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DURUM WHEAT QUALITY AS AFFECTED BY GENOTYPE AND NITROGEN

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Abstract

The quality properties of seven Bulgarian durum wheat genotypes (Progress, Vazhod, Victoria, Predel, Deana, Zvezdica and Elbrus) under influence of nitrogen fertilization (0, 60, 120 and 180 kg.ha^{-1}) during 2011-2013 were studied. The analysis of the results showed that the test weight of grain reached maximum value of 81.38 kg, and 1000 kernel weight - 55.04 g average for a period under the agroecological conditions of Institute of Field Crops – Chirpan, Bulgaria on the soil type Pellic Vertisols. The cultivar Progress has the highest test weight and 1000 grains weight. Average for the studied varieties vitreousness, concentration of protein and wet and dry gluten content in the grain increased respectively to 72.36 %, 15.49 %, 33.37 % and 12.60 % with increasing the nitrogen levels to N_{180}. New varieties Predel and Zvezdica have a tendency to a higher concentration of crude protein and gluten in grain, regardless of the year conditions.

Key words: *durum wheat, variety, nitrogen, quality, vitreousness, crude protein, gluten.*

INTRODUCTION

Durum wheat (*Tr. Durum* Desf.) takes up approximately 8% of the world's wheat production. In the last years Bulgaria has increased its grain growing from this crop and has increased the consumption of durum wheat products. The biology of durum wheat and the need to increase the productivity and quality require application of optimal fertilization rates complied with the region and field specifics. Most research on wheat fertilization refers mainly to common wheat and only a limited number of them are on durum wheat, though not to the present-day most widespread intensive varieties.

The productivity and quality of field crops, including durum wheat, varies to a wide range in dependence of a number of factors: agroecological conditions, genetic potential of the cultivar, crop-rotation, soil fertility, applied fertilization, cultivation technology, etc. (Delchev and Panayotova, 2010; Lalev et al., 2000; Moral, 2003; Panayotova, 1999, 2001; Panayotova and Kostadinova, 2011; Petrova, 2009). Weather conditions in the years and applied fertilizers exert great influence on the grain yield and quality of durum wheat (Abad et al., 2004; Ammes et al., 2003; Koleva-Lizama and Panayotova, 2002; Panayotova and Dechev, 1997). In order to obtain normal durum wheat yield are necessary a number of conditions, which directly or indirectly influence the growth and development in different vegetation periods. The differences between the biological requirements of the plants at a certain stage of their development and the conditions they are grown under, give rise to unfavourable stress situations.

Optimizing the mineral nutrition is one of the most important conventions for a favorable growth, production and quality of the plants, for ensuring their need of nutrient elements, for increasing the soil richness. The fertilization of durum wheat grown after cotton should be complied with the fact that a significant part of the nitrogen for cotton is not utilized by it, but remains in the soil. The two cultures are successfully developed in crop-rotation and when fertilized actively participate in the nutrient utilization (Panayotova, 1999).

A number of studies (Panayotova and Yanev, 2001; Pacucci et al., 2004) establish fertilization efficiency for varieties with different genetic endowments in different soil fertility. Panayotova (2001) appoints a genotype specific in relation with grain yield depending on the nutrition level. It is generally acknowledged that the varieties vary in their responsiveness to nitrogen accumulation in the vegetative parts.

In breeding rarely takes into account the specifics of output forms in terms of mineral nutrition and are predicted possible results. So in recent years, agrochemical assessment of varieties and hybrids are emerging as a component in modern selection (Johnson, 2004; Sylvester-Bradley and Kindred, 2009).

Grain quality is the most important criterion in the breeding of durum wheat to produce high-quality pasta. Experimental data indicate that the new genotypes combine high productivity with good quality. The problems for genetically transmitted and improved grain quality under different varieties of durum wheat are the subject of extensive scientific work (May et al., 2008; Mariani, 1995; Panayotova and Gorbanov, 1999; Panayotova and Valkova, 2010; Rharrabti et al., 2003; Uppal et al., 2002).

Many studies have been conducted to examine the effects of N fertilizers and preceding crops on cereal grain yield. Some authors (Carcea, 2003; Bauer et al., 1987; Kostadinova, 2000) reported that the increasing N rate and rich soil fertility enhanced the content of grain protein and N in the straw. The responsiveness of different cultivars to N accumulated in the vegetative plant parts was established (May et al., 2008; Panayotova, 2010).

The aim of this study was to investigate the influence of nitrogen fertilization on grain quality of new Bulgarian durum wheat varieties.

