КОРЕЛАЦИОННИ ЗАВИСИМОСТИ МЕЖДУ ПОКАЗАТЕЛИТЕ НА КЛАСА ПРИ ПЪРВО ПОКОЛЕНИЕ НА ПРАВИ И ОБРАТНИ КРЪСТОСКИ ТРИТИКАЛЕ (×*TRITICOSECALE* WITTM.)
CORRELATIONS BETWEEN SPIKE PARAMETERS OF FIRST GENERATION DIRECT AND RECIPROCAL CROSSES OF TRITICALE (×*TRITICOSECALE* WITTM.)

Христо Стоянов*, Валентин Байчев
Hristo Stoyanov*, Valentin Baychev

Добруджански земеделски инситут – Генерал Тошево
Dobrudzha Agricultural Institute – General Toshevo

***E-mail: hpstoyanov@abv.bg**

Abstract

The correlations between the spike productivity components are very important in the breeding of such a crop as triticale. On the one hand, they allow determining the components of yield which have the greatest impact on it, and on the other, they provide an opportunity to specify the influence of a particular genotype. In order to establish the correlations and a possible influence of the genotype on triticale, 10 direct and their respective reciprocal crosses were tested along with the six participating parental component varieties (*Kolorit, Akord, Respekt, Lovchanets, Blagovest* and *Borislav*). A high positive correlation between the weight of grains in the spike and the number of grains in the spike was established in all hybrid combinations regardless of the direction of crossing. The correlations between the length of the spike and the number of grains in the spike were high and positive. Differences between the direct and reciprocal crosses were observed in the correlation between the number of grains in the spike and the weight of 1,000 grains. That fact indicated that correlations related to the index 1,000 grain weight might be affected by the genotype involved, the impact of the environment on it and the direction of crossing. The absence of significant differences between the correlations in the parental forms indicated stability of the hybrid generation with regard to the formation of its productivity, making the studied crosses suitable for participation in breeding programs directed towards increasing the productivity of triticale.

Key words: correlations, direct and reciprocal crosses, triticale.

INTRODUCTION

Triticale is a cereal crop of high victual and economic importance. The increasing global demand for raw materials from cereals is the reason for the greater interest to this crop since it gives higher yields than bread wheat and possesses higher resistance to biotic and abiotic stress (Gulmezoglu et al., 2010). This imposes the necessity to develop triticale varieties combining high productivity and high grain quality.

One of the most important indices in the breeding of cereals is yield. Its value is a complex index related to other traits such as spike parameters (Rachovska and Ur., 2010; Reeves et al., 1999; Donmez et al., 2001), number of productive tillers (Nikolova and Panayotov, 2008), photosynthetic activity of the plant (Stoyanov, 2013a). Certain correlations are realized between these indices allowing to indirectly determine the yield from the crop as well as to calculate the production potentials of the plants.

Certain correlations are also formed between the morphological characteristics of the triticale spikes (length of spike, number of spikelets per spike, number of grains per spike, weight of grains per spike). Since triticale is a product from wide hybridization, the hybrid progeny in which the plant set is at the current moment, is significant for their values. This is due to the complex and long formative process typical for the amphidiploid forms. Thus for example, when investigating the correlation coefficients between the number and the weight of grins per spike in second and third hybrid triticale generations, Baychev (1996) reported significantly higher correlation coefficients in the second hybrid generation than in the third, the correlation values being significantly high in both generations. This can be explained by the variability of individuals of different productivity in third hybrid generation, and also by the existing tendency toward greater number of grains at the expense of their size.

This author pointed out that with regard to the correlations of 1000 grain weight with the number of grains per spike, rather differing correlations were observed depending on the generation and the investigated cross, the tendency being the higher grain number correlating with smaller size. This tendency was better expressed in third hybrid generation. The correlation between grain weight per spike and length of spike was also marked by great variability with regard to the generation and the investigated cross, the variation of the correlation being from low negative to very high positive (Baychev, 1996). There was also a low correlation between plant height and spike productivity, the values being from slightly negative to slightly positive. A tendency was observed toward triticale forms with more productive spike being high-stemmed. Similar data were reported for common wheat, both in stable cultivars and forms (Stoyanov, 2013b; Rachovska and Ur., 2010) and in early generations of hybrids (Nikolova and Panayotov, 2008). At the same time Zhang et al. (2012) reported that the greater number of grains per spike did not always determine higher yield, which was highly dependent on the genotype. The correlations existing between the different indices of spikes are very important for the breeding work with triticale. On the one hand, they allow determining the combinations between the individual components of productivity, and on the other – evaluation with regard to yield. Specifying such correlations in the hybrid progenies allows determining to what degree an individual genotype influences the formation of productivity.

Especially important in this respect is the analysis on the correlations in the first hybrid generation. The use of correlation data for direct and reciprocal crosses allows following the inheritance of productivity formation according to the initial forms involved (Fonseca and Patterson, 1968).

The aim of this investigation was to determine the variations between the correlations of the spike indices in direct and reciprocal crosses in first hybrid generation and to compare them to the same correlations in the parental forms.

MATERIALS AND METHODS

Ten direct and ten reciprocal crosses were used, which were in first hybrid generation between triticale cultivars Kolorit (K), Akord (A), Respekt (R), Lovchanets (L), Blagovest (Bv) and Borislav (Bs), breeding of Dobrudzha Agricultural Institute – General Toshevo (Table 1).

