ACTA AGROBOTANICA
vol. 34, z. 2 — 1982
169 - 194

Some genetic parameters of the spring wheat caryopsis characters

ROMUALD KOSINA

Institute of Botany, University of Wrocław,
Kanonia 6/8, 50-328 Wrocław, Poland

(Received: February 15, 1980)

Abstract

Nineteen characters of the single caryopsis of many pure lines and their F_2 generation hybrids of spring wheat were analyzed. A large differentiation of forms was ascertained. 'Manitoba' cultivar, *sphaerococcum and spelta* forms, hybrids of *durum* forms, hybrids of *spelta* and *sphaerococcum* forms were found to have the highest values of the DBC parameter. The characters were found to show a differentiated relative variation from a few to more than 100%. A great variation of F_2 generation as well as transgressions of characters appeared more marked in hybrids between various subspecies than between varieties of one subspecies. A specific gravity of the caryopsis is marked by a high value of coefficients of heritability in broad sense. An influence of asymmetry of distribution on the h^2 value was stated. The distributions of characters with a deviation from normal curve are only leptokurtic. The height of endosperm cavity revealed the largest number of deviations characterized by asymmetry and kurtosis. These deviations appeared smaller in the distributions of homozygous forms than of heterozygous forms. The interspecies hybrids are marked by more numerous genetic correlations in matrix of correlation coefficients than hybrids of less differentiated forms. Many reciprocal hybrids revelated a differentiation in the mean values of characters as well as in the range of transgression. These hybrids are similar to their maternal forms. A short consideration of an ideotype of wheat caryopsis was made.

INTRODUCTION

Leaving the reproduction problem aside, any activities by breeders concerning the single spring wheat caryopsis specimen can be brought down basically to two objectives: 1 — obtain the largest possible amount of flour from a single caryopsis, 2 — obtain flour of the highest quality in terms of the content of high-value protein. Both these characters are conditioned by many caryopsis characters which should be approached comprehensively with the application of the multivariate analysis (Kosina, 1978b, 1979b). After exploring the variations and relations between the caryopsis characters, we proceed to the next stage which is an evaluation of the genetic parameters of the populations under study. Such is also the objective of the present paper.

Two caryopsis characters: the total protein content and the weight of a single caryopsis have already been object of broader analyses (Haunold et al., 1962; Drozd, 1970; Khadr, 1970; Bhatt, 1972; Boyadzhieva, 1972; Sharma et al., 1975a, b). The other caryopsis characters such as specific gravity, for one, are analyzed much more rarely (Anand et al., 1970). Studies on the structure of the spring wheat caryopsis point to big importance of caryopsis elements such as: the aleurone layer, the subaleurone endosperm layer, the crease and the endosperm cavity of the caryopsis (Kent, 1969; Evers, 1970; Konarev, 1974; Kosina, 1979a). The wheat forms are differentiated also in respect of the afore-mentioned characters, a fact which holds out definite breeding possibilities (Kosina, 1978b). Of interest here, is the possibility of establishing the transgression of the characters, the degree of heritability of the characters, the existence of genetic correlations, or the influence of crossing directions on the characters. There is no information thorough enough about many caryopsis characters. We know about some characters such as the protein content or the single caryopsis weight to be differently heritable (Reddi and Heyne, 1970; Bhatt, 1972; Gill and Brar, 1973; Johnson et al., 1973; Halloran, 1975). Detailed research on the morphology, anatomy and quality of the caryopsis of the various spring wheat forms, yields information on the value of the individual species or varieties (Fritsch et al., 1977; Kosina, 1978b). The crossings of selected forms and the data on the genetic parameters of the offspring will draw the breeders closer to establishing the ideotype of the spring wheat caryopsis (Mazurkiewicz, 1975; Kosina, 1978b).

MATERIAL AND METHODS

The material for research was made up of large, random samples of pure-line caryopses and F_2 generation hybrids of the spring wheat. The experimental material is subject to one-way classification in the completely randomized design. The taxonomy of the forms is given according to Mac Key (1977). The following wheat forms (their symbols being given in brackets) were subjected to the research:

A. *Triticum aestivum* ssp. *vulgare* — pure lines of cultivars:

'Nagradowicka' (N), 'Opolska' (O1, O2, O3, O4), 'Gorzowska' 'Sztywna' (GS1, GS2), 'Rokicka' (R1, R2), 'Ostka Popularna' (OP1, OP2, OP3, OP4, OP5), 'Manitoba' (M), 'Oktawia' (Ok1, Ok2, Ok3), 'Capega' (C1, C2, C3, C4, C5).

B. *T. aestivum* ssp. *sphaerococcum* — pure lines: S1, S2, S3.

C. *T. aestivum* ssp. *spelta* — pure line: Sp.

D. *T. turgidum* ssp. *turgidum* conv. *durum* — pure lines: D1, D2, D3, D4 and conv. *polonicum* — pure line: P.

E. Reciprocal hybrids of the following *vulgare* form lines: OP5 and GS1, OP3 and M, C1 and N, Ok1 and R1, Ok2 and C2, OP4 and C3, R2 and O3, C4 and O4, Ok3 and GS2, OP2 and O2.

F. Hybrids of the *durum* form: D1/D2, D2/D3, D3/D2.

G. Hybrids of the *aestivum* form: Sp/S1, S2/Sp, OP1/S3.

H. Tetra- and hexaploid hybrids: O1/P, C5/D4, D4/C5.

Nineteen characters of the single caryopsis have been marked for the forms specified above:

1. Width (mm),
2. Thickness (mm),
3. Length (mm),
4. Weight (mg),
5. Depth of the crease (mm),
6. Width of the crease (mm),
7. Length of endosperm cavity appendices (μm),
8. Height of the cavity (μm),
9. Thickness of the fruit and seed coat — F_1 generation (μm),
10. Thickness of the aleurone layer (μm),
11. Thickness of the high-protein subaleurone endosperm layer (μm),
12. Specific gravity (g/cm^3),
13. Empirical volume of the caryopsis (mm^3),
14. Maximum, theoretical volume of the caryopsis (mm^3),
15. Filling of the caryopsis (abstract number),
16. Shape of the caryopsis — growth in the value of this character indicating a lengthening of the caryopsis (abstract number),
17. Caryopsis endosperm yield coefficient — reverse dependence of the values of the character and endosperm amount (abstract number),
18. Endosperm quality coefficient (abstract number),
19. DBC parameter defining the caryopsis quality (according to the Orange dye G12 fixed by 10 mg of flour).

The mentioned characters have been defined according to their relative variation, variation of F_2 generation hybrids, range of transgression and the number of transgressive individuals, heritability in broad sense according to Mahmund and Kramer (after Węgrzyn and Czembor, 1974), genetic correlations of some characters according to Petr and Frey (Węgrzyn and Czembor, 1975), asymmetry and kurtosis of distributions (Schmidtke and Jäger, 1976; Sharma et al., 1976a).

