Yield potential of spring malting barley (*Hordeum vulgare* L.) varieties in the growing conditions of south-western Slovakia

Úrodový potenciál odrôd sladovníckeho jačmeňa (*Hordeum vulgare* L.) v pestovateľských podmienkach juhozápadného Slovenska.

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Abstract

The field experiment was set up as a block plot design with four replications on the experimental base of the Central Controlling and Testing Institute in Agriculture situated in south-western Slovakia during 2011-2012. Spring malting barley varieties were growing after sugar beet and spring barley forecrops. Besides the year condition, the forecrop value significantly influenced the variability of grain yield. Interaction of forecrop with year condition contributed significantly to the overall variability of yield and was higher than that of the interaction of variety and year. Due to the balanced set of genotypes, variability of yield influenced by varieties was relatively low in both very contrasting years. Two year average yield was in relatively narrow range of 6.05 t*ha^{-1}- 6.66 t*ha^{-1}. Due to the very dry condition in 2012, mainly during crucial period of yield formation, average yield of evaluated genotypes decreases by 43% with comparison to 2011. The phenotypic plasticity of evaluated genotypes was reflected in less favourable weather condition of 2012 in range of 0.97 t*ha^{-1} grain or 1.14 t*ha^{-1} grain in good growing conditions of the year 2011, respectively. Better forecrop value of spring barley with comparison to sugar beet was confirmed in both evaluated year. Significantly higher yield (7.10 t*ha^{-1}) of grain was achieved after spring barley forecrop with comparison to 5.38 t*ha^{-1} of grain after sugar beet forecrop. For better interpretation of forecrop value it is proposed Environmental index for “forecrop gain” or “forecrop lost”, calculated separately as share of increasing or decreasing grain yield due to the forecrop for at least two agronomically different years.

Keywords: forecrop, grain yield, spring barley, varieties

Abstrakt

Poľný pokus bol založený blokovou metódou zo štyrmi opakovaniami na skúšobnej stanici Ústredného kontrolného a skúšobného ústavu poľnohospodárskeho v lokalite juhozápadného Slovenska v rokoch 2011-2012. Odrody sladovníckeho jačmeňa boli pestované po predplodinách repa cukrová a jačmeň jarný. Popri podmienkach ročníka, predplodina taktiež preukazne ovplyvňovala variabilitu úrody zrna. Interakcia predplodiny a podmienok ročníka preukazne prispela k celkovej variabilite úrody a bola väčšia než interakcia odrody a podmienok ročníka. Vzhľadom na vyrovnaný súbor testovaných genotypov, bol v oboch veľmi rozdielnych ročníkoch, vplyv odrody na variabilitu úrod relatívne nízky. Dvojročný priemer úrod bol v relatívne úzkom intervale 6,05 $t*ha^{-1}$ - 6,66 $t*ha^{-1}$. Vzhľadom na veľmi suché podmienky roku 2012, hlavne počas kľúčovej periódy formovania úrody, poklesla priemerná úroda hodnotených genotypov o 43% v porovnaní s rokom 2011. Fenotypová plasticita hodnotených genotypov v menej vhodných pestovateľských podmienkach roku 2012 bola na úrovni 0,97 $t*ha^{-1}$ zrna resp. 1,14 $t*ha^{-1}$ zrna v dobrých pestovateľských podmienkach roku 2011. Lepšia predplodinová hodnota jačmeňa jarného v porovnaní s repou cukrovou sa potvrdila v oboch sledovaných rokoch. Preukazne vyššia úroda (7,1 $t*ha^{-1}$) zrna sa dosiahla po predplodine jačmeň jarný v porovnaní s úrodou 5,38 $t*ha^{-1}$ zrna po predplodine repa cukrová. Pre lepšiu interpretáciu predplodinovej hodnoty bol navrhnutý Environmentálny index, pre „predplodinový zisk“ alebo „predplodinovú stratu“, počítať oddelene ako podiel nárastu alebo poklesu úrody zapríčinenú predplodinou minimálne pre dva pestovateľsky veľmi rozdielne roky.

