Correlations concerning the grape must sugar concentration and acidity as a result of soil maintenance influence

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Abstract Research was conducted in the vineyard of the Didactic Station, from Banat University of Agricultural Sciences and Veterinary Medicine of Timișoara, in 2011-2013, and were studied the correlations between sugar content and acidity of the grape must influenced by different soil maintenance variants. Observations and measurements were carried out on two grape varieties from different groups: Burgundy variety for superior red wines, and Silvania for table grape varieties.

In both varieties in which raw middles of experimental variants was maintain with grassy strips (V1, V5, V7) was obtained the lowest concentration of sugar in the must and obviously the higher acidity. Analyzing the average for the three years of study at Silvania variety, linear correlation between sugar concentration and acidity of grape must, was strongly negative (r = -.99***); the two variables are indistinguishable (p <0.0001) in almost 100% (r^2 = 0.99), the quantity of must sugar being conditioned by its acidity. The average for grape sugar concentration at Burgundy variety in three experimental years was 195 ± 4.27 g/l and 5.31 ± 0.23 g/l H_2SO_4 for grape acidity. As shown by the coefficient of variation values for both studied variants variability intensity is very low.

Key words correlation, acidity, sugar content, soil tillage

All morphological and biological periodically changes through which vines passes during a year, influencing the quality of grapes and wines. These changes are called phenological phases (phenophases) and have a hereditary nature, vines going through them in temperate, tropical or equatorial climates. The development of these phenophases is much influenced by the climatic conditions of the year, and growing area [4, 5].

Excessively vegetative development has proven to have negative effects on the colour and quality of the grapes (sugar, aroma, taste) as a result of competition in the ripening berries with shoots and late maturing [2].

On the other hand, a moderate drought in the area of roots may result in the accumulation of sugars by suppressing the growth of shoots and foliage density, thereby enabling a high photosynthesis [6].

Changes that occur during the formation of grape berries and their maturing determine the quality of the must. Specific composition of the must is not stable and is variable from year to year, changing continuously including during ripening. The amount of sugar in grape must range between 150 and 250 g/l during the fermentation, the yeast converts the sugars into alcohol and carbon dioxide. The amount of the alcohol is linked to the original quantity of sugars; as a result, by controlling the initial amount of sugar in the must, it can control the amount of alcohol in the wine [1].

The evolution of maturing is influenced by cultivar and climatic conditions. Maturing of varieties is different so it is very important to monitor the dynamics of grapes maturation to can establish the optimal time of grapes harvesting. The relationship between production and quality is difficult to be determined, being characteristic to each location. Garis (1999) [3] showed that production is low correlated with other indicators of quality such as colour or Baume index. Johnstone et al. (1996) tested the utility of viticultural parameters in addition to chemical analysis of grape must and grape berries composition as potential indicators of wine quality.

Materials and Methods

Research was conducted in the vineyard of the Didactic Station - Banat University of Agricultural Sciences and Veterinary Medicine of Timişoara, in 2011-2013 years. Two grape varieties from different groups were studied: Burgundy variety for superior red wines and Silvania variety with a medium maturing for table grape varieties.

The vineyard floor management was different in several experimental variants, as follows: V1 – row
middles herbs and grasses strip, bare soil by tillage
undervine (tractor and adjustable offset rotary tiller); V2 – bare soil by tillage floor between vines (cultivator) + herbicides treatment undervine; V3 – row middles bare soil by tillage (cultivator) + bare soil by tillage undervine (tractor and adjustable offset rotary tiller); V4 - row middles soil ripping (tractor and ripper) + bare soil by tillage undervine (tractor and adjustable offset rotary tiller); V5 – row middles herbs and grasses strip + manual hoeing undervine; V6 - bare soil by tillage middles row (tractor and rotary hoe) + rotary hoe undervine (tractor and adjustable offset rotary tiller); V7 – raw middles herbs and grasses strip + herbicides treatment undervine.

