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Evaluation of Herbicides for Chemical Weed Control in Lily Bulb Production

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1 Information on chemical weed control in lily bulb production in South America is scarce. Greenhouse and field studies were conducted to evaluate the phytotoxic effect and weed control of herbicides applied PRE and POST in lily bulb production in Argentina. In greenhouse studies, bromoxynil, 415 g ai ha^{-1}; fluroxypyr, 200 g ai ha^{-1}; metsulfuron, 3 g ai ha^{-1}; iodosulfuron-methyl-sodium, 3 g ai ha^{-1} + metsulfuron, 3 g ai ha^{-1}; oxyfluorfen, 240 g ai ha^{-1}; ioxynil, 529 g ai ha^{-1}; and linuron, 750 g ai ha^{-1}, produced severe phytotoxicity or death of bulbs. Glyphosate at 720 g ai ha^{-1} and aclonifen at 720 g ai ha^{-1} produced little to no symptoms and were considered safe to apply to lilies. In field conditions, PRE herbicides metolachlor, 960 g ai ha^{-1} + atrazine, 1,500 g ai ha^{-1}, and metolachlor, 960 g ai ha^{-1} + flumetsulam, 80 g ai ha^{-1}, provided good weed control but were phytotoxic for lily plants, with chlorosis as the main symptom. Metolachlor plus linuron resulted in little or no symptoms of injury and no reduction in bulb yield. Diuron, 800 g ai ha^{-1} POST was the most effective treatment without phytotoxicity, and, in combination with metolachlor, 960 g ai ha^{-1} + linuron, 750 g ai ha^{-1} PRE, controlled weeds until 40 d after diuron application without yield reduction. Results obtained with glyphosate indicate that the *Lilium* genus presents some tolerance to this herbicide, which justifies further evaluation for weed control in lily bulb production.

Nomenclature: Aclonifen; acloniphen (2-chloro-6-nitro-3-phenoxy-aniline); atrazine; bromoxynil; diuron; flumetsulam; fluroxypyr; glyphosate; iodosulfuron-methyl-sodium; ioxynil; linuron; metsulfuron; oxyfluorfen; metolachlor; lily, *Lilium* L. spp.

Key words: PRE, POST, emergence, phytotoxicity, symptoms, *Lilium* hybrids.

La información disponible sobre el control químico de malezas en la producción de bulbos de *Lilium* spp. en América del Sur es escasa. Se efectuaron estudios de invernadero y de campo para evaluar el efecto fitotóxico y el control de malezas utilizando herbicidas PRE y POST emergentes en la producción del bulbo de *Lilium* spp., en Argentina. En los estudios de invernadero, el bromoxynil, 415 g ia ha^{-1}; el fluroxypyr, 200 g ia ha^{-1}; el metsulfuron, 3 g ia ha^{-1}; el iodosulfuron-metil-sodio, 3 g ia ha^{-1} + metsulfuron, 3 g ia ha^{-1}; el oxyfluorfen, 240 g ia ha^{-1}; el ioxynil, 529 g ia ha^{-1} y el linuron, 750 g ia ha^{-1}, produjeron fitotoxicidad severa o muerte de los bulbos. El glifosato a 720 g ia ha^{-1} y el aclonifen a 720 g ia ha^{-1} produjeron pocos ó ningún síntoma y se consideraron seguros para la *Lilium* spp. En las condiciones de campo, el herbicida PRE-emergente metolaclor, 960 g ia ha^{-1} + atrazine, 1,500 g ia ha^{-1} y el metolaclor, 960 g ia ha^{-1} + flumetsulam, 80 g ia ha^{-1}, proporcionaron buen control de malezas pero resultaron fitotóxicos para las plantas de *Lilium* spp. con clorosis como el síntoma principal. El metolaclor más linuron causaron poco o ningún daño y no redujeron el rendimiento del bulbo. El diuron 800 g ia ha^{-1} POST-emergente fue el tratamiento más efectivo sin fitotoxicidad y en combinación con metolaclor, 960 g ia ha^{-1} + linuron, 750 g ia ha^{-1} en PRE-emergencia, controló las malezas hasta 40 días después de la aplicación de diuron sin reducción en el rendimiento. Los resultados obtenidos sin glifosato, indicaron que el género Lilium presenta cierta tolerancia a este herbicida, lo cual justifica una evaluación adicional para el control de malezas en la producción de bulbos de *Lilium* spp.