The trial was carried out during harvest year 2014–2015. The first hybrid generation from the used crosses was sown in plots, each plot consisting of 2 m long row, with spacing 30 cm between the rows and 10 cm within the rows. The number of rows for each hybrid combination depended on the seeds obtained from the cross in the previous year. Sowing was done manually, within the dates standard for triticale (10^{th} – 15^{th} October), planting 20 seeds per row. Harvesting of spikes was done at full maturity. Twenty spikes of good seed set were selected from each cross, without damages caused by diseases and pests. The application of this method in the trial approximated practical breeding, in which the best developed spikes were selected (Baychev, 1996).

Each spike was analyzed according to the following traits: length of spike (LS, cm), number of spikelets per spike (NSS), number of grains per spike (NGS), weight of grains per spike (WGS, g), 1000 grain weight, (M1000, g).

The data obtained were averaged by accessions and in general, taking into account the variation coefficient (VC) and the statistical error. Correlation analysis was carried out to determine the correlations between the spike indices of the investigated direct and reciprocal crosses and of the initial culti-

Table 1. Direct and reciprocal crosses by origin

Direct crosses			Reciprocal crosses		
No	Breeding No	Origin	No	Breeding No	Origin
1	2/14	Kolorit x Akord (K x A)	11	21/14	Akord x Kolorit (A x K)
2	3/14	Kolorit x Respekt (K x R)	12	31/14	Respekt x Kolorit (R x K)
3	10/14	Kolorit x Borislav (K x Bs)	13	101/14	Borislav x Kolorit (Bs x K)
4	23/14	Akord x Respekt (A x R)	14	32/14	Respekt x Akord (R x A)
5	27/14	Akord x Lovchanets (A x L)	15	73/14	Lovchanets x Akord (L x A)
6	29/14	Akord x Blagovest (A x Bv)	16	93/14	Blagovest x Akord (Bv x A)
7	30/14	Akord x Borislav (A x Bs)	17	103/14	Borislav x Akord (Bs x A)
8	37/14	Respekt x Lovchanets (R x L)	18	74/14	Lovchanets x Respekt (L x R)
9	39/14	Respekt x Blagovest (R x Bv)	19	94/14	Blagovest x Respekt (Bv x R)
10	40/14	Respekt x Borislav (R x Bs)	20	104/14	Borislav x Respekt (Bs x R)

vars. The significance of the obtained results was registered. Microsoft Excel 2003 was used for summarizing the data and for variation analysis, and IBM SPSS Statistics 19 – for correlation analysis.

RESULTS AND DISCUSSION

Variation analysis

The results from the variation analysis are presented in Table 2. The data allowed following the comparatively low values of variation of the parameters NSS and LS and the higher variation of NGS. At the same time, the lower variation of the values of all three indices in the first hybrid generation revealed the high level of homogeneity typical for F_1. The values of variation of the index NGS between the cultivars and the hybrids had very small differences emphasizing the greater effect of the heritability factors on the formation of this trait. Similar data for the behavior of NSS have been reported in various researches on triticale, Baychev, (1996), common winter wheat, Kashif and Khaliq (2004), Okuyama et al. (2004), Rawson (1969), Rahman and Wilson (1977), Mahmood and Shahid (1993), Akram et al. (2008) and other amphidiploid forms (Stoyanov, 2014). On the other hand, the higher variation values of the index NGS for the entire investigated plant set by cultivars and hybrids implied greater effect of the environmental conditions as compared to the effect of the genotype (Stoyanov, 2013b). With regard to LS, a large number of investigations specify this index as highly variable (Kashif and Khaliq, 2004; Fufa et al., 2005; Shahid, 2000; Mahmood and Shahid, 1993; Friend, 1965; Akram et al., 2008). The high variation of LS is a typical feature of the amphydiploid forms (Stoyanov, 2014), which triticale also is.

APPENDIX

Table 2. Results from the analysis of variances of the studied crosses and cultivars