MATERIALS AND METHODS

The experiment was established in 2011-2013 at the field of the Cotton and Durum Wheat Research Institute, Chirpan, Bulgaria under rainfed conditions. Split-plot randomised design with yield plot 10 m^2 in four replications was used. The cropping pattern is winter durum wheat (*Tr. durum* Desf.) – cotton.

The influence of nitrogen rates 0, 60, 120 and 180 kg/ha on the durum wheat varieties Progress, Vazhod, Victoria, Predel, Deana, Zvezdica and Elbrus were studied. The unfertilized Progress variety was accepted for control.

The nitrogen as ammonium nitrate (34% N) for durum wheat was applied by hand two times: one third - at sowing, and the rest as a top dressing at the end of wheat tillering stage (Feekes stage 4-5).

The seeds were sown on October 25-30, and for each genotype the sowing rate was 450 germinated seeds per m^2. Weeds were controlled between the tillering and shoot elongation stages with herbicides. There were no pathogens and pests above the threshold of harm during the durum wheat vegetation period in the three growing years and chemical spraying was not carried out. The harvest with plot combine occurred on July10-15.

The main quality parameters of grain were studied: test weight (kg/hl) - determined with libra; 1000 kernel weight (g) – by weighting two samples with 500 kernels; total vitreousness (%) - by cutting with pharinotom of Heinsdorf; the content of crude protein - by Kjeldahl standard method after combustion with sulfuric acid and derived according to: Protein, %= N (% DM) x 5.7; and wet and dry gluten (%) - with Gluten washing apparatus and by drying.

Information about the individual effect and interaction between the genotypes and nitrogen fertilization for each studied parameter was obtained by analysis of variance (ANOVA) and LSD test for evaluation of significant differences.

In regard with the meteorological conditions on grain quality unfavorable influence had the high temperatures during the period April to June in the three years and heavy precipitation in May-June in 2012 and 2013. During the winter period are not counted critical negative temperatures and no frostbite of crop.

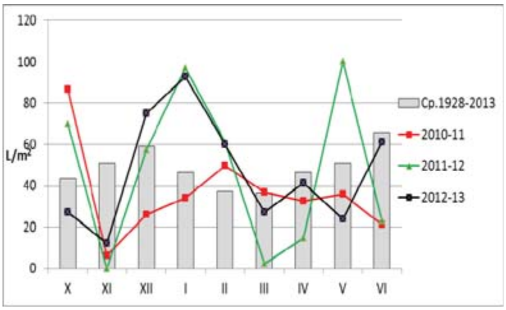

Figure 1. The average air temperatures during the vegetation period of durum wheat, 2011-2013

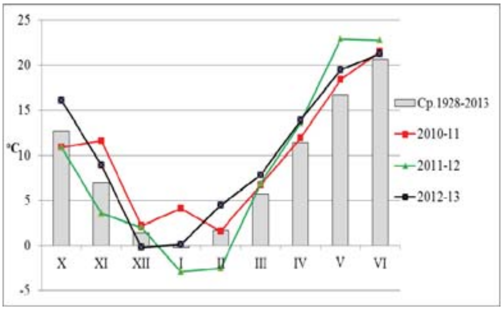

Figure 2. Sum of rainfall during the vegetation of durum wheat, 2011-2013

Soil samples from two replications were collected before durum wheat seeding and after harvest to a depth of 0.40 m. The soil in the field was *Pellic Vertisols* (FAO). It was with high humidity capacity and small water-permeability, defined by the sand-clay composition. The test field was with bulk weight of the plough soil layer - 1.2 g/m^3 and specific gravity - 2.45. The sorbcium capacity was 35-50 mequ/100 g soil. The soil was of slightly acid soil reaction, with total N – average 0.110 %, middle supplied with mineral nitrogen, low supplied with available phosphates and well provided with available potassium (Table 1).

