Use of introduced provenances to increase genetic diversity in local Scots pine populations

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To study the effect of Scots pine provenance transfer and the possibility of interprovenance hybridisation, a wide range of provenances from the former Soviet Union was studied in a series of provenance trials at the age of 20 to 40 years in Lithuania. Provenances from the step zone in southern Russia and Ukraine were superior in height growth over the local origins. However, adaptedness of the southerly provenances was less than that of the local and the northerly provenances. Hybrids between the introduced and the local provenances showed both better survival and superior height growth. Heritability of qualitative and quantitative traits as well as genetic gain from provenance transfer were evaluated and discussed. Variation among families within provenance was high, which allows to achieve further gain from individual selection.

Key words: Scots pine, provenance, family, geographical variation, interprovenance hybrids

INTRODUCTION

As regards the benefit of provenance transfer, Wangenheim [1] and later Vilmorin, Cieslar, Engler [2–4] were among the first to describe differences in growth between provenances. One of the first reports on performance of Scots pine provenances in France was presented by Louis de Vilmorin (1857). This study noted that the Latvian Scots pine provenance from Riga was superior in growth traits over the other 40 provenances studied. The Scots pine from Riga district in Latvia became famous for its straight stems and suitability for shipbuilding. Since then, many provenance trials have been established all over the world, and provenance testing still provides a continuous benefit for tree improvement.

After the second world war, the first Scots pine provenance trials in Latvia were established in 1967. However, this first series of trials was not successful, and a new series was established in 1975. In Estonia, the first series of Scots pine provenance trials were established in 1961–62 with 37 provenances from the former Soviet Union. Later on, in 1964–65, this provenance series was complemented by new provenances.

In Lithuania, the first series of provenance trials with 77 Scots pine provenances from the former Soviet Union were established in 1960 in the Paneriai forest district in Vilnius region [5]. Later on, in 1961, Scots pine provenance trial with 7 foreign and 11 local provenances was established by Džiaukštas in the Švenčionėliai forest district. In 1975, in the former Soviet Union, establishment of a large scale Scots pine provenance trials known as the Prokazin series was started. In Lithuania, within the network of the Prokazin series, 44 Scot spine provenances were planted at three sites in the Kazlų Rūda, Mažekiai and Plungė forest districts.

MATERIAL AND METHODS

Over the period from 1967 to 1987, Scots provenance trials with 130 provenances and the total area of 45 ha were established at various climatic zones in Lithuania. Methods of establishing these trials and a plantation design were uniform. In these trials, tree height, diameter, crown length were measured and a number of qualitative traits of stem and crown were assessed by using score scales (the scores are explained in the tables and figures) over a number of years. Analysis of variance was used to assess the effects of zone, provenance and family on an individual level as well as to calculate the variance components for the independent variables.

RESULTS AND DISCUSSION

Analysis of variance in tree height and diameter revealed significant differences between Scots pine pro-

venances. Mean height and diameter of 19 out of the 40 provenances studied were significantly different from the mean height and diameter of the local Vilnius provenance. The mean stem diameter of the Russian provenances introduced from Kharkov Izgomskij, Cherkas Cherkasskij, Sverdlovsk was most different from the mean diameter of the local Vilnius provenance. For instance, good growth of the provenances from Penza, Stalingrad, Bashkiria and Tataria may have been caused by nutrient contents of the soil rather than by genetic effects.

Adaptability, wood yield as well as stem quality of the provenances depend not only on the geographical location, but also on specific ecological conditions in the locality and peculiarities of the populations. Many Scots pine provenance studies showed that provenances transferred from the neighbouring regions may markedly differ in growth traits from each other, for instance, in our experiment, provenances from Nesterovskij and Kaliningradskij forest districts in Kalinigrad or provenances from Luchovitskij and Egorovskij forest districts in Moscow region, whereas provenances originating from comparatively distant areas were not significantly different from each other in growth traits and even in tree volume per ha, for instance, provenances from Komi Kožvinskij forest district in Komi region and provenances from Borzhomi forest district in Georgia; or another example: provenances from Belogorskij forest district in Amur region and provenances from Cherkaskij forest district in Saratov. This allows to assume that in every region there are populations which perform differently when transferred to another region.

To compare growth of the most productive genotypes within each provenance, several plus trees were selected within each of the provenances studied; for instance, provenances from Archedinskij district in Stalingrad and Kuznetskij and Jursavskij provenances from Penza region which were the highest possessed only medium plus tree parameters, whereas, the plus trees selected within the provenances from Tataria Prigorodnyj, Tataria Krasnoborskij, Kharkov Iziumskij, Cherkas Cherkasskij, Voronezh Annenskij were the highest. Thus, owing to a large selection differential, individual selection within the provenances mentioned above may be beneficial.

