References

AHUJA, M. R.: Somatic cell differentiation and rapid clonal propagation of aspen. Silvae Genetica **32**: 3–4 (1983). — AHUJA, M. R. and MUHS, H. J.: Control of growth and differentiation in tissues and protoplast derived callus in different genotypes of aspen. In: Proc. 5th Int. Cong. Plant Tissue and Cell Culture. Plant Tissue Culture 1982. pp. 177–178 (1982). — BEKKAOUI, F: Microbouturage *in vitro* et culture de meristemes de Douglas (*Pseudotsuga menziesii*); problemes physiologiques lies a l' age et au milieu de culture. These de Doctorat de L' Universite P. et M. Curie (Paris VI). pp. 173 (1986). — BROWN, C. L.: Application of tissue culture technology to production of woody biomass. National Swedish Board for Energy Source Development. IEA Report: NE 1981–18 (1981). — COLEMAN, G. D. and ERNST, S. G.: *In vitro* shoot regeneration of *Populus deltoides*: effect of cytokinin and genotype. Plant Cell Reports 8: 459–462 (1989). — CORNU, D. and CHAIX, C.: Multiplication par culture *in vitro* de merisiers adultes (*Prunus avium*): application a un large eventail de clones. In: Proc. IUFRO sect. S2 01 5. Int. Workshop "in vitro" for tree species. Fontainebleau, France, pp. 71–79 (1981). — CORNU, D. and JAY-ALLEMAND, C.: Micropropagation of hybrid walnut trees (*J. nigra* x *J. regia*) through culture and multiplication of embryos. Ann. Sci For. **46** (suppl.) 113s–116s (1989). — CORNU, D., RIFFAUD, J. L. and CAPELLI, P.: *In vitro* propagation of wild cherry tree (*Prunus avium* L.). In: Proc. IUFRO sect. S2 01 5. Int. Workshop "in vitro" for tree species. Fontainebleau, France, pp. 133–134 (1981). — DRIVER, J. and KUNIYUKI, A. H.: *In vitro* propagation of Paradox walnut rootstock. HortScience **19**(4) 507–509 (1984). — ERNST, S. G: *In vitro* culture of pure species non-aspen poplars. In: "Micropropagation of woody plants". AHUJA, M. R. (ed). Kluwer Academic Publishers. pp. 195–207 (1993). — EVERS, P. W., DONKERS, J. PRAT, A. and VERMEER, E.: Micropropagation of forest trees through tissue culture. EVERS, P. W., DONKERS, J., PRAT, A. and VERMEER, E. (eds). Pudoc, Wageningen (1988). — FOSTER, G. S.: Genetic control of rooting ability of stem cuttings from loblolly pine. Can. J. For. Res. **20**, 1361–1367 (1990). — GASPAR, T., KEVERS, C., HAUSMAN, J. F., BERTHON, J. Y. and RIPETTI, V.: Practical use of peroxidase activity as a predictive marker of rooting performance of micropropagated shoots. Agronomie **12**, 757–765 (1992). — GASPAR, T., KEVERS, C., HAUSMAN, J. F., BERTHON, J. Y. and RIPETTI, V.: Peroxidase activity and endogenous free auxin during adventitious root formation. In: "Physiology, Growth and Development of plants in culture". P. J. LUMSDEN, J. R. NICHOLAS and W. J. DAVIES (eds). Kluwer Academic Publishers, Netherlands (1994). — GRUSELLE, R., BADIA, N. and BOXUS, PH.: Walnut micropropagation: First results. Acta Horticulturae **212** (1987). — GRUSELLE, R. and BOXUS, P.: Walnut micropropagation. Acta Horticulturae **284:** 45–52 (1990). — HARTMANN, H. T. and KESTER, D. E.: Plant propagation. Principles and practices. Prentice Hall, Inc. Englewood Cliffs, New Jersey (1983). — HAISSIG, B. E. and RIEMENSCHNEIDER, D. E.: Genetic effects on adventitious rooting. In: "Adventitious root formation in cuttings". DAVIS, T. D., HAISSIG, B. E. and SANKHLA, N. (eds). Dioscorides Press, Portland, Oregon. pp. 47–60 (1988). — HORGAN, K.: *Pinus radiata*. In: "Cell and tissue culture in forestry". Vol 3. Case histories: Gymnosperms, Angiosperms and Palms. BONGA, J. M. and D. J. DURZAN (eds.). Martinus Nijhoff Publ. pp. 128–145 (1987). — JAY-ALLEMAND, C., CAPELLI, P. and CORNU, D.: Root development of *in vitro* hybrid walnut microcuttings in a vermiculite containing gelrite medium. Scientia Horticulturae **51**: 335–342 (1992). — JAY-ALLEMAND, C. and CORNU, D.: Culture *in vitro* d'embryons isoles de noyer commun (*Juglans regia* L.). Ann. Sci. For. **43**: 189–198 (1986). — LAND, S. B. and CUNNINGHAM, M.: Rooted cutting macropropagation of hardwoods. In: "Applications of vegetative propagation in forestry". Proc. of the Southern regional information exchange group biennial symposium on forest genetics. FOSTER, G. S. and A. M. DINER (eds.). Published by Southern Forest Experiment Station New Orleans, Louisiana. pp 75–96 (1994). — LEAKEY, R. R. B., NEWTON, A. C. and MCP. DICK, J.: Capture of genetic variation by vegetative propagation processes determining success. In: "Tropical trees: the potential for domestication and the rebuilding of forest resources". LEAKEY, R. R. B. and NEWTON, A. C. (eds.). London, HMSO. pp. 72–83 (1994). — MALVOTI, M. E., FINESCHI, S. and PIGLIUCCI, M.: Morphological integration and genetic variability in *Juglans regia* L.. J. Heredity **85**: 389–394 (1994). — MCGRANAHAN, G., LESLIE, C. A. and DRIVER, J. A.: In vitro propagation of mature persian walnut cultivars. Hortscience **23**(1): 220 (1988). — PANETSOS, K. P., ECONOMOU, A. and SCALTSOYIANNES, A.: Propagation *in vitro* of Aspen hybrid *Populus spartiatica* x *Populus tremula* from mature trees. Agricultural Research **11**: 449–459f (1987). — REVILLA, M. A., MAJADA, J. and RODRIGUEZ, R.: Walnut (*Juglans regia* L.) micropropagation. Ann. Sci. For. **46** suppl.: 149s–151s (1989). — RODRIGUEZ, R.: Callus initiation and root formation from *in vitro* culture of walnut cotyledons. HortScience **17**(2): 195–196 (1982a). — RODRIGUEZ, R.: Stimulation of multiple shoot-bud in walnut seeds. HortScience **17**(4): 592 (1982b). — RODRIGUEZ, R. and SANCHEZ-TAMES, R.: Cultivo detejitos y differentiation en nogal. Rev. Fac. Cienc. Univ. Oviedo (Ser Biologia) **22**: 21–28 (1981). — SCALTSOYIANNES, A., PANETSOS, K. P., ECONOMOU, A. and TSOULPHA, P.: Micropropagation of the pine hybrid *Pinus brutia* (TEN) x *P. halepensis* (MILL.) by culturing fascicle shoots. Ann. Sci. For. **51,** 175–182 (1994). — ZOBEL, B. J. and TALBERT, J. T.: In: "Applied Forest Tree Improvement". John Wiley and Sons Inc. (publ), New York, Toronto (1984). — ZSUFFA, L., SENNERBY-FORSSE, L., WEISBERGER, H. and HALL, R. B.: Clonal forestry. Vol. II. AHUJA, M. R. and LIBBY, W. J. (eds.). Springer Verlag. pp. 91–119 (1993).

Height Growth Variation in a Comprehensive Eurasian Provenance Experiment of (*Pinus sylvestris* L.)

By A. M. SHUTYAEV[1]) and M. GIERTYCH[2])

[1]) Research Institute of Forest Genetics and Breeding, Lomonosova 105, 394043 Voronyezh, Russia
[2]) Institute of Dendrology, 62-035 Kórnik, Poland

(Received 26th May 1997)

Summary

In the years 1974 to 1976, on the initiative of the Forest Research Institute in Pushkino, near Moscow, a major Scots pine experiment was established with 113 provenances over 33 planting sites, well scattered over the whole former USSR. Basing on reports from co-operating institutions information is compiled on the provenances used, on the planting sites and on the mean tree height at latest measurement. Interaction parameters are calculated and the data on tree heights, converted to units of standard deviation from location means, is plotted onto maps of the locations demonstrating the extent of genotype environment interaction. The range of the species in the former USSR can be divided into regions (North-western, Baltic, Western Continental, Northern Russia, Central European Russia, Middle Volga, Central Trans-Urals, Southern fringe, Eastern Siberia), that have characteristic for them responses to seed transfer in terms of height growth performance at various locations. Western populations (Baltic countries, Bielorussia, Ukraine) are clearly superior in height growth at most European locations. This zone with superior populations extends also to the region between rivers Volga, Oka and Don (Middle Volga region). Scots pine from that region is transferable further east, though not as successfully westwards. Around Moscow (Central European Russia) there is a region with reactive populations that are very successful within the region and they can be transferred eastwards to some extent but not in other directions nor over greater distances. Extensive longitudinal transfers of populations are possible within two latitudinal zones, Northern Russia and Central Trans-Urals. The latter is a central zone extending from the Urals to river Yenitsyei with populations of average growth performance relative to the much poorer growth of the northern, Far Eastern and southern populations.

Key words: geographic variation, origin, genotype-environment interaction, stability, Russia, USSR.

FDC: 232.12; 165.5; 181.64/.65; 561/562; 174.7 *Pinus sylvestris*; (470); (474); (571).

Introduction

Provenance variation of Scots pine (*Pinus sylvestris* L.) is fairly well known for the western part of the species range. It was investigated in numerous national and international (IUFRO) trials and there were summary reports from these investigations (GIERTYCH, 1979, 1991; GIERTYCH and OLEKSYN, 1992). The international trials rarely included seed lots from Russia and, if any were included, these were from European Russia (IUFRO trials of 1907, 1938, 1939, 1982). The large Russian trial of OGIYEVSKIĺ (FOMIN, 1940; GIERTYCH and OLEKSYN, 1981) established in the years 1910 to 1912 also included primarily European seed lots, with only two from Siberia and one from southern Caucasus. In a single experiment established near Voronyezh in 1959 a wide representation of Siberian provenances is included (VYERYESIN and SHUTYAEV, 1978, SHUTYAEV and VYERYESIN, 1990) but information from this trial has received little international notice. A fairly wide representation of Siberian provenances was also included in a series of trials established in the North Central Region of the USA in 1961 (WRIGHT et al., 1966) but there the interest was primarily in populations for Christmas trees and as a result there was not much of a follow up in the experiment beyond 12 years of growth.

The present paper is the first summary report on results from a Scots pine provenance trial established in the years 1974 to 1976 throughout the former USSR, covering 113 provenances and 33 planting sites. It is by far the most extensive provenance trial with this species and exceptional in that it includes many provenances and planting sites in the Asiatic part of its range. Since this is the first report on the trial, full details on the co-ordinates for provenances and locations and information about the establishment procedures is given. Obviously the prime interest in this study lies in the genotype environment interactions, which is presented here only for tree height. Other traits will be treated in further papers.

The political changes after 1990 have internationalised the study. There are plots in 7 countries (Azerbaijan, Bielorussia, Estonia, Lithuania, Russia, Ukraine) and the seed was also collected in Latvia. No agreements have yet been worked out about how to proceed in the future so as to maintain benefits of joint analysis of the full experiment. Possibly a IUFRO working party could play a role here.

Materials and Methods

Seed collection

In the years 1974 to 1976 throughout the former USSR a series of provenance experiments on Scots pine (*Pinus sylvestris* L.) was established, based on an executive order no. 29/1973 by the state Forestry Committee. The program was prepared by YE. P. PROKAZIN (1972) from the Forest Seed Laboratory of the All-Union Forest Research Institute (VNIILM), Pushkino, near Moscow. The program envisaged collection of seed material from 126 provenances. In fact seeds were collected from only 113 populations (*Table 1, Fig. 1*).

All seed lots were collected from specific well defined populations, as far as can be judged from authochtonous stands,

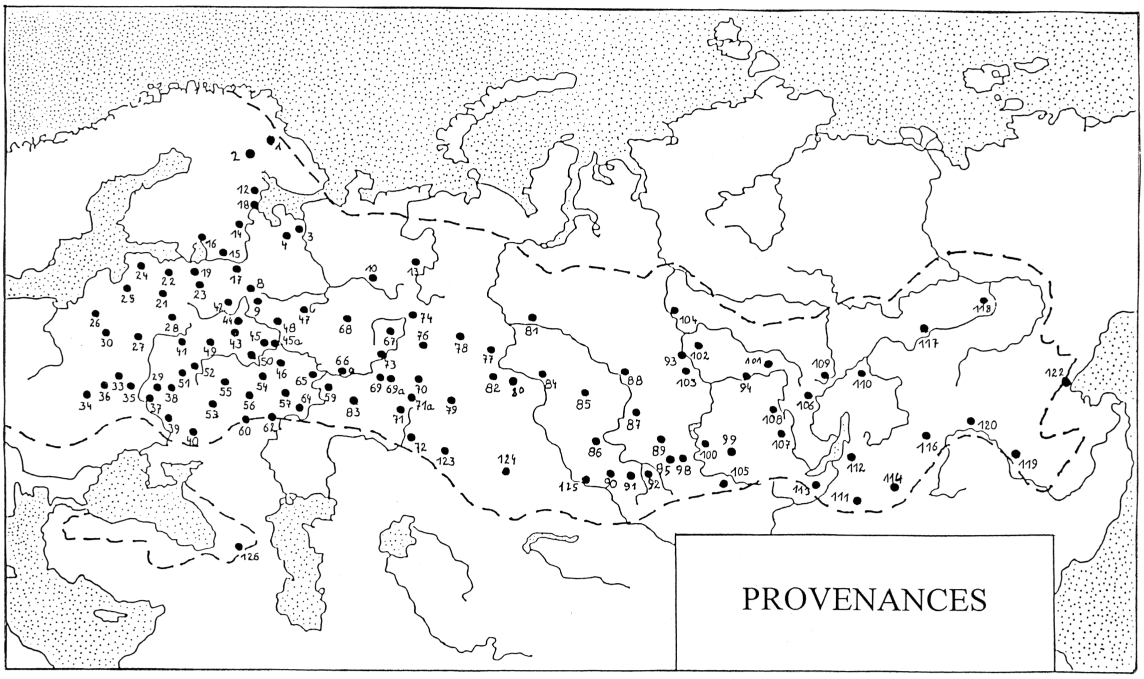

Fig. 1. – Location of seed collection sites. Details on individual provenances are given in *table 1* – see respective numbers. The broken line indicates roughly the extent of the range of distribution of Scots pine.

