ACTA HYDROLOGICA
SLOVACA

Ročník 17, č. 2, 2016, 260 – 264

WATER AVAILABILITY AND PROTEIN FORMATION INTERRELATIONS

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Agronomic and environmental impacts were studied in a field experiment to determine water availability and protein formation interrelations. Five winter wheat varieties and six nitrogen application levels were applied in two crop years representing different precipitation and temperature patterns to evaluate yield, yield components and quality manifestation. The results obtained suggest, that precipitation patterns in relation with the wheat development phenophases had profound influence on the protein formation of wheat crop. Varietal differences were determined regarding yield, protein values in relation with plant nutrition and crop year impacts.

KEY WORDS: precipitation, temperature, wheat, protein, crop year

VZÁJOMNÉ VZŤAHY MEDZI PRÍSTUPNOSŤOU VODY A TVORBOU PROTEÍNOV. V práci boli študované agronomické a environmentálne vplyvy na stanovenie vzájomných vzťahov medzi prístupnosťou vody a tvorbou proteínov v poľnom experimente. V dvoch rokoch reprezentujúcich rôzne zrážkové a teplotné pomery bolo zasiatych päť odrôd ozimnej pšenice a použitých šesť úrovní aplikačných dávok dusíka. Potom sa vyhodnotili úrody, ich zložky a kvalita. Získané výsledky naznačujú, že rozloženie zrážok v súvislosti s vývinom fenofáz pšenice, malo veľký vplyv na tvorbu proteínov v pšenici. Rozdiely v odrodách pšenice boli vyhodnotené podľa úrody, podľa obsahu proteínov v závislosti od obsahu živín v pôde a klimatických podmienok daného roka.

KĽÚČOVÉ SLOVÁ: zrážky, teplota, pšenica, proteín, hospodársky rok

Introduction

Grain yield and yield quality of winter wheat *Triticum aestivum* L. is highly influenced by the meteorological conditions of the given crop year, especially the amount and distribution of precipitation and the actual temperature (Grimwade et al 1996, Győri 2008, Pepó 2010). Weather conditions are evaluated and labelled favourable or non-favourable in relation with the optimum requirements of the crops' phenophases (Lásztity 1999; Ványiné and Nagy 2012). Concerning precipitation, the most vulnerable periods during growth and development of winter wheat are the phenophases of heading and flowering (Feekes 10–10,5; Zadoks 51–70). In relation with temperature, two critical periods can be detected. One is the vernalisation, and the other is the ripening stage (Feekes 1–2 and 11; Zadoks 10–13 and 71–99), (Pollhamer 1981, Kismányoky and Ragasits 2003).

Crop yield and grain quality can also be influenced by agronomic applications. Plant nutrition in general and N topdressing in particular should be considered as the most effective treatments within the technologies of winter wheat production. The amount of nitrogen and the timing and distribution of the application have an impact on wheat quality, especially on the protein production of the crop (Győri 2006. Pepó 2010, Vida et al 1996).

Material and methods

A wide range of high milling and baking quality winter wheat *Triticum aestivum* L. varieties were examined under identical agronomic conditions in a long term field trial. The small plot trials were run at the Nagygombos experimental field of the Szent István University, Crop Production Institute, Hungary. Soil type of

the experimental field is chernozem (calciustoll). Annual precipitation of the experimental site belongs to the 550–600 mm belt of the Northern edges of the Hungarian Great Plain. Experiments were conducted in a split-plot design with four replications. The size of each plot was 10 m^2. Plots were sown and harvested by plot machines (standard Wintersteiger cereal specific experimental plot machinery series). Various identical agronomic treatments were applied to plots. Plant nutrition applications were done in single and combined treatments. N topdressing variants were applied by single and repeated topdressings representing 6 levels: 0, 80, 80 + 40, 120, 120 + 40 and 160 kg·ha^{-1} N in single and split applications. All plots were sown with identical series of wheat varieties for studying their performance in relation with agronomic impacts. The recent study presents the performance and evaluations of six winter wheat varieties (Alföld-90, Mv Magdaléna, Mv Suba, Mv Toborzó and Mv Toldi) of the 2013 and 2014 crop years. Wheat grain quality parameters: protein, and wet gluten contents were determined from grain samples, as well as quality characteristics at the Research Laboratory of the SIU Crop Production Institute, and RET Regional Knowledge Centre laboratories according to Hungarian and EU standards (MSZ 1998; EK 2000). The protein figures were correlated with the treatments applied, and analyses were done by Microsoft Office 2003 statistical programmes (Horváth, 2014). Figure 1 demonstrates the phenophases of winter wheat by the grading of two internationally used systems. Phenological phases have been evaluated in accordance with the monthly precipitation and temperature figures of the respective crop years by the methods of Pollhamer (1981) and Kismányoky and Ragasits (2003).