Ornamental bulbs are produced mainly in the United States, Japan, and some European countries, with Holland accounting for 65% of the world production. Cultivation is also increasing in the Southern Hemisphere, taking advantage of the reciprocal growing season, favorable climate, and lower production costs. Southern countries are adapting production technology for their own agroclimatic and socioeconomic conditions. Manual labor is used intensively in plantations for weed control and postharvest operations. Cultural, mechanical, chemical, and manual techniques are usually used for weed control, and finding an appropriate combination of them is of utmost importance for successful and efficient cultivation.

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Information on the chemical control of weeds in lily cultivation is scarce. In Holland, the use of metamitron and asulam applied PRE and POST are recommended for the chemical control of broadleaf weeds in cultivation of ornamental Liliaceae (Koster et al. 1999). In the United States, metolachlor, prodiamine, DCPA, dithiopyr, and pendimethalin (Robinson et al. 2004) are registered as PRE herbicides for weed control in lilies, whereas diuron is recommended for POST weed control in the culture of Easter lily (*Lilium longiflorum* Thunb.) (Westerdahl et al. 1998). In 2
Chile, metolachlor, metamitron, and asulam are available and, combined with a series of POST graminicides of the aryloxyphenoxypropionates group, are also used for weed control in lily bulb production (Fuentes 1999). In Argentina, there are no products registered for weed control in lily crops, and metamitron is not commercially available. However, some herbicides are recommended in Argentina for weed control in cultivation of Liliaceae species, such as garden onion (*Allium cepa* L.) and cultivated garlic (*Allium sativum*

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L.) (Dall Armellina et al. 2001, CASAFE 2007), most of which were evaluated in the present work: aclonifen, bromoxynil, ioxynil, linuron, oxyfluorfen, metolachlor, and fluroxypyr. Herbicides with positional selectivity, such as atrazine and flumetsulam, which could be applied in PRE in lily, are also available in Argentina.

Because of the importance of finding a range of herbicides for the control of weeds in lily cultivation, with little phytotoxicity data available for the species, the objective was to evaluate the efficacy of PRE and POST herbicides and to identify safe and effective weed-control tools for lily production.

Materials and Methods

Plant Material. The following lily bulbs were used: *Lilium* hybrids 'Asiatic Navona' (Na), 'Oriental Montecristo' (Mo), and 'L/A Fangio' (Fa); and *Lilium longiflorum* 'White Heaven' (WH), 'Avita' (Av), and 'Snow Queen' (SQ).

Herbicides. *PRE Herbicides.* The following PRE herbicides were tested: metolachlor,[1] linuron,[2] atrazine,[3] and flumetsulam.[4]

POST Herbicides. The following POST herbicides were tested: glyphosate,[5] aclonifen,[6] fluroxypyr,[7] metsulfuron-methyl,[8] iodosulfuron-methyl-sodium,[9] bromoxynil,[10] oxyfluorfen,[11] ioxynil,[12] and diuron.[13]

Trials. Five trials were conducted, three in a greenhouse and two in the field, to determine the efficacy of PRE and POST herbicides in the control of weeds during the cultivation of lilies and to study the phytotoxic effect upon lily plants.

Trials 1 and 2 were done to identify selective herbicides for lily and, in trial 3, selected active ingredients were tested again. In trials 4 and 5, PRE and POST herbicides were evaluated twice in different combinations in the field.

Trial 1. Bulblets of Na and Mo hybrids were cultivated in 0.9-L black polyethylene pots[14] containing a 1 : 1 (v/v) mixture of commercial growth media[15] and sandy loam soil. Axilar Na bulblets and Mo bulblets, produced by scaling, with an average weight of 148 and 535 mg, respectively, were planted on December 18, 2004. Seventeen plants of Na, consisting of leaves arising from the bulb, without aboveground stems; 12 Mo plants, without aboveground stems; and 12 Mo plants, with aboveground stems, were sprayed per treatment. Plants were fertilized at 35 and 60 d after planting (DAP) with Polyfeed,[16] at a concentration of 5 g L^{-1}. At 60 DAP, the plants were sprayed with the insecticide Imidacloprid,[17] at 350 mg ai L^{-1}, and the fungicide Carbendazim,[18] at 50 mg ai L^{-1}. POST broadleaf herbicides and rates applied were selected among those recommended for other Liliaceae species, like garlic and onion (CASAFE 2003; Dall Armellina et al. 2001). Treatments included bromoxynil at 415 g ai ha^{-1}, fluroxypyr 200 g ai ha^{-1}, metsulfuron 3 g ai ha^{-1}, iodosulfuron-methyl-sodium 3 g ai ha^{-1} plus metsulfuron 3 g ai ha^{-1}, aclonifen 720 g ai ha^{-1}, and water plus 0.2% Tween 20 as a control. Herbicide solutions were prepared with tap water, and 0.2% Tween 20 was used as a surfactant. At 70 DAP, the herbicide application was made with a carrier rate of 409 L ha^{-1} between 10:00 A.M. and 1:00 P.M., using a CO_2-pressurized backpack sprayer with a 8004 flat-fan nozzle.[19] Phytotoxicity was evaluated immediately after application and periodically during the next 2 wk thereafter. 3 At the end of the trial, at 117 DAP, the quantity of dead bulbs, the fresh weight, and the diameter of the surviving bulbs were quantified.