Table 1. – Data on provenances included in the trial.

Prov. no.	Province	For. distr.	Lat. N	Long. E	1000 seed wt. g	No. of trials where planted
1	Murmansk	Monchegorsk	67°51'	32°57'	3,3	7
2	Murmansk	Kandalaksha	67°00'	32°33'	4,0	12
3	Arkhangyelsk	Pinyega	64°45'	43°14'	4,5	10
4	Arkhangyelsk	Plyesyetsk	62°54'	40°24'	4,8	18
8	Vologda	Chyeryepovyets	59°10'	38°00'		7
9	Vologda	Tot'ma	60°00'	43°00'	5,4	16
10	Komi	Kortkyeros	61°55'	51°30'		8
12	Karyelya	Chupa	66°20'	33°00'	4,9	9
13	Komi	Kadzhyerom	64°45'	55°55'		2
14	Karyelya	Myedvyezh'yegorsk	62°54'	34°27'	4,4	12
15	Karyelya	Pryazha	61°40'	33°40'	4,7	16
16	Karyelya	Sortavala	61°50'	30°28'	5,2	16
17	Karyelya	Pudozh	61°40'	36°33'		11
18	Karyelya	Kyem'	64°57'	34°31'		5
19	Sankt Pyetyersburg	Lisino	60°00'	30°25'	5,2	10
21	Pskov	Vyelikiye Luki	56°23'	30°30'	5,0	13
22	Pskov	Strugi-Krasnyye	57°50'	28°26'	5,8	11
23	Novgorod	Kryesttsy	58°15'	32°28'	5,9	11
24	Estonia	Elwa	58°10'	26°28'	5,4	12
25	Latvia	Jaunielgawa	56°27'	25°10'	5,8	15
26	Lithuania	Prienaj	54°42'	23°58'	5,4	14
27	Mogilyev	Osipovichi	53°18'	28°40'	5,8	11
28	Vityebck	Rossony	56°00'	29°20'	6,7	10
29	Gomyel'	Lyenino, Koryenyevka	52°14'	31°43'	6,7	13
30	Grodno	Slonim	53°25'	25°15'	6,0	11
33	Rovno	Dubrovitsa	51°32'	26°36'	5,9	15
34	L'vov	Sambor	50°55'	24°00'	6,9	10
35	Zhitomir	Olyevsk	50°24'	27°40'	6,2	9
36	L'vov	Rakhov	48°07'	24°00'	6,5	12
37	Kiyev	Borispol'	50°10'	32°10'	7,3	14
38	Sumy	Svyessa	52°01'	34°00'	6,4	15
39	Chyerkassy	Chyerkassy	49°37'	32°00'	10,0	11
40	Donyetsk	Slavyansk	48°50'	37°36'	9,3	9
41	Smolyensk	Roslavl'	54°00'	33°00'	5,6	17
42	Twyer	Byezhyetsk	57°45'	36°40'		15
43	Moskva	Kurovskoye	55°32'	38°57'	6,4	29
44	Vladimir	Kovrov	56°21'	41°15'	6,1	15
45	Nizhyegorod	Gorodyets	56°40'	43°28'	5,3	18
45a	Nizhyegorod	Gorodyets	56°40'	43°28'		5
46	Nizhyegorod	Pyervomaisk	54°56'	43°50'	5,9	20
47	Kostroma	Manturovo	58°22'	44°44'		17
48	Kostroma	Kostroma	58°00'	42°00'		19
49	Kaluga	Kaluga	54°25'	36°16'	6,2	16
50	Ryazan	Solotcha	54°40'	39°45'	6,1	22
51	Bryansk	Gavan'sk, Kukuyevka	53°00'	34°00'		20
52	Oryel	Turgyenev, Zhudro	53°00'	36°00'		12
54	Tambov	Chyelnovaya, Sosnovka	53°12'	41°20'	6,6	25

55	Voronyezh	Voronyezh, Grafskaya	51°38'	39°28'	7,8	20
56	Voronyezh	Khryenovolye, Sloboda	51°30'	40°15'	7,7	13
57	Pyenza	Nikol'sk	53°50'	46°00'	6,6	25
59	Ul'yanovsk	Myelyekyess	54°14'	49°35'	6,9	24
60	Rostov	Byeshyenskaya	49°36'	41°48'	7,9	9
62	Volgograd	Kamyshin	50°10'	45°24'	7,5	15
64	Saratov	Vol'sk	52°04'	47°21'	7,4	15
65	Tatarstan	Zyelyenodol'sk, Vasil'yevo	56°00'	48°00'		23
66a	Tvyer	Kama, Vyatskiye Polyany	55°40'	51°26'	5,9	22
67	Udmurtiya	Votkinsk	57°30'	54°00'	6,0	19
68	Tvyer	Slobodskoí	58°49'	50°06'	8,8	20
69	Bashkortostan	Dyurtyuli	55°30'	54°40'	8,6	24
69a	Bashkortostan	Dyurtyuli	55°30'	54°40'		1
70	Bashkortostan	Duvan	55°42'	57°54'	6,3	7
71	Bashkortostan	Vyerkhnií Avzyan	53°25'	57°40'	6,3	12
71a	Bashkortostan	Byeloryetsk	53°57'	58°24'	5,8	9
72	Bashkortostan	Zilaírskií	52°24'	58°40'	5,6	13
73	Pyerm	Okhansk	57°42'	55°25'		5
74	Pyerm	Krasnovishyersk	60°23'	57°03'		4
76	Yekatyerinburg	Ryevda	56°50'	59°58'	5,5	10
77	Yekatyerinburg	Tavda	58°04'	65°18'	5,6	15
78	Yekatyerinburg	Ivdyel, (Nizhnyaya Salda?)	60°40'	60°24'	4,9	10
79	Kurgan	Kurgan	55°28'	65°20'	5,9	14
80	Tyumen	Ishim	56°09'	69°27'		2
81	Tyumen	Surgut	61°25'	73°20'	4,7	12
82	Tyumen	Zavodoukovsk	56°30'	66°57'	5,4	15
83	Oryenburg	Buzuluk	52°47'	52°15'	8,1	19
84	Omsk	Tara	57°00'	74°40'	4,9	9
85	Novosibirsk	Kyshtovka	56°36'	76°40'	5,5	6
86	Novosibirsk	Suzun	53°50'	82°20'	5,9	28
87	Novosibirsk	Bolotnoye	55°36'	84°10'	5,9	7
88	Tomsk	Kolpashyevo	58°20'	83°00'	4,5	10
89	Kyemyerovo	Gur'yevsk	54°20'	86°00'	6,4	6
90	Altaískií Kraí	Rakity	51°32'	81°10'	8,7	10
91	Altaískií Kraí	Borovlyanka	53°38'	84°35'		4
92	Altaískií Kraí	Chyemal	51°28'	86°00'	7,2	11
93	Krasnoyarsk	Yartsyevo	60°15'	90°10'		4
94	Krasnoyarsk	Boguchany	58°39'	97°30'	4,8	13
95	Krasnoyarsk	Abaza	52°40'	90°00'		3
98	Krasnoyarsk	Abaza	52°40'	90°00'	6,5	10
99	Krasnoyarsk	Yermakovskoye	53°00'	94°00'	6,7	7
100	Krasnoyarsk	Minusinsk	53°45'	91°45'	6,7	11
101	Krasnoyarsk	Prospikhino, Kyezhma	58°40'	99°10'	4,9	4
102	Krasnoyarsk	Syevyero-Yenisyeísk	60°25'	93°00'	4,8	9
103	Krasnoyarsk	Yenisyeísk	58°20'	93°00'		9
104	Krasnoyarsk	Turukhansk	65°49'	87°59'		5
105	Tuva	Balgazyn	51°00'	95°12'	6,6	10
106	Irkutsk	Ust'-Kut	56°50'	105°45'	3,7	9
107	Irkutsk	Zima	54°00'	102°00'	4,5	4
108	Irkutsk	Vikhoryevka, Chyekanovskií	56°15'	101°30'		7
109	Irkutsk	Katanga, Yerbogachyen	57°00'	105°00'		7
110	Irkutsk	Mama	58°20'	113°00'	5,3	6
111	Buryatya	Zaudinskií, Ulan-Ude	50°00'	110°00'	6,7	7
112	Buryatya	Barguzin	53°45'	109°40'		4

(continuation *Table 1*)

113 Buryatya	Kyakhta	50°27'	106°15'	6,9	4
114 Chita	Nyerchinsk	51°58'	116°35'		5
116 Chita	Mogocha	53°45'	119°30'	5,2	7
117 Yakutiya	Olyekminsk	60°20'	120°30'	5,1	9
118 Yakutiya	Yakutsk	62°00'	130°00'	5,2	10
119 Amurskaya Obl.	Svobodnyi	50°12'	128°10'	6,0	9
120 Amurskaya Obl.	Urusha	53°00'	122°00'		6
122 Khabarovsk	Ayan	56°30'	138°00'	5,0	7
123 Kustanai	Ara-Karagaj, Krasnyi Kordon	52°30'	63°50'	6,0	12
124 Kokchyetav	Urumkai, Dmitriyevskoye	52°30'	70°00'	5,3	14
125 Syemipalatinsk	Dolon, Mostik	50°40'	80°33'	9,2	12
126 Azyerbaidzhan	Tauz	41°00'	45°30'		3
				Total	1320
				Mean	11,68

according to the same methodology. One seed lot was taken per region extending about 2° Lat. and 4° to 5° Long. for the western and southern parts of the range, 2° to 3° Lat. and 6° to 7° Long. for northern and north-eastern parts and 5° to 6° Lat. and 10° to 12° Long. for the Asiatic part of the range. For each of these areas a stand was selected that was as far as possible most representative for the forest sites in the area and no less than of average quality class. In the selected stand a part of it (by area) was cut to collect cones which were extracted locally. The remainder of the stand was left as a control to stand as a reserve for the duration of the provenance trial. This methodological requirement was in most places executed and the control (maternal) stands are available. Another requirement, that *in situ* a progeny stand be established from the seeds extracted from the collected cones was not fulfilled by all co-operators and information on this is in most places unavailable. The bulk of the extracted seeds was sent to the co-ordinator to be shared among co-operators depending on availability and planned need to test specific populations on specific sites. Not for all seed lots has the 1000 seed weight been recorded (*Table 1*).

Trial location and experimental design

Establishment of experimental plots on 37 sites was planned with a total of 829.5 ha experimental areas. In fact only 33 trial areas exist (*Table 2, Fig. 2*) totalling 545 ha. Four have perished in the establishment phase. The role of co-ordinator and supervisor of the establishment of the trial was placed with the All-Union Forest Research Institute (VNIILM) in Pushkino, and specifically with the late dr YE. P. PROKAZIN.

Seedlings were raised in nurseries close to the planting site, sowing density aiming at 30 seedlings per 1 m^2. The nursery success and other considerations resulted in not all provenances planned for a trial being represented at the given locations. The number varies from 10 to 90. At two locations, no. 16 near Pushkino and no. 17 near Voronyezh, an attempt was made to have the maximal number of provenances, but the average number of provenances per location is 40.

The choice of planting sites was determined by the desire to have as much as possible a full representation of geographic variation and by the possibilities of local forest districts. Site preparation according to a uniform methodology proved impossible for biological, organisational and economic reasons.

Planting was at a 2.5 m x 0.75 m spacing with 0.1 ha, 0.15 ha or 0.25 ha per plot (533 to 1333 trees per plot), depending on the availability of seedlings, with 3 replicate blocks planned and established on most sites. In Lithuania the three replicate blocks are at different locations (see *Table 2*). The provenances were randomised within the replicate blocks but with some transfers in the plan not to allow total surrounding by fast growing provenances of those expected to be slow growing.

Data collection

Locally the maintenance and data collection from an experimental area was handled by various research and teaching institutions (see *table 2*). In 1980 the role of co-ordinator was transferred to the Central Scientific Research Institute of Forest Genetics and Selection (TsNIILGiS) in Voronyezh and specifically to the senior author of this paper dr A. M. SHUTYAEV. Co-operating institutions make periodic reports to the co-ordinator on the latest measurements and observations. In most cases the latest reports, considered as final for the establishment phase of the trial, were for the year 1990 (see literature list). The present paper is based on these reports from the co-operating institutions (see *table 2* and Literature) deposited with the co-ordinator in Voronyezh and presumably also available in the institutions that produced them.

