Effects of rootstock and environment on the behaviour of autochthone grapevine varieties in the Douro region

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ABSTRACT
In an experiment at Quinta da Cavadinha, Sabrosa, Douro Region the behaviour of the varieties Touriga Nacional (TN), Tinta Barroca (TB), Touriga Franca (TF) and Tinta Roriz (TR), grafted onto the rootstocks Ruprestris du Lot, R110, R99, 1103P and 196-17, respectively, was accessed over 11 years (2001-2011). The main results point to a significant influence of the environmental conditions in different years, especially those providing reduced water availability and greater heat stress: 2004, 2005, and 2009. Crop yields followed the sequence TR, TF, TB>TN, with highest oenological aptitude for TN and climate adaptive capacity to the TF. In terms of the rootstocks we confirm the lower production induced by R. Lot compared with R99, whilst 196-17 offered a good compromise between yield and quality for a large range of climate conditions.

Key Words: grapevines, rootstocks, yield, quality, Douro Region

1 INTRODUCTION
Choice of rootstock is among the most important decisions a grower or vintner makes and the implications for quality are enormous [8]. Drivers for rootstock adoption are wide ranging with the more important being phylloxera, nematode and salt, tolerance to, but water-use efficiency and drought tolerance are increasingly important to achieve better performance, faced with a complex set of interactions [7]. Also in a grafted plant, the metabolic functions are divided between the two genotypes. It’s the root system of the rootstock that will ensure provision of all mineral and water, while it is the grape variety responsible for the carbohydrates [6, 5].

In the Douro Region located in Northeast Portugal, vines grow in a Mediterranean like climate with important inter-annual and spatial variability, consequently with a high “vintage” effect [1]. For this reason
the choice of rootstock is of vital importance in the implementation and cultural decisions associated with different stages of construction and success of the vineyard. This work explores the effect of rootstocks and year effect on grapevines varieties of the Douro Winegrowing Region.

2 MATERIALS AND METHODS
The experimental block was located at Quinta da Cavadinha (Symington Family Estates), Sabrosa, Douro Region, at an altitude of 220m and it was planted in 1997. It has a schistous soil and lies on a moderate slope (26%) facing northeast. The vines are unirrigated, spur-pruned and trained to a bilateral cordon with vertical shoot positioning (VSP), usually with 10-12 buds per vine. The behaviour of the varieties Touriga Nacional (TN), Tinta Barroca (TB), Touriga Franca (TF) and Tinta Roriz (TR), grafted onto the rootstocks Rupestris du Lot (R. Lot), R110, R99, 1103P and 196-17, respectively, was evaluated over 11 years between 2001 and 2011. The rootstock-variety combinations were laid out in a randomised block design with four replications and 6 vines per plot. During the course of the study the dates of the main phenological stages were recorded along with climatic data from a meteorological station situated inside the property. During grape maturation berry samples were taken and analysed for their oenological properties, usually on three different dates (for this results only use the second date - in average near 10 Sept.), and at harvest yield parameters were also recorded. Subsequently vine vigour was quantified through pruning weights.

Table 1- Average growing season temperature (GST), growing degree-days (GDD), number of days with temperature > 30ºC and 35ºC, and % of the days with temperature >35 ºC from June to August, and annual precipitation (2001-2011).