Tables 1 and 2 provide information on the deviation regarding monthly values of temperature and precipitation in favourable and non-favourable crop years during the vegetation period.

The monthly periods are labelled in the tables in accordance with the magnitude of deviation in relation with the long term mean temperature and precipitation values. A plus or minus 20 % of precipitation and 1 ^{o}C of temperature were applied as threshold values.

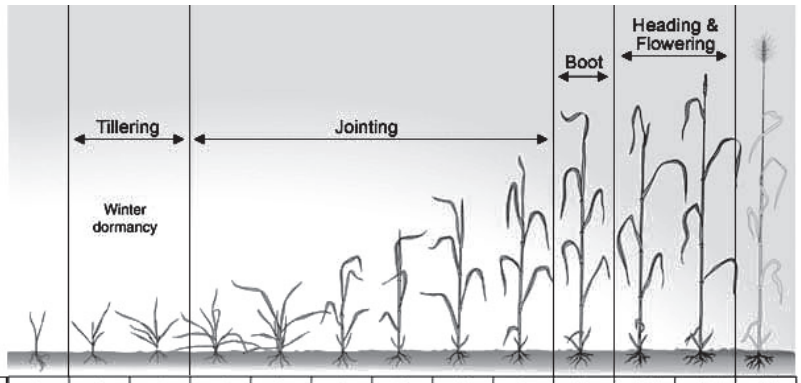
Results and discussion

The results of the trial are summarized in Figure 2 and 3. The total amount of protein yield (kg·ha^{-1}) is indicated for the two respective crops years by all the wheat varieties examined. The results obtained highlight three factors. The first of them is the difference between the amounts of protein yield. In 2013 the range of total amount of protein was between 412 and 1187 kg·ha^{-1}. In 2014, a non favourable crop year resulted in 513 and 988 kg·ha^{-1} protein yield values.

The second is the consequent differences between the impacts of N application levels. These differences were significantly bigger in the favourable crop year in comparison with those of the non-favourable vintage. The reason of such deviation was due to the amount of precipitation during the phenophases of flowering and grain filling of the respective crop years.

The third factor detected was the performance of varieties. From among the five varieties examined three cultivars – Mv Suba, Mv Toborzó and Mv Toldi proved to be the most efficient regarding the amount of total protein yield production. The highest protein yields were obtained by Mv Toborzó in 2013, while in 2014 the Mv Toldi cultivar produced superior figures.

Tables 3 and 4 present correlation figures of experimental variants for both crop years. For better understanding, the tables show data on further interrelations not discussed in this paper, but which may provide information on the protein formation performance. These are the following apart from protein values: grain yield, hectolitre weight, thousand grain weight, gluten and Zeleny figures.



Feekes	1	2	3	4	5	6	7	8	9	10	10.1	10.5	11
Zadoks	10	21	26	30	30	31	32	37	39	45	50	60	90

Fig. 1. Growth stages of winter wheat – Feekes and Zadoks values (Source Kismányoky and Ragasits, 2003).

Obr. 1. Rastové fázy ozimnej pšenice – hodnoty podľa Feekesa a Zadoksa (Zdroj Kismányoky a Ragasits, 2003).

Table 1. Precipitation and temperature patterns of the phenologically favourable crop year
Table 1. Zrážkové a teplotné pomery periodicky priaznivého hospodárskeho roka

	2012						2013					
	Autumn			Winter			Spring			Summer		
Month	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII
Mean temperature	18-19	11-12	7-8	-1,5 - (-2)	-0,5-(-1)	+2-(+3)	3-4	12-13	16-17	20-21	**22-23**	22-23
Precipitation	50-55	60-70	15-20	50-55	55-70	70-80	90-100	25-30	90-100	100-120	5-10	80-90

Table 2. Precipitation and temperature patterns of the phenologically non-favourable crop year
Table 2. Zrážkové a teplotné pomery periodicky nepriaznivého hospodárskeho roka

	2013				2014							
	Autumn			Winter			Spring			Summer		
Month	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII
Mean temperature	14-15	12-13	7-8	+1-(+2)	+2-(+3)	+4-(+5)	9-10	12-13	15-16	19-20	**22-23**	19-20
Precipitation	25-30	35-40	60-70	5-10	40-45	60-65	5-10	30-35	90-95	30-35	85-90	80-90

Legend
The period is within the range of the long term mean values
A period with minimum 20 % higher precipitation, or 1°C lower temperature
A period with minimum 20 % less precipitation, or 1°C higher temperature