The basic material for this paper consists of mean values for tree height extracted from the regional reports. Only means per provenance at each location are available at this stage. The plots are rather large with initially 533 to 1333 trees per plot, thus, at least at some locations, only one or two rows per plot were measured. These measurements were not made simultaneously at all locations and the actual age of trees at the last measurement varies substantially. *Table 3* presents the basic data. It is a 33 x 113 table with many gaps due to non-orthogonality of the design (not all provenances at all locations).

Statistical analysis

To start with an attempt was made to calculate genotypic stability and ecovalence for the studied provenances, according the formulae of FINLAY and WILKINSON (1963) and EBERHART and RUSSELL (1966). The average tree height per location was calculated and this was divided by the age at measurement. The obtained annual increment in height was used as an estimate of site quality. Since height increment naturally declines with age, the mean annual height increment is not a fully true estimate of site quality. It tends to overestimate locations that were measured at a younger age. The mean annual

Table 2. – Data on localisations of the experimental areas. (Plantings at locations 19, 20, 28 and 33 perished).

Loc. no.	Region	Forest District	Lat. N	Long. E	Year planted	Area ha	Replicates no.	Prov. no.	Survival %	Mean ht. of local prov. age	m	Supervising institution*	Scientists who established	Reference
1	Murmansk	Monchyegorsk	67°51'	32°57'	1976	9,4	1-3	35	45	14	0,8	Arkh. ILILKh	I.I. Sizov	Nakvasina et al. 1990
2	Arkhangyel'sk	Plyesyetsk	62°54'	40°24'	1977/8	8,1	1-3	26	41	15	3,4	Arkh. ILILKh	T.S. Nyepogod'yeva	Nakvasina et al. 1990
3	Vologda	Chyeryepovyets	59°15'	37°20'	1977	23,3	2	35	71	15	5,1	Arkh. ILILKh	N.V. Ulisova	Nakvasina et al. 1990
4	Komi	Kortkyeros	61°41'	51°31'	1977	7,5	1-3	23	29	15	2,9	Arkh. ILILKh	A.I. Barabin	Nakvasina et al. 1990
5	Karyelya	Chupa	65°57'	33°30'	1977	5,5	2-3	29	9	16	1,5	IL Karyel. NTs RAN	M.A. Shchyerbakova & E.M. Mar'in	Shchyerbakova & Malyshyev 1990
6	Karyelya	Myedvyezh'yegorsk	63°00'	34°03'	1976/7	13,9	2-3	45	32	16	1,3	IL Karyel. NTs RAN	M.A. Shchyerbakova & E.M. Mar'in	Shchyerbakova & Malyshyev 1990
7	St. Pyetyersburg	Lisino	59°30'	30°52'	1976	25,1	3	41	62	15	5,6	St.Pyet.NIILKh	N.I.Uvarova, G.K.Marisaya & L.N. Filimonova	Kovalyev 1990
8	Pskov	Pskov	57°50'	28°26'	1976	33,2	3	37	31	15	5,1	St.Pyet.NIILKh Pskov LOS	N.I. Uvarova, & A.I. Tolstopyatyenko	Kovalyev 1990
9	Estonia	Jarva	59°31'	25°30'	1976	20,0	3	45	15	11	1,1	Est. Inst.For.& Nat.Cons.	H. Paves	Paves 1985
10	Lithuania	Kazlu-Ruda Płungie Mažejkiaj	54°45' 56°00' 56°46'	23°35' 21°53' 22°40'	1975	23,1	3	41	66	5	0,4	Lith. Forestry Inst.	E. Barniškis	Ramanauskas 1990
11	Gomiel	Lenino	52°28'	31°00'	1975	12,0	3	41	85	15	6,2	IL ANB	Z.S. Podzharova	Podzharova & Volovich 1990
12	Khyerson	Tsyurupinsk	46°30'	32°30'	1976	10,6	1-2	38	46	16	5,9	Ukr NIILKhA	I.N. Patlai & I.D. Klimchuk	Patlai & Zhurova 1991
13	Khar'kov	Izyum	49°00'	37°30'	1975	5,6	1	42	36	15	7,0	Ukr NIILKhA	I.N. Patlai & P.T. Zhurova	Patlai & Zhurova 1991
14	L'vov	Sambor	50°00'	24°00'	1976	15,6	3	33	36	11	3,6	L'vov Lyesotech. Inst.	Z.Yu. Gyerushinskii & A.A. Bozhok	Gyerushinskii & Krinitskii 1986
15	Zhitomir	Olyevsk	51°00'	27°00'	1976	15,5	3	37	37	15	5,4	Ukr NIILKhA	I.N. Patlai, A.S. Ryabukha & G.D.Byel'yi	Patlai & Zhurova 1991
16	Vladimir	Kovrov	57°00'	42°00'	1976	30,0	3	90	26	15	4,8	VNIILM, NPO "Funduk"	E.P. Prokazin, V.K. Malkin A.A. Osipov, B.N. Kurakin	Malkin & Osipov 1990
17	Voronyezh	Davydovka	51°00'	39°00'	1976	38,0	3	86	60	17	5,4	NIILGIS	A.M. Shutyayev & O.K. Sviridov	Shutyayev & Dyemidyenko 1995
18	Pyenza	Lunino	53°00'	45°00'	1976	30,0	3	55	70	17	6,5	NIILGIS	A.M. Shutyayev & O.K. Sviridov	Shutyayev & Dyemidyenko 1995
21	Volgograd	Kamyshin	50°00'	45°00'	1976	17,6	2	32	44	17	5,7	VNIALMI, Don NI OS	G.Ya. Mattis	Maksimov & Cheplyanskii 1990
22	Tatarstan	Zyelyenodol'sk	55°00'	52°00'	1976	15,0	3	38	48	17	7,9	VNIILM, Tatar LOS	E.P. Prokazin & G.Sh. Kamaltinov	Krasnobayeva & Timyertayeva 1990
23	Bashkortostan	Ufa	55°00'	56°00'	1976	15,0		38	12	17	4,4	VNIILM, Bashkir LOS	E.P. Prokazin & I.Kh. Nugayev	Khaziagayev & Nugayev 1990
24	Pyerm	Kungur	57°26'	56°45'	1976	9,3	1	32	23	17	6,3	VNIILM, Perm LOS	E.P. Prokazin, N.I.Vlasova	Vlasova 1990
25	Yekatyerinburg	Ryevda	56°50'	59°58'	1976	11,5	3	34	52	17	6,0	IL UO RAN. Ural LOS	V.N. Korablyev	Korablyev et. al. 1990
26	Kurgan	Zvyerinogolovskoye	54°47'	64°58'	1976	17,0	3	32	23	17	7,2	IL UO RAN. Ural LOS	V.N. Korablyev	Korablyev et. al. 1990
27	Samara	Buzuluk	53°00'	52°00'	1976	21,4	3	38	43	17	7,2	VNIILM, Borovo LOS	E.P. Prokazin, A.A. Khirov	Khirov 1990
29	Novisibirsk	Suzun	53°46'	82°20'	1976	15,4	3	35	28	17	6,3	NIILGIS, Novosibirsk Lab.	Dyemidyenko 1995	Shutyayev & Dyemidyenko 1995
30	Krasnoyarsk	Boguchany	58°21'	97°30'	1977	30,0	3	73	60	16	3,8	ILID SO RAN	A.I. Iroshnikov, L.I. Milyutin & N.A. Kuz'mina	Milyutin et al.1990
31	Krasnoyarsk	Turukhansk	66°00'	89°00'	1979	4,6	3	36	3	14	1,9	ILID SO RAN	F.D. Avrov	Milyutin et al.1990
32	Buryatya	Zaudinsk	51°50'	107°40'	1979	10,0	2	51	36	16	1,4	ILID SO RAN	V.L. Chyeryepnin	Milyutin et al.1990
34	Amurskaya Obl.	Svobodnyi	51°00'	127°00'	1976	2,5		10	70	7	1,2	Dal'NIILKh, Amur LOS	V.I. Shtyelnikova, T.F. Zyel-yenskaya, T.F.Yemolkina	Shtyelnikova et al. 1980
35	Kokchyetav	Urumkai	52°30'	69°50'	1978	11,7	1-2	10	55	9	2,2	Kaz. NIILKhA	V.I. Mosin, N.S. Sidorova & V.N. Marushak	Mosin 1985
36	Syemipalatinsk	Dolon	50°40'	79°20'	1976/7	8,1	1-2	47	59	10	2,8	Kaz. NIILKhA	V.I. Mosin, N.S. Sidorova & N19V.N. Marushak	Mosin 1985
37	Azyerbaidzhan	Shyekinskii	41°17'	47°12'	1976	10,7	3	35	65	12	2,0	Azyerb.NIILKh	A.M. Gusyeinov & L.A. Gusyeinova	Gusyeinov & Gusyeinova 1986

* Explanation of abbreviations is given in the respective literature reference

height increment is also somewhat dependent on the choice of provenances planted at a given location. However this is the only estimate available to us and it gives some approximation to site quality. In a similar manner the average tree height for a provenance at each location was divided by the age at last measurement to obtain the annual height increment for the each provenance at each location.

Next the mean annual height increments, both for individual provenances and for the location averages were converted to natural logarithms. For all provenances represented on at least

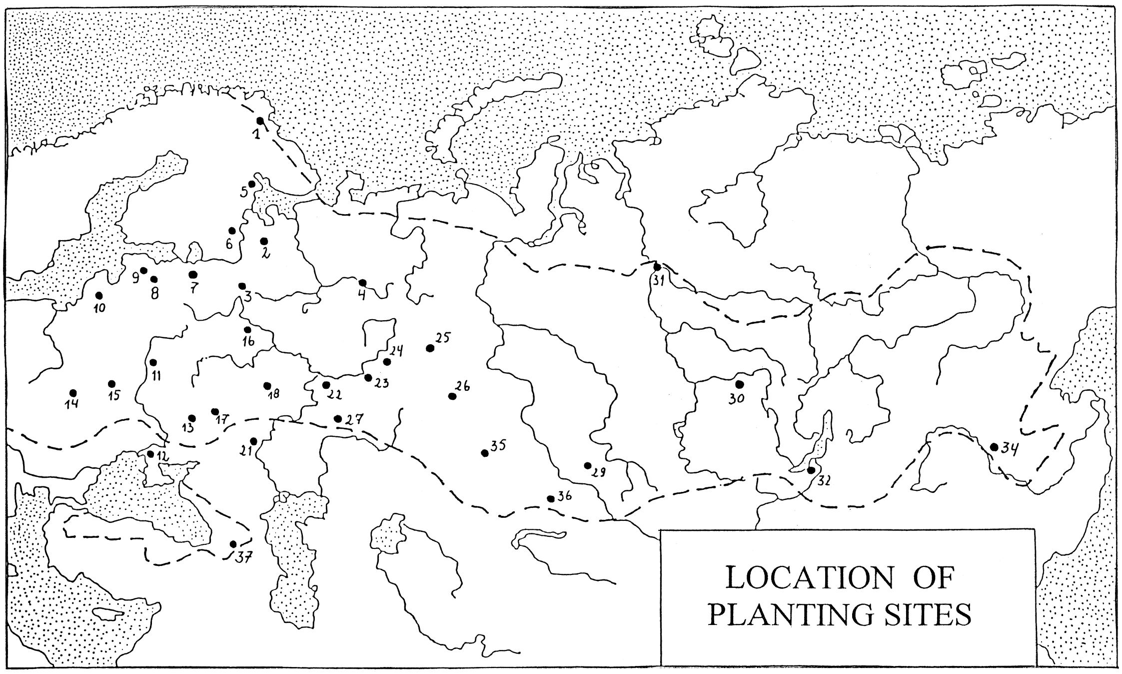

Fig. 2. – Location of planting sites. Details on individual sites are given in *table 2* – see respective numbers.

5 locations (N-2 ≥ 3) a regression analysis was made of $\log_n$ annual height increment on the $\log_n$ mean height increment per location. The calculated regression coefficient b is an inverse measure of "phenotypic stability" of FINLAY and WILKINSON (1963). It is given in *table 4*. A value of b ≈ 1 indicates adequate stability. Lower values (b < 1) indicate good adaptability to various environments. Higher values (b > 1) indicate adaptation to specific sites.

Simultaneously the correlation coefficient r was calculated (also given in *Table 4*). It is a measure of linearity obtained following the logarithmic transformation.

Variance of deviations from the regression V_d is the coefficient of EBERHART and RUSSELL (1966). It is calculated as:

$$Vd = N(V_y - bCov_{xy})/(N-2)$$

where y is the $\log_n$ annual height increment and x is the $\log_n$ mean height increment for location. High V_d values indicate unpredictable response. Obtained V_d values for each provenance are presented in *table 4*.

In view of the difference in age at which last measurements and observations were made it was necessary to make the results comparable by normalising them, i. e. expressing in units of standard deviation from the location mean. Another alternative would be to use the local population as the point of reference. The location mean was chosen since it is less dependent on freak results. However this would not make much difference because mean annual increments for the trial and for the local populations are closely correlated (r = 0.97 with N-2 = 31). A new major table was obtained (provenances x localities) with the deviations from location mean in place of actual readings. These are now comparable when judging the performance of each provenance at the various sites where it occurs. These deviations from location mean were also averaged for provenances over all locations at which they occur and the average values are given in *Table 4* and are plotted onto the provenance map *Fig. 3*.

The provenance x location interaction was studied ideographically by plotting the normalised data (deviations from location means) onto a map showing locations at which a given provenance was tested. This was done separately for each provenance. Sample results are shown in *Figs. 4 to 13*.

