THE YIELD AND QUALITY OF SPRING BARLEY AFFECTED BY NITROGEN FERTILIZATION DURING GROWING PERIOD

ÚRODA A KVALITA ZRNA JAČMEŇA SIATEHO JARNÉHO V ZÁVISLOSTI OD HNOJENIA DUSÍKOM POČAS VEGETÁCIE

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Abstract: *Spring barley malting varieties (Ebson, Malz, Nitran) and their response to environmental conditions, year and fertilization were investigated in 3-years experiment (2005 – 2007). Treatments of fertilization: 1. control, 2. LAV (ammonium nitrate with limestone) 20 kg ha^{-1} of net nitrogen, 3. LAV for grain yield level of 5 t ha^{-1} applied at the end of shooting, 4. DAM 390 (ammonium nitrate with urea) in rate 20 kg ha^{-1} of net nutrient N applied at the end of shooting. The highest yields of grain were achieved in 2005 and the lowest in 2007, which demonstrated the statistically significant influence of year. The lowest yield was at control variant – 5.09 t ha^{-1}. The average yields of grain in 3-years period were: Ebson – 6.82 t ha^{-1}, Nitran – 5.74 t ha^{-1} and Malz – 5.46 t ha^{-1}. Following parameters of grain quality were evaluated: thousand kernel weight (TKW), kernels bulk density and proportion of grain over the sieve 2.5 mm.*

Rezumat: *V trojročnom pokuse (2005–2007) boli skúmané odrody jačmeňa siateho jarného (Nitran, Ebson, Malz) a ich reakcia na podmienky prostredia, ročníka a hnojenie. Varianty hnojenia: 1. kontrola, 2. LAV 20 kg.ha^{-1} čistých živín N (BBCH 21), 3. LAV na úrodu zrna 5 t.ha^{-1} aplikovaný na začiatku odnožovania (BBCH 21), 4. DAM 390 v dávke 20 kg.ha^{-1} čistých živín N aplikovaný na konci odnožovania (BBCH 29). Najvyššie úrody zrna boli dosiahnuté v roku 2005 a najnižšie v roku 2007, čím sa prejavil štatisticky vysokopreukazný vplyv ročníka. Hnojenie a odrody pôsobili na úrodu zrna jačmeňa siateho jarného preukazne. Najvyššia úroda bola dosiahnutá po aplikácii LAV vypočítaného na úrodu zrna 5 t.ha^{-1} a tekutého hnojiva DAM 390 na konci odnožovania. Priemerné úrody odrôd za tri roky pokusu boli: Nitran – 5,74 t.ha^{-1}, Ebson – 6,76 t.ha^{-1} a Malz – 5,46 t.ha^{-1}. Z objektívnych a technologických ukazovateľov kvality zrna jačmeňa boli vyhodnotené: objemová hmotnosť, HTZ a podiel zrna nad sitom 2,5 mm. Každá odroda reagovala na podmienky ročníka a varianty hnojenia rozdielne.*

Key words: *spring barley, varieties, fertilization, yield, quality*
Cuvinte cheie: *jačmeňa siaty jarný, odrody, hnojenie, úroda, kvalita*

INTODUCTION

In year 2007, in Slovakia the spring barley was grown on 198.6 thousands ha and its average yield was 3.3 t ha^{-1} (MASÁR, 2007). Slovakia has sufficient soil-climatic conditions for growing of good quality spring barley. 90 - 92 % of all growing area represents spring barley, and only 8 – 10 % winter barley. Spring barley is very sensitive and its yield depends on climatic conditions (precipitation, temperature), forecrop, soil structure, good quality seeds, soil moisture and aeration and fertilization (SLEZIAK and HOREVAJ, 2000; KOVÁČ et al., 2005).

Spring barley is used mainly for malt production and as a feed for animals. The rest is used in food industry and as a seeds. The varieties have to be chosen properly, so that their genetic potential was fully used, therefore they have to be grown in appropriate conditions (PSOTA, 2000).

Great importance belongs also to the others intensifying factors, mainly terms and doses of fertilizers for reaching the good quality of grains. Spring barley sensitively reacts on nutrients shortage. The reason is weakly developed, shallow root system and short period of nourishing (KUBINEC and KOVÁČ, 1998; LOŽEK, 2001). The shortage of nutrients usually displays on seeds yield and yield components. 2/3 of the malt quality is influenced by outdoor conditions (soil, weather and cultivation), the rest by variety (ZIMOLKA et al., 2006).