RESULTS

Characters variation

Data on the mean value of the researched characters is contained in Table 1. Noteworthy are the minimal dimensions of the crease in the *durum* form and the maximal dimensions in the *vulgare* form. The D2

Table 1

Extreme mean values of caryopsis characters in wheat forms under study

No. of character	Minimum	Maximum
1	2.51 Ok2	3.39 OP4/C3
2	2.35 Sp/S1	3.14 D2
3	4.66 S3	9.95 P
4	20.02 Sp/S1	53.89 P
5	1.31 D1	1.75 OP4/C3
6	0.21 D1	0.87 C2
7	83.72 D2	704.18 OP3/M
8	3.82 C2	838.97 D2
9	37.49 Sp	63.50 S2
10	34.94 Sp	50.96 D4/C5
11	47.86 C4	94.95 D2
12	1.21 C5	1.37 OP3
13	15.37 Sp/S1	40.28 P
14	18.65 S2	44.52 P
15	0.73 Sp/S1	0.97 R1
16	1.18 S3	1.51 P
17	0.43 D1	0.59 C5/D4
18	0.06 O3	0.10 D3/D2
19	0.65 OP5	0.79 S3

form shows a specific cavity shape (very high cavity with short appendices). The *spelta* form has the thinnest seed coat and aleurone layer. Alnost twice as thick coats have the pure lines of the *sphaerococcum* form. The thickest aleurone layer has been found with the hybrid *durum/vulgare*. The thickest subaleurone endosperm layer has form D2, with equally thick layers being found in some hybrids of the *vulgare* form, hybrids O1/P and D4/O5. The maximal value of the DBC parameter has been found in the *sphaerococcum* form. Also of a high quality are caryopses of the following forms: M, S1, S2, D2, P, Sp/S1, S2/Sp, OP1/S3, D1/D2, D3/D2, O1/P, C5/D4, D4/C5. Among the above-mentioned forms there are also hybrids of tetra- and hexaploids of the wheat, whose caryopses show marked disturbances in their structure.

The variability of the researched characters is very differentiated. Generally, the characters can be classified into groups according to the values of the coefficient of variation:

I. $V<10\%$ — specific gravity, filling, shape, DBC parameter.

II. $V<20\%$ — caryopsis dimensions, thickness of fruit and seed coats, thickness of the aleurone layer, endosperm yield coefficient.

III. $V<50\%$ — weight of caryopsis, crease dimensions, length of cavity appendices, thickness of the subaleurone endosperm, volume, endosperm quality coefficient. The highest values $V>100\%$ have been registered for the length of cavity appendices in the *durum* form and the D/D hybrids.

IV. $V>100\%$ — height of cavity. The lowest value $V=39.9\%$ has been recorded for the D2 form.

The listed values for relative variation are characteristic of the pure lines. The hybrids show an increase in the characters variability, a fact particularly true of the hybrids of both ploidal series. For example, the variability of the aleurone layer thickness in form O1/P amounts to 34.2%, whereas in form D4/C5 — 44.9%. The differentiation of the parental forms in terms of the caryopsis structure is not homogeneous. The respective data are presented in Table 2. The pure lines of the *vulgare* form differ between themselves in from six (OP2-O2) to sixteen (Ọk2-C2) characters. Very differentiated are also the pure lines of 'Ostka Popularna' and 'Capega' (OP4-C3), or 'Gorzowska Sztywna' and 'Ostka Popularna' (GS1-OP5). The characters which most often determine the differences between the parental pairs are: length of caryopsis, width of crease, gravity and shape of caryopsis. The pure lines of the *durum* form are strongly differentiated particularly in terms of characters such as: width and thickness of caryopsis, height of cavity, thickness of coats, thickness of subaleurone endosperm, maximal theoretical volume of caryopsis and filling of caryopsis. The subspecies of the *aestivum* form, as well as the tetra- and hexaploids differ in a majority of the caryopsis characters, and, in particular: length and weight of caryopsis, thickness of aleurone layer, gravity, volume and shape. The

Table 2

Differentiation of parental wheat forms in combinative crossings (t-test)

No. of character	O4-C4	R1-Ok1	OP2-O2	C1-N	OP3-M	Ok2-C2	OP4-C3	GS2-Ok3	R2-O3	GS1-OP5	D1-D2	D2-D3	OP1-S3	Sp-S1	S2-Sp	O1-P	D4-C5
	Parental pairs																
1	3					3	3	1	3		3	3			1		
2	1		3			3			3	1	3	3	3	3	3	1	3
3	1	3	3	1	3	3	3		3	3	3	1	3	3	3	3	3
4	1					1	3		3				3	3	3	3	3
5			1	1		3			3	3	3		3				1
6	3	1	1	3	3	3	3			3	3	1		3	3	3	3
7	3	3			3	3	3	3				3		3	3		3
8				3		3		1		3	3	3	1	3	3	1	3
9		3			3	3		3			3	3	3	3	3	3	
10		1				1				3		1	3	3	3	3	3
11	3			1	1		3	1			3	3				3	3
12			3	3	3	3	3	3	3	3	3		3	3	3	3	3
13						3	3		3		1	1	3	3	3	3	3
14						3	3		3		3	3	3	3	3	3	3
15					3		1	1		1	3	3	3	3	3		3
16	3	3	3	1	3			1	3	3		3	3	3	3	3	3
17		1		3		3	3			3	3		1		3	3	3
18						3	1			1			1		1	3	3
19	3				3	3	3		3		3	1	3	3	3	3	
Characters total	9	7	6	8	9	16	13	8	10	11	14	14	15	14	17	15	16

1, 2, 3 — level of significance of differences between mean values for $\alpha=0.05$, 0.01, 0.001.

majority of the hybrids shows increased variability of all characters, except for the thickness of coats (F_1 generation). The causes of the increased variability vary with various hybrids. Aneuploidty is almost certain to play a role in the forms of the 4n/6n or 6n/4n types. The data contained in Table 3 concern what is a statistically significant increase in variability in comparison with both parents. In the case of the *vulgare* hybrids this is particularly true of the height of cavity and the pair of reciprocal hybrids GS1/OP5 and OP5/GS1. An increase in variability of the characters in hybrids of the *vulgare* subspecies occurred in 6% of the cases, whereas in the *durum* form it occurred in 7% of the cases. The variability increase is much more discernible in

Table 3
Combinative variation of caryopsis characters (F-test)

Hybrids	Characters																			Characters total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
O4/C4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
C4/O4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	1
R1/Ok1	—	—	—	—	+	—	—	—	—	—	—	—	+	—	—	—	—	—	—	2
Ok1/R1	—	—	—	—	—	+	—	+	—	—	—	—	—	—	—	—	—	—	—	2
OP2/O2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
O2/OP2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
C1/N	—	—	+	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	2
N/C1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
OP3/M	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	1
M/OP3	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	1
Ok2/C2	—	—	+	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
C2/Ok2	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	1
OP4/C3	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	1
C3/OP4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
GS2/Ok3	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	1
Ok3/GS2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	1
R2/O3	—	—	—	—	—	+	—	—	—	—	—	+	—	—	—	—	—	—	—	2
O3/R2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
GS1/OP5	—	—	+	—	—	—	—	+	—	—	—	+	—	—	—	—	—	—	—	3
OP5/GS1	—	—	—	—	—	—	—	+	—	—	+	—	—	—	—	—	—	+	—	3
D1/D2	—	—	+	—	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—	3
D3/D2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	1
D2/D3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
OP1/S3	—	—	—	+	+	—	—	—	—	—	—	—	+	+	—	—	—	—	—	4
Sp/S1	—	—	—	—	—	—	—	—	—	—	—	+	—	—	+	—	—	—	+	3
S2/Sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	1
O1/P	—	—	—	—	+	+	+	+	—	+	+	+	—	—	—	—	+	+	—	9
D4/C5	—	—	—	—	+	+	+	+	—	+	+	+	—	—	—	—	+	+	—	9
C5/D4	—	+	+	—	+	+	+	+	—	+	—	+	—	+	—	—	+	—	—	10

+ statistically significant increase in the variablity of the hybrid character in comparison with both parents.

the interline hybrids of the various subspecies of the *aestivum* form (14%) and in the hybrids of two ploidal series (49%). The following denotations have been adopted for the above calculations: 19 (number of characters) × number of hybrids of definite type = 100%.