Trial 2. Bulblets of the hybrids Na, Mo, WH, and Fa were planted on May 13, 2005, under the same conditions and phytosanitary treatments as used in trial 1. Herbicide solutions were also prepared as in trial 1. Treatments were oxyfluorfen at 240 g ai ha^{-1}, ioxynil 529 g ai ha^{-1}, linuron 1,500 g ai ha^{-1}, glyphosate 720 g ai ha^{-1}, and water plus 0.2% Tween 20 as a control. At 53 DAP, herbicides (438 L ha^{-1}) were applied between 10:00 A.M. and 2:00 P.M. At least 11 plants were sprayed per treatment (in the case of the hybrid Fangio, linuron was not applied because of a lack of plants). Phytotoxicity was evaluated immediately after the application of the herbicides and periodically during the next 2 wk. At 119 DAP, the quantity of dead bulbs and the fresh weight of surviving bulbs were recorded.

Trial 3. Basal bulbs of Fa with a fresh weight and diameter average of 2.8 g and 13.3 mm, respectively, were planted on September 28, 2005, and cultivated under the same conditions and phytosanitary treatments as used in the previous trials. The herbicides that produced little or no phytotoxicity symptoms and no reduction in the growth of bulbs in the previous trials were evaluated again. Aclonifen and glyphosate were applied at 720 g ai ha^{-1}, and water plus 0.2% Tween 20 was sprayed to control plants. The herbicide (430 L ha^{-1}) was applied 38 DAP between 10:00 A.M. and 1:00 P.M. Phytotoxicity was evaluated immediately after the application of the herbicides and periodically during the next 2 wk. At the end of the trial, at 79 DAP, the fresh weight and the diameter of the bulbs were recorded.

Trial 4. Sixty scalings (bulb scales with developed bulblets) of the hybrids Na and Av were planted per treatment and per block under field conditions on June 20, 2005. Plots (1.5 m long and 0.4 m wide) included two lines (separated by 30 cm) of planted scalings, one for each hybrid. The soil was sandy loam with 2.54% organic material and a pH of 6.9. Watering was performed using drip irrigation with emitters (4 L h^{-1} flow rate $emitter^{-1}$) spaced 0.3 m apart. Plants were fertigated at recommended rates (Miller 1992). Twelve treatments with three replications each were distributed in a randomized complete-block design as shown in Table 1.

Before plant emergence and application of the PRE herbicides, existing weeds were eliminated by spraying 960 g ai ha^{-1} of glyphosate. At 74 DAP (September 2, 2005), PRE herbicides (430 L ha^{-1}) were applied using a backpack sprayer. Plant emergence dates were September 9 and September 19 for Av and Na, respectively. Herbicide treatments were hand-weeded at 60 d after application (DAA), i.e., when weeds were at the cotyledon to three true leaf stage. Glyphosate and aclonifen were applied at 137 DAP (on November 4, 2005) to control a severe weed infestation. In addition, during the cultivation period, weed and lily coverage of the plots, weed species, and phytotoxicity

Table 1. Weed control treatments applied PRE and POST under field conditions in trial 4. Effect of herbicide treatments on yield of lily bulbs harvested per plot of Navona and Avita lily hybrids.[a] 4 5

