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EVALUATION OF BROOMRAPE RESISTANCE IN SUNFLOWER HYBRIDS

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SUMMARY

Broomrape (*Orobanche cernua* Loeffl.) is the most serious problem in sunflower production in Turkey, some East European countries and Spain. A research covering broomrape tests of sunflower hybrids in the trials based on National Sunflower Research Project was conducted in Trakya region, which holds 75% of the sunflower production in Turkey, in 2006, 2007 and 2008. Based on this project, in conditions of natural infestation, 306, 443 and 533 commercial and candidate hybrids, inbred lines, *etc.* were tested in 2006, 2007 and 2008, respectively. Of the tested materials, 12 in 2006, 56 in 2007 and 140 in 2008 were found to be resistant. During winter, broomrape tests continued in growth chambers and in pots, under conditions of artificial infestation. Broomrape seeds were collected from a naturally infested area in Trakya region and used to determine the reaction of developed hybrids and lines to the collected races. In this part of the study, 1752, 816 and 1389 genetic material were tested in 2006, 2007 and 2008, respectively. The tests showed that 332, 94, and 404 materials in 2006, 2007 and 2008, respectively, were resistant to the new races of broomrape used in the study.

Key words: sunflower, broomrape, tests, resistance

INTRODUCTION

Broomrape (*Orobanche cernua* Loeffl.) has been the most serious problem in sunflower production in Turkey, leading to considerable yield losses, up to 100%, and reducing of sunflower seed quality since 1960s. Furthermore, this parasite develops new and more virulent races year after year which overcome the resistance of the varieties and hybrids used in commercial production. Broomrape flowers produce a large number of very small seeds which fall to soil surface and so the parasite spreads easily and quickly by wind and it cannot be controlled efficiently with cultural methods such as rotation, later planting, *etc*.

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Although old races are known to exists in many countries (Sukno *et al*, 1999; Tang *et al.*, 2003; Shindrova, 2006), new races of *Orobanche* occurred only in Spain (F-Martínez *et al.* 2000; Melero-Vara *et al.*, 2000; Aktouch *et al.*, 2002; Pérez-Vich *et al.*, 2002) and Turkey (Kaya *et al.*, 2004b). However, the virulence of these new races was overcome by resistant hybrids (Jan *et al.*, 2002) and imidazilonone herbicides applyed post emergence in the so-called CLEARFIED® system (Kaya *et al.*, 2004a).

MATERIAL AND METHODS

Sunflower hybrids and lines were developed within National Sunflower Research Project at TARI (Trakya Agricultural Research Institute) in Edirne and the commercial sunflower hybrids that belong to other companies and institutions were tested against the new broomrape races under natural and artificial conditions in the period 2006-2008.

Under the conditions of artificial infestation, broomrape seeds were cleaned threshing the plants collected from different infested fields of Trakya Region having 75% of Turkey sunflower production. Broomrape tests were performed in pots, mainly in winter time. Before planting, about 1-2 g broomrape seeds were placed at the bottom of the pots. *Orobanche* plants were counted on each root after 35 days from planting, after washing the rots.

Under the natural conditions, broomrape test were conducted in infested Malkara region each year. Susceptible Sanbro hybrid and resistant P-4223 hybrid were used as controls at each 40 rows which were 1 m long between rows at 4 m plots. Broomrapes were counted on each plant in the rows between flowering and physiological stages. Broomrape occurrence was evaluated for frequency (F), intensity (I) and attacking rate (AR) based on Pustovoit method. Plants were accepted as resistant when having 0-10 frequency %, and 0-1 AR values (Vranceanu *et al.*, 1980). The plants with 10-20 frequency % were accepted as tolerant.

- F=% of plants with *Orobanche* (the plant number infested by *Orobanche*/total number of plants in the row × 100)
- I=the number of *Orobanche* in one infested plant (total *Orobanche*/total plants infested by *Orobanche* in the row)
- AR=F × I/100=the number of *Orobanche* on one plant in the row.