Transgressions of characters

The mentioned combinative variation of the hybrids finds reflection in the extent of the transgressions of characters (Tables 4 and 5). In the *vulgare* form, a small number of individuals exceed the aggregate

Table 4

Transgression of the caryopsis characters in interline hybrids of the *vulgare* and *durum* form (mean values)

No. of character	*vulgare* −/+	*durum* −/+
1	9/30	10/33
	79/80	40/106
2	7/7	7/10
	51/38	70/49
3	9/6	3/50
	82/21	7/76
4	11/26	0/13
	35/54	0/57
5	3/11	3/0
	56/49	19/0
6	9/19	0/7
	83/252	0/48
7	1/10	0/23
	2/74	0/231
8	0/2	—
	0/42	—
9	=	=
10	2/3	3/7
	32/66	48/220
11	6/17	3/7
	24/156	22/52
12	10/12	0/3
	106/148	0/12
13	10/21	1/23
	38/60	12/84
14	12/18	7/50
	36/57	30/119
15	6/10	3/3
	70/91	100/5
16	12/7	0/7
	51/79	0/120
17	6/10	7/3
	47/104	12/23
18	8/9	0/13
	31/101	0/118
19	11/7	0/3
	55/68	0/5

−/+: negative transgression, positive; $\times 10^1$.
above — % of transgressive individuals in tested sampl.
below — transgression range in % of aggregate parental range.
The table contains mean transgression values for 20 *vulgare* and 3 *durum* hybrids.

Table 5

Transgression of the caryopsis characters in hybrids of wheat subspecies and species

No. of character	OP1/S3 −/+	Sp/S1 −/+	S2/Sp −/+	O1/P −/+	C5/D4 −/+	D4/C5 −/+
1	0/90	80/0	30/0	10/0	0/10	0/10
	0/116	514/0	100/0	134/0	0/76	0/76
2	0/20	10/0	30/0	30/20	10/10	0/10
	0/76	33/0	20/0	72/88	176/290	0/166
3	—	—	—	10/0	10/10	—
	—	—	—	18/0	18/55	—
4	0/60	70/0	50/0	—	10/10	10/10
	0/163	92/0	117/0	—	17/55	59/38
5	10/30	0/30	20/10	10/50	0/10	0/10
	200/120	0/43	87/43	29/235	0/621	0/413
6	10/10	—	—	0/90	0/10	0/60
	59/59	—	—	0/667	0/560	0/414
7	0/50	—	—	0/100	0/10	0/10
	0/240	—	—	0/612	0/1143	0/1857
8	—	—	—	0/60	0/10	0/10
	—	—	—	0/585	0/314	0/1143
10	—	—	—	20/120	10/20	0/10
	—	—	—	333/4000	77/154	0/2308
11	—	10/0	10/0	0/50	0/10	0/30
	—	56/0	87/0	0/680	0/400	0/400
12	0/10	170/10	20/0	70/50	10/0	10/0
	0/30	1490/82	48/0	1076/60	216/0	238/0
13	0/100	80/0	50/0	—	10/10	10/10
	0/185	123/0	117/0	—	26/539	19/98
14	0/90	50/0	20/0	—	0/10	0/10
	0/165	70/0	82/0	—	0/421	0/127
15	—	520/10	170/0	0/20	10/0	10/10
	—	561/3845	344/0	0/107	240/0	8/83
16	—	—	—	—	—	—
	—	—	—	—	—	—
17	10/0	0/50	—	10/130	0/10	10/10
	159/0	0/153	—	24/1437	0/1343	242/1475
18	—	30/0	10/0	0/140	0/10	0/10
	—	88/0	70/0	0/933	0/284	0/1837
19	10/0	0/160	0/200	—	10/10	0/10
	55/0	0/213	0/589	—	305/345	0/966

−/+: negatiwe transgression, postive; $\times 10^2$.
Above — % of transgressive individuals in tested sample.
Bellow — transgression range in % of aggregate parental range.

range of the two parents. For some characters the transgression range is fairly large, for example character No. 6 — positive transgression. The transgression of the width of caryopsis, width of crease, specific gravity, filling and shape of caryopsis, endosperm yield coefficient and DBC parameter is manifest with more than 75% of the hybrids. Likewise, the *durum* form shows a small number of transgressive individuals. A larger transgression range has been recorded for the length of the cavity appendices and the thickness of the aleurone layer (positive transgression). In the *vulgare* form the height of cavity has shown only the positive transgression, whereas the remaining characters have shown transgression of both kinds. The *durum* form has failed to show transgression for the height of cavity, while its seven other characters show positive transgression. The depth of crease shows only negative transgression, while the remaining characters show transgression of both kinds. The hybrids of the *aestivum* form, within some characters, register many transgressive individuals and a significant trangression range. No transgression has been found in the length of caryopsis, height of cavity, thickness of the aleurone layer and shape of caryopsis. On average, six characters of these hybrids show only negative transgression, 3.7 characters — only positive transgression and 1.7 characters — transgression of both kinds. The "transgressions" of characters with the hybrids of both ploidal series are large both in terms of range and number of transgressive individuals. A particularly large range is registered by the positive transgression of the aleurone layer thickness with the hybrids O1/P and D4/C5. The interspecific hybrids, for an average of 1.3 characters, have shown only negative transgression; for 8.7 characters only positive and for 5.3 characters — both transgressions.

Heritability of characters

The value of the heritability coefficient in broad sense is calculated on the assumption that the characters distributions are normal. In reality, however, it is altered by the asymmetry in the character distribution of the parental form or the hybrid. The increase of distribution asymmetry, and hence hybrid character variance, leads to a sizeable growth in the value of the h^2 coefficient. A similar increase in the character variance of both parents removes the effect of asymmetry in the hybrid and the h^2 value is such as the value of symmetrical distributions. An asymmetry of distributions in both parents alone leads to marked decline in the h^2 value. The asymmetry of one parent together

Table 6
Heritability in broad sense of caryopsis characters of some spring wheat hybrids

Hybrids	Characters																	
	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17	18	19
C1/N	+8	+11	+46		33	−47		33	13		27		2		+9	38	+15	+32
N/C1								20	6		50					21		+29
OP3/M	−33	25		33	14	21	27		−15	.59		35	34	.8	.38	14	.1	
M/OP3	24	25		37		+5	41		.5	.50		38	36		.27			
OP4/C3					−2	−24	−41			.27								
C3/OP4				.15	−11		−36	40		.20	.8	.13	15			13		
GS1/OP5	18	−6	.48	15	13	41	15		35	7	+64	15	15		16	−36	+7	+12
OP5/GS1	15		.17	32	−6	+26	1		26	+56	.28	31	23	11	3		+42	
D1/D2	−30	18	−52	−31	45	48	55	43	25	11		−34	−38		.31		26	
OP1/S3		+38	+30	52	+55		15					53	46	+28				.2
Sp/S1	+18	20	+17		−36						+87			+88		9	8	54
S2/Sp			34		.18				10	.1	60			−46		9	.23	.33

"Empty" spaces — $h^2=0\%$.
+, ·, −, heritability coefficient values — overrated, slightly overrated, underrated due to asymmetry in character distribution. The remaining values are calculated for symmetrical distributions or distributions with neutralized asymmetry effects.

with the asymmetry in the hybrid slightly increases h^2, whereas when combined with the symmetry in the hybrid character distribution it produces a decline in the h^2 value by a similar proportion. Obviously, the reasons for the asymmetry in the character distributions vary with the hybrids (environment, dominance, multiplicative gene action and others), and with the parental forms (environment). The influence of the asymmetry of the character distribution on the h^2 coefficient value is presented in Table 6. Comparatively low h^2 values have been registered for the thickness of caryopsis in *vulgare* and *durum* forms. Higher values and a smaller h^2 range with the *vulgare* form is typical for the weight of caryopsis and the height of cavity. In the majority of cases, the h^2 values amount from several to about 40%. Much higher h^2 values have been found in the *durum* form, particularly for the length of caryopsis, width of crease and length of cavity appendices.