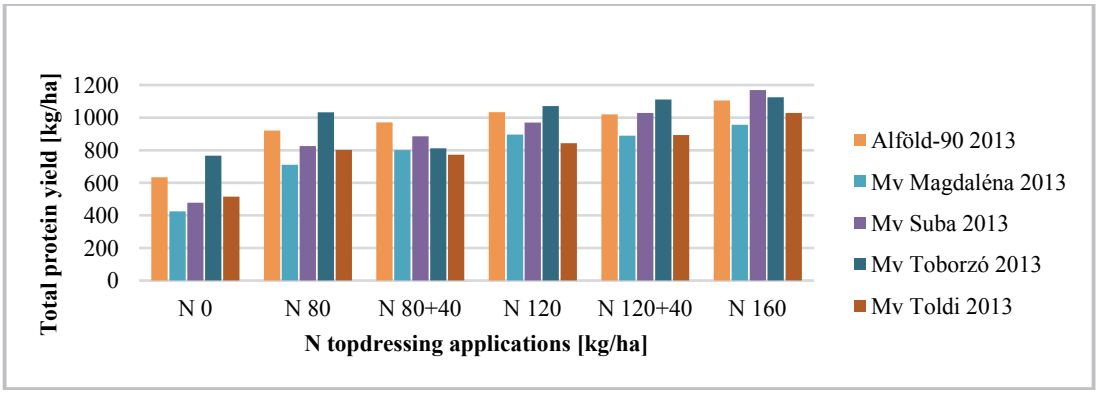


Fig. 2. Total protein yields in ascending N applications in favourable crop year (Nagygombos, 2013).
Obr. 2. Celkový obsah proteínov pri rôznych aplikačných dávkach dusíka (N) v klimaticky priaznivom hospodárskom roku (Nagygombos, 2013).

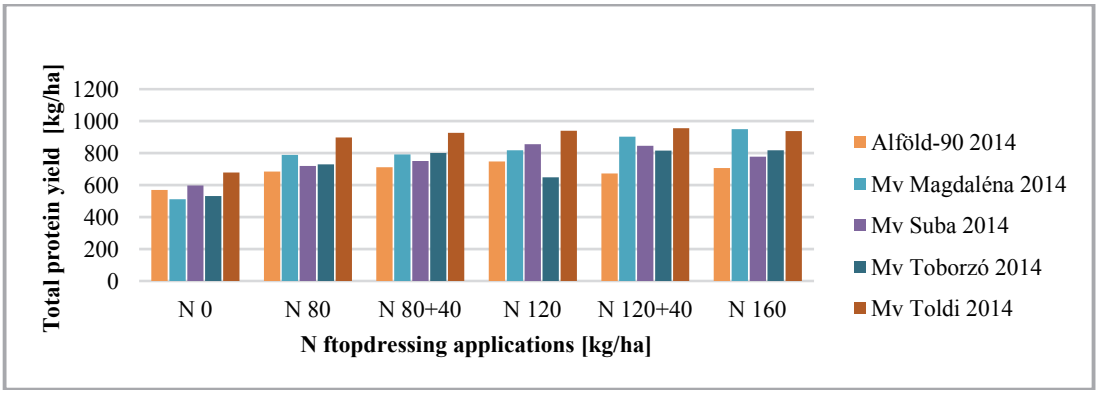


Fig. 3. Total protein yields in ascending N applications in non-favourable crop year (Nagygombos, 2014).
Obr. 3. Celkový obsah proteínov pri rôznych aplikačných dávkach dusíka (N) v klimaticky nepriaznivom hospodárskom roku (Nagygombos, 2014).

Table 3. Correlation between plant nutrition (control vs treatments), yield and protein yield by respective varieties (Nagygombos, 2013)

Tabuľka 3. Korelácia medzi výživou rastlín (kontrola verzus príslušný variant experimentu), celkovou úrodou a obsahom proteínov pre príslušné odrody (Nagygombos, 2013)

Wheat varieties	Yield [t/ha]	Hecto-litre weight [kg/hl]	Thousand grain weight [g]	NIR analysis data			
				Protein content [%]	Total amount of protein [kg·ha^{-1}]	Gluten [%]	Zeleny number [ml]
r (Alföld-90)	0,9837	0,9979	0,5640	0,9962	0,9909	0,9931	0,9806
r (Mv Magdaléna)	0,9883	0,9750	0,9563	0,4003	0,9901	0,2015	0,8071
r (Mv Suba)	0,9936	0,9144	0,9432	0,1305	0,9990	0,1414	0,8023
r (Mv Toborzó)	0,9452	0,7715	0,4595	0,9509	0,9661	0,9220	0,9124
r (Mv Toldi)	0,9802	0,9556	0,7422	0,6782	0,9863	0,6306	0,7531

Table 4. Correlation between plant nutrition (control vs treatments), yield and protein yield by respective varieties (Nagygombos, 2014)

Tabuľka 4. Korelácia medzi výživou rastlín (kontrola verzus príslušný variant experimentu), celkovou úrodou a obsahom proteínov pre príslušné odrody (Nagygombos, 2014)

