THE INFLUENCE OF STRESS FACTORS ON SPRING BARLEY YIELD

Eva CANDRÁKOVÁ, Nora POLLÁKOVÁ, Eva HANÁČKOVÁ

Slovak University of Agriculture in Nitra, Faculty of Agrobiology and Food Resources, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia
E-mail: Eva.Candrakova@uniag.sk

Abstract: *Spring barley malting varieties (Nitran, Ezer and Poprad) and their response to environmental conditions, year and fertilization were investigated in the field experiment of Slovak University of Agriculture enterprise in Oponice during years 2005 - 2007. Altitude of the area is 168 m above sea level, average annual precipitation is 607 mm, and temperature 9.5 °C. Main soil type was classified as Haplic Luvisol on loess with loamy texture. Treatments of fertilization were as follows: 1. control - without fertilization, 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 stage, 4. DAM 390 (ammonium nitrate with urea) in rate 20 kg ha^{-1} of net nutrient N applied at the end of shooting stage. 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 stage from depth of 0.3 and 0.6 m. The effect of moisture and temperature on grain yield was expressed by the value of internal energy (ΔU). Changes of ΔU in the non-vegetation period and in the critical growth stages of spring barley, and the influence of observed parameters on the yield formation in years with Y_{max} and Y_{min} were evaluated for the analysis of the thermo dynamical characteristics. Negative value of internal energy expresses the dominant effect of temperature beyond moisture and acts positively on grain yield. Positive ΔU values act opposite. The highest grain yields (Y_{max} 7.94 t ha^{-1}) were achieved in year 2005 and the lowest in year 2007 (Y_{min} 4.28 t ha^{-1}), what demonstrated the statistically significant influence of year, varieties and fertilization. Despite the fertilization by nitrogen promoted increasing of grain yield, but the effect of year was stronger.*

Key words: *spring barley, varieties, fertilization, water, temperature, yield*

INTRODUCTION

Effects of weather conditions on yield and crop quality significantly contribute to the stability of economic performance (ŠPÁNIK and ŠIŠKA, 2004; ŠPÁNIK, 2008). Local moisture conditions are primarily determined by the difference between precipitation and water evaporation. Minimum soil moisture for spring barley is 40-50 % of full water capacity (BIELEK, 2001). CHMIELEWSKI and KOHN (1999) concluded that weather conditions have up to 60 % rate on the variability of spring barley crops.

Slovak climate is characteristic by water scarcity often accompanied with high temperatures, what affects the radiation quantity and radiation efficiency during photosynthesis (KOSTREJ, 1998). For spring cereals the integral variable of temperature conditions during their growing season was chosen. The sum of active temperatures from sowing to wax maturity should be 1755 ˚C (SLEZIAK, 2000).

REPKOVÁ and BRESTIČ (2006) found that stressing high temperature occurs mainly in summer, when acts in interaction with water shortages and strong radiation. As a self-acting factor it significantly affects the course of primary photochemical processes.

Lack of water is the main of all abiotic stressor in the conditions without irrigation (KOVÁČ et al., 2005; MACÁK et al., 2008; SLAMKA et al., 2008). Due to the complex relationships between the amount of water in the plants and their surrounding environment including soil, it is not possible to use a simple criterion for objective assessing the measure of water stress for plants. Spring barley belongs to the plants with C_3 type of photosynthesis, which are common for some characters, for example minimum temperature is around 0 °C, and transpiration rate is 450-900 g water per 1 g of dry weight (PROCHÁZKA et al., 1998).

MATERIAL AND METHODS

The field experiment was realized at SUA enterprise in Oponice during years 2005-2007. Altitude of the area is 168 m, average annual precipitation 607 mm, 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. Depth of ploughing was 220-250 mm. Shear and compactor was used for seed bed preparation. The plots were 14 m^2 in size. Slovak varieties (Nitran, Ezer and Poprad) were used. 4.5 millions 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.

