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EVALUATION AND INHERITANCE OF RESISTANCE TO *Orobanche ramosa* IN CULTIVATED AND WILD TOMATO SPECIES

Khaled E.A.Abdel-Ati

Fac. Agric., Cairo Univ., Giza, Egypt

ABSTRACT

This study was conducted in a field heavily infested with broomrape in Giza Governorate, Egypt during the period from 2004 to 2007. Evaluation included Solanum lycopersicum accessions Castlerock, Edkawy, Giza 80, Oxheart, LA 2530, LA 2530 sel. A and PI 367977; and 38 accessions of 5 wild species, viz, S. lycopersicum var. cerasiforme , S. habrochaites, S. pennellii , S. peruvianum , and S. pimpinellifolium; and one accession of S. peruvianum × S. Lycopersicum. O.ramosa was the only broomrape species that appeared in the trial field in all seasons. Plants of S. pennellii LA 716 were completely free of broomrape infection in the two seasons. The most promising genotypes following S. pennellii LA 716 were S. pimpinellifolium PI 407546 and PI 407555 sel. C which showed moderate level of broomrape resistance. Parental , F_1 , and F_2 populations of the cross Castlerock × S. pennellii LA 716 were evaluated for broomrape resistance. Broomrape resistance was found to be recessive and controlled by two pairs of recessive duplicate epistatic genes any of which causes resistance.

Key words : ***Tomato, Solanum* spp.*, Evaluation, Broomrape resistance, Orobanche resistance, Genetics.***

INTRODUCTION

Broomrope, *Orobanche* spp. is an important tomato parasite, and infection is usually severe in the winter season to the extent that fields heavily infested are not suitable for tomato production (El-Helaly *et al* 1973b). Cultural and chemical control methods of *Orobanche* have generally been ineffective due to the close ecological and physiological relationship between host and parasite (Foy and Jain 1986).

Abu-Gharbieh *et al* (1978) screened over 100 tomato cvs for resistance to *O.ramosa*. None was resistant or highly tolerant, but 8 cvs showed low level of tolerance. Hassan and Abdel-Ati (1986) evaluated 27 tomato cvs, 23 wild accessions of 5 related species, viz., *S. lycopersicum* var. *cerasiforme* [previously *Lycoperoicon esculentum* var. *cerasiforme;* see Peralta *et al* (2006)] *S. habrochaites* (previously *L. hirsutem*), *S. peruvianum* (previously *L. peruvianum*), *S. pimpinellifolium* (previously *L. pimpinellifolium*), and *S. pennellii* (previously *L. pennellii*) for broomrope resistance. All tomato cvs were highly susceptible and sensitive to broomrape infection. All wild related *Solanum* accessions varied in their tolerance. The most tolerant were *S. habrochaites* LA 386, LA 1252, LA 1361 and LA 1777; *S. peruvianum* LA 1283; and *S. pimpinellifolium* LA 1256 and LA 1690. Parasitic broomrope species were *O. crenata*, *O. minor* and *O. ramosa*. *S. pennellii* LA 716 remained free of infection but only a single plant was evaluated. Avdeev (1986) reported that under artificial infestation with *O. aegyptiaca*, the most resistant were *S. lycopersicum* var. *cerasiforme* K 236756 and *S. lycopersicum* var *humboldtii* K 2884. Foy *et al* (1988) screened 1361 *Salanum* lines for resistance to *O. aegyptiaca*. They reported that all lines were susceptible to varying degrees. Kasrawi and Abu-Irmaileh (1989) evaluated 27 accessions of 5 *Solanum* species for *O. ramosa* resistance in a greenhouse pot experiment. Different levels of resistance were found in *S. peruvianum* LA 372 (5.0% of plants infected) and LA 1333 (34.1%); *S. pimpinellifolium* LA 1380 (38.1%), LA 1599 (63.1%), LA 1581 (87.8%) and LA 1478 (45.5%); and *S. lycopersicum* var. *cerasiforme* LA 1311 (45.0%), LA 1228 (52.8%), and LA 1268 (63.2%). No appreciable levels of resistance were found among *S. habrochaites* accessions. Qasem and Kasrawi (1995) evaluated 25 tomato cvs and one wild tomato accession for resistance to *O. ramosa*. They found relatively to moderate levels of resistance in cvs Tiny Tim, Acora, Castler, Pomodora, Orient and Red Alert and *S. pimpinellifolium* LA 1478. Avdeev (1998) reported that during field observations in the Astrakhan region of Russia in 1997, tomato cvs Astrakhan and Bakhtemir were practically uninfected with *O. aegyptiaca*, and there was no effect on yield. El-Halmouch *et al* (2006) evaluated 9 accessions of wild species and 6 cultivated tomato genotypes for resistance to *O. aegyptiaca*. The wild species *S. pennellii* LA 716, *S. habrochaites* P.I 247087, *S. pimpinellifolium hirsute* and *S. chilense* LA 1969 were shown to be the most resistant to *O. aegyptiaca*.