Herbicide	Hand weeding	Rate	Lily hybrid fresh wt	
			Navona	Avita
		g ai ha^{-1}	g	
No herbicide	Yes	0	403.8 b	1,254.0 b
No herbicide	No	0	77.1 a	220.7 a
Metolachlor + linuron	No	960 + 750	113.0 a	379.5 a
Metolachlor + atrazine	No	960 + 1,500	181.1 a	314.2 a
Metolachlor + flumetsulam	No	960 + 80	148.6 a	229.7 a
Metolachlor + linuron	Yes	960 + 750	288.5 b	932.6 ab
Metolachlor + atrazine	Yes	960 + 1,500	259.2 ab	789.8 ab
Metolachlor + flumetsulam	Yes	960 + 80	290.6 b	643.4 ab
Glyphosate	Yes	720	139.0 a	540.1 ab
Metolachlor + linuron fb glyphosate	Yes	960 + 750 fb 750	157.4 a	589.6 ab
Aclonifen	Yes	720	150.0 a	230.2 a
Metolachlor + linuron fb aclonifen	Yes	960 + 750 fb 720	174.6 a	332.7 a

[a] Means within a column followed by a letter are significantly different according to Dunnett's test at the 5% significance level from (a) the no-herbicide, hand-weeding treatment, and (b) the no-herbicide, no hand-weeding treatment.

symptoms on both hybrids were recorded. The plots were harvested on March 30, 2006 (at 283 DAP), and the total fresh weight of the bulbs produced was quantified per plot.

Trial 5. Bulbs, 6 cm in circumference, of Na and SQ were planted on July 7, 2006, under conditions similar to those in trial 4. In addition, before emergence and application of the PRE herbicides, glyphosate (960 g ai ha^{-1}) was applied to each plot to eliminate existing weeds. Both hybrids completely emerged on September 9 (64 DAP). Eight treatments with three replications each were arranged in a randomized complete-block design as shown in Table 2.

The PRE herbicides (180 L ha^{-1}) were applied at 59 DAP, on September 4, using a backpack sprayer. Glyphosate was applied at 0.75 L ha^{-1} at 110 DAP (October 25), followed by a sequential application at the same rate on 134 DAP
6 (November 18). Glyphosate at 1.5 L ha^{-1} was applied on 127 DAP (November 11). Diuron was applied at 117 (November 1) and 124 (November 8) DAP, in treatments with diuron alone and combined with PRE treatments of metolachlor + linuron, respectively. 7

The phytotoxicity symptoms on both hybrids were observed and recorded throughout the cultivation period. Bulbs were harvested on April 4, 2006 (at 271 DAP), and their number and total fresh weight per plot were quantified.

Table 2. Weed control treatments applied PRE and POST under field conditions in trial 5. Effect of herbicide treatments on yield per plot of harvested Navona and Snow Queen lily hybrids. All herbicide treatments included hand weeding at POST.[a]

Herbicide	Rate	Lily hybrid fresh wt	
		Navona	Snow Queen
	g ai ha^{-1}	g	
No herbicide, hand-weeding	0	351.1 b	857.6
No herbicide, no hand-weeding	0	231.2 a	732.4
Metolachlor + linuron	960 + 750	397.3	821.6
Metolachlor + linuron fb diuron	960 + 750 fb 800	282.5	1,001.0
Diuron	800	254.6	832.3
Glyphosate	360	172.0 a	394.9 a
Glyphosate	720	184.1 a	392.2 a
Glyphosate, 2 applications	360 fb 360	124.3 ab	305.1 ab

[a] Means within a column followed by a letter are significantly different according to Dunnett's test at the 5% significance level from (a) the no-herbicide, hand-weeding treatment, and (b) the no-herbicide, no hand-weeding treatment.

Phytotoxicity. Chlorosis symptoms and other color changes, morphological alterations of the organs (by twisting or nastic growth), and tissue necrosis were evaluated. A general visual evaluation of plants as showing or not showing phytotoxicity symptoms and death was also used. Herbicide treatments were considered unsafe for lilies when one or more leaves died, or when more than 10% of the plants did not recover from chlorosis. Treatments that reduced bulb fresh weight or diameter by more than 10% were also considered unsafe to lilies.

Statistical Analysis. For greenhouse trials, potted bulbs of each hybrid were divided randomly into three groups and cultivated separately as blocks. For field trials, plots were arranged in a randomized complete-block design. Three independent experiments were randomly distributed in the experimental field. Herbicide mixing, application, and fertigation were independent for each experiment.