The heritabilities indicate that provenance and individual selection for tree height, number of whorl branches and partially for branching angle would give the highest benefit.

Variation among families within a provenance was high, which allows to proceed with further improvement by selecting the best families. Open pollination provides a higher gene diversity through male pollen than do controlled crosses. Thus, selection of half sib families in breeding programmes may result in a higher gene diversity in the forest. Our study confirmed the following conclusions from the studies on Scots pine provenances: a higher number of male parents allows to use a higher selection intensity [6]; families within provenance differ significantly from each other, indicating a strong inheritance of the quantitative traits [7]; there are marked family differences in survival [8] and ability to compete [9].

A correlation between needle length and tree height was high on provenance level. Survival of northern and high altitudinal provenances was higher than that of southern provenances. When transferred southwards, Scots pine provenances stop growing earlier than do the local populations and thus may avoid autumn frosts and attain a higher degree of frost hardiness to survive in winter. On the mean provenance level, the correlation between tree height and survival was positive and significant (0.5).

Analysis of variance and estimation of variance components for geographical region, provenance, family and random error revealed the following:

1) the effect of region was significant for needle survival on the whorl branches and for damage level only;

2) the effect of provenance was significant for height class (by Kraft), stem straightness, branching angle, tree health, damage, needle colour and branch thickness at the base;

3) the family effect was significant for tree height, height to first living branch, damage, needle survival on the whorl branches, multiple leaders.

Genetic polymorphism is important when approaching the issue of adaptation. Low genetic diversity is a great disadvantage, as the competition between similar genotypes is comparably higher, nutrient reserves are utilised less efficiently, in case of a negative environmental effect all genetically uniform population is threatened and mating among related individuals may result in low wood yield of the subsequent generations in naturally regenerated forests.

Provenance tests may be used for seed collection, if according to the results from the tests a certain provenance is superior over the local one in a certain region as regards adaptedness, wood yield, wood quality, stem quality. Possible threats to local populations caused by introduced provenances via seed or pollen migration shall be considered.

CONCLUSIONS

Analysis of variation in many traits such as adaptedness, tolerance to environmental stresses showed that local populations were superior over the intro-

duced ones. However, the provenances transferred at a relatively short distance towards the north, especially the provenances from forest steps possessed a comparatively higher growth rate. Northerly provenances were characterized by shorter and lighter needles, narrower crowns, slower growth, lower volume of stem and branches, weaker tolerance to environmental stresses and drought as well as a lower ability to compete, if compared with the local populations.

Though growing faster, southerly provenances were of a lower survival, more sensitive to climatic fluctuations and possessed a lower wood quality as well as less straight stems. Local populations were superior in the traits mentioned above. It would be possible to improve certain traits of the local populations by crossing them with the introduces ones. Therefore, the benefit from provenance transfer may be increased by production of intra-provenance hybrids. Provenance studies may be used to reveal patterns of geographical variation in certain regions, and this information may be used for delineation of the breeding zones. Provenance trials may be used to forecast the effect of climatic changes.

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PUŠIES GENETINĖS ĮVAIROVĖS DIDINIMAS PANAUDOJANT TOLIMAS PROVENENCIJAS

S a n t r a u k a

Geografiniam provenencijų perkėlimui ir kryžminimui su vietinėmis panaudotas platus populiacijų spektras, apimantis per 130 skirtingų geografinių kilmių. Tirti 20–40 m. amžiaus bandomieji želdiniai, įveisti įvairiose augavietėse ir rajonuose. Nustatyta, kad kai kurios provenencijos geriau adaptuojasi ir sparčiau auga už vietines. Tai kai kurios Pietų Rusijos ir Ukrainos miško stepių kilmės. Pietinių provenencijų adaptyvumas menkesnis už vietines. Atkeltų provenencijų su vietinėmis hibridai gerai adaptavosi ir sparčiau augo, lenkdami vietines kilmes.

Tiriant želdinius įvertinta požymių paveldėjimo laipsnis ir jų atrankos efektas, taikant skirtingą atrankos intensyvumą ir metodus. Populiacijų požymių paveldėjimo laipsnis didesnis negu individų. Perspektyviose provenencijose pastebėti atskirų požymių esminiai skirtumai tarp šeimų, todėl taikant šeimų atranką galima gauti dar geresnių rezultatų. Vykstant laisvam apsidulkinimui padidinama genetinė įvairovė, įjungiant daugiau genų iš tėvinių žiedadulkių. Tokiu būdu nesudėtinga sudaryti sėklines plantacijas, kai motininiai medžiai pasirenkami iš atkeltų provenencijų, o tėviniai – iš vietinių populiacijų.

Raktažodžiai: provenencija, šeima, klonas, geografinis kintamumas, kryžminimasis