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall (Nov-Out) (mm)</th>
<th>Rainfall (Mar-Sep) (mm)</th>
<th>Rainfall (Jul-Sep) (mm)</th>
<th>GST (Mar-Sep) (ºC)</th>
<th>GDD (Mar-Sep) (ºC units)</th>
<th>nº days T&gt;30 (ºC)</th>
<th>nº days T&gt;35 (ºC)</th>
<th>% days T&gt;35 (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1635</td>
<td>524</td>
<td>50</td>
<td>20,6</td>
<td>2258</td>
<td>86</td>
<td>36</td>
<td>27%</td>
</tr>
<tr>
<td>2002</td>
<td>578</td>
<td>319</td>
<td>178</td>
<td>20,4</td>
<td>2224</td>
<td>99</td>
<td>32</td>
<td>27%</td>
</tr>
<tr>
<td>2003</td>
<td>1115</td>
<td>284</td>
<td>18</td>
<td>21,5</td>
<td>2456</td>
<td>101</td>
<td>39</td>
<td>30%</td>
</tr>
<tr>
<td>2004</td>
<td>513</td>
<td>136</td>
<td>54</td>
<td>19,7</td>
<td>2087</td>
<td>86</td>
<td>21</td>
<td>18%</td>
</tr>
<tr>
<td>2005</td>
<td>276</td>
<td>118</td>
<td>28</td>
<td>20,5</td>
<td>2287</td>
<td>91</td>
<td>46</td>
<td>38%</td>
</tr>
<tr>
<td>2006</td>
<td>697</td>
<td>279</td>
<td>123</td>
<td>20,8</td>
<td>2328</td>
<td>92</td>
<td>43</td>
<td>33%</td>
</tr>
<tr>
<td>2007</td>
<td>580</td>
<td>201</td>
<td>47</td>
<td>19,2</td>
<td>1996</td>
<td>72</td>
<td>12</td>
<td>8%</td>
</tr>
<tr>
<td>2008</td>
<td>496</td>
<td>254</td>
<td>34</td>
<td>19,0</td>
<td>1925</td>
<td>56</td>
<td>21</td>
<td>18%</td>
</tr>
<tr>
<td>2009</td>
<td>527</td>
<td>102</td>
<td>7</td>
<td>21,1</td>
<td>2166</td>
<td>80</td>
<td>33</td>
<td>25%</td>
</tr>
<tr>
<td>2010</td>
<td>964</td>
<td>252</td>
<td>11</td>
<td>20,1</td>
<td>2194</td>
<td>96</td>
<td>45</td>
<td>37%</td>
</tr>
<tr>
<td>2011</td>
<td>533</td>
<td>125</td>
<td>37</td>
<td>20,3</td>
<td>2272</td>
<td>85</td>
<td>24</td>
<td>20%</td>
</tr>
<tr>
<td>Avg.</td>
<td>738</td>
<td>264</td>
<td>53</td>
<td>20,3</td>
<td>2190</td>
<td>87</td>
<td>33</td>
<td>26%</td>
</tr>
</tbody>
</table>
3 RESULTS AND DISCUSSION
During the study period the grapevine varieties experienced significant fluctuation in yield, as mainly result of higher fertility and of climate conditions. Important anomalies occur in 2006 (hail storm), 2007 and 2011 (downy mildew pressure). The highest yield was observed with TB, TR and TF. In opposite TN showed the lowest yield, cluster weight, high fertility and the highest values in acidity, phenols and anthocyanins.

Table 2: Yield attributes, vigour, and fruit composition at harvest. Values represent the mean for the years studied for the ensemble of the varieties. Means followed with different letters are significantly different at P<0.05, (n.a) data not available.