Table 1. Soil properties in 0-40 cm soil layer of *Pellic Vertisols*, Chirpan

Depth (cm)	pH	Mineral N (mg/kg)			P_2O_5 (mg/ 100g)	K_2O (mg/ 100g)
		NH_4-N	NO_3-N	N_{min}		
0-20	6.3	25.80	15.40	41.20	3.2	19.8
20-40	6.5	20.02	10.01	30.03	2.8	17.8

RESULTS AND DISCUSSIONS

The test weight is an indirect classification parameter, normally in direct correlation with flour output, criterion for the health state of durum wheat. The test weight of durum wheat grain in 2011-2013 low depends on genotype and nitrogen level. At different levels of fertilization significant difference was found only in 2013, and the highest test weight was recorded at the rate of N_{180} – 78.66 kg, and it was lowest in N_0 - 77.47 kg. In the previous two years between the values no proven differences and at different levels of nitrogen fertilization were 81.24-81.57 kg in 2011 and 78.43-79.16 kg in 2012 (Table 2). Average values for the period demonstrated tend to increase to N_{120} - 79.66 kg, but differences with the other nitrogen levels were unessential. With the highest value were Progress and Victoria - 80.10 kg and 79.93 kg, and the Deana occurred the lowest test weight - an average of 78.66 kg. The differences were proven in three years. In 2011 the test weight of Progress was highest - 82.45 kg. In 2011, under the influence of favorable combination of temperature and precipitation the test weight had higher values - average 81.38 kg, with 3 and 4% more than in 2012 and 2013. This years were characterized by high temperatures at the end of May and the beginning of June and with lower humidity when formed grain.

The 1000 kernel weight of varieties unsignificant depends on the level of nitrogen fertilization (Table 3). There were no proven differences between the N levels in 2011 and 2012. The greatest weight of 1000 kernel average of the three years was formed at fertilization with N_{60} - 54.34 g, and the smallest in N_{180} - 53.22 g, but the difference between the levels of fertilization was unproven. Significant differences were observed regarding the influence of varieties, such as Progress proven exceeded all other genotypes, reaching a large weight of 1000 grains - 57.29 g, while Deiana is lowest - 51.20 g (with 11.9 % under control Progress). Proven differences between varieties had in each of the examined years. The weight of 1000 grains was greatest in 2012 - 55.04 g under the influence of rainfall in the amount of 100.2 L / m^2 in May and good humidity of wheat in flowering, and it was the lowest in 2013 - 52.33 g due to drought during ear formation-flowering.

The total vitreousness average for the period was low (Table 4). The values increased with increasing nitrogen rates. The vitreousness was highest at the rate of N_{180} - average 72.36% and proven exceed all other nitrogen levels. Positive changes were established in all years of study. Only vitreousness at higher rate N_{180} (72.36% on average) comes close to the quality standard. Vitreousness increased with the amount of nitrogen during the three years. In 2011 the highest value - 72.49% at N_{180} proven exceed other N levels, and the lowest value is at N_0 - 53.37%. No difference between the control and the low level of fertilization N_{60}. In 2012 the vitreousness at N_{180} reached 73.26%

and was higher than all other values, and at N_0 was lowest - 63.14%. Vitreousness was highest in 2012 - 67.88% (by 8 to 17% more than other two years) due to the drought in June. Rainfall during the pouring of grain in 2013 were the main reason for the decreased the grain vitreousness. Cultivar Predel was distinguished by the highest vitreousness - average 66.88%, followed by Progress - 65.37%, and at Vazhod was lowest, but differences between varieties was unsignifican.

Table 2. Test weight for durum wheat genotypes at nitrogen fertilization (kg), 2011-2013

Factors	2011	2012.	2013	Average	
				kg	%
A. Fertilization					
N_0	81.24 ns	79.16 ns	77.47 b	79.29 ns	100.0
N_{60}	81.41	78.88	78.40 ab	79.56	100.3
N_{120}	81.57	78.88	78.54 ab	79.66	100.5
N_{180}	81.27	78.43	78.66 a	79.45	100.2
Б. Genotype					
Progress	82.45 a	78.91 a	78.95 ab	80.10 a	100.0
Vazhod	81.03 bc	79.28 a	77.80 cd	79.37 b	99.1
Victoria	81.58 b	79.14 a	79.08 ab	79.93 a	99.8
Predel	81.18 bc	78.69 a	78.33 bc	79.40 b	99.1
Deana	81.28 b	77.78 b	76.94 d	78.66 c	98.2
Zvezdica	80.63 c	79.03 a	79.40 a	79.68 ab	99.5
Elbrus	81.50 b	79.04 a	77.39 cd	79.31 b	99.0
B. Year	81.38 a	78.84 b	78.27 c	79.49	-

Table 3. Weight of 1000 grains (g) in the durum wheat varieties depending on the nitrogen fertilization

