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ANALYSIS OF XENIA IN F_1 SEEDS OF YELLOW–GRAIN WINTER–RYE LINES

ABSTRACT

F_1 hybrid grains from the topcross of 90 winter rye yellow–seed inbred lines with the green–seed tester SMH–108 were analysed. Our previous results on the relation between crossing ability and the effect of xenia on 1000–grain weight were confirmed. Presently quantitative xenia was analysed basing on the green colour of the grain. 90 inbred lines of yellow grain differences in percent of crossing were ascertained. In 27% of the analysed lines a significant quantitative xenia (1000–grain weight) was found. Out of the 90 lines as many as 29% gave, on open pollination, from 66 to 85% of hybrid grain. In four lines selected, quantitative xenia amounted 38, 25, 20 and 12% and crossing ability 57, 84, 58 and 74%. These lines may be of practical use in producing heterotic hybrids.

Key words: heterotic hybrid, open pollination, rye, quantitative xenia, .

INTRODUCTION

Investigations carried out by Grochowski *et al.* (1994a, 1994b, 1995, 1996a, 1996b, 1996c) have shown that yellow–grain rye lines open pollinated by various green–grain testers, give in some combinations high percentage of crossing connected with quantitative xenia in respect to 1000 grain weight exceeding by 10% that of mother component and matching the standards of this trait level.

The present hybrid cultivars are produced basing on cytoplasmatic male sterility (Geiger, 1982, 1985; Geiger and Miedaner,1993; Madej, 1975). The use of quantitative xenia in the heterosis–oriented breeding could simplify and lower the costs of breeding of new cultivars, provided the qualitative xenia (grain colour) and quantitative xenia (1000–grain weight) (difference between parental line and F_1 grain) enable separation of hybrid grain by sorting–machines. The practical use of 1000–grain weight xenia could be still of greater importance ir–

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respective of grain–colour, because in this case control crossing may be also carried out on the basis of other markers.

In the present paper quantitative xenia of grain weight and crossing percentage were analysed using green colour of the grain as a marker in 90 yellow–grain lines openly pollinated with the green tester SMH–108.

MATERIAL AND METHODS

Ninety lines of the population SMH–47–8 were analysed. In 1988 in the SMH–47–8 nursery an individual plant containing 33% of yellow grains had been selected and yellow–grain plants were reproduced in the isolated nursery. In the inbred lines produced, both number of hybrid grains and quantitative xenia, were determined in their S_1 generation.

In autumn 1994, 90 lines, 20 kernels of each, were sown in the isolated topcross nursery. As a tester the population of SMH–108 of good combining ability was used. In the nursery one row of the lines and two rows of the tester were arranged. Manual, point–wise sowing was used in the 20 × 30 cm spacing.

Before blooming in the lines and the tester the untypical and weak plants were removed. From each line three the most representative individual plants were selected, and then from each line 10 open pollinated ears were collected. The ears and grain served for characterisation of lines, analysis of quantitative xenia (1000–grain weight) and determination of percentage of crossing. The analysis of variance was performed basing on complete randomization for an unequal number of observations. For classification of the lines in uniform, not overlapping groups, the test of Haufe and Geidel (1984) was used.

To compare the lines according to grain colour the two–factor variance analysis with unequal number of replications was carried out.

In the field experiments, particularly those concerning varieties (different genotypes), it is important to find out intergenotypic differences. In the case of multiple comparisons, it is important for practical purposes to form groups with the least variability within the group and the highest between groups. The Haufe–Geidel test (1984) provides a possibility of separating of uniform groups the mean value of which do not overlap. The test by suitable modification correcting the level of the least significant difference is defined by the following formula:

where:

$$GD = S_{\bar{x}} \times T(\alpha, p, k, FG)$$

S_x – standard error of the mean

a – significance level

p – number of objects

k – number of compared objects
FG – number of degrees of freedom of the error from variance analysis
T – table value of any test.
When
where:

$$GD_1 = \sqrt{\frac{S^2}{n}} \times \sqrt{2} \times t_{FG,\alpha}$$

S^2 – mean square of error from variance analysis
$t_{FG,\alpha}$ – table value of Student's test (with α=0,05 and FG – the number of degrees of freedom from variance analysis), is assumed as a limiting difference, critical value GD_1 is too high to compare more than one ob–ject, therefore the standard error of difference can be reduced according to the formula:
After correction the formula is modified as follows:

