Persistence of Progenies of Wild Cherry (*Prunus avium* L.) at Northern Limit of Natural Distribution Range in Transfer to Lithuania

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**Abstract**

The aim of this study was to analyse the possibility of enriching the local population of wild cherry (*Prunus avium* L.) with introduced material capable to withstand rigorous environmental conditions. Progenies of wild cherry from nine European countries were tested in northern marginal site of species’ distribution range. Persistence of progeny in relation to transfer to new environment refers here to the height loss due to frost damage and to the certain variability among morphological traits. The progenies were evaluated at two and three years of age in the provenance nursery trial in central Lithuania. *F*-ratios and significance of provenance and block fixed effects, Pearson and Spearman correlation coefficients, Tukey comparison lines for LS-means of provenances were estimated for set of traits: tree height at the end of the vegetation period and in the next spring, tree diameter, tree height to diameter ratio, the diameter of strongest branch or side stem, branch diameter to tree stem diameter ratio, and autumn over-coloration of shoot tips, leaf gland length in relation to petiole width, leaf gland colour.

The analysis of variance of most traits revealed that the effects of provenance, block, and provenance by block interaction were statistically significant and indicates a presence of genetic differences in populations’ general performance and in ecological reaction norms. Very weak correlation between tree height and tree brancheshness ratio gives an indication of breeding possibility of fast growing trees while retaining relatively slim branches.

Independent samples *t*-test and Levene’s test for equality of variances approved the relationship between tree morphology parameters and leaf gland characters of survived saplings. Determination of changes in morphology of wild cherry survivors showed that induction of gland pigments is not subjected to stress.

The autumn over-coloration of cherry shoot tips was considered as stress indicator in this study. The more damaged tree tips were in autumn, the less tree height was next spring.

It was found strong and significant correlation between gland number and hardness zone index at populations’ origin locations (*r* = 0.60, *P* = 0.03). Positive correlations between the maximum number of glands and hardness zone index, tree height in spring of 2011 and longitude were moderate but not sufficiently significant.

In general, wild cherry reproductive material from Poland and Austria may be candidates for further testing for the potential introduction of the most fitted populations to Lithuania.

**Key words:** *Prunus avium*, wild cherry, introduction, persistence, growth, morphology.

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**Introduction**

*Prunus avium* (L.) includes sweet cherries, cultivated for human consumption, and wild cherry trees, also called mazzards, grown for their wood (Webster 1996, Ganopoulos et al. 2011). The origin of sweet cherry is believed to be in the region close to the Caspian and Black Seas and this species is indigenous to countries to the south of the Caucasus Mountains (Webster 1996). The initial spread of the wild cherry was caused by bird migrations and the distribution was depending on the movement distances of bird populations (Webster 1996). The secondary spreading of the wild cherry was mostly human-caused for use in horticulture and the natural range of wild sweet cherry expanded from place of origin northwards to the southern Sweden, eastwards to the northern India and southwards to isolated islands of Portugal. The Baltic Sea region is the northern limit of range of distribution of *P. avium*. In Lithuania *P. avium* is scattered throughout temperate broadleaf forest (Gudžinskas 2000), with prevalence in the western part of the country (Petrokas 2011; Figure 1). This abundance is possible due to it grows best in beech or beech-hornbeam forests (Chukhina 2008) and the northern boundary of the European hornbeam (*Carpinus*...
nus betulus L.) natural distribution range lies across Lithuania (Karazija 1988).

We chose to focus on the efforts on the wild cherry as it is native forest tree species, which can grow on a wide variety of soil types. It has the advantage of fast growing, producing a high quality hardwood timber in about 70 years which is in demand for furniture making and able to substitute for wood of tropical hardwoods. Wild cherry is the most important European timber species in the family Rosaceae (Russell 2003). In Lithuania wild cherry is spreading to forest stands naturally from domesticated sources or from already escaped semi-wild trees. There are no mature stands of P. avium in Lithuania although groups or individual trees grow as admixture in some stands of other tree species while young trees are abundant in understory of many stands. Our aim is to develop vigorous, locally well adapted trees with good stem form suitable for wider use in forestry and farm woodland plantings. At the time, wild cherry do not have a very good forestry reputation, as many trees were of unknown origin or quality; many were probably of sweet cherry type.

Based on the assumption that natural selection has optimised populations to their local environment, European guidelines for the sustainable management of forests in Europe (MCPFE 1995, Anon. 1999) advocate and encourage the use in forestry high quality local seed sources that are genetically and phenotypically adapted to the site. However, in many cases an environmentally induced variation appears to be non-adaptive (e.g. de Jong 2005, van Kleunen and Fisher 2005). It is argued that stressful environments that are outside the natural range can break down genetic buffering mechanisms, and increase the variance associated with different traits (e.g. Rutherford 2000, 2003). Carroll et al. (1997) emphasizes the importance of measuring fitness related traits, and paying attention to the subset of individuals that persist and flourish in the new environments. Ghalambor et al. (2007) summarises that ‘if an identifiable subset of individuals that possesses a particularly favourable combination of plastic traits is found to be the successful colonizers of new environments, such evidence could show an important role of plasticity in facilitating adaptation’. Analysis of provenance transfer tests shows remarkable width of adaptability and persistence and, in consequence, the extended width of ‘local’ adaptation even under dramatic changes in thermal conditions and, to a lesser extent, in moisture supplies (Mátyás 2007). This phenomenon indicates the substantial conservatism in the climatic adaptation of numerous tested tree species, which has an inherent genetic basis and may have been enhanced by evolution (Mátyás and Nagy 2005). Therefore, we expect that some provenances or individuals of wild cherry could be able to succeed even outside their current natural range and thus would show viability in a study like this. In general, it was concluded that research of the wild cherry and similar species which are bird-dispersed (ornithochory) are very complex and have to be based on individual tree level research (Ballian et al. 2012, Petrokas 2010).

