Weed Technology. 2004. Volume 18:490–496

Egyptian Broomrape (*Orobanche aegyptiaca*) Control in Tomato with Sulfonylurea Herbicides—Greenhouse Studies[1]

HANAN EIZENBERG, YAAKOV GOLDWASSER, SHMUEL GOLAN, DINA PLAKHINE, and JOSEPH HERSHENHORN[2]

Abstract: Broomrapes (*Orobanche* spp.) are root holoparasitic plants that cause severe damage to economically important crops, especially in Mediterranean countries. Egyptian broomrape is the most troublesome weed on tomatoes grown for processing in Israel. In the present study, we tested the efficacy and selectivity of four sulfonylurea herbicides in controlling Egyptian broomrape on tomatoes grown in pots under greenhouse conditions. MON 37500, rimsulfuron, HOE 404 and SL-160 were applied postemergence (POST) and preplant incorporated (PPI) followed by POST applications. MON 37500 and rimsulfuron were more selective to tomato and controlled the parasite more effectively than HOE 404 and SL-160. MON 37500 and rimsulfuron at 50 and 100 g ai/ha and at 100, 150, and 200 g ai/ha, respectively, applied on tomato foliage 14, 28, and 42 d after planting (DAP) and followed by sprinkler irrigation to field capacity, resulted in complete control of the parasite. However, a significant reduction in control efficacy was observed when the experiment was repeated with charcoal-topped pots, suggesting that the herbicides act mainly through the soil. Except for rimsulfuron, the PPI followed by two POST treatments was more phytotoxic to tomato plants than the POST treatments. The PPI plus POST applications controlled Egyptian broomrape effectively, but tomato plants were injured by HOE 404 at all PPI application rates and by MON 37500 at the high rate at 150 g/ha. The present study determined that three POST applications or a PPI application followed by two POST applications of MON 37500 at 50 or 100 g/ha, or rimsulfuron at 100, 150, or 200 g/ha were effective and selective in controlling Egyptian broomrape on tomato, under greenhouse conditions.

Nomenclature: HOE 404, 2-ethoxyphenyl [[(4,6-dimethoxy-2-pyrimidinyl) amino]carbonyl]sulfamate; MON 37500, *N*-[[(4,6-dimethoxy-2-pyrimidinyl) amino] carbonyl]-2-(ethylsulfonyl)imidazo[1,2-*a*]pyridine-3-sulfonamide; rimsulfuron; SL-160, *N*-[[(4,6-dimethoxy-2-pyrimidinyl)amino] carbonyl]-3-(trifluoromethyl)-2-pyridinesulfonamide; Egyptian broomrape, *Orobanche aegyptiaca* Pers. #[3] ORAAE; tomato, *Lycopersicon esculentum* Mill.

Additional index words: Activated charcoal, *Orobanche* control, parasitic weeds.

Abbreviations: DAP, days after planting; POST, postemergence; PPI, preplant incorporated.

INTRODUCTION

The broomrapes (*Orobanche* spp.) are parasitic plant species that are common in Israel, where, in many cases, they are the weeds that cause the most economic damage in field crop and vegetable production. Nine species of broomrape have been found in Israel, of which five are economically important (Eizenberg and Joel 2001; Parker and Riches 1993).

Egyptian broomrape is common throughout Israel, where it parasitizes a wide range of crops belonging to numerous botanical families. This species causes severe damage for processing tomatoes and endangers the future existence of this crop by its heavy infestations in tomato-growing regions. Furthermore, in the winter of 2001, there were reports of Egyptian broomrape damage to tomatoes grown in greenhouses in Western Galilee and the Western Negev (Eizenberg and Joel 2001).

Greenhouse studies have shown that MON 37500 (a.i. 75% water-dispersible granule [WG]), applied preplant incorporated (PPI) and postemergence (POST), was highly selective to tomato and effectively controlled pur-

[1] Received for publication January 15, 2003, and in revised form December 4, 2003.

[2] Research scientist, research scientist, technician, research scientist, and research scientist, respectively, Department of Weed Research, Agriculture Research Organization, Newe Ya'ar Research Center, P.O. Box 1021, Ramat Yishay 30095, Israel. Corresponding author's E-mail: eizenber@volcani.agri.gov.il.