Cultivar/Cross	LS, cm		NSS		NGS		WGS, g		M 1000, g	
	$\overline{X} \pm S_{\bar{x}}$	VC, %	$\overline{X} \pm S_{\bar{x}}$	VC, %	$\overline{X} \pm S_{\bar{x}}$	VC, %	$\overline{X} \pm S_{\bar{x}}$	VC, %	$\overline{X} \pm S_{\bar{x}}$	VC, %
Kolorit (K)	12,6±0,41	14,57	30,6±0,59	8,64	106±4,7	19,70	5,4±0,28	23,18	51±1,9	17,41
Akord (A)	14,8±0,32	9,71	34,5±0,49	6,41	96±3,5	16,24	5,6±0,26	20,95	58±1,4	10,98
Respekt (R)	13,3±0,30	10,21	33,7±0,45	5,97	91±4,8	23,37	5,0±0,35	30,90	54±1,4	11,62
Lovchanets (L)	13,4±0,49	16,70	30,4±0,70	10,37	100±5,8	25,76	5,3±0,36	30,88	52±1,2	10,37
Blagovest (Bv)	12,9±0,45	15,49	32,8±0,82	11,25	116±5,7	21,79	6,3±0,35	25,09	54±1,3	11,13
Borislav (Bs)	14,1±0,31	9,81	31,0±0,54	7,83	74±2,7	16,33	4,6±0,25	24,29	62±1,9	14,29
2/14 (K x A)	13,1±0,26	8,85	30,2±0,60	8,90	99±3,1	13,94	5,2±0,22	18,45	52±0,9	7,51
21/14 (A x K)	14,0±0,34	10,88	32,2±0,67	9,26	82±4,4	24,18	4,9±0,35	31,60	60±1,8	13,66
3/14 (K x R)	14,6±0,31	9,46	34,2±0,49	6,41	107±5,7	23,85	5,9±0,33	24,98	56±1,8	14,51
31/14 (R x K)	13,0±0,30	10,27	31,7±0,70	9,82	96±4,7	21,93	5,6±0,38	30,12	58±1,5	11,66
10/14 (K x Bs)	12,9±0,19	6,77	30,9±0,42	6,16	73±2,3	14,01	4,6±0,17	16,63	62±0,9	7,11
101/14 (Bs x K)	13,1±0,34	11,55	32,5±0,73	10,01	75±3,7	22,11	4,7±0,29	27,79	62±1,6	11,75
23/14 (A x R)	13,3±0,27	9,15	32,6±0,59	8,13	79±2,9	16,38	4,9±0,29	26,29	62±2,1	15,00
32/14 (R x A)	12,0±0,22	8,20	30,0±0,64	9,49	78±2,2	12,49	4,4±0,15	15,53	57±1,7	13,09
27/14 (A x L)	12,3±0,18	6,54	29,9±0,47	7,02	71±2,3	14,29	3,9±0,14	15,88	55±1,1	9,19
73/14 (L x A)	12,9±0,23	7,81	31,2±0,50	7,16	96±3,7	17,28	5,1±0,25	22,02	53±1,0	8,81
29/14 (A x Bv)	12,5±0,29	10,39	30,5±0,54	7,94	78±3,7	20,88	4,3±0,27	28,65	54±1,4	11,18
93/14 (Bv x A)	11,9±0,34	12,91	29,8±0,68	10,19	86±5,1	26,42	4,6±0,29	27,72	54±1,3	10,35
30/14 (A x Bs)	14,1±0,35	11,02	31,2±0,55	7,88	83±3,2	17,32	5,1±0,22	19,71	61±1,4	10,58
103/14 (Bs x A)	12,3±0,29	10,89	28,2±0,52	8,25	71±3,1	19,28	4,2±0,26	27,83	58±1,6	12,43
37/14 (R x L)	12,4±0,32	11,68	31,6±0,52	7,38	84±2,9	15,27	5,0±0,28	25,17	59±1,7	12,92
74/14 (L x R)	12,5±0,24	8,63	30,3±0,37	5,46	87±2,5	13,02	4,5±0,16	15,86	52±1,1	9,56
39/14 (R x Bv)	12,8±0,33	11,41	32,2±0,65	9,10	88±4,3	21,95	4,8±0,32	29,53	54±1,7	14,06
94/14 (Bv x R)	12,4±0,27	9,59	33,2±0,69	9,25	88±2,9	15,14	5,2±0,27	20,26	59±1,2	8,75
40/14 (R x Bs)	12,2±0,32	11,73	30,9±0,79	11,49	69±3,5	22,44	4,2±0,26	28,10	60±1,5	11,24
104/14 (Bs x R)	14,4±0,20	6,11	31,5±0,46	6,48	88±2,3	11,69	5,8±0,18	13,57	66±1,4	9,85
Total	13,1±0,07	12,05	31,4±0,13	9,46	87±0,9	23,78	4,9±0,06	26,64	57±0,3	13,37

LS – Length of spike, NSS – Number of spikelets per spike, NGS – Number of grains per spike, WGS – Weight of grains per spike, M 1000 – Weight of thousand grains.

The variation of the weight indices was also comparatively high (WGS, M 1000). The high variation of WGS was valid for both the cultivars and the first hybrid progeny, which was indicative for the identical influence of the environmental conditions on the different genotypes. This thesis is supported by the minimum and maximum values of variation of the index: 13,57-31,60. Such high values are related to variable plumpness of grains in individual plants, and also to variable seed set. The values of NGS and M 1000 indicate that the high variation of WGS is due to a greater extent to the non-identical seed set than to the differences in grain plumpness. Similar data have been reported for triticale, as well as for bread wheat and other amphidiploid species.

Correlation analysis

Correlations between length of spike and number of spikelets per spike

The data on the correlations between NSS and LS are presented in Table 3. Regardless of the type of cross and its origin, comparatively high and highly significant correlations between the two traits were observed. Crosses 27/14 (A x L), 103/14 (Bs x A) and 104/14 (Bs x R) were exceptions. The lack of significant correlations is probably related to the lack of homogeneity in the first hybrid progeny, which is a typical feature of the hybrids in the amphidiploid plant forms.

In the group of direct crosses, the correlation coefficients varied from 0,435 (cross 27/14) to 0,898 (cross 2/14). Respectively, in the group of reverse crosses, the correlation coefficients were from 0,409 (cross 103/14) to 0,833 (cross 31/14). Significant differences in the correlation coefficients of the set of direct crosses and the set of reciprocal crosses were not observed.

The predominant high and significant correlations implied that the higher spike length determined higher number of spikelets. The same tendency was valid for the parental forms as well. In some of the crosses (2/14 and 21/14; 3/14 and 31/14; 23/14 and 32/14; 29/14 and 93/14; 39/14 and 94/14), correlation coefficients were observed which were closer to one of the two parental components, regardless of the direction of crossing. This is probably related to the quantitative heritability of the traits and the dominance of certain allelic states over other. Gulmezoglu et al. (2010) also reported high correlations between these two indices in triticale, averagely 0,723**. On the other hand, Fantahun and Belay (2012) recorded different and opposite data averaged for 49 triticale accessions. Similar data have been reported on the behavior of the correlations between NSS and LS in common winter wheat by Kashif and Khaliq (2004), Okuyama et al. (2004), Rawson (1969), Rahman and Wilson (1977), Mahmood and Shahid (1993), Akram et al. (2008), Stoyanov (2013b).