RESULTS AND DISCUSSION

In the conditions of natural infestation, 1282 genetic material were tested between 2006 and 2008. Resistant materials were increased extremely (from 12 to 140) in last year (Table 1). Similarly, the number of resistant material were 50% more than 2006s observations (Table 2). These results indicated that sunflower breeding program at TARI improved efficiently broomrape resistance. Materials that belonged to institutions other than TARI were also tested in this period. Although there were no resistant lines from Dobroudja, Szeged and Karaj institutes,

Uludag University and USDA Sunflower Research Unit, some resistant lines and hybrids were observed in the material from Soltis and Fundulea Institute (Tables 3, 4 and 5). From the sunflower hybrids which are commonly sold on the Turkish market, only P-4223 from Pioneer Seed Co, Tunca from Limagrain Seed Co and Muson from May Seed Co. showed resistance in this study (Tables 6, 7 and 8).

Table 1: Broomrape tests under the conditions of natural infestation conducted in summer

Type	Year		
	2006	2007	2008
Number of tested material	306	443	533
Number of resistant material	12	56	140

Table 2: Broomrape tests in pots conducted in winter time in the period 2006-2008

Year	Tested material	Susceptible	Tolerant (1-5 Bromrape)	Resistant
2006	1702	1072	278	352
2007	2167	1501	389	277
2008	1389	721	264	404

Table 3: Broomrape tests under conditions of natural infestation conducted in Malkara in 2006

Institution	Type	Total material	Susceptible	Tolerant	Resistant
Dobroudja-Bulgaria	*cms* Line	13	13	-	-
Szeged GKI-Hungary	*cms* Line	10	10	-	-
TARI	Candidate Hybrid	40	38	1	1
TARI × Maisadour	Joint Hybrid	9	9	-	-
TARI × Szeged	Joint Hybrid	33	33	-	-
TARI × Soltis	Joint Hybrid	72	66	5	1
TARI × Fundulea	Joint Hybrid	6	6	-	-
TARI × Novi Sad	Joint Hybrid	12	12	-	-
Soltis-France	Hybrid	40	33	4	3
Karaj-Iran	Hybrid	6	6	-	-
FAO Network Trials	Hybrid	13	12	1	-
Registration Trials (Oil Type)	Hybrid	23	17	2	4

Table 4: Broomrape tests under conditions of natural infestation conducted in Malkara in 2007

Institution	Type	Total material	Susceptible	Tolerant	Resistant
Soltis-France	*cms* Line	10	4	3	3
Szeged GKI-Hungary	*cms* Line	5	5	-	-
Fundulea Romania	*cms* Line	7	-	2	5
USDA Germplasm	*cms* Line	19	18	1	-
USDA Germplasm	Restorer Line	11	9	2	-
TARI	Candidate Hybrid	47	6	3	37
Hibrisol-Spain	Candidate Hybrid	41	27	11	3
Uludag University	Candidate Hybrid	6	5	1	-
TARI × Dobroudja	Joint Hybrid	62	60	2	-
TTAE × Szeged GKI	Joint Hybrid	119	105	12	2
TTAE × Maisadour	Joint Hybrid	18	17	1	-
Registration Trials (oil type)	Hybrids	33	22	4	7

Table 5: Broomrape tests under conditions of natural infestation conducted in Malkara in 2008

Institution	Type	Total material	Susceptible	Tolerant	Resistant
TARI	*cms* Line	18	-	-	18
TARI	Candidate Hybrid	98	60	2	36
AARI	Candidate Hybrid	12	11	-	1
TARI × Szeged GKI	Joint Hybrid	134	100	2	32
TARI × Soltis	Joint Hybrid	26	16	1	9
TARI × Hibrisol	Joint Hybrid	7	2	-	5
TARI × Maisadour	Joint Hybrid	14	6	1	7
TARI × Novi Sad	Joint Hybrid	10	5	-	5
TARI × Fundulea	Joint Hybrid	10	10	-	-
AGROMAR	Hybrid	3	2	-	1
Registration Trials (Oil Type)	Hybrid	22	2	-	20
Registration Trials (Confectionery)	Hybrid	6	6	-	-

Table 6: Broomrape resistance of the most popular commercial hybrids in Turkey tested in Malkara in 2006