[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

ple nutsedge (*Cyperus rotundus* L.), black nightshade, (*Solanum nigrum* L.), mustard (*Sinapis arvensis* L.), redroot pigweed (*Amaranthus retroflexus* L.), and field bindweed (*Convolvulus arvensis* L.) (Eizenberg et al. 2003).

Three main approaches have been suggested for chemical control of broomrape: soil fumigation (Foy et al. 1989; Goldwasser et al. 1995), application of the herbicide through the soil (Eizenberg et al. 2001; Goldwasser et al. 2001; Hershenhorn et al. 1998a, 1998b, 1998c), or foliage application in which the herbicide translocated through the host plant foliage into the root-attached parasite (Aly et al. 2001; Goldwasser et al. 2002; Jacobsohn et al. 2001; Kleifeld et al. 1998). Herbicide application through the soil is intended to control germinating broomrape seeds or young attachments on host roots. The effectiveness of this mode of application depends mainly on the phytotoxicity of the herbicide to the parasite and its selectivity to the host crop (Eizenberg et al. 2001; Goldwasser et al. 2001; Hershenhorn et al. 1998a, 1998b, 1998c). Studies based on cultivation in polyethylene bags revealed that injection of MON 37500, SL-160 (a.i. 25% WG), rimsulfuron (a.i. 25% WG) and HOE 404 (a.i. 60% WG) into the tomato root zone caused necrosis and death of Egyptian broomrape attachments, whereas HOE 404 caused damage to the tomato plants (Plakhine et al. 2001). Egyptian broomrape control or a considerable delay in its onset (or both) was achieved by chemigating (delivery of herbicide in the irrigation water) tomatoes with chlorsulfuron and triasulfuron (Hershenhorn et al. 1998a). Foliar applications of rimsulfuron, by addition to sprinkler irrigation water, was found effective in controlling Egyptian broomrape and branched broomrape (*O. ramosa* L.) in potatoes (*Solanum tuberosum* L.) (Goldwasser et al. 2001).

Low rates of glyphosate were found effective in controlling crenate broomrape (*O. crenata* Forssk.) in hosts from the Apiaceae family such as carrot (*Daucus carota* L.) and parsley (*Petroselinim crispum* L.) (Goldwasser et al. 2002; Jacobsohn et al. 2001; Kleifeld et al. 1998). Low rates of glyphosate applied to tobacco (*Nicotiana* tabacum L.) foliage achieved limited control of nodding broomrape (*O. cernua* Loefi.) (Kogan and Ureta 1996; Raju 1996), and foliar application of glyphosate and imazaquin effectively controlled crenate broomrape in broad beans (*Vicia faba* L.) (Sauerborn et al. 1989). Reports from Spain state that glyphosate and imidazolinone herbicides controlled sunflower broomrape (*O. cumana* Wallr.) in sunflower (*Helianthus annuus* L.), and that imazapyr controlled crenate broomrape in broad beans (Garcia-Torres and Lopez-Granados 1991; Garcia-Torres et al. 1995). Imazethapyr has been found effective for controlling crenate broomrape in peas (*Pisum sativum* L.) and is registered for commercial use in Israel (Jacobsohn et al. 1998). Sequential foliage application of imazapic effectively controlled sunflower broomrape in sunflower in Israel (Aly et al. 2001).

The objectives of the present study were to determine the effectiveness and selectivity of MON 37500, rimsulfuron, HOE 404, and SL-160, applied by PPI or POST for control of Egyptian broomrape in tomato.

MATERIALS AND METHODS

Experiments were performed in the winters of 1999 and 2000, in a heated greenhouse (35/20 C maximum/minimum) at Newe Ya'ar Research Center, in Jezreel Valley in northern Israel.

Seeds of Egyptian broomrape were collected from an infested tomato field in Usha, in the Galilee coastal region and were kept at 4 C until used. Egyptian broomrape seeds, at a rate of 10 mg/kg (approximately 3,000 seeds), were uniformly mixed into air-dried medium-heavy clay–loam soil (55% clay, 23% silt, 20% sand, 2% organic matter, pH 7.1) by means of a cement mixer. The mixture was placed in 4-L pots and irrigated to field capacity by sprinklers. A single 4-wk-old (10 to 12 true leaves) cell-grown tomato plant (cv 'Brigade') was transplanted into a pot, the plants were sprinkler irrigated thereafter. Tomato development was visually estimated weekly on a scale where 0 represented dead plants and 100 represented healthy, vigorous plants with respect to height, vitality, and leaf color. The number of emerged Egyptian broomrape inflorescences in each pot was counted weekly. Tomato plants were harvested when broomrape inflorescences in the nontreated control pots started to develop seeds.

