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Genetics and Breeding

Investigation on the possibility to efficiently use Ukrainian cultivars for developing of early winter wheat lines
I. Grain productivity

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Abstract. *Situation and aims. This investigation was carried out with the aim to determine the suitability of some Ukrainian wheat cultivars for improvement of the productivity of the Bulgarian ecotype of winter wheat. The economic traits and properties of promising breeding lines from crosses between them were studied. The focus was on the breeding possibilities of compromise combining early maturation with grain yield.*
Methods. A total of 50 genotypes were investigated: 40 of them were lines (from 4 hybrid combinations), 8 parental lines and several standard cultivars for comparison. Data were obtained from competitive varietal trials after growing for several successive years. The main traits directly or indirectly related to productivity were analyzed. The combination of earliness with the other economic traits and indices is discussed from the point of view of the combining ability of the early parents involved in the combinations.
Key results. Although each studied combination involved an early parent, it was found that early forms were obtained with the participation of cultivars Obriy and Mironovskaya 29. The percent of early lines was highest in the combinations with their participation. In the crosses involving Albatros odeskiy and Mironovskaya 27, the productivity of the early lines was lower than the productivity of the parental lines. Cultivar Obriy was most promising for breeding work, especially for combining early heading with higher grain yield through high values of number of productive ears and grain size.
Conclusions. Cultivars Albatros odeskiy and Obriy were most suitable for obtaining higher productivity in combination with earliness. The deriving of lines with earlier date to heading and higher productivity from the early cultivars Mironovskaya 29, Galateya and Enola was completely successful. By using specific cultivars, there is the possibility to combine high yield with earliness but within the limits of the specific parental cultivars for each individual combination.

Keywords: yield, productivity components, grain quality, early maturity, combining ability, breeding lines

Abbreviations: DH – date of heading, HOS – height of stem, NPE – number of productive ears, WGS – weight of grain per spike, NGS – number of grains per spike, TGW – thousand grain weight, GY – grain yield

Introduction

Wheat is a main crop for human food both worldwide and in Bulgaria due to its specific nutrition qualities (Van Ittersum et al., 2013). The ostensible climatic changes in the recent years and the anomalies occurring during the individual periods of a given season require developing of early forms (Eid, 2009). The earlier date to heading and maturity is in strong negative correlation with grain yield (Domnez et al., 2001; Andonov**,** 2012). Therefore it has always been difficult to achieve a compromise combining of high productivity with earliness (Boyadjieva, 1996; Tsenov et al., 2009). The early cultivars manage to more rationally utilize the autumn-and-winter moisture reserves in soil which is a prerequisite for guaranteed higher yields. Due to the same reason the early cultivars also express functional tolerance to late spring and summer droughts, which is an advantage under such conditions (Andonov**,** 2012; Boyadjieva et al., 2009). In the wheat (Tsenov et al., 2005) and barley (Mersinkov, 2005) cultivars developed in Bulgaria, a limit of earliness has been reached, beyond which grain yield decreases, especially in the earlier forms. When combining early with medium early or late forms, the inheritance of the trait date to heading is usually intermediary, or there is a partial dominance of the early parent in the best case (Tsenov, 2005; Akinci, 2009). Due to this genetic peculiarity of the trait, the developing of forms earlier than the ones used in the crosses is difficult and comparatively rare, especially of forms with productivity above the level of the used model cultivars (Tsenov and Atanasova, 2007). A possible explanation is that a "critical" level of earliness has been reached under which productivity sharply decreases. Having in mind that this information is valid under the conditions of Bulgaria, the breeding efforts have been directed toward increasing productivity by reaching the earliness of the cultivars already released (Tsenov et al., 1999, 2011c). In breeding, the date to heading is used as a level of earliness, which completely reflects the duration of the vegetation period of wheat in spring (2009). The elongation of the period to full maturity is often related to the negative effect of the grain-filling conditions (rainfalls or dry winds) on grain yield and quality in Bulgaria; therefore a compromise variant of high yield as a result from rapid grain-filling (early forms) is being sought. A typical example in this respect are cultivars Katya, Bolyarka, Sadovo, Stoyana, etc., in which high productivity is related with earliness (Boyadjieva, 2002; Tsenov et al., 2009). It is not by chance that almost all cultivars developed under annual drought in the southern part of Bulgaria (Sadovo) are earlier than the cultivars developed at Dobrudzha Agricultural Institute (DAI), General Toshevo (Chamurliyski et al., 2011).