In *Figs. 3 to 13* the radius of the black dots corresponds to a deviation of 0.15 standard deviations, whence any value between –0.15 and +0.15 is shown as a dot only. Larger deviations, up or down from the dot, indicate the value of the provenance. The actual origin of individual provenances in *Fig. 3* can be identified by comparing with *Fig. 1* and reading the provenance number from *Table 1*. Plotted are only those average deviations which are based on 5 or more readings. The actual locations at which a provenance grows as shown in *Figs. 4 to 13* can be identified by comparing with *Fig. 2* and reading the location numbers from *Table 2*.

Results

Adaptability parameters

As can be seen from *Table 4* the correlation coefficient r of $\log_n$ provenance annual height increment on logn location mean annual height increment is not significant for 2 provenances (nos. 45a and 116), is significant at 0.05 level for 6 provenances (nos. 36, 40, 85, 89, 108, 119) and it is highly significant (0.01 level) for the remaining 92 provenances. This indicates that generally the logarithmic transformation has assured good linearity. Of the two provenances with not significant r one (no. 45a) has a high value of r, (0.84) and its non-significance is only the consequence of few degrees of freedom (N-2 = 3). With provenance 116 (Chita, East of Lake Baíkal) there also few degrees of freedom (N-2 = 4) but the r value is very low indicating that a correlation between performance of this provenance and the means over locations does not exist. Thus in some ways this provenance is special and requires individual treatment.

Now let us look at stability (b, the coefficient of FINLAY and WILKINSON 1963) and compare it with mean deviation from location means. As can be seen from *Table 4* values of b < 1 (good adaptability) are characteristic for all provenances from the limits of the species range, especially from northern Karyelia (nos. 1, 2), northern Yakutsya (nos. 109, 117, 118), the Far East (nos. 116, 119, 122), southern Siberia (nos. 90, 92, 98,

Table 3. – Mean tree height in cm per provenance at each location.

Location no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	21	22	23	24	25	26	27	29	30	31	32	34	35	36	37	
Age	14	15	15	15	13	13	15	15	11	5	15	16	15	11	15	17	17	17	18	17	17	17	17	17	17	20	17	10	15	7	9	10	12	
Mean ht.	46,7	285	489	245	163	120	503	478	100	36	595	538	542	285	490	490	416	593	582	778	415	575	604	666	663	814	359	164	165	82	183	269	245	
Ann. ht. incr.	3,34	19	32,6	16,3	12,5	9,26	33,5	31,8	9,11	7,2	39,7	33,6	36,1	25,9	32,6	28,8	24,4	34,9	32,4	45,8	24,4	33,8	35,6	39,2	39	40,7	21,1	16,4	11	11,7	20,3	26,9	20,4	
Proven.																															1)	1)		N
1	84	243		148	179	103																					220	130						7
2	87	283		181	131	88										260	274	200					400				330	147	95					12
3	70	278		264	186	101																	390				311	148	100					9
4	52	337	460	308	153	88	430	390	107	21						490	392					556	590			770	400		140	86				18
8	35		580	264		85	440		107																				176					7
9	45	320	510	328	155	120	470	470	113	34	560					480				749		580	590				460							16
10	35					90	380		111																		310		130					6
12	65	308		204	154	99																					310	152		59				8
13	45					86																												2
14	40	324	520	280	175	130	480	400	110							440	405																	11
15	60	284	500	288	182	128	480	420	111	29	510					480	425										390		180	77				16
16	52	320	520	250	173	120	520		121	32	540		410			440	367										370	147	150					16
17	39	310	530	288	162	134	470	400	105		560																400							11
18	38				166	116										530													200					5
19		290	490	307		105	560	540	107	34	580																							9
21			530			85	540	540	101	43	590				470	520	456	630									350							12
22		230	450			87	590	480	118	39	580					530	448					503												11
23		260	470			100	570	530	110	36	540		560			540	428																	11
24			500			116	510	540	113	34	610		580		430	540	434										250							12
25			490				530	520	110	36	670		620		520	560	463	610		803	324				620		350							15
26							520	510	95	40	660		550		510	530	477	660		814	388				620									13
27							650	560	105	44	680	670	620		470	590	471	640																11
28							550	590	111	38	630		560		480	570	491	640																10
29							520	570	91	40	620	670	620	328	510	520	468	600																12
30							530	630	101	41	700		670		600	540	454	640																10
33										40	650	560	580	316	600	510	493	660	540	791	456				590				170				301	15
34												640	520	364	530	450	487	640	580														283	9
35												520	550	337	540	520	451	700	619														293	9
36											640	600	390	393	550	520	465	650	673			606											286	11
37										34	620	740	580	313	560	510	474	620		769	376				720		200						277	14
38										41	630	440	610	329	580	470	494	630	668	787	424				790		210						290	15
39										36	650	630	600	310	470	540	523	660	527														293	11
40												620	610	184	470	530	472	500	640														242	9
41						75	540	520	84	30	630	640	550	298	400	610	443	660		797	395	526			670									17
42		280	420			130	580	530	102	33	540					590	372	600		793		557			620				155					15
43	39		510			95	560	530	101	40	560	470	550	314	480	630	458	660	558	813	425	562	610	701	640	920	360	162	130				226	27
44	37		520		172	120	550	520	83		520	550				500				807	395		610				370							14
45			570			156	500	420	103	40	570		540		420	600	421	580		797		607	620		610		400		200					18
45a																610	457				379		620		620									5
46			550				480	490	90	35	580	530	630	286	530	540	473	650		762	316	498	620	710	580									19
47		300	520	252		130	590	480	90	33	560					600				787	354	561	640		730				130					16
48		300	520	244		130	490	480	106	34	580					580	401	680		770	371	600	640		690		340	161						19
49							520	500	85	39	620	490	580	288	460	500	451	590	542	786	409				650									16
50			550				520	530	95	35	600	580	670	301	440	500	444	660	554	788	383	571		705	730		260		170				231	22
51							600	540	95	34	610	560	600	324	450	580	477	720	580	816	418	558					280		180				278	19
52										35	630	600	540	277	530	570	458	600	577	750													237	12
54			570				570	480	103	41	590	540	530	301	520	610	489	650	547	830	422	577	630	756	690	930	300		190				244	24
55									97	31	610	650	610	305	470	530	539	640	480	830	486	585			690	870	290		180				289	19
56												640	620	295	440	540	538	600	508	785	481				780								277	12
57			630				400	450	100	34	580	510	510	300	430	530	461	650	586	797	440	560	620	691	670	930	420		200				262	24
59							460	430	100	35	630	550	570	308	490	560	503	580	520	759	438	604	540	756	680	860	360		190				234	23
60												640	640	329	480	490		570	629														300	8
62												650	580	318	480	530	469	650	572		424			750	640	850			160				275	14
64												540	580	317		510	436	570	698	789	461			683	660	860	320						259	14
65			530				520	470	103	34	540	410	610	294	500	590	468	630	695	815	426	602	670	695	670	990	390							22
66a	25		410					320	98	34		390	510	220	450	550	426	650	600	764	414	570	610	725	670				200					20
67		280	490	287		130	480	300	98	41						530	443	660		761	405	584	640	677	720		410		170					19
68	38	290	300		131	94	530	400	98	31	570					500	413	530		732	405	577	640	651	670		380							20
69			550				410	410	94	42	560	440	530	230	500	520	423	600		791	466	610	650	635	610	830	330		190				246	23
69a																610																		1
70									86								382			718	453		620	631					140					7
71												320				500	379			788	420	590	630	559	600		340						184	11

99, 100, 105, 111), and the most southern provenances of Ukraine (nos. 34, 35) and central European Russia (nos. 56, 60). The northern provenances have negative deviations from the location mean in tree height and therefore their good adaptability (consistently slow growth) is of little practical value. However the southern Russian and Ukrainian provenances have the highest positive deviations (+0.58 to +0.66) which coupled with adaptability (consistently fast growth on various sites) makes them very attractive as breeding material. Also among the southern Siberian provenances most of them (90, 98, 99, 100, 105) have negative mean deviations (–0.09 to –0.54) thus they are not likely to be

(continuation *Table 3*)

71a																480	349	500		738	410	533	620										193	8
72												460		166		340	336	500		682	430		620	614	610	820	400						171	13
73						165	380		95																		350		180					5
74	27					160	330		110																									4
76																530	400				411	571	570	622	640	850	420	210						10
77	44	300		298		130										500	359			741	403	586	630	654	610		420							13
78	50	290		227	132	80															430	549	600	610	630									10
79																540	418	600	567	789	454	605	640	719	660	850	420		190				218	14
80																						607												1
81	54	300	410	283	195	160										320	378						550	555		700	300							12
82	39	280	440	230		170										520	347	550				568	630	723			370		190					13
83							420	390	73	34	530	440		279	510	530		620	649	770	500		650	726	720	840	340						253	19
84																490	419				392	588	650	669		820	410					270		9
85																610	437							726		800	330							5
86	27		550			165	460	390	88	38	560	500	400	272	430	600	479	610	622	779	396	659	550	701	670	900	450		200				241	26
87																580	426	550						634		830	330							6
88		300				125										410	400	500						568		770	440							8
89																490	386									810	410						221	5
90												480		195		430		500	550	726				546			420		170		190	280		11
91																										730	350							2
92						160			87							450	343									750	340		190			260	203	9
93	33					115																							190		150			4
94	40		430			130										380	408	500								720	380		160	79		280		11
95																											330				190			2
98												410				410	395		466				620			810	390		190			280		9
99																	418	500								820	350	171	175		180			7
100													360			510	420	600	613				640			730	430		175			270	180	11
101																304	340									810								3
102	46		370			135										370	303									620	370		120					8
103	52		370		158	,110										330	324									580	340	158						9
104	36					105																					320	189	120					5
105													390			390	408	500	575							870	420		180			210		9
106	44		370	237												390	360										350	154	150					8
107																470	387										390		140					4
108													340			370	352									820	450		150					6
109	59	230		161		144										440											420							6
110	45			190												430	375										470							5
111																400	362										340		140	83				5
112																											320	172	169					3
113																											390		200	87				3
114																410	382										340							3
116																210	348										390	187	210	106				6
117	45			118		150										290	283										320		140	66				8
118	55	220				170											271										350	167	130	58				8
119													310			460	323										390		200	119		260	198	8
120																420	418										390		160			280		5
122	54	240															272										310		140					5
123												490		183		420	434	550	539					705	680	840					210	290	210	12
124												540	380		420	310	406	600	540					598	620	750			140		190		224	13
125												320		119		480	410	400						629	730	840	330				170	280	215	12
126																	321		620														251	3
N	35	26	35	23	16	45	41	37	45	41	41	38	42	33	37	90	86	55	32	38	38	32	34	32	38	35	73	15	51	10	7	11	35	1247

1) height was not measured for all provenances, reasons unknown

of wider use in spite of their consistent performance. The very low value of b for provenance 116, cannot be considered evidence for its adaptability in view of the very low value of r obtained for this population.

Provenances that are characteristically reactive (b > 1) are concentrated in the region around Moscow (in a triangle between Smolyensk, Vologda and Nizhyegorod - nos. 8, 41, 43, 44, 46, 47, 48, 49, 50). These provenances generally have mean deviations close to zero (+0.15 to –0.16), thus their overall performance has to be considered as average. Reactivity of these provenances suggests that some very fast growing populations can be selected for specific sites. There are also a few rather reactive provenances from southern Urals (Bashkortostan and Kustanai in north-eastern Kazakhstan - nos. 70, 71a, 72, 123), but their mean deviations are decidedly negative (–0.09 to –0.78).

All other provenances have b ≈ 1, which means they have adequate stability.

Finally a word about the variance of deviations from the regression, (V_d, the coefficient of EBERHART and RUSSELL, 1966). This is equivalent to ecovalence when b ≈ 1. Generally the values are very low, but there is some geographicity in its magnitude. As can be seen from *Table 4* and the lowest values of V_d have been obtained from medium latitudes throughout the range, the zone being wider in Europe than in the Far East. Higher values were obtained for both northern and southern populations. This means that for provenances from the southern and northern extremes of the species range the results are less predictable.

Average performance of provenances

As can be seen from *Fig. 3* relatively best tree height is attained by western populations from the frontier with Poland to a line from Smolyensk to Oryel, Voronyezh and Samara on the Volga river. All northern populations, especially eastern Siberian and northern Karyelian ones have very poor relative

Table 4. – Means for normalised data on tree height (as deviations from location means averaged over all locations at which a given provenance occurs) and genotype x environment interaction parameters (coefficients b of FINLAY and WILKINSON, V_d of EBERHART and RUSSELL and r – correlations of $\log_n$ annual height increment of a provenance with the $\log_n$ mean height increment per location), for all provenances represented on at least 5 locations.

