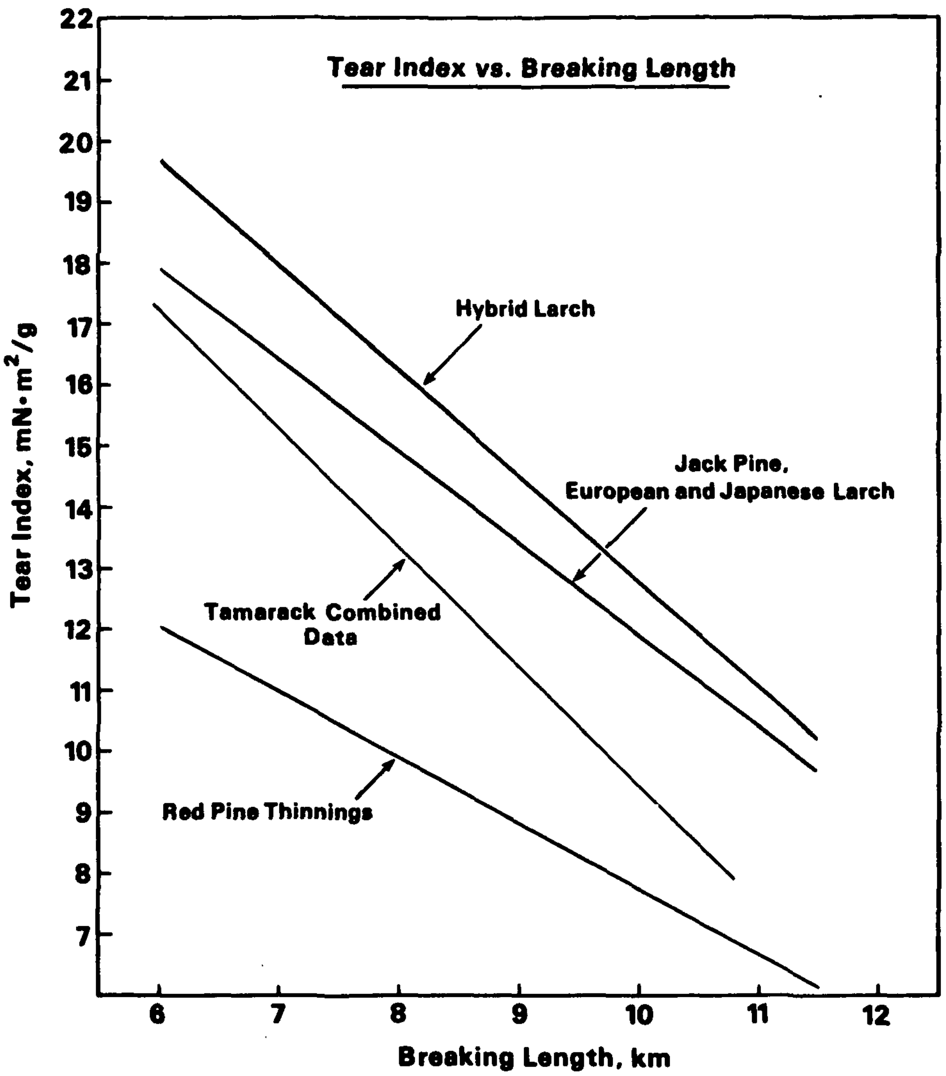

Figure 21. Tamarack pulps were 6-20% lower than jack pine and European and Japanese larch when evaluated at comparable breaking lengths.