Were aimed the correlations established between content of grape must in sugars and must acidity as the main indicators of must quality, under the influence of different soil maintenance systems. Acidity was determined by titrimetric method and the sugar content was determined by refractometer.

**Results and Discussions**

In the first experimental year 2011 values for the concentration of sugar in the must and its acidity in Burgundy variety, are graphically represented in the figure below.

As shown in the chart columns, in the experimental variants in which the soil row middles was maintained grassy (V5 and V7) wine had the lowest concentration of sugar (respectively 186 and 186 g/l) but at the same time the higher level of the acidity (5.8 to 6 g/l H$_2$SO$_4$).

Most of variants have had sugar concentrations above 190 g/l and an acidity of 5.3 g/l H$_2$SO$_4$.

Maturation index ranges from a minimum 30.83 in grapes from the seventh variant and reaches a maximum of 36.23 in the sixth variant. By comparison, at Fetească regală cultivated in Jidvei area the full maturation index values of the grapes (Z/A) ranges from 29 to 34.

![Graph of must concentration and acidity](image)

**Table 1**

<table>
<thead>
<tr>
<th>Parameters of must sugar concentration (g/l) and must acidity (g/l H$_2$SO$_4$) at Burgundy variety in 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Sugar in must g/l</td>
</tr>
<tr>
<td>Must acidity (g/l H$_2$SO$_4$)</td>
</tr>
</tbody>
</table>
Average concentration of sugar in the Burgundy grape variety in 2011, was 189 ± 2.58 g/l, while the average acidity of the must was at a relatively high value of 5.57 ± 0.29 g/l H$_2$SO$_4$. Lower coefficient of variation of sugar in the must (1.37%), indicating a lack of variability, values obtained being nearly equal to each other. For grape acidity, coefficient of variability shows close results around the mean.

The two variables are nearly indistinguishable as indicated the coefficient of linear correlation very significant negative (r = -0.97 **), the high concentration of the must being explained in a proportion of 94%, by lower acidity of the grapes (p < 0.0001). In figure 2 are shown the results obtained for sugar concentration and acidity of Burgundy grape must, in 2012, for experimental and control variants.

Like the year before, in the experimental variations with grassy row middles (V1, V5, V7) was obtained the lowest concentration of sugar in the must, and obviously the highest acidity. Maturity index ranged between 36.41 and 43.75, values that are optimal for producing a quality wine. However, the strong atmospheric and soil drought in June and August of 2012, led to the accumulation of large amounts of sugars in the grapes harvested in some experimental variants (V2, V3, V4, V6), as indicated by the average of 202.4 ± 6.86 g/l. Climatic factors have influenced the acidity of the must, the average of this parameter in the second experimental year being of 5.04 ± 0.19 g/l H$_2$SO$_4$.

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Min-Max</th>
<th>Standard deviation</th>
<th>Standard Error</th>
<th>Coef var.%</th>
<th>C.I./95%</th>
<th>r</th>
<th>r$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar in must g/l</td>
<td>8</td>
<td>202,4</td>
<td>193 - 210</td>
<td>6,86</td>
<td>2,42</td>
<td>3,39</td>
<td>196,7 - 208,2</td>
<td>-</td>
<td>0,94</td>
</tr>
<tr>
<td>Must acidity (g/l H$_2$SO$_4$)</td>
<td>8</td>
<td>5,04</td>
<td>4,8 – 5,3</td>
<td>0,19</td>
<td>0,06</td>
<td>3,80</td>
<td>4,88 – 5,2</td>
<td>0,94</td>
<td>0,88</td>
</tr>
</tbody>
</table>
Among the two variables, there is a highly significant negative linear correlation ($r = -0.94$ ***), so that a higher concentration of sugar must entail a lower acidity ($p < 0.0001$). Up to 88% ($r^2 = 0.88$) from total variation of the sugar content can be explained by a linear relationship between the concentration of sugar and acid content of the must. For the third experimental year values of sugar concentration and acidity of must are illustrated graphically below.