The hybrids of the *aestivum* form have high h^2 values for the weight, gravity, volume and filling of caryopsis. Noteworthy is the high value of h^2 for the DBC parameter with the hybrid Sp/S1 marked by symmetrical distributions.

Genetic Correlations

The values of the genetic correlation coefficients are supplied for hybrids D1/D2, O1/P and C5/D4 (Table 7). In hybrid D1/D2 many characters show high correlation values. Noteworthy is the high positive correlation of the crease dimensions, the length of cavity appendices with the length of the caryopsis, the negative correlation of the height of the cavity with the caryopsis thickness, the positive correlation of the thickness of the aleurone layer with the length of the caryopsis and the cavity depth, as well as the negative correlation of the thickness of the aleurone layer with the cavity height. A number of genetic correlations are equally high as phenotypic correlations. Assuming a common line of development for many of the researched characters, the genetic correlations in the form D1/D2 indicate the pleiotropy of the genes rather than their linkage. The forms O1/P and C5/D4 show a big number of significant coefficients in the matrix of their genetic correlations. The hybrid O1/P is noteworthy for its high correlations of the crease depth with the length and weight of the caryopsis, as well as with the crease width; the caryopsis thickness with the crease width, the caryopsis weight with the length of cavity appendices and the thickness of subaleurone endosperm, as well as the caryopsis volume with the crease width, length of cavity appendices and thickness of

Table 7

Genetic correlations of some caryopsis characters ($r_g \times 10^2$)

D1/D2

	1	2	3	4	5	6	7	8	10	11	13
2	74...										
3	70...	92...									
4	90...	88...	92...								
5	68...										
6					70...						
7			79...	53...	31.	43..					
8	−37..	−60...		−59...							
10			80...	63...	89...		36..	−69...			
13	85...	93...	93...	99...			54...	−57...	68...	80...	
14	85...	97...	93...	99...			45...	−58...	67...	69...	99...

O1/P

	2	3	4	5	6	7	8	10	11	12	13	14
3	91...											
4	77...											
5		88...	85...									
6	75...		54...	98...								
7	56...	53...	76...	40..	33.							
8	49...											
10				28.	38..	37..						
11	−42..		80...									
12	−47...	−28.		−77...								
13	88...		90...		93...	76...			−60...	−44..		
14			81...			99...	39..		−82...	−65...		
15		28.										
17	71...		35.	91...	84...	62...		41..		−99...	73...	95...
18			−69...					71...	82...		−47...	−63...

C5/D4

	1	2	3	4	5	6	7	11	12	13	15	18
2	−34.											
3	63...	68...										
4	−39..	82...	88...									
5		94...	77...	90...								
6		54...	54...		65...							
7			34.		28.	39..						
8		72...	39..		56...							
10	31.											
11	36..			57...								
12			−62...			−79...						
13		83...	88...	94...	96...	72...						
14		78...	96...	82...	93...	83...			−52...	95...		
15		40..		81...	29.	−33.			39..	45...		
17					89...	79...	59...		−87...			
18		−57...	−47...		−59...	−43..		90...	27.	−95...		
19						32.		−43..	−81...		−62...	−51...

Significance level of r_g: . for α — 0.05
.. for α — 0.01
... for α — 0.001

subaleurone endosperm. The hybrid C5/D4 shows high correlations of the crease depth with the thickness, length and weight of the caryopsis, the cavity height with the caryopsis thickness, the caryopsis gravity and length, the caryopsis volume with the crease dimensions. Meaningful are high negative correlations of the DBC parameter with the gravity and filling of the caryopsis. Seemingly surprising are the negative correlations of the DBC parameter with the thickness of the subaleurone endosperm and the endosperm quality coefficient. In the hybrid C5/D4, the caryopses develop with disturbances and contain proportionately more protein. The disturbances concern, among other things, the development of both internal and subaleurone endosperm. High values of genetic correlations for the genetically remote forms such as *vulgare* and *polonicum*, indicate the gene linkage rather than the gene pleiotropy.

Multiplicative Gene Action; Distribution of Characters

The hybrids of the *vulgare* subspecies were investigated for the correlation between the mean and variance values. Such correlation exists for the characters: 4, 7, 8, 11, 12, 13, 14, 18. In the case of asymmetrically positive distributions, this may be indicative of the multiplicative gene action. Out of the listed characters only the cavity height shows markedly shifted mean values towards the lower mean values of the parent character. A very high value of the variability coefficient points up the necessity of carrying out the logarithmic transformation. The mean logarithmic values undergo a marked shift towards the arithmetic mean values of the parents, which would point to the multiplicative action of the genes which determine this character. In the case of the *aestivum* form hybrids one can speak of the multiplicative gene action for the DBC parameter in hybrid OP1/S3.

An analysis of the distribution of characters for 10 pure lines and 7 hybrids has been carried out. The largest number of deviations from the normal distribution has been registered for the height of cavity (positive asymmetry — leptokurtosis), the caryopsis gravity (negative asymmetry — leptokurtosis), and, particularly with hybrids, for the filling of caryopsis (negative asymmetry — leptokurtosis). The asymmetrical — leptokurtic distributions in the remaining characters occur much more seldom. All established significant values for the kurtosis apply to the leptokurtosis. This is evidence of a high concentration of the measurement values around the mean value for the majority of the populations under study. The hybrids show higher mean values for asymmetry than the parental forms in the case of fourteen characters and for the kurtosis — in the case of nine characters. The number of characters having significant asymmetry or kurtosis values is higher with the heterozygous form than with the homozygous forms.

Reciprocal Hybrids (Tables 8)

The hybrids C4/O4 and O4/C4, Ok1/R1 and R1/Ok1, as well as GS1/OP5 and OP5/GS1 are different in the biggest number of characters. The least differentiated are: OP3/M and M/OP3, OP4/C3 and C3/OP4, as well as R2/O3 and O3/R2. In many cases reciprocal hybrids of the *vulgare* subspecies are similar to the maternal forms. This applies, in particular, to the hybrids descending from forms O4-C4, R1-Ok1, C1-N, GS2-Ok3. The hybrids GS1/OP5 and OP5/GS1 show much lesser similarity to the maternal forms.

The differentiation of the reciprocal hybrids representing the *durum* form applies only to the DBC parameter. The hybrids *spleta/sphaerococcum* are most similar to their mothers. The differention of the *durum/vulgare* reciprocal hybrids is insignificant.