Fertilization treatments:

1. control – without fertilization
2. nitrogen 20 kg ha^{-1} LAV (ammonium nitrate with limestone) at the beginning of shooting (BBCH 21)
3. rate of nitrogen (LAV) calculated for anticipated grain yield 5 t ha^{-1} at the end of shooting stage (BBCH 29)
4. DAM 390 (ammonium nitrate with urea) 20 kg ha^{-1} at the end of shooting (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 stage from depth of 0.3 and 0.6 m. For nitrogen rate calculation was followed method by FECENKO and LOŽEK (2000) who advice to use 24 kg ha^{-1} of nitrogen per 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.

The amount of kinetic energy transformed to a potential energy was expressed by relationship (KUDRNA, 1985): $\Delta U = \frac{Y}{tc} tcn - \frac{Y}{hs} hsn$

ΔU - change of total internal energy in system,
tc - the sum of average daily temperatures for crop growth,
tcn - average daily air temperature during relevant period (month),
hs - total monthly rainfall during crop growth,
hsn - rainfall during relevant period (month).

The aim of the work reported here was to point to the impact of temperature and moisture conditions on the grain yield of spring barley (Y). Data were collected in the experimental base during the course of three years (2005-2007). In 2005 it was gained maximal grain yield (Y_{max}) and in 2007 minimal (Y_{min}). Temperature and moisture support of spring barley was analyzed during the growing season (sowing-harvest) and non-growing season in particular years.

RESULTS AND DISCUSSIONS

Achieving a high grain yield of spring barley is influenced by many factors. One of them is the weather. During the growing period barley is subjected to stressor effects of drought or low temperature. Several authors stated significant impact of the year on spring barley grain yield (VIDOVIČ and ŽÁK, 2001; MACÁK et al., 2004; KOVÁČ et al., 2006) and its qualitative parameters, especially grain and malt quality (MACÁK et al., 2009; JURESCU and PIRSAN, 2010).

Criterion for assessing the effect of basic agro-climatic conditions (temperature, water, etc.) during the crops vegetation in the system: solar energy → energy of plant communities is the value of internal energy (ΔU), which represents the amount of cellular energy that keeps the progress of transformation processes (KUDRNA, 1985).

The influence of temperature and moisture conditions on spring barley crop was evaluated for the period 2005-2007. In 2005 it was gained maximal yield (Y_{max}) and in 2007 minimal (Y_{min}). The onset of particular growth stages as well as temperature and moisture conditions during spring barley growth stage in years Y_{max} and Y_{min} are listed in Table 1.

Table 1

Thermal and moisture conditions in growth phases of spring barley in years Y_{max} and Y_{min}

Stage (interval)	Y_{max} (2005) 7.34 t ha^{-1}			Y_{min} (2007) 4.76 t ha^{-1}	
	average daily temperature °C	∑ precipit. mm		average daily temperature °C	∑ precipit. mm
Non-vegetation (October – 15 March)	2.18	208.3	Non-vegetation (October-1 April)	6.63	204.7
Sowing - seedling (16 March. - 11 April)	8.16	18.2	Sowing - seedling (2 April – 26 April)	12.0	0.0
Shooting (12 April - 9 May)	12.3	91.2	Shooting (27 April – 11 May)	14.1	30.2
Stalk (10 May - 23 May)	13.5	28.3	Stalk (12 May – 8 June)	18.5	84.6
Ear – wax maturity (24 May - 26 June)	18.2	32.3	Ear – wax maturity (9 June – 14 July)	20.7	54.3
Full maturity - harvest (27 June - 17 July)	19.4	41.9	Full maturity - harvest (15 July – 24 July)	27.1	8.2
Vegetation	14.3	211.9	Vegetation	18.4	177.3

In 2005, spring barley was sown in mid-March and overall growing season lasted 125 days. Compared to that, in 2007 sowing of barley began in April and vegetation lasted only 94 days. Especially in 2007, barley crop was during the growing period under stress factors, particularly the lack of moisture and elevated temperature. Mainly April was very critical, after sowing did not rain for several days, and barley plants had only 30.2 mm available water during shooting stage. In Table 2 the ideal water and temperature needs for each month of barley growing season, as well as the normal values (multi annual averages in years 1961-1990) are referred.