The average sugar content of the must in 2013 was $193.8 \pm 3.44$ g/l and grape acidity was $5.36 \pm 0.28$ g/l H$_2$SO$_4$. For both parameters, the lower coefficient of variation indicates a very high homogeneity of the values obtained in the experimental variants. From all the results, up to 95% are in the range of confidence interval (CI = 95%). Maturity index values at full grapes ripening were between 32.58 and 38.82 depending on the experimental variant.

Table 3

<p>| Parameters of must sugar concentration (g/l) and must acidity (g/l H$_2$SO$_4$) at Burgundy variety in 2013 |
|-------------------------------------------------|------------|-------------|---------------|-------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th>N</th>
<th>Mean</th>
<th>Min-Max</th>
<th>Standard deviation</th>
<th>Standard Error</th>
<th>Coef var.%</th>
<th>C.I./95%</th>
<th>r</th>
<th>r$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar in must g/l</td>
<td>8</td>
<td>193,8</td>
<td>189 - 198</td>
<td>3,44</td>
<td>1,21</td>
<td>1,77</td>
<td>191 - 196,7</td>
<td>-</td>
</tr>
<tr>
<td>Must acidity (g/l H$_2$SO$_4$)</td>
<td>8</td>
<td>5,36</td>
<td>5,0 – 5,8</td>
<td>0,28</td>
<td>0,09</td>
<td>5,27</td>
<td>5,12 – 5,59</td>
<td>0,98</td>
</tr>
</tbody>
</table>

A highly significant negative linear correlation ($r = -0.98$ *** ) was established in 2013 between the concentration of sugar and acidity in the must ($p <0.0001$). In this experimental year, up to 95% of the must acidity can be explained by the increased value of the sugar concentration in the must and the remaining 5% is assigned to other factors. For a higher accuracy analysis of the results obtained during the three experimental years, the average was calculated for the studied parameters, and graphical representation can be observed in the figure below.
The average of the three experimental years for must sugar concentration was 195 ± 4.27 g/l, while for must acidity was of 5.31 ± 0.23 g/l H$_2$SO$_4$. Variability was very low, as the coefficient of variation values shows for both studied variables. Maturity index ranged from minimum 33.15 and maximum 40.98 depending on the variant.

Overall, in the three experimental years, up to 96% ($r^2 = 0.96$) of the total must acidity variation can be explained by the linear relationship between the sugar concentration and must acidity, and only 4% from variance of this parameter is a result of other factors. Among the two variables, it was a highly significant negative linear correlation ($r = - 0.98$ *** ) keeping the trend of the interdependence of must sugar concentration and its acidity ($p <0.0001$).

Results for the second variety studied - Silvania, in different experimental variants of soil maintenance rows middles and undervine are shown in the diagram below (fig. 6).

At the variety Silvania in the first experimental year, sugar concentration in the grape must, had a mean of 171.6 ± 1.99 g/l, and an average acidity of all seven variants of 4.76 ± 0.34 g/l H$_2$SO$_4$.

Coefficients of variation values were very low, confirming that the mean is very representative for both analyzed parameters. Maturity index determined ranged from 30.75 at the must obtained of grapes harvested from the seventh experimental variant and 40.45 to variant six. By comparison, at the Sauvignon blanc, maturity index values at full grapes ripening (Z / A) ranges from 32 to 36.