Avdeev and Shcherbinin (1975) reported that a high level of resistance to *O. aegyptiaca* found in selections of the resistant tomato line 43-1 was dominant and controlled by 2-3 major genes and 2-4 minors. Avdeev (1986) reported that under artificial infestation with *O. aegyptiaca*, UZ1 was the most resistant ($\leq 2.41 \pm 0.45$ shoots of the parasite/plant, vs. $\geq 7.99 \pm 1.42$ in other varieties). F_1 hybrids involving UZ1 showed resistance. A homozygous line selected from UZ1 had resistance controlled by a single dominant gene designated *Ora*. The broomrape resistant cv. Bakhtemir, bred with this source of resistance, yielded 50-60 t/ha.

Avdeyev *et al* (2003) studied the nature of resistance to *O. aegyptiaca* controlled by *Ora*. They found that the parasite dies when it contacts host and partially penetrates root paranchyma cells or, less often, root vessels. El-Halmouch *et al* (2006) reported that root exudates of *S. pennellii* LA 716 inhibited the germination of *O. aegyptiaca* seeds. Both number of tubercles and biomass of *O. aegyptiaca* decreased, while spike emergence was retarded in pot experiments when susceptible genotypes were watered with *S. pennellii* LA 716 exudates.

The present investigation was conducted to search for resistance to broomrape in tomato accession and study its inheritance.

MATERIALS AND METHODS

This study was conducted in a field heavily infested with broomrape in a private farm in Giza Governorate, Egypt, during the period from 2004 to 2007.

Evaluation trials

In the first season, seed sowing and transplanting of evaluated tomato cvs and accessions were on December 6 2004 and February 5, 2005, respectively. Evaluation included *S. lycopersicum* accessions Castlerock, Giza 80, LA 2530, and LA 2530 sel. A;38 accessions of 5 wild species, viz., *S. lycopersicum* var. *cerasiforme*, *S. habrochaites*, *S. pennellii*, *S. peruvianum*, and *S. pimpinellifolium;* and one accession of *S. perunianum* × *S. lycopersicum*.

In the second season, seed sowing and transplanting were on December 10, 2005 and February 13, 2006, respectively. Evaluation included *S. lycopersicum* accessions Castlerock, Edkawy, Giza 80, Oxheart, LA 2530, LA 2530 sel. A and PI 367977; and 35 accessions of wild species that were evaluated in the first season.

In both seasons, accessions were planted in a randomized complete block design (RCBD) with 3 replicates. Seeds of evaluated accessions (Table 1) were kindly provided by the Tomato Genetics Resources Center, University of California, Davis, except *S. peruvianum* sel. INRA which was provided by Dr. H. Laterrot, INRA, Montfavet, France. Experimental units consisted of 2 rows, each 1.2 m wide and 4.5 m long. Each row had 5 plants, which were given the common agricultural practices.

Plants were evaluated for broomrape infection in mid-May in both seasons. Each plant was given a disease score according to the number of broomrape spikes parasitizing it as follows: 1, no visible symptoms; 2, slight (1-5 stems/ plant); 3, moderate (6-15 stems/ plant); and 4, severe infection (> 15 broomrape stems/ plant). A mean disease score was calculated for each plot. Percentage of infected plants was also determined. *Orobanche* species were identified using V. Tackholm's key as described by El- Helaly *et al* (1973a). Data of percentage of infected plants were transformed using arc sine prior to statistical analysis. Data obtained were statistically analyzed according to Steel and Torrie (1981) and mean comparisons were based on the revised LSD test (Waller and Duncan 1969).