Table 2

Data for ΔU (change of total internal energy) calculation of spring barley

Month	Normal (1961-1990)		Ideal		Y_{max} (2005)		Y_{min} (2007)	
	∑p mm	x dt °C	∑p mm	x dt °C	∑p mm	x dt °C	∑p mm	x dt °C
March	30	5.0	35	6	2.3	6.8	-	-
April	39	10.4	50	8	78.7	11.0	0.0	12.2
May	58	15.1	60	13	60.9	15.2	106.7	16.6
June	66	18.0	70	16	31.5	18.0	36.0	21.1
July	52	19.8	45	18	38.5	20.7	27.6	22.7
∑p mm	215	-	225	-	211.9	-	170.3	-
x dt °C	-	15.8	-	14	-	14.3	-	18.1
∑ dt °C	-	63.3	-	55	-	71.7	-	72.6

The critical period for cereals water needs is mid-May to mid June (LORENČÍK and DŽUGAN, 1993). LÍŠKA et al. (1994) stated that spring barley has increased water demands during plant emergence and during stalk and ear stages, which in Slovakia falls on May. Beside sufficient moisture, also temperature is important. This is evidenced by the results of our experiment. In 2007, with a minimum yield (Y_{min}), barley vegetation was lack for 54.7 mm of water compared to the ideal need, and 45.7 mm compared to long-term average. In addition, the temperature was higher by 4.1 °C compared to ideal and 2.3 °C compared to long-term average. The high temperature in April expressed by positive value ΔU (0.71) acted negatively in the following period, although May was wet, what reflects negative (-1.70) ΔU value (Table 3). Compared to normal, the moisture deficit widened and temperature increased in June and July.

Table 3

Changes of internal energy ΔU for spring barley

Month	Y_{max} (2005)			Y_{min} (2007)		
	Y_t	Y_{hs}	ΔU	Y_t	Y_{hs}	ΔU
March	0.75	0.08	0.67	-	-	-
April	1.21	2.94	-1.73	0.71	0.00	0.71
May	1.68	2.27	-0.59	0.97	2.67	-1.70
June	1.99	1.17	0.82	1.24	0.90	0.34
July	2.29	1.44	0.85	1.33	0.69	0.64

The temperature and moisture approximated to the ideal values in year 2005 when maximal spring barley yield was gained. Negative ΔU values in April (-1.73) and May (-0.59) maintained a positive impact on crop production, although in June and July the values were positive. The temperature during growing season (14.3 °C) was nearly identical to the ideal one (14 °C), what had positive effect on barley grain yield.

SLEZIAK et al. (2000) stated that appropriate moisture during the spring barley growing season is from 255 to 285 mm. These values were nearly reached only in year 2005 (211.9 mm). Compared to that, barley had only 170.3 mm of available water during the growing season in the year 2007.

Key factors of spring barley production stability and quality were defined as follows: weather, nitrogen fertilization and forecrops (VIDOVIČ, 2001; HUNKOVÁ et al., 2008). At our experiment, spring barley was sown after sugar beet, which is considered as a good forecrop. Beside the temperature and moisture, barley grain yield was also influenced by treatments of fertilization (Table 4). In 2005, the highest yield was achieved after nitrate application at the beginning of shooting stage at the doses calculated for grain yield 5 t ha^{-1} (at BBCH 21). In 2007, barley crop better responded to application of liquid fertilizer DAM 390 at the end of shooting stage (BBCH 29), at a dose of nitrogen calculated on the estimated grain yield of 5 t ha^{-1}. The lowest spring barley grain yields were in treatments without fertilization. Similar results were determined also in other varieties and treatments of spring barley fertilization (CANDRÁKOVÁ, 2008; CANDRÁKOVÁ et al., 2009). Grain yields for three years of spring barley cultivation are shown in Fig. 1.

