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Height Increments and Survival of *Pinus sylvestris* Climatypes in Provenance Trials in the Western Trans-Baikal Region

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Abstract

Scots pine provenance trials established in Buryatia (western Trans-Baikal region) in Siberia were studied. The features of linear increment of 57 progenies representing a significant part of the total Scots pine area in Russia are shown. Interpopulation variability in Scots pine progenies' linear increment index was found to increase in provenances during optimal moisture conditions during growing seasons. The correlation coefficients, between the linear increment indexes and the climatype survival rate, showed a mostly positive link based on the contrast in conditions of the originating maternal populations.

Key words: climatypes, *Pinus sylvestris*, provenance trials, survival, height increment

Introduction

Scots pine provenance trials (*Pinus sylvestris*) are more common than other major woody species; they are carried out in Europe, Asia, and on other continents (Albensky 1959; Rohmeder and Schönbach 1959; Pravdin 1964; Konovalov and Pugach 1968). These trials revealed a wide range of genetically different Scots pine varieties (Wright and Bull 1963; Przybylski *et al*. 1976; Wright 1976; Morgenstern 1996).

Recent studies have shown that the major forest woody species to be among the most reliable indicators of environmental changes (Giertych and Mátyás 1991; Shutyaev and Giertych 1997). Therefore, the results of the major woody species (including Scots pine) provenances trials are actively used in spatial modeling of intraspecies taxon changes and location in the context of global climate change (Rehfeldt *et al*. 2002, 2003; Savva *et al.* 2003). In this report, I tried to analysis of the variation of Scots pine that distributed through the central Siberia from the view of effort of forest tree breeding in future.

Materials and Methods

Scots pine provenance trials have been conducted in the Republic of Buryatia, West Zabaikalye, Russia, as a part of a full-scale experiment in establishing a provenance trial network covering the major woody species of Russia and adjacent countries. These provenance trials are studied using a common methodology (1972).

Scots pine provenance trials were established in the western Trans-Baikal region (51º50' NL; 110º EL) in 1979 by the V.N. Sukachev Institute of Forest.

The aim of the studies was to identify Scots pine biological characteristics with respect to their intraspecific differentiation and to analyze sustainability and productivity of Scots pine tree progeny from differing ecological and geographical origins when moved to an extreme arid continental climate.

Western Trans-Baikal region is characterized by an extreme continental climate – a continentality of 90% (Borisov 1967) with high daily and annual air temperature fluctuations and markedly low precipitation (Zhukov 1960).

According to the Russian forest vegetation zoning system (Korotkov 1994), the Scots pine provenances under study are situated in the sub-taiga-steppe Scots pine forest belt in the Selenga forest province, of the southern Trans-Baikal forest region. The major woody species of this forest province are larch and Scots pine stands of moderate productivity. The percentage of forested land is 35%.

The provenance trials were established in a forest-steppe site near the southern Scots pine distribution limit (51º50' NL; 110º EL). Each plantation was 10 ha in size. Our provenance trials involved progenies of 59 climatypes representing a considerable part of Scots pine distribution area: 27 from European Russia, 28 from Siberia, 1 from Kasakhstan, and 3 from the Russian Far East (Fig. 1). Two of the climatypes from European Russia were totally eliminated during the first several years. To establish the provenance trials, seeds from Scots pine stands of the most regionally diverse Russian forest types were used. For example, taiga Scots pine seeds from stands with feather moss-bilberry and feather moss-whortleberry-dominated ground vegetation.

The climatypes were presented in two replications. The survival of each climatype was evaluated as a percentage of surviving trees, with the total number of trees planted in 1979 as 100%. For calculating height increment, 50 trees from each replication were taken. Where survival rates were low (southern and central European climatypes), all trees were used in the analysis.

