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Seed Collection and Seed Quality of *Larix* spp. from Russia
– Initial Phase on the Russian-Scandinavian Larch Project –

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Abstract

Larch (*Larix* Mill.) is one of the most important elements of the boreal forests. The widest distribution of larch in the world is to be found in Russia. The wide genetic variation of larch species in Russia has, to a great extent, not earlier been available for forest research in western Europe. The objective of the Russian-Scandinavian Larch Project is to study the genetics of the four main larch species within Russia, *Larix sukaczewii* Dyl., *L. sibirica* Ledeb., *L. gmelinii* Rupr., and *L. cajanderi* Mayr., and to make future research on genotype-environment interaction in other parts of the northern hemisphere possible. The project started in 1994 and the first step, collection of seed and wood cores, was finished in 2000. The project was initiated and co-ordinated from Sweden. However, it is a result of co-operation between four different Russian research organisations, two partners in Scandinavia, one in Japan and one in the USA. Up to the end of 2000 seed and wood cores were collected from 1005 larch trees distributed over 16 regions and 45 stands. In addition to that larch seed has been bulk collected from 8 stands. Collected seed from 802 open-pollinated families were tested for germination in the summer of 2000. The average germination rate of the seed was 25 %, but with great variation among larch stands and regions.

Key words: *Larix*, Siberian larch distribution, seed collection, seed quality.

Introduction

A major part of the boreal forest of Eurasia is larch in pure or mixed stands. Larch is the most common tree species in Russia. Larch is also an important forest tree species in China, Korea, Mongolia, Tibet and Japan as well as in the boreal and mountain forests of central and eastern Europe and North America (Schmidt 1995). Nine thousand years ago larch was also native tree species in Scandinavian forests, but for some unknown reason it disappeared already in prehistoric time (Kullman 1998). In the middle of the 18th century larch was re-introduced by man into Scandinavia (Schotte 1916).

The main reason for the early interest and introduction of larch into western Europe was primarily the wood quality. The wood of larch was early utilized as construction material for buildings, bridges, ships, etc and appreciated for its mechanical strength and resistance to decay, especially under open-air conditions and in contact with soil and water (Kharuk 1961, Gorchin & Chernetsov 1966, Lomakin 1990, Polubojarinov *et al.* 2000).

Larch trees have unique wood properties. Larch develops coloured, but not wet heartwood and the proportion of it is approximately twice as big as in Scots pine grown under similar conditions. The density, strength and decay resistance of larch heartwood is higher than any other commercial conifer in Europe and approximately 30-60 % higher than the heartwood of Scots pine (Chubinsky *et al.* 1990). In Scandinavia artificial impregnation of Scots pine sapwood has been the common material to use, where high decay resistance has been required. The use of heavy metals and other chemical elements for impregnation of pine wood is of environmental concern. Larch heartwood is a naturally decay resistant material adapted to ecological cycles and a possible substitute to artificially impregnated wood for several purposes, such as for construction of bridges, posts, fences etc. The natural beauty and hardiness of larch wood makes it also suitable as material for furniture, flooring, wood panelling and different kinds of furnishing. Larch wood is therefore suitable as raw material for a wide range of products.

