STUDIES ON INBRED SIB-MATING IN RYE (*SECALE CEREALE* L.) II. COMBINING ABILITY OF LINES OBTAINED FROM SIB-MATING DEPENDING ON THE ORIGIN AND DEGREE OF SELF-INCOMPATIBILITY[1]

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Summary. Results of 3-year field experiments show that the combining ability of inbred lines of rye obtained from sib-mating depends on the state of self-incompatibility genes. Generally, a higher degree of self-incompatibility of lines is accompanied by a larger combining ability.

The origin of lines is of minor importance. Valuable appeared to be not only the lines derived from the cv. Dańkowskie Złote, but also part of the lines originating from hybrids involving a degenerated line.

The first part of these studies devoted to the problems of the obtaining of inbred rye lines with a high combining ability (Ruebenbauer et al. 1983), describes changes in the properties of lines during the going on inbred sib-mating. The authors have explained causes of a frequent seed setting under isolators by comparing the distribution of the observed degree of seed-setting with the theoretical distribution of the genotypes, assuming the control of self-incompatibility by two dominant genes, chiefly (Z and S) and by at least three pairs of gene modificators (V, X, W). It has been found that the observed frequencies of dominant genes causing partial seed-setting of spikes agree with the theoretical assumptions and that there exists an identical frequency of the occurrence of dominant and recessive genes ($p=q=0.5$). The probability of choosing randomly simultaneously two homozygotes, dominant with regard to five pairs of genes, which would transmit fully self-incompatibility to their progeny in sib-mating, is very little. It is about $P=0.000001$, i.e. 1 case per million. Considerably larger is a chance of choosing two self-incompatible phenotypes, which will, however, segregate in the progeny into self-incompatible and compatible individuals. It is about $P=0.056$, i.e. 5.6%. The chance of choosing one individual-partially self-compatible and another one--self-incompatible amounts to $P=0.362$ (36.2%), whereas the chance of choosing two individuals partially self-compatible, is $P=0.582$ (58.2%). For that reason at the initial stage of sib-mating there generally occurred partial self-compatibility in two individuals isolated together.

Despite a short-lasting inbred sib-mating and a large variation of the grain yield per plant, it was observed that the fertility steadily declined, irrespective of weather during these years. Individual inbred strains differed in the rate of decline of the grain yield per plant. Strains, self-compatible to a high degree as a result of self-pollination, showed a more rapid yield decline in comparison to self-incompatible strains. The remaining traits, i.e. tillering, plant height and spike length, generally showed no such a rapid depression, caused by sib-mating. A longer straw and a longer spike were accompanied by a larger grain yield per plant.

The aim of the studies carried out in 1980 - 1985 was to find dependences of the combining abilities of the lines on the state of genes controlling self-incompatibility and on the initial material.

MATERIAL AND METHODS

The control of self-incompatibility in sib-mating was performed in 1980 - 1982 by placing auxiliary shoots of two related plants under a common isolator at a simultaneous separate isolation of the main shoots of these plants.

In 1982, 24 lines from sib-mating were intercrossed, and a tester was the population variety Dańkowskie Złote. The obtained seeds of the selected 14 hybrids were sown out in 1983 - 1985 in the field experiment laid out by the method of random blocks in three replications on 1.5 m² plots. At the same time in 1983 - 1985 sib--mating of lines was performed, but that was without the control of self-incompatibility. The lack of self-incompatibility control in 1983 - 1985 made it impossible to trace dependences between self-incompatibility and combining value.

RESULTS AND DISCUSSION

Table 1 contains the values of the correlation coefficients for the yield per plot, yield per plant and 1000-seed weight per individual years and for the means of three years. The last values are smaller than those calculated for individual years, since their value was influenced by variation of seasons. Generally it is observed that the correlation coefficients increase with an increase of the inbreeding degree. This fact may be explained by the increase of inbred line homozygosity, as a result of which hybrids of the first generation with the passage of time display a more and more larger levelling. It might be suggested that between the values concerning the yield per plot and yield per plant there will occur negative correlation, since a smaller plant density causing yield decline in q/ha will makes it possible for plants growing more rarely to tiller better and, thereby will permit to increase the yield per plant. There, however, occurred positive correlation. The correlation coefficient for the 3-year means was $r=0.766$, ranging in different years from 0.688 to 0.937. The occurrence of positive correlation between the yield per plant and that per

Table 1. Correlation coefficients between plot yield, plant yield and 1000-seed weight of rye hybrids derived from crossing of sib-mating lines with cv. Dańkowskie Złote

Correlation between	Years			Mean of 3 years
	1983	1984	1985	
Plot yield and plant yield	0.688	0.817	0.937	0.766
1000-seed weight and plot yield	0.688	0.761	0.859	0.646
1000-seed weight and plant yield	0.741	0.629	0.862	0.544

area indicate that the share of the yield per plant in the total yield of individual hybrids is significant.