The aim of this study was to analyse the possibility of enriching the local population of P. avium trees better designed to withstand rigorous environmental conditions. The first goal was to analyse survival, growth, and morphology of the wild cherry at northern marginal site of species’ distribution in transfer to Lithuania from West and Central European countries. The second goal was to provide some methodical guidance to facilitate the establishment and analysis of future clonal tests.

Materials and Methods

Test material

Progeny of wild cherry from nine European countries was tested in the Dubrava nursery trial in Central Lithuania. Information on geographical origin and type of basic material of Austrian (AtK, Art), Belgian (BeM), British (GbH), Danish (DkF, DkNZ, DkS), German (De127, De129, De131), Italian (ItBF, ItL, ItMB), Lithuanian (LtT), Polish (PlK, PIZ), and Spanish (EsCL) test material is presented in Table 1. Hardiness zones of wild cherry provenances studied (Table 1) are indicated based on the map by Heinze and Schreiber (1984). This map divides Lithuania into the two zones based on average lowest winter temperatures (Figure 2).

The provenance trial was established in 2010 by the Institute of Forestry, Lithuanian Research Centre.
Table 1. Origin, type and amounts of progeny of wild cherry in Dubrava nursery trial. ID – provenance identification code (the first and the second letters indicate country code), HZ – hardness zone, N_{2010} and N_{2011} – number of survived and measured individuals in 2010 and 2011.

<table>
<thead>
<tr>
<th>Provenance ID</th>
<th>Provenance</th>
<th>Type of basic material</th>
<th>Latitude</th>
<th>Longitude</th>
<th>HZ</th>
<th>N_{2010}</th>
<th>N_{2011}</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECL</td>
<td>O’Gourl Lugo</td>
<td>Seed source</td>
<td>43.01</td>
<td>77.56</td>
<td>9</td>
<td>53</td>
<td>20</td>
</tr>
<tr>
<td>IBF</td>
<td>Bosco Fontana</td>
<td>Selected stand</td>
<td>45.12</td>
<td>10.44</td>
<td>8</td>
<td>171</td>
<td>70</td>
</tr>
<tr>
<td>ILB</td>
<td>Monté Baldo</td>
<td>Seed source</td>
<td>45.46</td>
<td>10.51</td>
<td>8</td>
<td>164</td>
<td>41</td>
</tr>
<tr>
<td>ILB</td>
<td>Lusiana</td>
<td>Seed source</td>
<td>45.47</td>
<td>11.34</td>
<td>8</td>
<td>64</td>
<td>18</td>
</tr>
<tr>
<td>AK</td>
<td>Koenighof</td>
<td>Seed orchard</td>
<td>48.01</td>
<td>16.74</td>
<td>7</td>
<td>225</td>
<td>91</td>
</tr>
<tr>
<td>A1</td>
<td>Turin</td>
<td>Seed orchard</td>
<td>48.33</td>
<td>16.08</td>
<td>7</td>
<td>147</td>
<td>54</td>
</tr>
<tr>
<td>Dc131</td>
<td>Zweibrücker Hügelstad</td>
<td>Selected stand</td>
<td>49.22</td>
<td>7.32</td>
<td>7</td>
<td>199</td>
<td>89</td>
</tr>
<tr>
<td>PZ</td>
<td>Zwirzczynek Adamrow</td>
<td>Stand</td>
<td>50.58</td>
<td>23.12</td>
<td>6</td>
<td>154</td>
<td>122</td>
</tr>
<tr>
<td>Bc1</td>
<td>Mommstedel</td>
<td>Seed orchard</td>
<td>50.82</td>
<td>4.74</td>
<td>8</td>
<td>106</td>
<td>5</td>
</tr>
<tr>
<td>Pk</td>
<td>Krasnystaw Borek</td>
<td>Stand</td>
<td>51.00</td>
<td>22.95</td>
<td>6</td>
<td>199</td>
<td>142</td>
</tr>
<tr>
<td>Dc127</td>
<td>Hildesheimer Wald</td>
<td>Selected stand</td>
<td>52.12</td>
<td>9.88</td>
<td>7</td>
<td>187</td>
<td>42</td>
</tr>
<tr>
<td>Gbh</td>
<td>Hardwick</td>
<td>Seed orchard</td>
<td>52.47</td>
<td>22.43</td>
<td>8</td>
<td>99</td>
<td>47</td>
</tr>
<tr>
<td>Dc129</td>
<td>Chorin</td>
<td>Selected stand</td>
<td>52.89</td>
<td>13.90</td>
<td>7</td>
<td>42</td>
<td>21</td>
</tr>
<tr>
<td>DcF</td>
<td>Buskiegard</td>
<td>Selected stand</td>
<td>55.15</td>
<td>15.05</td>
<td>8</td>
<td>119</td>
<td>56</td>
</tr>
<tr>
<td>DkS</td>
<td>Sooroe</td>
<td>Seed source</td>
<td>55.42</td>
<td>11.58</td>
<td>8</td>
<td>71</td>
<td>22</td>
</tr>
<tr>
<td>DkNz</td>
<td>North Zealand</td>
<td>Seed source</td>
<td>55.83</td>
<td>12.24</td>
<td>8</td>
<td>139</td>
<td>39</td>
</tr>
<tr>
<td>LIT</td>
<td>Patrelia</td>
<td>Seed source</td>
<td>56.03</td>
<td>21.82</td>
<td>6</td>
<td>1167</td>
<td>485</td>
</tr>
</tbody>
</table>