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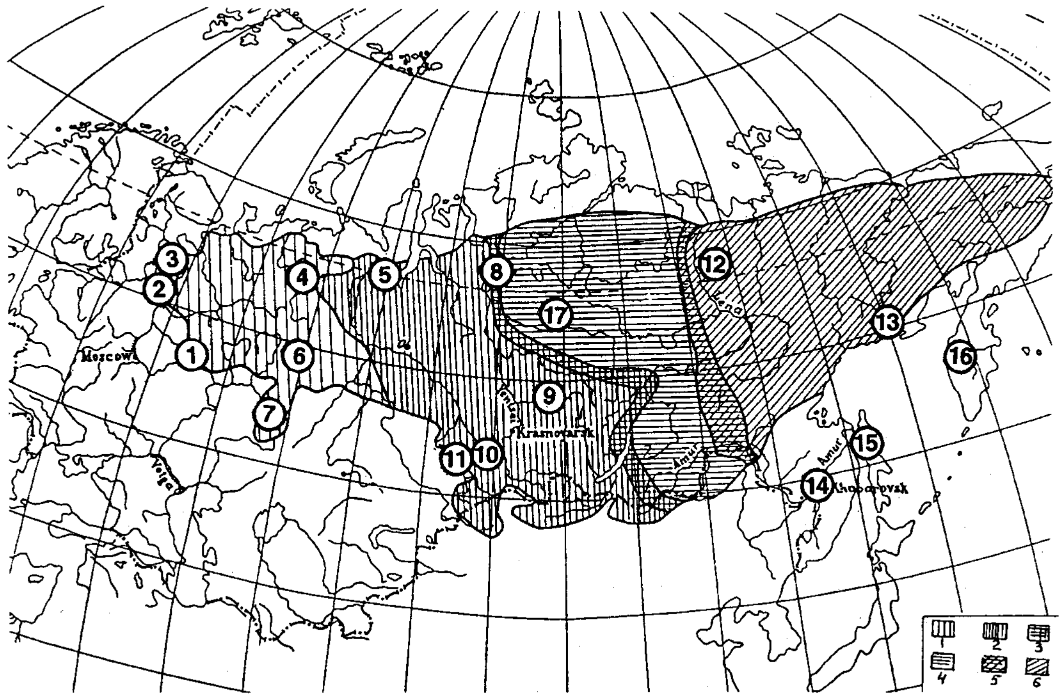

Fig. 1. Distribution areas of the main larch species in Russia and the localities of the 17 seed collection regions of the project according to Table 1.
1=*Larix sukaczewii*, 2=*Larix sibirica*, 3=*Larix czekanowskii*,
4=*Larix gmelinii*, 5=*Larix gmelinii* x *L. cajanderi*, 6=*Larix cajanderi*

The international research on genetics and breeding of larch has been concentrated on European larch (*L. decidua* Mill.), and from the 1950s also on Japanese larch (*L. kaempferi* Carr.) and American larches (*L. occidentalis* Nutt. and *L. laricina* (Du Roi) K. Koch). However, the largest geographical distribution and the largest concentration of larch are to be found in Russia. The forest area of Russia is covered by larch to 40%. The timber volume of larch is estimated about 25,4 bill m^3, corresponding to 34% of the total timber volume in Russia (Milyutin & Vishnevetskaja 1995). At least four different species of larch and their hybrids are distributed over this vast area (Abaimov *et al.* 1998) (Fig. 1). Larch has been extensively studied for a long time in Russia, mainly in its southern area of distribution. However, most of the published material is available only in the Russian language. Reviewing and translation into English of scientific reports previously published in Russian, has recently been made available (Putenikhin & Martinsson 1995, Abaimov *et al.* 1998, Polubojarinov *et al.* 2000)

The already introduced seed sources of Siberian larch in northern Scandinavia, Finland and Iceland have a narrow genetic origin. With some few exceptions the introduced material originates from the area of Archangelsk or the district south of Krasnoyarsk city. A representative collection of breeding material from the wide natural distribution of Siberian larches has never been available for international forest research. Experimental plots of Siberian larch existing in Norway, Finland, Iceland and Sweden indicate a great potential for growth and ecological adaptation of Siberian larch. Considering the wood quality, especially the stem straightness, wood density and decay resistance, the larches native to Russia are superior to larches of most other areas. Efforts to introduce more breeding material of Siberian larches into Scandinavia and Iceland should be of great benefit.

Collection of seed, representing larch over the whole range of genetic and geographic variation has been discussed between Russian and Swedish authorities since the 1950s (Anon 1958). The Russian-Scandinavian larch project started in 1994 with the following objectives:

1. Obtaining seed of larch representing the four main larch species in Russia in order to make future research on larch possible, *e.g.* breeding, studies on genotype-habitat interaction, geographic-taxonomic analysis of the genus *Larix* Mill., genetic structure and polymorphism within and between populations, intra-specific differentiation, etc.
2. Description of stand structure and habitat of the northern Russian taiga.
3. Obtaining wood samples of selected seed trees for investigation of wood quality of larch and its variation over the natural range of distribution in Russia.

