Sunflower Breeding for Resistance to the New Races of Broomrape (*Orobanche cumana* Wallr.) in Romania

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Abstract

The actual spectrum of the broomrape races in Romania has changed. The study of the sunflower differential set for the broomrape races, under natural and artificial infestation demonstrated the existence of a new spectrum of these races. We assigned the new race with F and the corresponding gene for resistance, with *Or6* gene. In our breeding work for resistance to this new race of the parasite, the results we have this far achieved in introducing genes for resistance to broomrape into sunflower value inbred lines are important. Our use of convergent crosses based on transgressive recombination has proven very suitable as a method for incorporating resistance genes into standard sunflower lines. The χ^2 test has shown the inheritance of resistance to be controlled by a single dominant gene. The results have also confirmed that the presence of broomrape in plant materials can be diagnosed very early in the season using a modification of the Pancenko method. An assessment made 40 days after sowing showed that broomrape plants were for the most part well developed by that time.

Keywords: broomrape (*Orobanche cumana* Wallr.); broomrape races; resistance genes; resistant genotypes; sunflower (*Helianthus annuus* L.)

INTRODUCTION

The genus *Orobanche* has more than 100 species which infect the roots of many crops of economic importance in the Mediterranean regions, Eastern Europe and the former URSS countries.

Broomrape (*Orobanche cumana* Wallr.) is one of the most dangerous parasites of sunflower. It is a typical obligate parasite that deprives the plant of water and mineral substances.

Broomrape is known to be spread by insects, water floods and wind, while opinions vary as to whether or not it can also be spread by seeds. Its first record came from Russia in the early 19th century, and spread gradually, in parallel with the expansion of surfaces cropped with sunflower.

BURLOV and KOSTIUK (1976) and POGORELITSKIJ and GESELE (1976) established that resistance to broomrape is controlled by the dominant gene *Or*. VRÂNCEANU *et al*. (1981) identified a series of differential lines for distinguishing between races C, D, E. Some researchers, however, determined that the inheritance of broomrape resistance is not monogenic. KROHIN (1980), for instance, reports finding two complementary genes for this trait, while DOMINIGUEZ (1996) made crosses with inbred line R-41 and determined that the resistance is controlled by two independent recessive genes.

Orobanche spp. as crop pests is known in Romania over sixty years.

The most severe losses from broomrape in Romania have been recorded in southern Moldavia, eastern Muntenia and Dobroudja, where the cultivars cropped, known as resistant have been progressively attacked by this parasite.

New races of broomrape can significantly endanger sunflower production. The development of hybrids resistant to the new races of this parasite is therefore essential, as is the incorporation of resistance genes into standard lines that have proven themselves in large-scale production and that have good production properties and high GCA (general combination ability). This is surest and most economical way to control.

Using dominant genes for resistance to broomrape in Romania, at the Research Institute for Cereals and Industrial Crops – Fundulea was developed on intensive

Table 1. The physiological spectrum of the races in broomrape populations in Romania (2001)

Differentials	Broomrape races						The reaction of the resistance	Resistant genes
	A	B	C	D	E	F		
AD-66	S	S	S	S	S	S	Ro	*Or0*
K-A41	R	S	S	S	S	S	R1	*Or1*
J-01	R	R	S	S	S	S	R2	*Or2*
Record	R	R	S	S	S	S	R3	*Or3*
S-1358	R	R	R	R	S	S	R4	*Or4*
P-1380-2	R	R	R	R	R	S	R5	*Or5*
LC-1093	R	R	R	R	R	R	R6	*Or6*
The ratio of the broomrape races (%)	44.8	21.4	7.2	9.8	15.1	1.7		

Table 2. Reaction of sunflower differentials to broomrape attack (populations of different sources), under artificial infestation (1995–2001)