Cultivar	Plant #	Plant # with *Orobanche*	*Orobanche* number	Frequency (%)	Intensity	Attacking rate
P-4313	10	9	50	90	5.55	5.00
P-4223	10	0	0	0	0	0
MUSON	10	0	0	0	0	0
MERIC	10	9	55	90	6.11	5.50
PACTOL	10	9	50	90	5.55	5.00
SANBRO	10	9	60	90	6.66	6.00
COBAN	10	9	57	90	6.33	5.70
C-70165	10	9	53	90	5.88	5.30
TUNCA	10	0	0	0	0	0

Table 7: Broomrape resistance of the most popular commercial hybrids in Turkey tested in Malkara in 2007

Cultivar name	Plant #	Plant # with *Orobanche*	*Orobanche* number	Frequency (%)	Intensity	Attacking rate
C-70165	7	4	7	57	1.75	1.00
COBAN	7	4	11	57	2,75	1.57
MERIC	10	2	3	20	1.50	0.30
DKF-2525	10	1	1	10	1.00	0.10
MUSON	8	0	0	0	0	0
P-4223	8	0	0	0	0	0
SANBRO	8	3	7	38	2.33	0.88
TUNCA	7	0	0	0	0	0

Table 8: Broomrape resistance of the most popular commercial hybrids in Turkey tested in Malkara in 2008

Cultivar	Plant #	Plant # with *Orobanche*	*Orobanche* number	Frequency (%)	Intensity	Attacking rate
MERIC	5	3	10	60	3.33	2.00
P-4223	5	0	0	0	0	0
DKF-2525	5	1	1	20	1.00	0.20
SANBRO	6	4	8	66	2.00	1.32
TUNCA	6	0	0	0	0	0

Each year, resistant sunflower hybrids from different seed companies are released on the market. DKF-2525, from Monsanto Seed Co., released in 2006, was observed together with other resistant commercial hybrids and some broomrape plants were observed on its roots (Tables 7 and 8). While only some materials were observed as resistant in 2006 (Table 9), many lines and hybrids exhibited resistant behavior in 2007 and 2008 (Tables 10 and 11).

Table 9: Broomrape tests under conditions of natural infestation conducted in Malkara in 2006

#	Material	Origin	Type	Plant #	Plant # with *Orobanche*	*Orobanche* number
1	Tunca	Sygenta	Commercial Hybrid	10	1	1
3	Muson	Sygenta	Commercial Hybrid	10	1	1
5	2478-A	TARI	*cms* Line	10	1	1
C	P-4223 (Resistant Check)	Pioneer	Commercial Hybrid	10	0	0
C	SANBRO (Susceptible Check)	Sygenta	Commercial Hybrid	10	9	>50
70	ED/9	SOLTIS	Hybrid	10	0	0
86	ED/25	SOLTIS	Hybrid	10	0	0
95	ED/34	SOLTIS	Hybrid	10	0	0
106	SOLF 2585j/A	SOLTIS	*cms* Line	10	0	0
164	LG1234/A × 6973-R	SOLTIS	Joint Hybrid	0	0	0
203	2517-A × 9216-R	TARI	Candidate Hybrid	10	0	0

Both joint hybrids with other institutions and the hybrids from TARI were observed in the study, especially in 2007 and 2008 (Tables 10 and 11). Additionally, both finished inbred lines from TARI, early breeding lines and numerous F_4 F_5 and F_6, genetic material were found resistant both under natural and artificial conditions in the winter tests. The increased number of resistant material lines and hybrids, especially in recent years, showes the success of the sunflower breeding program conducted at TARI.

Results on broomrape resistance results for some years were not entirely reliable due to drought during sunflower growing season and inconsistency in broomrape distribution in all parts of the experiment field. Therefore, to confirm the results of natural infestation and also previous control of genetic material before planting in breeding nursery, the material evaluated under natural conditions was also tested against new broomrape races under conditions of artificial infestation.