The breeding materials from Ukraine have been used in Bulgarian breeding since the 1980s, always considering their economic properties: a) positive: high cold resistance, high

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resistance to the diseases powdery mildew, brown rust, septoria, moderate resistance to root rot, black and yellow rust, high grain quality (from the point of view of bread making quality), and b) negative: long growing season, slow growth rate and development in spring, insufficient dough strength, insufficient lodging resistance. Accessions from Ukrainian breeding centers have been used for many years as a result from intensive exchange of breeding materials (Panayotov and Kostov, 2007). As a result seven winter wheat cultivars have been developed up to now: Laska = F2498-W1-2/Obriy; Elitsa = Yuzhnaya Zarya/Pliska (1997) (Tsenov et al., 1998); Iveta = Obriy/Mironovskaya 61 (2000) (Tsenov et al., 2013); Liliya = Pryaspa/Mironovskaya 27 (2000); Zlatitsa = Er.10071/Pryaspa (2003) (Tsenov et al., 2003); Zlatina = Obriy/129-171-1 (2003) and Bozhana = Obriy/ Milena (2010) (Tsenov et al., 2011b). It is impressive that more than half of these cultivars involve directly cultivar Obriy. This cultivar was used very intensively some 20-25 years ago due to its complex of valuable properties (Lifenko, 1987). Besides having an excellent combination between a number of valuable traits, Obriy also possesses high combining ability with regard to yield, grain quality, resistance to diseases and stress plus earliness (Tsenov et al., 2011a). In this investigation we selected crosses with the most valuable Ukrainian accessions due to their combining ability for yield and grain quality. The first major criterion for crossing was the presence of at least one component of earliness to shorten the date to heading, which is typical for most of the Ukrainian wheat varieties, from the point of view of Bulgarian breeding. The second major criterion was height of stem, in the heritability of which there is a strong heterosis effect even when using short-stemmed cultivars such as Obriy (75 cm), as a result of which the height of the derived lines was more than 100 cm in many of the crosses.

The aim of this investigation was to find out if it is possible to obtain via breeding highly productive and early lines of common winter wheat by involving late accessions from Ukraine with high combining ability of their economic properties related to productivity.

Material and methods

This investigation included common wheat breeding lines developed by combining Bulgarian and Ukrainian varieties (Table 1). The selected Ukrainian varieties were from two breeding centers, Odessa and Mironovka, which are long-standing partners of DAI. The breeding lines were obtained through the conventional Pedigree method which involves hybridization, screening in hybrid progenies till stabilizing the lines in F_6. After screening, the progenies are initially tested in control trials without replications to obtain sufficient seeds for initiation of replication trials The investigated traits are studied in a preliminary varietal trial (PVT) in three replications, the plot size being 15 m^2.

The testing was carried out during 2009 – 2011, selecting and analyzing data from each replication on the following productivity-related traits: date to heading (DH), presented as number of days from 1st January to heading; height of stem (HOS) in cm, measured from the base of the plant to the base of the spike; number of productive ears/m^2 (NPE), calculated on ¼ m^2 from each plot; weight of grain per ear (WGE), calculated as relation of grain yield to number of ears per 1 m^2 from each plot; number of grains per spike (NGS) calculated as relation of grain weight per spike and grain size, 1000 grain weight (TGW) determined by counting two samples each of от 250 grains from each replication, and grain yield (GY), recalculated to ton/ha from the grain yield obtained from each investigated plot. After developing all breeding lines, the parental components and the model varieties were tested for laboratory cold resistance by the method of Tsenov and Petrova, (1984).