One of the most important nutrients is nitrogen. FECENKO and LOŽEK (2000) advice use the whole dose of nitrogen before sowing, and in the case of fertilizing during spring barley growing, in the phase of $3^{rd} – 4^{th}$ leaves.

The aim of the work reported here was to know the influence of different forms and doses of nitrogen fertilisers applied during spring barley growing season on its grain yield and quality.

MATERIALS AND METHOD

The field experiment was realized at SAU enterprise in Oponice during years 2005-2007. Altitude of area is 168 m, average year precipitation 607 mm, and temperature 9.5 °C. Main soil type is Haplic Luvisol on loess with loamy texture.

The experiment was a split-plot designed with three replicates. Spring barley was grown after sugar beet fertilized with 35 t ha^{-1} farm yard manure (FYM). Depth of ploughing was 220-250 mm. In spring, land leveller and compactor were used for seed bed preparation. The plots were 14 m^2 in size.

We used varieties Nitran (Slovak), Ebson and Malz (Czech). 4.5 millions of fertile seeds were sown per ha, to the depth of 40 mm and inter-rows of 125 mm. Just before harvest the plants samples were taken for mechanical analyses and seeds were used for qualitative parameters determination.

Fertilization treatments:

1. control – without fertilization
2. nitrogen 20 kg ha^{-1} (NH_4NO_3 + $CaCO_3$) (LAV) at the beginning of shooting (BBCH 21)
3. rate of nitrogen (NH_4NO_3 + $CaCO_3$) (LAV) calculated for anticipated grain yield level of 5 t ha^{-1} in the end of shooting phase (BBCH 29)
4. nitrogen 20 kg ha^{-1} (DAM 390) in the end of shooting phase (BBCH 29).

Rates of fertilizers were calculated on the base of agrochemical soil analyses, which were done from samples collected before sowing and at the beginning of shooting phase from depth of 0.3 and 0.6 m. For nitrogen rate calculation we followed method by Fecenko and Ložek (2000) who advice to use 24 kg ha^{-1} of nitrogen for 1 ton of grain and straw.

Terms of sowing: April 2, 2005; April 7, 2006; March 16, 2007.

Terms of harvesting: June 24, 2005; June 27, 2006; June 17, 2007.

RESULTS AND DISCUSSIONS

In climatic condition of Slovakia all agricultural plants are strongly influenced by weather condition during vegetation period. Average year precipitation and temperature are in table 1.

The most favourable temperature and moisture conditions for spring barley were in year 2005. Great disproportion in rainfall between particular months was in year 2006. Year 2007 was very dry in spring, when after sowing did not rain during 3 weeks.

The goal was through reached yield to prove the reaction of selected spring barley varieties on growing condition and nitrogen fertilization (table 2).

For statistical evaluation was used analysis of variance by Tukey´s test in program

STATGRAPHICS Plus. Evaluated years and varieties highly significantly influenced the yield of grains. The lowest yield was in year 2007 and the highest in 2005. Between varieties, the best results reached Ebson, varieties Nitran and Malz reached similar yields.

Table 1

Rainfall and temperature conditions of years 2005 - 2007 in comparison with long-term average normal

Year	Temperature (°C)	Anomaly (°C)	Rainfall (mm)	Anomaly (mm)
Normal (1951 - 1980)	9.7	-	561.0	-
2005	9.6	- 0.1	638.3	+113.80
2006	10.1	+ 0.4	507.1	- 90.39
2007	11.2	+ 1.5	617.0	+ 56.0

Table 2

Grain yield of spring barley evaluated in software STATGRAPHICS Plus (Tukey test)

Factor	Yield (t ha^{-1})	α 0.05	α 0.01
Year			
2005	7.41 c	0.3174	0.3992
2006	5.57 b		
2007	4.97 a		
Variety			
Nitran	5.73 a	0.7622	0.9570
Ebson	6.75 b		
Malz	5.46 a		
Fertilization			
Control	5.09 a	0.9737	1.1925
LAV 20 kg ha^{-1} N	5.98 ab		
LAV for yield 5 t ha^{-1}	6.46 b		
DAM 390 – 20 kg ha^{-1} N	6.41 b		

Means followed by the same letter are not significantly different at the α 0.05 and α 0.01.

