

THE VARIETY - MAIN FACTOR FOR INCREASING YIELD AND QUALITY OF DURUM WHEAT GRAIN

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Abstract

During the period 2013-2016 a field experiment was conducted in the Experimental and Implementation Base of the Agricultural University of Plovdiv, Bulgaria in order to establish the influence of the variety on the productivity and chemical-technological properties of durum wheat grain in the ecological conditions of Plovdiv region. The object of the study were the Bulgarian varieties of durum wheat: Progress, Saturn, Victoria, Beloslava, Vazhod, Deyana, Predel, Zvezditsa and Zagorka and the foreign varieties of different origin: Auradur (Austria), Karur and Pescadou (France) Selyendur (Hungary), Grecale and Levante (Italy), Janejro (Spain). Variety Progress was used as standard for productivity and variety Saturn 1 was used as standard for quality. The experiment was based on the block method in 4 replications with a harvest plot size of 15 m² after predecessor rapeseed. As a result of the field experiment it was found:

On average for the three-year study period most productive are the Bulgarian varieties of durum wheat Deyana, Predel and Zvezditsa, for which the grain yield increased respectively by 44.0 kg/da (12.8%); 38.1 kg/da (11.1%) and 33.9 kg/da (9.9%) compared to the Progress variety. Of the foreign varieties with higher grain yield on average for the study period, the varieties Karur and Pescadou are distinguished, for them the increase was by 22.3 kg/da (6.5%) and 20.6 kg/da (6%) more than the standard. The group of Bulgarian varieties is characterized by a higher thousand-kernel weight (TKW) and hectolitre weight (HW). The group of foreign varieties is characterized by a higher content of yellow pigments and volume of SDS-sedimentation number. The values in terms of crude protein and yield of wet and dry gluten in all durum wheat varieties are close but foreign varieties have better quality protein, respectively gluten. The Austrian variety Auradur is with highest quality, and Predel is with highest quality among the Bulgarian varieties.

Key words: durum wheat, varieties, productivity, grain quality.

INTRODUCTION

The data presented in the scientific literature show the great opportunities for regulating the yields and quality of durum wheat based on a good study of the biological characteristics of the new varieties, as well as the role of environmental factors for their manifestation. All this is a prerequisite for crop management in accordance with the specific soil and climatic conditions and varietal composition of durum wheat. A study conducted at the Field Crops Institute - Chirpan on the genetic distance of Bulgarian and European varieties of durum wheat found that Bulgarian varieties are among the best in yield and show better stability by years (Dechev, 2008). The author finds that according to the studied economic indicators, durum wheat varieties are divided into three groups that are genetically distant. Most Bulgarian varieties are in one group. The group of the most remote varieties is dominated by French ones.

When testing the Bulgarian durum wheat varieties Zagorka and Progress and the Italian Simeto, Balsamo and Rasioso (Delchev et al., 2000) it was reported that the Italian varieties in years with more severe and prolonged winters are risky in terms of yield and are not suitable for growing in our country, but due to the good quality of gluten they can serve as a starting material in the selection of high quality. For the same purpose or for direct implementation in the production, 15 samples of different origin were assessed (France, Greece, Jordan and Russia) from the collection of durum wheat in the National Gene Bank - Institute of Plant Genetic Resources, Sadovo (Mangova, 2007; Popova, 2001). The authors reported that the accessions Agathe, Mauragani iraclion, № 97102050, and Kubanka were distinguished by a high content of protein, yellow pigments and strong gluten, and according to a complex of valuable features the accessions No. 97102004, No. 97102025 and No. 97102033 are of interest for the practice.

Comparative studies have been made for the first time on the influence of varietal characteristics on the physical properties, chemical composition, technological properties of the grain of six varieties of common wheat - two Bulgarian and four grown in Northern Greece (Yanchev and Ivanov, 2012). The Bulgarian variety Pobeda (belongs to the group of strong wheat) and the varieties Panifor and Pandas, which belong to the group of wheat with increased strength and can be successfully implemented in grain production in Northern Greece under different agronomic conditions, are characterized by the best physical properties, chemical composition and technological properties of the grain. Outside the varietal characteristics, excessive nitrogen fertilization has an adverse effect on the colour of the grain due to the proven inverse relation of colour-protein content (Autran et al., 1986). Almaliev et al. (2013) found that in durum wheat the structural elements of yield (wheat-ear length, number of spikelets per wheat-ear, number of grains per wheat-ear, grain weight in 1 wheat-ear), productivity (grain yield and grain protein) and grain quality (grain protein concentration, wet and dry gluten content, total grain vitreousness) are strongly related to the applied nitrogen fertilization within the norms 0-18 kg/da.