### Table 4

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Min-Max</th>
<th>Standard deviation</th>
<th>Standard Error</th>
<th>Coef var.%</th>
<th>C.I./95%</th>
<th>r</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar in must g/l</td>
<td>8</td>
<td>195</td>
<td>189 - 200</td>
<td>4.27</td>
<td>1.51</td>
<td>2.19</td>
<td>191.4 – 198.6</td>
<td>-</td>
<td>0.98</td>
</tr>
<tr>
<td>Must acidity (g/l H$_2$SO$_4$)</td>
<td>8</td>
<td>5.31</td>
<td>5.1 – 5.7</td>
<td>0.23</td>
<td>0.08</td>
<td>4.32</td>
<td>5.12 – 5.5</td>
<td>0.98</td>
<td>0.96</td>
</tr>
</tbody>
</table>
Table 5

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Min-Max</th>
<th>Standard deviation</th>
<th>Standard Error</th>
<th>Coef var.%</th>
<th>C.I./95%</th>
<th>r</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar in must g/l</td>
<td>8</td>
<td>171.6</td>
<td>163 - 178</td>
<td>5.63</td>
<td>1.99</td>
<td>3.28</td>
<td>166.9 - 176.3</td>
<td>-</td>
<td>0.99</td>
</tr>
<tr>
<td>Must acidity (g/l H₂SO₄)</td>
<td>8</td>
<td>4.76</td>
<td>4.4 - 5.3</td>
<td>0.34</td>
<td>0.12</td>
<td>7.18</td>
<td>4.47-5.04</td>
<td>0.99</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Very significant and negative correlation coefficient with a value close to -1 (r = - 0.99 *** ) indicate a very strong relationship between the two variables (p <0.0001). In fact, the greater the concentration of sugar in the must, the grape acidity decreases. In 2011, up to 99% (r² = 0.99), one of the two variables was influenced by the other.

In 2012, grape acidity and concentration in sugar are presented graphically in the image below.

![Graph showing sugar and acidity in must](image)

With small values very close to each other, as regards sugar concentration, can be distinguished the experimental variants (V1, V5, V7), with grassy rows middles.

At the same experimental variants were determined the highest values of the grape must acidity. The rest of the experimental variants, as can be seen from the chart above, showed almost equal values for both sugar content and acidity of grape must.

Maturity index value in 2012, according to the experimental variants of soil maintenance, ranged between 32.94 and 43.33.

Average sugar content of grape must in 2012 was 176 ± 6.11 g/l. The acidity of the must had an average of 4.56 ± 0.34 g/l H₂SO₄. For both variables the average is representative, up to 95% of the values obtained being within the limits of the confidence interval.
Table 6

Parameters of must sugar concentration (g/l) and must acidity (g/l H$_2$SO$_4$) at Silvania variety in 2012

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Min-Max</th>
<th>Standard deviation</th>
<th>Standard Error</th>
<th>Coef var.%</th>
<th>C.I./95%</th>
<th>r</th>
<th>r$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar in must g/l</td>
<td>8</td>
<td>176</td>
<td>168 - 182</td>
<td>6,11</td>
<td>2,16</td>
<td>3,48</td>
<td>170,9 – 181,1</td>
<td></td>
<td>0,96</td>
</tr>
<tr>
<td>Must acidity (g/l H$_2$SO$_4$)</td>
<td>8</td>
<td>4,56</td>
<td>4,2 -5,1</td>
<td>0,34</td>
<td>0,12</td>
<td>7,50</td>
<td>4,27 – 4,84</td>
<td>0,98</td>
<td></td>
</tr>
</tbody>
</table>

Also this year, between sugar concentration and acidity of the grape must, it was a very highly significant linear correlation ($r = -0.98$ ***; $p <0.0001$), up to 96% of the variation in the grape must sugar content being determined by acidity.

At Silvania variety in 2013 was obtained for sugar concentration and acidity of the must, the following results, which are presented graphically, bellow (fig. 7).

Values almost identical to those obtained in the previous year for both variables studied, have yielded an average of 173.7 ± 5.7 g/l for concentration of sugar in the must, and respectively 4.67 ± 0.35 g/l H$_2$SO$_4$ for the grape must acidity. Maturity index ranged from 31.73 to the seventh variant (rows middles covered by grass) and 42.85 (sixth variant).

