Heterotic and Heterobelthiotic Potentials of Bread Wheat (*Triticum aestivum* L.) Hybrids for Yield and Yield Components

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In this study, the heterotic and heterobelthiotic performance of 22 bread wheat hybrids were evaluated for plant yield and some important yield components during 2006-07 growing season under Tekirdağ, Thrace conditions. Wide genetic variability was observed in the experimental material for the characters. The maximum heterosis and heterobelthiosis were recorded in Syrena x Bezostaja and Sana x Bezostaja (-5.05 and -14.01%) for plant height, Krasunia x Sana and Syrena x Krasunia (25.93 and 9.40%) for spike length, Sadovo 1 x Bezostaja (26.96 and 26.56%) for grains/spike, Pehlivan x Krasunia (25.00 and 22.28%) for grain weight/spike, Bezostaja x Sana and Bezostaja x Sadovo 1 (8.62 and 5.45%) for 1000 grain weight, Sadovo 1 x Bezostaja (9.28 and 9.14%) for harvest index and Pehlivan x Krasunia (27.85 and 24.10%) for grain yield/plant respectively. It is concluded that parents Pehlivan, Sana, Sadovo 1 and Krasunia should be utilized to improve certain traits in hybridization scheme and the hybrid combinations Sana x Bezostaja, Syrena x Krasunia, Sadovo 1 x Bezostaja, Pehlivan x Krasunia and Bezostaja x Sadovo 1 could be recommended for improved yield and enhanced biological production of bread wheat.

Key Words: Bread wheat, hybrid, heterosis, heterobelthiosis, plant yield, yield components.

Ekmeklik Buğday (*Triticum aestivum* L.) Melezlerinin Verim ve Verim Unsurları İçin Heterotik ve Heterobeltiotik Potansiyelleri

Bu çalışmada, 2006-07 yetiştirme döneminde Tekirdağ, Trakya koşullarında 22 ekmeklik buğday melezinin bitki verimi ve bazı önemli verim unsurları için heterotik ve heterobeltiotik performansları incelenmiştir. Deneme materyalinde incelenen özellikler için oldukça geniş bir genetik varyabilite gözlenmiştir. En yüksek heterosis ve heteroeltiosis oranları sırasıyla; bitki boyu için Syrena x Bezostaja ve Sana x Bezostaja'da (%-5.05 ve %-14.01), başak uzunluğu için Krasunia x Sana ve Syrena x Krasunia' da (%25.93 ve %9.40), başakta tane sayısı için Sadovo 1 x Bezostaja' da (%26.96 ve %26.56), başakta tane ağırlığı için Pehlivan x Krasunia' da (%25.00 ve %22.28), 1000 tane ağırlığı için Bezostaja x Sana ve Bezostaja x Sadovo 1'de (%8.62 ve %5.45), hasat indeksi için Sadovo 1 x Bezostaja'da (%9.28 and %9.14) ve bitki verimi için Pehlivan x Krasunia' da (%27.85 ve %24.10) hesaplanmıştır. Pehlivan, Sana, Sadovo 1 ve Krasunia anaçlarının melezleme çalışmalarında belirli özellikleri iyileştirmek için kullanılabileceği ve sırasıyla Sana x Bezostaja, Syrena x Krasunia, Sadovo 1 x Bezostaja, Pehlivan x Krasunia ve Bezostaja x Sadovo 1 melez kombinasyonlarının ekmeklik buğdayda verim artışı için önerilebilecekleri sonucuna varılmıştır.

Anahtar Kelimler: Ekmeklik buğday, hibrit, heterosis, heterobeltiosis, bitki verim, verim unsurları

Introduction

Wheat is the most important source of plant based food in the world. Its importance is increasing day by day due to increased human population pressure. The changing climatic conditions and environmental stresses such as salinity, drought, insect and pest attack and some other diseases are adversely affecting the wheat production. All of them are the signs of caution towards our wheat breeding programs to increase unit area yield. There is a great need to accelerate researches on developing high yielding wheat genotypes which are superior and adaptive to wide range of agro-climatic conditions. This could be achieved only by revealing maximum genetic potential from appropriate genetic material. The choice of parental material used in the hybridization scheme does contribute significantly for the development of a suitable genotype.