<table>
<thead>
<tr>
<th>Clusters /vine</th>
<th>Yield /vine (kg)</th>
<th>Cluster weight (kg)</th>
<th>Pruning weight (kg)</th>
<th>Berry weight (g)</th>
<th>Brix (°B)</th>
<th>Acidity (TA) (%)</th>
<th>pH</th>
<th>Phenols (mg/l)</th>
<th>Anthocyanins (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>21.9</td>
<td>3.13</td>
<td>0.15</td>
<td>0.75</td>
<td>1.86</td>
<td>21.4</td>
<td>4.23</td>
<td>3.58</td>
<td>n.a.</td>
</tr>
<tr>
<td>2002</td>
<td>13.4</td>
<td>2.15</td>
<td>0.20</td>
<td>0.58</td>
<td>2.02</td>
<td>23.6</td>
<td>4.29</td>
<td>3.60</td>
<td>n.a.</td>
</tr>
<tr>
<td>2003</td>
<td>14.3</td>
<td>2.67</td>
<td>0.20</td>
<td>0.68</td>
<td>2.08</td>
<td>24.2</td>
<td>3.82</td>
<td>3.74</td>
<td>n.a.</td>
</tr>
<tr>
<td>2004</td>
<td>15.6</td>
<td>2.16</td>
<td>0.14</td>
<td>0.53</td>
<td>2.14</td>
<td>20.3</td>
<td>4.50</td>
<td>3.41</td>
<td>n.a.</td>
</tr>
<tr>
<td>2005</td>
<td>16.0</td>
<td>2.03</td>
<td>0.14</td>
<td>0.41</td>
<td>1.69</td>
<td>22.1</td>
<td>4.72</td>
<td>3.49</td>
<td>n.a.</td>
</tr>
<tr>
<td>2006</td>
<td>14.7</td>
<td>1.99</td>
<td>0.13</td>
<td>0.51</td>
<td>1.92</td>
<td>22.3</td>
<td>4.33</td>
<td>3.82</td>
<td>n.a.</td>
</tr>
<tr>
<td>2007</td>
<td>17.3</td>
<td>1.93</td>
<td>0.11</td>
<td>0.43</td>
<td>2.35</td>
<td>22.5</td>
<td>4.80</td>
<td>3.50</td>
<td>59b</td>
</tr>
<tr>
<td>2008</td>
<td>17.0</td>
<td>2.16</td>
<td>0.14</td>
<td>0.52</td>
<td>2.10</td>
<td>20.8</td>
<td>5.40</td>
<td>3.36</td>
<td>63b</td>
</tr>
<tr>
<td>2009</td>
<td>11.9</td>
<td>1.36</td>
<td>0.12</td>
<td>0.47</td>
<td>2.14</td>
<td>22.7</td>
<td>4.70</td>
<td>3.58</td>
<td>64b</td>
</tr>
<tr>
<td>2010</td>
<td>13.0</td>
<td>1.72</td>
<td>0.14</td>
<td>0.50</td>
<td>2.17</td>
<td>22.6</td>
<td>4.58</td>
<td>3.63</td>
<td>81c</td>
</tr>
<tr>
<td>2011</td>
<td>15.6</td>
<td>2.08</td>
<td>0.14</td>
<td>0.71</td>
<td>2.29</td>
<td>22.7</td>
<td>3.94</td>
<td>3.75</td>
<td>64b</td>
</tr>
</tbody>
</table>

Figure 2: Effect of the year on the yield from the grapevine varieties (TB, TF, TN and TR). Means followed with different letters are significantly different at P<0.05

Table 3: Yield attributes, vigour, and fruit composition at harvest. Values represent the mean (2001-2011, *2007-2011) for the varieties TB (Tinta Barroca), TF (Touriga Franca), TN (Touriga Nacional) and TR (Tinta Roriz), and for the rootstocks 103P, 196-17, R110, R99 and Rupestris du Lot (R. Lot). Means followed with different letters are significantly different at P<0.05