Correlations between length of spike and number of grains per spike

Very high correlations were observed between the indices LS and NGS in the investigated crosses. Fantahun and Belay (2012) also reported high significant correlations of the two indices in triticale. This is related to the higher seed set of the longer spikes, which, on the one hand, is due to the greater number of spikelets in the longer spikes, and on the other – to the correlation of the shorter spikes producing lower number of fertile spikelets. Nine out of the ten direct crosses had correlation coefficients exceeding 0,600 at a very high level of significance. The only exception was cross 29/14 (A x Bv). The reciprocal crosses followed the same tendency with the exception of cross 74/14 (R x L). The direct and the reciprocal crosses in a large number of the cases did not differ significantly by their correlations regardless of the differences between the parental forms. Exceptions were crosses 29/14 and 74/14, in which there was no correlation between LS and NGS.

The straight and reverse combinations of Kolorit and Akord had highest values of the correlation coefficients (0,834** and 0,798**, respectively). These hybrid combinations were characterized with the formation of lower number of grains. Since Baychev (1996) and Gulmezoglu et al. (2010) have reported negative correlation of M1000 with NGS, these crosses can be expected to form heavier grains.

The high values of NGS in cultivar Kolorit and its increased variation, together with the lower values of LS and their greater variation, allow making the assumption that this cultivar possesses plasticity with regard to seed set. This is so because even the short and small spikes formed higher number of grains. Such a correlation was not observed in the rest of the cultivars and in most of the crosses, regardless of the direction of crossing. Probably crosses 29/14 and 74/14 followed an identical tendency.

Correlations between length of spike and weight of grains per spike

High, positive and significant correlations of the indices WGS and LS were realized in the investigated genotypes. On the one hand, this is related to the possibility of the longer spikes forming more and heavier grains, and on the other – to the fact that the smaller grains usually originated from secondary tillers and received less nutrition. Nevertheless, the high and significant correlation coefficients deter-

Table 3. Results from the correlation analysis of the studied crosses and cultivars

Genotype	Cultivar/ Cross	Correlations								
		LS and NSS	LS and NGS	LS and WGS	LS and W1000	NSS and NGS	NSS and WGS	WGS and NGS	WGS and W1000	NGS and W1000
Cultivar A	***Kolorit***	0,640**	0,052	0,212	0,270	0,457*	0,731**	0,734**	0,600**	-0,089
Cultivar B	***Akord***	0,595**	0,470*	0,506*	0,244	0,371	0,284	0,856**	0,622**	0,133
A x B	***2/14***	0,898**	0,834**	0,748**	0,298	0,794**	0,683**	0,910**	0,738**	0,394
B x A	***21/14***	0,659**	0,798**	0,850**	0,601*	0,841**	0,681**	0,927**	0,792**	0,529*
Cultivar A	***Kolorit***	0,640**	0,052	0,212	0,270	0,457*	0,731**	0,734**	0,600**	-0,089
Cultivar B	***Respekt***	0,713**	0,761**	0,792**	0,497*	0595**	0,644**	0,933**	0,637**	0,328
A x B	***3/14***	0,856**	0,752**	0,580**	-0,227	0,580**	0,467*	0,869**	0,412	-0,080
B x A	***31/14***	0,833**	0,761**	0,779**	0,578**	0,546*	0,558*	0,964**	0,839**	0,675**
Cultivar A	***Kolorit***	0,640**	0,052	0,212	0,270	0,457*	0,731**	0,734**	0,600**	-0,089
Cultivar B	***Borislav***	0,823**	0,863**	0,665**	0,200	0683**	0,499*	0,842**	0,794*	0,346
A x B	***10/14***	0,706**	0,688**	0,671**	0,195	0,447*	0,378	0,911**	0,539*	0,147
B x A	***101/14***	0,602**	0,718**	0,687**	0,448*	0,721**	0,707**	0,953**	0,710**	0,477*
Cultivar A	***Akord***	0,595**	0,470*	0,506*	0,244	0,371	0,284	0,856**	0,622**	0,133
Cultivar B	***Respekt***	0,713**	0,761**	0,792**	0,497*	0,595**	0,644**	0,933**	0,637**	0,328
A x B	***23/14***	0,842**	0,657**	0,446*	0,139	0,614**	0,462*	0,847**	0,838**	0,440
B x A	***32/14***	0,740**	0,627**	0,632**	0,158	0,248	0,238	0,590*	0,599**	-0,289
Cultivar A	***Akord***	0,595**	0,470*	0,506*	0,244	0,371	0,284	0,856**	0,622**	0,133
Cultivar B	***Lovchanets***	0,832**	0,885**	0,783**	0,127	0,698**	0,659**	0,930**	0,606**	0,277
A x B	***27/14***	0,435	0643**	0,620**	0,116	0,006	0,105	0,835**	0,507*	-0,046
B x A	***73/14***	0,802**	0,619**	0,639**	0,340	0,429	0,382	0,930**	0,651**	0,328
Cultivar A	***Akord***	0,595**	0,470*	0,506*	0,244	0,371	0,284	0,856**	0,622**	0,133
Cultivar B	***Blagovest***	0,644**	0,539**	0,666**	0,583**	0,797**	0,731**	0,936**	0,543*	0,219
A x B	***29/14***	0,806**	0,365	0,620**	0,535*	0,214	0,363	0,947**	0,792**	0,566**
B x A	***93/14***	0,808**	0,548*	0,704**	0,458*	0,539*	0,622**	0,921**	0,318	-0,070
Cultivar A	***Akord***	0,595**	0,470*	0,506*	0,244	0,371	0,284	0,856**	0,622**	0,133
Cultivar B	***Borislav***	0,823**	0,863**	0,665**	0,200	0,683**	0,499*	0,842**	0,794**	0,346
A x B	***30/14***	0,807**	0,705**	0,587**	0,022	0,495*	0,382	0,858**	0,544*	0,046
B x A	***103/14***	0,409	0,813**	0,735**	0,317	0,666**	0,549*	0,933**	0,778**	0,508*
Cultivar A	***Respekt***	0,713**	0,761**	0,792**	0,497*	0,595**	0,644**	0,933**	0,637**	0,328
Cultivar B	***Lovchanets***	0,832**	0,885**	0,783**	0,127	0,698**	0,659**	0930**	0,606**	0,277
A x B	***37/14***	0,816**	0,789**	0,771**	0,651**	0,721**	0,710**	0,950**	0,913**	0,751**
B x A	***74/14***	0,517*	0,235	0,401	0,331	-0,084	0,020	0,802**	0,589**	-0,006
Cultivar A	***Respekt***	0,713**	0,761**	0,792**	0,497*	0,595**	0,644**	0,933**	0,637**	0,328
Cultivar B	***Blagovest***	0,644**	0,539**	0,666**	0,583**	0,797**	0,731**	0,936**	0,543*	0,219
A x B	***39/14***	0,834**	0,870**	0,908**	0,616**	0,747**	0,738**	0,914**	0,747**	0,419
B x A	***94/14***	0,819**	0,663**	0,549*	0,168	0,705**	0,649**	0,918**	0,743**	0,423
Cultivar A	***Respect***	0,713**	0,761**	0,792**	0,497*	0,595**	0,644**	0,933**	0,637**	0,328
Cultivar B	***Borislav***	0,823**	0,863**	0665**	0,200	0,683**	0,499*	0,842**	0,794**	0,346
A x B	***40/14***	0,787**	0,861**	0,807**	0,296	0,590**	0,506*	0,910**	0,635**	0,263
B x A	***104/14***	0,465*	0,551*	0,782**	0,403	0,408	0,224	0,658**	0,551*	-0,262