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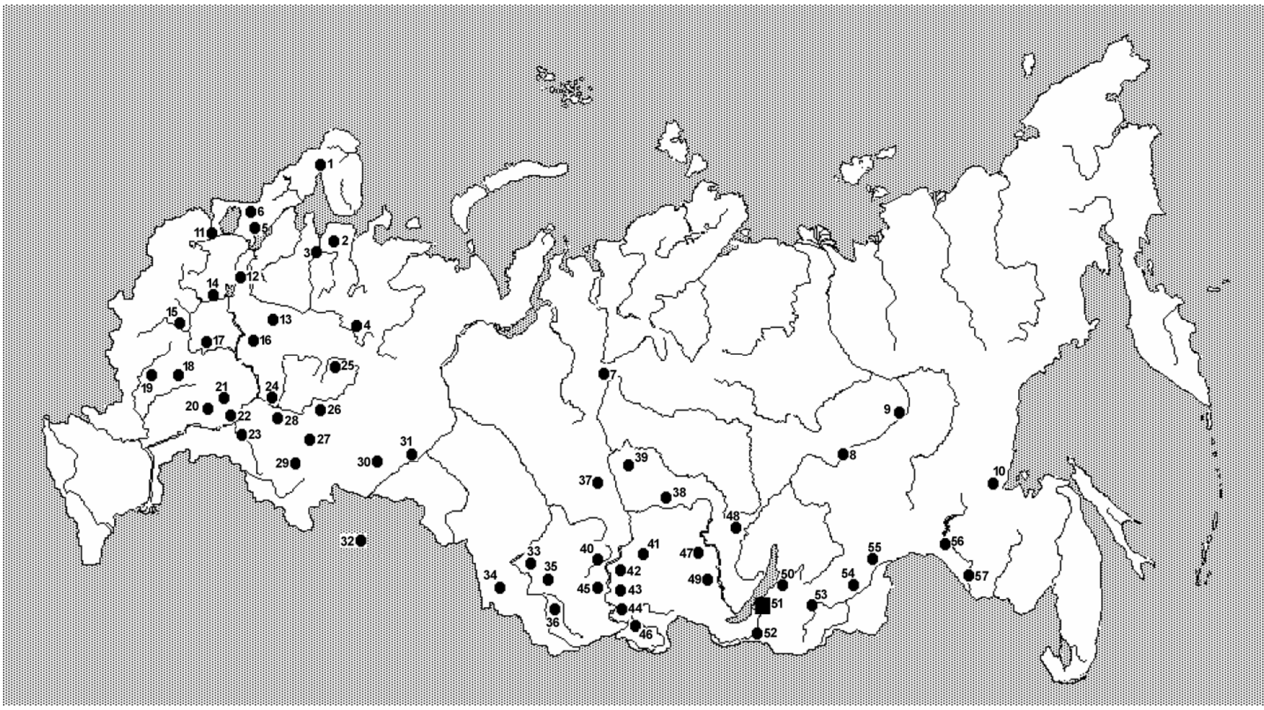

Fig. 1. Origin of Scots pine seeds used in provenance trials in the West Zabaikalye. (Numbering of climatypes is given in accordance with Table 2)
■ - The place of provenance trials; ● - Place of origin of climatypes

Results and Discussion

This paper describes some of the results of the long-term study of seasonal height increment of Scots pine tree progenies of differing geographical origins.

The inventories carried out at an early age of the provenances (Cherepnin 1999; Novikova 2002) showed 100% elimination of the most southwestern climatypes from the Bryansk region (Bryansk provenance 53º15' NL; 34º15' EL,) and Ukraine (Dubrovitsa provenance, 51º32' NL; 26º36' EL), which were the least adaptable to the study area’s environmental and climatic conditions. Our study found considerable survival differences between the climatypes that were moved to the western Trans-Baikal region. The first stage of elimination of individuals not adaptable to the environmental and climatic conditions occurred at an early progeny age. The climatype sustainability indexes appeared to stabilize when the provenances became 15 years old (Novikova 2002), with the progeny survival rate ranging from 2.7 - 63% depending on the provenance. The 20-year-old trees killed by fire were also measured and included in the analysis. Within the given amount of time, enough progenies of the climatypes have survived to consider adapted to the conditions of West Zabaikalye region. The second stage of elimination will occur in the provenances’ crown closure period due to an increase in competition among individuals for light, moisture and nutrition and the impact of hereditary features of the climatypes.

Along with the indices of survival (Novikova 2003), annual height increments of Scots pine from various geographical origins were studied during a variety of years (Novikova 2005). The analysis of growth, i.e. height increment indices in separate, contrasting hydrothermal regime growing seasons allowed us to estimate the speed of Scots pine climatypes growth in connection with fluctuations in weather factors and reaction to stress caused by moisture deficits or low temperatures. The strongest impact of low-temperature stress revealed itself in the elimination of low-sustainable individuals in the 4-5th years. The older trees (15-year old) of all climatypes suffered slight injuries to new foliage caused by late light frosts in the period of most active growth (June) when overnight temperatures reached -12ºC.