Materials and Methods

Plant materials

The project was accomplished in the period 1996-2000. Seed, wood cores and field data were collected in 16 regions from Kamchatka in the east to Onega in the west (Fig. 1). Species name of larch were followed by Abaimov *et al.* (1998). In each region 3-5 stands of larch were identified and seed and wood cores were collected from 20-30 individual trees of each stand (Photo 1-3). Each tree has its own recognition number, which represents region, site in a region, and tree number in a site. For instance, 1B42 means this tree was located in region 1 (Nizhnij Novgorod), site B (Vetluga), and tree number in the site was 20. In total, material was collected from 1005 open pollinated trees distributed over 45 stands (Table 1). In addition to that, larch seed was bulk collected in 8 stands. All selected seed trees were recorded and stands were described by tree species composition and forest vegetation type. The first phase of the project is now completed according to the objectives.

Germination test

In order to obtain information for the coming production of seedlings for progeny trials, a germination and seedling formation test of the collected seed was carried out. The seed was transported from Krasnoyarsk, Ufa and Arkhangelsk to Umeå, Sweden on 4 different occasions 1994-2000. The seed was stored in cold storage (-5° C) until the test was started in June 2000. Fifteen seeds of each seed lot were seeded, one seed per pot in Flexipot 110 ml, filled with *Sphagnum* peat. All 15 seeds from a seed lot were arranged in one plot of 15 pots without replication. In total 803 different seed lots were included in the test. The material was placed in an ordinary green-house used for production of forest tree seedlings (Photo 4). Irrigation was handled manually. Temperature was set to 22° C in daytime and 16° C in the night. However, the temperature was not under complete control in this greenhouse. The formation of seedlings was determined two months after seeding.

Results and Discussion

Details of selected seed trees and stands of larch are summarized in Table 2. Species composition of tree stands was determined on the basis of share of the volume of each tree species in the total growing stock. The composition is expressed in decimal unit, i.e. one unit corresponds to 10% share of given species in the total growing stock (Putenikhin and Martinsson, 1995). Hence, formula 7Pine1Larch2Birch+Spruce means that 70% of the total growing stock consists of summarized volume of all pine trees, 10% of larch, 20% of birch and less than 10% of spruce trees. Forest type is a site in the forest which is characterized by uniform forest-growing conditions, similar species composition and ground cover and which demands the same silvicultural methods (Sukachev and Zonn, 1961). Most of the selected seed trees were more than 100 years old and selected in stands where larch was dominating. The highest and thickest trees were selected in the western and central regions, 1, 6 and 9. The maximum tree height among all selected trees was 46 m and found in region 9B. The larch trees selected in northern and eastern regions were usually smaller. However, the selection of trees was not done according to tree size.

The collected material will be the base for research on Siberian larch species. Up to present, test of seed germination and seedling formation has been accomplished. On an average 25 % of the seeds developed into seedlings. However, the variation between trees, stands and regions was large (Photo 5-7). A seed germination above 50 % was found only in two stands, site 9 A and 16, while the germination was very low in some of the more northern regions (Tab. 3). There are significant differences in the seed germination rate among sites, and also among regions (Tab. 4). Height growth of seedlings also varied greatly among trees, stands, regions and species. For instance, seedlings from Altai region (No. of region: 11) was over twice as high as the ones from Yakutiya (No. of region: 12) (Photo 8).

The quality of seedlings reflects integration of many physiological and morphological characteristics. Ritchie (1984) divided components of seedling quality into material attributes (*e.g.*, dormancy status, water relations, nutrition and morphology) and performance attributes (*e.g.*, root growth potential, hardiness to frost, and resistance to stress). Material attributes are more easily measured than performance attributes, considered individually, however, they often have relatively low predictive value for seedling success unless they fall outside some normal range (Kozlowski and Pallardy, 1997). Continuous investigation of the seedlings should be necessary to understand the total quality of the seeds from Siberia. The collected material of larch seed and wood samples has a very wide geographical range and will generate a lot of useful information in the future, especially in progeny tests which will be established