One of the most important developments in plant breeding has been the extension of the use of heterosis to many crops to increase yield. Shull (1914) put forwarded the term heterosis to describe the improved vigour of F_1 hybrids in comparison to their parental homozygous lines. Pal and Sikka (1956) reported that heterosis is a quicker, cheaper and an easier method of increasing crop production per unit area, thus sparing large amounts of land for other uses such as environmentally benign nature preserves (Duvick 1999). Previously, exploitation of heterotic effects for grain yield was largely attributed to cross-pollinated crops but Freeman (1919) and Briggle (1963) reported presence of heterosis in considerable quantity for grain yield and its components in various F_1 wheat crosses. The increase or decrease in the productivity and vigour of hybrids compared to those of their parents is generally attributed to heterotic effects expressed in F_1's and following generations. Estimation of mid-parent and better-parent heterosis may be useful in identifying true heterotic crosses (Singh et al 2004). With superior level of heterosis, commercial production of hybrids would be justified (Sharif et al 2001) and studies of heterosis also provide useful information about combining ability of the parents and their usefulness in breeding programmes (Sharma et al 1986 and Borghi et al 1988).

The present study was conducted to estimate the level of heterosis and heterobelthiosis effects among F_1 hybrids of seven bread wheat cultivars, and to investigate the performance and relationship of F_1 hybrids and parents and to select suitable parents and population for designing an effective wheat breading programme.

Material and Methods

The experiment was conducted at the experimental area, Department of Field Crops, Agricultural Faculty, Namık Kemal University, Tekirdağ ($27^o34'$ E, $40^o59'$ N and altitude of 10 m). Diverse originating seven bread wheat cultivars viz, Bezostaja (Russia), Sana (Croatia), Pehlivan (Turkey), Flamura 85 (Romania), Sadovo 1 (Bulgaria), Krasunia (Ukraine) and Syrena (Ukraine), were used to attempt F_1 crosses during 2005-06 crop season. The list of crosses is given below.

Table 1. The cross combinations used in the experiment

Crosses			
1	Bezostaja x Sana	12	Syrena x Bezostaja
2	Bezostaja x Pehlivan	13	Krasunia x Sana
3	Bezostaja x Flamura 85	14	Krasunia x Pehlivan
4	Bezostaja x Sadovo 1	15	Krasunia x F-85
5	Bezostaja x Krasunia	16	Krasunia x Sadovo 1
6	Bezostaja x Syrena	17	Krasunia x Syrena
7	Sana x Bezostaja	18	Sana x Krasunia
8	Pehlivan x Bezostaja	19	Pehlivan x Krasunia
9	Flamura 85 x Bezostaja	20	F-85 x Krasunia
10	Sadovo 1 x Bezostaja	21	Sadovo 1 x Krasunia
11	Krasunia x Bezostaja	22	Syrena x Krasunia

In November of the 2006-07 growing year, these crosses were materialized in the field using randomized complete block design to evaluate their performance as compared to their parent. The seeds of seven parents and above mentioned twenty-two crosses were sown in the two rows with 2 m length keeping plant to plant distance of 10 cm and row to row distance of 20 cm in four replications. All agronomic practices were done in time to achieve good crop stand. At maturity, 10 guarded main stem were selected at random and data were recorded for plant height (cm), spike length (cm), grains/spike (no), grains weight/spike (g), 1000 grain weight (g), harvest index (%) and grain yield/plant (g).

Analyses of variance (ANOVA) were performed to determine the significance in differences among the experimental material (Steel & Torrie 1960), and significance differences where indicated were further subjected to Duncan's New Multiple Range (DMR) Test for the each character. The characters showing significant differences were subjected to heterosis calculations. The percent increase (+) or decrease (-) of F_1 hybrids over mid as well as better parent was calculated to estimate possible heterotic effects for the characters by using the formula of Fonseca and Patterson (1968) as under.

$$Ht\ (\%) = \frac{F_1 - MP}{MP} x100 \qquad (1)$$

$$Hbt\ (\%) = \frac{F_1 - BP}{BP} x100 \qquad (2)$$

Where, Ht = Heterosis, Hbt = Heterobelthiosis, MP = Mid parent value, BP = Better parent value. The "t" test was done to determine whether F_1 hybrid means were statistically significant from mid parent and better parent means as follow (Wynne et al 1970).

$$tij = F_1ij - MPij \Big/ \sqrt{\frac{3}{8}EMS} \qquad (3)$$

$$tij = F_1ij - BPij \Big/ \sqrt{\frac{1}{2}EMS} \qquad (4)$$

Where, F_1ij = The mean of the ijth F_1 cross, MPij = The mid parent for ijth cross, BPij = The better parent value for ijth cross, EMS = Error mean square.