Fig. 2. Low temperature injuries of trees’ sprouts.

In the region of our trial (West Zabaikalye) where moisture is a limiting factor plants' seasonal growth directly depends on the amount of precipitation in May-June of the growing season.

From long-term studies it was found that the linear increment of Scots pine climatypes, depending on the amount of moisture supplied during the growing season, was on the whole not characterized by high indices due to the young age of the progenies (up to 15 years old) and the extreme natural-climatic conditions of the trial region. A characteristic of the growing season is that the least precipitation (Fig. 4) occurs in April-May and a bit more in June. The amount of the linear increment is mostly influenced by June precipitation as this month has the most intensive vegetation growth. The dynamics of seasonal height increment of all climatypes is characterized by sharp decreases in dry periods, and increases in the wetter years.

Therefore, the smallest Scots pine height increments (Fig. 5) can be seen in 1979 when there was little precipitation in May (15.9mm), and an extreme shortage of moisture in June, (3.1mm) accompanied by higher than normal temperatures (Fig. 3) that were closer to those of July (20ºC).

June 1980 was the second driest (16.5mm), and the average temperature was 18ºC. In this year all climatypes experienced small height increments. For the years of 1981, 1985, 1990 the average temperatures for June were about 16ºC and 1981 and 1985 were marked with high precipitation in the growing seasons. The most favorable of the years studied was the growing season of 1985 (33.7mm in May and 85.5mm in June), which also had the largest annual height increments. The growing season of 1990 was characterized by a lack of precipitation in May (2mm) and low precipitation in June (35.8mm), which set conditions for a decrease in linear increments for all climatypes (Figs. 4, 5).

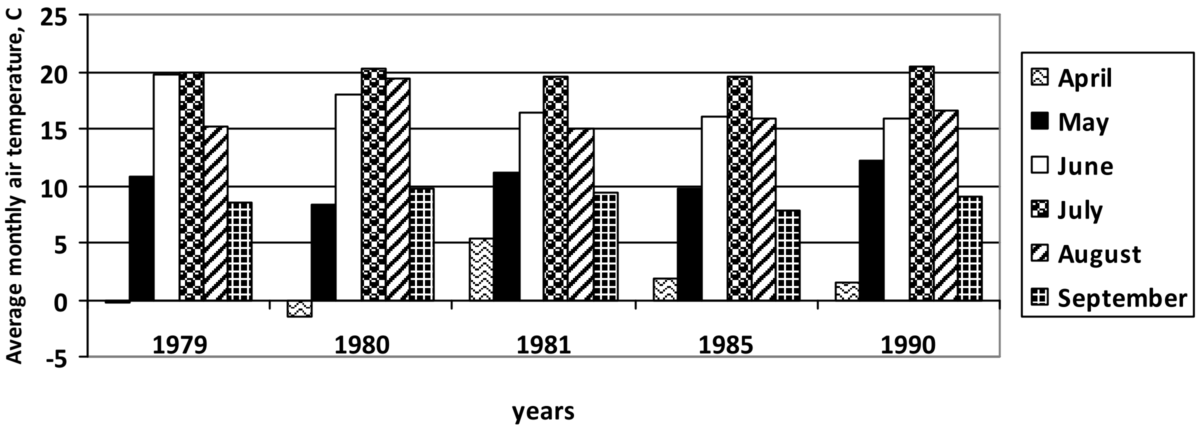

Fig. 3. Average monthly air temperature in the growing season of various years.