The difference between the reciprocal hybrids is also found in the extent of their transgression. Figures 1 and 2 present the largest differentiation of the transgression range in reciprocal hybrids. Breeders find beneficial a direction of crossing which yields a larger, desirable transgression. Noteworthy findings: large, disfavourable transgression of crease width in hybrid R2/O3, transgression of cavity appendices in form O3/R2, disfavourable transgression of cavity height in Ok1/R1. One should recognize as favourable the transgression of the aleurone layer thickness and the subaleurone endosperm thickness in hybrid OP3/M. Unfavourable are negative transgressions of caryopsis specific gravity in form GS1/OP5 and DBC parameter in O2/OP2. Favourable are positive transgressions of the aleurone layer thickness in hybrid D3/D2 and DBC parameter in S2/Sp. Reciprocal hybrids of the *spelta-sphaerococcum* forms show big differences in transgression range for the width, gravity and filling of the caryopsis, the endosperm yield coefficient and DBC parameter, while reciprocal hybrids of the *durum-vulgare* forms show such differences in the height of cavity, thickness of the aleurone layer, volume and filling of the caryopsis, endosperm yield and quality coefficient as well as DBC parameter.

Table 8

Differentiation of reciprocal hybrid pairs (t-test)

Hybrids	Caryopsis characters 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Characters total
O4/C4—C4/O4	+3*	+3*	+3*	+3*	+1*		+1*		+3*		+3*		+3*	+3*	+1*	−3*	−1*			13
R1/Ok1 — Ok1/R1	−1	−1*	−1*	−3*	−1*			−1*		−3*	+1*		−3*	−1*			−1*	+1	−3*	13
OP2/O2—O2/OP2									−1	−1								−1	−3*	4
C1/N — N/C1		−3*		−3*			−3*					−3*	−3*		−3					6
OP3/M — M/OP3															−3*					1
Ok2/C2 — C2/Ok2	−1*	−1*										−3					+3		+3	5
OP4/C3 — C3/OP4		+1*																		1
GS2/Ok3 — Ok3/GS2	+3*			+3*		−3*						−1*	+3*	+1*	+3*	−3*	−3			9
R2/O3—O3/R2												+3*								1
GS1/OP5—OP5/GS1	−3	−3	−3*	−3*	−3	−1*	−3		−3				−3*	−3*	−3*		−3	+1	−3	14
D3/D2—D2/D3																			+3*	1
Sp/S1 — S2/Sp	−3*			−3				−1*	+1		−3*		−3*		−3*	+3		−1*		9
D4/C5 — C5/D4		+1*									+3*				+3			+3*		4

1, 2, 3, — level of significance of differences between mean values respectively for $\alpha=0.05$, 0.01, 0.001.

+, −: mean value of 1st hybrid greater, smaller than mean value of 2nd hybrid.

* — both hybrids similar to their mothers.

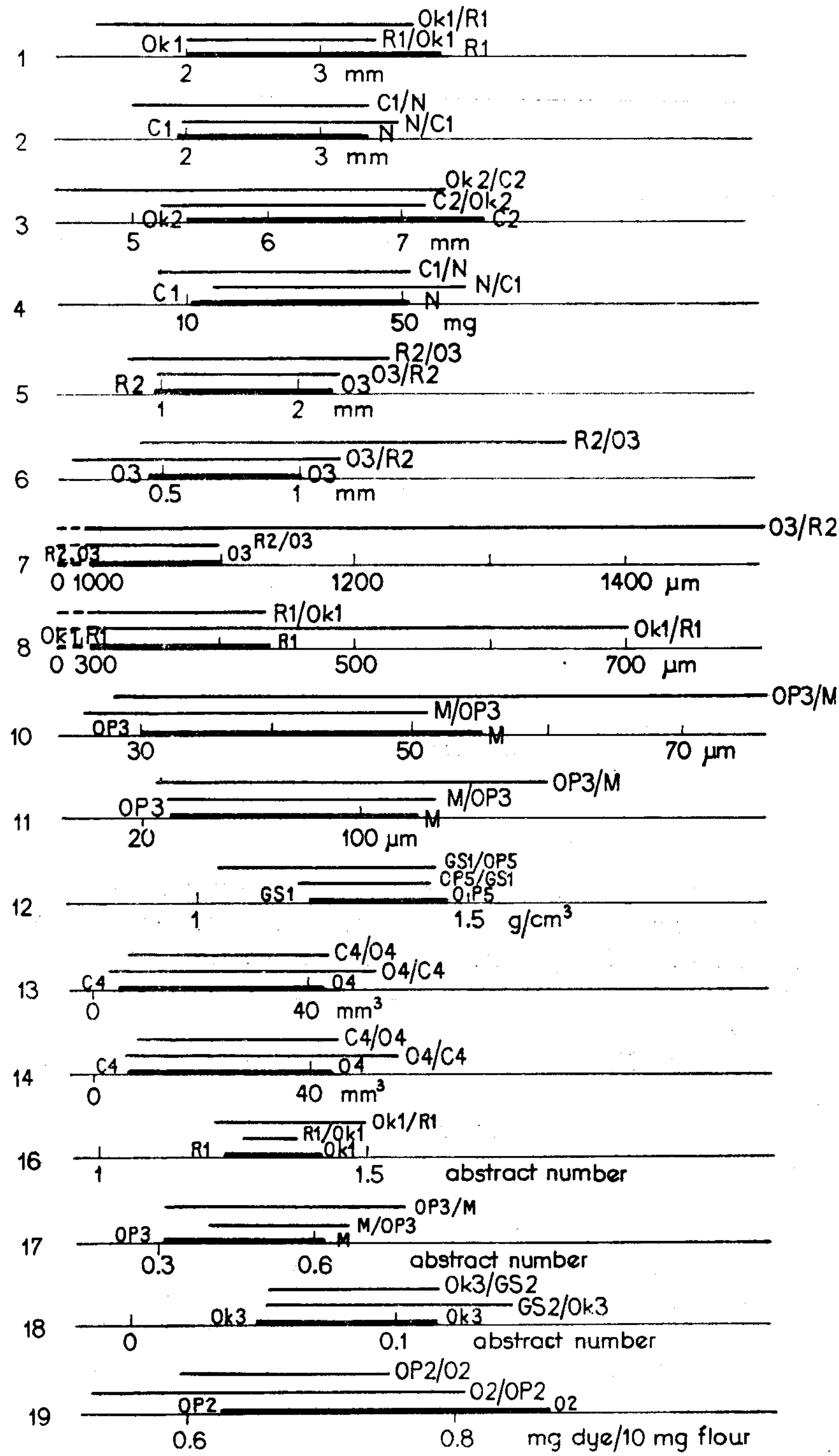

Fig. 1. Transgression of caryopsis characters in some pairs of reciprocal hybrids of the *vulgare* type (marked on the numerical axis is the range of the parent's or parents' character; above, are variability ranges in hybrid characters)

