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INFLUENCE OF FERTILIZER AND CULTIVAR ON THE GLUTEN QUALITY OF WINTER WHEAT

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Abstract

During our experiments in 2017/2018 crop year at Látókép Experimental Farm of University of Debrecen, we examined the effect of different cultivars and increased dosages of artificial fertilizer (control, $N_{90}PK$, $N_{150}PK$) on quality of wheat gluten. The gluten quality parameters of winter wheat were significantly influenced by fertilizing and cultivar. $N_{90}PK$ dosage improved significantly the measured parameters, further fertilizer application had no statistically provable effect. Application of artificial fertilizers increased significantly the gluten spread of the samples, compared to the control ones. KG Kunhalom had significantly higher crude protein (CP), wet gluten (WGC), dry gluten, gluten ratio and Zeleny index (ZI) parameters, this means that KG Kunhalom had the best protein and gluten quality potential. Also only KG Kunhalom with $N_{150}PK$ fertilizing treatment complied with the Hungarian premium class. According to Hungarian standard, samples with control treatment and Hybiza with any fertilizing treatment were unfit to bakery use. Using Pearson's correlation analysis results, CP and ZI were in tight positive; WGC was in medium positive, while gluten index was in loose negative correlation with fertilizing. In the case of growing wheat for baking use, there is a need to put great emphasis on selecting the right cultivar and agrotechnology practices.

Key words: winter wheat, cultivar, fertilizing, gluten quality, crude protein

INTRODUCTION

Wheat flour plays a very important role in our daily diet, which is the basic material of many industries (Ragasits, 1998). The quality parameters of wheat can be affected by many agrotechnical factors (Erdei, Szániel, 1975). Considering these factors, one of the most important is proper nutritional supply, which can be achieved by artificial fertilizing (Győri, Győriné, 1998). The usage of artificial fertilizers is influenced by nutrient reactionary properties of the cultivated wheat genotype (Pepó, 2011), as a result the basic condition of economical wheat production is the selection of the proper genotype (Ágoston, Pepó, 2005). According to Borghi et al., 1995, nitrogen fertilizer has a decisive influence on the baking quality of wheat. Above a certain threshold, increasing fertilizer dosage does not improve statistically yield and quality of winter wheat. This threshold was 180 kg ha^{-1} N in Walsh et al., 2018 and 168 kg ha^{-1} N in Shi et al., 2007 researches. The recommended optimal N fertilizer dosage is between 120-150 kg ha^{-1} (Asthir et al., 2017; Horváth et al., 2014, Montemurro et al.,

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2007) to realize yield and quality potential of the genotype, to avoid nitrogen leaching out and plant lodging.

Nitrogen fertilizing can affect significantly the ratio and the amount of gluten proteins (Wieser, Seilmeier, 1998), therefore the baking test volume and the gluten spreading (GS) as well (Pollhamer, 1973). The cultivar properties had medium significant effect on wet gluten content (WGC), Zeleny index (ZI), crude protein (CP) and gluten index (GI) (Lukow, McVetty, 1991; Masauskiene, Ceseviciene, 2005). In the 4-year experiment of Pepó, 2002, when 120 kg ha-1 N was given the WGC of GK Öthalom increased with average 5% comparing to the control ones. Fertilizer dosage was in medium correlation with gluten spread, tight positive correlation with crude protein and wet gluten content (Masauskiene, Ceseviciene, 2005; Eser et al., 2017), while Tanács, Gerő, 2003 did not find any relation between fertilizing and gluten spread.

Good quality wheat has above 40 ml Zeleny index, while ZI under 20 ml can result in unsatisfactory product quality (Baltás, 1998). Zeleny index is determined mainly by the effect of genotype (Branlard et al., 2001). Considering the Hungarian wheat standard, premium wheat flour has 14% CP, 34% WGC and 45 ml ZI.

The Glutomatic system is capable of giving information about not only gluten quantity, but quality as well. During this method, the washed gluten is put into a special sieve, then centrifuged. The percentage of wet gluten, that remains on the sieve is giving the gluten index. Gluten index (GI) above 90 refers to strong gluten, while GI under 30 refers to weak quality (Preston, Williams, 2003). According to Hlisnikovsky et al., 2014, elite class wheat has 25-27% WGC and 80-90 GI (Table 1).