CONCLUSIONS

There was considerable variation in broomrape resistance among the inbred lines and hybrids screened in this study. Resistant inbred lines and hybrids from TARI and other institutions were observed both in natural and artificial conditions because the final objective is to develop material resistant to new broomrape races for Turkish market (about 2.000 MT hybrid seed). There is no option to sell nonre-

Table 10: Broomrape tests under conditions of natural infestation conducted in Malkara in 2007

#	Material	Origin	Type	Total plant	Result
1	F5AA410/A	Soltis	*cms* Line	10	R
5	SF49CCO1JO/A XEGF646J-0	Soltis	*cms* Line	10	R
10	SOLF0618 J/A × SP-R-96	Soltis	*cms* Line	10	R
C	P-4223 (Resistant Check)	Pioneer	Commercial Hybrid	10	R
C	SANBRO (Susceptible Check)	Sygenta	Commercial Hybrid	10	S
118	3009-A × K4-R S.N:53	TARI	Candidate Hybrid	10	R
119	7751-A × K6-R S.N:10-15	TARI	Candidate Hybrid	10	R
120	HA-89-1-A × K7-R S.N:6	TARI	Candidate Hybrid	10	R
121	0195-A × MMR-471-2 S.N:8 (2006)	TARI	Candidate Hybrid	10	R
122	HA-821-A × MMR-471-2 S.N:8 (2006)	TARI	Candidate Hybrid	10	R
123	2517-A × MMR-471-2 S.N:6 (2006)	TARI	Candidate Hybrid	10	R
124	2517-A × K3-R S.N:14,15,16	TARI	Candidate Hybrid	10	R
126	2517-A × K3-R S.N:33,34,35,36	TARI	Candidate Hybrid	10	R
127	2453-A × K3-R S.N:17,18,19	TARI	Candidate Hybrid	10	R
225	H-114-H-115-HO × K7-R SN:6	TARI	Candidate Hybrid	10	R
231	6626-A × K4-R S.N:53	TARI	Candidate Hybrid	10	R
232	62001-A × K4-R S.N:46	TARI	Candidate Hybrid	10	R
233	62003-A × K4-R S.N:46	TARI	Candidate Hybrid	10	R
234	6522-A × K4-R S.N:51,52	TARI	Candidate Hybrid	10	R
235	6522-A × K4-R S.N:53	TARI	Candidate Hybrid	10	R
236	65371-A × MMR-471-2 S.N:8 (2006)	TARI	Candidate Hybrid	10	R
237	3009-A × K7-R SN:6	TARI	Candidate Hybrid	10	R
239	7751-A × K7-R SN:6	TARI	Candidate Hybrid	10	R
240	62003-A × K7-R SN:6	TARI	Candidate Hybrid	10	R
241	6398-A × K6-R SN:10-15	TARI	Candidate Hybrid	10	R
242	BAH-4-A × K6-R SN:10-15	TARI	Candidate Hybrid	10	R
243	G5-K8 AD SN:1 × K7-R SN:6	TARI	Candidate Hybrid	10	R
244	BAH SN:1(8525-A) × K7-R SN:6	TARI	Candidate Hybrid	10	R
245	0704-A × K7-R SN:2,3,4,5	TARI	Candidate Hybrid	10	R
247	62001-A × MMR SN:8	TARI	Candidate Hybrid	10	R
248	6626-A × K4-R SN:50	TARI	Candidate Hybrid	10	R
249	6545 × K6-R S.N:10-15	TARI	Candidate Hybrid	10	R
250	TQ97BR (TAT TOHUM)	TAT	Inbred Line	10	R
317	F610730	SOLTIS	Candidate Hybrid	10	R
318	F610731	SOLTIS	Candidate Hybrid	10	R
319	F610732	SOLTIS	Candidate Hybrid	10	R
388	6626-A × K4-R SN:58	TARI	Candidate Hybrid	10	R
389	2517-A × K7-R SN:2,3,4,5	TARI	Candidate Hybrid	10	R
390	2517-A × K6-R SN:10-15 (9786)	TARI	Candidate Hybrid	10	R
391	2453-A × K4-R SN:46	TARI	Candidate Hybrid	10	R
393	G5-K8 AD SN:1 × K6-R SN:10-15	TARI	Candidate Hybrid	10	R
394	G5-K8 AD SN:2 × K7-R SN:6	TARI	Candidate Hybrid	10	R
395	G5-K8 AD SN:3,4,5 × K7-R SN:6	TARI	Candidate Hybrid	10	R
396	G5-K8 AD SN:3,4,5 × K6-R SN:10-15	TARI	Candidate Hybrid	10	R
397	8245-A × K7-R SN:6	TARI	Candidate Hybrid	10	R
398	G4-K7 AD SN:4-9 × K7-R SN:6	TARI	Candidate Hybrid	10	R
400	2517-A × K7-R SN:6 (9702)	TARI	Candidate Hybrid	10	R