Foliage fresh and dry weights (dried for 72 h at 60 C) were determined at the end of the experiments, 80 d after planting (DAP). The time sequence of emerged Egyptian broomrape on tomato was monitored, starting at 21 DAP. At the end of the experiment, Egyptian broomrape inflorescences were counted and their fresh and dry weights were determined.

The following herbicides were applied POST on tomato foliage: MON 37500 at rates of 50, 100, and 150 g/ha; rimsulfuron at 100, 150, and 200 g/ha; HOE 404 at 100, 150, and 200 g/ha; and SL-160 at 50 and 100 g/ha (Table 1). The herbicides were applied 14, 28, and 42 DAP, at 200 L/ha, with a motorized sprayer equipped

Table 1. Timetable for PPI and POST herbicides applications on tomato.[a]

Treatments			Days from planting			
Application method	Broomrape	C[b]	−1	14	28	42
POST	+[c]	−		POST	POST	POST
POST	−[d]	−		POST	POST	POST
PPI plus POST	+	−	PPI		POST	POST
PPI plus POST	−	−	PPI		POST	POST
Control	−	−				
Control	+	−				
POST	+	+		POST	POST	POST
POST	−	+		POST	POST	POST
PPI plus POST	+	+	PPI		POST	POST
PPI plus POST	−	+	PPI		POST	POST
Control	−	+				
Control	+	+				

[a] Abbreviations: POST, postemergence; PPI, preplant incorporated.
[b] Herbicides applied on activated charcoal–topped pots (C+).
[c] Soil artificially infested with Egyptian broomrape seeds at 10 mg/kg.
[d] Noninfested soil.

with a flat fan 8001E nozzle[4] and operated at a pressure of 300 kPa. Four hours after the herbicide application, sprinkler irrigation was applied to field capacity of the soil. An additional set of treatments included PPI followed by two POST applications (Table 1). MON 37500 at 50, 100, and 150 g/ha; rimsulfuron at 100, 150, and 200 g/ha; HOE 404 at 100, 150, and 200 g/ha; and SL-160 at 50 and 100 g/ha were sprayed on the soil surface at 200 L/ha, with the same motorized sprayer, 1 d before tomato transplanting. PPI application was achieved by taking soil from the treated 4-L pots after 1 h, homogenizing the soil and herbicides in a cement mixer, and then returning the treated soil to the same pots. The soil in the pots was watered to field capacity, and tomatoes were transplanted into the soil 1 d later. POST treatments were applied 28 and 42 DAP, as described above.

The same treatments were repeated with activated charcoal–topped pots to distinguish whether the herbicide acts by translocation through the plant or through the soil (Table 1). Activated charcoal (50 g) was homogenized with 0.5 L of water and applied uniformly to the surface of each pot before each POST application. Herbicide-treated pots with no Egyptian broomrape seeds in their soil and nontreated pots whose soil contained broomrape seeds served as controls. The activated charcoal–topped control pots included one set with and one set without Egyptian broomrape seeds incorporated into the soil. All pots were sprinkler irrigated 4 h after herbicide application and thereafter as needed (Table 1).

[4] Spraying Systems Co., North Avenue, Wheaton, IL 60188.

The experiments were arranged in a completely randomized design with six replications for each treatment; the experiments were performed twice during the winter of 1999 and the winter of 2000. There was no year by treatment interaction for all the variables; therefore, results of experiments were combined and presented as 12 replications for each treatment. Treatments were compared using analysis of variance with a full factorial model (herbicides, broomrape inoculation, application method, charcoal) using the JMP® software.[5] Means were separated by an LSD, on the basis of Tukey–Kramer Honestly Significant Difference test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Tomato development in the herbicide-treated, broomrape-free pots, with and without charcoal, was similar; therefore, it can be concluded that the addition of charcoal on top of the pots had no influence on tomato development (Tables 2 and 3).