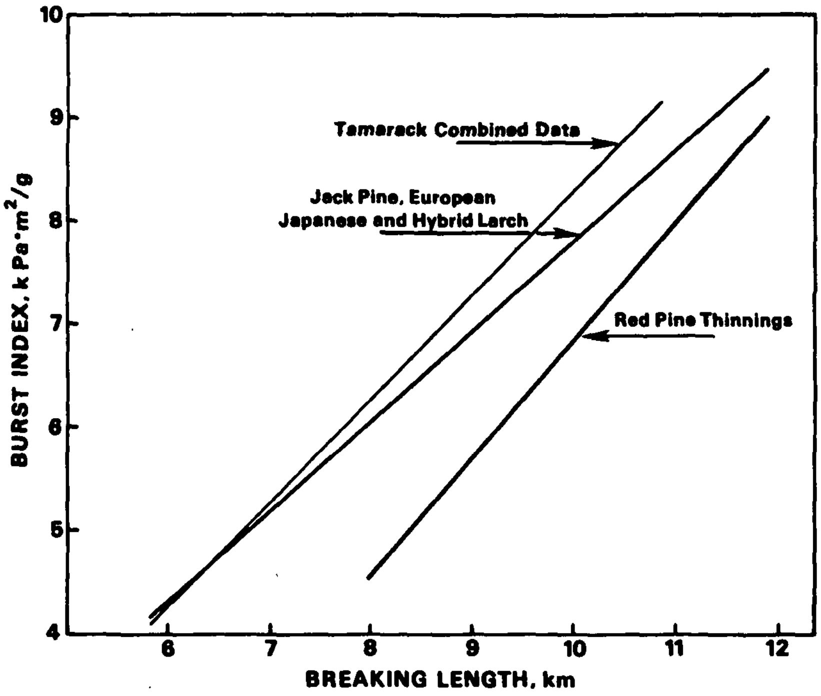

Figure 22. Burst index vs. breaking length. Burst index for tamarack is about the same as jack pine, European, Japanese and hybrid larch. At breaking length 9 km the difference is approximately 5%.

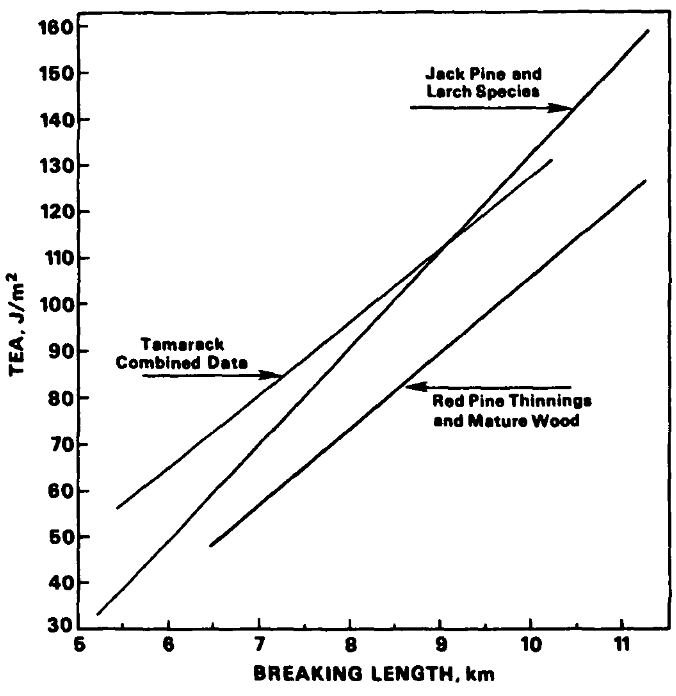

Figure 23. TEA vs. breaking length. Comparison of pulps at equivalent breaking lengths demonstrated that tamarack pulps have TEA levels similar to jack pine and larch species and greater than red pine.

PLANS FOR 1988/89

Work in the coming year will include the planting of 10,000 bareroot 2-0 hybrid larch seedlings. The grafting work will emphasize replacements of ramets in existing seed orchards and new clones for additional European larch seed orchards. Controlled pollinations will be undertaken, flower availability permitting. Flower stimulation treatments undertaken this past spring will be evaluated and additional treatments applied this spring. Replicated trials and plantings scheduled for evaluation will be measured. Larch seed acquisition from documented origins will continue. A hybrid larch seed orchard will be planted in Maine. Pursuit of the activities listed above may exceed available time and funds. Work will proceed according to priorities set during discussion at the annual meeting. The level of time and funding devoted to each activity will also be discussed.