The data collected on the traits were analyzed with the help of several statistical programs such as XLSTAT 2009.4.05 (descriptive data and significance of differences between the variants for comparison) and IBM SPSS 19 (analysis of variances and correlations).

Results and discussion

The analysis of variances of each trait revealed expression of highly significant effects, both independently of the factors year and genotype, and of their interaction (Table 2). This allowed evaluation of the collected data and was a prerequisite for correct application of other statistical analyses. Although the effects of the individual factors were significant at high level, the values of the mean squares (MS) showed that the variation caused by the year conditions was highest, followed by the cultivar; the variation caused by the interaction of the two factors was lowest. These data confirmed the assumption that the effect of the year conditions is highest, as established in various investigations of Sharma et al. (2010); Muhe and Assefa (2011) Chamurliyski and Tsenov (2013), while the role of the cultivar for grain yield formation is high but second in importance. In traits related to productivity, the role of the genotype was also significant under changeable environments and the influence of strong factors such as previous crop and mineral fertilization (Dechev, 2005; Tsenov et al., 2008a; Ivanova and Tsenov, 2011).

Table 3 presents the values of the investigated traits of each breeding line developed from the various hybrid combinations. The data will be consequently analyzed based on two traits used as main criteria for the choice of the parental components for crosses: date to heading and stem height.

Date to heading (DH). The values of this trait in all four crosses as a whole were between the values of the cultivars used as parents. Two or three lines were obtained from each combination A, C and D, which were a little earlier than the early parent from the cross, and

Table 1. Crosses between Bulgarian cultivars and cultivars with origin from Ukraine

Cultivar, Female component	Origin	Cultivar, Male component	Origin
Obriy	GBRI, Odessa *	Yantar	DAI, G. Toshevo***
Albatros odeskiy	GBRI, Odessa	Galateya	DAI, G. Toshevo
Mironovskaya 27	MWBI, Mironovka**	Enola	DAI, G. Toshevo
Mironovskaya 29	MWBI, Mironovka	Pobeda	IPGR, Sadovo****

* - Genetic and Breeding Research Institute, Odessa; ** - Mironovskiy Wheat Breeding Institute, Mironovka;
*** - Dobrudzha Agricultural Institute, G. Toshevo; **** - Institute of Plant Genetic Recourses, Sadovo

Table 2. Analysis of variances of the investigated factors and traits

Trait	Term	Source of variation		
		A: Year	B: Variety	A x B
	DF	2	39	78
DH	MS	12.453	0.104	0.0482
	p-value	0.0000*	0.0000*	0.0000*
HOS	MS	741.784	84.245	45.161
	p-value	0.0000*	0.0000*	0.0000*
NPE	MS	575378.4	18530.22	6056.078
	p-value	0.0000*	0.0000*	0.0000*
NKS	MS	2741.454	64.969	35.661
	p-value	0.0000*	0.0000*	0.0000*
TKW	MS	1748.376	50.22072	17.25844
	p-value	0.0000*	0.0000*	0.0000*
GY	MS	98000.0	8740.413	6211.983
	p-value	0.0000*	0.0000*	0.0000*

Table 3. Economic traits of the wheat lines from each combination involving Ukrainian materials averaged for the period 2009–2011