$$S_d = \sqrt{\frac{S^2}{n} + \frac{S^2}{kn}}$$

When GD_1 is expressed as LSD, $\sqrt{\frac{k+1}{2k}}$ becomes a correction coefficient

$$GD_k = \sqrt{\frac{S^2}{n}} \times \sqrt{\frac{k+1}{k}} \times t_{FG,\alpha}$$

For instance, the correction coefficients for the consecutive comparisons

$$GD_k = GD_1 \times \sqrt{\frac{k+1}{2k}}$$

are:
Comments on the method:

k – Number of consecutive comparisons	Corrective coefficients $\sqrt{\frac{k+1}{2k}}$
1	1
2	0.8660
3	0.8165
4	0.7906
5	0.7746
10	0.7416
15	0.7303
20	0.7246

a. when application of this method does not mean that comparisons of all pairs of the objects are possible,
b. limits of these groups are established by division of the objects' means relating to the value of critical difference,
c. the number of groups preliminary and is established using cluster analysis.

The number of groups is finally determined taking into account the value of critical difference and through classification of the objects.

Objects' means could be arranged in increasing or decreasing order. The first object is designated $KW_1 = 1$. We find the difference "D" between the second and the first object and compare it with the value GD_1. If $D > GD_1$, the second object is ranked to a higher group. If $D < GD_1$, the second object belongs to the first group. Then, we calculate the difference "D" between the third object and the mean of the objects from the previous group – in this case $D = x_3 - 0.5\,(x_1 + x_2)$. This difference is further related to the value GD. Depending on the result, the procedure is analogously followed with the next value.

The Haufe–Geidel method gives results similar in the cluster analysis.

RESULTS

The common origin of 90 lines from a single plant indicates of their genetic similarity. However, the analysis of variance for such traits as: number of grains per an ear, grain weight per ear and 1000–grain weight revealed their significant differentiation at the level of $\alpha = 0.01$ (Table 1a). The 1000–grain weight was determined on the base of total number of grains and then separated into groups with green and yellow grains. To ascertain the statistically significant xenia, the two–factor analysis of variance for grain colour and lines was applied (Table 1b).

Table 1a

Mean squares of ear traits in yellow – grain winter rye lines

Source ofvariation	Number of degrees of freedom	Number of grains in ear	Grain weight from ear	1000 grain weight		
				Lines	Green "F_1"	Yellow
Lines	89	42.1**	0.07**	43.3**	39.3**	47.8**
Error	141	19.5	0.03	7.9	9.4	11.5

** – significant at $\alpha = 0{,}01$

Table 2 presents the variation ranges and differention of yellow–grain lines into separate homogeneous groups according to Haufe–Geidel. The number of grains per ear ranged from 23.9 to 43.5, and it was possible to distinguish a, b and c. The low grain number in ears was responsible for the relatively low grain weight per ear. In respect of this trait, the lines could be separated into three uniform groups: a – 67 lines, b – 19 lines and c – 4 lines (Table 2).

Table 1b

Mean squares of 1000 grain weight according to grain colour

Source of variation	Number of degrees of freedom	1000 grain weight
Lines	89	81.7**
Grain colour (B)	1	281.9**
Interaction (A × B)	89	5.2
Error	282	10.4

** – significant at $\alpha = 0{,}01$

Table 2

Classification of yellow – grain lines into separate homogenous groups according to the Haufe–Geidel's test

Number of grains per ear			Grain weight per ear			Percentage of crossing		
Lines	Group	Range	Lines	Group	Range	Lines	Group	Range
51	a	33.75–43.50	67	a	1.34–1.80	10	a	75.70–85.3
34	b	28.05–33.55	19	b	1.14–1.33	16	b	66.25–74.27
5	c	23.87–26.10	4	c	0.86–1.09	41	c	65.07–55.67
						10	d	47.53–54.53
						4	e	41.23–45.20
						5	f	30.40–35.7
						3	g	21.47–23.80
						1	h	15

The high percentage of crossing, in terms of open pollination, is one of the basic conditions for the use of lines in programmes of hybrid breeding without the use of cytoplasmatic sterility. The crossing per–centage enabled to classify the analysed material into eight uniform groups: a, b, c, d, e, f, g and "H". Out of the 90 lines, as many as 26 be–longing to groups a and b crossed in 66.0 – 85.3%. Such crossing level may already be satisfactory in heterotic breeding programmes, provided at the same time there is a sufficiently high quantitative xenia, enabling a mechanical separation of green „F_1" from yellow, „non – hybrid" grain. In rye with lowered fertility and for lax ears, bigger grains of higher 1000–grain weight may dominate. This did not hold yellow–grain lines.