LS – Length of spike, NSS – Number of spikelets per spike, NGS – Number of grains per spike, WGS – Weight of grains per spike, W 1000 – Weight of thousand grains.
** - Correlations are significant at α=0.05*
*** - Correlations are significant at α=0.01*

mined a tendency toward positive correlation of the two indices. Since LS is an index characterized with higher variation depending on the specific genotype, contradictory data are often reported for this correlation (Gulmezoglu et al., 2010; Fantahun and Belay, 2012).

Significant variations between the correlation coefficients of the direct and reciprocal crosses were not observed. Some increase of the correlation between WGS and LS was noticed when the cross involved cultivar Respekt as a mother form. This may be due to the fact that the highest correlation coefficient was realized in this cultivar (0,792**), and that this trait was inherited through it as a female parent. This correlation was evident in crosses 31/14, 32/14, 37/14, 39/14, 40/14.

Among the investigated cultivars, Kolorit formed the lowest correlation of the two indices (0,212), which was low and statistically not significant. This was due to the fact that the seed set of Kolorit was not dependent on the length of the spike, as emphasized by the lack of correlation of LS with NGS and of LS with M 1000. However, the crosses which involved this cultivar were not influenced by these correlations, regardless of the direction of crossing.

Correlations between length of spike and 1000 grain weight

The presence of a correlation between W1000 and LS is related to increase of grain size in the larger grains. Usually, the main spike of the plant and the other larger spikes receive are well supplied with sufficient nutrients, the grains on the smaller spikes remaining smaller due to the weaker uptake of assimilates. The same dependency could be observed also with regard to the correlations between NGS and LS, depending, however, on the values of NGS. The presence of a correlation between W 1000 and LS can also be due to the higher number of grains on the spike (their greater compactness), regardless of their fertility because the more compact spikes formed smaller grains.

Among the investigated cultivars, such type of correlation was observed in Respekt and Blagovest. Both cultivars were characterized with almost equal values of LS, NSS and M 1000 but they differed by NGS. This indicated that their correlation coefficients resulted from different mechanisms related to variations in the seed set of the two cultivars.

Among the crosses, significant correlations were found in 21/14, 29/14, 31/14, 37/14, 39/14, 93/14. The values of the correlation coefficients were moderate, within the range 0,5-0,6. Apart from the above crosses, no significant differences were found in the other, regardless of the direction of crossing and the cultivars involved, without a definite tendency and dependencies being clearly formed. Similar data for triticale and lack of a clearly expressed tendency have also been reported by Gulmezoglu et al. (2010).

Correlations between number of spikelets and number of grains per spike

It has quite often been reported in various investigations (Baychev, 1996; Vajieka (1998); Gulmezoglu et al., 2010; Fantahun and Belay (2012); Kashif and Khaliq, 2004; Mahmood and Shahid, 1993, Sinclair and Jamieson, 2006, Siddique et al., 1989; Akram et al., 2008) that the two traits usually correlate highly and significantly. This is especially valid for bread wheat, in which the biometrical indices possess high stability in each specific genotype.

A different tendency was observed in the investigated cultivars and early hybrid generations of triticale. The correlation coefficients were in a large number of the cases low and insignificant (negative in cross 74/14). The values of the direct crosses varied from 0,006 to 0,794, and of the reciprocal crosses – from -0,084 to 0,841. Correlations were not observed in cultivar Akord as well, and low values were read in cultivars Kolorit and Respekt.