R - resistant; T - tolerant; S - susceptible

Table 11: Broomrape tests under conditions of natural infestation conducted in Malkara in 2008

#	Material	Origin	Type	Total plant	Result
C	P-4223 (Resistant Check)	Pioneer	Commercial Hybrid	9	R
C	SANBRO (Susceptible Check)	Syngenta	Commercial Hybrid	8	S
19	2453-A × K4-R SN:117,118	TARI	Candidate Hybrid	5	R
21	2453-A × K4-R SN:28-34	TARI	Candidate Hybrid	5	R
22	2517-A × K4-R SN:49,50,51,52	TARI	Candidate Hybrid	5	R
24	2517-A × K4-R SN:182	TARI	Candidate Hybrid	4	R
108	H-114/H-115 × K4-R SN: 28,29-34	TARI	Candidate Hybrid	5	R
114	H-114/H-115 × K4-R SN: 119-129	TARI	Candidate Hybrid	5	R
125	H-144/ H-145 × K4-R SN: 28,29-34	TARI	Candidate Hybrid	5	R
126	H-144/ H-145 × K4-R SN: 107-110	TARI	Candidate Hybrid	5	R
127	H-144/ H-145 × K4-R SN: 119-129	TARI	Candidate Hybrid	5	R
131	TF- 539-1/06 × K4-R SN: 28,29-34	TARI	Candidate Hybrid	7	R
132	TF- 539-1/06 × K4-R SN: 119,120-129	TARI	Candidate Hybrid	8	T
143	TA-4142 / 06 × K4-R SN: 28,29-34	TARI	Candidate Hybrid	7	R
144	TA-4142 / 06 × K4-R SN: 130-133	TARI	Candidate Hybrid	7	T
151	TH-2930 / 04 × K4-R SN: 28,29-34	TARI	Candidate Hybrid	7	R
156	TH-331-332 / 06 × K8-R SN: 10-13	TARI	Candidate Hybrid	7	R
157	TH-331-332 / 06 × K4-R SN: 28,29-34	TARI	Candidate Hybrid	8	R
225	6388-A × K4-R SN: 54,-59	TARI	Candidate Hybrid	6	R
226	6388-A × K8-R SN: 8,9	TARI	Candidate Hybrid	7	R
229	7751-A × K4-R SN: 54-59	TARI	Candidate Hybrid	7	R
240	2453-A × K5-R SN:114,115,116-124	TARI	Candidate Hybrid	7	R
241	0704-A × K4-R SN:130,131,132,133	TARI	Candidate Hybrid	7	T
242	6626-A × K4-R SN:64,65,…..73	TARI	Candidate Hybrid	4	R
243	6626-A × K4-R SN:86,87…91	TARI	Candidate Hybrid	4	R
244	6626-A × K4-R SN:168,169…178	TARI	Candidate Hybrid	4	R
245	2453-A × K5-R SN:125,126,127,128	TARI	Candidate Hybrid	5	R
246	2453-A × K5-R SN:83,84,85,86	TARI	Candidate Hybrid	4	R
247	2453-A × K5-R SN:67,68,69,70,71	TARI	Candidate Hybrid	5	R
249	30002-A × K4-R SN:54,55…59	TARI	Candidate Hybrid	7	R
266	2453-A × K8-R SN:17,18	TARI	Candidate Hybrid	7	R
267	2453-A × K5-R SN:139,140,….145	TARI	Candidate Hybrid	7	R
273	2453-A × K5-R SN:57…66	TARI	Candidate Hybrid	7	T
274	2453-A × K5-R SN:72…76	TARI	Candidate Hybrid	7	T
275	2453-A × K5-R SN:87,88	TARI	Candidate Hybrid	7	R
278	2453-A × K5-R SN:129…132	TARI	Candidate Hybrid	7	R
281	2453-A × K5-R SN:168…178	TARI	Candidate Hybrid	7	R
284	2453-A × K5-R SN:12…15	TARI	Candidate Hybrid	7	R
289	2453-A × K5-R SN:14…16	TARI	Candidate Hybrid	7	T
291	6626-A × K5-R-SNO-57…66	TARI	Candidate Hybrid	7	T
292	6626-A × K8-R-SNO-7…9	TARI	Candidate Hybrid	7	T
294	6626-A × K8-R-SNO-14…15	TARI	Candidate Hybrid	7	R