<table>
<thead>
<tr>
<th>Clusters /vine</th>
<th>Yield /vine (kg)</th>
<th>Cluster weight (kg)</th>
<th>Pruning weight (kg)</th>
<th>Berry weight (g)</th>
<th>Brix (°B)</th>
<th>Acidity (TA) (%)</th>
<th>pH</th>
<th>Phenols (mg/l)</th>
<th>Anthocyanins (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB</td>
<td>13.2</td>
<td>2.14</td>
<td>0.16</td>
<td>0.58</td>
<td>2.39</td>
<td>23.2</td>
<td>4.59</td>
<td>3.61</td>
<td>62b</td>
</tr>
<tr>
<td>TF</td>
<td>12.7</td>
<td>2.21</td>
<td>0.18</td>
<td>0.52</td>
<td>2.17</td>
<td>20.3</td>
<td>4.34</td>
<td>3.56</td>
<td>65b</td>
</tr>
<tr>
<td>TN</td>
<td>22.8</td>
<td>1.86</td>
<td>0.09</td>
<td>0.57</td>
<td>1.54</td>
<td>23.0</td>
<td>5.01</td>
<td>3.46</td>
<td>74a</td>
</tr>
<tr>
<td>TR</td>
<td>13.5</td>
<td>2.22</td>
<td>0.16</td>
<td>0.55</td>
<td>2.18</td>
<td>22.6</td>
<td>3.99</td>
<td>3.65</td>
<td>65b</td>
</tr>
<tr>
<td>103P</td>
<td>15.0</td>
<td>2.26</td>
<td>0.16</td>
<td>0.56</td>
<td>2.14</td>
<td>22.3</td>
<td>4.60</td>
<td>3.58</td>
<td>64b</td>
</tr>
<tr>
<td>196-17</td>
<td>14.3</td>
<td>1.90</td>
<td>0.14</td>
<td>0.51</td>
<td>1.92</td>
<td>23.2</td>
<td>4.30</td>
<td>3.59</td>
<td>71a</td>
</tr>
<tr>
<td>R110</td>
<td>16.7</td>
<td>2.35</td>
<td>0.14</td>
<td>0.56</td>
<td>2.03</td>
<td>22.1</td>
<td>4.41</td>
<td>3.55</td>
<td>63b</td>
</tr>
<tr>
<td>R99</td>
<td>17.2</td>
<td>2.45</td>
<td>0.16</td>
<td>0.65</td>
<td>2.24</td>
<td>21.4</td>
<td>4.80</td>
<td>3.54</td>
<td>67a</td>
</tr>
<tr>
<td>R. Lot</td>
<td>14.6</td>
<td>1.60</td>
<td>0.12</td>
<td>0.51</td>
<td>2.04</td>
<td>22.3</td>
<td>4.37</td>
<td>3.57</td>
<td>67a</td>
</tr>
</tbody>
</table>
Over the years, it was noted that on average R110, R99 and 1103P rootstocks induced higher yield, while 196-17 and mainly R. Lot had a tendency to have the lowest yield per vine (Table 3), with different effects on the varieties (Figure 2) to the yield and quality (sugar accumulation). The yield levels achieved by R110, R99 and 1103P rootstocks were similar to those confirmed by several authors [6, 1].

On the other hand, the results obtained by [3], in the warmest Sub-Region of Douro Superior, point to the maintenance of high yield on R99 and R110, and a weaker performance on 1103P, which would appear to suggest an ecological influence on the performance of this rootstock, also referred by [6].

It should be mentioned that the performance of the R. Lot rootstock, traditionally used in the past plantations in the Douro region through the mid-1980s, generally induces the lowest vigour expressed through the pruning weight, and unit yields without compensation in the sugar content, mainly in the Tinta Roriz.

**Figure 2: Effect of the rootstock in the yield vs. quality relationship, for the varieties studied. Values represent the average 2001-2011**
Sugar content regularly reached highest values on 196-17 while the lowest values were found for R99. In the results there is an influence of the rootstock on the acidity, higher on R99 (Figure 2) and no significant differences in pH, phenols and anthocyanins content for the ensemble of the grapevine varieties.

4 CONCLUSIONS
In Mediterranean field conditions, as in the Douro Region, water deficits usually develop gradually during the summer and are normally associated with high temperature and irradiance stresses. The temperature and the heat load during summer expressed in growing degree days (GDD) and number of the days with temperatures above the optimum for photosynthetic activity shows substantial differences between years.
The Touriga Nacional confirms its high potential to produce both Porto and Douro wines, while Touriga Franca seems to be best adapted to the climate variability. Rootstocks can be a very important tool to manage the behaviour of the grapevines varieties under different climate conditions at Douro region. Finally, rootstock selection therefore involves more compromises than would be desirable, taking into account the diversity of criteria affecting the choice, mainly due to interactions with both the environment and the variety grafted. It is thus advantageous for the selection process to be carried out using a process of elimination, in accordance with conditioning characteristics of the environment (e.g. drought, humidity, acidity, soil fertility, etc.). Further work is needed to better explore the effect on vegetative growth of the vines, adaptation to stress and impact on ripening, in order to support the knowledge transfer to the growers by ADVID (Association for the Development of Viticulture in Douro).

REFERENCES

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