A minor developmental delay in tomato was observed with MON 37500 POST at 150 and 200 g/ha, in the broomrape-infested as well as in the noninfested tomatoes. This delay was attributed to the herbicides and not to Egyptian broomrape. The tomato plants recovered by 49 DAP; however, the development in the nontreated tomato plants grown in infested soil was still delayed (Table 2). The developmental retardation was first manifested as yellowing leaves and the initial signs of withering, followed by severely impaired development of the tomato plants by 77 DAP (Table 2). The MON 37500–treated tomato plants grown in the Egyptian broomrape–infested pots were vigorous and healthy and developed normally until the end of the experiment, in contrast to the nontreated controls (Table 2). When charcoal was applied on to the pot surface, the same tomato development inhibition was observed as in the broomrape-infested nontreated tomatoes.

PPI plus POST treatment with MON 37500 at 100 and 150 g/ha were phytotoxic to tomato plants (Table 3) in contrast to the POST-only treatments (Table 2). Developmental retardation was observed in tomato plants treated PPI plus POST with MON 37500 at rates of 100 and 150 g/ha and was not influenced by charcoal treatment. This response indicates the delay was due to herbicide toxicity rather than parasite damage. These plants did not recover as shown in the tomato dry weight (Table 4).

Excellent control of Egyptian broomrape was obtained

[5] Version 4.0.3, SAS Institute Inc., SAS Campus Drive, Cary, NC 27513.

Table 2. Visually estimated effect of sulfonylurea herbicides POST on tomato development at 21, 49, and 77 DAP.[a]

		Tomato development[b]											
		Egyptian broomrape noninfested						Egyptian broomrape infested					
		POST[c]			POST plus C[d]			POST[c]			POST plus C		
Herbicide	Rate	21	49	77	21	49	77	21	49	77	21	49	77
	g/ha	%											
MON 37500	50	95	96	96	94	96	98	93	98	96	96	80	76
MON 37500	100	92	98	96	94	95	96	90	100	100	96	80	72
MON 37500	150	84	94	100	86	100	100	84	94	100	88	82	70
Rimsulfuron	100	98	96	96	98	96	96	96	98	96	98	76	68
Rimsulfuron	150	98	98	96	96	96	98	100	98	96	98	80	70
Rimsulfuron	200	96	96	98	98	98	97	96	97	98	100	84	76
HOE 404	100	90	95	96	96	94	94	92	96	96	90	84	72
HOE 404	150	90	96	96	90	96	96	90	98	96	90	76	76
HOE 404	200	84	90	90	86	88	100	84	90	92	80	80	84
SL-160	50	96	96	94	98	96	96	96	96	94	96	80	80
SL-160	100	90	96	94	94	96	94	94	93	94	92	80	78
Control[e]	0	98	96	96	98	96	94	98	80	68	96	78	74
LSD (0.05)		9	8	7	10	8	7	9	8	7	10	8	7

[a] Abbreviations: DAP, days after planting; POST, postemergence.

[b] Tomato development scaled from 0 (dead plants) to 100 (healthy plants).

[c] Herbicides applied POST, 14, 28, and 42 DAP.

[d] Herbicides applied POST on activated charcoal (C) topped pots, 14, 28, and 42 DAP.

[e] Nonherbicide treated pots.

with POST or PPI plus POST treatments of MON 37500 when compared with high levels of parasitism in the nontreated controls, (data not shown). However, when the surfaces of the pots were covered with a charcoal layer, no Egyptian broomrape control was achieved. In PPI plus POST treatments covered with charcoal, delay in Egyptian broomrape parasitism was observed. Broomrape shoots emerged 76 DAP in comparison with 48 DAP in the nontreated control. The broomrape infection reduced the dry biomass of nontreated tomato plants growing in charcoal-covered pots to the same extent as that of nontreated plants growing in the pots without

Table 3. Visually estimated effect of PPI plus POST sulfonylurea herbicides on tomato development at 7, 21, 49, and 77 DAP.[a]