Line, Variety	DH	HOS	NPE	WGS	NGS	TGW	GY
A. Obriy / Yantar							
A1	126.4	91.3	633	1.24	30.3	41.1	7.88
A2	127.2	77.0	619	1.28	29.8	42.9	7.92
A3	128.0	82.5	623	1.36	29.1	46.6	8.45
A4	129.3	78.5	646	1.29	33.3	38.8	8.35
A5	130.0	83.6	658	1.32	28.6	46.2	8.70
A6	131.0	87.7	665	1.30	29.1	44.7	8.65
A7	132.1	88.3	567	1.45	32.5	44.7	8.23
A8	133.0	90.1	608	1.39	31.1	44.8	8.47
A9	134.5	79.2	596	1.29	32.0	40.2	7.67
A10	135.0	76.2	602	1.36	32.5	41.7	8.17
Obriy	128.1	74.6	642	1.19	31.5	37.8	7.65
Yantar	133.5	94.2	595	1.36	31.1	45.0	8.13
Mean A	130.7	83.6	621.2	1.32	30.9	42.88	8.19
SE	0.850	1.904	8.380	0.020	0.443	0.843	0.102
B. Albatros odesskiy / Galateya							
B1	130.1	88.8	633	1.26	31.3	40.2	7.97
B2	130.7	85.5	625	1.28	30.3	42.3	8.06
B3	130.8	77.0	685	1.27	29.2	43.5	8.76
B4	131.4	85.8	655	1.28	32.4	39.5	8.43
B5	132.2	90.0	650	1.31	29.5	44.4	8.55
B6	133.5	81.3	634	1.33	30.2	44.0	8.49
B7	133.7	80.2	693	1.28	28.1	45.5	8.88
B8	133.8	94.2	677	1.12	28.9	38.8	7.58
B9	134.4	90.8	625	1.25	26.2	47.7	7.85
B10	136.8	79.8	601	1.27	30.9	41.1	7.67
Albatros odesskiy	134.8	96.2	668	1.22	30.8	39.6	8.15
Galateya	125.3	78.8	608	1.29	27.0	47.8	7.85

Mean B	132.5	85.4	647.4	1.26	29.4	43.11	8.21
SE	0.908	1.986	9.413	0.017	0.545	0.954	0.134
C. Mironovskaya 27 / Enola							
C1	125.2	88.6	655	1.23	28.9	42.5	8.08
C2	125.5	82.8	577	1.41	30.1	46.8	8.15
C3	126.0	90.2	590	1.30	32.7	39.8	7.66
C4	127.6	85.0	645	1.27	28.9	44.0	8.22
C5	128.5	88.7	667	1.25	27.5	45.5	8.33
C6	129.4	82.7	625	1.34	33.3	40.2	8.37
C7	131.8	94.5	683	1.24	29.2	42.5	8.44
C8	131.3	80.4	658	1.22	28.9	42.2	8.00
C9	132.4	85.5	634	1.37	31.2	44.0	8.68
C10	135.2	98.8	666	1.18	28.3	41.7	7.85
Mironovskaya 27	134.3	104.5	678	1.14	26.7	42.7	7.75
Enola	127.1	83.3	596	1.35	30.3	44.5	8.05
Mean C	129.8	88.8	638.1	1.28	29.7	43.1	8.14
SE	0.996	2.297	11.149	0.025	0.618	0.644	0.094
D. Mironovskaya 29 / Pobeda							
D1	126.6	84.4	617	1.19	27.7	43.0	7.33
D2	126.8	93.9	639	1.23	28.0	44.0	7.88
D3	128.0	90.2	693	1.08	24.0	45.0	7.47
D4	128.3	83.7	682	1.11	24.2	45.8	7.55
D5	128.6	88.3	623	1.32	28.3	46.8	8.25
D6	129.2	100.6	655	1.19	28.8	41.5	7.82
D7	130.6	95.8	688	1.25	29.5	42.2	8.57
D8	131.2	95.6	606	1.31	29.6	44.4	7.96
D9	132.8	105.6	634	1.30	30.4	42.7	8.23
D10	135.0	102.8	673	1.21	29.1	41.4	8.12
Mironovskaya 29	128.5	80.0	612	1.33	27.9	47.7	8.11
Pobeda	137.7	108.7	677	1.10	25.2	43.7	7.45
Mean D	130.6	95.0	652.9	1.22	27.7	44.11	7.95
SE	1.008	2.722	9.531	0.028	0.678	0.631	0.107
Liliya	136.5	98.8	697	1.16	28.8	40.3	8.11
Iveta	130.0	103.3	647	1.31	30.0	43.7	8.45