Prov.	Tree ht.	N-2	r	b F&W	Vd E&R	Prov.	Tree ht.	N-2	r	b F&W	Vd E&R
1	-0,64	5	0,87**	0,48	0,037	60	0,59	6	0,86**	0,79	0,009
2	-1,52	10	0,79**	0,54	0,084	62	0,43	12	0,98**	1,03	0,005
3	-0,58	7	0,91**	0,74	0,056	64	0,38	12	0,96**	1,00	0,005
4	-0,31	16	0,97**	1,02	0,035	65	0,47	20	0,98**	1,03	0,010
8	-0,06	5	0,98**	1,13	0,035	66a	-0,28	18	0,97**	1,11	0,035
9	0,16	14	0,99**	0,99	0,013	67	0,17	17	0,97**	0,94	0,017
10	-0,81	4	0,98**	1,00	0,029	68	-0,49	18	0,99**	1,06	0,018
12	-0,33	6	0,94**	0,80	0,031	69	-0,01	21	0,98**	0,93	0,011
14	0,16	9	0,99**	0,99	0,014	70	-0,59	5	0,99**	1,08	0,007
15	0,03	14	0,99**	0,92	0,012	71	-0,59	9	0,86**	1,06	0,032
16	-0,08	14	0,99**	0,93	0,013	71a	-0,78	6	0,97**	1,17	0,008
17	0,09	9	0,99**	1,01	0,015	72	-0,96	11	0,87**	1,17	0,035
18	0,22	3	0,99**	1,14	0,013	73	-0,07	3	0,95**	0,71	0,026
19	0,26	7	0,99**	1,05	0,012	76	0,21	8	0,96**	0,74	0,005
21	0,26	10	0,98**	1,06	0,018	77	-0,01	11	0,99**	0,98	0,010
22	-0,13	9	0,97**	1,02	0,027	78	-0,52	8	0,99**	1,03	0,022
23	0,06	9	0,99**	1,04	0,010	79	0,41	12	0,98**	0,94	0,005
24	0,02	10	0,98**	1,02	0,020	81	-0,34	10	0,97**	0,80	0,022
25	0,29	13	0,98**	1,01	0,010	82	0,08	11	0,98**	0,99	0,022
26	0,38	11	0,99**	1,00	0,005	83	-0,04	17	0,97**	1,09	0,016
27	1,09	9	0,99**	1,00	0,008	84	0,19	7	0,97**	0,96	0,003
28	0,73	8	0,99**	1,00	0,005	85	0,41	3	0,94*	1,09	0,016
29	0,56	10	0,99**	1,05	0,007	86	0,13	24	0,97**	1,05	0,032
30	1,14	8	0,99**	1,05	0,006	87	-0,03	4	0,94**	1,00	0,011
33	0,59	13	0,98**	0,96	0,008	88	-0,30	6	0,97**	0,84	0,014
34	0,58	7	0,82**	0,74	0,011	89	-0,06	3	0,95*	1,00	0,011
35	0,66	7	0,93**	0,79	0,004	90	-0,54	9	0,93**	0,84	0,019
36	0,78	9	0,67*	0,64	0,021	92	-0,37	7	0,96**	0,85	0,020
37	0,28	12	0,94**	1,13	0,040	94	-0,37	9	0,99**	0,98	0,012
38	0,59	13	0,92**	1,01	0,039	98	-0,27	7	0,93**	0,79	0,016
39	0,58	9	0,98**	1,02	0,010	99	-0,09	5	0,99**	0,89	0,004
40	0,07	7	0,77*	1,19	0,039	100	-0,15	9	0,89**	0,89	0,032
41	-0,11	15	0,98**	1,20	0,016	102	-1,03	6	0,98**	0,88	0,025
42	-0,10	13	0,99**	1,01	0,010	103	-0,98	7	0,99**	0,81	0,009
43	0,13	25	0,99**	1,08	0,010	104	-0,47	3	0,98**	1,14	0,030
44	-0,07	12	0,99**	1,09	0,007	105	-0,53	7	0,90**	0,80	0,026
45	0,27	16	0,98**	0,89	0,009	106	-0,67	6	0,99**	0,93	0,007
45a	0,11	3	0,84-	0,88	0,020	108	-0,58	4	0,87*	0,85	0,065
46	-0,16	17	0,97**	1,56	0,032	109	-0,18	4	0,95**	0,82	0,059
47	0,03	14	0,97**	1,44	0,058	110	-0,10	3	0,98**	1,00	0,051
48	0,15	17	0,96**	1,43	0,051	111	-0,62	3	0,98**	0,91	0,008
49	-0,03	14	0,98**	1,53	0,026	116	0,05	4	0,19-	0,12	0,069
50	0,12	20	0,97**	1,48	0,038	117	-1,04	6	0,90**	0,75	0,070
51	0,35	17	0,98**	1,06	0,012	118	-0,58	6	0,91**	0,77	0,057
52	0,20	10	0,99**	1,03	0,004	119	-0,29	6	0,75*	0,43	0,030
54	0,52	22	0,98**	0,99	0,008	120	0,03	3	0,97**	0,97	0,011
55	0,39	17	0,98**	1,06	0,015	122	-1,02	3	0,99**	0,78	0,012
56	0,63	10	0,87**	0,85	0,014	123	-0,09	10	0,87**	1,09	0,026
57	0,23	22	0,98**	0,97	0,011	124	-0,76	11	0,93**	0,99	0,022
59	0,17	21	0,99**	0,99	0,007	125	-0,68	10	0,70**	1,07	0,089

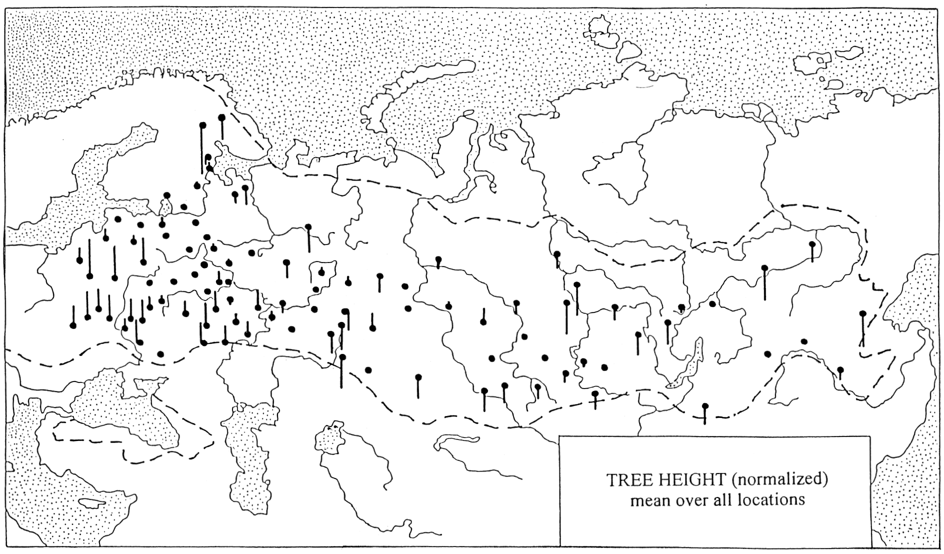

Fig. 3. – Tree height for individual provenances averaged over all planting sites, in units of standard deviation from location means (based on data from not less than 5 planting sites). Values between −0.15 and +0.15 are within the radius of the black dot. For details on individual provenances see number in *figure 1* and data in *tables 1, 3* and *4*.

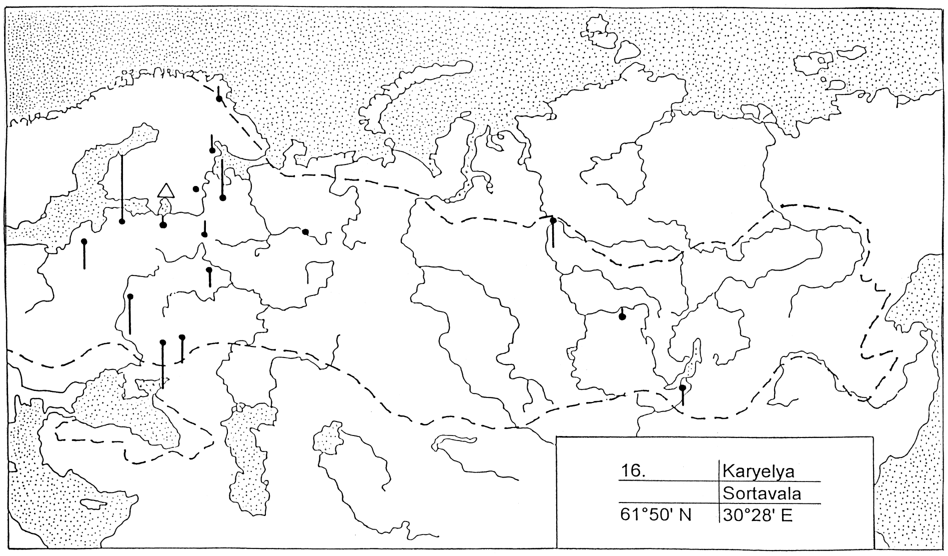

Fig. 4. – Sample pictograms of provenance x location interaction in tree height. Each figure refers to one provenance. The triangle indicates the place of its origin. Black dots indicate locations where the given provenance was tested. For details on locations find number in *figure 2* and data in *table 2*. The lines above and below the dots indicate deviations from the location mean in units of standard deviation. Values between −0.15 and +0.15 are within the radius of the black dot.

height growth. Also the populations from southern Urals are very poor, as well as East of them along the southern fringe of the range all the way to the Okhotsk Sea. In between there is a zone of populations with average tree height, extending from the Baltic countries, through Moscow, central Urals and as a narrowing strip to lake Baíkal and beyond to the Amur river.

Provenance x location interactions

The overall picture demonstrated by data averaged over all locations can be very misleading in that it does not show the extent of usefulness of individual provenances. Relative performance of a provenance at various locations is best revealed by plotting the results onto a map of the locations. Such maps were made for all 113 provenances. It is impossible to show them all here. However certain geographic regularities appeared. In general the range can be divided into several characteristic regions which will be discussed separately.

A. North-western region

There is a group of provenances from Kola Peninsula, Karyelya and the Arkhangyelsk region (nos. 1, 2, 3, 4, 12, 14, 15, 16), which give satisfactory results in that region and nowhere else. Typical for this group of provenances are the results for provenance no. 16 from Sortavala, Karyelya (*Fig. 4*). These provenances are useful locally but distant transfers will result in failures. Also in the cold regions of northern Siberia these provenances are not to be recommended.

Only no. 18, geographically from this region, is somewhat different in that it is more akin to the neighbouring Northern Russia region discussed below.

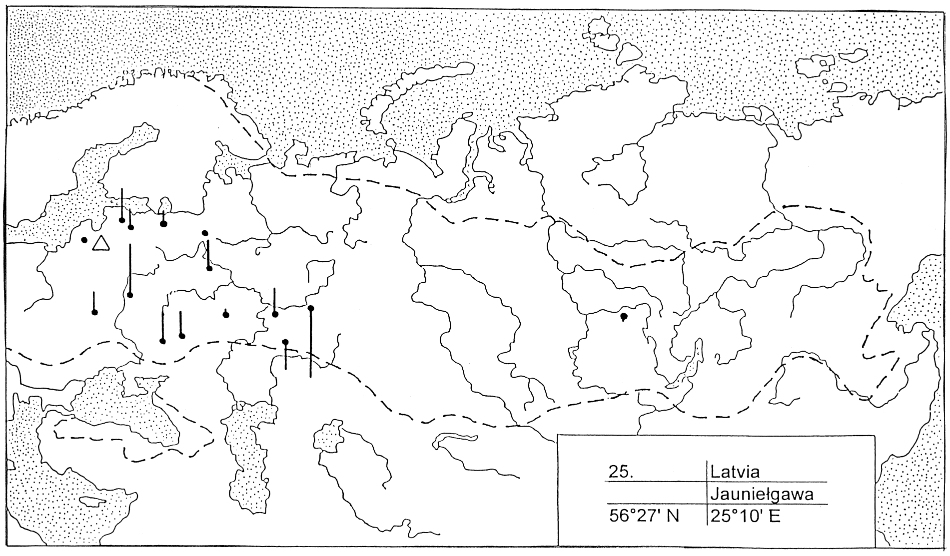

Fig. 5. – Sample pictograms of provenance x location interaction in tree height. Each figure refers to one provenance. The triangle indicates the place of its origin. Black dots indicate locations where the given provenance was tested. For details on locations find number in *figure 2* and data in *table 2*. The lines above and below the dots indicate deviations from the location mean in units of standard deviation. Values between –0.15 and +0.15 are within the radius of the black dot.

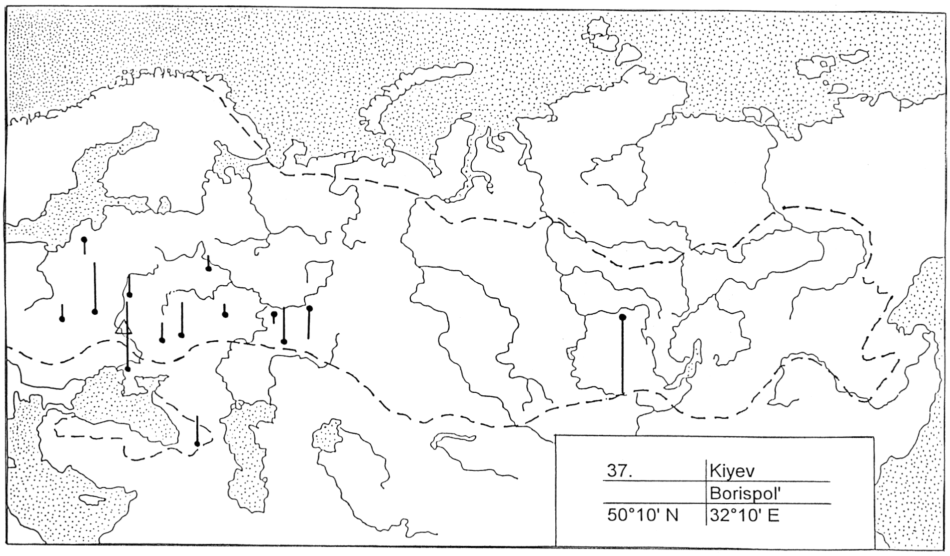

Fig. 6. – Sample pictograms of provenance x location interaction in tree height. Each figure refers to one provenance. The triangle indicates the place of its origin. Black dots indicate locations where the given provenance was tested. For details on locations find number in *figure 2* and data in *table 2*. The lines above and below the dots indicate deviations from the location mean in units of standard deviation. Values between –0.15 and +0.15 are within the radius of the black dot.