Table 1. Localities and number of selected seed trees of larch

Number of region	Name of region	Site	Nearest village	Latitude N	Longitude E	Elevation, m	Number of selected seed trees	Species of larch
1	Nizhnij Novgorod	A	Vetluga	57º 30'	45º 10'	-	7	*Larix sukaczewii*
		B	"	57º 30'	45º 10'		29	*Larix sukaczewii*
		C	"	57º 30'	45º 10'		17	*Larix sukaczewii*
		D	"	57º 30'	45º 10'		13	*Larix sukaczewii*
2	Plesetsk	A	Emtsa	63º 05'	40º 21'	100	20	*Larix sukaczewii*
		B	Korasi	63º 00'	40º 25'	120	25	*Larix sukaczewii*
		C	Sheleksa	62º 09'	40º 19'	120	18	*Larix sukaczewii*
3	Onega	A	Leskhoz Onezhskii	64º 01'	38º 15'	110	7	*Larix sukaczewii*
4	Petchora	A	Usinsk	66º 00'	57º 48'		64	*Larix sukaczewii*
5	Salechard	A	Beloyarsk	63º 41'	66º 44'	60	20	*Larix sukaczewii*
		B	Kharp	66º 56'	65º 45'	130	20	*Larix sukaczewii*
		C	Labytnangi	66º 28'	66º 39'	40	20	*Larix sukaczewii*
6	Perm	A	Okhansk, Yugo- Kamsky	57º 19'	55º 27'	160	20	*Larix sukaczewii*
		B	Nyazepetrovsk, Uzaim	56º 09'	59º 32'	460	20	*Larix sukaczewii*
		C	Kyshtym	55º 43'	60º 27'	480	20	*Larix sukaczewii*
		D	Nizhnij Tagil	57º 30'	59º 48'	350	12	*Larix sukaczewii*
		E	Sotrino	59º 27'	60º 59'	110	Mix of 30 trees	*Larix sukaczewii*
7	Ufa	A	Maginsk	55º 45'	56º 58'	370	20 + mix of 10	*Larix sukaczewii*
		B	Miass	54º 58'	60º 07'	380	20 + mix of 10	*Larix sukaczewii*
		C	Zlatoust	55º 07'	59º 30'	600	20	*Larix sukaczewii*
		D	Ziliar	52º 13'	57º 25'	550	Mix of 10 trees	*Larix sukaczewii*
		E	Bolshoy Iremel	54º 33'	58º 57'	1200	10	*Larix sukaczewii*
8	Norilsk (vacant)							*Larix sibirica*
9	Boguchany	A	Boguchany	58º 39'	97º 30'	158	27	*Larix sibirica*
		B	Karabula	"	"	96	25	*Larix sibirica*
		C		"	"	--	23	*Larix sibirica*
10	Novokuznetsk	A		53º 48'	88º 00'	mountain	20	*Larix sibirica*
		B		54º 12'	88º 42'	"	20	*Larix sibirica*
		C		52º 48'	87º 24'		20	*Larix sibirica*
11	Altai	A	Kosh-Agash Tenedu	50º 16'	87º 54'	1630	26	*Larix sibirica*
		B	Kosh-Agash Karnagalu	50º 12'	87º 47'	1580	26	*Larix sibirica*
		C	Kosh-Agash, Turgune	50º 14,5'	87º 3'	1630	26	*Larix sibirica*
12	Yakutiya	A	Zhigansk	66º 45,5'	123º 22'	70	20	*Larix cajanderi*
		B	Zhigansk	66º 51'	123º 21'	80	20	*Larix cajanderi*
		C	Zhigansk	66º 45'	123º 22'	90	20	*Larix cajanderi*
13	Magadan	A		59º 30'	150º 15'	60	25	*Larix cajanderi*
		B		59º 20'	152º 30'	100	25	*Larix cajanderi*
		C		59º 30'	148º 30'	80	25	*Larix cajanderi*
14	Khabarovsk	A	Vaninskyi	49º 08'	149º 00'	90	20	*Larix gmelinii* var. *olgensis*
		B	Vaninskyi	49º 09'	149º 00'	100	20	*Larix gmelinii* var. *olgensis*
		C	Vaninskyi	49º 12'	149º 00'	125	20	*Larix gmelinii* var. *olgensis*
15	Sachalin (missing data)						60	*Larix gmelinii* var. *japonica*
16	Kamchatka (missing data)						60	*Larix gmelinii* var. *kamchatica*
17	Evenkiya	A	Tura	64 19'	100º 13'	285	25	*Larix gmelinii*
		B	Tura	64 19'	100º 14'	310	25	*Larix gmelinii*
		C	Tura	64 17'	100º 16'	270	25	*Larix gmelinii*