Data obtained were analyzed (by ANOVA) using the randomized complete-block design. Treatment means were compared at 5% using Tukey's honestly significant difference (HSD) test or against the controls at the 5% level using Dunnett's test.

Results and Discussion

Trial 1. Bromoxynil, metsulfuron, and iodosulfuron plus metsulfuron were too injurious to all lily hybrids. Fluroxypyr severely injured Na plants. Only aclonifen was found to be selective, and it was chosen for further evaluation (Table 3).

Table 3. Effect of herbicide treatment in trial 1 on the fresh weight of hybrid Montecristo and Navona lily bulbs for plants with (AS+) and without (AS−) aboveground stems.[a]

Herbicide	Rate	Lily hybrid fresh wt		
		Montecristo AS−	Montecristo AS+	Navona
	g ai ha^{-1}	g		
No herbicide	0	4.94	8.60	8.73
Bromoxynil	415	3.00*	3.96*	4.79*
Fluroxypyr	200	4.39	7.13	5.17*
Metsulfuron-methyl	3	3.29*	5.94*	6.48*
Iodosulfuron plus metsulfuron	3 + 3	2.80*	4.27*	5.66*
Aclonifen	720	5.13	7.38	9.03

* Mean is significantly different from the no-herbicide control according to Dunnett's test at the 5% significance level.

Table 4. Effect of the herbicide treatments on fresh weight of lily hybrid bulbs of Fangio, Navona, White Heaven, and Montecristo in trial 2. 8

Herbicide	Rate	Lily hybrid fresh wt			
		Fangio	Navona	White Heaven	Montecristo
	g ai ha^{-1}	g			
No herbicide	0	3.66	2.08	5.84	4.56
Oxyfluorfen	240	3.58	1.29*	7.13	2.77
Ioxynil	529	1.88*	1.69	4.43	1.99*
Linuron	750	—	1.35*	4.91	3.43
Glyphosate	720	2.58	2.57	6.46	4.52

* Mean is significantly different from the no-herbicide control according to Dunnett's test at the 5% significance level.

Trial 2. Oxyfluorfen, ioxynil, and linuron lacked sufficient selectivity on all hybrids based on phytotoxicity symptoms. In addition, oxyfluorfen and linuron reduced bulb fresh weight compared with the control in Na, and ioxynil affected Fa and Mo (Table 4).

Glyphosate-treated plants showed some chlorosis in the apical area, which disappeared within a few days. Fresh weight of the bulbs from the four hybrids was not affected (Table 4). Considering glyphosate is a nonselective herbicide that would greatly improve weed control under production conditions, it was selected for trial 3.

Trial 3. Aclonifen quickly produced leaf chlorosis, but plants recovered. In addition, aclonifen significantly reduced the fresh weight of the bulbs compared with the control. Bulb diameter was not affected. Glyphosate did not produce phytotoxic symptoms and did not affect fresh weight nor diameter of bulbs compared with the control.

Trial 4. By 29 DAA of PRE herbicides, weed coverage was approximately 0.5% in all herbicide treatments, and 1% in the nonherbicide treatments, with the dominant weed species being Italian ryegrass (*Lolium multiflorum* Lam.) and
9 perennial wall rocket [*Diplotaxis tenuifolia* (L.) DC.].

For the metolachlor + atrazine treatment, phytotoxicity symptoms of chlorosis and necrosis were observed in the apical zone of the leaves of both lilium hybrids, and death of the whole leaf in the smallest plants. For the metolachlor + flumetsulam treatment, leaves showed a mild chlorosis and a smaller size than in the control, with Av more affected than Na. For the treatment with metolachlor + linuron, a mild chlorosis was observed on the border of the leaves of both hybrids, but it quickly disappeared, without affecting the plants.

At 59 DAA, the relative coverage by weed and lily plants was estimated, and weed densities were determined (Table 5). Metolachlor + atrazine produced apical necrosis in almost 20% of plants and 10% of the plants were dead. Phytotoxicity symptoms were not observed in plants treated with metolachlor + linuron. The chlorosis previously observed in plants treated with metolachlor + flumetsulam disappeared, but these plants showed a slightly slower development, in comparison to the weeds-free control plants. The number of weeds was higher in weedy control plots, whereas the three PRE treatments were effective (Table 5).

