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COMBINING ABILITY FOR SELECTED CHARACTERS IN WINTER RYE

ABSTRACT

General (GCA) and specific (SCA) combining abilities for four agronomic characters were determined in two experiments. The first included 24 F^1 hybrids produced by crossing 6 restorers (R) to four CMS single crosses (CMS–SC). The second experiment included 20 F_1 hybrids derived by crossing ten restorers to two CMS single crosses. The following characters were assessed: grain yield, heading date, plant height and lodging. Analysis of the combining ability was carried out according to the factorial mating design (North Carolina II Design) with the WAKOMBK (TP) computer software.

General combining ability of both males and females was significant for all the characters in the experiment 1. In the second experiment GCA of females proved to be significant for all the characters, but GCA of males was significant only for plant height. Significant specific combining ability was detected only for the heading date in the first experiment and for all the characters except for plant height in the second one. Additive gene effects seems to be more important than nonadditive gene effects in controlling all the characters under study. The restorers and CMS single crosses with significant and favourable GCA effects were selected for further stages of hybrid breeding programme.

Key words: winter rye, *Secale cereale* L., hybrid breeding, male sterility, restorers, combining ability, additive and nonadditive gene effects

INTRODUCTION

A fundamental problem in a hybrid breeding programme of rye is the proper choice of parental components to produce best hybrids. Assessment of the combining ability will enable a breeder to make the right choice. Numerous authors have reported general combining ability (GCA) and specific combining ability (SCA) for agronomic traits in rye (Morgenstern and Geiger 1975, Łapiński 1976, Geiger 1982, Węgrzyn and Madej 1989, Bujak *et al.* 1995, Grochowski *et al.* 1996, Kaczmarek *et al.* 1996). Unfortunately, only little information is available concerning

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combining ability of the materials developed in the IHAR hybrid rye breeding programme (Kolasińska and Węgrzyn 1998, 2000)

Thus, the aim of this work was to determinate the combining ability of selected restorers (R) and male sterile single crosses (CMS–SC) developed in the course of this programme.

MATERIAL AND METHODS

General (GCA) and specific (SCA) combining abilities for four agronomic characters were determined in two experiments. The first included 24 F_1 hybrids produced by crossing 6 restorers (R) to four CMS single crosses (CMS–SC) in a factorial mating design. The second experiment included 20 F_1 hybrids derived by crossing ten restorers to two CMS single crosses (CMS–SC 1 and CMS–SC 2). These CMS–SC's were testers in both experiments. Parental components were developed in the hybrid rye breeding programme carried out at the Plant Breeding and Acclimatization Institute at Radzików. The crosses were made in polyethylene greenhouses in 1998. In 1999 hybrids were sown in field trials (3 locations, 3 replicates, plot size – $5m^2$, sowing density – 320 viable kernels/m^2). The following characters were assessed: grain yield, heading date, plant height and lodging. Analysis of the combining ability was carried out according to the factorial mating design – North Carolina II Design or Design II of Comstock and Robinson (1952) with the WAKOMBK (TP) computer software, elaborated at the Department of Cereal Plants in Kraków.

RESULTS

Analysis of variance, presented in Tables l and 2, revealed significant differences among hybrids with respect to all the characters studied. It was found out, that hybrids × environments interaction was significant for the grain yield and the heading date in the first experiment (Table 1) and for the heading date and lodging in the second one (Table 2).

General combining ability of both males and females was significant for all the characters in the experiment 1 (Table 1). Significant interaction of GCA × environment was found for grain yield and heading date. Furthermore, significant interaction between GCA of females and environment was proved for lodging. In the second experiment GCA of females appeared to be significant for all the characters, but GCA of males was significant only for plant height (Table 2). Interaction between GCA of males and environment was significant for all the characters except for height. Interaction of females GCA × environment was significant only for lodging. Significant specific combining ability was detected only for the heading date in the first experiment (Table 1) and for all the characters except for plant height in the second one (Table 2). No significant interaction of SCA × E except for the heading date (Exp. 1) has been found. Significant interaction between the main factor and the en–vironment suggests liability of this factor. Consequently, it is necessary to conduct trials in various environments to obtain a reliable assess–ment of the main effects.