Wheat varieties	Yield [t/ha]	Hecto-litre weight [kg/hl]	Thousand grain weight [g]	NIR analysis data			
				Protein content [%]	Total amount of protein [kg·ha^{-1}]	Gluten [%]	Zeleny number [ml]
r (Alföld-90)	0,4578	0,7055	0,3952	0,9877	0,8826	0,9924	0,9974
r (Mv Magdaléna)	0,9463	0,9174	0,0151	0,9954	0,9828	0,9917	0,9753
r (Mv Suba)	0,5977	0,8952	0,7827	0,9463	0,8592	0,9405	0,9513
r (Mv Toborzó)	0,5716	0,6887	0,8961	0,9536	0,8645	0,9453	0,9662
r (Mv Toldi)	0,7506	0,7831	0,8343	0,9729	0,9308	0,9757	0,9838

The results obtained suggest that the strongest correlation was detected between the total amount of protein and the experimental treatments, regardless to the impact of crop years' weather in accordance with the findings of Győri (2008) and Pepó (2010). Yield figures of the cultivars were in close correlation with plant nutrition with a few exceptions only. However this correlation proved to be stronger and at the same time more balanced in the favourable crop year. The correlations of crop yield components were much weaker in both crop years in comparison with those of yield and protein values. The most vulnerable phenological periods of winter wheat were the stages of heading and flowering in relation with precipitation and vernalisation and ripening concerning temperature performance in accordance with the results of Pollhamer (1981) and that of Kismányoky and Ragasits (2003).

Conclusion

Impacts of precipitation and temperature were studied in a long term field experiment to determine water availability and protein formation interrelations. The aim of the study was to evaluate favourable and non-favourable crop year conditions for winter wheat *Triticum aestivum* L. Five winter wheat varieties and six nitrogen topdressing application levels were applied in two consecutive crop years representing different precipitation and temperature patterns to evaluate yield, yield components and quality manifestation. The results of the experiment suggest that precipitation patterns in relation with the wheat development phenophases had profound influence on the protein formation of the crop. From among phenophases flowering and grain filling periods proved to be the most influential stages. The two crop years resulted in different amounts of protein yield. The favourable one significantly increased the total amount of protein in comparison with that of the non-favourable vintage. There were detectable differences in the protein yield of the wheat varieties studied. However the efficiency of the respective varieties also differed in the two crop years. Strong correlation was detected between the total amount of protein and the experimental treatments in both years. Yield figures of the wheat varieties were in close correlation with plant nutrition in general. Correlations of crop yield components were lower in both crop years in comparison with those of yield and protein values.

Acknowledgement

This paper presents research results gained from a long term trial supported by TÁMOP and VKSZ funds of the Government of Hungary.

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VZÁJOMNÉ VZŤAHY MEDZI PRÍSTUPNOSŤOU VODY A TVORBOU PROTEÍNOV

V práci boli študované agronomické a environmentálne vplyvy na stanovenie vzájomných vzťahov medzi prístuponosťou vody a tvorbou proteínov v poľnom experimente. Cieľom štúdie bolo zhodnotiť podmienky klimaticky priaznivého a nepriaznivého hospodárskeho roka pre ozimnú pšenicu (*Triticum aestivum* L.). V dvoch hospodárskych rokoch bolo zasiatych päť odrôd ozimnej pšenice a použitých šesť úrovní aplikačných dávok dusíka. Každý rok bol reprezentovaný rôznymi zrážkovými a teplotnými pomermi. Vyhodnocovali sa úrody, ich zložky a kvalita.

Výsledky experimentu ukazali, že zrážkové pomery v súvislosti s vývojovými fenofázami pšenice mali silný vplyv na tvorbu proteínov v plodine. Ukázalo sa, že najviac ovplyvnené fenofázy boli medzi obdobiami kvitnutia a plnenia zŕn. V dvoch po sebe nasledujúcich rokoch boli dosiahnuté rôzne obsahy proteínov v plodinách. V klimaticky priaznivom hospodárskom roku významne stúplo celkové množstvo proteínov v porovnaní s klimaticky nepriaznivým hospodárskym rokom. Tiež boli zistené rozdiely v obsahu proteínov pre rôzne odrody pšenice. Avšak výkonnosť príslušných druhov pšenice sa tiež líšila medzi klimaticky priaznivým a nepriaznivým hospodárskym rokom.

V oboch rokoch bola zistená silná korelácia medzi celkovým množstvom proteínov a variantmi experimentu. Všeobecne boli úrody rôznych odrôd pšenice v úzkej korelácii s výživou plodín. Korelácia mezi kvalitou úrody plodín bola nížšia ako medzi úrodou a obsahom proteínov v oboch rokoch.

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