The numerical classification of the lines according to ear traits is pre–sented in Fig. 1. It follows from this figure that the lines characterised by better fertility are mainly located also in the groups with higher grain weight per ear and 1000 grain weight. 51 lines belonging to group „a" with respect to the number of grains per ear, 5 are classified in group „a" for 1000 grain weight. Within the lines showing a low number of grain per ear there are also some which belong to group „a” because of their grain weight per ear and 1000 grain weight. Considering the lines according to their hierarchy defined in Fig. 1, the frequency of the lines in groups give evidence of their inconsistency. Lines situated in groups of better and worse fertility include also those with high grain weight per ear and high 1000 grain weight.

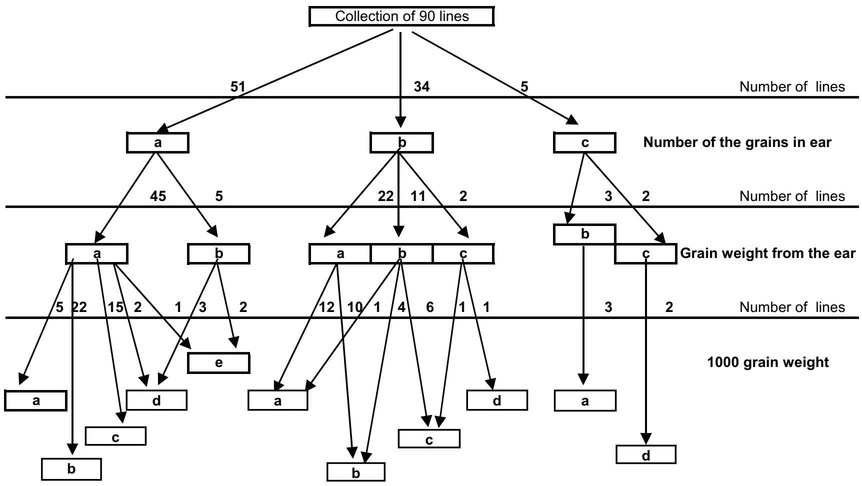

Fig. 1 A scheme of distribution of yellow seeds in F_1 hybrid according to the following criteria: grain number per one ear, grain weight per ear and 1000 grain weight

Table 3

1000 grain weight in F_1 grains of 90 lines open polinated with the green–grain tester SMH–108 non–separated and separated into groups according to grain colour

Grains non–selected for grain colour			Grains selected for grain colour						No. of lines produ–cing signi–ficant xenia	Xenia per cent
			Yellow			Green				
No. of lines	Group	1000 grain weight [g]	No. of lines	Group	1000 grain weight [g]	No. of lines	Group	1000 grain weight [g]		
20	a	44.54–51.1	33	a	42.13–50.7	21	a	44.90–51.3	9	5.9–9.9
37	b	40.35–44.18	38	b	37.55–42.00	38	b	40.55–44.60	9	7.2–20.3
21	c	36.75–40.15	18	c	31.45–36.25	19	c	37.80–40.13	5	11.5–38.0
9	d	33.04–36.14	1	d	28.3	9	d			
3	e	28.94–32.42				3	e	34.80–36.50		

Table 3 presents classification of the lines in uniform groups with regard to the variation of 1000 grain weight as well as to the effects of quantitative xenia connected with the hybrid or non–hybrid character of grains. The 1000 grain weight of the lines ranged from 28.9 to 51.1 g.