Table 1

Analysis of variance in a factorial mating design (experiment 1)

Source of variance	DF	Mean squares			
		Yield	Heading	Height	Lodging
Environments (E)	2	3176.05**	1409.46**	1403.10*	29281.58**
Hybrids (H)	23	113.91**	3.64**	30.80**	136.85**
GCA of males (m)	5	172.08**	4.69*	45.35**	195.07*
GCA of females (f)	3	464.47**	14.06**	95.04**	396.41*
SCA	15	24.41	1.21**	13.10	65.52
Interaction H × E	46	32.04*	0.96**	18.66	114.69
GCA (m) × E	10	44.85**	1.09*	16.25	71.01
GCA (f) × E	6	75.27**	2.61**	24.91	396.62**
SCA × E	30	19.13	0.59**	18.22	72.86
Error	144	18.66	0.23	13.17	81.30

*, ** – significant at the α = 0.05 and α = 0.01 probability levels, respectively

Table 2

Analysis of variance in a factorial mating design (experiment 2)

Source of variance	DF	Mean squares			
		Yield	Heading	Height	Lodging
Environments (E)	2	1686.87**	646.21**	2687.06*	37095.94**
Hybrids (H)	19	186.31**	2.37**	17.20**	142.91**
GCA of males (m)	9	58.32	2.74	27.26**	77.97
GCA of females (f)	1	2601.25**	2.70*	44.13**	868.95*
SCA	9	45.98*	1.96*	4.14	127.17**
Interaction H × E	38	34.03	1.44*	15.29	96.84**
GCA (m) × E	18	51.93**	1.90**	19.27	92.46*
GCA (f) × E	2	1.37	2.84	3.00	319.06**
SCA × E	18	19.75	0.83	12.68	76.53
Error	144	24.22	0.96	14.79	52.36

*, ** – significant at the α = 0.05 and α = 0.01 probability levels, respectively

The comparison of mean squares of GCA and SCA revealed an addi–tive action of genes for grain yield, plant height and lodging in the ex–periment 1 and plant height in the experiment 2. The predominance of additive over non–additive forms of gene action was found only for heading in the first experiment and for all the characters studied except for height in the second one. Additive gene effects seems to be more im–portant than nonadditive gene effects in controlling all the characters under study. The results indicated that for this set of parents, breeding procedures that utilized GCA effects should be most effective to improve all the characters.

Substantial additive variance was found for most agronomic charac–ters in several materials (Geiger and Morgenstern 1979). Estimates of general and specific combining ability variance indicate that for most traits the additive variance was much larger than all other components taken together. Even in grain yield non–additive effects generally con–tributed less to genetic variation than additive effects (Geiger 1982). The prevalence of GCA over SCA in rye was found by other authors: Morgenstern and Geiger (1975), Bujak *et al.* (1995), Grochowski *et al.* (1996), Kaczmarek *et al.* (1996), Kolasińska and Węgrzyn (1998, 2000). However, Łapiński (1976) detected a more important role of SCA in the total variability of grain yield per ear and grain yield per plant. The au–thor made it evident that additive variance was the main component of the total genetic variance as regards the heading date and plant height, although non–additive variance was significant.

Table 3

Effects of general combining ability (experiment 1)

Parents	Yield	Heading	Height	Lodging
		CMS–SC's		
1	–2.67**	–0.30**	0.56**	–1.37**
2	3.66**	–0.17**	0.04**	4.03**
3	–2.07**	0.76**	–1.85**	–0.92**
4	1.04**	–0.30**	1.25**	–1.75**
		Restorers		
10	1.00**	–0.40**	–1.28**	–2.24**
15	2.11**	0.27**	0.47**	–0.45
20	–1.24**	–0.09**	0.66**	–1.09**
25	–0.79**	0.02	–0.56**	1.85**
30	0.65**	0.10**	0.77**	0.11
35	–1.68**	0.10**	–0.06	1.81**

*, ** – significant at the $\alpha = 0.05$ and $\alpha = 0.01$ probability levels, respectively

The effects of general combining ability for grain yield, heading date, plant height and lodging in first experiment are presented in Table 3. The restorers 10, 15 and 30 appears to be the best at transmitting high yielding potential to their offspring (positive different from zero GCA effects). On the other hand, the restorers 20, 25 and 35, which GCA ef–fects were negative and significantly different from zero, decreased the yield of hybrids. Among all the females, CMS–SC 2 and 4 were the best at transmitting the ability to produce high yield. By contrast, CMS–SC 1 and 3 had unfavourable effect on the yield of its hybrids with restorers. The restorers 10 and 20 and the females 1, 2 and 4 transmit the early heading date to their offspring (significant negative GCA effects). Significant positive GCA effects of the restorers 15, 30 and 35 and the two remaining female suggest that they would delay the heading date of their offspring. The restorers 10 and 25 and the CMS–SC 3 decreased the plant height of the offspring (significant negative GCA effects). The other restorers (15, 20, 30) as well as the other females (1, 2, 4) increased plant height. It was found that the restorers – 25 and 35 and CMS–SC 2 were able to increase the resistance to lodging of their offspring. On the other hand, the restorers 10, 20, and CMS–SC's – 1, 3, 4 affected negatively this character.