		Tomato development[b]															
		Egyptian broomrape noninfested								Egyptian broomrape infested							
		PPI plus POST[c]				PPI plus POST plus C[d]				PPI plus POST				PPI plus POST plus C			
Herbicide	Rate	7	21	49	77	7	21	49	77	7	21	49	77	7	21	49	77
	g/ha	%															
MON 37500	50	94	94	96	98	96	96	100	96	94	92	98	96	92	96	100	90
MON 37500	100	80	86	84	82	84	86	82	84	80	82	84	84	84	86	82	80
MON 37500	150	70	76	86	82	74	74	84	86	70	72	80	82	80	84	84	82
Rimsulfuron	100	94	96	98	100	94	96	96	96	98	96	97	96	100	96	96	72
Rimsulfuron	150	96	96	97	94	94	96	96	94	96	98	98	96	96	94	94	74
Rimsulfuron	200	94	96	96	100	96	94	98	95	94	100	96	96	100	98	94	70
HOE 404	100	40	40	30	30	40	30	20	10	36	34	26	30	50	36	20	10
HOE 404	150	30	20	10	10	40	40	10	6	26	18	10	10	40	40	10	10
HOE 404	200	20	10	4	2	20	20	4	2	20	10	10	2	36	20	4	2
SL-160	50	90	90	96	100	92	90	100	100	90	90	96	100	88	90	100	76
SL-160	100	80	90	94	96	84	88	90	96	80	90	94	96	86	86	90	72
Control[e]	0	96	96	98	94	96	98	100	94	96	96	82	76	97	98	80	70
LSD (0.05)		10	9	8	7	10	10	8	7	10	9	8	7	10	10	8	7

[a] Abbreviations: DAP, days after planting; POST, postemergence; PPI, preplant incorporated.

[b] Tomato development scaled from 0 (dead plant) to 100 (healthy plant).

[c] PPI plus POST application −1, 28, and 42 DAP, respectively, followed by overhead irrigation to pot capacity.

[d] PPI plus POST application −1, 28, and 42 DAP, respectively, followed by overhead irrigation to pot capacity. The pots were topped with activated charcoal (C).

[e] Nonherbicide treated pots.

Table 4. Effects of sulfonylurea herbicides, application methods, and Egyptian broomrape infestation on treated tomato dry weight as percent of nontreated control.[a]

		Tomato dry weight							
		Egyptian broomrape noninfested				Egyptian broomrape infested			
Herbicide	Rate	POST[b]	POST plus C[c]	PPI plus POST[d]	PPI plus POST plus C	POST[b]	POST plus C[c]	PPI plus POST[d]	PPI plus POST plus C
	g/ha	% of control							
MON 37500	50	93	96	104	98	98	70	98	97
MON 37500	100	91	91	81	62	98	57	74	61
MON 37500	150	95	93	67	69	100	62	62	66
Rimsulfuron	100	101	101	107	99	89	66	103	95
Rimsulfuron	150	98	96	99	98	97	52	98	98
Rimsulfuron	200	103	100	97	104	102	61	95	93
HOE 404	100	98	91	37	30	95	67	39	33
HOE 404	150	94	95	31	23	98	64	25	23
HOE 404	200	86	96	10	15	102	69	13	8
SL-160	50	95	95	99	98	92	62	93	97
SL-160	100	102	98	102	93	90	67	98	102
Control[e]	0	100	100	99	98	52	62	57	61
LSD (0.05)		NS		15		23			

[a] Abbreviations: DAP, days after planting; POST, postemergence; PPI, preplant incorporated.

[b] POST application 14, and 28, and 42 DAP.

[c] POST application 14, 28, and 42 DAP on plants grown in charcoal-covered pots.

[d] PPI application 1 d before planting and POST application at 28 and 42 DAP.

[e] Dry weight as a percentage of the value in Egyptian broomrape–free, nontreated pots.

Table 5. Effects of sulfonylurea herbicides and application methods on Egyptian broomrape dry weight per pot as percent of nontreated control.[a]

		Orobanche dry weight			
Herbicide	Rate	POST[b]	POST plus C[c]	PPI plus POST[d]	PPI plus POST plus C
	g/ha	% of control			
MON 37500	50	0	90[e]	0	56
MON 37500	100	0	78	0	62
MON 37500	150	0	93	0	40
Rimsulfuron	100	12	81	0	82
Rimsulfuron	150	20	100	0	92
Rimsulfuron	200	0	97	0	100
HOE 404	100	0	92	—[f]	—
HOE 404	150	0	89	—	—
HOE 404	200	0	99	—	—
SL-160	50	0	79	0	76
SL-160	100	19	96	11	82
LSD (0.05)		19			

[a] Abbreviations: DAP, days after planting; POST, postemergence; PPI, preplant incorporated.

[b] POST application 14, 28, and 42 DAP.

[c] POST application 14, 28, and 42 DAP on plants grown in charcoal-covered pots.

[d] PPI application 1 d before planting and POST application at 28 and 42 DAP.