The correlation coefficients between the 1000-seed weight and yield per plot, $r=0.646$, and between the 1000-seed weight and yield per plant, $r=0.544$, are indicative of a significant influence of the 1000-seed weight on the yield per area in q/ha and on the yield per plant. The value of individual hybrids may be exhibited not only by their yields in q/ha, but also by the yield per plant and by the 1000-seed weight.

A high dependence between the yield per plot and the yield per plant is of great importance for a proper determination of the fertility of individual hybrids on the basis of a small population of F_1.

The performed selection towards the choice of pairs of isolated rye plants with the both self-incompatible components had its influence on the increase of their number, which is seen in Table 2. According to the assumptions concerning the occurrence of self-incompatibility it should be suggested that the frequently encountered compatibility in 1980 was related with the homozygous state of the main recessive genes of self-incompatibility S and Z. Two high-compatible plants intercrossed may have the following genetic composition: $S. zf \ zfV.yyW. \times sfsfZ. vvY.vw$ (full stops mean the probability of the occurrence of a given gene in both dominant and recessive forms). According to the data contained in the paper of Ruebenbauer (1976) the both plants should set seeds in about 50%. They are, therefore, high-compatible, which does not mean that it is impossible to obtain both fully self-incompatible pairs with the formula $S.Z.V.Y.W.$ in the progeny of these plants hybrids.

According to the theoretical assumptions discussed in the paper by Ruebenbauer (1976), a consequent selection towards elimination of recessive genes should be accompanied by an increase of the combining value. Cases of that kind are observed for hybrids of strains No. 3 and 13, where a consequent elimination of self-incompatibility genes is accompanied by high yields per plot or per plant and by fairly high regression coefficients, indicating that the yield increases with the passage of time. Somewhat different are these dependences for hybrids No. 5, 9 and 10. In all these cases the percentage of seed setting in 1980 was low, not exceeding 22%. According to the data contained in the papers of Ruebenbauer

Table 2. Regression coefficients of yield from 3-year experiments for 14 rye hybrids and the percentage of seed setting of the main spikes

Hybrid No.	Regression coefficients for % values		Percentage of seed setting		
	yield in q/ha	plant yield	1980	1981	1982
1	40.1	17.05	1.08	0.00	68.75
			17.50	0.00	0.00
2	77.8	−5.05	51.39	0.00	2.38
			50.00	0.00	0.00
3	5.15	20.65	51.39	0.00	0.00
			50.00	0.00	0.00
4	3.95	20.35	20.24	0.00	0.00
			80.95	0.00	0.00
5	2.85	13.60	4.17	0.00	0.00
			2.38	4.35	0.00
6	−34.20	−25.50	20.59	0.00	30.00
			2.50	11.84	7.50
7	6.15	1.60	51.39	0.00	0.00
			50.00	11.84	0.00
8	−10.95	0.95	11.11	21.59	0.00
			36.84	0.00	0.00
9	11.95	0.55	22.22	0.00	0.00
			2.93	1.19	0.00
10	−5.20	−4.70	22.22	0.00	1.56
			2.93	1.19	25.00
11	−35.95	−31.55	2.50	27.38	0.00
			6.36	0.00	38.64
12	10.95	−8.10	54.41	37.50	0.00
			33.82	11.96	17.20
13	18.95	20.55	54.41	37.50	0.00
			33.82	11.96	0.00
14	6.47	−6.90	10.71	5.00	0.00
			0.00	2.94	11.36

(1976) and Ruebenbauer et al. (1983) the corresponding strains should have dominant genes S and Z and most of dominant gene-modifiers. Selection for the self-incompatibility increase performed during the next years in that case could not give larger results and in this connection it should have been expected that the combining value of these lines did not differ much in different years. Generally low regression coefficients indicated that already during the first two years relatively high yields were obtained, which affected the 3-years means of the yield values. These observations confirm, therefore, the effectiveness of selection of lines towards self-incompatibility to increase their combining value. Hybrids No. 1, 6, 11 and 12, distinguishing by the lowest combining value, are accompanied by the regression coefficients of different value (chiefly negative), however, in all these cases it can be observed that selection towards self-incompatibility was ineffective, since in 1982 there occurred high-compatible individuals, whose seed-setting of spikes reached 69%. In that case, plants with the majority of pairs of recessive genes,

especially homozygotes with the formula *sfsfzfzfvfvfyfyf*, were selected. The low combining value of these plants confirms the suggestion about the effectiveness of selection in the direction of self-incompatibility. High, positive regression coefficients should not accompany higher percentage values of yields per both plots and plants. They show rather tendencies than the absolute values of yields in different years. An example of that fact are data concerning hybrid No. 1. The yield per plot and plant in the both first years of the experiment deviated markedly from the average and only in 1985 it reached its high value, which did not improve significantly the mean value for the years 1983 - 1985.