Genetic study

Based on results of the first evaluation season, in which *S. pennellii* LA 716 remained free of broomrape infection, this accession was crossed with cv. Castlerock (female parent) to produce the F_1 during the 2005 fall season. F_1 seeds were directly sown to produce F_2 seeds. F_1 and F_2 seeds were produced in the greenhouse at Fac. Agric., Cairo University. Seeds of the parental, F_1, and F_2 populations were sowed on December 13, 2006 and plants were field-transplanted on February 8, 2007 in the same field which was used for the evaluation trials. Different populations were planted in a RCBD with 4 replicates. Each replicate consisted of one row of each of the non-segregating populations, i.e., parents and F_1 and 10 rows of the F_2 population. Plant spacings were as previously mentioned under evaluation trials. Plants were given the common agricultural practices, and were evaluated for broomrape infection on the first of May as described before. The Chi-square test was applied to reveal the mode of inheritance of broomrape resistance. Plants were classified as resistant (having disease score 1) and susceptible (having disease scores 2, 3, or 4).

RESULTS AND DISCUSSION

Orobanche ramosa was the only broomrape species that appeared in the trial field in all seasons. Plants of *O. ramosa*, as described by El-Helaly *et al* (1973a), are bluish in colour, 25-35 cm in length and richly branched in most cases, with thin stems. Flowers are elongated (10-15 mm long) with yellowish to bluish corolla constricted at the middle. Bracteoles are present.

Evaluation trials

Data obtained on the reaction of domestic and wild tomato species to natural infection with broomrape in both evaluation seasons are presented in Table (1).

In the first season, mean scores of the evaluated tomato accessions ranged from 1.0 to 3.7 and most of them were more than 2.0. Infected plants ranged from 0.0% to 95.2%. Plants of *S. pennellii* LA 716 were completely free of broomrape infection. The most promising other genotypes were *S. peruvianum* PI 379029 and *S. pimpinellifolium* LA 1579, PI 407544 sels A and B, PI 407546, and PI 407555 sel. B. Their mean infection scores ranged from 1.3 to 1.9 and their percentage infection ranged from 8.9% to 30.0%.

In the second season, mean scores of the evaluated tomato accessions ranged from 1.0 to 4.0 and most of them had mean scores more than 3.0.

Table 1. Reaction of domestic and wild tomato species to natural infection with *O. ramosa*[Z].