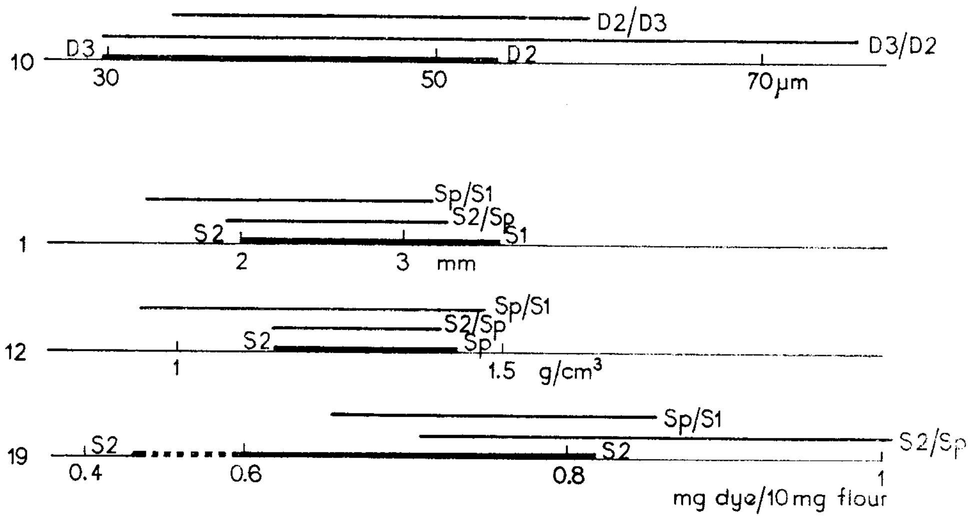

Fig. 2. Transgression of some caryopsis characters in pair of reciprocal hybrids of *durum* and *spelta-sphaerococcum forms* (the numerical axis shows the range of the parent's or parents' character; above, are variability ranges in hybrid characters)

Ideotype of wheat caryopsis

On the basis of data found in respective writings, as well as the author's own findings and observations, the following direction of caryopsis character changes has been established as the most favourable:

I. Characters Nos. 1, 2, 4, 10, 11, 13, 14, 15, 18, 19 — change towards higher values,

II. Characters Nos. 3, 5, 6, 8, 9, 16, 17 — change towards lower values,

III. Character No. 7 — long and narrow cavity appendices can enrich endosperm with aleurone cells and, therefore, one should endeavour to increase the value of this character. On the other hand, the appendices may form into empty, fairly large lateral cavities largely decreasing the amount of endosperm, a case for reducing them.

IV. Character No. 12 — in the case of correctly developed caryopsis, a reduction in the value of the character would indicate a higher protein content (lower specific gravity of protein than starch).

In view of the number of characters representing mean values approximating the ideotype, one should evaluate positively the following pure lines: O3, R1, M — in the *vulgare* subspecies, and D2 — in the *durum* form. The *sphaerococcum* form is of interest because of its shape and a high quality. The mentioned forms do not represent a fully ideal caryopsis because they may, at the same time, show disfavourable characters such as the excessively deep crease in form O3. The most beneficial hybrid forms are those which yield the largest number of individuals within a large favourable transgression range. The following *vulgare* form hybrids have registered a large, positive transgression range and, at the same time, a fairly large number of transgressive segregants for respective characters: 1 — O4/C4, 2 — O3/R2, 3 — O3/R2, 4 — O4/C4, 5 — R2/O3, 6 — O3/R2, 7 — M/OP3, 10 — Ok3/GS2, 11 — O4/C4, 12 — OP2/O2, 13, 14 — O4/C4, 15 — OP2/O2, 16 — C3/OP4, 17 — R1/Ok1, 18 — OP5/GS1 and 19 — O2/OP2.

The hybrids S2/Sp and Sp/S1 show interesting positive transgressions for DBC parameter with a big number of transgressive segregants. The hybrid OP1/S3 is marked by a larger number of such segregants for the caryopsis volume.

DISCUSSION

The knowledge of the variability of the caryopsis characters is of relevant importance to the processing of grains. Similar results concerning the variability of caryopsis dimensions have been obtained by, among others, Khadr (1970) and Kosina (1974). A similar variability of the caryopsis weight was obtained by Khadr (1970), both for control forms and those treated with mutagenes. There are few data available in scientific writings on the variability of the crease dimensions. The biggest interest in this matter is shown by Soviet researchers (Torzhinskaya et al., 1965; Petrenko, 1968). They concluded that the dimensions of the crease are very useful in characterizing the varieties. Mealy forms usually have a fairly wide crease, vitreous forms, for example *polonicum, durum,* have a less wide crease. A relevant caryopsis element from the practical viewpoint is endosperm cavity. It may sizeably reduce the amount of endosperm in the caryopsis. Some of the studied forms show marked deviations in the cavity structure (Kosina, 1979a). One can speak of the characteristic cavity types, for example, *vulgare, spelta, durum.* Kaniewski and Dalkiewicz (1959) associate the thickness of fruit and seed coats differentiation with the separability of the glumes in threshing. A weakening of the coats of caryopses in lemma and palea has been found in the *Stipa* and *Agrostis* genera by Maze and Bohm (1974). Boronoeva et al., (1968) obtained a similar relative variability of caryopsis coats in spring rye, as the author has found in wheat.

The aleurone layer and the subaleurone endosperm are decisive for the protein content, that is quality of the caryopsis. The development of both layers is quite differentiated among the wheat varieties (Kosin a, 1979a) which indicates the possibility of changing these characters with a view to obtaining caryopses of a higher quality. Jonard (1961) pointed to a relationship between the gravity of the caryopsis and its protein content. This is connected with the difference in the gravity of starch and protein. High-protein caryopses should have a somewhat lower gravity. Also a dependence has been discovered between the gravity and quality of the caryopsis (Kosina, 1978b), which is rather linked to the structure of the crease, cavity and endosperm underdevelopment, and not to the differences in the gravity of both storage components. For wheat, Anand et al. (1970) give the specific gravity range of 1.04-1.73 g/cu. cm, with the mealy grains having a lower gravity. What is a decisive factor in this case is the structure of endosperm. It has been pointed out that the DBC parameter for grain microsamples is tantamount to the amount of protein (Kosina, 1978a), but also to the quality of protein (Sharma and Kaul, 1976b). Sharma et al. (1976a), while studying the cultivars and hybrids of wheat, established the variability range of the DBC parameter between 3.2 and 8.8%, that is similar to the one established by this author. The combinative variation of the characters in the hybrids of the *aestivum* form subspecies is greater than in the hybrids cultivars of one subspecies. Such hybrids develop free of disturbances caused by the aneuploidy.

It is not always that the variability of F_2 generation exceeds the parental variability. For example, the variability of the lysine content in wheat attained the maximal variability registered by the parents (Haunold et al., 1962; Johnson et al., 1973), or was smaller (Sharma et al., 1975a). The latter authors obtained similar results for the variability of the weight of 1000 grains. Kosina (1974) obtained an increase in the variability of the dimensions of the wheat caryopsis in an insignificant number of cases. As already mentioned, an increase in variability has been obtained for a majority of characters and hybrids under research, but a statistically significant increase has been recorded by a much smaller number of cases.

The transgressions of the caryopsis characters are of relevant practical importance. For the protein content in the grain, they were found to be essential by, among others, Drozd (1970), Boyadzhieva (1972), Brej (1972), Johnson et al. (1973), for the caryopsis weight — by Khadr (1971), Bhatt (1972), and for the caryopsis dimensions — by Kosina (1974). The "transgressions" of the hybrid characters between the wheat tetra-and hexaploids are caused, most probably, by the aneuploidal condition of the caryopsis and they are given in order to illustrate the variability of the characters of the hybrids of this type rather than for their practical importance. In view of ascertaining significant correlations between various generations (F_2/F_3, F_3/F_4, etc.) for the protein content (Haunold et al., 1962; Rachinski and Rachinska, 1968; Brej, 1971; Boyadzhieva, 1972; Sharma et al., 1975b), the possibility has expanded to utilize the transgressions in practice.

Sharma et al. (1975b) have also ascertained such correlations between the DBC parameter and the grain weight.