Application of nitrogen positively influenced yield of grains. Between fertilization treatments were found statistically significant differences. Equable yield was reached after application LAV for grain yield level of 5 t ha^{-1} and after application of DAM 390 (6.46 t ha^{-1} a 6.41 t ha^{-1}). The lowest yield was reached in variant without fertilization.

From technological parameters we evaluated thousand of kernels weight (TKW), amount of kernels larger than 2.5 mm and kernels bulk density. TKW for different varieties was influenced by weather conditions and fertilization. For Nitran variety the lowest TKW was in year 2007. TKW was positively influenced by DAM 390 application at the end of shooting. At N fertilization for grain yield 5 t ha^{-1}, the TKW decreased by 2.38 g. Ebson variety reached the highest TKW in year 2006. Fertilization treatments had for Ebson variety similar influence as for Nitran. At Malz variety, the highest TKW was reached in year 2007 (47.73 g) and the lowest (44.77 g) similarly as at Ebson variety in year 2005. At Malz variety, the N fertilization in rate 20 kg ha^{-1}, did not positively affect beginning of shooting phase. In average of three years, the highest TKW was reached by Nitran variety (47.32 g) and the lowest by Ebson (44.54 g).

For barley processing on malt purposes it is desirable equal grain size, what is stated as an amount of kernels larger than 2.5 mm. Average values of three years are in table 3.

Table 3

Amount of kernels larger than 2.5 mm (%) (average values for years 2005-2007)

Fertilization treatments	Variety			
	Nitran	Ebson	Malz	Average
Control	90.91	91.78	93.20	91.96
LAV 20 kg ha^{-1} N	92.24	94.46	93.86	93.52
LAV for yield 5 t ha^{-1}	86.11	94.84	94.51	91.82
DAM 390 20 kg ha^{-1} N	94.15	96.13	96.42	95.57
Average	**91.60**	**94.30**	**94.50**	**93.47**

Varieties Malz and Ebson had amount of kernels larger than 2.5 mm by 2.7 – 2.9 % higher than Nitran. Good results of Malz and Ebson were positively influenced also by fertilization with DAM 390 and LAV in rate 20 kg ha^{-1}. Applied rate for grain yield 5 t ha^{-1} was les favourable. Kováč et al., (2006) stated, that growing year, forecrop and fertilization influence the TKW, amount of kernels larger than 2.5 mm, kernels bulk density and N content.

Kernels bulk density is not primary indicator of grain technological quality, but indicates size and weight of grain. Results are in table 4.

Table 4

Average values of kernels bulk density (g l^{-1}) in years 2005 - 2007

Fertilization treatments	Variety			
	Nitran	Ebson	Malz	**Average**
Control	645.4	661.36	670.98	659.25
LAV 20 kg ha^{-1} N	655.3	668.34	673.39	665.68
LAV for yield 5 t ha^{-1}	651.9	669.79	671.73	664.47
DAM 390 20 kg ha^{-1} N	650.8	670.94	672.86	664.87
Average	**650.7**	**667.61**	**672.24**	**663.52**

The highest kernels bulk density had Malz (672.24 g l^{-1}) variety and the lowest Nitran (650.70 g l^{-1}). This parameter was positively influenced with application 20 kg ha^{-1} LAV.

For spring barley fertilization is important to consider variety specifications. Nitrogen is primary nutrient important in quantitative and qualitative parameters of spring barley. Nitrogen fertilization increases yield of grains and content of N in grain slightly decreases TKW and the amount of kernels larger than 2.5 mm (Ložek, 2003; Slamka et al., 2008).

Majority of qualitative parameters were more influenced by weather conditions than by nitrogen fertilization and crop management (Peter et al., 2002; Macák et al., 2008a, b), what is in agreement with our results.

The content of proteins in barley grains is crucial for malt and beer quality. The content of nitrogen in grains is inheritable characteristic and it is strongly influenced by year, site and crop management, therefore also fertilization of malt spring barley by nitrogen is problematic (Kandera, 1994). Nowadays, breweries request content of proteins 10.7 – 11.2 % and extract 80.9 – 82.5 %. Our results are in Table 5 - 7.