Results and Discussion

Analysis of variance for all the characters under study indicated highly significant differences at 1 percent probability level among the genotypes (i.e. parents and F_1 hybrids). The mean performance of parents and F_1 crosses regarding the characters is presented Table 2. The estimates of heterosis of F_1, over mid and better parents for all the characters are given in Table 3.

Plant height: The means of genotypes (Table 2) indicated that among parents Bezostaja had maximum plant height (98.5 cm). The Sana had minimum plant height (72.6 cm). Among the F_1 hybrids, Sadovo 1 x Bezostaja had maximum plant height (94.1 cm) whereas Sana x Krasunia had minimum plant height (79.9 cm). Taller plants are likely to lodge quite often. Tall plants

require more energy to translocate solutes to the grain and have lower grain weight (Inamullah et al., 2006). Short stature wheat is therefore preferred and negative heterosis is desirable (Budak and Yıldırım 1996). Maximum negative heterosis was shown by Syrena x Bezostaja (-5.05%) followed by Pehlivan x Bezostaja (-4.94%) and Bezostaja x Krasunia (-3.79%) whereas maximum negative heterobelthiosis was induced by the hybrid Sana x Bezostaja (-14.01%) followed by Sana x Krasunia (-12.77%). Nearly all of the hybrids showed negative heterosis and heterobelthiosis. Previously, Sadeque et al (1991), Ahmad et al (2006) and Bhutta et al (2005) reported negative heterosis for plant height. It is concluded that effective selection of desirable recombinants from crosses with significant heterobelthiosis is possible.

Spike length: It is apparent from Table 2 that among the parents Krasunia and Sana had maximum (11.7 cm) and minimum value (7.2 cm) for spike length, respectively. Maximum spike length was observed from cross combination Syrena x Krasunia (12.8 cm) and minimum from Sana x Krasunia (9.8 cm) among the hybrids. Positive heterosis over mid parent was observed for 19 crosses from which 16 were significant ($P \leq 0.01$) and remaining was non-significant. While positive heterobelthiosis over better parent was observed from 14 out of 22 crosses, among them two were significant ($P \leq 0.01$), three were significant ($P \leq 0.05$) and the others were non-significant. Sana x Krasunia and Sana x Bezostaja crosses were negative significant ($P \leq 0.01$) heterobelthiosis for spike length. Maximum positive heterosis (25.93%) and heterobelthiosis (9.40%) were observed for Krasunia x Sana and Syrena x Krasunia crosses, respectively. These findings are supported by the results of Moiscu et al (1984) and Chowdhry et al (2005).

Grains/spike: Grains/spike directly determines the yield of a genotype and it was considered that grains/spike played important role in yield fluctuations (Fischer 1975). The maximum and minimum grains/spike values were observed from the cross Sana x Krasunia (47.0 no) and parent Sadovo 1 (31.8 no), respectively (Table 2). It was shown in Table 3 that 19 out of 22 crosses had positive heterosis and 15 out of 22 crosses had positive heterobelthiosis for grains/spike. Maximum positive heterosis was recorded for Sadovo 1 x Bezostaja (26.96%) followed by Krasunia x Bezostaja (25.36%) and Flamura 85 x Bezostaja (24.62%), whereas positive heterobelthiosis was showed by Sadovo 1 x Bezostaja (26.56%) followed by Flamura 85 x Bezostaja (22.73%). These results could be verified from the findings Khan and Bajwa (1989), Ahmad et al (2006) and Akbar et al (2007).

Grain weight/spike: Individual comparison of average grain weight/spike (Table 2) showed that among the hybrids cross (Sana x Bezostaja) was at the top with an average of 2.34 g and followed by Pehlivan x Krasunia (2.25 g), Bezostaha x Sana (2.16 g), Bezostaja x Flamura 85 (2.15 g), Krasunia x Sadovo 1 (2.14 g) and Krasunia x Flamura 85 (2.12 g). Positive heterosis ranged from 0.56 (Bezosyaja x Krasunia) to 25.00% (Pehlivan x Krasunia) whereas the magnitute of heterobelthiosis ranged from 0.54 (Bezostaja x Sadovo 1) to 22.28% (Pehlivan x Krasunia). Similar findings are reported by Yağdı and Karan (2000), Yağbasanlar (1990) and Dağüstü and Bölük (2002).