Species and accession	2005 / 2006			2006 / 2007		
	No. of evaluated plants	Mean score[Y]	Infected plants (%)	No. of evaluated plants	Mean score[Y]	Infected plants (%)
Solanum lycopersicum						
Castlerock	22	3.3 a-d	76.8 a-e	25	3.7 a-c	100.0 a
Edkawy	-	-	-	21	3.8 ab	100.0 a
Giza 80	23	3.0 a-f	69.0 a-g	20	3.6 a-d	91.7 a-c
Oxheart	24	2.4 a-g	45.6 c-h	12	2.4 hi	56.7 def
LA 2530	18	2.7 a-g	57.3 a-g	18	3.9 ab	100.0 a
LA 2530 sel.A	-	-	-	13	3.3 a-g	85.0 a-e
PI 367977	-	-	-	17	3.9 ab	95.2 ab
S. *lycopersicum* var.*cerasiforme*						
LA 2394	16	2.0 c-g	36.1 c-h	17	3.3 a-g	86.7 a-d
PI 365923	11	2.2 b-g	38.9 d-h	-	-	-
PI 365925	11	2.5 a-g	61.9 a-g	11	3.3 a-g	91.7 a-c
PI 390648	16	3.4 a-c	78.6 a-d	11	2.7 e-i	68.9 a-e
S. peruvianum x S.lycopersicum						
PI 306812	18	3.7 a	95.2 a	6	4.0 a	100.0 a
S. habrochaites						
LA 1777	13	2.3 a-g	53.3 b-h	24	3.8 ab	95.8 ab
PI 379014	18	2.9 a-f	66.8 a-g	13	4.0 a	100.0 a
PI 390516	11	2.5 a-g	50.0 b-h	10	3.3 a-g	82.2 a-e
PI 390517	14	2.9 a-f	66.7 a-f	5	3.7 abc	100.0 a
PI 390659	17	2.4 a-g	46.4 b-h	9	3.2 a-h	88.9 a-d
PI 390660	6	2.4 a-g	50.0 b-h	-	-	-
S. pennellii						
LA 716	4	1.0 h	0.0 i	6	1.0 k	0.0 g
S. peruvianum						
CMV sel. INRA	15	2.5 a-g	66.7 a-f	11	3.7 a-c	100.0 a
LA 2172	17	2.9 a-d	64.4 a-g	7	3.9 ab	100.0 a
PI 379018	11	3.3 a-g	76.7 a-d	13	2.5 g-i	61.7 c-f
PI 379029	16	1.9 d-g	29.3 d-h	8	3.3 a-g	75.0 b-e
PI 390669	18	2.8 a-f	56.0 a-h	6	4.0 a	100.0 a
PI 390670	16	2.7 a-g	62.9 a-g	8	3.4 a-f	83.3 a-d
PI 390681	13	2.5 a-g	51.7 b-h	16	3.2 a-h	81.1 a-e
PI 390682	17	2.9 a-f	64.5 a-g	11	3.2 a-h	88.9 a-d
PI 475838	19	3.5 a-b	88.6 ab	12	3.1 a-h	82.2 a-e
TMV sel. I.NRA	22	3.2 a-e	82.7 a-c	12	2.8 d-i	83.3 a-d
S. pimpinellifolium						
LA 373	20	3.2 a-e	73.8 a-d	5	2.5 g-i	50.0 ef
LA 1579	20	1.3 g	8.9 h	19	3.6 a-d	95.2 ab
PI 344102	21	3.7 a	95.2 a	23	3.9 ab	96.3 ab
PI 344103	15	2.9 a-f	72.2 a-f	21	3.7 a-c	90.3 a-d
PI 407543 sel A	19	2.6 a-g	56.2 a-h	19	3.4 a-f	87.5 a-d
PI 407543 sel B	24	2.9 a-f	68.1 a-e	7	4.0 a	100.0 a

Table 1. ***Continued.***

Species and accession	2005 / 2006 No. of evaluated plants	Mean score[Y]	Infected plants (%)	2006 / 2007 No. of evaluated plants	Mean score[Y]	Infected plants (%)
PI 407543 sel C	24	2.0 c-g	46.0 b-h	8	3.7 a-c	100.0 a
PI 407544 sel A	12	1.7 fg	30.0 e-h	10	2.6 f-i	72.2 a-e
PI 407544 sel B	23	1.8 e-g	25.0 f-h	7	2.9 c-h	75.0 a-e
PI 407544 sel C	21	2.7 a-g	64.8 a-g	-	-	-
PI 407545	22	2.3 a-g	44.1 b-h	-	-	-
PI 407546	21	1.7 fg	29.8 d-h	12	2.0 ij	33.3 f
PI 407555 sel A	22	2.5 a-g	53.4 b-h	14	3.4 a-f	83.3 a-d
PI 407555 sel B	16	1.6 fg	22.2 gh	18	3.5 a-f	87.5 a-d
PI 407555 sel C	17	2.4 a-g	51.8 b-h	5	1.5 jk	33.3 f
PI 407555 sel D	22	2.3 a-g	46.4 b-h	13	3.3 a-g	83.3 a-d
PI 407555 sel E	18	3.4 a-c	89.7 ab	16	3.7 a-c	93.3 ab

[Z]Statistical analysis and significant differences were performed for arc sine transformed data but actual values are tabulated.

Mean separation within columns is based on revised LSD test at 5% level.

[Y]Infection score was based on the number of broomrape spikes parasitizing the plant as follows : 1, no visible infection; 2 , slight (1-5 spikes/ plant); 3, moderate (6-15 spikes/ plant); and 4 , severe (> 15 broomrape spikes / plant).