On average for a three-year period of research in Pazardzhik region, Progress variety forms the highest grain yield - 3.88 t/ha. Higher yields in the other studied varieties Predel and Victoria are achieved when applying the first term of sowing and double fertilization with nitrogen fertilizer. (Dragov, & Samodova, 2020).

The relevance of this research is related to Bulgaria as a member of the European Union, which is a serious motivation for expanding and consolidating the area of distribution of durum wheat according to the specific climatic conditions of individual regions and countries.

In harmony with the developed strategy for the development of durum wheat and the criteria adopted by the EU under Chapter 7 "Agriculture", the areas of durum wheat in Bulgaria is to reach 218 thousand hectares with a single production of 60-70 thousand tons. In this way we will approach the average European level of

consumption of pasta per person per year in the range of 7-8 kg. A significant part of this production can be offered on international markets as an export item, from which our country will receive additional revenues.

MATERIALS AND METHODS

The experimental material consisted of nine Bulgarian and seven foreign varieties of durum wheat with a complex of valuable economic characteristics. As a standards are adopted varieties Progress (for productivity) and Saturn 1 (for quality).

Biological indicators

1. Structural elements of yield: wheat-ear length; number of spikelets in the wheat-ear; number of grains in the wheat-ear and mass of grains in the wheat-ear
2. Grain yield, kg/da.

Biochemical and technological indicators

The biochemical and technological quality of grain samples from nine Bulgarian varieties of durum wheat: Progress, Saturn, Victoria, Beloslava, Vazhod, Deyana, Predel, Zvezditsa and Zagorka and seven foreign varieties of different origin were studied: Auradur (Austria), Karur and Pescadou (France), Selyendur (Hungary), Grecale and Levante (Italy), Yaneiro (Spain) grown in the experimental field of the Agricultural University-Plovdiv.

HW (hectolitre weight) and TKW (thousand-kernel weight) are determined according to BDS EN ISO 7971: 2009 and BDS ISO 520: 2010. The glass vitreous content of the grain is determined according to standard EN 15585:20081. The protein content in the grain is determined by the Kjeldahl method ($N \times 5.7$) according to BDS ISO 1871: 2001, and that of wet gluten - according to BDS EN ISO 21415-2: 2008. The functional quality of protein/gluten is determined by the sedimentation volume of ground grain with sodium dodecyl sulphate (SDS) [ICC 151: 1990] and the viscoelastic properties of wet gluten in terms of loosening and compressibility [BDS 13375: 1988]. The yellow pigment content was determined from a standard curve with pure β carotene [ISO 11052: 1994].

Field experiment

Durum wheat is sown after rapeseed as a precursor crop. Before tillage, the experiment was fertilized with P8 kg/da (triple superphosphate) and N4 (ammonium nitrate - 1/3 of the fertilizer rate). Then the soil was disc-processed three times diagonally with disc harrows. The field experiments were conducted using a randomized block design with four replications and a cultivated plot of 15 m².

The sowing of sixteen durum wheat varieties was carried out with a Wintershtaiger seeder in the optimal sowing period from 20.10. to 05.11. Early in the spring, the remaining 2/3 of the nitrogen fertilizer norm was fed. After sowing, the soil was compacted by rolling.

Weed, disease and pest control is carried out as needed after inspection of the crop and with appropriate pesticides (Yanev et al., 2008). Harvesting of the tested varieties of durum wheat was carried out in the phase of full maturity with a Wintershtaiger plot harvester.

Precipitation during the growing season of durum wheat is as follows: 2013/2014 - 458.1 mm/m²; 2014/2015 - 388.5 mm/m², 2015/2016 - 396.5 mm/m² with a climatic standard of 419.0 mm/m². In the studied years favourable for the growth and development of durum wheat with good rainfall distribution was the harvest year 2016 (despite less than the climatic standard, but better distributed rainfall during the critical phenophases of plant development) when higher yields were obtained from all durum wheat varieties. The second year 2014/2015 was unfavourable for the development of the plants due to the lower rainfall in April, when the structural elements of the yield are formed. (Figure 1) and (Figure 2).