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APPENDIX

A code system devised for handling parent trees, crosses, and clones in the aspen project has proven to be an efficient and descriptive method. A similar system was devised for the larch project. Most tree improvement programs use a simple numerical system for labelling materials. Although these systems have the advantage of rapid labelling and filing, they limit the usefulness of plot and tree tags in the field. Without a cross reference to the particular plant material the label number provides little information.

The utility of the aspen identification system has been proven over 30 years of use. It incorporates into the system the ability to identify the species of selected parent trees, the type of cross or seedlot, the parentage of controlled crosses, a method of designating clones, and the year the trees were selected or the cross was made or seedlot acquired. The following list alphabetically gives the symbols encountered in the larch project record system.

LD = *Larix decidua*
LDa = *L. dahurica*
LG = *L. gmelini*
LL = *L. leptolepis*
LS = *L. sibirica*
S-1, S-2, S-3 ... = selected individuals
TK = *L. laricina*
X = cross or seedlot

To illustrate, LD-10-80 = the tenth *Larix decidua* clone selected in 1980; XLD-LL-1-79 is the first seedlot acquired in 1979 and is a cross between a *L. decidua* female (in hybrid cross designations, the female parent is listed first and the male second) and a L. leptolepis male; XLL-12-59, S-1 is the first selected individual from the 12th seedlot acquired in 1959 involving L. leptolepis parentage.

Although this system may appear cumbersome at first glance, once it is understood it becomes a very useful method of identifying larch materials in the field without having to carry extensive records or wait until returning to the office to determine what was looked at.

Table 15. European larch parent tree selections.

Material	Origin	Distribution Group[a]	Clone Origin
LD-10-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-11-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-12-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-1-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-2-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-3-80	Wroclaw, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-4-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-5-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-6-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-7-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-8-80	SSUI[b]	Alpen	Wisconsin DNR, LaCrosse, WI
LD-9-80	SSUI[b]	Alpen	Wisconsin DNR, LaCrosse, WI
LD-10-80	SSUI[b]	Alpen	Wisconsin DNR, LaCrosse, WI
LD-11-80	Tirol, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-12-80	Rundforbi, Denmark	Sudeten	Canadian Forestry Service, Chalk River, Ont.
LD-13-80	Rundforbi, Denmark	Sudeten	Canadian Forestry Service, Chalk River, Ont.
LD-14-80	Rundforbi, Denmark	Sudeten	Canadian Forestry Service, Chalk River, Ont.
LD-15-80	Rundforbi, Denmark	Sudeten	Canadian Forestry Service, Chalk River, Ont.
LD-16-80	Zagnansk, Poland	Sudeten	Canadian Forestry Service, Chalk River, Ont.
LD-17-80	Zagnansk, Poland	Sudeten	Canadian Forestry Service, Chalk River, Ont.
LD-18-80	Unknown	Unknown	U.S. Forest Service, Rhinelander, WI
LD-19-80	Nodebo, Denmark	Sudeten[b]	Danish Forest Service, Humlebaek, Denmark
LD-20-80	Kronborg, Denmark	SSUI[b]	Danish Forest Service, Humlebaek, Denmark
LD-21-80	Palsgaard, Denmark	Sudeten	Danish Forest Service, Humlebaek, Denmark
LD-22-80	Nodebo, Denmark	Sudeten	Danish Forest Service, Humlebaek, Denmark
LD-23-80	Unknown	Unknown	Hammermill Paper Co., Warren, PA
LD-24-80	Unknown	Unknown	Hammermill Paper Co., Warren, PA
LD-25-80	Unknown	Unknown	Hammermill Paper Co., Cattaraugus, NY
LD-26-80	Unknown	Unknown	Hammermill Paper Co., Warren, PA
LD-27-80	Unknown	Unknown	Hammermill Paper Co., Warren, PA
LD-28-80	Unknown	Unknown	Hammermill Paper Co., Mina Hollow, PA
LD-29-80	Unknown	Unknown	Hammermill Paper Co., Mina Hollow, PA
LD-30-80	Unknown	Unknown	Hammermill Paper Co., Mina Hollow, PA
LD-31-80	Unknown	Unknown	Hammermill Paper Co., Mina Hollow, PA
LD-1-81	Rundforbi, Denmark	Sudeten	Canadian Forestry Service, Chalk River, Ont.
LD-2-81	Zagnansk, Poland	Polen	Canadian Forestry Service, Chalk River, Ont.
LD-3-81	Aroretet, Denmark	Unknown	Danish Forest Service, Humlebaek, Denmark
LD-4-81	Palsgaard, Denmark	Polen	Danish Forest Service, Humlebaek, Denmark
LD-5-81	Nodebo, Denmark	Polen	Danish Forest Service, Humlebaek, Denmark
LD-6-81	Palsgaard, Denmark	Polen	Danish Forest Service, Humlebaek, Denmark
LD-7-81	Unknown	Unknown	Hammermill Paper Co., Warren, PA
LD-8-81	Unknown	Unknown	Hammermill Paper Co., Potter, PA
LD-9-81	Unknown	Unknown	Hammermill Paper Co., Potter, PA
LD-10-81	Unknown	Unknown	Hammermill Paper Co., Potter, PA
LD-11-81	Unknown	Unknown	Hammermill Paper Co., Warren, PA
LD-12-81	Unknown	Unknown	Scott Paper Co., Waterville, ME
LD-13-81	SSUI[b]	SSUI	Scott Paper Co., Waterville, ME