An absence of a significant increase in the variability of the caryopsis characters in hybrids is the reason for zero values of h^2 in many cases. Studies on the extent of heritability have been carried out for few caryopsis characters. They were mainly concerned with the protein content and the caryopsis weight. The protein content estimates made by other researchers are as follows:

Haunold et al. (1962)	26-58%
Rachinski and Rachinska (1968)	15-80%
Boyadzhieva (1972)	63-85%
Sharma et al. (1975b)	60-89%

The latter authors achieved a similar result for the DBC parameter. A somewhat lower result for this character has been obtained for hybrid Sp/S1 (54%). For the other forms, however, much lower values have been arrived at. For the caryopsis weight the authors supply the following results:

Anand et al. (1970)	24%
Khadr (1971)	60-78%
Bhatt (1972)	87-89%
Sharma et al. (1975b)	95-99%

The h^2 values of the caryopsis weight for the studied samples have a large range and arrive at a value of 52% in hybrids D1/D2 or OP1/S3. The other characters of the caryopsis have been analyzed sporadically: specific gravity (80%), hardness (85%) — Anand et al. (1970).

A similar value of h^2, though additionally raised by the asymmetry of the hybrid character distribution, was obtained for the caryopsis gravity for Sp/S1 hybrid, while not overrated values were obtained for S2/Sp or N/C1. The authors referred to in no case analyze the dependence between the asymmetry of the distributions of characters and the h^2 values. The asymmetry of the DBC parameter distributions in hybrids C1/N and N/C1 indicates that the factor of dominance may play a role in the shaping of this character. The data supplied by Halloran (1975) indicate a large share of the additive variation in the variation of protein content, while the data provided by Johnson et al. (1973) indicate the dominance variation. The dominance of low protein content is observable more often. The protein content is often strongly influenced by the maternal organism and in that case the F_1 generation is like the mother (Drozd, 1970; Singh and Nanda, 1976). The similarity of reciprocal hybrids R1-Ok1, OP2-O2 and D2-D3 to their mothers in terms of the DBC parameter is partly corroborated by the above statement. The symmetrical distributions of the caryopsis weight are corroborated by the Bhatt (1972) data on the additive variation of this character.

The data on the genetic correlations of the caryopsis characters are very meagre. The statistical value of the genetic correlation is ridden by a big error (Falconer, 1974) which reduces the room for conclusions. The application of the Petr and Frey formula may produce non-sense values in the event of negative covariations of the parents or of greater variances of the parents than those of the hybrids. That commands additional consideration. The results, however, point to a bigger number of coefficients in the matrix table and higher values of the genetic correlations of characters in interspecies hybrids than in hybrids of one species or subspecies. That difference may arise from the fact that in one case we have to do with gene linkage, while in the other case with pleiotropy. The obtained data on the multiplicative gene action require supplementary information on other breeded generations (F_1, F_3, BC_1, BC_2). The multiplicative gene action for the characters where such action could be expected (caryopsis weight, volume), have not been ascertained.

While examining the caryopsis dimensions, Kosina (1974) found significant values of the asymmetry and kurtosis both for the parental forms and hybrids. The majority of the distributions were asymmetrically negative and leptokurtic. In the material presented, the distributions showing a significant deviation from the normal distribution for all characters, were leptokurtic. The data supplied by Sharma et al. (1976a), concerning the weight of 1000 grains, the total protein content, protein quality and DBC parameter indicate a big difference in the asymmetry and kurtosis of the distributions of the homo- and heterozygous material. The material presented in this paper reveals a similar phenomenon, though less distinctly.

An analysis of reciprocal hybrids revealed their big differentiation and, in many cases, their similarity to their mothers. It should be noted that a number of characters under study concerns triploidal tissues with the double maternal genome, hence the similarity to the maternal forms can result not only from the action by cytoplasm. The hybrids of the *spelta* and *spaerococcum* forms can be regarded as reciprocal hybrids in view of the close similarity of both pure lines S1 and S2 (Kosina, 1978b). The absence of major differences between the reciprocal hybrids of the *vulgare-durum* forms is due, most certainly, to the obliteration of the cytoplasmic differences between both forms in effect of the considerable disturbances in the development of caryopses. An observation of the F_1 *vulgare-durum* caryopsis, on the other hand, shows marked differences between reciprocal hybrids and their similarity to their mothers. Earlier studies on the intervarietal hybrids of spring wheat revealed significant differences in the morphology of grain of the reciprocal hybrids of the F_2 generation (Kosina, 1974), The significant influence of the mother on the protein content is pointed up, among others, by the studies carried out by Drozd (1970), Sharma et al. (1976a), as well as Singh and Nanda (1976). The revealed differences in the transgression of characters between the reciprocal hybrids attest to the practical sense of reciprocal crossing.

Mazurkiewicz (1975), in discussing the ideotype of the wheat plant, also took account for some caryopsis characters. Kamra (1971) and Konarev (1974) argue for increasing the number of aleurone layers and the thickness of the subaleurone endosperm. In view of the differentiation of the wheat forms concerning the structure of the crease, cavity, aleurone and subaleurone layers, a change of some caryopsis characters appears possible (Kosina, 1979a). Kamra (1971) also points to the possibility of changing the proportion: embryo — endosperm. In this way it is possible to expand the share of high-protein parts in bran or in flour with bran.

The studies by Fritsch et al. (1977) revealed the difference in the size of the embryo in the *Triticum* genus amounting to 1.5%, and in the *Aegilops genus* — to 3.3%. Konarev (1974) perceives the chance of increasing the protein content in new genotypes from the world wheat colllections, whereas Jakubziner and Pokrovskaya (1971) point to the high quality of protein in the wild forms of wheat found in these collections.

Acknowledgements for

Prof. Dr. S. Marek, Prof. Dr. S. Brej and Dr. A. Bartkowiak for their warm assistance.

REFERENCES

Anand S. C., Aulakh H. S., Jain R. P., 1970. Genetic variability for different physical characters in wheat kernels. Wheat Inform. Serv. 31: 5-7.

Bhatt G. M., 1972. Inheritance of heading date, plant height, and kernel weight in two spring wheat crosses. Crop Sci. 12: 95-98.

Boyadzhieva D. B., 1972. Nasledyavane na proteina v zàrnoto pri nyakoi knibridi na *Triticum aestivum* L. Genet. Sel. 5: 103-110.

Boronoeva G. S., Kazakov E. D., Nelyubina G. M., Shurygina V. A., 1968. Morfologicheskie kriterii zerna yarovoi rzhi. IVUZ Pishchevaya Tekhnologiya 4: 9-12.

Brej S., 1971. Wpływ selekcji na zawartość białka w ziarnie F_3 międzyodmianowych mieszańców pszenicy jarej. Hod. Rośl. Aklim. 15: 421-428.

Brej S., 1973. Zawartość białka w ziarnach mieszańców F_2 pszenicy zwyczajnej formy jarej. Hod. Rośl. Aklim. 17: 419-423.

Drozd D., 1970. Studies on the inheritance of total protein level in wheat grain. Genet. pol. 11: 321-339.

Evers A. D., 1970. Development of the endosperm of wheat. Ann. Bot. 34: 547-555.

Falconer D. S., 1974. Dziedziczenie cech ilościowych. PWN, Warszawa.

Fritsch R., Kruse J., Ohle H., Schäfer H. I., 1977. Vergleichend-anatomische Untersuchungen im Verwandtschaftskreis von *Triticum* L. und *Aegilops* L. (*Gramineae*). Kulturpflanze 25: 155-265.