Table 1

Some quality parameters of Czech national standard for wheat (Hlisnikovsky et al., 2014) and Hungarian national standard for wheat (MSZ 6368:2017)

	Czech wheat standard			Hungarian wheat standard		
Parameters	Elite class	Quality class	Bread class	Premium	I. class	II. class
Crude protein	12.6	11.8	11	14	12.5	11.5
Zeleny index	49	35	21	45	35	30
Wet gluten	25-27	23-25	20-23	34	30	26
Gluten index	80-90	66-80	41-65	-	-	-

MATERIAL AND METHOD

The experiment was set up at Látókép Experimental Farm of University of Debrecen in the 2017/2018 growing season, which has a

chernozem soil type. The area has medium humus content, medium phosphorus and potassium supply and neutral pH. The forecrop of the experiment was sweet maize. Effect of three fertilizer levels (control, $N_{90}P_{67,5}K_{79,5}$; $N_{150}P_{112,5}K_{132,5}$) was tested in 10 m^2 plots in 4 repetitions. The 50 % of nitrogen and the whole amount of the phosphorus and potassium were applied in autumn, the remaining 50 % of the nitrogen fertilizer was applied in spring as top dressing. Following winter wheat genotypes were tested: GK Öthalom, Mv Ispán, GK Csillag, KG Kunhalom and Hybiza (hybrid genotype).

First the samples were treated by SLN Pfeuffer sample cleaner, then we conditioned them to 15.5 % moisture content, lastly ground into flour with Brabender Quadrumat Senior laboratory mill. Crude protein (Kjeldahl method), wet gluten content (ISO 21415-2:2015), Zeleny index (MSZ EN ISO 5529), dry gluten content (ISO 21415-4:2006), gluten index (ISO 21415-2:2015) parameters were defined at the Institute of Food engineering, University of Szeged, Faculty of Engineering.

For processing the results of the measurements IBM SPSS Statistics 22 program's one- and two-way ANOVA (with Tukey and Bonferroni post-hoc tests, on 0.05 significance level) and Pearson's correlation analysis were performed. According to Tóthné, 2011, there are tight, medium and loose correlations if the correlation coefficient is between 0.75-1, 0.5-0.75 and 0.25-0.5, respectively.

For graphical representation Python 3.7 version's Seaborn 0.9.0 library was used.

RESULTS AND DISCUSSION

Months of the autumn were mild, and gradually cooling down with an abundant amount of rainfall. The mild weather of December and January was also favorable for wheat plants. Due to the cold weather of February and March, the plants were underdeveloped in the beginning of April. It was very hot in April and May, which was unfavorable for the vegetative development of wheat and shortened the phenological stages. In May, the rainfall and the fall in temperature could not compensate the negative effects of the previous period. The summerlike weather of June shortened the grain filling and maturity periods. To summarize, the weather of the 2017/2018 growing season was unfavorable for the vegetative and generative development of wheat plants.

According to our results, fertilizing and cultivar had significant effect on gluten quality parameters (Table 2). The main parameters varied between 7.9-14.4 (crude protein); 16.7-34.8 (wet gluten) and 20.4-45.2 (Zeleny index).

Gluten index was affected significantly by both cultivar and fertilizing. Considering $N_{90}PK$ treatment, GI was decreased significantly compared to control samples. GK Öthalom (98.7-81.2) and Hybiza (96.1-93.2) had the highest gluten index. According to Preston, Williams, 2003, these two genotypes had strong gluten, and belonged to the 'Elite class (80-90), 1st class in Czech standard'. Meanwhile Mv Ispán (83.5-66.3) belonged to the "Quality class (66-80), 2nd class in Czech standard". KG Kunhalom (56.9-43.2) and GK Csillag (65.7-36.1) belonged to the 'Bread class (41-65), 3rd class in Czech standard' (Hlisnikovsky et al., 2014). Genotypes in different quality classes differed significantly. The results of Hybiza were pretty interesting, because this hybrid genotype was unfit to bakery use with any fertilizing treatment (Hungarian wheat standard), but its GI was one of the best, which means it had a very strong gluten.

Wet and dry gluten contents were significantly affected by $N_{90}PK$ fertilizing treatment. Cultivar had also significant effect. KG Kunhalom had significantly higher, while Hybiza had significantly lower WGC and DGC results compared to the other genotypes.