51Thr BZ001 Dubrava nursery trial 54.85 24.05 5 3326 1364

Figure 2. Hardiness zones of plants in Europe (Heinze and Schreiber 1984) and location of wild cherry provenances studied. Provenances indicated with squares and codes: Austrian (Atk, AtT), Belgian (BcM), British (GbH), Danish (DkF, DkNz, DkS), German (Dc127, Dc129, Dc131), Italian (ItBF, ItL, ItMB), Lithuanian (LtT), Polish (Pik, Piz), and Spanish (EsCL).

for Agriculture and Forestry, and Dubrava Experimental and Training Forest Enterprise transplanting 1-year greenhouse raised seedlings of open pollinated progenies to nursery in linear row plots, replicated in two blocks. Spacing between rows was 0.45 m; distance between trees was 0.20 m. About 3,300 trees have been planted in 2010.

Trait estimation

Wild cherry traits were estimated at age two and three. In total, the number of measured trees (valid cases, N) was 2,251 in the year 2010 and 1,117 in the year 2011.

The height (in cm) of tree stem to upper alive bud (H_{2010}) and the diameter (in mm) of stem over bark at root collar (D_{2010}) were measured with crosswise calliper after the end of the vegetation period at the nursery trial in 2010. The ratio of tree height to diameter (H/D) was obtained to characterise tree slenderness. In spring of 2011, the height to upper green (alive) bud was measured (H_{2011} in cm) to characterise the extent of spring frost damage on each survivor. Frost damage during winter and spring 2010/2011 was estimated as the height loss (H_{2011} = H_{2010} - H_{2011}). Tree survival rate of each population was estimated as the percentage of the remaining trees at the end of the vegetation season of the year 2011 from the initial number of trees in the year 2010.

 Stem branchiness and forking at age two was evaluated as the ratio of the diameter (in mm) of strongest branch or secondary stem to the diameter (in mm) of stem (D_{2}/D).

The autumn over-coloration of cherry shoot tips was considered as stress indicator. Autumn over-coloration of green tree (shoot) tips was defined at age two as follows: 1 – yellowish – the tip is healthy, 2 – reddish – the tip is slightly damaged, 3 – brown – the tip is moderately damaged but still alive, 4 – blackish – the tip is dry.

In this study distinctive characters refer to the leaf gland traits of wild cherry scored at age three at mid-July 2011. Observations were made on the fifth leaf from the top of summer shoot and on all the successive leaves of that shoot of survivors. We have done
the following evaluations of leaf glands and transformations of scores:

1) the pigmentation or ground coloration: 0<sup>th</sup> – white or petiole colour, 1<sup>st</sup> – orange or yellowish, 2<sup>nd</sup> – red or reddish, 3<sup>rd</sup> – purple or dark reddish; gland colour: 0 – not red (0<sup>th</sup> + 1<sup>st</sup>), 1 – red (2<sup>nd</sup> + 3<sup>rd</sup>);

2) the maximum length of glands when viewed from above: 1<sup>st</sup> – up to half the width of a petiole, 2<sup>nd</sup> – over half the width of a petiole, 3<sup>rd</sup> – petiole width and more; gland length: 0 – 1<sup>st</sup>, 1 – 2<sup>nd</sup> + 3<sup>rd</sup>;

3) the maximum number of glands (1, 2, 3, 4, 5 or 6); gland number: 0 – 1-2, 1 – 3-6.

Data analyses

Analyses initially included all trees. Peculiarities of growth variation were determined at the species and provenance levels. The variance analysis was done with the MIXED procedure in SAS Software (SAS Institute, Inc., SAS/STAT Software, Release 9.3, 2012) which uses mixed model equations (MME) and the restricted maximum likelihood (REML) method. F tests were carried out to determine when the fixed effects (population and blocks) were significantly different from zero. The following linear model was used for data analysis:

\[ y_{ijn} = \mu + b_i + p_m + p_{bm} + e_{ijn} \]

where \( y_{ijn} \) is an observation on the \( n \)th tree from the \( m \)th provenance, \( \mu \) is the field trial mean, \( b_i \) is the fixed effect of the \( i \)th block, \( p_m \) is the fixed effect of the \( m \)th provenance, \( p_{bm} \) is the fixed effect of interaction between the \( m \)th provenance and the \( i \)th block, and \( e_{ijn} \) is the random residual.

The normality of residuals’ distribution and homogeneity of variances were determined with SAS GLM and UNIVARIATE procedures (SAS Institute, Inc., SAS/STAT Software Release 9.3, 2012).

Pearson and Spearman correlation coefficients between traits and correlation coefficients between provenance trait means and geographical data were calculated using SAS CORR procedure. LS-means and Tukey comparison lines for LS-means of provenances were estimated using SAS GLM procedure (SAS Institute, Inc., SAS/STAT Software Release 9.3, 2012).

Independent samples t-test of SPSS (Statistical Package for the Social Sciences) 16.0 for Windows* was used to compare two classes of a growth parameter that were not related. The results for t-test indicated where the means for the two independent classes were significantly different at the 5%-probability level. Prior to conducting statistical analyses, each variable was tested for deviations from the normal distribution and for homocedasticity using Levene’s test for equality of variances.