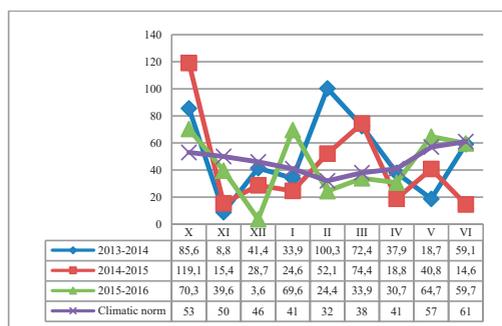


Figure 1. Precipitation by months, sum mm/m² (2013-2016)

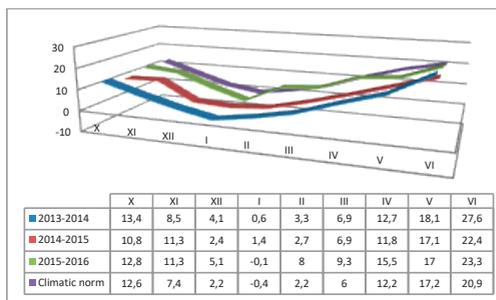


Figure 2. Monthly temperatures (average 2013-2016)

The statistical processing of the data obtained for the studied indicators was performed with BIOSTAT software (Penchev, 1998).

RESULTS AND DISCUSSIONS

Structural elements of yield and productivity of the tested varieties of durum wheat.

For the surveyed period the longest wheat-ears are observed in the plants of Zvezditsa variety 9.14 cm (1.6%) followed by the Karur variety 9.05 cm (0.6%). The length of the wheat-ear of the other tested varieties was shorter than that of the standard Progress variety (Table 1).

Table 1. Structural elements of yield (average 2013-2016)

Varieties	Wheat-ears	Number of spikelets in the wheatear	Number of grains in the wheatear	Mass of grains in the wheatear (g)
1. Progress	9,0	23,0	49,3	2,43
2. Saturn I	8,36	21,7	47,6	1,96
3. Vuzhod	7,60	23,8	50,6	2,18
4. Victoria	6,90	25,1	51,7	2,35
5. Zvezditsa	9,14	23,6	55,4	2,44
6. Predel	8,12	25,5	52,9	2,38
7. Deyana	8,32	25,7	54,1	2,53
8. Beloslava	8,06	24,2	52,6	2,09
9. Auradur	8,91	22,7	42,3	1,90
10. Levante	8,28	21,6	43,1	2,07
11. Karur	9,05	25,0	52,3	2,21
12. Selyendur	7,72	23,5	49,5	1,71
13. Grecale	7,92	21,8	44,7	1,64
14. Pescadou	8,84	24,0	51,1	2,20
15. Yaneiro	7,93	21,1	44,4	1,47
GD 5 %	0,42	1,48	3,69	0,19

During the three-year period of the experiment it was found that Deyana variety forms the largest number of spikelets in the wheat-ear 25.7 (11.7%) followed by Predel variety with 25.5 pcs. (10.9%), Victoria 25.1 pcs. (9.1%), and Karur 25.0 pcs. (8.7%), which is respectively by 2.7 pcs, 2.5 pcs, 2.1 pcs. and 2.0 pcs. of

spikelets more than the standard (Table 1). Of the foreign varieties, more spikelets in the wheat-ear were formed by Karur and Pescadou varieties.

It was found that on average for the study period Zvezditsa variety has the highest number of grains in the wheat-ear of 55.4 pcs. (12.4%). In second place is Deyana variety 54.1 pcs. (9.7%), followed by the variety Predel with 52.9 pcs. (7.3%). Beloslava, Victoria, Karur and Pescadou varieties formed a larger number of grains than the standard. In the varieties Saturn 1, Grecale, Yaneiro, Levante and Auradur, the number of grains in the wheat-ear was lower than of Progress variety (Table 1).

During the three-year period of the experiment it was found that with a higher mass of grains in the wheat-ear compared to the standard variety Progress are distinguished the plants of varieties Deyana 2.53 g (4.1%) and Zvezditsa 2.44 g (0.4%) (Table 1). The mass of the grains in the wheat-ear of the other varieties tested was lower than Progress. The smallest were the grains of the variety Yaneiro 1,47 g.

The highest grain yield (Table 2) on average for the conditions of the studied period was obtained from Deyana variety 387.8 kg/da, which is 44.0 kg/da (12.8%) more than the standard Progress variety. This was followed by Predel variety with 381.9 kg/da (11.1%) and Zvezditsa variety with 377.7 kg/da (9.9).