[e] Egyptian broomrape dry weight as a percentage of the value in the *Orobanche*-infested nontreated control.

[f] The data that were obtained from the HOE 404 treatments were omitted from the statistical analysis because the tomato plants were heavily damaged.

charcoal (Table 4). Broomrape shoots in POST MON 37500 treatments, covered with charcoal, did not differ from the nontreated control; however, PPI plus POST treatments reduce the broomrape biomass (Table 5).

Tomato plants were not injured with POST or PPI plus POST treatments of rimsulfuron at 100, 150, and 200 g/ha (Tables 2 and 3). These treatments effectively controlled Egyptian broomrape, although a few broomrape shoots were observed 62 DAP (data not shown). Tomato dry weights with rimsulfuron treatments did not differ from the nontreated control. When pots were covered with charcoal, broomrape was not controlled (Figures 1 and 2) and tomato dry weight was reduced (Table 4). The number of broomrape shoots in the charcoal-covered treatments was not different from the nontreated control (Table 5).

SL-160 POST at 50 and 100 g/ha or a PPI plus POST treatment at 50 g/ha did not injure tomato plants (Table 2). However, SL-160 PPI plus POST at 100 g/ha inhibited tomato development (Table 3), but tomato recovered from the injury as documented by dry weight responses (Table 4). SL-160 POST or PPI plus POST controlled but failed to control the weed when the pot surface was covered with charcoal (Figures 1 and 2).

Tomato plants treated with HOE 404 at 100 and 150 g/ha were not injured. However, plants treated with 200 g/ha exhibited initial developmental delay (Table 2). This delay was attributed to the herbicides and not to

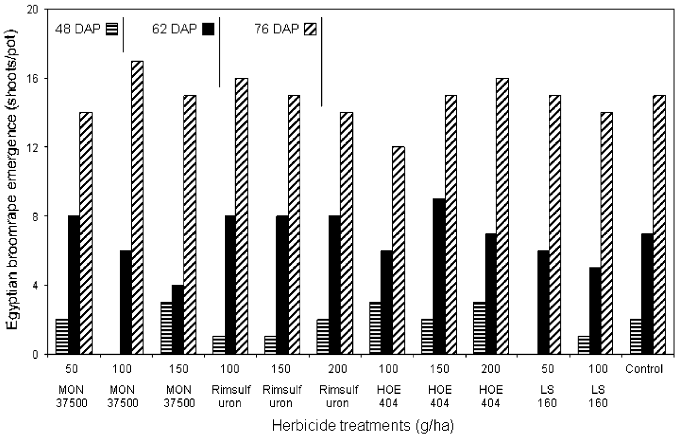

Figure 1. Effects of MON 37500, rimsulfuron, HOE 404, and SL-160 POST on Egyptian broomrape emergence on tomato plants grown in charcoal-topped pots. Means were separated by Tukey–Kramer Honestly Significant difference (HSD) test ($P \leq 0.05$). Vertical bars represent the HSD within each DAP.

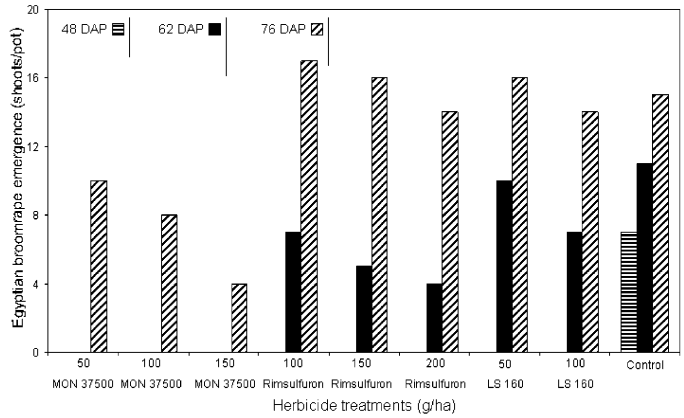

Figure 2. Effects of MON 37500, rimsulfuron, HOE 404, and SL-160 applied preplant incorporated plus postemrgence on Egyptian broomrape emergence on tomato plants grown in charcoal-topped pots. Means were separated by Tukey–Kramer Honestly Significant difference (HSD) test ($P \leq 0.05$). Vertical bars represent the HSD within each DAP.