B. Baltic region

Riga pine has a good reputation in western Europe dating to early XIX c. and this is confirmed also for most of European Russia, Bielorussia and Ukraine. This positive evaluation of Baltic pine races has been demonstrated in this study for a group of provenances (nos. 21, 22, 23, 24, 25, 26) which are well exemplified by provenance no. 25 Jaunielgawa, Latvia (*Fig. 5*). These provenances do well in regions between latitudes 50 °N and 60 °N but not reaching the Ural Mts. At extreme northern and southern latitudes and beyond longitude 55 °W they are not to be recommended.

C. Western continental region

Perhaps the best Scots pine provenances are to be found in a region of the mixed-forest zone covering Bielorussia and Ukraine (nos. 27, 28, 29, 30, 33, 34, 35, 36, 37, 38, 39, 40). Most of these provenances have been tested on European locations only. However when they were tested in the East they did not perform well. They are well exemplified by provenance no. 37, Borispol', Kiev (*Fig. 6*).

D. Northern Russia

There is a block of provenances from northern Russia, but not from the extreme North, which have a common pattern of performance in height growth (nos. 8, 9, 10, 17, 18, 19, 68, 74, 77, 81, 88, 93, 94, 101, 102, 110, 117). It extends from St. Pyetyersburg, through Vologda, Tvyer, Pyerm, Tomsk to Krasnoyarsk and Yakutsya. This roughly corresponds to the taiga. The region is not strictly latitudinal, because in the West its limit is between 59 °N and 65 °N and in the East between

58 °N and 62 °N. Scots pine from this region grows well throughout the region with extensive East or West transfers possible, but it is not successful beyond the region. Its performance is well exemplified by provenance no. 77, Tavda, Yekatyerinburg (*Fig. 7*).

The Turukhansk, Krasnoyarsk, provenance of Lat. 65°49' (no. 104) clearly does not belong to the Northern Russia region – if any thing it is akin to the North-western region in that it is relatively fast growing locally (far North) but nowhere else. The Yakutsk provenance no. 118, of Lat. 62° and Long. 130°, appears to be somewhat intermediate in that it is good only in the North but transferable longitudinally over great distances.

E. Central European Russia

This is a region that in some ways is an eastwards extension of the western continental one, being likewise located in the mixed-forest zone, however the height growth performance is not as good in the West, while on the other hand its utility extends further East. The group of provenances in question (nos. 41, 42, 43, 44, 45, 45a, 46, 47, 48, 49, 50, 51, 52), exemplified well by provenance no. 43, Kurovskoye, Moscow (*Fig. 8*), includes almost all of those listed above as very reactive (high b, coefficient of FINLAY and WILKINSON - nos. 8, 41, 43, 44, 46, 47, 48, 49, 50). This seems to differ the group from the western continental one. The pines are growing fairly well at medium latitudes, even further East than the western continental provenances, but not so well in Ukraine nor anywhere along the southern limit of the range.

F. Middle Volga region

Further south and south-west (Voronyezh, Saratov, Kazan, Magnitogorsk, to the Urals) there is group of provenances (nos.

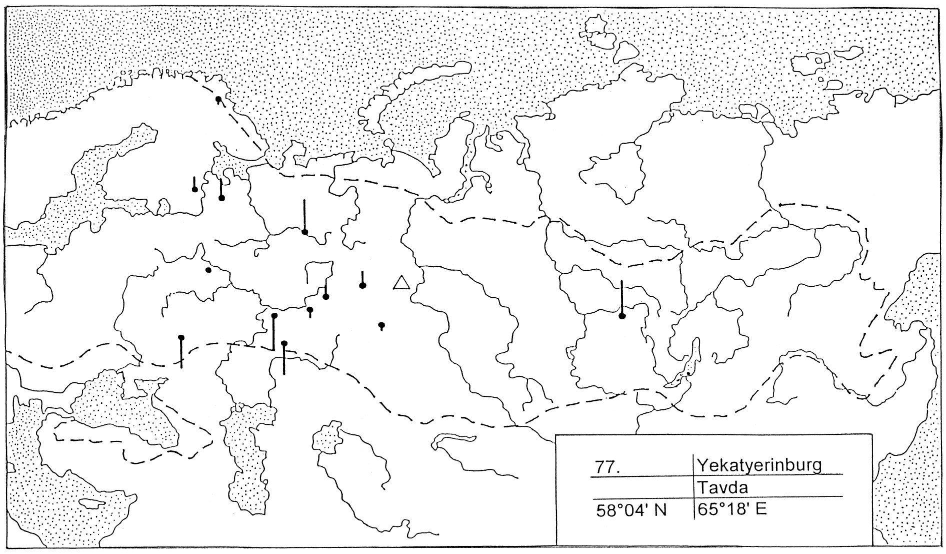

Fig. 7. – Sample pictograms of provenance x location interaction in tree height. Each figure refers to one provenance. The triangle indicates the place of its origin. Black dots indicate locations where the given provenance was tested. For details on locations find number in *figure 2* and data in *table 2*. The lines above and below the dots indicate deviations from the location mean in units of standard deviation. Values between –0.15 and +0.15 are within the radius of the black dot.

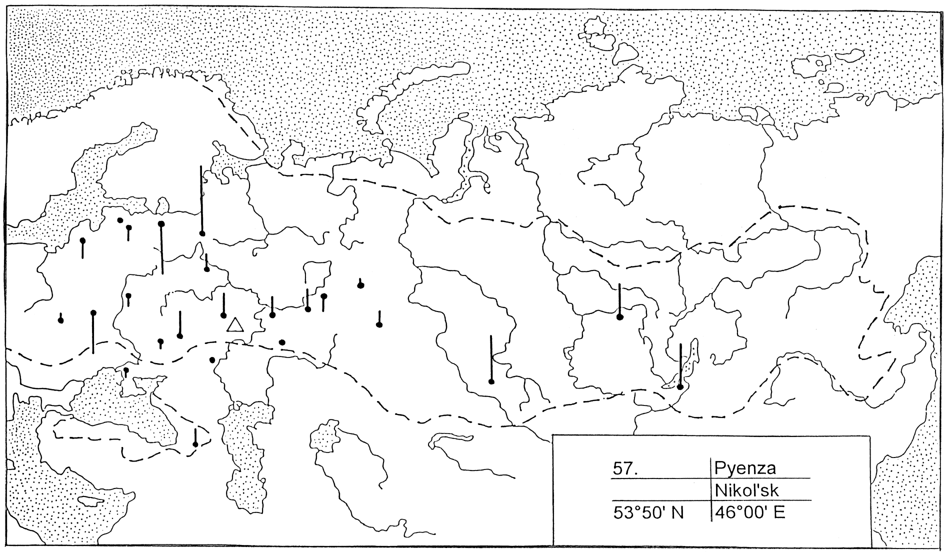

Fig. 9. – Sample pictograms of provenance x location interaction in tree height. Each figure refers to one provenance. The triangle indicates the place of its origin. Black dots indicate locations where the given provenance was tested. For details on locations find number in *figure 2* and data in *table 2*. The lines above and below the dots indicate deviations from the location mean in units of standard deviation. Values between –0.15 and +0.15 are within the radius of the black dot.

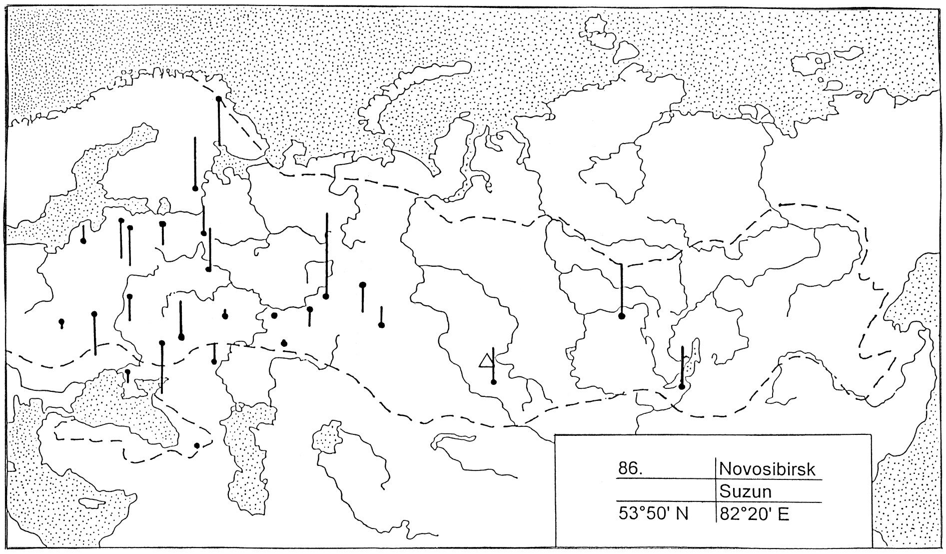

Fig. 10. – Sample pictograms of provenance x location interaction in tree height. Each figure refers to one provenance. The triangle indicates the place of its origin. Black dots indicate locations where the given provenance was tested. For details on locations find number in *figure 2* and data in *table 2*. The lines above and below the dots indicate deviations from the location mean in units of standard deviation. Values between –0.15 and +0.15 are within the radius of the black dot.

54, 55, 56, 57, 59, 64, 65, 66a, 67, 69, 70, 71, 73) which are not growing too well in the West, nor in the South, but are quite satisfactory in their own region and are transferable both northwards and eastwards, all the way to lake Baíkal. Typical for that region is provenance no. 57, Nikol'sk, Pyenza (*Fig. 9*).

G. Central Trans-Urals region

East of the Urals there is a group of provenances (nos. 76, 78, 79, 82, 84, 86, 89, 90, 92, 98, 99, 100, 105) extending from Yekatyerinburg, through Omsk and Novosibirsk to the Altai and Sayan Mts. and upper Yenitsyei River on the Mongolian border. In some respects it is comparable to the Northern Russian region in that it is a narrow belt parallel to it, with gradually lower latitudes as one moves eastwards, and in that fairly wide East-West transfers within the region are possible, however behaviour of provenances from that region is much less predictable. These provenances can be represented by no. 86 Suzun, Novosibirsk (*Fig. 10*).

Two provenances within the Central Trans-Urals region, nos. 85 and 87, both from Novosibirsk province, are somewhat different in that they sustain westward but not eastward. transfers.

H. Southern fringe region

Near the southern limit of the range there are some provenances (nos. 60, 62, 83, 113, 119, 123, 124, 125, 126) which have quite acceptable height growth near their origin but are not transferable northwards nor to any distance longitudinally. Typical for this group is provenance no. 125, Dolon, Semipalatinsk (*Fig. 11*).

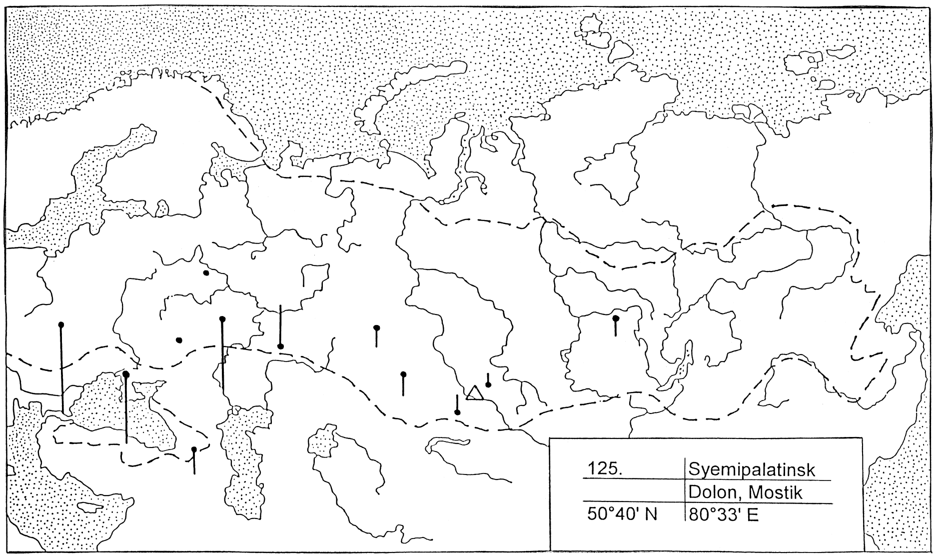

Fig. 11. – Sample pictograms of provenance x location interaction in tree height. Each figure refers to one provenance. The triangle indicates the place of its origin. Black dots indicate locations where the given provenance was tested. For details on locations find number in *figure 2* and data in *table 2*. The lines above and below the dots indicate deviations from the location mean in units of standard deviation. Values between –0.15 and +0.15 are within the radius of the black dot.

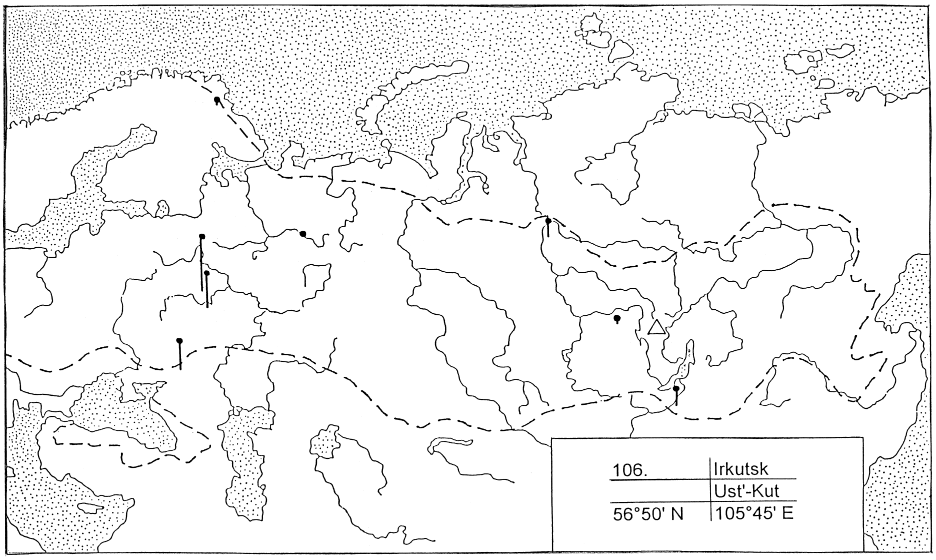

Fig. 12. – Sample pictograms of provenance x location interaction in tree height. Each figure refers to one provenance. The triangle indicates the place of its origin. Black dots indicate locations where the given provenance was tested. For details on locations find number in *figure 2* and data in *table 2*. The lines above and below the dots indicate deviations from the location mean in units of standard deviation. Values between –0.15 and +0.15 are within the radius of the black dot.