Differentials	Year	Reaction to broomrape races	Source of broomrape seeds and infestation index (I%)					
			Constanta	Tulcea	Brăila	Vaslui	Ialomita	Teleorman
LC-1093		E–A	0.0	0.0	0.0	0.0	0.0	0.0
P-1380-2		E–A	0.0	0.0	0.0	0.0	0.0	0.0
S-1358		D–A	15.7	9.2	16.8	4.9	9.7	0.0
Record	1995	C–A	30.1	26.5	37.7	26.4	25.2	0.0
Jd-01		B–A	51.7	47.7	55.2	44.9	47.1	42.2
K-A41		A	69.1	63.5	62.5	62.4	64.1	62.1
AD-66		susceptible to all races	77.2	72.5	69.5	62.7	69.7	62.9
LC-1093		E–A	0.0	0.0	0.0	0.0	0.0	0.0
P-1380-2		E–A	3.8	2.6	3.9	0.0	0.0	0.0
S-1358		D–A	17.2	10.5	14.7	5.9	12.4	0.0
Record	1996	C–A	29.4	24.2	41.4	29.2	27.5	7.7
Jd-01		B–A	47.4	50.8	48.3	47.2	38.5	35.5
K-A41		A	57.2	49.4	59.2	67.5	59.5	61.3
AD-66		susceptible to all races	78.5	68.7	71.7	65.4	60.3	0.5
LC-1093		E–A	0.0	0.0	0.0	0.0	0.0	0.0
P-1380-2		E–A	5.4	4.3	5.5	0.0	4.7	0.0
S-1358		D–A	18.3	11.2	14.7	11.4	22.3	0.0
Record	1998	C–A	28.4	14.7	24.5	21.3	29.8	5.2
Jd-01		B–A	48.2	38.5	50.4	55.4	58.3	43.3
K-A41		A	49.1	57.6	61.3	60.7	57.4	2.7
AD-66		susceptible to all races	69.2	77.7	70.9	64.8	78.5	68.7
LC-1093		F–A	0.0	0.0	0	0.0	0.0	0.0
P-1380-2		E–A	7.5	9.2	15.7	0.0	8.7	0.0
S-1358		D–A	19.1	5.4	18.4	11.0	19.8	5.2
Record	2001	C–A	29.2	7.1	23.2	22.4	33.1	9.4
Jd-01		B–A	46.7	3.2	49.5	57.4	55.1	41.3
K-A41		A	47.2	44.1	59.7	61.4	57.2	66.3
AD-66		susceptible to all races	71.2	69.4	71.8	68.2	75.4	78.7

program for obtaining sunflower hybrids, available for the attack of the new races of the parasite.

By backcross method, *Or* gene is introduced in the valuable inbred lines resulting good resistant hybrids. There were obtained new resistant hybrids, to the new races of the parasite.

As a results of tests carried out with the differential set under artificial infestation, using the broomrape's seeds collected from different zones of the country in 1996 we found that the spectrum of physiological races of the parasite has changed. P-138-2 which has the *Or5* gene, controlling the resistance to the 5 races of the parasite (A, B, C, D, E) was not completely resistant in Constanta, Tulcea, Brãila zones.

MATERIAL AND METHODS

We used the convergent cross method based on transgressive recombination which enables on to almost fully restore the recurrent parent in a span of five generation. Resistant plants from the broomrape test are transferred to the greenhouse, first in small pots, until the stage of 3–4 permanent leaves, either into buckets containing the infested substrate or into infested field.

The pots are filled with a mixture of sand and humus in the proportion of 1:1, infested with broomrape seeds, collected from mature broomrape plants picked from the infested materials in the field.

RESULTS AND DISCUSSION

Research developed in Romania in the period 1976–1980, regarding the parasite – host plant interaction, resulted in identifying some differential sunflower genotypes, which stood at the basis of establishing new broomrape races: C, D, E, and of corresponding resistance genes: *Or3*, *Or4*, *Or5* (Table 1).

As a results of the tests carried out with the differential set under artificial infestation, using the broomrape seeds collected from different zones of the country, in 1996 we found that the spectrum of the physiological races of the parasite has changed, P-1380-2, which has the *Or5* gene, controlling the resistance to the 5th race of the parasite, was not completely resistant in Constanta, Tulcea and Brãila zones. The inbred line LC-1093 was completely resistant (Table 2).

A new race of the parasite appeared – race F. We assigned the corresponding gene for the new race, race F, with *Or6*.

This new race of the parasite is spreading every year in other zones of the country (Table 2).

The study of the crosses between different genotypes with different types of resistance has shown that LC-1093 has a gene, which is able to control the resistance to this new race of the parasite (Table 3).