Infected plants ranged from 0.0% to 100%. *S. pennellii* LA 716 was the only genotype that was completely free of broomrape infection as was found in the first season. These results confirmed those obtained by Hassan and Abdel-Ati (1986) and El-Halmouch *et al* (2005) who reported that LA 716 was resistant to broomrape infestation.

S. pimpinellifolium PI 407546 and PI 407555 sel. C showed moderate level of broomrape resistance as their mean scores were 2.0 and 1.5, respectively. The latter accession had a mean score of 2.4 in the first evaluation season. Both accessions had 33.3% infection and ranked second after LA 716. Such resistance is reported here for the first time.

Inheritance of resistance

Data obtained on broomrape resistance of parental, F_1, and F_2 populations of the cross Castlerock × *S. pennellii* LA 716 are presented in Table (2). All evaluated plants of cv. Castlerock were infested with broomrape, whereas those of LA 716 were resistant. All F_1 plants of this cross were infected indicating that broomrape resistance is recessive. Plants of the F_2 population segregated as 61 resistant and 99 susceptible. These numbers fit the ratio of 7 resistant: 9 susceptible (P = 0.10 – 0.20). This ratio

Table 2. Expression of broomrape resistance in parental , F_1 and F_2 plants of the cross Castlerock × *S. pennellii* LA 716.

	No. of observed plants[z]		Total No.
	Res.	Sus.	of plants
Castlerock	-	13	13
LA 716	5	-	5
F_1	-	11	11
F_2	61	99	160

[z]Res. : plants free from broomrape infection ; Sus. : Plants having any level of infection.

denoted that broomrape resistance was controlled by two pairs of recessive duplicate epistatic genes any of which causes resistance. This is the first report on the inheritance of broomrape resistance in the accession LA 716. These results differ from those reported by Avdeev and Shcherbinin (1975) who found that resistance to *O. aegyptiaca* in tomato line 43-1 was dominant and controlled by 2-3 major genes and 2-4 minors. My results differ also from those of Avdeev (1986) who reported that resistance to *O. aegyptiaca* in a homozygous line selected from line UZ 1 is controlled by a single dominant gene. Such differences may be attributed to differences in genetic materials used. Also, former studies were on the resistance to *O. aegyptiaca*, not to *O. ramosa* as in the present study; which may have different genetic mechanisms for resistance.

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التقييم ووراثة المقاومة للهالوك فى أنواع الطماطم التجارية و البرية

خالد السيد على عبد العاطى

كلية الزراعة ــ جامعة القاهرة ــ الجيزة

أجريت هذه الدراسة في حقل موبوء بشدة بالهالوك بمحافظة الجيزة وذلك خلال الفترة من ٢٠٠٤ إلى ٢٠٠٧ وذلك للتقييم لمقاومة الهالوك في أصناف الطماطم كاسل روك , وإدكاوي , وجيزة ٨٠ , و أوكس هـارت والسلالات LA 2530 ، و LA 2530 sel.A ، و PI 367977 ، بالاضافة إلى ٣٨ سلالة تابعة لخمسة

أنواع بريــة ، هــي : *S. lycopersicum var. cerasiforme* ، و *S. habrochaites*، و *S. pennellii*، و *S.pimpinellifolium*، و *S. peruvianum* و ســلالة تابعــة لــــ *S. Lycopersicum* × *S. peruvianum* لم يظهر في حقل التجربة في مواسم التقييم سوى نوع الهالوك *O.ramosa* أظهرت الــسلالة LA 716 التابعة للنوع *S.pennellii* مقاومة للهالوك حيث لم يصب أي نبات منها خلال موسمي التقيــيم ، كمــا أظهرت السلالتان PI 407546 ، و PI 407555 sel.C التابعتــان للنــوع *S.pimpinellifolium* مــستوى متوسطاً للمقاومة. أجري التهجين بين السلالة *S.pennellii* LA 716 والصنف كاسل روك الــذى أســتخدم كــأم لإنتاج الجيل الأول ، ثم أنتج الجيل الثاني لهذا التلقيح. قيمت عشائر كــل مــن الآبــاء والجيلــين الأول والثــاني للمقاومة الهالوك ,و كانت صفة المقاومة متنحية وتحكم فيها زوجان من العوامل الوراثية أيا منهــا يــؤدى إلــى مقاومة الهالوك .

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