Table 2. Data of selected seed trees and stands of larch

Region and site	Mix of tree species	Forest type	Selected larch trees			
			Number of trees per ha	Range of tree height, m	Range of dbh, cm	Age, years
1 A	7Pine1Larch2Birch	Pinetum tiliosum		30-37	36-70	100
1 B	8Larch1Spruce1Birch	Laricetum tiliosum		29-37	48-80	140
1 C	8Larch1Spruce1Birch	Laricetum tiliosum		24-32	23-68	100
1 D	5Pinus1Spruce2Larch2Birch	Pinetum tiliosum		27-33	42-64	100
2 A	6Pine2Larch1Spruce1Birch	Pinetum myrtillosum		13-29	29-58	130
2 B	5Pine5Larch	Pineto-Laricetum vacciniosum		17-28	19-50	150
2 C	5Pine2Larch2Spruce1Birch	Pinetum vacciniosum		16-25	21-42	90
3 A	5Pine3Larch1Spruce1Birch	Pinetum vacciniosum		13-29	29-58	130
5 A	5Larch4Pine1Birch	Lariceto-Pinetum vaccinioso-hylocomiosum	230	15-23	22-44	130
5 B	9Larch1Spruce	Laricetum ledoso-vacciniosum	400	13-19	18-32	100
5 C	9Larch1Spruce	Laricetum nanoso-ledosum	600	8-14	12-24	-
6 A	5Larch4Spruce1Pine	Lariceto-Piceetum tiliosum	100	27-34	34-54	120
6 B	7Larch3Pine	Laricetum herbosum	250	24-27	35-53	110
6 C	6Larch3Pine1Birch	Laricetum vaccinioso-graminosum	180	24-27	40-50	135
6 D	6Larch2Fir1Spruce1Pine	Laricetum herboso-hylocomiosum	200	-	-	130
7 A	7Larch2Pine1Spruce	Laricetum hylocomiosum	200	24-29	28-40	90
7 B	8Larch1Pine1Birch	Laricetum stepposum	270	25-31	38-68	130
7 C	6Larch2Pine2Birch	Laricetum herbosum	260	25-30	35-52	95
7 D	4Larch6Pine	Lariceto-Pinetum herbosum	220	-	-	110
7 E	2Larch5Birch3Spruce	Lariceto-Betuletum magnoherbosum	350	-	-	100
9 A	7Larch3Spruce	Laricetum herbosum	110	27-36	22-40	94
9 B	7Larch2Spruce1Pine+P sib	Laricetum hylocomiosum	110	29-46	36-54	140
9 C	6Larch4Pine	Laricetum herboso-hylocomiosum	145	17-22	28-48	110
10 A	8Larch2Birch		275	15-21	24-40	90
10 B	8Larch1Birch1Fir		210	17-22	24-44	95
10 C	7Larch2Birch1Aspen		184	16-22	28-40	110
11 A	10Larch	Laricetum stepposum	276	9-16	22-43	-
11 B	10Larch	Laricetum stepposum	573	11-19	21-41	-
11 C	10Larch	Laricetum stepposum	250	9-15	19-32	-
12 A	10Larch	Laricetum vaccinioso-hylocomiosum	780	5-9	10-22	120
12 B	10Larch	Laricetum vaccinioso-hylocomiosum	1100	5-14	8-28	160-180
12 C	10Larch	Laricetum fruticoso-vacciniosum	450	7-11	9-24	200+
13 A	10Larch	Laricetum herbosum	340	14-20	14-24	60-80
13 B	10Larch	Laricetum herbosum	408	20-26	16-28	100-180
13 C	10Larch	Laricetum herbosum	320	14-22	16-38	200+
14 A			60			
15 A			60			
16 A			60			
17 A	10Larch	Laricetum vaccinioso-lichenosum	275	8-15	10-23	83-330
17 B	6Larch4Birch	Laricetum vaccinioso-hylocomiosum	775	11-18	9-19	36-73
17 C	10Larch +Pinus sibirica	Laricetum fruticuloso-lichenoso-hylocomiosum	425	8-22	8-33	65-340