Table 2

Effect of different cultivars and fertilizing treatments on the gluten quality parameters, (Debrecen, Hungary, 2018)

Cultivar	Treatment	GI	WGC	DGC	GR	GS	ZI	CP
GK Öthalom	Control	98.7	16.7	5.9	2.8	0.4	20.4	8.8
	$N_{90}PK$	87.0	25.2	8.9	2.8	1.0	32.4	12.0
	$N_{150}PK$	81.2	28.3	9.6	3.0	0.8	36.7	13.1
Mv Ispán	Control	83.5	20.7	7.1	2.9	1.4	25.9	9.6
	$N_{90}PK$	69.4	27.1	9.3	2.9	1.5	35.1	12.0
	$N_{150}PK$	66.3	28.8	9.9	2.9	1.1	38.2	12.8
GK Csillag	Control	65.7	20.7	7.1	2.9	2.4	23.7	9.7
	$N_{90}PK$	35.8	29.7	10.1	2.9	5.3	34.9	12.8
	$N_{150}PK$	36.1	31.8	10.8	3.0	5.8	35.8	13.5
KG Kunhalom	Control	56.9	24.3	8.3	2.9	3.6	32.6	10.7
	$N_{90}PK$	44.3	34.0	11.5	3.0	4.2	42.5	13.8
	$N_{150}PK$	43.1	34.8	11.7	3.0	4.9	45.2	14.4
Hybiza	Control	96.1	16.8	5.7	2.9	0.4	23.8	7.9
	$N_{90}PK$	95.4	22.0	7.6	2.9	0.8	33.0	10.1
	$N_{150}PK$	93.2	23.2	7.9	2.9	0.8	35.1	10.5

Abbreviations: GI= gluten index, WGC= wet gluten content, DGC= dry gluten content, GR= gluten ratio, GS= gluten spreading, ZI= Zeleny index, CP= crude protein

Gluten ratio was not affected by fertilizer dosages. The GR results of KG Kunhalom were significantly higher than GK Öthalom.

Fertilizing, cultivar and the interaction of them had significant effect on gluten spread. Application of artificial fertilizers increased significantly the gluten spread of the samples, which result correlates well with Pollhamer, 1973. Studying the GS results two groups can be made: 1) GK Öthalom, Hybiza and Mv Ispán (0.4-1.5); 2) KG Kunhalom and GK Csillag (2.4-5.8). The GS results differed significantly between the two groups.

Zeleny index and crude protein were increased significantly by $N_{90}PK$ fertilizing dosage, further fertilizer application did not have statistical effect. The ZI and CP results of KG Kunhalom were significantly higher than the other genotypes. Mv Ispán had higher ZI compared to Hybiza and GK Öthalom. Hybiza had significantly lower CP than the other 4 cultivars. The following statements proved that the Zeleny index is determined mainly by the effect of genotype, the findings of Branlard et al., 2001.

There was only one sample (KG Kunhalom, N150PK), that met the parameters of premium class (Hungarian standard), moreover GK Csillag ($N_{150}PK$) and KG Kunhalom ($N_{90}PK$) complied with the 1st class, till then Mv Ispán ($N_{90}PK$, $N_{150}PK$) and GK Öthalom ($N_{150}PK$) complied with 2nd class (Hungarian standard) (Fig. 1). According to Hungarian wheat standard, samples with control treatment and Hybiza with any fertilizing treatment were unfit to bakery use.

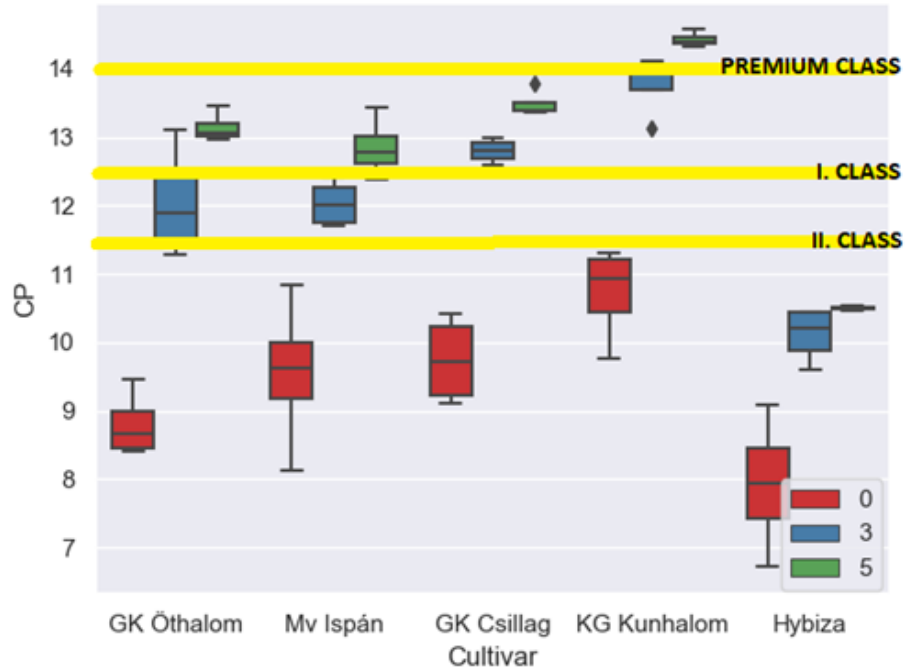

Fig. 1. Crude protein in the case of 3 treatments (0=control, 3=$N_{90}PK$, 5=$N_{150}PK$) (Debrecen, Hungary, 2018)