In some cases the straight and reverse crosses differed considerably by their correlation coefficients (27/14 and 73/14; 23/14 and 32/14). This was probably due to the effect of the parental components on NSS and to the different response to the environment with regard to NGS. In spite of these correlations, the most of the correlations were significant and high. Especially high were the values of crosses 2/14 (K x A) and 21/14 (A x K) inspite of the low correlation coefficients of the two initial cultivars (Akord (0.371) and Kolorit (0.457*)). The absence or the low values of this type of correlations is often related to non-identical seed set in some plants. On the other hand, it is related to the very strong influence of the environmental conditions on fertility. Such a thesis is confirmed by the variation values of the index NGS (Table 2).

Correlations between number of spikelets per spike and weight of grains per spike

The correlations between WGS and NSS were highly variable and strictly dependent on the investigated accession. This was due to the fact that the seed sets of the spikes were not identical in the different cultivars. In the investigated cultivars and crosses this was clearly emphasized by the correlation coefficients of cultivars Akord (0,284 – lack of correlation), Borislav (0,499* - positive and moderately significant correlation) and Blagovest (0,731** -

positive and highly significant correlation). Therefore similar correlation was expected in the crosses. Gulmezoglu et al. (2010) also pointed out a significant and high correlation (0,607**) between the two indices, averaged for the investigated cultivars.

Regardless of the participating parental components and the direction of crossing, there was no clear and definite tendency with regard to the formation of correlation. Only some advantage of cultivar Respekt was observed, which was involved as a female component, but in contrast to the correlation of LS with M1000, in this case the cross 32/14 was an exception.

In four crosses involving cultivar Akord (23/14, 27/14, 29/14, 30/14), and in the cultivar itself a correlation was absent. Cross 21/14, which included Kolorit as well, was an exception. It is possible that Kolorit increased the value of the correlation when involved as a male component in the cross. This emphasized the high importance of the number of spikelets formed in this cultivar.

Correlations between weight of grains per spike and number of grains per spike

The data presented on the investigated cultivars and crosses showed very high positive correlation between the traits WGS and NGS. This, on its part, means that the increased number of grains leads to a respective increase of the spike productivity. Particularly high correlation coefficients were formed in the studied crosses, the values of 13 out of 20 crosses being higher than 0,9 at the highest levels of significance. Moderate correlation was formed in crosses 32/14 and 104/14 without being related to lower correlation in some of the initial parental cultivars included in the cross.

A clear tendency was formed, regardless of the investigated genotype, of a high correlation existing between the indices M 1000 and NGS similar to a functional one. These data are in accordance with the results of Blanco et al. (2001) for triticale. Dogan et al. (2009) also reported high correlations of the two indices in old and recently developed lines of hexaploid triticale. However, other researches report that such a correlation was in strict relation with the values of M 1000 and the correlation formed between NGS and M 1000 (Baychev, 1996). Stoyanov (2013b) reported that in wheat the correlation of WGS with NGS was also high. A clear and distinct relation between the lower correlation coefficients and the values of M 1000 was not observed in the investigated hybrid progenies.

The presence of such high values means that in the investigated accessions the number of grains is the main component which forms spike productivity. This was particularly evident in cultivars Respekt, Lovchanets and Blagovest. A specific correlation with regard to the direction of the cross or the involved cultivars was not observed. Similar data have been reported also for common winter wheat (Okuyama et al., 2004; Rachovska and Ur, 2010; Shahid, 2000; Fischer and HilleRisLambers, 1978; Fonseca and Patterson, 1968, Mohsin et al., 2009).

Correlations between weight of grain per spike and thousand grain weight

Correlations were observed similar to those between WGS and NGS. Although the values did not approximate 0,9 (from 0,318 to 0,913**, mostly (13 out of 20) within the range 0,6-0,8), the tendency toward comparatively high, positive and highly significant values remained the same. Two of the participating crosses were exceptions - 3/14 and 93/14. The highest correlation coefficient was formed in cross 37/14 (0,913**), and the lowest significant coefficient – in cross 104/14 (0,551*). In cultivar Borislav, the highest correlation was formed (0,794**), and the lowest one was in cultivar Kolorit (0,600**). Gulmezoglu et al. (2010) and Dogan et al. (2009) reported the opposite data on the correlation with M 1000: significant correlation coefficients were not formed in the genotypes they investigated.

The high correlations indicated that the grater spike productivity was related to bigger grain size. This, on the one hand, emphasized the significance of M 1000 as the component second in importance for productivity, and on the other – defined this index as important for triticale from a breeding point of view. Numerous investigations (Kashif and Khaliq, 2004; Fufa et al., 2005; Mahmood and Shahid, 1993) have determined M 1000 as the yield component influenced to a very high degree by the environment. This allows to contend that the high correlation coefficients of the investigated cultivars and hybrids indicate that there are comparatively good conditions for the development of this crop. The results were realized under a well expressed drought (May–June) during yield formation (Stoyanov, personal communication). These data emphasize the high tolerance of triticale to unfavorable environments during the reproductive period.

No clear tendency was observed in the investigated crosses dependent on the direction of the cross or the involved components. It can be assumed that this was due to the rather similar correlation coefficients between the initial cultivars. Regardless of this, the higher or lower values of the direct and reciprocal crosses can not be related to a certain genotypic affiliation.