Using the convergent cross method, after five generation, the percentage of resistance to *Orobanche cumana* could be increased up to 100% (Table 4).

Table 3. The reaction to the broomrape attack of F_1, F_2 and test-cross generations, resulted from the crosses between inbred lines with different resistance types

Crosses	Resistance type	Generations	Resistant plants*	Susceptible plants**	Expected segregation ratio	*P* (%)
	R6	F_1	64	0		
LC-1093 × A-1566		F_2	63	22	3:1	0.50–0.75
	R4	test-cross	59	61	1:1	0.50–0.75
	R6	F_1	65	0		
LC-1993 × P-1380-2		F_2	62	20	3:1	0.90–0.95
	R5	F_2	65	22	3:1	0.90–0.95
	R5	F_1	65	0		
P-1380-2 × 0-7240		F_2	61	21	3:1	0.10–0.25
	R4	F_2	64	22	3:1	0.99
	R4	F_1	66	0		
0-7240 × 0-7586		F_2	64	20	3:1	0.90–0.95
	R3	F_2	65	22	3:1	0.90–0.95
	R2	F_1	63	0		
F-3004 × AD-66		F_2	66	21	3:1	0.90–0.95
	R0	test-cross	58	60	1:1	0.25–0.50

* resistance similar to the type of the resistant parent

**resistance similar to the type of the susceptible parent

Table 4. Evaluation of the reaction of different sun ower generation of selection for resistance to broomrape

Origin	Selection No.	Generation	Infestation degree (I%)
1064C × R1	S – 021	F_3	1.7
1064C × R1	S – 034	F_4	1.5
1066C × R1	S – 102	F_4	2.4
1066C × R1	S – 107	F_3	3.2
1085C × R1	S – 212	F_3	1.9
1085C × R1	S – 222	F_4	0.7
1095C × R1	S – 328	F_2	4.9
1095C × R1	S – 334	F_3	2.1
1103C × R1	S – 402	F_3	1.8
1103C × R1	S – 454	F_2	3.1
1103C × R1	S – 448	F_4	0.7

Table 5. Reaction to the attack of broomrape (*Orobanche cumana*) of several sun ower wild species

Variant	Infestation	Infestation (%)
AD-66 (check)	88.27	100
H. annuus	22.3	25.3
H. petiolaris	14.8	15.8
H. agrestis	0.0	0.0
H. anomalus	0.0	0.0
H. debilis	7.9	7.5
H. divaricatus	0.8	0.9
H. maximiliani	39.7	42.5
H. decapetalus	0.0	0.0
H. laeti orus	0.9	1.1
H. pauci orus	0.0	0.0
H. grosseseratus	0.0	0.0
H. nuttallii	0.0	0.0
H. strumosus	0.0	0.0
H. mollis	0.0	0.0
H. resinosus	0.0	0.0
H. tuberosus	0.0	0.0
H. occidentalis	0.0	0.0

The parasite forms new physiological races, that overcome existing resistance. For this reason one should look for various donors of *Or* genes. This necessitates a continuous search for new sources of resistance.

Table 6. Evaluation of the reaction of interspecific hybrids (F1 BC generations), to *Orobanche cumana*

Origin	Generation	Infestation index (%)
H. nuttallii × A-2024 (S-042)	F1 BC2	8.2
H. nuttallii × A-2024 (S-063)	F1 BC4	10.1
H. nuttallii × A-2024 (S-082)	F1 BC5	11.7
H. nuttallii × R-1032 (S-004)	F1 BC2	6.7
H. nuttallii × R-1032 (S-009)	F1 BC6	14.2
H. grosseserratus × A-3028 (S-081)	F1 BC4	11.8
H. grosseserratus × A-3028 (S-007)	F1 BC8	12.4
H. grosseserratus × R-1008 (S-005)	F1 BC2	5.2
H. grosseserratus × R-1008 (S-005)	F1 BC5	6.8

We have investigated annual and perennial *Helianthus* species as potential sources for resistance to *Orobanche cumana* (Table 5).

The variation in the degree of resistance to *Orobanche cumana* was due to the fact that the wild species were maintained as populations and that hybridization was carried out with pollen mixture. As a result of segregation various degrees of resistance to *Orobanche cumana* were obtained (Table 6).

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