one line from each combination, which was later than the respective late parent. The mean values of each group of lines within the cross were close to the mean level of the parents. The achieved level of variability by this trait was considerably high from the point of view of practical breeding for earliness and was a prerequisite for developing of forms with different combinations of the trait and the components of productivity. A detailed comparison of the means of each cross to the level of a given parental trait revealed that a predominant part of the traits have on the whole reached the mean level of the parents. This situation was logical within the situation of our experiment having in mind that the crosses involved parents with contrasting traits with the main aim to obtain new recombinations of traits. On the whole, the lines from the cross (C=129.8 days) were earliest, and the lines from the cross (B=132.5 days) were latest.

*Height of stem (HOS).*_In crosses (A) and (C) the variation between the parents by this trait was about 20 cm, and in crosses (B) and (D) the variation was within 13–17 cm. The mean values of the crosses as a whole were at the mean level of the parents, although the variation between the parents in the individual combinations was different. There was only one line in each group of crosses with height of stem close to that of the respective short-stemmed parent. The situation was the same for all lines from each group. All other

Table 4. Variation of the traits in the investigated groups of crosses

Stat Parameters	DH	HOS	NPE	WGS	NGS	TGW	GY
min	125.2	76.2	567	1.08	24.0	38.80	7.33
max	136.8	105.6	693	1.45	33.3	47.70	8.88
Range	11.6	29.4	126	0.37	9.36	8.90	1.55
VC %	9.0	38.5	22.2	34.6	39.0	22.9	21.1

Table 5. Variation of the mean values of the traits in early and late breeding lines

Group of different lines	DH	HOS	NPE	WGS	NGS	TGW	GY
1. The Earliest 10 lines (25 %)	126.4	85.5	617.9	1.28	29.4	43.64	7.90
2. The Latest 10 lines (25 %)	135.3	93.6	650.9	1.21	29.0	41.72	7.85
Difference (1-2)	-8.9	-8.1	-33.0	0.07	0.30	1.92	0.05
Standard Deviation	3.29	8.16	33.04	0.08	2.11	2.52	0.38

708 lines had height of stem about the mean level of the parents.

Very high variation was observed for all investigated traits, including the index date to heading (Table 4). According to its rate the traits can be divided into 3 groups: 1 – low variation up to 10 % for the trait date to heading; 2 – high variation up to 25 % for the traits number of productive ears, 1000 grain weight and grain yield; 3 – very high variation over 30 % typical for height of stem, weight of grain per spike and number of grains per spike.

When the investigated lines were grouped into early and late according to their date to heading (Table 5), it became clear that there was a significant variation in the mean values of the two groups only by this trait. In all other traits, in spite of the high rate of variation, there was no significant difference in the mean values of the rest of traits in the two groups. Differences were found for height of stem, grain weight per spike and number of productive ears which were on the fringe of significance. Nevertheless it can be assumed that the early lines are to a certain degree shorter and with higher grain weight per spike, but with lower number of productive ears. Lowest and insignificant were the differences between the early and the late lines by grain yield and number of ears per spike. This makes the