Kľúčové slová: predplodina, úroda zrna, jačmeň jarný, odrody

Introduction

In Slovakia, the cereals are cultivated on an area of about 780 thousand hectares, and the proportion of barley is 18%. In 2011 and 2012, the average yield of barley was 3.87 $t*ha^{-1}$ and 3.18 $t*ha^{-1}$, respectively (Candráková and Macák, 2015). Spring barley and barley products belong to the important products in Slovakia, resulting mainly from the fact that Slovakia has in Europe after Germany, France and the Czech Republic the most suitable conditions for growing (Křen et al., 2014). The grain yield is a prerequisite for successful cultivation of spring barley in Slovakia. Successful growing of spring barley for malting purposes depends on many factors. An increase in crop productivity involves a comprehensive approach and knowledge of the genetic background of crops. Productivity is the final result of the effect and interactions of several yield-determining traits, which are basically polygenic and, as such, they do not allow separate determination of their contribution (Madić et al., 2014). The yield formation can be defined as the interaction effect of soil and climatic conditions, genotype, fertilization and growing technology (Barczak and Majcherczak, 2008). Crop rotation is one of the major agro-technical measures to ensure the production of crops. Growing barley after a suitable previous crop is an important eco-stabilizing factor (Šrek and Kunzová, 2011). Barley varieties differ in their sensitivity to management inputs and to environmental condition and for those with a malting classification this in turn influences the probability of their received as malt barley.

The aim of this study was to evaluate the yield potential of spring malting barley growing after different forecrops in south-western part of Slovakia.

Materials and methods

The experiment was carry out during 2011-2012 on the Central Controlling and Testing Institute in Agriculture in south-western Slovakia, at the experimental site Veľké Ripňany (N 48° 30´; E 17° 59) which belong to the sugar beet production area. Soil type is moderate brown soil with topsoil depth of 0.60 m. The set of spring malting barley (*Hordeum vulgare* L.) varieties Salome, Signora, Slaven, Shuffle, Calcule, Danielle, Petrus, and Wiebke were tested. The experiment design was set up as a block plots with four replications. At full harvestable maturity, plot grain yield was measured from a 10 m^2 harvest area. Standard procedure for official varietal trials was used. In 2011, sowing/harvest date was 16^{th} March/13^{th} July after spring barley forecrop and 22^{nd} March/14^{th} July after sugar beet forecrop. In 2012, sowing/harvest date was 22^{nd} March/19^{th} July after spring barley forecrop and 21^{th} March/19^{th} July after sugar beet forecrop. After spring barley forecrop stubble disc plow with partial incorporation of crop residues was used. Deep autumn mouldboard ploughing was applied each year in both forecrops. On the spring the soil was settled and mineral fertilizer was incorporated by soil compactor. During 2012, the field after sowing was harrowed and rolled. The standard dose of NPK was used after both forecrops (30 kg*ha^{-1} N, 30 kg*ha^{-1} P and 30 kg*ha^{-1} K) and 40 ton*ha^{-1} of FYM was applied before sugar beet growing. For statistical evaluation software Statistica version 10.0 MR1 was used. Before using multifactorial ANOVA, the data were subjected to homogeneity by using Hartley, Cochran and Bartlett tests.

Results and discussion

Due to short vegetation period extending for about 100 days and poorly developed root system, spring barley is very sensitive to drought stresses, even if they are temporary (Pecio and Wach, 2015). Increasing temperature, even without significant changes in precipitation may cause the deepening of the already negative water balance (Kozyra et al., 2009).

In 2011, the air temperature of the experimental site was in concordance to the climatological normal, except of April with higher month temperature by + 2.6 °C. Precipitation doses during the vegetation period of spring barley were mostly above the climatological normal. June was the wettest month of the 2011, with precipitation doses by +30 mm about climatological normal (Figure 1 and 2).

Figure 1. Average temperature in °C (y-axis) and climatological normal at Veľké Ripňany locality, 2011-2012

Obrázok 1. Priemerná teplota v °C (os-y) a klimatologický normál na lokalite Veľké Ripňany, 2011-2012

Except April, air temperature in 2012 was higher throughout the growing period of spring barley compared to 2011. The year conditions with comparison to climatological normal were characterised as warm, with higher air temperature in range from +1.4 °C (April) to + 2.8 °C (March) in 2012.