See end of table for footnotes.

Table 15 (Continued). European larch parent tree selections.

Material	Origin	Distribution Group[a]	Clone Origin
LD-1-82	Zagnansk, Poland	Polen	Canadian Forestry Service, Chalk River, Ont.
LD-2-82	Lot 55, Sweden	SSUI	Canadian Forestry Service, Chalk River, Ont.
LD-3-82	Zagnansk, Poland	Polen	Canadian Forestry Service, Chalk River, Ont.
LD-4-82	Berthierville, Quebec	SSUI	Ministry of Lands & Forests, Quebec, Canada
LD-5-82	Berthierville, Quebec	SSUI	Ministry of Lands & Forests, Quebec, Canada
LD-6-82	Berthierville, Quebec	SSUI	Ministry of Lands & Forests, Quebec, Canada
LD-7-82	Berthierville, Quebec	SSUI	Ministry of Lands & Forests, Quebec, Canada
LD-8-82	Berthierville, Quebec	SSUI	Ministry of Lands & Forests, Quebec, Canada
LD-9-82	Berthierville, Quebec	SSUI	Ministry of Lands & Forests, Quebec, Canada
LD-10-82	Berthierville, Quebec	SSUI	Ministry of Lands & Forests, Quebec, Canada
LD-11-82	Dobris, Czechoslovakia	SSUI	University of Michigan, Ann Arbor, MI
LD-12-82	Dobris, Czechoslovakia	SSUI	University of Michigan, Ann Arbor, MI
LD-13-82	Zabreh-Dubicko, Czechoslovakia	Sudeten	University of Michigan, Ann Arbor, MI
LD-14-82	Ruda nad Morovou, Czechoslovakia	Sudeten	University of Michigan, Ann Arbor, MI
LD-15-82	Skarzysko, Poland	Polen	Canadian Forestry Service, Fredericton, N.B.
LD-16-82	Skarzysko, Poland	Polen	Canadian Forestry Service, Fredericton, N.B.
LD-17-82	Schlitz, Germany	SSUI	University of Michigan, Ann Arbor, MI
LD-18-82	Skarzysko, Poland	Polen	Canadian Forestry Service, Fredericton, N.B.
LD-19-82	Schlitz, Germany	SSUI	University of Michigan, Ann Arbor, MI
LD-20-82	Unknown	Unknown	Diamond International, Milo, ME
LD-22-82	Pinczow, Poland	Polen	State of New Hampshire, Hillsboro, NH
LD-23-82	Salzburg, Austria	Alpen	State of New Hampshire, Hillsboro, NH
LD-24-82	Brenensky, Czechoslovakia	Sudeten	State of New Hampshire, Hillsboro, NH
LD-26-82	Salzburg, (Bluhnbach) Austria	Alpen	State of New Hampshire, Hillsboro, NH
LD-27-82	SSUI	SSUI	University of Maine, Orono, ME
LD-28-82	SSUI	SSUI	University of Maine, Orono, ME
LD-1-83	SSUI	SSUI	Champion International, Nathan, MI
LD-2-83	Val di Fiemme, Italy	Alpen	State of New Hampshire, Hillsboro, NH
LD-3-83	County Moray, Scotland	SSUI	State of New Hampshire, Hillsboro, NH
LD-1-84	SSUI	SSUI	State of Maine, Atkinson, ME
LD-1-85	Kroscienko Forest Dist. Poland	Polen	IPC Larch Trial I, Eagle River, WI
LD-1-86	Morayshire, Scotland	SSUI	Harvard Forest, MA
LD-2-86	Morayshire, Scotland	SSUI	Harvard Forest, MA
LD-3-86	Czechoslovakia	SSUI	Arnold Arboretum, MA
LD-1-87	Bruntal, Czechoslovakia	Sudeten	Forest Institute of Hesse, Germany
LD-2-87	Krnov, Czechoslovakia	Sudeten	Forest Institute of Hesse, Germany
LD-3-87	SSUI	Sudeten	Forest Institute of Hesse, Germany
LD-4-87	Krnov, Czechoslovakia	Sudeten	Forest Institute of Hesse, Germany
LD-5-87	SSUI	Sudeten	Forest Institute of Hesse, Germany