Table 2. Grain yield, kg/da (average 2013 - 2016)

Varieties	2013-2014	2014-2015	2015-2016	Average	%
1. Progress	340,5	301,5	389,3	343,8	100,0
2. Saturn 1	334,4	297,2	365,1	332,2	96,6
3. Vuzhod	364,7	323,2	401,5	365,1	106,2
4. Victoria	371,8	329,1	416,3	372,4	108,3
5. Zvezditsa	392,3	311,6	429,1	377,7	109,9
6. Predel	383,1	324,3	438,4	381,9	111,1
7. Deyana	387,5	343,8	432,2	387,8	112,8
8. Beloslava	378,6	308,6	413,7	367,0	106,7
9. Auradur	257,8	228,6	315,3	267,2	77,7
10. Levante	266,3	280,9	327,1	291,4	84,8
11. Karur	367,7	323,8	406,8	366,1	106,5
12. Selyendur	359,2	314,3	397,9	357,1	103,9
13. Grecale	272,7	283,5	309,3	321,8	93,6
14. Pescadou	365,7	323,5	404,1	364,4	106,0
15. Yaneiro	294,5	295,2	339,6	309,8	90,1
GD 5 %	26,8	22,5	25,3		

The high productivity is due to the large, and very well-grained wheat-ear with a high grain mass per class. Of the tested foreign varieties Karur, Pescadou and Seliendur are characterized by high productivity, as their yield is by

22.3 kg/da (6.5%); by 20.6 kg/da (6.0%), and by 13.3 kg/da (3.9%) more than the standard. The obtained grain yield from the varieties Auradur, Levante, Yaneiro, Grecale and Saturn 1 was lower than the standard variety Progress.

Biochemical and technological evaluation of Bulgarian and foreign varieties of durum wheat (*Triticum durum* Desf.)

The grain of the samples was dry, with moisture around the baseline between 13.1% -13.5%.

Depending on the variety, year and origin of the wheat, the TKW and HW of the world collection of durum wheat are in the range of 30-62 g, and 72-87 kg/hl respectively. The studied Bulgarian varieties are characterized by larger and heavier grain. They have the TKW above the standard Saturn 1 and for the variety Zvezditsa the highest value is measured 55.8 g.

Table 3. Physical properties of the grain of Bulgarian and foreign varieties of durum wheat (*Tr. durum* Desf.)

Varieties	Moisture %	TKW G	HW kg/hl	Vitreousnes s %
1. Progress	13,56	54,5	80,8	98
2. Saturn 1	13,50	49,0	82,0	92
3. Vuzhod	13,31	49,8	82,8	92
4. Victoria	13,04	51,4	82,0	96
5. Zvezditsa	13,09	54,0	82,4	96
6. Predel	13,13	53,6	80,8	98
7. Deyana	13,36	55,8	82,4	72
8. Beloslava	13,25	54,0	81,6	90
9. Auradur	13,33	46,8	80,4	88
10. Levante	13,25	45,6	78,4	90
11. Karur	13,13	42,4	82,4	90
12. Selyendur	13,17	47,0	74,4	92
13. Grecale	13,13	48,0	80,4	90
14. Pescadou	13,10	44,0	81,6	90
15. Yaneiro	13,33	46,6	79,2	86
16. Zagorka	13,18	48,4	83,2	74

Bulgarian varieties are characterized by a higher TKW and HW compared to foreign durum wheat varieties. The HW of the Bulgarian varieties varies from 80.8 kg/hl for the varieties Progress and Predel to 83.2 kg/hl for Zagorka variety. For foreign durum wheat varieties, the HW ranges from 74.4 kg/hl for Selyendur to 82.4 kg/hl for Karur (Table 3).

The relationships between the HW and TKW, as indicators of the endosperm-grain husk ratio, with the milling properties of wheat are quite variable according to the place and year of cultivation. The variability explains the preferences for one or the other indicator as forecast for high yield of semolina and the different strength of their relations with the milling

quality. According to Dexter (1996), when the HW decreases, the milling potential of wheat deteriorates due to the combined effect of lower semolina yield, higher ash content, and lower yellow pigment content in semolina. In a field experiment, four varieties of winter wheat were tested, sown on three sowing dates and fertilized with five rates of nitrogen. On average for all sowing dates and fertilization rates, the highest grain mass was reported in the variety Pobeda - 44 g, while the lowest was reported in the variety PKB - Lepoklasa (38 g). The highest TKW was registered for all wheat varieties in 1999, when the meteorological conditions were good for the development of wheat. The date of sowing and the amount of nitrogen fertilizers have a significant effect on the mass of 1000 grains (Protic et al., 2007). Despite the contradictory opinions, HW is a generally accepted standard indicator in the classification of durum wheat as a measure of the health status, as all factors that defect the grain also affect the HW (frost, immaturity, shrinking, quick sprouting, disease).

Table 4. Biochemical and technological evaluation of Bulgarian and foreign varieties of durum wheat (*Triticum durum* Desf.)