In year 2005 breweries request fulfilled only Nitran variety. Proteins content was higher at variety Ebson and Malz. The content of extract was at all varieties more than 82.5 %. Nitrogen fertilization affected each variety differently. At Nitran and Ebson varieties slightly increased proteins content after application 20 kg ha^{-1} LAV at the beginning of shooting and after application 20 kg ha^{-1} DAM 390 the end of shooting. Malz variety distinctly increased proteins content (12.02 %) after LAV application in rate counted for grain yield 5 t ha^{-1}.

Table 5

Proteins and extract contents in spring barley grains in year 2005

Fertilization treatments	Nitran		Ebson		Malz	
	Protein	Extract	Protein	Extract	Protein	Extract
Control	10.78	82.70	12.30	82.50	10.39	82.30
LAV 20 kg ha^{-1} N	11.47	82.70	11.75	83.00	11.84	83.40
LAV for yield 5 t ha^{-1}	10.76	83.30	11.35	82.90	12.02	83.30
DAM 390 20 kg ha^{-1} N	10.97	83.80	11.75	81.80	11.23	83.20
Average	**11.00**	**83.10**	**11.79**	**82.55**	**11.37**	**83.05**

In year 2006 no of examined varieties reached requested nitrogen content, and it was only 9.40 – 9.80 %. The content of extract was 82.80 % - 83.40 %. Nitran variety replied for nitrogen fertilization similarly as in year 2005. At Ebson and Malz variety, compared to control variants, increased proteins content after application of LAV counted for grain yield level of 5 t ha^{-1}, hence the proteins content requested by brewery was fulfilled (table 6).

Table 6

Proteins and extract contents in spring barley grains in year 2006

Fertilization treatments	Nitran		Ebson		Malz	
	Protein	Extract	Protein	Extract	Protein	Extract
Control	9.60	82.80	9.40	81.90	9.20	83.50
LAV 20 kg ha^{-1} N	11.00	82.60	9.50	82.10	9.40	83.70
LAV for yield 5 t ha^{-1}	9.30	83.00	10.60	83.00	10.10	83.20
DAM 390 20 kg ha^{-1} N	10.00	82.80	9.60	82.00	8.90	83.10
Average	**9.97**	**82.80**	**9.80**	**82.30**	**9.40**	**83.40**

The year 2007 was quite favourable for proteins content (10.49 – 11.70 %), but the extract content was very low and did not reach values requested by brewery (table 7).

Application of LAV for grain yield 5 t ha^{-1} and DAM 390 slightly increased proteins content in Nitran and Ebson. At Malz variety the highest proteins content was at LAV applied in rate 20 kg ha^{-1}. Lover proteins contents were in relationship with increased extract contents.

Table 7

Proteins and extract contents in spring barley grains in year 2007

Fertilization treatments	Nitran		Ebson		Malz	
	Protein	Extract	Protein	Extract	Protein	Extract
Control	11.33	78.59	10.15	81.79	11.99	79.71
LAV 20 kg ha^{-1} N	11.30	78.81	9.81	81.19	12.13	79.71
LAV for yield 5 t ha^{-1}	11.47	78.27	11.60	80.01	11.56	79.62
DAM 390 20 kg ha^{-1} N	11.43	78.59	10.39	81.80	11.10	79.91
Average	**11.13**	**78.57**	**10.49**	**81.20**	**11.70**	**79.74**

CONCLUSIONS

From 3-years experiment (2005 – 2007) we can conclude, that yield of spring barley was statistically highly significantly influenced by year, variety and nitrogen fertilization during vegetation. The highest yield of all varieties was in year 2005. Grain yield was favourably influenced by application of LAV for grain yield level of 5 t ha^{-1} and DAM 390 at the end of shooting phase.

From grain qualitative parameters the highest TKW were at Nitran variety in year 2005 (48.00 g), at Ebson in year 2006 (46.07 g) and at Malz in year 2007 (45.89 g). Each variety replied on year weather conditions differently. At Nitran variety the highest TKW was reached at LAV with nitrogen rate 20 kg ha^{-1} (48.72 g). Varieties Ebson and Malz replied positively on DAM 390 with N rate 20 kg ha^{-1} at the end of shooting phase.

The amount of kernels larger than 2.5 mm was the highest at all varieties in year 2005 and the lowest in year 2007. The size of grains was improved after DAM 390 application. Similar reaction of all varieties was found at kernels bulk density.

Proteins and extract content in spring barley grains was influenced mainly by weather conditions during years. Qualitative parameters requested by brewery were nearly reached in year 2005. Spring barley reacted on nitrogen fertilization in relationship with year and variety.

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