To calculate subgroup means and related univariate statistics for the dependent variables of tree height, height loss, H/D ratio, and branchiness ratio D<sub>2010</sub>/D<sub>2010</sub> within categories of gland maximum length the Means procedure of SPSS 16.0 for Windows* was used. Using this procedure, we had layered position within the level of gland maximum length and observed how average height loss differs by gland coloration.

Results

The analysis of variance revealed that the effects of Provenance, Block, and Provenance × Block interaction were statistically significant for most of traits (Table 2) except the Block effect for D<sub>2010</sub>/D<sub>2010</sub> ratio and tree height in spring of 2011. Phenotypic correlations between traits of wild cherry progeny in Dubrava nursery trial are presented in Table 3. There was statistically significant positive relationship between tree height in spring of 2011 and tree tip autumn over-coloration in 2010. It means the more damaged tree tips were in autumn, the smaller tree height was next spring. It must be noted statistically significant negative relationship between tree tip autumn over-coloration in 2010 and leaf gland length in 2011 as well as statistically significant positive relationships between the leaf gland length and the rest of the traits. Hypothetically, it means the greater length of the glands the better.

The two classes of gland colour had about the same amounts of variability between the scores of morphology parameters at the 5%-probability level, as

<table>
<thead>
<tr>
<th>Trait</th>
<th>Provenance effect</th>
<th>Block effect</th>
<th>Provenance × Block interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>D&lt;sub&gt;2010&lt;/sub&gt;</td>
<td>55.296 ***</td>
<td>162.849 ***</td>
<td>11.886 ***</td>
</tr>
<tr>
<td>D&lt;sub&gt;2010&lt;/sub&gt;/D&lt;sub&gt;20&lt;/sub&gt;</td>
<td>14.110 ***</td>
<td>2.538 ***</td>
<td>6.771 ***</td>
</tr>
<tr>
<td>D&lt;sub&gt;2&lt;/sub&gt;</td>
<td>26.641 ***</td>
<td>22.243 ***</td>
<td>11.615 ***</td>
</tr>
<tr>
<td>GIl&lt;sub&gt;e&lt;/sub&gt;</td>
<td>4.888 ***</td>
<td>11.720 ***</td>
<td>2.600 ***</td>
</tr>
<tr>
<td>GIl&lt;sub&gt;i&lt;/sub&gt;</td>
<td>7.033 ***</td>
<td>43.479 ***</td>
<td>4.724 ***</td>
</tr>
<tr>
<td>GIl&lt;sub&gt;c&lt;/sub&gt;</td>
<td>7.069 ***</td>
<td>45.787 ***</td>
<td>3.831 ***</td>
</tr>
<tr>
<td>H&lt;sub&gt;2010&lt;/sub&gt;</td>
<td>46.973 ***</td>
<td>331.155 ***</td>
<td>12.006 ***</td>
</tr>
<tr>
<td>H/D</td>
<td>44.234 ***</td>
<td>175.036 ***</td>
<td>9.142 ***</td>
</tr>
<tr>
<td>H&lt;sub&gt;2011&lt;/sub&gt;</td>
<td>38.225 ***</td>
<td>0.143 ***</td>
<td>6.129 ***</td>
</tr>
<tr>
<td>TiOC</td>
<td>7.146 ***</td>
<td>13.899 ***</td>
<td>2.786 ***</td>
</tr>
</tbody>
</table>

Level of significance: * – 0.05 > P > 0.01, ** – 0.001 > P < 0.01, *** – P < 0.001
the resulting significance values of Levene’s test were greater than 0.05 (Table 4). However, only univariate mean values of tree H/D ratio were significantly different within both classes of gland colour at the highest probability level (see the significance values of the t-test from the top row in Table 4): red gland colour was characteristic of the survivors having greater class mean of tree H/D ratio, i.e. red gland colour was characteristic of slimmer trees (Table 5). Tree branchiness ratio Dw/D, autumn tip over-coloration, or spring height were not related with gland colour in such a way as described above.

The univariate mean values of tree H/D ratio or Dw/D ratio (Table 6) were significantly different within both classes of gland length at the 0.1%-probability or the 0.9%-probability level, respectively (see the significance values of the t-test from the top row). Over half the width of a petiole gland length was characteristic of the survived saplings having greater class mean of tree H/D ratio or Dw/D ratio (Table 7). The estimation of statistical relationships between gland length and autumn tip over-coloration or spring height was not possible as the classes of gland length had different amounts of variability between the scores (Table 6, Levene’s test).

Height loss due to the frost damage did not vary simply as a function of gland maximum length (Table 8); therefore it must take into account both gland length and gland colour. Mean ± SE column shows how average height loss differs by gland pigmentation or ground coloration of skin within level of gland maximum length. Although greater height loss was

**Table 3.** Phenotypic correlations and their level of significance for the traits of wild cherry. For traits abbreviations description see Table 2