[a]Four separate distributional groups are recognized within the geographical range of European larch: Alpen, Sudeten, Tatra, and Polen plus several smaller outliers in Rumania. Major genetic differences are found between and within these groupings.
[b]Seed source under investigation.

Table 16. Japanese larch parent tree selections.

Material	Origin	Clone Origin
LL-4-59,S-1	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-4-59,S-2	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-12-59,S-1	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LL-1-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-2-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-3-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-4-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-5-80	Tochigi Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-6-80	Tochigi Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-7-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-8-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-9-80	Latitude 35° 54', longitude 137° 34'	Packaging Corporation of America, Bear Lake, MI
LL-10-80	Latitude 35° 54', longitude 137° 34'	Packaging Corporation of America, Bear Lake, MI
LL-11-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-12-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-13-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-14-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-15-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-16-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-17-80	SSUI[a]	Canadian Forestry Service, Chalk River, Ont.
LL-18-80	SSUI[a]	Canadian Forestry Service, Chalk River, Ont.
LL-19-80	SSUI[a]	Canadian Forestry Service, Chalk River, Ont.
LL-20-80	SSUI[a]	Canadian Forestry Service, Chalk River, Ont.
LL-21-80	SSUI[a]	Canadian Forestry Service, Chalk River, Ont.
LL-22-80	Unknown	Canadian Forestry Service, Chalk River, Ont.
LL-23-80	Unknown	Glatfelter Pulp Wood Co., Hershey, PA
LL-24-80	Unknown	Glatfelter Pulp Wood Co., Hershey, PA
LL-1-81	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-3-81	Nagano Prefecture, Japan	Canadian Forestry Service, Chalk River, Ont.
LL-4-81	Gumma Prefecture, Japan	Canadian Forestry Service, Chalk River, Ont.
LL-6-81	Nagano Prefecture, Japan	Canadian Forestry Service, Chalk River, Ont.
LL-7-81	Nagano Prefecture, Japan	Canadian Forestry Service, Chalk River, Ont.
LL-8-81	Nagano Prefecture, Japan	Canadian Forestry Service, Chalk River, Ont.
LL-9-81	Nagano Prefecture, Japan	Canadian Forestry Service, Chalk River, Ont.
LL-10-81	Nagano Prefecture, Japan	Canadian Forestry Service, Chalk River, Ont.
LL-11-81	Nagano Prefecture, Japan	Canadian Forestry Service, Chalk River, Ont.
LL-12-81	SSUI[a]	Scott Paper Co., Oxford City, ME
LL-2-59,S-1	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-5-82	Hokkaido, Japan	IPC Larch Trial I, Eagle River, WI
LL-6-82	Hokkaido, Japan	IPC Larch Trial I, Eagle River, WI
LL-7-82	SSUI	International Paper Co., Readfield, ME
LL-8-82	SSUI	Glatfelter Pulp Wood Co., Fort Littleton, PA
LL-9-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Huston, PA
LL-10-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Maddensville, PA