Table 2. Mean performance and statistical significance for the characters in 2006/07.

Crosses and parents	Plant height (cm)	Spike length (cm)	Grains/ spike (No)	Grains weight/ spike (g)	1000-grain weight (g)	Harvest index (%)	Grain yield/ plant (g)
Bezostaja x Sana	91.2 bcd	11.1 ef	38.5 c-i	2.16 ab	41.6 c-f	41.4 a-e	3.56 abc
Bezostaja x Pehlivan	93.9 ab	12.1 a-e	35.5 f-j	1.97 abc	43.0 ab	40.7 a-f	3.49 abc
Bezostaja x Flamura 85	88.8 b-f	12.1 a-e	38.3 c-i	2.15 ab	40.8 e-i	39.9 a-g	3.27 a-d
Bezostaja x Sadovo 1	92.5 a-d	11.7 a-e	36.0 e-j	1.87 abc	42.6 abc	40.8 a-f	3.13 a-d
Bezostaja x Krasunia	91.5 bcd	11.5 b-e	40.3 a-g	1.81 abc	41.6 c-f	40.7 a-f	3.12 a-d
Bezostaja x Syrena	90.5 b-f	11.3 de	33.0 ij	1.55 c	38.1 op	37.1 g	2.96 cd
Sana x Bezostaja	84.7 fg	9.9 g	45.8 ab	2.34 a	37.4 p	43.2 a	3.90 a
Pehlivan x Bezostaja	90.5 b-f	11.1 ef	34.5 g-j	1.79 abc	44.0 a	41.7 a-d	3.12 a-d
Flamura 85 x Bezostaja	88.7 b-f	11.3 cde	40.5 a-f	1.88 abc	39.2 lmn	39.5 a-g	3.15 a-d
Sadovo 1 x Bezostaja	94.1 ab	11.7 a-e	40.5 a-f	1.88 abc	42.2 bcd	41.8 abc	3.24 a-d
Krasunia x Bezostaja	93.4 abc	12.5 ab	43.0 abc	1.82 abc	41.6 cde	37.3 g	3.07 bcd
Syrena x Bezostaja	88.3 b-f	12.0 a-e	38.8 c-i	1.73 bc	40.3 g-k	37.1 g	2.88 cd
Krasunia x Sana	87.1 def	11.9 a-e	39.0 b-h	1.87 abc	39.4 j-n	38.5 c-g	3.29 a-d
Krasunia x Pehlivan	92.1 a-d	12.5 ab	41.5 a-e	1.84 abc	40.9 e-h	37.2 g	2.79 cd
Krasunia x F-85	89.2 b-f	12.3 a-d	42.0 a-d	2.12 ab	39.8 i-m	38.1 efg	3.03 bcd
Krasunia x Sadovo 1	93.6 ab	12.6 ab	38.0 c-i	2.14 ab	40.3 g-l	39.3 b-g	3.58 abc
Krasunia x Syrena	89.1 b-f	12.4 abc	37.5 c-j	1.72 bc	40.0 h-l	37.1 g	2.97 cd
Sana x Krasunia	79.9 g	9.8 g	47.0 a	1.92 abc	38.4 no	41.6 a-d	3.34 a-d
Pehlivan x Krasunia	90.7 b-e	11.3 de	38.5 c-i	2.25 ab	41.1 d-g	39.0 b-g	3.81 ab
F-85 x Krasunia	90.1 b-f	12.5 ab	37.3 c-j	1.81 abc	39.5 j-m	38.3 d-g	3.08 a-d
Sadovo 1 x Krasunia	90.5 b-f	12.0 a-e	38.8 c-i	1.78 abc	42.5 abc	38.4 c-g	2.92 cd
Syrena x Krasunia	90.3 b-f	12.8 a	33.8 hij	1.70 bc	39.6 j-m	38.8 c-g	2.61 d
Bezostaja	98.5 a	11.6 b-e	32.0 j	1.86 abc	40.2 g-l	38.2 efg	3.23 a-d
Sana	72.6 h	7.2 i	46.5 a	1.99 abc	36.3 r	42.7 ab	3.57 abc
Pehlivan	91.9 a-d	11.0 ef	35.8 e-j	1.84 abc	42.0 b-e	38.7 c-g	3.07 bcd
Flamura 85	85.0 efg	8.6 h	33.0 ij	1.81 abc	40.1 g-l	38.2 efg	2.99 cd
Sadovo 1	92.6 a-d	8.9 gh	31.8 j	1.78 bc	40.4 f-j	38.3 d-g	3.00 bcd
Krasunia	91.6 a-d	11.7 a-e	36.5 d-j	1.75 bc	38.9 mno	37.8 fg	2.89 cd
Syrena	87.4 c-f	10.0 fg	33.5 hij	1.74 bc	39.2 k-n	38.8 c-g	2.86 cd