<table>
<thead>
<tr>
<th>Trait</th>
<th>H2010</th>
<th>D2010</th>
<th>H2D</th>
<th>D10</th>
<th>DvD</th>
<th>TiOc</th>
<th>H2011</th>
<th>GiCo</th>
</tr>
</thead>
<tbody>
<tr>
<td>D2010</td>
<td>0.706</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H/D</td>
<td>0.691</td>
<td>0.033</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dw</td>
<td>0.325</td>
<td>0.593</td>
<td>-0.207</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dv/D</td>
<td>-0.062</td>
<td>0.123</td>
<td>-0.270</td>
<td>0.824</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TiOc</td>
<td>-0.216</td>
<td>-0.246</td>
<td>-0.016</td>
<td>-0.076</td>
<td>0.047</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H2011</td>
<td>0.276</td>
<td>0.400</td>
<td>-0.048</td>
<td>0.200</td>
<td>0.008</td>
<td>-0.335</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GiCo</td>
<td>0.210</td>
<td>0.108</td>
<td>0.154</td>
<td>0.009</td>
<td>-0.042</td>
<td>0.003</td>
<td>-0.015</td>
<td></td>
</tr>
<tr>
<td>GiLe</td>
<td>0.324</td>
<td>0.329</td>
<td>0.122</td>
<td>0.195</td>
<td>0.064</td>
<td>-0.063</td>
<td>0.131</td>
<td>0.184</td>
</tr>
</tbody>
</table>

Level of significance: * - 0.05 > P > 0.01, ** - 0.001 > P < 0.01, *** - P < 0.001
1 Pearson correlation coefficient and its P-value
2 Spearman correlation coefficient and its P-value

**Table 4.** The univariate tests of morphology parameters of wild cherry survivors used to compare two independent classes of their leaf gland colour at age three in 2011. M ± SE = mean ± standard error, Sig. = significance, CI = confidence interval

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Equal variances</th>
<th>F</th>
<th>Sig.</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>M ± SE</th>
<th>Difference</th>
<th>95% CI of the Difference</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree H/D ratio in 2010</td>
<td>assumed</td>
<td>0.128</td>
<td>0.721</td>
<td>-5.532</td>
<td>1114</td>
<td>0</td>
<td>-7.62 ± 1.38</td>
<td>-0.33</td>
<td>-4.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree branchiness ratio Dv/D in 2010</td>
<td>assumed</td>
<td>2.845</td>
<td>0.092</td>
<td>1.474</td>
<td>1114</td>
<td>0.141</td>
<td>0.02 ± 0.01</td>
<td>-0.01</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tip over-coloration in 2011</td>
<td>assumed</td>
<td>0.071</td>
<td>0.789</td>
<td>-0.143</td>
<td>1114</td>
<td>0.886</td>
<td>-0.01 ± 0.05</td>
<td>-0.10</td>
<td>0.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring height in 2011</td>
<td>assumed</td>
<td>0.224</td>
<td>0.636</td>
<td>0.096</td>
<td>1361</td>
<td>0.924</td>
<td>0.16 ± 1.63</td>
<td>-3.05</td>
<td>3.36</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 5.** Group statistics of gland colour for the tree H/D ratio of wild cherry at age three in 2011. N = the number of valid cases, M ± SE = mean ± standard error, SD = standard deviation

<table>
<thead>
<tr>
<th>Growth parameter</th>
<th>Gland colour</th>
<th>N</th>
<th>M ± SE</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree H/D ratio in 2010</td>
<td>Not red</td>
<td>740</td>
<td>85.64 ± 0.78</td>
<td>21.21</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>376</td>
<td>93.27 ± 1.17</td>
<td>22.79</td>
</tr>
</tbody>
</table>

characteristic of survivors having red gland colour across all the levels of gland maximum length, the gap widens over the increase in gland length. The extent of frost damage of survived saplings having glands of petiole width and larger can be characterised by average height loss of 77.51 ± 2.60 cm while that of the sapling having glands over half the width of a

**Table 6.** Group statistics of gland colour for the tree H/D ratio of wild cherry at age three in 2011. N = the number of valid cases, M ± SE = mean ± standard error, SD = standard deviation

<table>
<thead>
<tr>
<th>Growth parameter</th>
<th>Gland colour</th>
<th>N</th>
<th>M ± SE</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree H/D ratio in 2010</td>
<td>Not red</td>
<td>740</td>
<td>85.64 ± 0.78</td>
<td>21.21</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>376</td>
<td>93.27 ± 1.17</td>
<td>22.79</td>
</tr>
</tbody>
</table>
Table 6. The univariate tests of morphology parameters of wild cherry survivors used to compare two independent classes of their leaf gland length at age three in 2011. M ± SE = mean ± standard error, Sig. = significance, CI = confidence interval.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Equal variances</th>
<th>Levene’s test</th>
<th>H-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig.</td>
<td>df</td>
</tr>
<tr>
<td>Tree H/D ratio in 2010</td>
<td>assumed</td>
<td>1.666</td>
<td>0.197</td>
</tr>
<tr>
<td></td>
<td>not assumed</td>
<td>-4.134</td>
<td>784.630</td>
</tr>
<tr>
<td>Tree branchiness ratio Dv/D in 2010</td>
<td>assumed</td>
<td>0.982</td>
<td>0.327</td>
</tr>
<tr>
<td></td>
<td>not assumed</td>
<td>-2.593</td>
<td>773.211</td>
</tr>
<tr>
<td>Tip over-coloration in 2010</td>
<td>assumed</td>
<td>10.516</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>not assumed</td>
<td>2.043</td>
<td>717.899</td>
</tr>
<tr>
<td>Spring height in 2011</td>
<td>assumed</td>
<td>40.349</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>not assumed</td>
<td>-5.385</td>
<td>1076.440</td>
</tr>
</tbody>
</table>

Table 7. Group statistics for gland length of wild cherry’s growth parameters at age three in 2011. N = the number of valid cases, M ± SE = mean ± standard error, SD = standard deviation.