in different parts of the northern hemisphere. Seedling production from the collected seed material for establishment of progeny field tests will start in the spring of 2002. Initially, three experimental areas will be established in Sweden, two in Norway and one in the northwest of Russia. Seed material is also reserved for different genetic experiments in Japan, Canada and Russia. Research on European, Japanese and American larch species has already a long history (Langner 1958, Schober 1958, Farnsworth *et al.* 1972, Toda and Mikami 1976, Schober 1977, Giertych 1979, Schober & Rau 1992, Wyckoff *et al.* 1992, Martinsson 1995, Jaquish *et al.* 1995) while the international co-operation on research of Asian larch species has been rather limited outside Russia and China. The collected seed material will make future international co-operation possible on research on larch, representing a very wide genetic and geographic distribution of larch.

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Table 3. Average germination and seedling formation (%) of collected larch seed

Region	Site A	Site B	Site C	Site D	Site E	Total
1	24.8	47.8	41.6	22.6		38.8
2	32.2	25.1	3.3			21.2
3	20.0					20.0
5	13.7	15.3	21.3			16.8
6	24.0	28.0	31.7	4.4		24.0
7	13.0	37.3	26.3		40.0	28.8
9	52.3	44.8	43.6			47.5
10	21.3	21.3	18.7			20.4
11	70.8	24.4	64.5			53.1
12	46.0	34.3	37.7			39.3
13	18.6	20.0	14.4			17.7
15	39.9					39.9
16	50.9					50.9
Total average						25.2

Table 4. ANOVA of seedling formation

Factor	Sum of Squares	Df	F-value	Significance
Site	4386.43	35	18.4	<0,001
Region	2904.36	12	28.5	<0.001

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Photo. 1. Seed trees from European Russia and Urals.
top left; Onega (region No. 3), top right; Labytnangi, Salechard (region No. 5), bottom left; Plesetck (region No. 2), bottom right; Vetluga, Vizhnij Novgorod (region No. 1) Each tree has its own recognition number, which is the combination of numerals and alphabet representing region, site in a region, and tree number in a site.

Photo. 2. Seed trees from central Siberia.
top left; Novokuznetck (region No. 10), top right; Boguchany (region No. 9), bottom left; Altai (region No. 11), bottom right; Miass, Ufa (region No. 7)
Each tree has its own recognition number, which is the combination of numerals and alphabet representing region, site in a region, and tree number in a site.

Photo. 3. Seed trees from central and eastern Siberia.
top left; Zhigansk, Yakutiya (region No. 12), top right; Magadan (region No. 13), bottom left; Boguchany (region No. 9), bottom right; Tura, Evenkiya (region No. 17)
Each tree has its own recognition number, which is the combination of numerals and alphabet representing region, site in a region, and tree number in a site.

Photo. 4. Germination test in green house.

Photo. 5. Seedlings developed from seeds from Vizhnij Novgorod (region No. 1)

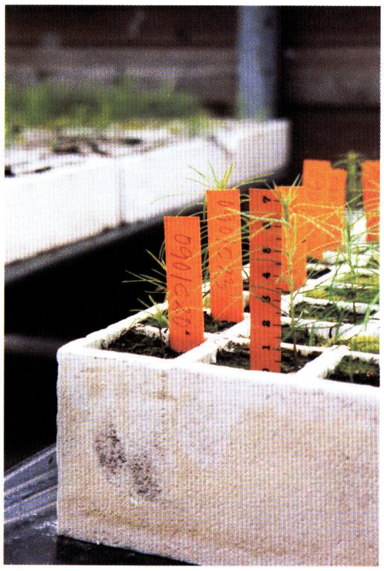

Photo. 6. Seedlings developed from seeds from Ufa (region No. 7)

Photo. 7. Seedlings developed from seeds from Boguchany (region No. 9)

Photo. 8. Seedlings developed from seeds from Altai (region No. 11) and Yakutiya (region No. 12). Four lines in the left side are Altai, and four lines in the right side are Yakutiya.