1000 grain weight: A variation is evident (Table 2) for average 1000 grain weight among the parents and hybrids which varied from 36.3 g (Sana) to 44.0 g (Pehlivan x Bezostaja). Regarding heterotic estimates, Bezostaja x Sana contributed maximum heterosis i.e. 8.62% while Bezostaja x Sadovo 1 had the maximum heterobelthiosis effect with value of 5.45%. Hybrid vigour expressed for this character is also reported earlier by Khaliq et al (1985), Munir et al (1999), Rasul et al (2002) and Hussain et al (2007).

Harvest index: The harvest index means of parents and hybrids ranged from 37.1% (Bezostaja x Syrena, Syrena x Bezostaja, Krasunia x Syrena) to 43.2% (Sana x Bezostaja - Table 2). Heterotic investigations revealed that 6 out of 22 crosses showed positive heterosis for harvest index (Table 4).

The maximum positive heterosis and heterobelthiosis were displayed by Sadovo 1 x Bezostaja (9.28-9.14%) followed by Pehlivan x Bezostaja (8.31-7.75%) and Bezostaja x Krasunia (7.11-6.55%); which is agreement with the findings of Ahmad et al (2006) and Mahmood et al (2006).

Grain yield/plant: Data on means for grain yield/plant denoted that it was the highest for hybrid Sana x Bezostaja (3.90 g) and Pehlivan x Krasunia (3.08 g), as shown in Table 2. Heterotic studies revealed that 16 out of 22 crosses were positive heterosis. Among them three crosses (Pehlivan x Krasunia, Krasunia x Sadovo 1 and Sana x Bezostaja) were significant ($P \leq 0.01$). The maximum positive and significant heterobelthiosis was only displayed by Pehlivan x Krasunia (24.10%) followed by Krasunia x Sadovo 1 (19.33%). Almost similar results reported by Rasul et al (2002) and Chowdhry et al (2005).

Table 3. Estimation of percent heterosis (Ht%) and heterobelthiosis (Hbt%) for the characters in 2006/07.