<table>
<thead>
<tr>
<th>Growth parameters</th>
<th>Gland length</th>
<th>N</th>
<th>M ± SE</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree H/D ratio in 2010</td>
<td>Up to half the width of a petiole</td>
<td>391</td>
<td>84.50 ± 1.12</td>
<td>22.19</td>
</tr>
<tr>
<td></td>
<td>Over half the width of a petiole</td>
<td>725</td>
<td>90.21 ± 0.81</td>
<td>21.72</td>
</tr>
<tr>
<td>Tree branchiness ratio Dv/D in 2010</td>
<td>Up to half the width of a petiole</td>
<td>391</td>
<td>0.38 ± 0.01</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Over half the width of a petiole</td>
<td>725</td>
<td>0.38 ± 0.01</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Table 8. Growth parameters by gland traits statistics for wild cherry survivors at age three in 2011. N = the number of valid cases, H2010 ± SE = mean ± standard error of tree height (cm) in 2010 yr., HL2011 ± SE = mean ± standard error of tree height loss (cm) due to frost damage in 2010/2011.

petiole was 62.63 ± 1.63 cm, and that of the sapling having glands up to half the width of a petiole was 54.49 ± 1.63 cm. The average height loss of the saplings of red gland colour was 72.75 ± 3.59 cm while that of the saplings of red gland colour was 55.74 ± 1.68 cm. The largest gland maximum length was characteristic of the slimmest saplings (88.21 ± 0.66 is the mean of tree H/D ratio) of purple (dark reddish) gland coloration, the smallest gland maximum length was characteristic of the thickest saplings of white (petiole colour) gland coloration. Frost damage of survived saplings having glands of petiole width and larger can be characterised by average height loss of 92% of initial tree height while that of the sapling having glands over half the width of a petiole was 74%, and that of the sapling having glands up to half the width of a petiole was 65%. One individual from Poland (PIK7) had no leaf glands at all however it lost 76 cm of height (78 cm) due to the frost damage of yr. 2010/2011. Frost damage of survived sapling having red
Table 9. Statistics for wild cherry’s provenances at Dubrava nursery trial. S – survival (in %), ID – national identification number, $H_{2010}$ and $H_{2011}$ – tree height (cm) at the end of 2010 and in spring of 2011, $D_{2010}$ – tree diameter (mm) in 2010, $D_{2011}$ – the diameter (mm) of strongest branch or side stem, $D_{1/4}$ – the ratio of $D_{1/4}$ to $D_{2010}$, $M \pm SE$ – mean ± standard error, $CV$ – coefficient of variation in %

<table>
<thead>
<tr>
<th>Provenance ID</th>
<th>S</th>
<th>$H_{2010}$</th>
<th>$H_{2011}$</th>
<th>$D_{2010}$</th>
<th>$H_{1/4}$</th>
<th>$D_{1/4}$</th>
<th>$D_{2011}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0</td>
<td></td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>165.40</td>
</tr>
<tr>
<td>Max</td>
<td>211</td>
<td>170</td>
<td>21</td>
<td>13</td>
<td>1.33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $LS$-means with the same letter are not significantly different (Tukey HSD test, $P < 0.05$).

Table 10. Statistics for wild cherry’s provenances at Dubrava nursery trial. S – survival (in %), ID – national identification number, $M \pm SE$ – mean ± standard error, $CV$ – coefficient of variation, $G$ – glend colour in 2010, $G_{2E}$ – glend colour in 2011

<table>
<thead>
<tr>
<th>Provenance ID</th>
<th>S</th>
<th>Tip autumn coloration in 2010</th>
<th>Gland length in 2010</th>
<th>Gland colour in 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Ranges from 0 (up to the width of a petiole) to 1 (over half the width of a petiole)

**agosites**

<table>
<thead>
<tr>
<th>Provenance ID</th>
<th>S</th>
<th>$H_{2010}$</th>
<th>$H_{2011}$</th>
<th>$D_{2010}$</th>
<th>$H_{1/4}$</th>
<th>$D_{1/4}$</th>
<th>$D_{2011}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0</td>
<td></td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>165.40</td>
</tr>
<tr>
<td>Max</td>
<td>211</td>
<td>170</td>
<td>21</td>
<td>13</td>
<td>1.33</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $LS$-means with the same letter are not significantly different (Tukey HSD test, $P < 0.05$).

**agosites**

<table>
<thead>
<tr>
<th>Provenance ID</th>
<th>S</th>
<th>Tip autumn coloration in 2010</th>
<th>Gland length in 2010</th>
<th>Gland colour in 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
according to the distinctive morphological characters of leaf glands.

Correlations (Pearson correlation coefficients and their P-values) between trait means of provenances of wild cherry and geographical data are given in Table 11. There was strong statistically significant positive relationship between gland number and hardness zone index ($r = 0.60, P = 0.03$). The moderate or strong positive correlations, i.e. between gland maximum number and hardness zone index, tree height in spring of 2011 and longitude, were not sufficiently significant (Table 11).