Correlations between number of grains per spike and thousand grain weight

Different investigations often report negative correlations between the indices M 1000 and NGS (Baychev, 1996; Dogan et al., 2009; Gulmezoglu et al., 2010; Fantahun and Belay, 2012). This is explained by the fact that usually the greater the number of the grains formed in the spikes, the smaller they remain. Such correlation is typical not only for triticale but for most types of wheat (Khaliq et al., 2004; Kashif and Khaliq, 2004; Shahid, 2000; Mahmood and Shahid, 1993; Akram et al., 2008; Zhang et al., 2012; Stoyanov, 2013b).

The reciprocal correlation of larger grains being formed in spikes with lower fertility is a peculiarity of a great number of amphidiploids, especially at the early generations (Stoyanov, 2014). The small number of grains, which, however, are very large, is typical for common winter wheat under recurrent and severe drought which changes the correlation between M 1000 and NGS (Petrova, 2003). Therefore this correlation is assumed to be strongly influenced by the environment. Such correlations outline the expectation that a negative correlation will also be formed in the investigated cultivars and hybrids, or that a correlation will be absent. In a large number of crosses (14 out of 20), the general tendency was valid of M 1000 and NGS not forming significant correlation. It is interesting to mention that in six crosses a high, positive and significant correlation was observed between the two traits; in three of these crosses (29/14, 31/14, 37/14) the correlation coefficients were within the range 0,6-0,7 at the highest levels of significance.

The data from the variation analysis additionally emphasized the high value of these crosses since, apart from the high correlation, the mean values of NGS and WGS were also very high. Such genotypes should be further investigated to determine the heritability of their correlations.

Significant correlations were not observed in the investigated cultivars. With the exception of the above crosses, considerable variations among the first hybrid generation were not found as well, regardless of the direction of crossing. The presence of significant and high correlations among the hybrids could not be related to the effect of a certain parental component.

Correlations between number of spikelets per spike and thousand grain weight

These correlations were not significant for the investigated cultivars and hybrids because significant values of the correlation coefficients were not formed in neither of the investigated accessions. Fantahun and Belay (2012) reported a significantly high negative correlation between these two indices. The absence of any tendency means that grain size was not influences by the number of formed spikelets. This indicates that different genetic systems are related to the expression of the two traits.

Breeding value of the analyzed material

The presence of high correlation coefficients of the correlations between WGS and NGS, as well as between WGS and M 1000 in the investigated hybrids did not give a sufficiently clear idea of the crosses from a breeding point of view. Therefore selection should be directed toward the higher values of the correlations pointed out above, but some negative correlations should also be avoided. Such are the absence of a correlation between M 1000 and NGS, the low correlations between NSS and LS, as well as the absence of a correlation between NGS and NSS. None of the investigated cultivars met these criteria. This was related to the presence and the advantage of a specific component of yield which dominated over the other. Therefore productivity was balanced in first hybrid generation and as a result the direct and reciprocal crosses did not differ significantly by their correlation coefficients as a general tendency. The requirements outlined above, however, were met by crosses 31/14, 37/14 and 101/14. All three crosses were characterized with moderate values of the indices LS, NSS, NGS and WGS, and with moderately high values of M 1000. Therefore it is necessary to carry out purposeful selection in the next generations of these progenies to obtain grain triticale lines with balanced productivity.

CONCLUSIONS

The presented results allow the following conclusions:

1. The investigated direct and reciprocal crosses in a large number of the cases had high values of the correlations of weight of grains per spike (WGS) with the number of grains per spike (NGS) and the weight of 1000 grains (M 1000), of the length of spike (LS) with the number of grains per spike (NGS), and of the number of spikelets per spike (NSS) and the number of grains per spike (NGS).

2. Regardless of the direction of crossing and of the significant differences between the two initial cultivars, the correlations did not vary significantly by value in general, with certain exceptions.

3. A large number of the investigated crosses were characterized with high correlations between WGS and NGS, NGS and LS, and NGS and NSS, which emphasized their high breeding value because such correlations are often related to increased productivity of spike.

4. The investigated cultivars differed slightly between themselves in comparison to most of the crosses according to their correlations, with the exception of the correlations with M 1000, for which a specific tendency could not be formed.

5. The effect of the initial parent could not be determined in the investigated direct and reciprocal crosses due to the absence of a definite tendency, with the exception of the supposed influence of cultivar Respekt on the correlation between WGS and LS.

6. Some of the investigated crosses (31/14, 37/14 and 101/14), apart from the high correlation coefficients of WGS with NGS and of WGS with M 1000, also demonstrated high correlation of M 1000 with NGS, of NSS with NGS and LS simultaneously, which makes them a potential source for developing of grain triticale lines with well balanced productivity.

REFERENCES

Akram, Z., S.U. Ajmal, and M. Munir, 2008. Estimation of correlation coefficient among some yield parameters of wheat under rainfed conditions. Pakistan Journal of Botany, 40(4), 1777–1781.

Baychev, V., 1996. Genetichni korelatsii mezhdu produktivnostta na klasa i nyakoi drugi priznatsi pri hibridni formi triticale. Rastenievadni nauki, god. XXXIII, 5, 32–36. *Blanco, A., S. Rajaram and W.E. Kronstad*, 2001. Agronomic potential of synthetic hexaploid wheat derived populations. Crop Science 41: 670–676.

Dogan, R., O. Kacar, N. Coplu and N. Azkan, 2009. Characteristics of new breeding lines of triticale. African Journal of Agricultural Research, 4(2): 133–138.