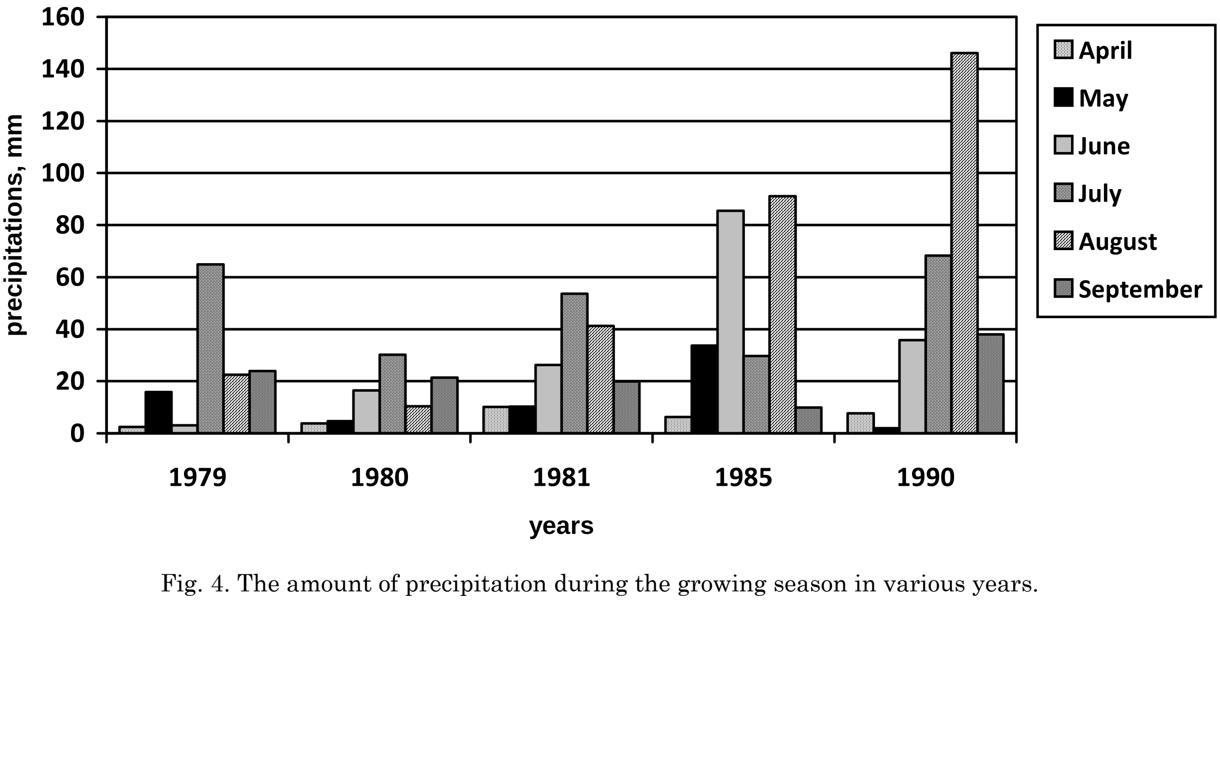

Fig. 4. The amount of precipitation during the growing season in various years.

Long-term observations also found sufficient interpopulation variability of height increments in Scots pine climatypes within their area of origin. In the years studied the obvious variable impacting height increments in all 57 climatypes was a large amount of precipitation in the vegetation periods; variation coefficients by year were: 1979 – 32.5%; 1980 – 20.6%; 1981 – 14.2%; 1985 – 14.7%; 1990 – 32.4%. In looking at this series of values it is evident that the height increments vary the most in vegetation periods with unfavorable precipitation (C_v=32.4-32.5%).

Variability of height increments is also typical of climatypes within physical-geographical provinces. In the case of 1985 (10-year old Scots pine trees) the most intensive growth in most climatypes was in the ones from the central regions of European Russia (20.7-26.2 cm), and the regions of Ural and West Siberia (20-27cm). With localization of maternal plantations farther to the north there were lower increment indices up to minimum values in the climatypes from the Arkhangelsk and Murmansk regions (13.2-16.1cm). According to the climatype progenies index, the amplitude increment of the regions of East Siberia and the Far East was found to be 18.7-25.3cm. The exceptions were the Turukhansk, Olekminsk,Yakutsk, Ayan climatypes representing the northern, north-eastern and eastern regions of the area (15.3-17.1 cm).

It is known that a decrease in the size of the crown and needles, lower transpiration, as well as a sharp reduction of linear growth are adaptive reactions to stress (Suntsov 1984), i.e. Scots pine grown under severe and harsh environmental condition allocates more to roots but not to trunks or branches (Sazonova 1998).

To study the problems of adaptation, the analysis of survival rates of Scots pine geographical progenies in connection with annual height increments is of a special interest. Studies have shown that the seasonal height growth of climatypes from different parts of an area will vary in reaction to extreme conditions in the growing season. For example, in 1985 there was an optimal amount of precipitation in the growing season and there was an increase in height growth, but in contrast to the 1990 growing season it was extremely dry and there was the sharpest decrease of Scots pine linear growth. In Scots pine trees from the Far East the average increment value declined 3.6-4.2 times, and from Yakutiya (Olekminsk and Yakutsk climatypes) it was 3-3.8 times. The decline was much lower (1.2-2 times) in Siberian climatypes, growing in optimal or close to optimal conditions.