Table 11. Pearson correlation coefficients (and their P-values in italics) between provenance trait means at Dubrava nursery trial and geographical and ecological data at provenances’ origin locations. Strongest or significant correlations are in bold

<table>
<thead>
<tr>
<th>Trait</th>
<th>Hardness zone</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree height at the end of 2010 ($H_{ave}$)</td>
<td>0.098</td>
<td>0.232</td>
<td>0.059</td>
</tr>
<tr>
<td>Tree diameter in 2010 ($D_{ave}$)</td>
<td>0.976</td>
<td>0.371</td>
<td>0.822</td>
</tr>
<tr>
<td>Ratio of $H_{ave}$ to $D_{ave}$ ($H/D$)</td>
<td>0.023</td>
<td>0.236</td>
<td>0.034</td>
</tr>
<tr>
<td>Ratio of $H_{ave}$ to $D_{ave}$ ($H/D$)</td>
<td>0.932</td>
<td>0.361</td>
<td>0.898</td>
</tr>
<tr>
<td>Tree height in spring of 2011 ($H_{ave}$)</td>
<td>0.063</td>
<td>0.023</td>
<td>0.002</td>
</tr>
<tr>
<td>Tree height loss due to frost damage ($H_{ave}$)</td>
<td>0.811</td>
<td>0.930</td>
<td>0.993</td>
</tr>
<tr>
<td>Diameter of strongest branch or side stem ($D_{ave}$)</td>
<td>0.170</td>
<td>0.185</td>
<td>0.061</td>
</tr>
<tr>
<td>Branchiness ratio of $D_{ave}$ to $D_{ave}$ ($D_{ave}/H_{ave}$)</td>
<td>0.455</td>
<td>0.090</td>
<td>-0.458</td>
</tr>
<tr>
<td>Gland pigmentation (GIP)</td>
<td>0.118</td>
<td>0.770</td>
<td>0.116</td>
</tr>
<tr>
<td>Gland colour (GICO)</td>
<td>0.201</td>
<td>0.242</td>
<td>-0.237</td>
</tr>
<tr>
<td>Gland max. length in relation to petiole width (GILm)</td>
<td>0.439</td>
<td>0.350</td>
<td>0.360</td>
</tr>
<tr>
<td>Gland length in relation to petiole width (GILa)</td>
<td>0.198</td>
<td>0.103</td>
<td>-0.312</td>
</tr>
<tr>
<td>Gland number (GInm)</td>
<td>0.445</td>
<td>0.694</td>
<td>0.223</td>
</tr>
<tr>
<td>Gland number (GINu)</td>
<td>0.211</td>
<td>-0.178</td>
<td>-0.013</td>
</tr>
</tbody>
</table>

Discussion and conclusions

The genetic diversity of *P. avium* has been shown to be weakly spatially structured (Mariette et al. 1997, Mohanty et al. 2001). The pattern of genetic variability in this species implies that forest reproduction material should be collected from unrelated trees spread out over large enough areas (Jarni et al. 2012). Since *P. avium* is an entomophilous species, high pollen flow which would homogenise the populations is improbable, even if wild cherry pollen is easily located by insects (Frascaria et al. 1993, Gömöry and Paule 2001). Earlier study in wild cherry indicates that the vast majority of seed was dispersed no further than 50 m from the mother tree (Turcek 1968). Variability inside selected seed stands, of which the area is very limited, is not large (Fernandez et al. 1994), because natural suckering of wild cherry leads to clones covering varying areas (Frascaria et al. 1993): as a consequence, seeds are effectively harvested on very few genotypes in selected seed stands. So, the test material for our study was collected from the broad area of species’ distribution range. The EUFORGEN gene conservation strategy for wild cherry recommends using a minimum of 50 clones per seed orchard which should be regionally structured by the ecological conditions (Kleinschmit and Stephan 1997). Based on izyme studies of distribution of wild cherry clones in populations, it is recommended to select and use in plantations a mixture of at least 5 to 10 clones, mostly from different origins, in order to improve heterogeneity and self-sustainability (Ducci and Santi 1997).

The preliminary results, which give the first indications of the improvement potential for wild cherry in Lithuania in relation to introduction and which confirm some results obtained by Santi et al. (1998), are encouraging. It is also necessary to incorporate studies on susceptibility to bacterial canker and cherry leaf spot in the future. Cherry leaf spot (*Blumeriella jaapii* (Rehm) Arx.) has been recognized as the most serious sanitary problem of wild cherry (grown for timber) in some European countries (Motta et al. 1994, Santi et al. 1998), which results in premature leaf defoliation, vigour decrease, especially in diameter, and winter hardness reduction, which can even induce tree death due to low winter temperatures (Wharton et al. 2003).

Bacterial canker (*Pseudomonas syringae* Van Hall, 1904) is a major cause of dieback in wild cherry plantations (Santi et al. 2004). Both diseases thrive in moist and cool conditions (Eisensmith and Jones 1981, Hirano and Upper 2000), so the projected increase of atmospheric moisture content in northern latitudes (Frei et al. 2000) may benefit the diseases in Lithuania.

Our interest was in selecting the vigorous trees with small branches. Branches with large diameter or very fastigiated result in bigger wounds and necessitate rapid and severe pruning (Santi et al. 1998). There is an indication of breeding possibility of fast growing trees while retaining relatively slim branches as the correlation between tree height and tree branchiness ratio was very weak (see Table 3). The related unfavourable correlation was reported by Currel et al. (2003) that the tallest clones of wild cherry tended to be more forked.

A significant clone × site interaction had no negative impact on genetic gain at first multistate clonal test of wild cherry in Belgium (Currel et al. 2003). Studying the clones for the characters where the G × E interaction is detectable allows the breeder for the
The results of the study showed that, conversely to the pigmentation of shoot tips, induction of cherry gland pigments is not subjected to stress. Anthocyanins may be developmentally permanent in this case. The red coloration of shoot tips and leaves in many woody plants occurs in tandem with the onset of dormancy and cold hardiness due to induction of anthocyanins (Chalker-Scott 1999), nevertheless, securing timely growth cessation and dormancy induction in autumn are missing among P. avium species (Hemery et al. 2009). The red coloration of cherry shoot tips is probably based on anthocyanin biosynthesis, which is caused by stress like drought (Balakumar et al. 1993), nutrient deficiencies (Rajendran et al. 1992), wounding (Ferrer et al. 1997) or pathogen infection (Dixon et al. 1994).