For both sugar concentration and acidity of the grape must, the coefficient of variation shows a very tight grouping around the average values obtained.
Table 7

Parameters of must sugar concentration (g/l) and must acidity (g/l H₂SO₄) at Silvania variety in 2013

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Min-Max</th>
<th>Standard deviation</th>
<th>Standard Error</th>
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<th>C.I./95%</th>
<th>r</th>
<th>r²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar in must g/l</td>
<td>8</td>
<td>173,7</td>
<td>165 – 180</td>
<td>5,7</td>
<td>2,01</td>
<td>3,28</td>
<td>168,9 – 178,5</td>
<td>-</td>
<td>0,99</td>
</tr>
<tr>
<td>Must acidity (g/l H₂SO₄)</td>
<td>8</td>
<td>4,67</td>
<td>4,2 – 5,2</td>
<td>0,35</td>
<td>0,13</td>
<td>7,65</td>
<td>4,37 – 4,97</td>
<td>0,99</td>
<td>0,98</td>
</tr>
</tbody>
</table>

In 2013 as in the first experimental year, between the sugar concentration in the grape must and acidity was a highly negative and significant linear correlation ($r = -0.99$ **); $p <0.0001$). Up to 98% ($r² = 0.98$) of grape sugar concentration was influenced by the lowering of must acidity.

Average results obtained in the three experimental years at Silvania variety as regards the concentration of sugar in must and its acidity is illustrated in the chart 8.

Maturity index values at full maturation of the grapes ranged from a minimum 31.78, in the variant with grassy rows middles and herbicides undervine (V7), and maximum 42.25 in the sixth variant in which both row middles and undervine soil was processed by rotary hoe.

The average grape must sugar concentration during the three experimental years was 173.7 ± 5.81 g/l, while the average acidity was of 4.66 ± 0.35 g/l H₂SO₄. Variability was low for both parameters, as indicated by the coefficient of variation values.

Table 8

Parameters of must sugar concentration (g/l) and must acidity (g/l H₂SO₄) at Silvania variety in 2011-2013 period

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Min-Max</th>
<th>Standard deviation</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Sugar in must g/l</td>
<td>8</td>
<td>173,7</td>
<td>165,3 - 180</td>
<td>5,81</td>
<td>2,06</td>
<td>3,35</td>
<td>168,9 – 178,6</td>
<td>-</td>
<td>0,99</td>
</tr>
<tr>
<td>Must acidity (g/l H₂SO₄)</td>
<td>8</td>
<td>4,66</td>
<td>4,26 – 5,2</td>
<td>0,35</td>
<td>0,12</td>
<td>7,44</td>
<td>4,37 – 4,95</td>
<td>0,99</td>
<td>0,99</td>
</tr>
</tbody>
</table>
If is analyzed the average over the three years of study at the Silvania variety as regards the concentration between sugar and grape must acidity, linear correlation was negative and very strong ($r = -0.99$ ***) , the two variables being indistinguishable ($p <0.0001$); in almost 100% ($r^2 = 0.99$) the quantity of sugar in grape must was conditioned by acidity.

**Conclusions**

Over the three experimental years in Burgundian variety the average of grape must sugar concentration was $195 \pm 4.27$ g/l and grape must acidity of $5.31 \pm 0.23$ g/l H$_2$SO$_4$. Variability was very low as shown by the variation coefficients for both studied variables. A highly significant negative linear correlation ($r = -0.98$ ***) was established in 2013 between the concentration of sugar in the grape must and its acidity ($p <0.0001$). In this experimental year, up to 95% of the must acidity can be explained by the increased value of the sugar concentration in the grape must and the remaining 5% is attributed to other factors.

At the Silvania variety, in the first experimental year, concentration of sugar in the grape must was of $171.6 \pm 1.99$ g / l, and the acidity had an average for all seven variants of $4.76 \pm 0.34$ g/l H$_2$SO$_4$. The average grape must sugar concentration during the three experimental years was $173.7 \pm 5.81$ g/l, while the average acidity was of $4.66 \pm 0.35$ g/l H$_2$SO$_4$.

**Bibliography**