Variety	Crude protein %	Wet gluten production %	Dry gluten %	Yellow pigment ppm d. m.	SDS - sedimentation number cm ³
Progress	16,76	35,7	13,1	7,05	25
Saturn 1	11,17	31,1	11,0	6,75	46
Vuzhod	14,42	26,8	9,7	7,96	20
Victoria	12,77	33,8	12,2	5,13	25
Zvezditsa	16,82	39,0	13,7	6,46	38
Predel	15,16	33,7	12,5	6,82	30
Devana	13,57	27,1	9,9	6,22	30
Beloslava	15,96	33,8	12,3	8,98	43
Auradur	16,76	37,0	13,4	10,55	54
Levante	14,36	36,0	12,8	9,90	65
Karur	11,17	36,8	13,0	9,64	84
Selyendur	15,16	44,5	15,3	9,03	71
Grecale	15,96	40,1	13,8	10,49	46
Pescadou	13,57	33,2	11,8	10,33	73
Yaneiro	11,97	34,8	12,0	10,82	35
Zagorka	11,97	31,4	10,9	6,49	30

Vitreousness as a standard indicator reflects the structure of the endosperm, due to its proven relation with yield and size of semolina, ash content, protein and yellow pigments in semolina. In dry years such as the 2015 crop, vitreousness is high, with an average of 90% for the tested varieties, while in wet years, vitreousness decreases significantly, especially if there is precipitation during the grain harvest

period, such as the previous 2014 with an average value of 50.5%.

The presence of more flour grains leads to a reduction in the amount of semolina during grinding and its quality.

The colour potential depends on the amount of natural pigments in the grain. The pigments have a yellow and brown colour. Carriers of the yellow component are carotene and xanthophyll and water-soluble flavones. Brown pigments are the products present in the grain from the decomposition of chlorophyll, products from the action of basic proteins, and the isomerization of carotenoids. Durum wheat contains 2 to 5 times more yellow pigments than bread wheat. The better colour potential of the studied foreign varieties included in the project is genetically determined. They have an average of 10.11 ppm d.m. against 6.87 ppm d.m. for the Bulgarians. The grain of the Spanish variety Yaneiro demonstrates the highest content of yellow pigments 10 ppm d.m. Excessive nitrogen fertilization can have an adverse effect on the colour, due to the inverse relation of colour-protein content, or improper storage of wheat in granaries.

Grain crude protein ranges from 11.17% to 16.82% depending on the variety and environmental conditions. Modern pasta production requires semolina with over 14% protein, which corresponds to over 15% in wheat. The highest protein content for the study period was determined for the varieties Vuzhod 16.82%, Predel 15.96%, the Austrian variety Auradur 16.76%, the French Pescadou 15.96%, and the Italian Grecale 15.16%.

According to the standard method of ICC (International Cereal Chemists) twice as high SDS - sedimentation number was determined for foreign varieties - 61 cm³, while the Bulgarian varieties significantly lag with an average value of 32 cm³ on average for the study period.

The quantity and quality of gluten are key indicators in wheat selection and variety testing programs worldwide. They depend on the variety and are strongly influenced by the growing conditions. During the three-year experiment, the foreign varieties have an average value of 37.5% and are superior to our varieties having an average value 32.5 %.

CONCLUSIONS

On average for the three-year study period the most productive are the Bulgarian varieties of durum wheat Deyana 387.8 kg/da; Predel and Zvezditsa, where the increase in grain yield is higher by 44.0 kg/da (12.8%), 38.1 kg/da (11.1%), and 33.9 kg/da (9.9%) respectively, compared to Progress variety.

Of the foreign varieties with higher grain yield on average for the study period are distinguished the varieties Karur 366.1 kg/da and Pescadou 364.4 kg/da, which is by 22.3 kg/da (6.5%) and 20.6 kg/da (6.0%) more than the standard Progress variety.

The high productivity is a result of the large and very well-grained class with a high grain mass in the wheat-ear of these varieties.

The studied varieties included in the experiment show their potential for quality in the dry, with favourable climatic conditions year of 2015. The wet 2014 and especially the rainfall during the harvest period, strongly negatively affected the indicators TKW and vitreousness of the grain, yield of wet, and dry gluten. The content of crude protein, yellow pigments and the volume of the SDS-sedimentation number were also negatively affected, though to a weaker extent.

Bulgarian varieties are characterized by a higher TKW and HW compared to foreign durum wheat varieties.

The group of foreign varieties of different origin is characterized by a higher content of yellow pigments and volume of SDS-sedimentation number.

The values of crude protein and wet and dry gluten yield are close for all durum wheat varieties studied, but the foreign varieties have better quality protein, respectively gluten.

Of the highest quality is the Austrian variety Auradur, and of the Bulgarian varieties - Predel variety.

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