It must be noted statistically significant positive relationships between the leaf gland length and the rest of wild cherry traits, except last year autumn overcoloration of shoot tips (Table 3). It means the greater length of the glands the better. In general, it may be stated that those conditions which produce vigorous vegetative growth favour gland development, since on old trees or on trees subjected to unfavourable growth conditions, the petiolar glands became much reduced, sometimes even disappearing, although normally present in the varieties (Dorsey and Weiss 1920). Finally, we have found that gland number is the best indicator of initial hardiness of transferred provenances.

Wild cherry possesses high level of genetic variation (Russell 2003). It is therefore likely that cherry is capable to adapt successfully with some shift in climate space. The results of this study approved our expectations that some individuals of wild cherry could be able to succeed even outside their current range of hardiness and thus show viability in long distance transfer. We have found few Italian ItBF individuals originating from provenances from hardiness zone 8, which showed no height loss due to frost damage at hardiness zone 5 at all. Moreover, the survival rate for this progeny was close to that of local Lithuanian LrT provenance (see Table 9).

In general, the uniformity of the data observed for some traits of European wild cherry (transferred from hardiness zones 6, 7, 8, and 9) suggests some tendency for its putative hardiness at central part of Lithuania (hardiness zone 5). According to the CVs calculated for the mean values of spring height (H_2011), the similar progenies showing the best uniformity of the data (or the lowest CVs), i.e. Polish PIZ and PIK from hardiness zone 6, were also the best survivors (see Table 9). The similar progenies showing the worst uniformity of the data (or the highest CVs), i.e. Bel-
gian BeM and German Del27 from hardiness zone 8 and 7 correspondingly, were the worst survivors. In conclusion, forest reproductive material from Poland (PIK and PIZ from hardiness zone 6) and Austria (AtK and AtT from hardiness zone 7) is candidate for further testing for the potential introduction of most fitted populations of wild cherry to the western and central parts of Lithuania (hardiness zone 6 and 5).

Using provenances instead of progenies has downsides as not allows for estimating genetic parameters, however, it brings in valuable information on ability of populations to survive in different environments (important issue when assessing effects climate change to forestry), and is low cost method to improve growth and quality of tree species where more costly breeding efforts are not possible.

Acknowledgements
The study was done under long term research program “Sustainable forestry and global changes”. Our sincere thanks go to the partners from European countries that have shared their P. avium material for our study. The anonymous reviewers are acknowledged for the valuable comments and advise.

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СОХРАНЕНИЕ ПОТОМСТВА ЧЕРЕШНИ (Prunus avium L.) НА СЕВЕРНОМ ПРЕДЕЛЕ ЕЕ ЕСТЕСТВЕННОГО АРЕАЛА ПРИ ПЕРЕМЕЩЕНИИ В ЛИТВУ

Р. Петрокас, А. Плюра

Резюме

Целью данного исследования было проанализировать возможность обогащения местных популяций черешни (Prunus avium L.) интродуцированным материалом, способствующим существованию при значительных отклонениях от оптимума вида. Потомства черешни из девяти стран Европы были испытаны на северном пределе ее естественного ареала. Данные сохранения потомства здесь относятся к потере высоты из-за ущерба от заморозков и к определенной вариабельности признаков деревьев. Исследования потомства черешни проводились на испытательном участке в центральной Литве в возрасте двух и трех лет. F-отношения фиксированных эффектов происхождения и блока, коэффициенты корреляции Пирсона и Спирмена, различия Тьюки были вычислены для следующего набора адаптивных и морфологических признаков: высота дерева осенью и весной, диаметр ствола дерева, соотношение этой высоты и диаметра осенью, диаметр сильнейшей боковой ветви или ответвления стебля, соотношение этого диаметра с диаметром дерева, осенняя окраска верхушек побегов, длина желез листьев по отношению к ширине черешков, цвет желез листьев.

Дисперсионный анализ большинства признаков показал, что эффекты происхождения, блока, и взаимодействия между происхождением и блоком были статистически значимыми. Это указывает на присутствие генетических различий между популяциями в общей продуктивности и в экологических нормах реакции. Очень слабая корреляция между высотой деревьев и соотношением ветвистости деревьев позволяет судить о возможности разведения быстрорастущих особей, сохраняя относительно тонкие ветви.

T-тест для независимых выборок и тест Левена на равенство дисперсий подтвердили связь между показателями роста выживших деревьев и признаками желёзок листьев. Определение изменений в морфологии выживших особей показало, что индукция пигментов желёзок не подвергается стрессу. Осенняя окраска верхушек побегов черешни считается показателем стресса в данном исследовании. Чем больше поврежденных деревьев было осенью, тем меньше высота дерева была следующей весной.

Была обнаружена сильная и значимая корреляция между числом желез и индексом климатической зоны в местах происхождения популяций (R = 0.60, P = 0.03). Положительные корреляции между максимальным количеством желез и индексом климатической зоны, высотой деревьев весной 2011 и долготой были умеренными, но недостаточно значимыми.

В общем, лесорепродукционный материал черешни из Польши и Австрии может быть использован для дальнейшего тестирования на потенциал интродукции наиболее приспособленных популяций в Литву.

Ключевые слова: Prunus avium, черешня, интродукция, сохранение, рост, морфология.