Egyptian broomrape parasitism because the same phenomenon was observed 21 DAP, both with and without broomrape-seed infestation. Tomato plants treated with HOE 404 in broomrape-infested soil recovered by 49 DAP, whereas development in the nontreated tomato plants grown in infested soil was still delayed. The developmental retardation was first manifested as yellowing leaves and the initial signs of withering, followed by severely impaired development of the tomato plants 77 DAP (Table 2).

The same tomato growth inhibition that was characterized as withering and yellowing leaves that was observed in the nonherbicide-treated infested controls was also observed in tomato plants treated with HOE 404 and grown in charcoal-topped pots containing soil infested with broomrape seeds (Table 2). HOE 404 POST controlled the parasite (Figures 1 and 2; Table 5).

HOE 404 PPI plus POST treatments at 100, 150, or 200 g/ha were phytotoxic to tomato plants. The treated plants did not recover from the injury as evidenced by biomass reductions of 62 to 89% compared with untreated controls 80 DAP (Table 4).

All the POST herbicide treatments controlled Egyptian broomrape, as compared with the high parasitism level observed in the nontreated controls (data not shown). However, when the surfaces of the pots were covered with a charcoal layer before POST herbicide application, Egyptian broomrape was not controlled (Figure 1). The lack of control was attributed to herbicide adsorption to the charcoal that inactivated the herbicide.

In pots without charcoal, PPI plus POST treatments controlled Egyptian broomrape (data not shown). The data that were obtained from the HOE 404 treatments were omitted from the statistical analysis because the tomato plants were heavily damaged.

When charcoal was added to the pot surfaces, the PPI plus POST treatments prevented the Egyptian broomrape parasitism in the initial stages of tomato development (Figure 2). Because herbicide-treated tomato grown in broomrape-infested soil developed normally whereas tomato growth was inhibited in the charcoal-covered pots grown in broomrape-infested soil, it can be concluded that Egyptian broomrape parasitism inhibited the tomato growth. The lack of broomrape control in charcoal-covered pots was attributed to adsorption, and thus inactivation, of the herbicides by the charcoal.

Tomato plants produced fruits after all herbicide treatments. There was no difference between tomato fruit dry weight including the treatment with HOE 404 (data not shown).

In the present study, the best combination of Egyptian broomrape control and tomato tolerance was achieved by POST herbicide treatment on the broomrape foliage, followed by sprinkler irrigation that washed the herbicide off of the foliage. Egyptian broomrape was controlled by MON 37500 at 50, 100, and 150 g/ha; rimsulfuron at 100, 150, and 200 g/ha; HOE 404 at 100, 150, and 200 g/ha; and SL-160 at 50 and 100 g/ha, applied POST at 14, 28, and 42 DAP. Egyptian broomrape was also controlled by PPI herbicide treatment, but MON 37500 treatments at 100 to 150 g/ha and HOE 404 at 100 to 200 g/ha were phytotoxic to tomato plants.

Similar findings regarding the action of the sulfonylurea herbicides in the soil were reported previously (Eizenberg et al. 2001; Goldwasser et al. 2001; Hershenhorn et al. 1998b, 1998c). Tomato development was affected by two main factors: herbicide phytotoxicity (Eizenberg et al. 2003), and Egyptian broomrape parasitism (Eizenberg et al. 2001). Egyptian broomrape control was achieved with MON 37500, SL-160, HOE 404, and rimsulfuron applied directly to the tomato root zone (Plakhine et al. 2001). In that study as well as in the present study, HOE 404 was phytotoxic to tomato when applied to the root zone. These findings for the sulfonylurea herbicides differ from those for glyphosate and imidazolinone herbicides that controlled broomrape successfully by translocation of the herbicides through the host plant foliage and roots, into the attached parasite (Aly et al. 2001; Goldwasser et al. 2002; Jacobsohn et al. 2001; Kleifeld et al. 1998).

In the present study, we have demonstrated that several herbicides applied POST can effectively and selectively control Egyptian broomrape on tomatoes under greenhouse conditions. The results of this study also suggest that for successful field use, these herbicides should be available in the rhizosphere throughout most of the tomato growing season, therefore repeated herbicide treatments may be necessary. Field studies to evaluate these hypotheses are currently in progress.

ACKNOWLEDGMENTS

We thank the herbicide companies, Agan Chemicals (Luxemburg), and Milchen Brother (Israel), for providing the herbicides and the Chief Scientist, Ministry of Agriculture and Rural Development for partial supporting of this study.

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