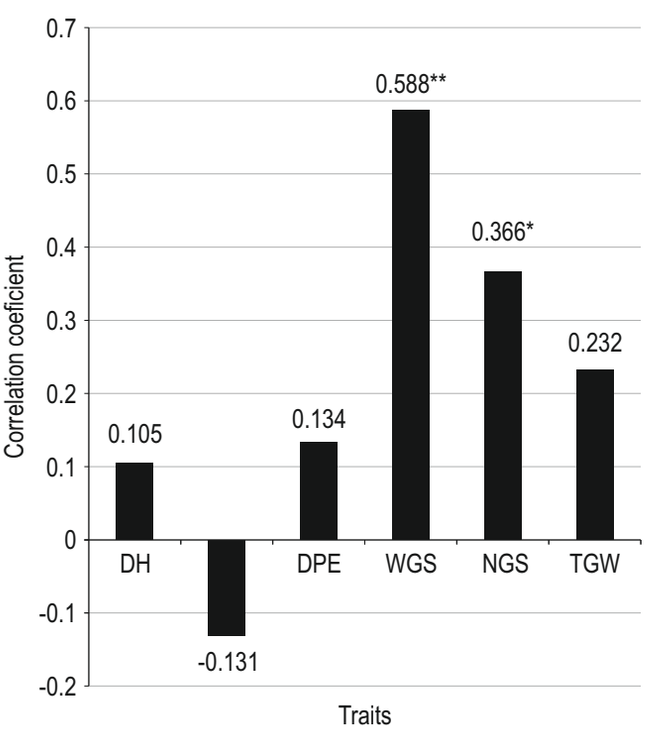

Figure 1. Correlation of grain yield with the productivity-related traits

used Ukrainian wheat cultivars a good source for increasing productivity regardless of their negative agronomy characteristics as mentioned in the Introduction.

Grain yield depends directly on the traits WGS and NGS which had significant correlations (Figure 1). The correlations with the other traits were insignificant. There was no correlation between grain yield and height of stem which makes the use of accession even with high stem desirable for hybridization. This is interesting from the point of view of the preceding information for strong positive correlation of HOS with GY (Ivanova and Tsenov, 2009, 2011). According to the investigations of Ivanova and Tsenov (2011) there are strong positive correlations between the components of productivity and grain yield, without exception. The correlations are higher under stress and when growing wheat after "bad" previous crop. The studies of Tsenov et al. (2008b) showed that grain yield was determined primarily by the number of grains per spike, and this was partially confirmed in this investigation as well. Similar results have been reported by Talebi et al. (2008) in studies on durum wheat with regard to the role of grains per spike. These authors proved the

Table 6. Spearman correlations between the traits of productivity

Variables	HOS	NPE	WGS	NGS	TGW
DH	0.297*	0.241	-0.092	0.099	-0.242
HOS		0.351*	-0.359*	-0.235	-0.109
NPE			-0.679*	-0.487*	-0.164
WGS				0.533*	0.379*
NGS					-0.519*

lack of correlation of grain yield with height of stem. On the other hand, Ivanova and Tsenov (2012) reported strong positive correlations of grain yield with all traits which directly determine it, including with NPE, which contradicts the data presented here and in previous investigations (Boyadjieva and Andonov, 2010).

There were strong correlations of height of stem with the elements of productivity (Table 6). The data from this experiment showed negative correlations of height of stem and the other traits. There was a significant correlation of this trait with date to heading. This is important to have in mind when developing early breeding lines. Date to heading was in positive correlation (insignificant) only with number of productive ears, while the correlations with the other traits were of different directions but did not differ from zero. There was a high and positive correlation of grain weight per spike with the main elements determining it: number of grains per spike and grain size, and the correlation between them naturally was strong and negative. The correlations of weight of grain per spike with height of stem and number of productive ears were high and negative. This is a prerequisite for very difficult increasing of grain yield, through high tillering capacity, but with actual possibility of combining with short stem. A direct proof of this is the data on the mean values of the two traits in the groups of early and late lines (Table 5).