F_1 hybrid	Plant height (cm)		Spike length (cm)		Grains/spike (No)		Grains weight/spike (g)		1000-grain weight (g)		Harvest index (%)		Grain yield/ Plant (g)	
	Ht (%)	**Hbt (%)**	**Ht (%)**	**Hbt (%)**	**Ht (%)**	**Hbt (%)**	**Ht (%)**	**Hbt (%)**	**Ht (%)**	**Hbt (%)**	**Ht (%)**	**Hbt (%)**	**Ht (%)**	**Hbt (%)**
Bezostaja x Sana	5.37**	-7.41**	18.09**	-4.31	-2.04	-17.20**	11.92	8.54	8.62**	3.48**	2.22	-3.05	4.71	-0.28
Bezostaja x Pehlivan	-1.37	-4.67*	7.08**	4.31	4.72	-0.84	6.49	5.91	4.62**	2.38**	5.71*	5.17	10.79	8.05
Bezostaja x Flamura 85	-3.27	-9.85**	19.80**	4.31	17.85**	16.06**	16.85*	15.59	1.62*	1.49	4.45	4.45	5.15	1.24
Bezostaja x Sadovo 1	-3.24	-6.09**	13.59**	0.86	12.85**	12.50*	2.75	0.54	5.71**	5.45**	6.67**	6.53*	0.32	-3.10
Bezostaja x Krasunia	-3.79*	-7.11**	-1.29	-1.71	17.49**	10.41*	0.56	-2.69	5.05**	3.48**	7.11**	6.55*	1.96	-3.41
Bezostaja x Syrena	-2.69	-8.12**	4.63	-2.59	0.61	-1.49	-13.89	-16.67	-4.03**	-5.22**	-3.64	-4.38	-2.95	-8.36
Sana x Bezostaja	-1.05	-14.01**	5.32	-14.66**	16.54**	-1.51	21.24**	17.59*	-2.35**	-6.97**	6.67**	1.17	14.71*	9.24
Pehlivan x Bezostaja	-4.94**	-8.12**	-1.77	-4.31	1.77	-3.63	-3.24	-3.76	7.06**	4.76**	8.31**	7.75**	-0.95	-3.41
Flamura 85 x Bezostaja	-3.38	-9.95**	11.88**	-2.59	24.62**	22.73**	2.17	1.08	-2.37**	-2.49**	3.40	3.40	1.29	-2.48
Sadovo 1 x Bezostaja	-1.57	-4.47*	13.59**	0.86	26.96**	26.56**	3.30	1.08	4.72**	4.46**	9.28**	9.14**	3.85	0.31
Krasunia x Bezostaja	-1.79	-5.18**	7.30**	6.84*	25.36**	17.81**	1.11	-2.15	5.05**	3.48**	-1.84	-2.36	0.33	-4.95
Syrena x Bezostaja	-5.05**	-10.36**	11.11**	3.45	18.29**	15.82**	-3.89	-6.99	1.51*	0.25	-3.64	- 4.38	-5.57	-10.84
Krasunia x Sana	6.09**	-4.91*	25.93**	1.71	-6.02	-16.13**	0	-6.03	4.79**	1.29	-4.47*	-9.84**	1.86	-7.84
Krasunia x Pehlivan	0.33	0.22	9.65**	6.84*	14.64**	13.70**	2.22	0	0.99	-2.62**	-2.87	-3.88	-6.38	-9.12
Krasunia x F-85	1.02	-2.62	20.59**	5.13	20.69**	15.07**	19.10*	17.13	0.76	-0.75	0.26	-0.26	3.06	1.34
Krasunia x Sadovo 1	1.63	1.08	22.33**	7.69**	11.11*	4.11	20.90*	20.23*	1.51*	-0.25	3.15	2.61	21.36**	19.33*
Krasunia x Syrena	-0.45	-2.73	13.76**	5.98*	7.14	2.74	-1.43	-1.71	2.30**	2.04*	-3.13	-4.38	3.13	2.77
Sana x Krasunia	-2.68	-12.77**	3.16	-16.24**	13.25**	1.08	2.67	-3.52	2.13**	-1.29	3.23	-2.58	3.41	-6.44
Pehlivan x Krasunia	-1.20	-1.31	-0.88	-3.42	6.35	5.48	25.00**	22.28*	1.48*	-2.14**	1.83	0.78	27.85**	24.10**
F-85 x Krasunia	2.04	-1.64	22.55**	6.84*	7.18	2.19	1.69	0	0	-1.50	0.79	0.26	4.76	3.01
Sadovo 1 x Krasunia	-1.74	-2.27	16.51**	2.56	13.45**	6.30	0.57	0	7.05**	5.20**	0.79	0.26	-1.02	-2.67
Syrena x Krasunia	0.89	-1.42	17.43**	9.40**	-3.43	-7.40	-2.58	-2.86	1.28	1.02	1.31	0	-9.38	-9.69

Conclusion

A review of the results made it clear that most of crosses exhibited remarkable heterosis and heterobelthiosis for the characters except grain weight/spike, harvest index and grain yield/plant. It is concluded that parents Pehlivan, Sana, Sadovo 1 and Krasunia should be utilized to improve certain traits in hybridization programme. However, crosses Sana x Bezostaja, Sana x Krasunia, Krasunia x Sana, Syrena x Krasunia, Sadovo 1 x Bezostaja, Flamura 85 x Bezostaja, Pehlivan x Krasunia, Bezostaja x Sadovo, Pehlivan x Bezostaja, Bezostaja x Krasunia and Krasunia x Sadovo 1 may be considered for selection as hybrid or pure line wheat varieties after achieving desired homozygosity.

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