Factors	2011	2012	2013	Average	
				g	%
A. Fertilization					
N_0	53.70 ns	55.35 ns	50.86 b	53.30 ns	100.0
N_{60}	54.30	55.14	53.57 a	54.34	101.9
N_{120}	53.12	54.89	52.41 ab	53.47	100.3
N_{180}	52.41	54.77	52.49 ab	53.22	99.8
Б. Genotype					
Progress	55.76 a	61.55 a	54.56 a	57.29 a	100.0
Vazhod	54.15 ab	54.21 c	53.22 ab	53.86 bc	94.0
Victoria	53.85 b	55.35 c	51.71 ab	53.64 bc	93.6
Predel	51.16 c	52.40 d	50.86 b	51.47 de	89.8
Deana	50.52 c	52.65 d	50.44 b	51.20 e	88.9
Zvezdica	53.51 b	59.15 b	52.06 ab	54.91 b	95.8
Elbrus	54.73 ab	49.95 e	53.50 ab	52.73 cd	92.0
B. Year	53.38 b	55.04 a	52.33 b	53.58	-

Table 4. Vitreousness (%) of durum wheat varieties depending on nitrogen fertilization

Factors	2011 г.	2012 г.	2013 г.	Средно
A.Fertilization				
N_0	53.37 c	63.14 c	42.09 d	52.87 d
N_{60}	57.83 c	66.71 bc	53.14 c	59.23 c
N_{120}	66.80 b	68.40 b	65.09 b	66.76 b
N_{180}	72.49 a	73.26 a	71.34 a	72.36 a
Б. Genotype				
Progress	63.75 ns	70.95 ns	61.40 ns	65.37 ns
Vazhod	57.58	64.60	52.80	58.33
Victoria	66.13	69.05	59.45	64.88
Predel	68.50	70.50	61.65	66.88
Deana	59.68	67.65	54.25	60.53
Zvezdica	63.63	67.75	63.50	64.96
Elbrus	59.10	64.65	52.35	58.70
B. Year	62.62 b	67.88 a	57.91 b	62.80

At growing of durum wheat without fertilization was formed grain with protein content of 12.44%. With increasing fertilization to N_{180} content reached 15.49 % (Table 5). This proved exceed the checks and N_{60} and the requirements of the purchasing organizations and guarantee high biological value of the grain. The difference between N180 and N_{120} was not proven. The data confirmed that nitrogen fertilization is crucial to the concentration of protein in the grain. In each of the years the protein content rising along with the increasing of nitrogen rate.

Table 5. Content of crude protein (%) in the grain of durum wheat varieties depending on nitrogen fertilization

Factors	2011	2012	2013	Average
A.Fertilization				
N_0	12.99 b	11.78 b	12.54 b	12.44 b
N_{60}	13.04 b	12.33 b	12.85 b	12.74 b
N_{120}	15.32 a	14.08 a	14.64 a	14.68 a
N_{180}	16.03 a	14.90 a	15.54 a	15.49 a
Б. Genotype				
Progress	14.32 ns	13.20 ns	13.78 ns	13.77 ns
Vazhod	13.31	12.44	12.97	12.90
Victoria	14.41	13.32	13.91	13.88
Predel	15.31	13.80	14.51	14.54
Deana	13.64	12.78	13.36	13.26
Zvezdica	14.93	14.11	14.71	14.58
Elbrus	14.49	13.26	14.00	13.92
B. Year	14.35 a	13.27 b	13.89 ab	13.84

There were no evidence of differences between the control and the low rate of N_{60}, as well as between N_{120} and high rate of N_{180}. The values of the index were proven higher at N_{120} and N_{180}, compared to N_0 and N_{60} during the whole period of study. In 2011 the protein content of the grain was in the range from 12.99 to 16.03%, in 2012 was 11.78 to 14.90% and in 2013 was 12.54 to 15.54%. The average concentration of crude protein was highest in variety Zvezdica - 14.58%, and the lowest in Vazhod - 12.90%, but the difference between varieties is not proven. In 2011 the highest values were recorded in the Predel - 15.31%, and the lowest were in Vazhod - 13.31%. In 2012 and 2013 with the highest crude protein content in grain were variety Zvezdica, respectively 14.11 and 14.71%, while the lower the Vazhod - 12.44 and 12.97%.