The most valuable characteristics of each developed breeding line is grain yield, which is a resultant values from the expression of each of the investigated traits. For each of the 40 lines, the relative yield was calculated against the mean level of the parents (mean standard) for the respective cross; the data are presented in Table 7

Table 7. Economic characteristics of the most productive (over 8 t/ha) lines

Line, Check	DH	Variety	Freezing tolerance at -180 C,%	Relative grain yield, %
1	2	3	4	5
A3	128.0	*lutescens*	66 d	105.7
A5	130.0	*erythrospermum*	58 c	108.7
A6	131.0	*lutescens*	70 b	108.1
B3	130.8	*erythrospermum*	77 b	109.5
B7	133.7	*erythrospermum*	81 b	111.0
C9	132.4	*erythrospermum*	88 a	108.5
C5	128.5	*lutescens*	82 b	105.2
D7	130.6	*lutescens*	90 a	107.2
Obriy	128.1	*erythrospermum*	58 c	96.0
Albatross odesskiy	134.8	*erythrospermum*	68 c	102.0
Pryspa	134.5	*lutescens*	35 d	101.7
Iveta	130.0	*erythrospermum*	76 b	104.0
Mironovskaya 808	141.1	*lutescens*	94 a	85.1

together with the data on the laboratory cold resistance.

Accepting as a standard the level of productivity of cultivar Pryaspa, it was found that 8 lines had significantly higher grain yield than it, with 5 to 11 %. This was exactly 20 % from all investigated lines and can be considered a good breeding achievement. Only two lines were similar to the early cultivar Obriy, simultaneously being with about 10 % more productive, exceeding with 5 % the standard Pryaspa. By their date to heading, the rest of the cultivars were ranked between the model cultivars Iveta and Pryaspa (130–133 days).

The most productive line B7 was similar to Albatross Odeskiy by date to heading, but was with 9 % higher productivity. Two of the lines (C7 and D9) had the highest level of cold resistance at the level of Mironovskaya 80, which is the highest possible model on the standard scale. Other four lines marked with d in column 4 of the Table possessed cold resistance at the level of cultivar Iveta, i.e. cultivar Bezostaya 1, which is still high for the conditions of Bulgaria. A breeding achievement with very high value is line (C5) which combines compromisingly high grain yield with earliness similar to cultivars Galateya and Enola, plus cold resistance approximating the level of Mironovskaya 808. Therefore breeding line (C5) is a unique combination of high cold and winter resistance with earliness, which makes it very valuable as initial breeding material for future breeding in DAI.

It can be concluded that the use of wheat accessions from Ukraine is important for wheat breeding in Bulgaria. In spite of some negative traits and properties, they remain a valuable source for increasing wheat productivity by enhancing its adaptability (cold resistance, earliness, optimal height of stem). Some cultivars as Obriy, Mironovskaya 27, Mironovskaya 61, etc., seem to be donors of a complex of valuable properties, especially with regard to the efforts to achieve a compromise combination of high grain yield levels (Chamurliyski et al., 2011), grain quality (Panayotov and Kostov, 2007) and cold resistance (Tsenov et al., 2012). Their intensive use is the reason for the development of cultivars with remarkable adaptability such as Iveta (Tsenov et al., 2013), yield - cultivar Zlatitsa (Tsenov et al., 2003) and grain quality – cultivar Bozhana (Tsenov et al., 2011b). The suitability of the Ukrainian cultivars for improvement of grain quality will be considered in detail in the second report of this investigation. The use of cultivars with origin from Ukraine could be compared to the role of the Russian cultivar Bezostaya 1 in the breeding of DAI, since about 8 % from all cultivars were developed with the direct involvement of Ukrainian cultivars (Panayotov and Kostov, 2005; Tsenov et al., 2010).

Conclusions

Cultivars Albatross Odeskiy and Obriy are most suitable for combining with the aim to increase productivity in combination with earliness.

Deriving of lines with earlier date to heading and higher productivity from the early model cultivars Galateya and Enola is possible if the other component for crossing is properly selected.

Using specific cultivars, there is a possibility to combine high yield with earliness but within the limits of the traits of the specific parental cultivars for each individual combination.

The use of well known Ukrainian cultivars is a prerequisite for recombination of high productivity with high cold resistance against the background of earliness, which is difficult to achieve in conventional breeding.

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