Winter barley yield and quality parameters in relation to weather conditions, variety and fertilizations

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Abstract
In years 2011 to 2013 we monitored the effect of year, variety, leaf nutrition and stimulator on the height and quality of winter barley grain yield. Yield difference between the years was statistically significant. Factor year statistically significantly influenced the proportion of grain and the bulk density. Among the varieties statistically significant difference in grain yield was at the interaction Year*Variety in favor of the variety Yatzy. In terms of quality significantly better results reached the Casanova. The Zincuran Sc and Sunagreen lead compared to control by the increase in yield, the statistically significant difference in the crude protein and extract content.

Key words: winter barley, leaf nutrition, growth stimulator, technological quality

Introduction
Thanks to new double-rowed winter barley varieties its cultivation and malting use throughout Europe has been increasingly expanding (Deudon et al., 2001). Declining tendency of spring barley growing areas in Slovakia puts higher demands on increasing the efficiency of winter barley cultivation and on meeting the needs of malting industry. Key position in the system of malting industry, grower and the variety. For its success and market are crucial especially technological indicators of malting quality (Gupta et al., 2010). Decisive indicators of quality are: the proportion of the 1st Class grain, bulk density, crude protein and extract content (Kosař, Psota et al., 2000, Muchová et al., 2007, Leistrumaitė et al., 2007, Fox et al., 2009). Share of the variety on achieved yields is estimated at 25 % to 40 % depending on the growing conditions of the year (Molnárová, Pepó, 2010). Negative impact of a bad year can be corrected to some extent with scientifically controlled nourishment based on the analysis of plants, by which, in addition to N we straighten the deficit of other micro and macro elements (Molnárová, Pačuta, 2013). Results of several authors confirm the importance of growth stimulators, which should provide a leveling of tillers and eliminate unproductive tillers (Křováček, Černý, 2007).

Material and methods
Through years 2011-2013 we monitored the influence of the year, foliar nutrition Zincuran SC and growth stimulator Sunagreen on height and selected chemical indicators of winter barley grain yield technological quality. The research task was solved within polyfactorial field trials established at EXBA FAFR SUA in Nitra, on moderate heavy brown soil, moderately stocked with P and well-stocked with K, with humus content 2.16 to 2.23 % and soil pH from 5.29 to 5.7. Average annual rainfall according to the 30-year climate normal (1960-1990) is 532.5 mm and the average temperature is 9.8 °C. Experiments were established after white mustard with two varieties of winter barley (Casanova and Yatzy), five variants of the crop treatments with a method of divided blocks, keeping the randomness, in triplicata: a = 0 control, b = 60 kg N + 30 kg P + 120 kg K, c = 60 kg N + 30 kg P + 120 kg K + Zincuran SC + Sunagreen, d = 80 kg N + 30 kg P + 120 kg K, e = 80 kg N + 30 kg P + 120 kg K + Zincuran SC + Sunagreen. Foliar fertilizer (Zincuran SC) was applied at the growth stage (BBCH 25) at a dose of 1 liter per hectare and the growth stimulator (Sunagreen) was applied at the growth stage (BBCH 32) at a dose of 0.5 l ha⁻¹. Grain yield after harvest was converted to standard moisture of 14 %.
The differences between the monitored treatment variants as well as varieties and years were evaluated with multifactor analysis of variance with Statistica 10 and the evidence was tested using the “Tukey” test.

**Results and discussion**

**Year**

The research results showed the statistically high significant (p > 0.99) impact of the year on the grain yield of monitored winter barley varieties (Figure 2). From the monitored three years the highest grain yield we reached in 2010/2011, in average for the monitored varieties 8.49 t ha⁻¹, what was in comparison with the years of 2011/12 and 2012/13 about 5.21, respectively 2.5 t ha⁻¹ more. Mentioned year were favorable in terms of the rainfall distribution during vegetation. Rich rainfall in the months of September to December with climate average from 131.75 to 191.75 % provided a good full sprouting and ideal crop condition for good wintering (Molnárová, Kufelj, 2000). Extremely wet March with rainfall 310.67 % of climate average, ensured a sufficient moisture for the formation of tillers and grains, which had a positive impact on crop yield. On the contrary, the lowest yield we reached for the cultivation year 2011/2012 in average for the whole experiment 3.28 t ha⁻¹, which was characterized by a severe drought in the autumn and also in the spring season. Rainfall in the months of August to November amounted to only 2.18, respectively 52.8 % of climate average, what resulted in a low number of individual plants per unit area and a low number of tillers. Similarly during the spring vegetation trough the months of March, May and June were extremely dry with a climate average (17.33, respectively 25.42 %) and so small numbers of plants and tillers could not be offset by the number of grains and thousand grains weight. At the monitored mechanical quality indicators STN 461100-5 criterion was met in all three years in the grain proportion over sieve 2.5 mm (from 94.78 to 99.77 %). At the bulk density the minimum value (680 g l⁻¹) mentioned by the authors Leistrumaité et al. (2007) was slightly exceeded only in 2012. There was a statistically significant difference (p > 0.99) at the both mechanical quality indicators (Table 1). As optimal crude protein content Petterson and Eckersten (2007) report 9.5 to 11.5 %. In average for the monitored varieties and treatment variants this value was exceeded in a dry year 2012 (11.87 %). Statistically significant difference (p > 0.99) was between the year 2013 and 2011-2012 (Table 1). The inverse relation between the crude protein content and extract was confirmed (Muchová et al., 2007). At the lowest crude protein content (10.39 %) in 2013 was achieved the highest extract content (78.39 %). Our results confirm the view of Fox et al. (2009) that the extract content is significantly determined by genotype, agro-ecological conditions and cultivation technology.