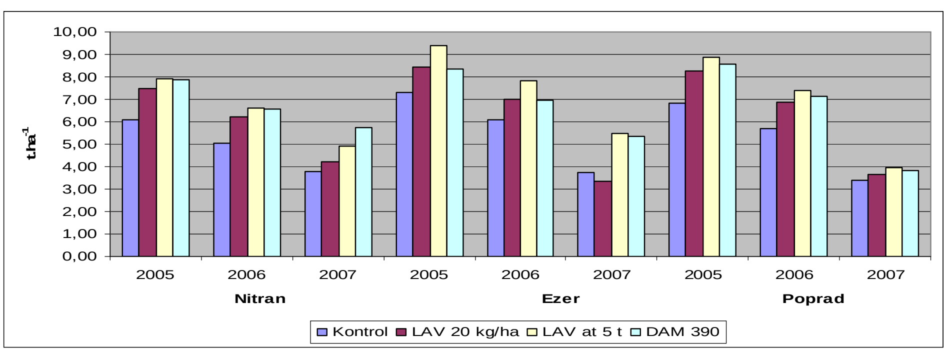

Figure 1: Grain yield of spring barley varieties Nitran, Ezer and Poprad in years 2005-2007

Table 4

Yields of spring barley in years Y_{max} and Y_{min}

Y			$Y_{max} - Y_{min}$ (t.ha^{-1})	Variants fertilization - Y (t.ha^{-1})			
	year	(t.ha^{-1})		K	LAV 1	LAV 2	DAM
Y_{max}	2005	7.94	3.66	6.73	8.04	8.73	8.25
Y_{min}	2007	4.28		3.63	3.72	4.77	4.98
$Y_{average}$		6.11		5.18	5.88	6.75	6.61

Table 5

Analysis of Variance for yield - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
MAIN EFFECTS					
A: year	247.836	2	123.918	2519.40	0.0000
B: variety	5.92918	2	2.96459	60.27	0.0000
C: fertilization	41.2533	3	13.7511	279.58	0.0000
D: replications	0.0213574	2	0.0106787	0.22	0.8054
INTERACTIONS					
AB	11.8136	4	2.9534	60.05	0.0000
AC	5.42545	6	0.904241	18.38	0.0000
AD	0.00301481	4	0.000753704	0.02	0.9995
BC	3.27724	6	0.546206	11.11	0.0000
BD	0.00843704	4	0.00210926	0.04	0.9964
CD	0.0057463	6	0.000957716	0.02	1.0000
RESIDUAL	3.34461	68	0.0491855		
TOTAL (corrected)	318.918	107			

All studied factors influenced statistically highly significantly and significantly grain yield of spring barley (Table 5). The highest yield was reached in year 2005 (7.94 t ha^{-1}) and Poprad variety was identified as the most productive (6.59 t ha^{-1}). Among fertilization treatments, the highest spring barley yield was highly significantly reached after application of liquid fertilizer DAM 390 at the end of shooting stage.

CONCLUSIONS

Results of three years experiment (2005-2007) examining three spring barley varieties of domestic Slovak breeding (Nitran, Ezer, Poprad), and different nitrogen fertilization during the growing season showed a statistically significant influence of examined factors. Grain yield was highly significantly influenced by harvest year, variety and fertilization. High difference of grain yields (3.66 t ha^{-1}) between the highest grain yield (Y_{max} 7.94 t ha^{-1}) in 2005 and the lowest one (Y_{min} 4.27 t ha^{-1}) in 2007 was due to lack of moisture and elevated air temperature during barley shooting and grain formation stages. Fertilization by solid and liquid forms of nitrogen promoted increasing of grain yield, but the effect of year was stronger.

Acknowledgements

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