By 7 DAA with aclonifen, chlorosis and necrosis symptoms were observed on the weeds but not on lily plants, whereas glyphosate had not yet affected the weeds. At 21 DAA, 90% of aclonifen sprayed plants from both hybrids showed chlorosis followed by bleaching and, eventually, necrosis of the leaves of the biggest plants, symptoms typically caused by herbicides that inhibit carotenoid synthesis (Leguizamón 2004). Loss of turgor, bleaching, necrosis, and mortality were also observed in the smaller plants. As for the treatments that included glyphosate, a marked phytotoxic effect was observed on the weeds, whereas the lily plants showed a mild chlorosis in the actively growing zones, with Na more affected than Av.

By 39 DAA, the largest plants from the aclonifen-treatment plots recovered, whereas the smaller ones showed total necrosis of the aerial part. This result differs from those under greenhouse conditions, i.e., in trial 1, a similar rate of aclonifen did not produce phytotoxicity in Na, and in trial 3, the symptoms were less severe, and the plants recovered.

Because of the role of light in the mode of action of aclonifen, higher light intensities in the field likely increased injury compared with the greenhouse where lower light intensities may have resulted in less injury.

At 39 DAA of glyphosate, plants showed necrosis in the apexes of leaves, but they recovered from chlorosis, and only some of the smallest plants were killed.

For both hybrids, all combinations of herbicides resulted in an increase in the total fresh weight of bulbs harvested per plot with respect to the weedy control (Table 1). However, differences were only significant ($P < 0.05$) for PRE treatments followed by hand-weeding, and for Av in treatments that included glyphosate (Table 1).

No significant differences were found in total fresh weight between bulbs from the weed-free control and metolachlor + linuron followed by hand-weeding or metolachlor + flumetsulam followed by hand-weeding for Na (Table 1). In the case of Av, although all treatments produced fresh weight values significantly lower than the weeds-free control, metolachlor + linuron followed by hand-weeding produced the highest values within the herbicide treatments, followed by metola-

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Table 5. Relative coverage of plots by weeds and lily plants and weed densities at 59 d after application for the following treatments: no herbicide, with and without hand-weeding; metolachlor + linuron; metolachlor + atrazine; or metolachlor + flumetsulam, without hand-weeding, in trial 4.[a]

			Coverage			
			Lily hybrid			
Treatment	Hand-weeding	Rate	Avita	Navona	Weeds	Weed density
		g ai ha^{-1}	%			No. 0.4-m^{-2}
No herbicide	Yes	0	48 a	32 a	0.0 b	0 b
No herbicide	No	0	43 a	30 a	28.0 a	115 a
Metolachlor + linuron	No	960 + 750	47 a	37 a	1.3 b	12 b
Metolachlor + atrazine	No	960 + 1,500	43 a	25 a	0.7 b	10 b
Metolachlor + flumetsulam	No	960 + 80	50 a	33 a	1.0 b	15 b
			%			
Coefficient of variation			6.7	14.1	196.7	156.7

[a] Means within the same column followed by the same letter do not differ significantly (P ≤ 0.05) according to Tukey's honestly significant difference test.

chlor + atrazine followed by hand-weeding, and metolachlor + flumetsulam followed by hand-weeding (Table 1).

It is interesting to note the tolerance of the lily hybrids to glyphosate, which was also observed in greenhouse experiments. Although some phytotoxicity symptoms were observed under field conditions, in most cases, plants recovered and only the smallest ones died, although the decrease in yield was significant, and the treatment lacked sufficient selectivity for the lilies.

Trial 5. By 36 DAA, coverage of weeds in plots treated with the combinations of PRE herbicides was lower than 0.5%, and no phytotoxic symptoms were observed on the plants. In the rest of the plots, weed coverage reached approximately 1%.

The treatments metolachlor + linuron followed by hand weeding, metolachlor + linuron followed by diuron application, and diuron alone did not produce visible phytotoxic effects on plants, which were comparable to the controls. It should be noted that the combination metolachlor + linuron followed by a diuron application provided excellent weed control, and it was not necessary to hand-weed until 40 DAA of the diuron.

Glyphosate produced chlorosis in the upper leaves and in the apical zone, but plants recovered. Glyphosate as a sequential application provided effective control of weeds, mainly *Panicum* spp., wall rocket, common saltwort (*Salsola kali* L.), and yellow starthistle (*Centaurea solstitialis* L.) and produced marked phytotoxic effects on lily plants: chlorosis, necrosis of the upper leaves and apical zone, and death of some of the smaller plants. For both hybrids, bulb fresh weight was significantly lower in glyphosate treatments compared with the bulb weights in the weed-free control. When compared with the weight of bulbs from the weedy control, sequential glyphosate led to significantly lighter bulbs (Table 2).