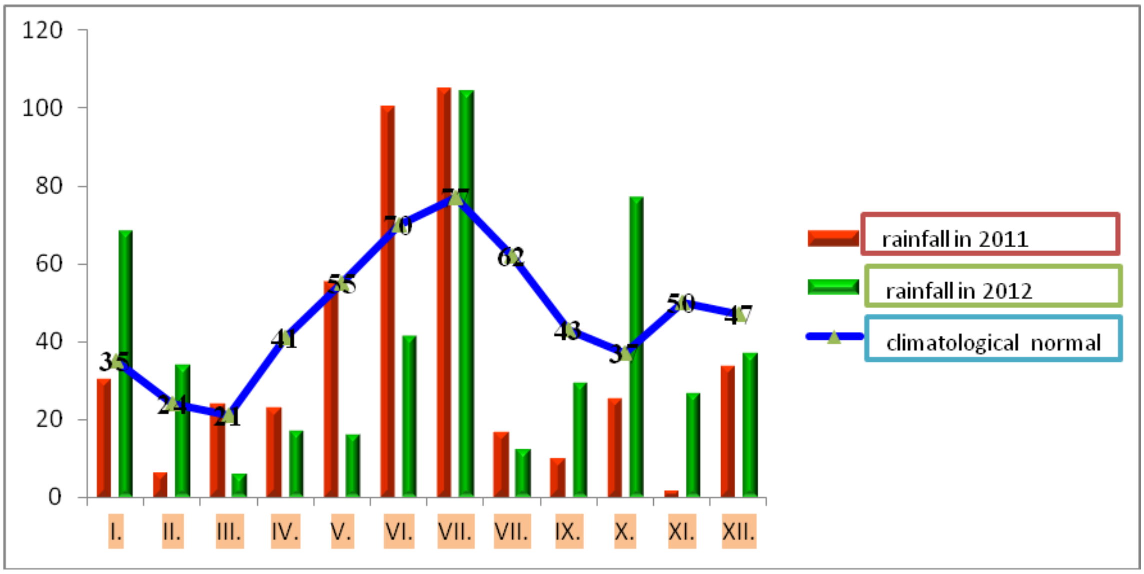

Figure 2. Precipitation pattern in mm (y-axis) and normal rain distribution at Veľké Ripňany locality, 2011-2012

Obrázok 2. Priebeh zrážok v mm (os-y) a zrážkový normál na lokalita Veľké Ripňany, 2011-2012

Except of July 2012, the growing season was substantially dry. May was the driest month with rainfall deficit of 39 mm under climatological normal (Figure 2).

A crop yield is influenced by rainfall and temperatures not only in terms of quantity but especially by distribution pattern during the vegetation period (Kováč et al., 2005). According precipitation pattern differences mainly during May and June, the great differences in suitable growing conditions for spring barley were noted between evaluated years. In 2011, during important period of spring barley development in May and June, barley plant received about 118 mm of rain water more in 2011 with comparison to 2012. Deficit of rainfall in May and June of 2012 was 87 mm below normal.

According results of ANOVA, the year conditions, forecrop value and variety significantly influenced the variability of spring barley grain yield (Table 1). Grain yield was significantly affected particularly by the year (seasonal weather conditions). Interaction of forecrop with year conditions also contributed significantly to the variability of yields and was substantially higher than that of the interaction of variety and year. Besides the year conditions main source of variability of grain yield was also forecrop value.

Contribution of components on variability of grain yield was calculated according share of sum of squares. The share of forecrop on the variability of barley yield at the level of 26% demonstrates the great importance of selecting the appropriate forecrop. The share of weather condition on yield variability calculated according sum of squares on the level of 59% was also noted. It is in compliance with the research of Klink et al. (2014). Average yield of genotypes was significantly higher in 2011 (7.51 t*ha^{-1}) compared to 2012 (4.25 t*ha^{-1}). Due to the balanced set of genotypes in official variety trial, variability of yield influenced by cultivars was relatively low.

Table 1. Analysis of variance of grain yield of eight varieties of malting spring barley growing after spring barley and sugar beet forecrop, 2011-2012

Tabuľka 1. Analýza variancie úrody zrna ôsmich odrôd sladovníckeho jačmeňa pestovaného po predplodinách jačmeň jarný a repa cukrová, 2011-2012

Component	Sum of squares	F - ratio
Varieties (V)	5.8	4.9**
Forecrop value (F)	95.0	561.1**
Year condition (Y)	217.8	1286.1**
V x Y	3.9	3.3**
F x Y	25.0	147.6**
Residual	12.4	

** significant at the $P < 0.01$ probability level.

** preukazné na hladine významnosti $P < 0,01$.

The average yield of set of eight tested varieties documented much contrasted year conditions for spring barely growing conditions, mainly in very sensitive period of yield formation components. According Kováč et al. (2005) moisture deficit during April and May significantly decrease the grain yield. The relationship among characters defining grain yield and its components were also explored as a function of the length of different barley development phases and water deficit during grain filling period (Pržulj and Mihajlovic, 2012). Varieties Slaven, Signora, Wiebke and Petrus as a first group achieved the yield in a very narrow insignificant range 6.05 $t*ha^{-1}$ - 6.09 $t*ha^{-1}$ but with comparison to Danielle (6.39 $t*ha^{-1}$), Salome (6.44 $t*ha^{-1}$), and Calcule (6.66 $t*ha^{-1}$), have significantly less yield. Shuffle variety was in the middle of the spectrum without significant differences to all other tested varieties except the most yielding variety Calcule.