R - resistant; T - tolerant; S - susceptible

sistant or non IMI resistant hybrids in Trakya region (75% of the total production area) because in that part of Turkey 90 % of sunflower acreage are infested with new broomrape races. Based on these results, TARI developed new resistant inbred lines and hybrids which will be released in 2009 and, after seed multiplication, these hybrids will appear on the market in 2010, for linoleic types. Oleic type broomrape- resistant hybrids will also be released in 2010.

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EVALUACIÓN DE LA RESISTENCIA DEL JOPO EN HÍBRIDOS DE GIRASOL

RESUMEN

El jopo (*Orobanche cernua* Loeffl.) es el mayor problema que enfrenta el girasol en Turquía, en algunos países de Europa del este y en España. La investigación que abarca las pruebas de híbridos frente a este parásito en ensayos del Proyecto Nacional de Investigación de Girasol se llevó a cabo en Trakya, región que generó el 75% de la producción turca de girasol durante 2006-2008. Bajo infección natural, se probaron 306 materiales genéticos (híbridos comerciales y candidatos, líneas puras, *etc*.) en 2006, 443 en 2007 y 533 en 2008. De estos materiales, 12 de ellos se detectaron resistentes en 2006, 56 en 2007 y 140 en 2008. Durante el invierno, se realizaron inocula-

ciones asistidas en cámara de crecimiento y en macetas. Semillas de jopo, colectadas en el área infectada naturalmente en Trakya, se utilizaron para determinar el comportamiento de híbridos y líneas frente a estas razas. En este estudio, 1752 materiales genéticos se probaron en 2006, 816 en 2007 y 1389 en 2008. De acuerdo a estas pruebas, 332 materiales genéticos fueron encontrados como resistentes a nuevas razas de jopo durante 2006, 94 en 2007 y 404 durante 2008.

EVALUATION DE LA RÉSISTANCE À l'*Orobanche* CHEZ LES HYBRIDES DE TOURNESOL

RESUME

L'*Orobanche* (*Orobanche cernua* Loeffl.) est l'un des problèmes majeurs pour la production de tournesol en Turquie, en Europe de l'Est et en Espagne. Des essais sur la tolérance à l'*Orobanche* des hybrides de tournesol ont été effectués, dans le cadre du National Sunflower Research Project, dans la région de Trakya, représentant 75% de la production de tournesol en Turquie en 2006, 2007 et 2008.

Ainsi, en condition d'infestation naturelle 306 cultivars de tournesol (hybrides commerciaux et en cours d'inscription, lignées parentales) ont été testés en 2006, 443 en 2007 et 533 en 2008. Parmi ce matériel, 12 cultivars ont été reconnus comme résistants à l'*Orobanche* en 2006, 56 en 2007 et 140 en 2008.

Durant l'hiver, les tests se sont poursuivis en serre et phytotrons sous infestation artificielle. Les semences d'Orobanche ont été prélevées dans les zones naturellement atteintes de Trakya et utilisées pour déterminer les réactions des hybrides et lignées développés *vis-à-vis* des différentes races.

Pour cette étude, 1752 cultivars ont été examinés en 2006, 816 en 2007 et 1389 en 2008. Les résultats montrent que 332 en 2006, 94 en 2007 et 404 en 2008 étaient résistants aux nouvelles races d'*Orobanche*.

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