I. Eastern Siberian region

Finally a word is needed about the Far Eastern provenances (nos. 106, 107, 108, 109, 111, 112, 114, 120, 122). They have not been very well represented in the experiment being planted on only few locations. Quite often they have not been tested locally. The performance of these provenances is as a rule not very satisfactory on most sites where they have been tested. This can be illustrated by nos. 106, Ust'-Kut, Irkutsk (*Fig. 12*) and 122, Ayan, Khabarovsk (*Fig. 13*).

Odd populations

There are a few, surprisingly few, provenances which in terms of adaptation to various conditions cannot be easily classed as belonging to any of the above defined regions or as being intermediate between them (as discussed above for nos. 18, 85, 87, 104, 118), because their height growth performance is very unlike that of neighbouring provenances.

On the eastern extremity of the Middle Volga region, in southern Ural Mts., there are two provenances, nos. 71a and 72, both from Bashkortostan, which are different in that they are decidedly of poor growth on almost all sites where tested.

One provenance from the Northern Russia region, no. 103, Yenisyeisk, Krasnoyarsk, or rather from its southern fringe, has a different pattern of behaviour – also not falling within the Central Trans-Urals region with which the Northern Russia region borders. If anything the provenance is comparable to the much more eastern provenances of the Eastern Siberian region in that it has very poor growth on all sites.

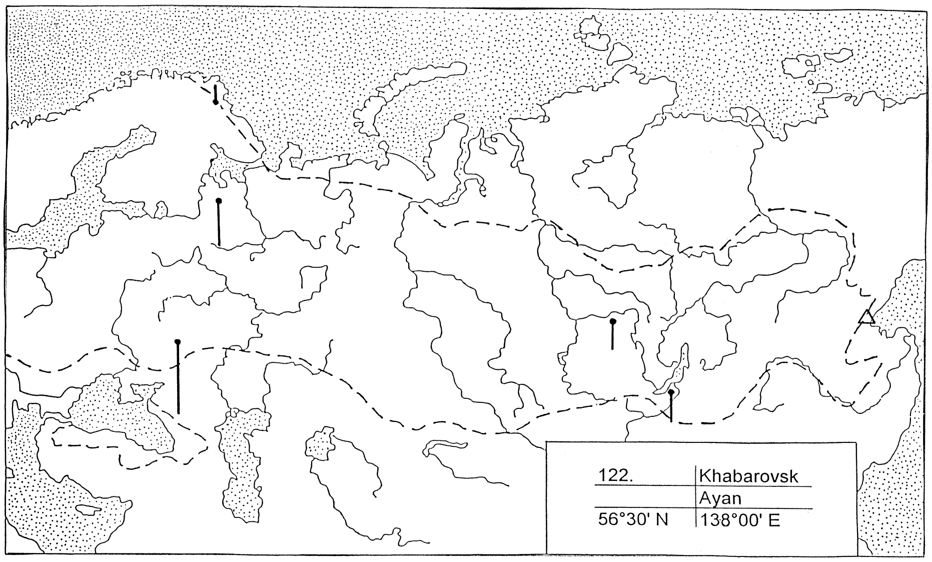

Fig. 13. – Sample pictograms of provenance x location interaction in tree height. Each figure refers to one provenance. The triangle indicates the place of its origin. Black dots indicate locations where the given provenance was tested. For details on locations find number in *figure 2* and data in *table 2*. The lines above and below the dots indicate deviations from the location mean in units of standard deviation. Values between –0.15 and +0.15 are within the radius of the black dot.

Finally a word is needed about provenance no. 116, Mogocha, Chita. Geographically it could be classed as belonging to the Eastern Siberian region or to the Southern Fringe populations, yet it is very different from both. It is the only provenance that does not correlate with the mean results for locations (*Table 4*). This provenance included in only 6 trials grows relatively very well on 4 locations, in the east and north-east, but very poorly at the two European locations.

Discussion

Overall it appears that European populations are superior in height growth to Siberian ones. Thus if anyone was expecting some undiscovered riches in the Scots pine gene pool in the East, this study clearly shows that they do not exist, at least not for transfer and use in the western part of the former USSR.

Since most of the planting sites are located in the European part of the area under study (*Fig. 2*) the average value over all locations plotted in *fig. 3* is likely to reflect performance in Europe rather than over the whole area. However it emerges from the studied genotype environment interactions, that the eastern populations are of some value locally. Westward transfers however are generally not to be recommended except perhaps within the taiga region of northern Russia.

The growth inferiority of the eastern and far northern populations was already reported for older trials near Moscow (PRAVDIN and BAKUROV, 1968) and near Voronyezh (VYERYESIN and SHUTYAEV, 1978; SHUTYAEV and VYERYESIN, 1990) and this was confirmed also for a second generation trial based on seed collections in this older experiment near Voronyezh (SHUTYAEV, 1983). However very few eastern populations were included in earlier studies. In OGIYEVSKIĬ's 1910 to 1916 series (GIERTYCH and OLEKSYN, 1981) there were two provenances from regions east of the Urals, from what were then enormous Syemipalatinsk and Akmolinsk provinces. The former population perished and the latter survived on one site only, in Ukraine (near Sumy), where its height performance was much below average. On the rediscovered experimental plot in Poland of that series (under Russia in 1912 when outplanted) the two Siberian provenances (seeds from Tobolsk and Yenisyesk) are both well below average in volume production (OLEKSYN and GIERTYCH, 1984). In the USA Christmas tree study of 1951 that included several Scots pine provenances from Siberia it was found (RUBY and WRIGHT, 1976) that a race called "NE-Siberia" (from Yakutsya) grows very slowly, similarly as those from northern Sweden and Finland, var. *mongolica* from the Lake Baíkal and river Angara watersheds is also very slow growing, a race called "Krasnoyarsk" from the upper Yenisyei and Ob river watersheds is generally slower growing than the general average for the USA study while var. *altaica* (from the Altai Mts.) and var. *uralensis* from the southern Urals have tree heights comparable to the experiment average in USA. A study established in Hungary in the years 1978/1979 (MÁTYÁS, 1987) has shown that at age 11 provenances from the region of Lake Baíkal and Angara river had well below average tree heights. Those from the Sayan Mts. were taller and those from the Altai Mts. taller still but all were below average for the whole experiment. In a Czech study, near Pilsen, where small seed lots from the PROKHAZIN collection discussed in the present paper were used for planting in Sofronka Arboretum, it was found (KAŇAK, 1980) that the best growing provenances came from the central zone of western USSR, in agreement with the present data, from the steppes at the feet of the southern Urals and from outlier populations at the feet of the Altai Mts., the information for the latter two zones not being confirmed now. However these two zones are also mentioned as being best from among the Siberian populations when grown near Moscow (NARYSHKIN et al., 1983), and the Altai populations also when grown near Minusinsk in the Sayan Mts. (CHYERYEPNIN, 1977). In the latter study only these Altai provenances were substantially superior in 14-year tree height to local ones. All other Siberian and most European (except Voronyezh) populations were much slower growing. In other trials in the same region and further north near Krasnoyarsk there was a tree height superiority of populations from the upper Ob river and to a lesser extent from the region where Yenisyei and Angara join, from Tomsk and from central Urals, while numerous other Siberian provenances tested were much inferior to the local one (European populations were not included in these trials) (IROSHNIKOV, 1977). A report from the vicinity of Novosibirsk, on river Ob, claims superiority for the local population and for European ones but not for other Siberian ones (DYEMIDYENKO et al., 1984). Further east on the Amur river near Khabarovsk 30 Far Eastern provenances were tested. When measured at age 28 local ones were superior in all growth traits. These were followed by Chita and Buryat (east of Lake Baíkal). In another plot near by, where provenances from Irkutsk and from Samara were included, the latter two were superior (TAGIL'TSEFA, 1986).

To summarise, the data available so far indicates that populations from regions east of the Urals are inferior in growth to European ones, but they are differentiated and sometimes other than local populations were recommended. However these recommendations are not confirmed by the present study. Those mentioned above as potentially better from among the Siberian ones are decidedly poor growing in the present series of trials. We are referring here to the populations from the feet of the Altai and Sayan Mts. and upper Irtysh and Ob rivers (nos. 125, 90, 92 and 98) and from the region downstream from where Yenisyei and Angara meet (nos. 93, 102, 103). On the other hand the superiority of populations from central Urals (nos. 73, 76) is confirmed at least in relative terms to other eastern populations.

The Caucasian populations in all known studies are consistently poor growing, also here (no. 126).

Throughout the range there is a consistent latitudinal variation in growth performance of Scots pine populations indicating that both northern and southern origins are inferior in growth performance, except locally, to those from more central latitudes. This was already apparent from an analysis of the 1910 to 1916 study of OGIYEVSKIÍ (GIERTYCH and OLEKSYN, 1981) where the populations from the taiga (northern) and from the forest steppe (southern) were inferior to those from the zone of mixed forest. This result was for European Russia only, but the general pattern seems to be extendible all the way to the Far East. In this case one cannot argue that the result is a consequence of over representation of planting sites in the central zone because in fact the distribution of these sites covers northern and southern regions rather well (*Fig. 2*) and if anything it is the central zone that has fewer sites.

Within the western populations obviously those from Bielorussia and central Ukraine are superior in growth performance (*Figs. 3* and *6*). This confirms many earlier evaluations (reviewed and summarised in GIERTYCH and OLEKSYN, 1981). The zone with valuable populations extends further south than was indicated by the earlier results, to Kiev, Kharkov and eastwards to the whole area between rivers Volga, Oka and Don (Voronyezh, Tambov, Nizhny Novogorod, Penza, Volgograd nos. 54, 55, 56, 57, 64, 65 - *Figs. 3* and *9*).

Among good performers within a well defined latitudinal region one has to include populations from the St. Pyetyersburg region and eastwards to Vologda and Kostroma.

It is interesting that for so much of the data clear and logical geographicity was obtained. This concerns both the b and V_d coefficients (*Table 4*), the average performance of provenances (*Fig. 3*) and the performance of individual provenances over several sites (Figs. 4 to 13). The geographicity of growth results from wide range provenance trials is worth remembering when trying to interpret the usually haphazard data on genetic variation obtained from molecular studies (isozymes, terpenes, DNA). It is obvious that growth data bears a relation to migration history and adaptation processes, whereas by molecular genetics most of the time we seem to be investigating the scatter of mutations that are neutral from the point of view of adaptation.