LL-11-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Huston, PA
LL-12-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Huston, PA
LL-13-82	SSUI	Diamond International, Milo, ME
LL-1-83	Yatsuga Mts., Japan	University of Wisconsin, Rhinelander, WI
LL-2-83	Yatsuga Mts., Japan	University of Wisconsin, Rhinelander, WI
LL-3-83	Yatsuga Mts., Japan	University of Wisconsin, Rhinelander, WI
LL-4-83	SSUI	University of Wisconsin, Rhinelander, WI
LL-5-83	SSUI	University of Wisconsin, Rhinelander, WI
LL-6-83	Unknown	State of New Hampshire, Hillsboro, NH
LL-7-83	Central Japan	State of New Hampshire, Hillsboro, NH

[a]Seed source under investigation.

Table 17. *Larix gmelini* and *Larix dahurica* parent tree selections seed origin.

Material	Origin	Cooperator and Location
LDa-14-59, S-1	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LDa-14-59, S-2	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LDa-1-83	Unknown	State of New Hampshire, Hillsboro, NH
LG-13-59, S-1	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI

GLOSSARY

FOREST GENETICS TERMS

Clone - A group of plants derived from a single individual (ortet) by asexual reproduction. All members (ramets) of a clone have the same genotype and, consequently, tend to be uniform.

Compression wood - Wood of dense structure formed at the bases of some trees and on the underside of branches in conifers.

Cyclophysis - Abnormal growth that occurs in a graft when scion material is collected from too low an area in the crown.

Cytochromes - Cytochrome a, b, and c are heme-containing proteins widely occurring in cells and acting as oxygen carriers during cellular respiration.

F_1 generation - The first generation of a mating. If each parent is true breeding (homozygous), the F_1 individuals always resemble each other.

F_2 generation - The second generation successive to the parents and produced by crossing or selfing the F_1 individuals. The individuals within an F_2 generation characteristically vary greatly when their F_1 parent or parents are heterozygous.

F_3 generation - The third generation produced by intercrossing or selfing F_2 individuals. Individuals within an F_3 generation characteristically vary greatly.

Full-sib - Progeny, irrespective of sex, having the same male and female parent but from separate fertilizations.

Half-sib - Progeny, irrespective of sex, having only one parent in common.

Hedging - Reducing a plant to a more juvenile stage by repeatedly cutting it back and forcing a large number of shoots.

Heterozygosity - Presence in the same plant of both the dominant and recessive gene. A heterozygous individual characteristically does not breed true.

Homozygosity - Presence in a plant of either the dominant or recessive gene but not both. A homozygous individual breeds true when mated with the same genotype for the character(s) in question.

Inbreeding depression - Loss of vigor and/or fertility through intercrossing or selfing related organisms.

Isozyme (isoenzyme) - Multiple forms of a single enzyme. Isozymes often have different isoelectric points and therefore can be separated by electrophoresis.