![Figure 1](image1.png)  
**Figure 1. Impact of the year on the yield of winter barley grain**

![Figure 2](image2.png)  
**Figure 2. Impact of the variety on the yield of winter barley grain**

*(Figure 1: rok· year, Figure 2: odroda·variety, úroda·yield)*
Variety

When comparing the varieties Casanova and Yatzy at the grain yield for the monitored years and treatment variants there was no statistically significant difference (Figure 2). Statistically significant difference (p > 0.99) was at the interaction Year*Variety. In the rainfall favorable year (2010/2011) yield difference between the varieties reached 1.67 t ha$^{-1}$ in favor of the Yatzy variety. For quality indicators statistically significant difference (p > 0.99) between the varieties was at the extract content, the grain proportion over sieve 2.5 mm and a bulk density in favor of Casanova variety. In average for three years the criteria STN 461100-5 meet the monitored varieties only at the crude protein content (from 11.18 to 11.31 %) and the grain proportion over sieve 2.5 mm (96.45 - 98.92 %) (Table 2). In terms of the extract content neither one of the monitored varieties reached the required 80%, the values of which are mentioned by the authors Kosař, Psota et al. (2000), Leistrumaitė et al. (2007).

Treatment variants

Treatment of Zincuran SC and Sunagreen increase the yield in comparison with the untreated control. We found the most increase of the yield at the variant e (about 0.91 t ha$^{-1}$), but this was not statistically significant (Figure 3). Statistically significantly (p > 0.99) was the crop treatment in rainfall favorable year 2010/11 and 2012/13 at the variety Casanova (1.65 t ha$^{-1}$, respectively 1.60 t ha$^{-1}$) and at the variety Yatzy in 2012/2013 (1.64 t ha$^{-1}$). Křováček, Černý (2007) using the treatment of barley with a growth stimulator Sunagreen they achieved the yield increase of 0.7 t ha$^{-1}$. Crop treatment with leaf fertilizer Zinkuran SC together with Sunagreen (variant c, e) resulted in statistically significant differences (p > 0.99) in comparison with a control at the crude protein and extract content. With a treatment impact the bulk density increased, and slightly decreased the grain proportion over sieve 2.5 mm, but the differences were not statistically significant (Table 3). This confirms the view of Chloupek (2005) that the growth stimulators do not have a clear impact on the grain technological quality.

(Figure 3: ošetrenie-treatment, úroda-yield)
Table 1. The Analysis of variation at a significance level $\alpha = 0.01$ – winter barley technological quality in the years 2011, 2012 and 2013 (Tukey test)

<table>
<thead>
<tr>
<th>Year</th>
<th>Crude pro extract (%)</th>
<th>Extract (%)</th>
<th>Prop of gr. (%)</th>
<th>Bulk. Dens. (g l$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>HG</td>
<td>average</td>
<td>HG</td>
</tr>
<tr>
<td>2011</td>
<td>11.48</td>
<td>x</td>
<td>77.84</td>
<td>x</td>
</tr>
<tr>
<td>2012</td>
<td>11.87</td>
<td>x</td>
<td>76.18</td>
<td>x</td>
</tr>
<tr>
<td>2013</td>
<td>10.39</td>
<td>x</td>
<td>78.39</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 2. Statistical evidence ($\alpha = 0.01$) of the variety impact on the selected indicators of winter barley grain technological quality in the average for years 2011-2013, (Tukey test)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Crude pro extract (%)</th>
<th>Extract (%)</th>
<th>Prop of gr. (%)</th>
<th>Bulk. Dens. (g l$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>HG</td>
<td>average</td>
<td>HG</td>
</tr>
<tr>
<td>Casanova</td>
<td>11.31</td>
<td>x</td>
<td>77.64</td>
<td>x</td>
</tr>
<tr>
<td>Yatzy</td>
<td>11.18</td>
<td>x</td>
<td>77.30</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 3. Statistical evidence ($\alpha = 0.01$) of the treatment impact on the selected indicators of winter barley grain technological quality in average for years 2011-2013, (Tukey test)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crude pro extract (%)</th>
<th>Extract (%)</th>
<th>Prop of gr. (%)</th>
<th>Bulk. Dens. (g l$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
<td>HG</td>
<td>average</td>
<td>HG</td>
</tr>
<tr>
<td>a</td>
<td>10.78</td>
<td></td>
<td>77.94</td>
<td>x</td>
</tr>
<tr>
<td>b</td>
<td>11.18</td>
<td></td>
<td>77.62</td>
<td>x</td>
</tr>
<tr>
<td>c</td>
<td>11.67</td>
<td>x</td>
<td>76.96</td>
<td>x</td>
</tr>
<tr>
<td>d</td>
<td>11.17</td>
<td>x</td>
<td>77.46</td>
<td>x</td>
</tr>
<tr>
<td>e</td>
<td>11.44</td>
<td>x</td>
<td>77.38</td>
<td>x</td>
</tr>
</tbody>
</table>

Conclusions

From the three-year results of our research with winter barley we state the following conclusions:

- Yield difference between the years reached 5.21, respectively 2.5 t.ha$^{-1}$ in favor of the year 2010/2011, resp. 2012/2013. Year statistically significantly influenced the proportion of grain above sieve 2.5 mm and the bulk density.

- Factor variety influenced the height of grain yield in interaction with the year. In the three-year average variety Yatzy provided higher yield. For quality indicators statistically significant difference between the varieties was at the extract content, the proportion of grain above sieve 2.5 mm and the bulk density in favor of the variety Casanova.

- Crop treatment using foliar fertilizer Zinkuran SC and Sunagreen led to an yield increase in combination with a dose of N 80 kg ha$^{-1}$. From quality indicators the treatment significantly influenced the crude protein content in grain and the extract content.

Acknowledgements

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