The correlation coefficient of increment indices with normalized average annual temperatures in natural stands of source plantations (for all climatypes being investigated) had a negative link of average closeness (R= -0.45). The closer negative link (R= -0.85) reveals itself between these indices for the group of climatypes from the northern regions of European Russia: Kandalaksha, Pinega, Plesetsk, Kortkeros, Pryazha, Sortavala. Moreover, a negative link (R= -0.77) also exists between the indices of survival and height of these climatypes, so the highest survival rate (53% each) is among the climatypes with sufficiently reduced 2.3-2.7 times growth rate under unfavorable growing seasons.

The variability in annual height increments of Scots pine growing in conditions different from the climatypes place of origin is shown in Fig. 5. It shows where climatypes from optimal and the worst conditions occupy the marginal upper and marginal lower positions, respectively.

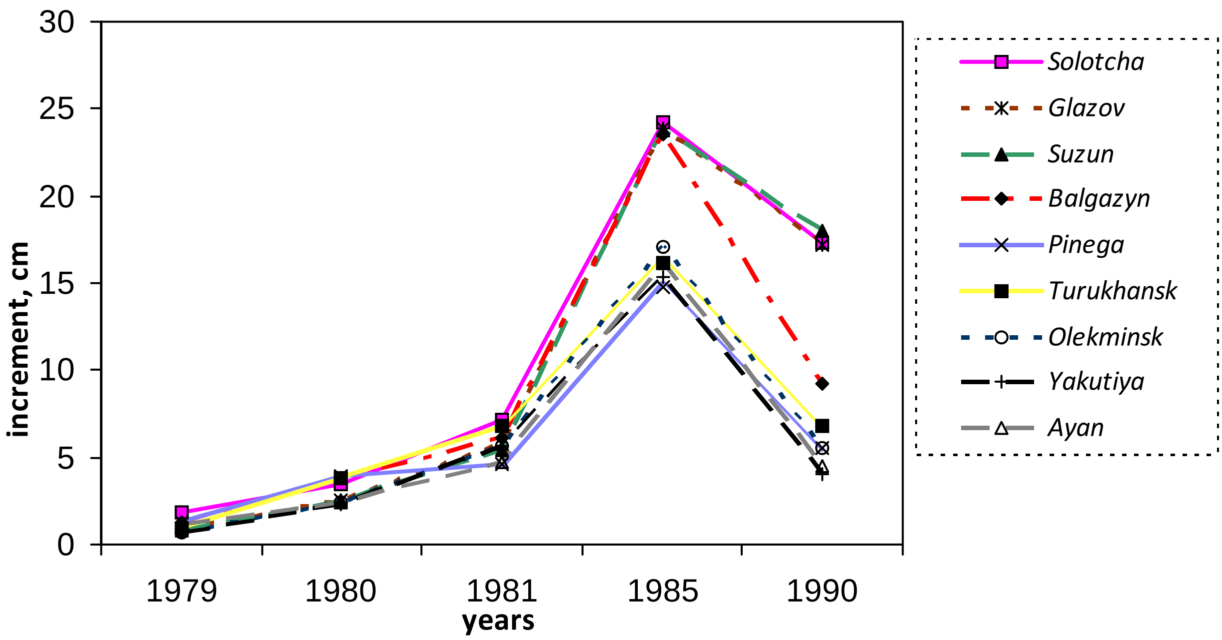

Fig. 5. Seasonal Linear Increments of Scots Pine Climatypes.

Insular coniferous forests in the south of East Siberia are represented in the provenances by Balgazyn, Minusinsk, Zaudinsk and Kyakhta climatypes and occupy an intermediate position.

Under favorable moisture conditions, Scots pine increased in height according to the climatype, however its height growth at unfavorable conditions showed an intermediate value between that at optimal condition and that at the worst condition (Table 1). In Siberian experimental plots of provenances with higher temperature requirements (Novosibirsk territory, North Kazakhstan) the height increments were close to those of the highly productive local and regional climatypes.

Table 2 shows the coefficient of correlation between the survival of climatypes by origin and increment indices in growing seasons with different hydrothermal regimes. Climatypes are joined into subspecies (Pravdin 1964).