On the ground of the Haufe–Geidel test (Table 3). the lines were divided into five uniform groups. In twenty of them belonging to the group "a", the 1000–grain weight amounted 44.6 – 51.1 g. After separation of grains into two categories according to grain yellow colour (yellow non–hybrid grain, green hybrid grain) it was possible following the Haufe–Geidel test to distinguish four uniform groups showing yellow grains and five with green. The homogeneous groups of the lines “a”, “b”, “c”, “d” and “e’ of green grain groups are characterised by a higher 1000–grain weight compared to the analogous groups of lines having non–hybrid yellow grain. The obtained results (Table 3) indicate the occurance of xenia of qualitative type but this is not a rule, since it does not appear in all lines. The increment of 1000 green grain weight com–paring to the yellow grain weight has been expressed in per cent. The statistically significant xenia was found in 24 objects. In group „a” sig–nificant differences occurred in 10 lines and ranged from 5.9 to 9.9%. The lower the 1000 grain weight, the higher is the level of xenia ex–pressed in per cent. In one object xenia reached even 38%. Xenia over 10% may already be of practical meaning. The of level xenia and its frequency in 24 lines given below:

Xenia range [%]	Number of lines	Frequency of green grain lines [%]
5.9 – 10	14	14.4
10.1 – 20	7	7.7
20.1 – 30	2	2.2
30.1 – 40	1	1.1

The two–factor analysis of variance (Table 1b) enabled to separate the homogeneous groups in the categories of yellow and green grain (Table 3).

In our previous paper (Grochowski *et al*. 1995) it was assumed that 10% xenia is significant. In the present paper statistical significance was reached already at 5.5% of xenia. Higher xenia. exceeding 20% was rare and occurred merely in 3 lines. On the basis of the analyses four perspective lines 54, 67, 83 and 87 which gave 38, 25, 20 and 12% xenia were selected. These lines will be the object of further testing and will be used in practice for producing hybrids.

CONCLUSIONS

In the group of 90 inbred lines of yellow grain differences in% of cross–ing were ascertained and in 27% of them a significant quantitative xenia (1000 grain weight) was found.

Among the 90 lines as much as 29% of them produced under open pol–lination. from 66.2 to 85% of hybrid grain. Our previous results that the lines of smaller grain may show higher percentage of quantitative xenia have been confirmed.

There were selected four lines; 54, 84, 58 and 74, which gave a quantitative xenia in 38, 25, 20 and 12% and crossing of 57, 84, 58 and 74%. These lines may be of practical use in producing heterotic hybrids.

REFERENCES

Geiger H. H., 1982. Breeding methods in diploid rye (*Secale cereale* L.). Tag.–Ber. Akad. Landwirtsch.–Wiss. DDR: 305–332.

Geiger H. H., 1985. Hybrid breeding rye. Proc. Eucarpia Meet. Cereal Sect. of Rye. Svalov. Sweden: 237–266.

Geiger H. H., Miedaner T., 1993. Züchtgartenführer Hybridroggen. Universität Hohenheim. Zeit C: 1–12.

Grochowski L., Kaczmarek J., Kadłubiec W.. Bujak H.. 1994a. Analiza zmienności i zdolności kombinacyjnej linii wsobnych żyta o żółtym ziarnie. Cz. I. Wstępna ocena wartości hodowlanej linii krzyżowanych z formami SMH–108 i Motto. Biul. IHAR 190: 3–8.

Grochowski L., Kaczmarek J., Kadłubiec W., Bujak H., 1994b. Analiza zmienności i zdolności kombinacyjnej linii wsobnych żyta o zółtym ziarnie. Cz. II. Ocena hodowlana linii krzyżowanych z populacją CHDM 16. Biul. IHAR 190: 9–15

Grochowski L., Kaczmarek J., Kadłubiec W., Bujak H., 1995. Using xenia in the breeding of rye hybrids. Acta Soc. Bot. Pol. 64. 2: 175–180.

Grochowski L., Kaczmarek J., Kadłubiec W., Bujak H., 1996a. Genetic analysis of variability and combining ability of rye hybrid cultivars. Plant Breed. Seed Sci. 40. 3–4: 35–45.

Grochowski L., Kaczmarek J., Kadłubiec W., Bujak H., 1996b. Genetic variability of rye–xenic–hybrid traits. Acta Soc. Bot. Pol. 64. 3–4: 329–333.

Grochowski L., Kaczmarek J., Kadłubiec W., Bujak H.. 1996c. Characterisation of xenic rye hybrids. Vortrage für Pflanzenzücht 35: 66–67

Haufe W., Geidel H., 1984. Arbeitsgemeinschaft der Saatzüchtleiter. A 8952: 257–290

Madej L., 1975. Research on male sterility in rye. Hod. Rośl. Aklim. 19. 5/6: 421–422