The effects of general combining ability for the characters under study in the second experiment are presented in Table 4. Among the restorers the best transmitter of high yielding potential to offspring were: 40, 49, 55, 67. An early heading date were well transmitted by the restorers 43, 58 and 67. Plant height of offspring was decreased by the restorers 46, 58 and 61. The restorers 49, 52 and 55 were a good transmitter of lodging resistance to their offspring.

Table 4

Effects of general combining ability (experiment 2)

Parents	Yield	Heading	Height	Lodging
		CMS–SC's		
1	–3.80**	–0.12**	0.50**	–2.20**
2	3.80**	0.12**	–0.50**	2.20**
		Restorers		
40	2.16**	0.18**	0.34	–0.31
43	–2.09**	–0.43**	0.06	0.72
46	–0.36	0.23**	–0.44*	–4.88**
49	1.56**	–0.04	0.56**	3.30**
52	0.10	0.07	0.28	1.86**
55	1.22**	0.23**	0.01	4.03**
58	–1.06**	–0.65**	–0.44*	–1.10**
61	–2.49**	0.40**	–0.88**	–2.60**
64	–0.55	0.18**	–0.11	–0.72
67	1.50**	–0.16**	0.62**	–0.29

*, ** – significant at the $\alpha = 0.05$ and $\alpha = 0.01$ probability levels, respectively

The tests allowed to select valuable parental components for further stages of hybrid rye breeding programme. The restorers 49 and 55 seems to be an excellent transmitter of grain yield and lodging resis–

Table 5

Effects of specific combining ability (experiment 2)

Crosses	Yield	Heading	Lodging
1 × 40	2.16**	0.18**	–0.31*
1 × 43	–2.09**	–0.43**	0.72**
1 × 46	–0.36**	0.23**	–4.88**
1 × 49	1.56**	–0.04*	3.30**
1 × 52	0.10	0.07**	1.86**
1 × 55	1.22**	0.23**	4.03**
1 × 58	–1.06**	–0.65**	–1.10**
1 × 61	–2.49**	0.40**	–2.60**
1 × 64	–0.55**	0.18**	–0.72**
1 × 67	1.50**	–0.16**	–0.29*
2 × 40	–2.16**	–0.18**	0.31*
2 × 43	2.09**	0.43**	–0.72**
2 × 46	0.36**	–0.23**	4.88**
2 × 49	–1.56**	0.04*	–3.30**
2 × 52	–0.10	–0.07**	–1.86**
2 × 55	–1.22**	–0.23**	–4.03**
2 × 58	1.06**	0.65**	1.10**
2 × 61	2.49**	–0.40**	2.60**
2 × 64	0.55**	–0.18**	0.72**

*, ** – significant at the $\alpha = 0.05$ and $\alpha = 0.01$ probability levels, respectively

tance. Moreover, the restorers 15 and 30 were capable of transmitting high yielding potential to offspring. The usefulness of the restorer 10 is questionable because it combined the favourable GCA effects for grain yield, heading date and plant height with significantly unfavourable GCA effects for resistance to lodging. The restorers: 20, 58, 61 should not be used in the production of hybrids as they has a negative effect on grain yield and lodging resistance of the offspring. The other restorers improved one or two characters under study, but as they had a negative effect on the remaining characters, their breeding value is rather low. One of the examined females is noticeable – CMS–SC 2. It was effective in transmitting two positive characters (high yield, resistance to lodg–ing) in both experiments (Table 3, Table 4). The remaining females transmit more negative than positive characters to their offspring and should not be used in the production of hybrids.

Some hybrids with significant favourable effects of SCA for characters studied were observed (Table 5). The following hybrid combinations combined significant positive SCA effects for the grain yield and lodging with significant negative SCA effects for heading: 1 × 49, 2 × 46, 2 × 61 and 2 × 64 (Table 5). These hybrids yielded better, lodged less and headed earlier than expected based on the average performance of hybrids made with their parental components.

CONCLUSIONS

Results of this study indicate that additive gene effects were more important than non–additive ones in controlling all the characters studied. This provides an opportunity to improve the characters studied through selection in early generations.

Valuable parental components – the restorers: 49, 55, 15, 30 and CMS single cross 2 were selected for further stages of the rye hybrid breeding programme.

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