Correlation coefficients reflect a positive link between climatypes survival rates with increment indices (R=0.55 and R=0.58 for ssp. *sibirica* Ldb. and ssp. *lapponica* Fries, respectively) (Table 2). These climatypes are also characterized by a positive link of average closeness (R=0.62 and R=0.71, respectively) and continentality indices (Conrad 1947) of the climatypes originating regions with increment indices. This dependence is caused by hereditary adaptive reaction of ssp. *sibirica* Ldb. to stressful climatic factors, which are peculiar to an extreme continental climate (a wide range in day and night temperatures and considerable variation in heat and precipitation during the growing season). Similar reaction of ssp. *lapponica* Fries climatypes along with the continentality of climatypes' originating regions is also influenced by other climatic factors - redundant humidification and low warmth supply. A negative link between these indices is characteristic of the Ssp. *sylvestris* L. (a variety of *Pinus sylvestris*) climatypes, which grow in optimal and close to optimal conditions.

Hence, the average closeness of positive link in general is peculiar to the series of climatypes, whose originating regions differ sufficiently by hydrothermal regime or continentality of climate.

The analysis showed that a decrease of stem share in relation to common phytomass is an adaptive reaction of Scots pine in its struggle for survival and sign of the ability of single climatype to withstand the impact of unfavorable natural-climatic factors, including those in West Zabaikalye where the experiments were conducted.

The given regularity is not typical of marginal populations growing in severe conditions with rigid limits of natural-climatic resources. The following climatypes are related to this type: Yakutsk (Yakutiya), Kandalaksha (Murmansk region), Turukhansk (Krasnoyarsk region), Urumkai (Kokchetav region) and Kamyshin (Volgograd region). Most of them are mildly resistant in new conditions (survival rate is 21-40%).

Analyzing the data obtained in the years of observation it can be seen that the closeness of positive link between average values of annual increment of the 57 studied climatypes and duration of vegetation periods in their places of origin increases with more precipitation. The following correlation coefficients R=0.37; R=0.08; R=0.22; R=0.61; R=0.53 reflect the highest closeness of link (R=0.61) of the given indices in 1985 the wettest year.

Conclusion

On the basis of the analysis it can be concluded that heightened sustainability of a number of climatypes is based on the ability to efficiently minimize the need for water use by means of the most effective decrease of linear growth in unfavorable environmental conditions. The given climatypes, having a wide range of reactions, are characterized by flexibility, high adaptive properties and show sustainability under changes in natural-climatic factors. Along with being highly productive climatypes they have great value in practical selection.

Acknowledgements

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Table 1. Increment Indices of Scots Pine Climatypes from Southern Regions of the Area.

№	Climatype	Lat. N	Long. E	Increment in year, cm				
				1979	1980	1981	1985	1990
44	Minusinsk	53°-45'	91°-45'	1.0	3.5	8.0	24.0	11.6
46	Balgazyn	51°-00'	95°-12'	1.3	3.8	6.1	23.5	9.2
50	Zaudinski	51°-50'	110°-00'	1.0	2.3	6.0	19.5	9.1
52	Kyakhta	50°-27'	106°-15'	1.3	2.8	7.1	23.6	11.6

Table 2. Correlation coefficients of increment indices with survival rate of Scots Pine climatypes.