These results suggest that, the optimal fertilizing dosage is $N_{90}PK$, application of more fertilizer also improves the parameters, but it is not statistically provable. If we take all information into account by Asthir et al., 2017; Horváth et al., 2014; Montemurro et al., 2007, we can see that in our research the recommended fertilizer dosage is lower. Presumably this was influenced by the year, cultivar and forecrop improving effect. In our research sweet maize was the forecrop, which does not exploit the nutrient and water supplies of the soil, and creates favorable condition for winter wheat.

Using Pearson's correlation analysis results (Table 3), we can state that CP (0.753**) and ZI (0.783**) were in tight positive; WGC (0.714**) and DGC (0.716**) were in medium positive, while GI (- 0.298*) was in loose negative correlation with fertilizing. This finding proved the statement of Masauskiene, Ceseviciene, 2005. WGC (0.971**), DGC (0.977**) and ZI (0.902**) were in tight positive; GS (0.553**) was in medium positive; GI (-0.680**) was in medium negative correlation with crude protein content. GS (- 0.917**) and WGC (- 0.759**) were in tight negative correlation with gluten index. Gluten spread did not correlate with fertilizing, so we confirmed the results of Tanács, Gerő, 2003.

Table 3

Correlation analysis between gluten quality parameters (Debrecen, Hungary, 2018)

	Fertilizing	GI	WGC	DGC	GR	GS	ZI	CP
Fertilizing	1							
GI	-.298*	1						
WGC	.714**	-.759**	1					
DGC	.716**	-.740**	.995**	1				
GR	.207	-.382**	.329*	.230	1			
GS	.220	-.917**	.645**	.621**	.383**	1		
ZI	.783**	-.549**	.922**	.916**	.325*	.444**	1	
CP	.753**	-.680**	.971**	.977**	.223	.553**	.902**	1

Abbreviations: GI= gluten index, WGC= wet gluten content, DGC= dry gluten content, GR= gluten ratio, GS= gluten spreading, ZI= Zeleny index, CP= crude protein

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

CONCLUSIONS

Summarizing our results, the gluten quality parameters of winter wheat were significantly influenced by fertilizing and cultivars. On the basis of our measurements, $N_{90}PK$ dosage improved significantly the measured

parameters, further fertilizer application had also improver effect, but this was not statistically provable. If we take all information into account by Asthir et al., 2017, Horváth et al., 2014, Montemurro et al., 2007, in our research the recommended fertilizer dosage was less than the amount they recommended (120-150 N kg ha-1). Presumably this was because of the year, cultivar and forecrop improving effect. Application of artificial fertilizers increased significantly the gluten spread. GK Öthalom and Hybiza had the highest gluten index (belonged to the Elite class in Czech standard). The results of Hybiza were pretty interesting, because this hybrid genotype was unfit to bakery use with any fertilizing treatment (Hungarian wheat standard), but its gluten index was one of the best, which means it had a very strong gluten.

Using Pearson's correlation analysis results, gluten spread did not correlate with fertilizing, so we confirmed the results of Tanács, Gerő, 2003. CP and ZI were in tight positive; WGC was in medium positive, while GI was in loose negative correlation with fertilizing. Gluten index was in medium negative correlation with crude protein content.

In the year of 2018 with sweet maize as forecrop, KG Kunhalom had significantly higher CP, WGC, DGC, GR and ZI parameters, this means that KG Kunhalom had the best protein and gluten quality potential. Also only KG Kunhalom with $N_{150}PK$ fertilizing treatment complied with the Hungarian premium class. According to Hungarian wheat standard, samples with control treatment and Hybiza with any fertilizing treatment were unfit to bakery use.

In the case of growing wheat for baking use, there is a need to put great emphasis on selecting the right cultivar and agrotechnology practices. In the future we will do the measurements in the next season as well, to extend our research with the year effect.

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