Donmez, E., R.G. Sears, J.P. Shroyer and G.M. Paulsen, 2001. Genetic Gain in Yield Attributes of Winter Wheat in the Great Plains, 41–5, 1412–1419

Fantahun, B. and G. Belay, 2012. Correlation and Path Coefficient Analysis on some Breeding Lines of the Man Made Crop (Triticale). Journal of the Drylands, 5(1): 384–395.

Fischer, R.A. and D. Hille Ris Lambers, 1978. Effect of environment and cultivar on source limitation to grain weight in wheat. Australian Journal of Agricultural Research, 29(3), 443–458.

Fonseca, S. and F.L. Patterson, 1968. Yield Component Heritabilities and Interrelationships in Winter Wheat (*Triticum aestivum* L.). Crop Science, 8–5, 614–617.

Friend, D.J.C., 1965. Ear Length and Spikelet Number of Wheat Grown at Different Temperatures and Light Intensities. Canadian Journal of Botany, 43(3), 345–353.

Fufa, H., S.P. Baenziger, B.S. Beecher, R.A. Graybosch, K.M. Eskridge and L.A. Nelson, 2005. Genetic improvement trends in agronomic performances and end-use quality characteristics among hard red winter wheat cultivars in Nebraska. Euphytica, 144, 187–198.

Gulmezoglu, N., O. Alpu and E. Ozer, 2010. Comparative performance of triticale and wheat grains using path analysis. Bulgarian Journal of Agricultural Science, 16(4): 443–453.

Kashif, M. and I. Khaliq, 2004. Heritability, Correlation and Path Coefficient Analysis for Some Metric Traits in Wheat. International Journal of Agriculture and Biology, 6–1, 138–142.

Khaliq, I., N. Parveen and M.A. Chowdhry, 2004. Correlation and Path Coefficient Analyses in Bread Wheat. International Journal of Agriculture and Biology, 6–4, 633–635.

Mahmood, A. and M. Shahid, 1993. Inheritance and inter-relationship studies of some quantitative characteristics in wheat. Pakistan Journal of Agricultural Research, 14–2/3, 121–125.

Mohsin, T., N. Khan and F.N. Naqvi, 2009. Heritability, phenotypic correlation and path coefficient studies for some agronomic characters in synthetic elite lines of wheat. Journal of Food, Agriculture & Environment, 7–3/4, 278–282.

Nikolova, E. and I. Panayotov, 2008. Basledyavane na kolichestveni priznatsi v F1 hibridi zimna obiknovena pshenitsa (*Triticum aestivum* L.). Nauchni saobshteniya na SUB kl. Dobrich, 10 (Agrarni nauki), 11–18.

Okuyama, L.A., L.C. Federizzi and J.F.B. Neto, 2004. Correlation and path analysis of yield and its components and plant traits in wheat. Ciencia Rural, Santa Maria, 34–6, 1701–1708.

Petrova, T., 2003. Vliyanie na sushata varhu vrazkite mezhdu produktivnostta I nyakoi neini komponenti pri zimnata pshenitsa (*Triticum aestivum* L.). Izdatelstvo Saiuz na uchenite – Stara Zagora, tom I Agrarni nauki, chast 1. Rastenievadstvo, 167–171.

Rachovska, G. and Z. Ur, 2010. Nasledyavane, heterozis I variabilitet na kolichestveni priznatsi, svarzani s produktivnostta v F1 hibridi obiknovena zimna pshenitsa. Field Crop Studies, 6(3), 361–367.

Rahman, M.S. and J.H. Wilson, 1977. Determination of spikelet number in wheat. I. Effect of varying photoperiod on ear development. Australian Journal of Agricultural Research, 28(2), 265–274.

Rawson, H.M., 1969. Spikelet Number, Its Control And Relation To Yield Per Ear In Wheat. International Journal of Biological Sciences, 23, 1–15.

Reeves, T., S. Rajaram, M. van Ginkel, R. Trethowan, H.-J. Braun and K. Cassaday, 1999. New Wheats for a Secure, Sustainable Future. Mexico, D.F.: CIMMYT, p. 28.

Shahid, M., 2000. Path coefficient analysis in wheat. Disertation, NAUP, Peshawar (Pakistan), 41 p.

Siddique, K.H.M., E.J.M. Kirby and M.W. Perry, 1989. Ear: Stem ratio in old and modern wheat varieties; relationship with improvement in number of grains per ear and yield. Field Crops Research, 21–1, 59–78.

Sinclair, T.R. and P.D. Jamieson, 2006. Grain number, wheat yield, and bottling beer: An analysis. Field Crops Research, 98–1, 60–67.

Stoyanov, H.P., 2013a. Izchislyavane na listnoploshten indeks pri obiknovena zimna pshenitsa (*Triticum aestivum* L.). Godishnik na Tehnicheski universitet – Varna, tom 2, 30–35.

Stoyanov, H., 2013b. Korelatsiya mezhdu harakteristiki na klasa pri sortove obiknovena zimna pshenitsa (*Triticum aestivum* L.). Nauchni trudove na Institut po zemedelie – Karnobat, 2(1), 95–104.

Stoyanov, H., 2014. Analysis and assessment of amphidiploids of *Triticum-Aegilops* group as a source of genetic diversity. Bulgarian Journal of Agricultural Science, 20 (Supplement 1), 173–178.

Vajieka, A., 1998. The characterization of triticale under Lativian conditions 2:160–162. Proceeding of the 4th Triticale Symposium, Red Deer Alberta, Canada.

Zhang, W., A., Li, J., Tian and L., Zhao, 2012. Development of Near Isogenic Lines of Wheat Carrying Different Spike Branching Genes and Their Agronomic and Spike Characters. Journal of Agricultural Science; 4–8, 215–221.