The yield of protein in the grain increased with increasing nitrogen fertilization to N_{180}, reaching the highest average of 718 kg/ha, but the differences with N_{120} were unsignificant. The study shows that moderate N_{120} and high N_{180} rates manifest a strong influence on the yield of protein and as regards of this indicator were the most effective (Table 6). The relative yield of protein increased by 14; 51 and 53% with increasing of the nitrogen rates, which shows the strong influence of nitrogen on the yield of grain protein. In 2011 and 2013, the yields of grain protein increased with increasing nitrogen rate to N_{120}, respectively 862 and 723 kg/ha, but the difference was not proven. In 2012 this indicator increased with the increasing of nitrogen rate to N_{180} and was within 364-636 kg/ha. Between durum wheat cultivars during the period there were no significant differences in the average yield of protein. Progress was characterized with low average yield of grain protein - 534 kg/ha. New varieties Elbrus and Zvezdica were distinguished by the highest average values reached 675 and 630 kg/ha, with 26 and 18% over the standard Progress. Variety Predel also realized high yield grain protein - 628 kg/ha. At the interaction nitrogen rates x cultivar regarding the yield of grain protein with the highest average values of seven varieties differs Elbrus, fertilized with N_{120} - 823 kg/ha and N_{180} - 785 kg/ha, exceeding average for the period with 92 and 83% Progress without nitrogen. Lowest was protein yield of variety Vazhod grown without fertilization - 399 kg/ha, followed by Progress at N_0 - 429 kg/ha.

Table 6. Yield of protein in the grain (kg/ha) depending on the variety and nitrogen fertilization

Factors	2011	2012	2013	Average	
				kg/ha	%
A.Fertilization					
N_0	536 c	364 c	510 b	470 b	100
N_6	613 b	414 c	576 b	534 b	114
N_{12}	862 a	542 b	723 a	709 a	151
N_{18}	833 a	636 a	684 a	718 a	153
Б. Genotype					
Progress	684 ns	451 ns	468 ns	534 ns	100
Vazhod	678	429	577	561	105
Victoria	741	459	659	619	116
Predel	757	458	671	628	118
Deana	653	534	629	606	113
Zvezdica	695	535	661	630	118
Elbrus	768	558	699	675	126
B. Year	711	489	623	608	-

The content of wet and dry gluten increased with an increase in nitrogen rate in each of the years (Table 7). The standard requirement for the content of wet gluten in durum wheat grains is over 28% and for dry gluten - over 10%. Average for study period values at fertilization variants of wet (from 29.26 to 33.37%) and dry (from 10.60 to 12.60%) gluten comply with the standard of quality with only exception of unfertilized control. Average for the study in all varieties and levels of fertilization, the gluten content in 2012 reached 35.23% for wet and 13.07% for dry and exceed the remaining two years, where the precipitation in June were the cause of most low values of the index in 2013 - 23.22% and 8.33% wet and dry.The variety has no significant impact on the indicator. Average for the period with the lowest values was variety Elbrus - 28.28% and 10.16% wet and dry gluten, and the highest was Vazhod - 31.50% for wet and Victoria - 11.75% for dry gluten, but there is no evidence of differences between the values for the varieties.

CONCLUSIONS

The optimal fertilization rate out of those tested for realization of high-yield grain is 12 kg N/da. Application of higher nitrogen rates decreases the test weight and 1000-kernel weight. Grain vitreousness and wet and dry gluten increase with the increase of the nitrogen rate up to N_{180}.

The Progress standard manifested the highest test weight - an average of 80.10 kg and bigger grain - 57.29 g, high vitreousness and best suitability for production of hulled wheat.

The Predel variety manifested high vitreousness, crude protein content, wet and dry gluten and suitability for production of healthy wholesome foods.

Table 7. Concentration of wet and dry gluten (%) in the grain of durum wheat under nitrogen fertilization

Factors	Wet gluten, %				Average dry gluten, %
	2011	2012	2013	Average	
A. Fertilization					
N_0	29.96 c	31.66 c	18.64 c	26.75 d	9.47 d
N_6	31.16 bc	35.11 b	21.50 c	29.26 c	10.60 c
N_{12}	32.87 ab	36.37 ab	24.81 b	31.35 b	11.59 b
N_{18}	34.41 a	37.77 a	27.91 a	33.37 a	12.60 a
Б. Genotype					
Progress	30.33 b	36.28 ns	22.48 ns	29.69 ns	10.53 ns
Vazhod	34.68 a	37.18	22.65	31.50	11.63
Victoria	33.15 ab	35.68	23.45	30.76	11.75
Predel	31.68 ab	33.85	22.60	29.38	10.79
Deana	33.13 ab	33.88	23.78	30.26	11.21
Zvezdica	31.93 ab	35.13	27.18	31.41	11.39
Elbrus	29.83 b	34.63	20.40	28.28	10.16
B. Year	32.10 b	35.23 a	23.22 c	-	-

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