№	Climatype	Lat. N	Long. E	Increment, cm		* Increment Indices	Survival, %
				1985 г	1990 г		
1	2	3	4	5	6	7	8
ssp. *lapponica* Fries							
1	Kandalaksha	67°-00'	32°-33'	13.2	6.4	2.06	36.5
2	Pinega	64°-45'	43°-14'	14.8	5.5	2.70	52.7
3	Plesyetsk	62°-54'	40°-24'	16.1	6.6	2.44	40.6
4	Kortkeros	61°-55'	51°-30'	19.1	8.3	2.30	53.3
5	Pryazha	61°-40'	33°-40'	23.3	12.0	1.90	40.4
6	Sortavala	61°-50'	30°-28'	17.6	12.3	1.43	23.6
7	Turukhansk	66°-00'	89°-00'	16.1	6.8	2.37	28.6
8	Olekma	60°-20'	120°-30'	17.1	5.5	3.11	42.3
9	Yakutsk	62°-00'	130°-00'	15.3	4.0	3.83	40.3
10	Ayan	56°-30'	130°-00'	16.2	4.5	3.60	63.0
						R=+0.58	
ssp. *sylvestris* L.							
11	Tosno	60°-00'	31°-00'	22.4	10.4	2.15	57.0
12	Cherepovets	60°-00'	43°-00'	19.2	8.9	2.16	28.0
13	Manturovo	58°-22'	44°-41'	24.6	9.2	2.67	12.5
14	Bezhetsk	57°-45'	36°-40'	18.9	13.6	1.39	24.3
15	Kurovskoye	55°-32'	38°-57'	20.7	10.7	1.93	21.9
16	Borsk	56°-40'	43°-28'	25.9	13.8	1.88	11.2
17	Solotcha	54°-40'	39°-45'	24.2	17.3	1.40	12.0
18	Chyelnovaya	53°-12'	41°-20'	18.6	10.8	1.72	13.9
19	Voronezh	51°-38'	39°-28'	23.6	10.4	2.27	11.9
20	Penza	53°-10'	45°-00'	24.8	11.7	2.12	9.8
21	Sursk	55°-15'	46°-30'	24.8	13.6	1.82	9.0
22	Melekess	54°-14'	49°-35'	22.5	10.4	2.16	2.7
23	Kamyshyn	50°-10'	45°-24'	26.2	10.3	1.96	21.0
24	Kama	55°-40'	51°-26'	22.0	11.2	1.96	21.0
25	Glazov	58°-15'	52°-45'	23.9	17.2	1.39	22.2
26	Dyurtyuli	55°-30'	54°-40'	22.6	12.8	1.77	32.7
27	Duvan	55°-42'	57°-54'	20.4	10.5	1.94	19.3
28	Zilair	52°-24'	58°-40'	22.0	15.2	1.45	33.4
29	Okhansk	57°-42'	55°-25'	24.2	13.0	1.86	55.8
						R=-0.11	
ssp. *sibirica* Ldb.							
30	Zavodoukovsk	56°-30'	66°-57'	19.6	16.1	1.20	42.0
31	Kurgan	55°-28'	65°-20'	27.0	16.5	1.60	32.4
32	Urumkai	52°-30'	70°-00'	18.2	7.0	2.60	35.2
33	Suzun	53°-50'	82°-20'	23.8	18.0	1.32	26.6
34	Rakity	51°-32'	81°-10'	22.2	19.2	1.16	16.0
35	Borovlyanka	53°-38'	84°-35'	22.5	18.0	1.25	31.2
36	Chemal	51°-28'	86°-00'	21.6	15.8	1.37	39.7
37	Nizhne-Yeniseisk	60°-21'	87°-49'	21.8	15.2	1.43	41.4
38	Boguchany	58°-39'	97°-30'	19.8	9.3	2.12	56.4
39	Achinsk	56°-17'	90°-30'	21.6	12.6	1.71	42.6
40	Daursk	55°-22'	92°-18'	20.6	12.0	1.72	42.4
41	Kansk	56°-12'	95°-41'	22.2	13.6	1.63	36.0
42	Abaza	52°-40'	90°-00'	22.8	12.5	1.82	38.0
43	Yermakovskoye	53°-00'	94°-00'	24.4	12.2	2.00	46.4
44	Minusinsk	53°-45'	91°-45'	24.0	11.6	2.10	46.9
45	Severo-Yeniseisk	60°-25'	93°-00'	18.7	9.2	2.03	56.6
46	Balgazyn	51°-00'	61°-00'	23.5	9.2	2.55	51.2
47	Zima	54°-00'	102°-00'	20.0	9.6	2.08	40.1
48	Vikhorevka	56°-15'	101°-30'	20.6	9.7	2.12	48.8
49	Ust-Kut	56°-50'	105°-45'	17.9	7.3	2.50	29.8**
50	Zaudinski	51°-50'	110°-00'	19.5	9.1	2.14	54.1
51	Barguzin	53°-45'	109°-40'	21.1	9.5	2.22	58.6
52	Kyakhta	50°-27'	106°-15'	23.6	11.6	2.03	49.2
53	Nerchinsk	51°-58'	116°-35'	23.6	12.1	1.95	56.6
54	Chita	52°-03'	113°-29'	25.3	13.2	1.92	46.3
55	Mogocha	53°-45'	119°-30'	23.6	11.6	2.03	46.3
56	Urusha	53°-50'	122°-00'	22.7	5.7	4.00	24.3**
57	Svobodnyi	50°-12'	128°-10'	24.6	5.9	4.17	49.8
						R=+0.55	

* index-relationship of increments signs 1985-1990

** These climatypes were excluded from the analysis due to their low survival rate (accidental elimination).

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