Sample variability and the relatively good performance of the weedy control (Table 2) in this experiment did not allow a clear evaluation of the effect of the herbicides on productivity in the cultivation. However, we highlight the observations regarding phytotoxicity. Combinations of PRE metolachlor plus linuron or PRE metolachlor plus linuron plus POST diuron performed well, and, considering the results obtained with diuron, mainly on the hybrid SQ, further evaluation of this herbicide in lily-bulb production is warranted. 10

This study showed that all the herbicides and the rates evaluated as POST applications, except for diuron, produced some degree of phytoxicity on lilies. In general, the Oriental hybrid (Mo) showed more sensitivity than the Easter lily hybrids L/A and Asiatic. The POST herbicide aclonifen applied in the field cultivation produced distinct phytotoxicity symptoms, death of leaves and plantlets, and decreased yields. Its use is not recommended, at least under the conditions tested in this work. Diuron applied POST is a promising treatment for the control of weeds.

Glyphosate produced variable symptoms of phytotoxicity and excellent control of weeds. The results obtained with glyphosate indicate that the *Lilium* genus presents some tolerance to this herbicide, which justifies continuing its evaluation for weed control in lily cultivation. This is the first report that shows the tolerance of lily to glyphosate.

The PRE combination of 960 g ai ha^{-1} metolachlor and 750 g ai ha^{-1} linuron combined with POST diuron at 800 g ai ha^{-1} is considered safe and is recommended for weed control in the production of lily bulbs.

Sources of Materials

[1] S-Metolachlor, Dual Gold® 96 EC, Syngenta Argentina, Libertador Av. 1855, Vicente Lopez, Argentina.

[2] Linuron, Linuron® 50 FW, Magan Argentina SA, Cerrito 1186, Buenos Aires, Argentina.

[3] Atrazine, Atrazina Trac® 50 FL, Agar Cross SA, Mitre 907, 2000 Rosario, Argentina.

[4] Flumetsulam, Preside® 80 WG, Dow AgroSciences Argentina, Madero 900, Buenos Aires, Argentina.

[5] Glyphosate, Round Up® 48 LS, Monsanto Argentina SA, Maipú 1210, Buenos Aires, Argentina.

[6] Aclonifen, Prodigio® 60 SC, Bayer Argentina SA, Ricardo Gutierrez 3652, 1605 Munro, Argentina.

[7] Fluroxypyr, Starane® 20 EC, Dow AgroSciences Argentina, Madero 900, Buenos Aires, Argentina.

[8] Metsulfuron-methyl, Escort® 60 WG, Du Pont Argentina SA, Madero 1020, Buenos Aires, Argentina.

[9] Iodosulfuron-methyl-sodium, Hussar® 5 WG, Bayer Argentina SA, Ricardo Gutierrez 3652, 1605 Munro, Argentina.

[10] Bromoxynil, Weedex® 34.6 EC, Bayer Argentina SA, Ricardo Gutierrez 3652, 1605 Munro, Argentina.

[11] Oxyfluorfen, Koltar® 24 EC, Rohm and Haas Latin America INC., Santa Fe 962, Buenos Aires, Argentina.

[12] Ioxynil, Totril® 35.25 EC, Bayer Argentina SA, Ricardo Gutierrez 3652, 1605 Munro, Argentina.

[13] Diuron, Diurex® 80 FW, Magan Argentina SA, Cerrito 1186, Buenos Aires, Argentina.

[14] 0.9-L black polyethylene pots, Ing, Carluccio y Asoc. Carril 4389, 1419 Buenos Aires, Argentina.

[15] Grow Mix SF®, Terrafertil SA, Pio Collivadino 1559, 1744 Moreno, Argentina.

[16] Polyfeed®, IQA Almidar SA, Iguazú 833, Buenos Aires, Argentina.

[17] Imidacloprid, Confidor® 35S, Bayer Argentina SA, Ricardo Gutierrez 3652, 1605 Munro, Argentina.

[18] Carbendazim, CarbendaGlex®, Gleba SA, Calle 520 Int. RP 36, Melchor Romero, La Plata, Argentina.

[19] Teejet Spray System Co., P.O. Box 7900, Wheaton, IL 60188.

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