According our post hoc testing process, significantly higher yield (7.10 $t*ha^{-1}$) of spring barley grain was achieved after spring barley as a previous crop with comparison to 5.38 $t*ha^{-1}$ of grain after sugar beet forecrop during 2011-2012.

Table 2. Yield potential of spring barley varieties in $t*ha^{-1}$ growing after sugar beet and spring barley forecrop, 2011-2012

Tabuľka 2. Úrodový potenciál odrôd jačmeňa jarného v $t*ha^{-1}$ pestovaného po predplodine repa cukrová a jačmeň jarný, 2011-2012

Varieties	2011		2012	
	Sugar beet	Spring barley	Sugar beet	Spring barley
Shuffle	6.86	7.92	3.49	7.26
Petrus	7.03	7.82	3.65	5.85
Wiebke	7.16	7.77	3.41	6.65
Danielle	7.6	8.43	3.56	6.23
Salome	7.16	8.43	4.04	6.94
Calcule	7.72	7.64	3.9	6.38
Signora	6.86	7.63	3.45	6.32
Slaven	6.87	7.77	3.76	5.82
Total	57.26	63.41	29.26	51.45
Average	7.158	7.926	3.658	6.431
Forecrop gain		0.769		2.774

The main difference of grain yield in an average of two years was 1.72 $t*ha^{-1}$, but this difference do not reflect the forecrop rate in specific year conditions of 2011 and 2012 (Table 2).

Mean grain yield of all genotypes at a location is broadly recognise as an Environmental index (EI) with statistical evidence (Costa and Bollero, 2001). For better interpretation of forecrop value in particular year, it is proposed EI for “forecrop gain” or “forecrop lost”, calculated as percentage share of increasing or decreasing grain yield due to the forecrop value for minimum two years. This calculation will be appreciated especially in very different year conditions and help to elucidate the crop and forecrop relationship in agronomically different year.

In 2011, the cumulative grain production of eight tested varieties of spring barley increased by 6.15 tons after spring barley forecrop with comparison to cumulative yield of grain after sugar beet forecrop. In the less favourable year 2012, the total cumulative grain production of spring barley was even higher by 22.19 tons after spring barley forecrop compared with cumulative grain production of spring barley growing after sugar beet forecrop.

Expressed in term of EI as “forecrop gain”, the share of better forecrop on increasing yield in 2011 accounting for 21.7% or 78.3% in year 2012, respectively. Sugar beet is traditionally consider as a suitable forecrop for barley, but the barley management practice using the traditional previous crop sugar beet is not the same either, since beet tops are not harvested and or producer have reduced a tillage system (Váňová et al., 2006).

The most sensitive response to the forecrop expressed variety Salome in the agro climatic conditions of the 2011. Variety Salome growing after spring barley achieve higher yields by 1.27 $t*ha^{-1}$ as compared to the yield achieved after the sugar beet. In the less favourable year conditions of 2012, were even more expressed differences in the forecrop value, to which most responded varieties Shuffle, Wiebke, Salome reducing the yield of 2.9 $t*ha^{-1}$ to 3.77 $t*ha^{-1}$.

Conclusion

In the years 2011-2012, forecrop value contributed to the overall variability by 26%. Due to the balanced set of genotypes tested in official variety trial, variability of yield influenced by varieties was relatively low.

On the base of the two year field testing trials of eight prospective spring barley varieties was confirmed that in besides of year condition, forecrop and genotype significantly influence the variability of yield. Interaction of forecrop with year condition also contributed significantly to the overall variability of yield of spring barley substantially higher than that of the interaction of variety and year.

Worse forecrop value of sugar beet with comparison to spring barley was confirmed in both agronomically very contrasting years. Average focrecrop gain of spring barley compare to sugar beet calculated over two years was 1.77 $t*ha^{-1}$. Significantly higher yield (7.10 $t*ha^{-1}$) of malting spring barley grain was achieved after spring barley as a previous crop with comparison to 5.38 $t*ha^{-1}$ of grain after sugar beet forecrop during

2011-2012. For better interpretation of forecrop value, Environmental index for “forecrop gain” or “forecrop lost” calculated as percentage share of increasing or decreasing grain yield is strongly recommended for at least two agronomically different years.

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