Hybrids distinguished by higher yields in q/ha, as compared to the control, which was the cv. Dańkowskie Złote, however, yields per plant were lower. These results should be explained by the fact that Dańkowskie Złote overwintered worse than the leading hybrids, as a result of which its yields per plot were lower, though rarely growing plants of the cv. Dańkowskie Złote gave higher yield per plant. It should be mentioned, however, that these data cannot be generalized, since the experiments were carried out on small plots. Nevertheless, they point out to the tendencies, which justify the suitability of the obtaining of inbred lines by the described method. Since the combining value of inbred lines presumably depends not only on their high degree of self-incompatibility, the obtaining of lines with a high combining value in the breeding practice should be based on a large initial material.

Regarding the initial material for the obtaining of inbred lines it appears that valuable hybrids frequently involve lines derived from the cv. Dańkowskie Złote. However, striking is the fact that inbred lines, the initial material of which were hybrids of cultivars of certain regions (Dańkowskie Złote and Pancerne) with the lines designated Rg, display both a large combining ability (hybrids No. 4 and 9) and low (hybrids No. 21 and 22). The Rg lines used for crossing had in fact the composition rg rg and distinguished by reduced hulls and glumes. These lines, being mutants, were characterized by a pleiotropic action of rg rg genes on many quantitative traits and particularly by a negative influence on plant fertility.

While the further selection of plants for inbred from the Rg rg hybrids, having nonreduced hulls, normal individuals were chosen, as a result of which the rg rg gene could not exert its negative action. However, some genes of that degenerated line had a favourable effect on the combining ability of the part of inbred lines obtained by that way, presumably as a result of the effect of heterosis of the overdomination type. Other lines, in which recessive homozygotes occurred, gave no heterosis effects.

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STUDIA NAD SIOSTRZANYM CHOWEM WSOBNYM U ŻYTA (*SECALE CEREALE* L.) II. ZDOLNOŚĆ KOMBINACYJNA LINII UZYSKIWANYCH Z CHOWU SIOSTRZANEGO W ZALEŻNOŚCI OD POCHODZENIA ORAZ STOPNIA SAMONIEZGODNOŚCI

Streszczenie

Na podstawie wyników trzyletnich doświadczeń polowych stwierdzono, że wartość kombinacyjna prowadzonych metodą chowu siostrzanego linii wsobnych żyta zależy od stopnia ich samoniezgodności. Okazało się ponadto, że linie o wyższym stopniu samoniezgodności charakteryzuje wyższa wartość kombinacyjna.

Stwierdzono także, że pochodzenie linii ma mniejsze znaczenie dla ich wartości kombinacyjnej. Otrzymano bowiem wartościowe pod tym względem linie wyprowadzone tak z odmiany Dańkowskie Złote jak i z mieszańców pochodzących z krzyżowania tej odmiany ze zdegenerowaną linią rg.

ИССЛЕДОВАНИЯ ИНБРИДИНГА РЖИ (*SECALE CEREALE* L.) ПУТЁМ СКРЕЩИВАНИЯ СИБСОВ II. КОМБИНАЦИОННАЯ СПОСОБНОСТЬ ЛИНИЙ, ПОЛУЧЕННЫХ ОТ СКРЕЩИВАНИЯ СИБСОВ В ЗАВИСИМОСТИ ОТ ПРОИСХОЖДЕНИЯ И СТЕПЕНИ САМОНЕСОВМЕСТИМОСТИ

Резюме

Результаты трёхлетних полевых опытов указывают на значительную зависимость комбинационной способности инбредных линий ржи, полученных в результате скрещивания сибсов, от состояния генов самонесовместимости. Обычно линии с высшей степенью самонесовместимости имеют высшую комбинационную способность.

Происхождение линий играет меньшую роль. Ценными оказались не только линии, полученные из сорта Даньковске Злоте, но также часть линий, происходящих от гибридов с дегенерированной линией rg.