Literature

CHERYEPNIN, V. L.: Gyeografichyeskiye kul'tury sosny obyknovyennoí v yuzhnoí lyesostepi krasnoyarskogo kraya. In: E. G. MININA and A. I. IROSHNIKOV (Eds.): "Gyeografichyeskiye kul'tury i plantatsii khvoínykh v Sibiri". Izd. Nauka, Novosibirsk: 111–123 (1977). — DYEMIDYENKO, V. P., ALYEKSYEYEV, JU. B. and URUSOV, V. H.: Gyeografichyeskiye kul'tury sosny i yeli na yugye zapadnoí Sibiri. Lyesnoye Khozyaistvo (**3**): 40–42 (1984). — EBERHART, S. A. and RUSSELL, W. A.: Stability parameters for comparing varieties. Crop Science **6**: 36–40 (1966). — FINLAY, K. W. and WILKINSON, G. N.: The analysis of adaptation in plant-breeding programme. Australian Journal of Agricultural Research **14**: 742–754 (1963). — FOMIN, F. I.: Opyt raíonirovaniya syemyennogo khozyaístva sosny obyknovyennoí na osnovye izuchyeniya yeye klimatichyeskikh yekotipov. In: "Isslyedovaniya po lyesosyemyennomu dyelu". Sbornik trudov TsNIILKh. Izd. Goslyestyekhizdat, Moscow-Leningrad 3–106 (1940). — GIERTYCH, M.: Summary of results on Scots pine (*Pinus sylvestris* L.) height growth in IUFRO provenance experiments. Silvae Genetica **28**(4): 136–152 (1979). — GIERTYCH, M.: Provenance variation in growth and phenology. Chapter 8 in GIERTYCH, M. and MÁTYÁS, CS. (Eds.): "Genetics of Scots pine". Elsevier: 87–101 (1991). — GIERTYCH, M. and OLEKSYN, J.: Summary of results on Scots pine (*Pinus sylvestris* L.) volume production in OGIEVSKIJ's pre-revolutionary Russian provenance experiments. Silvae Genetica **30**(2–3): 56–74 (1981). — GIERTYCH, M. and OLEKSYN, J.: Studies on genetic variation in Scots pine (*Pinus sylvestris* L.) coordinated by IUFRO. Silvae Genetica **41**(3): 133–143 (1992). — GUSYEÍNOV, A. M. and GUSYEÍNOVA, L. M.: Izuchit' gyeografichyeskogo i ekologichyeskuyu izmyenchivost' glavnykh lyesoobrazuyushchikh porod dlya sovyershyenstvovaniya lyesosyemyennogo raíonirovaniya (sosna). Final report on a research project. Barda Azyerbaídzhan Forestry Research Institute (Azyerb NIILKh), 63 pp. (1986). — GYERUSHINSKIÍ, Z. YU and KRINITSKIÍ, G. T.: Rost gyeografichyeskikh kul'tur sosny obyknovyennoí na L'vovskom Rostoch'ye. Final report on a research project. L'vov Forest Technical Institute, 72 pp. (1986). — IROSHNIKOV, A. I.: Gyeogryfichyeskye kul'tury khvoínykh v yuzhnoí Sibiri. In: E. G. MININA and A. I. IROSHNIKOV (Eds.): "Gyeografichyeskiye kul'tury i plantatsii khvoínykh v Sibiri". Izd. Nauka, Novosibirsk: 4–110 (1977). — KAŇAK, K.: Provenienční studie s borovicí lesní v Českých zemích. Proc. from conf. "Provenienční výzkum lesních dřevin", 9 to 11 Oct. 1979, Praha, ČSSR, 83–104 (1980). — KHAZIAGAYEV, S. M. and NUGAYEV, I. KH.: Usovyershyenstvovat' myetody sozdaniya postoyannykh syemyennykh plantatsií osnovnykh lyesoobrazuyushchikh porod dlya poluchyeniya syemyan pyervogo gibridnogo pokolyeniya. Final report on a research project. Ufa, All-Russian Forest and Melioration Research Institute, Bashkir Forest Research Station (VNIILM, Bashir LOS), 70 pp. (1990). — KHIROV, A. A.: Usovyershyenstvovat' myetody i tyekhnologii sozdaniya postoyannoí lyesosyemyennoí bazy glavnykh lyesoobrazuyushchikh porod na gyenyetiko-syelyektsionnoí osnovye v Sryednyem Povolzh'ye i na Yuzhnom Uralye. Final report on a research project. P. Opytnoye Oryenburskoi obl. All-Russian Forest and Melioration Research Institute, Borovo Forest Research Station (VNIILM, Borovo LOS), 85 pp. (1990). — KORABLYEV, V. I., TISHYECHKIN, A. N. and KAMYESHKOV I. L.: Razrabotat' i vnyedrit' myetody i tyekhnologii syelyektsii osnovnykh lyesoobrazuyushchikh porod s tsyel'yu poluchyeniya khozyaístvyenno-tsyennykh form i sortov. Final report on a research project. Yekatyerinburg (Svyerdlovsk) Forest Institute of the Ural Branch of the Russian Academy of Sciences, Ural Forest Research Station (IL UO RAN, Ural LOS), 70 pp. (1990). — KOVALYEV, M. S.: Razrabotat' i vnyedrit' myetody i tyekhnologii syelyektsii osnovnykh lyesoobrazuyushchikh porod s tsyel'yu poluchyeniya khozyaístvyenno-tsyennykh form i sortov. Final report on a research project. St. Petersburg, Institute of Forestry, Pskov Forest Research Station (St. Pyet. NIILK, Pskov LOS), 70 pp. (1990). — KRASNOBAYEVA, K. V. and TIMYERTAYEVA, F. YU.: Provyesti sravnityel'nuyu otsyenku i ispytanye pyerspyektivnykh ekotipov inoraionnogo proiskhozhdyeniya s tsyel'yu vydyelyeniya kandidatov v sorta-populyatsii. Final report on a research project. Kazan', All-Russian Forest and Melioration Research Institute, Tatar Forest Research Station (VNIILM, Tatar LOS), 67 pp. (1990). — MAKSIMOV A. N. and CHYEPLYANSKIÍ, I. YA.: Usovyershyenstvovat' myetody sozdaniya postoyannykh plantatsií osnovnykh lyesoobrazuyushchikh porod dlya poluchyeniya syemyan pyervogo gibridnogo pokolyeniya. Final report on a research project. S. Vyeshyenskaya Rostovskoí obl. All-Russian Scientific Research Institute of Agroforestry Amelioration, Don Scientific Research Station (VNIALMI, Don NI OS), 23 pp. (1990). — MALKIN, V. K. and OSIPOV, A. A.: Razrabotat' i vnyedrit' myetody i tyekhnologii syelyektsii osnovnykh lyesoobrazuyushchikh porod s tsyel'yu poluchyeniya khozyaístvyenno-tsyennykh form i sortov. Final report on a research project. Ivantyeyevka, Moskovskaya Obl. Scientific Production Institute "Funduk" (VNIILM, NPO "Funduk"), 100 pp. (1990). — MÁTÁJAS, CS.: Adaptation processes in forest tree populations. Abstract of habilitation thesis. Univ. of Sopron, Faculty of Forestry, 164 pp. (1987). — MILYUTIN, L. I., KUZ'MIN, H. A., SUNTSOV, A. V. and NOVIKOVA, T. H.: 1990 Razrabotat' i vnyedrit' myetody i tyekhnologii syelyektsii osnovnykh lyesoobrazuyushchikh porod s tsyel'yu poluchyeniya khozyaístvyenno-tsyennykh form i sortov. Report on a research project. Krasnoyarsk, The V. N. SUKACHYEV Institute of Forestry and Wood Products, Siberian Branch of the Russian Academy of Sciences (ILiD SO RAN), 88 pp. (1990). — MOSIN, V.: Izuchit' gyeografichyeskogo i ekologichyeskuyu izmyenchivost' glavnykh lyesoobrazuyushchikh porod dlya sovyershyenstvovaniya lyesosyemyennogo raíonirovaniya (sosna, pikhta, listvyennitsa). Final report on a research project, Shuchinsk, Kazakh Research Institute of Forestry (KazNIILKhA), 65 pp. (1985). — NAKVASINA, E. N., SIZOV, I. I., TARKHANOV, S. N. and ULISOVA, N. V.: Provyesti sravnityel'nuyu otsyenku i ispytanya ekotipov inoraionnogo proiskhozhdyeniya osnovnykh lyesoobrazuyushchikh porod s tsyel'yu vydyelyeniya populyatsií, pyerspyektyvnykh dlya lyesovyrashchivaniya na Yevropyeískom Syevyerye. Final report on a research project. Arkhangyel'sk, Arkhangyelsk Forest and Forest Chemistry Institute (Arkh. ILiLKh), 91 pp. (1990). — NARYSHKIN, M. A., VAKUROV, A. D. and PETERSON, JU. V.: Gyeogrfichyeskiye kul'tury sosny obyknoviyennoí pod Moskovoí. Lyesovyedyeniye (**2**): 50–57 (1983). — OLEKSYN, J. and GIERTYCH, M.: Results of a 70 years old Scots pine (*Pinus sylvestris* L.) provenance experiment in Pulawy, Poland. Silvae Genetica **33**(1): 22–27 (1984). — PATLAÍ, I. N. and ZHUROVA, P. T.: Osushchyestvit' ryealizatsiyu programmy rasshiryeniya gosudarstvyennoí syeti gyeografichyeskikh kul'tur, zakladky syeti populyatsionnoekologichyeskikh kultur luchshikh klimatipov, sovyermyenstvovat' lyesosyemyennoye raíonirovaniye osnovnykh lyesoobrazuyushchikh porod. Final report on a research project. Khar'kov, Ukrainian Research Institute of Forestry (UkrNIILKhA), 115 pp. (1991). — PAVES, H. K.: Provyesti izuchyeniye rosta i razvitiya gyeografichyeskikh kul'tur sosny i yeli. Final report on a research project. Tartu, Estonian Institute of Forestry and Nature Conservation, 12 pp. (1985). — PODZHAROVA, Z. S. and VOLOVICH, P. I.: Razrabotat' i vnyedrit' myetody i tyekhnologii syelyektsii osnovnykh lyesoobrazuyushchikh porod s tsyel'yu poluchyeniya khozyaístvyenno-tsyennykh form i sortov. Final report on a research project. Gomyel', Byelorussian Forest Research Institute (ByelNIILKh), – now Forest Institute of the Byelorussian Academy of Sciences (IL ANB), 52 pp. (1990). — PRAVDIN, L. F. and BAKUROV, A. D.: Rost sosny obyknovyennoí (*Pinus silvestris*) raznogo gyeografichyeskogo proiskhozhdyeniya v podzonye khvoí-shirokolistvyennykh lyesov. In: "Slozhnyye bory khvoíno-shirokolistvyennykh lyesov i puti vyedyeniya lyesnogo khozyaístva v lyesoparkovykh usloviyakh Pomoskov'ya". Publ. "Nauka": 160–195 (1968). — PROKAZIN, YE. P.: Izuchyeniye imyeyushikhsya novykh gyeografichyeskikh kul'tur (programma i myetodika rabot). Pushkino, All-Russian Forest and Melioration Research Institute (VNIILM). 53 pp. (1972). — RAMANAUSKAS, V. I.: Provyesti sravnityel'nuyu otsyenku tsyennogo gyenofonda sosnovykh i yelovykh populyatsií po adaptatsii ikh potomstyev k razlichnym lyesorastityel'nym usloviyam Litovskoí SSR i razrabotat' programmu-myetodiku sozdaniya lyesosyemyennykh plantatsií vtorogo pokolyeniya. Report on a research project. Girionis, Lithuanian Forestry Institute, 8 pp. (1990). — RUBY, J. L. and WRIGHT, J. W.: A revised classification of geographic varieties in Scots pine. Silvae Genetica **25**: 169–175 (1976). — SHCHYERBAKOVA, M. A. and MALYSHYEV, I. N.: Izuchyeniye i sortoispytaniye osnovnykh lyesoobrazuyushchikh porod s tsyel'yu razrabotki regional'nykh programm ikh syelyektsii. Final report on a research project. Pyetrozavodsk, Forest Research Institute, Karelian Research Center of the Russian Academy of Sciences (ILKaryel.NTs RAN), 65 pp. (1990). — SHTYEÍNIKOVA, V. I., ZVELYENKLAYA, T. F. and EMOLKINA, T. F.: Izuchit' gyeografichyeskuyu i ekologichyeskuyu izmyenchivost' glavnykh lyesoobrazuyushchikh porod, razrabotat'lyesosyemyennoye raíonirovaniye dlya povyshyeniya produktivnosti nasazhdyení (sosna). Final report on a research project, vol. 2, Khabarovsk, Far Eastern Forest Research Institute, Amur Forest Research Station (Dal'NIILKh Amur LOS), 99 pp. (1980). — SHUTYAEV, A. M.: Osobyennosti klimatipov sosny obyknovyennoí v gyeografichyeskikh kul'turakh vtoroí gyenyeratsii. Lyesovyedyeniye (**1**): 69–71 (1983). — SHUTYAEV, A. M. and DYEMIDYENKO, V. P.: Analiz ranyeye zalozhyennykh gyeografichyeskikh kul'tur osnovnykh lyesoobrazuyushchikh porod. Final report on a research project, Voronyezh, Research Institute of Forest Genetics and Breeding (NIILGiS), 168 pp. (1995). — SHUTYAEV, A. M. and Vyeryesin, M. M.: Produktivnost' gyeografichyeskikh populyatsií sosny obyknovyennoí. Lyesnoye Khozyaístvo (**11**): 36–38 (1990). — TAGIL'TSEVA, V. M.: Sosna obyknovyennaya v Khabarovskom kraye. Lyesnoye Khozyaístvo (**1**): 44–46 (1986). — VLASOVA, N. P.: Provyesti izuchyeniye gyeografichyeskikh kul'tur osnovnykh lyesoobrazuyushchikh porod v usloviyakh Sryednyeural'skogo i Vyatskogo lyesosyemyennykh raíonov. Final report on a research project. Perm, All-Russian Forest and Melioration Research Institute, Perm Forest Research Station (VNIILM, Perm LOS), 30 pp. (1990). — VYERYESIN, M. M. and SHUTYAEV, A. M.: Ispytaniye potomstv gyeografichyeskikh populyatsií sosny obyknovyennoí v Voronyezhskoí oblasti. In: "Zashchitnoye lyesorazvyedyeniye i lyesnyye kul'tury", issue 5, Voronyezh University Publ. (1978). — WRIGHT, J. W., PAULEY, S. S., POLK, R. B., JOKELA, J. J. and READ, R. A.: Provenance of Scotch pine varieties in the North Central Region. Silvae Genetica **15**(4): 101–110

Age Trends in Douglas-fir Genetic Parameters and Implications for Optimum Selection Age

By G. R. JOHNSON, R. A. SNIEZKO and N. L. MANDEL

U.S.D.A. Forest Service, Forestry Sciences Laboratory, Corvallis, OR 97331-4401, USA

(Received 16th June 1997)

Abstract

Trends in genetic variation were examined over 51 progeny test sites throughout western Oregon. Narrow sense heritabilities for height and diameter showed an increasing trend to age 25, the oldest age examined. Before age 10, height heritabilities were relatively unstable. Type B site-site genetic correlations increased slowly with age for height and remained relatively stable for diameter. Age-age correlations were used to develop an equation to predict age-age correlations by using the log of the age ratios (LAR). Optimum selection age was calculated for a 60-year rotation by using two measures of efficiency: gain per year and discounted gain. The optimum selection age for height tended to be 2 to 3 years earlier than for diameter. Gain per year was maximized at age 10 for height and age 13 for diameter.

Key words: heritability, age-age correlations, Type B genetic correlation, gain efficiency, *Pseudotsuga menziesii* (MIRB.) FRANCO.

FDC: 165.3; 165.6; 181.65; 181.79; 232.19; 174.7 *Pseudotsuga menziesii*; (795).