Gill K. S., Brar G. S., 1973. Genetic analysis of grain protein and its relationship with some economic traits in wheat. Indian J. Agric. Sci. 43: 173-176.

Halloran G. M., 1975. Genetic analysis of grain protein percentage in wheat. Theor. Appl. Gen. 46: 79-86.

Haunold A., Johnson V. A., Schmidt J. W., 1962. Genetic measurements of protein in the grain of *Triticum aestivum* L. Agron. J. 54: 203-206.

Jakubziner M. M., Pokrovskaya N. F., 1971. Biokhimicheskaya kharakteristika zerna diploidnykh pshenic. Sel'sk. Biol. 6: 669-675.

Johnson V. A., Mattern P. J., Schmidt J. W., Stroike J. E., 1973. Genetic advances in wheat protein quantity and composition. Proc. 4th Int. Wheat Gen. Symp., Columbia: 547-556.

Jonard P., 1961. Etudes sur la densite rèelle du grain de blè tendre. Bull. Èc. Franc. Meun. 183: 133-140 (not. bibl.).

Kamra O. P., 1971. Genetic modification of seed protein quality in cereals and legumes. Z. Pfl. zücht. 65: 293-306.

Kaniewski K., Dalkiewicz H., 1959. Badania porównawcze nad budową okrywy owocowej ziarniaków pszenicy. RNR 84-D: 5-106.

Kent N. L., 1969. Structural and nutritional properties of cereal proteins. [In:] Proteins as human food. Proc. 16th Easter School in Agric. Sci., Univ. Nottingham: 280-299.

Khadr F. H., 1970. Variation and covariation of seed weight and its components in wheat following irradiation, EMS and hybridization. Theor. Appl. Gen. 40: 280-285.

Khadr F. H., 1971. Variability and covariability for plant height, heading date, and seed weight in wheat crosses. Theor. Appl. Gen. 41: 100-103.

Konarev V. G., 1974. Molekulyarno-geneticheskie aspekty i strategiya uluchshenija rastitel'nogo belka selekciei. Vestnik Sel'skokhoz. Nauki 4: 40-48.

Kosina R., 1974. Zmienność i analiza regresji wielokrotnej cech morfologicznych ziarna odmian i mieszańców pszenicy jarej. Biul. IHAR 1-2: 61-68.

Kosina R., 1978a. Zastosowanie metody mikro-DBC do oceny jakości ziarna wczesnych pokoleń hodowlanych. Biul. IHAR 133: 89-95.

Kosina R., 1978b. Analiza cech morfologiczno-anatomicznych i jakości ziarna mieszańców pokolenia F_2 przenicy jarej. Ph.D. Thesis University of Wrocław.

Kosina R., 1979a. Association between structure and quality of the wheat grain. Cereal Res. Comm. 7: 11-17.

Kosina R., 1979b. Choice of the most representative structural characters of the wheat kernel. Wheat Inform. Serv. 49: 10-13.

Mazurkiewicz B., 1975. Model przyszłościowej odmiany pszenicy na podstawie literatury i badań własnych. Biul. IHAR 1-2; 105-116.

Mac Key J., 1977. Sect. *Dicoccoidea* Flak sb. of wheat, its phylogeny, diversification, and subdivision. Symp. on Extended Availability of Wheat Genetic Resources. Bari: 1-22.

Maze J., Bohm L. R., 1974. Embryology of *Agrostis interrupta* (*Gramineae*). Can. J. Bot. 52: 365-379.

Petrenko T. P., 1968. Tekhnologicheskoye znacheniye struktury pshenichnogo zerna. IVUZ Pishchevaya Tekhnologiya 4: 18-22.

Rachinski T., Rachinska C., 1968. Nasledyavane sadarzanieto na protein v zàrnoto i efektivnost na otbora po tozi priznak pri nyakoy mezdusortovi khibridi na mekata pshenica. Genet. Sel. 1: 335-345.

Reddi M. V., Heyne E. G., 1970. Inheritance of plant height and kernel weight in two wheat crosses. Indian J. Gen. Plant Breed. 30: 109-115.

Schmidtke A., Jäger R., 1979. Tabellen zur Überprüfung der Normalität von Schiefe und Exzeb. Biom. Z. 18: 413-418.

Sharma T. R., Banarjee S. K., Kaul A. K., 1975a. Study of the inheritance of grain weight and protein content in wheat (*Triticum aestivum* L.) based on single grain analysis. Acta Biol. Jugoslav., Genetika 7: 167-179.

Sharma T. R., Banerjee S. K., Singh D., Kaul A. K., 1975b. Heritability of grain weight and some quality characters in wheat (*Triticum aestivum* L.). Acta Biol. Jugoslav., Genetika 7: 181-189.

Sharma T. R., Banerjee S. K., Singh D., Kaul A. K., 1976a. Study of distribution parameters and correlation among various quality characters in wheat (*Triticum acstivum* L.). Acta Biol. Jugoslav., Genetika 8: 1-15.

Sharma T. R., Kaul A. K., 1976b. Rationale of using dye-binding capacity (DBC) for the evaluation of protein content and quality in segregating lines of wheat. Z. Pfl. zücht. 76: 204-214.

Singh A. N., Nanda J. S., 1976. Effect of the genotype of seed and sporophyte on the protein content of seed in bread wheat (*Triticum aestivum* L.). Cereal Res. Comm. 4: 51-54.

Torzhinskaya L. R., Romenskii N. V., Umleva N. G., 1965. Ob èlementakh anatomii i morfologii zernovok luchshich sortov pshenic. IVUZ Pishchevaya Tekhnologiya 4: 15-18.

Węgrzyn S., Czembor H., 1974. Dziedziczenie niektórych cech u odmian i mieszańców jęczmienia jarego. Hod. Rośl. Aklim. 18: 51-60.

Niektóre parametry genetyczne cech ziarniaka pszenicy jarej

Streszczenie

Analizowano 19 cech ziarniaka szeregu linii czystych i ich mieszańców pokolenia F_2 pszenicy jarej. Stwierdzono duże zróżnicowanie form. Najwyższymi wartościami parametru DBC charakteryzowały się: odmiana Manitoba, formy *sphaero-*

coccum i *polonicum*, mieszańce form *durum*, mieszańce form *sphaerococcum* i *spelta*. Cechy charakteryzują się zróżnicowaną zmiennością względną od kilku do ponad 100%. Zmienność kombinacyjna oraz transgresje cech silniej przejawiały się u mieszańców między różnymi podgatunkami niż między odmianami jednego podgatunku. Wysoką odziedziczalnością „sensu lato" charakteryzuje się gęstość ziarniaka. Ustalono wpływ asymetrii rozkładów na kształtowanie się wartości h^2. Rozkłady cech z odchyleniami od rozkładu normalnego charakteryzują się wyłącznie leptokurtozą. Największą liczbą odchyleń dotyczących symetrii i kurtozy charakteryzuje się wysokość kawerny. Rozkłady cech form homozygotycznych wykazują mniejsze takie odchylenia niż formy heterozygotyczne. Mieszańce międzygatunkowe charakteryzują się liczniejszymi korelacjami genetycznymi w macierzy współczynników korelacji niż mieszańce form mniej zróżnicowanych. Szereg mieszańców przeciwnych wykazało zróżnicowanie w średnich wartościach cech oraz w zakresie transgresji, z równoczesnym podobieństwem do formy matecznej. Poczyniono krótkie rozważania nad ideotypem ziarniaka pszenicy.