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Susceptibility of Easter Lily to Glyphosate Injury

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Abstract. **Although foliar applied glyphosate to Easter lily (*Lilium longiflorum* Thunb.) caused little damage at concentrations up to 540 × 10^{-4}M (2.2 kg/ha), direct exposure of roots to glyphosate at concentrations as low as 2.7 × 10^{-4}M (0.1 kg/ha) resulted in death. Glyphosate application after simulated flooding of the greenhouse floor indicated that plant injury would not occur if glyphosate is applied as recommended.**

Glyphosate, a broad spectrum, foliar applied herbicide was registered in 1983 for use in greenhouses. The label recommends that desirable vegetation be removed and air circulation fans turned off prior to application to minimize spray or drift injury to crops. Isolated cases of suspected glyphosate injury have been reported for several greenhouse floral crops since glyphosate labeling, but none actually have been confirmed to be a direct result of glyphosate injury. Recently, a commercial Easter lily pot crop showed growing point injury and malformed flower buds similar to that which could result from herbicide injury. Since flooding had occurred after glyphosate application and the placement of Easter lilies on the greenhouse floor, there was potential for injury through root exposure to flood water containing glyphosate.

Research generally has shown that glyphosate applied directly to mineral soil (1), clay loam, and muck soil (6) is inactivated rapidly and shows no herbicidal effects on subsequent crops planted in the treated soil. Rodrigues et al. (4), however, found that glyphosate applied to wheat foliage was exuded into several soil types, and caused root inhibition and foliar injury on maize growing in the soil. Brewster and Appleby (2) applied glyphosate to a moist, sandy loam soil and found injury to wheat plants subsequently emerging from this soil. These results and other research on glyphosate application to sandy loam and organic soil (5) suggest that some soil conditions may be conducive to residual glyphosate activity, although in most soils glyphosate appears to be inactivated rapidly (3, 6, 7).

Conditions often exist in greenhouses whereby glyphosate is applied to cement, soil, or gravel that is moist. It has been suggested that this practice may lead to injury of plants subsequently placed on the sprayed surface. Injury also could occur when exposed roots contact glyphosate in areas where spray runoff has collected. Sprankle et al. (7) showed that glyphosate uptake by wheat roots from solution resulted in subsequent foliar injury. Although their experiments were conducted using solution culture, conditions exist in greenhouses where roots may be exposed to glyphosate solutions. Floral crops often are planted in sandy soils, and roots often are found along the edge of the pot or exposed through drainage holes. Preliminary research with marigold and petunia suggested that exposure of foliage and roots to glyphosate could result in plant injury. To investigate further this potential for glyphosate causing injury to greenhouse floral crops, a systematic study was conducted with Easter lilies to determine: 1) Easter lily susceptibility to glyphosate injury from foliar or root applications; 2) if growth inhibition by glyphosate can occur following simulated greenhouse flooding shortly after a spray application to the greenhouse floor; and 3) the potential for glyphosate injury to floral crops when used under standard application techniques in greenhouses.

Experiments were conducted under greenhouse conditions of natural daylength with day temperatures of 21° ± 5°C and night temperatures of 15° ± 2°. 'Ace' and 'Nellie White' Easter lily bulbs (7–8 cm case-cooled) were obtained from 2 commercial sources, planted in 15.2 cm diameter standard plastic pots in a greenhouse soil mixture (2 peat : 2 perlite : 1 soil, by volume) and grown using a commercial forcing schedule. Glyphosate (acid equivalent) treatments were applied 5–6 weeks after greenhouse forcing was initiated, to coincide with flower initiation. All experiments were completely randomized designs with 3 to 5 replications.

The 1st experiment was designed to determine the susceptibility of Easter lily 'Ace' and 'Nellie White' to foliar application of glyphosate. Glyphosate was applied by spraying Easter lily foliage with a CO_2 pressurized back pack sprayer delivering 243 liter/ha at 207 kPa using concentrations of: 540, 270, 27, and 2.7 × 10^{-4}M (2.2 to .0001 kg/ha).

Application of glyphosate to Easter lily foliage did not reduce days to flower, number of flowers or plant height at any of the spray concentrations studied (Table 1), but plants showed injury at the highest glyphosate concentrations. Four plants of 'Nellie White' would have been unmarketable and one plant was damaged but marketable, whereas all plants of 'Ace' were unmarketable due to malformed buds at 540 × 10^{-4}M (2.2 kg/ha). The 270 × 10^{-4}M (1.1 kg/ha) concentration resulted in some initial injury to both cultivars as noted by leaf chlorosis, but by the end of the experiment, all plants sprayed with this concentration of glyphosate were of marketable quality. These results show that Easter lily is quite tolerant to foliar spray applications of glyphosate at low concentrations, and only a spray application to plant foliage at recommended weed control rates would cause injury.

A 2nd experiment was designed to determine if Easter lily injury would occur if glyphosate was applied to a greenhouse floor at a concentration of 540 × 10^{-4}M (2.2 kg/ha) and then the area was flooded by 5.0 cm of water for various periods of time. Greenhouse flooding was simulated in all tests. The experiment tested plant response after various periods of plant exposure (1, 2, 4, 8, 12, 24, and 48 hr) to a glyphosate concentration (2.0 × 10^{-5}M) expected in the flood water. This concentration of glyphosate was chosen as a realistic solution concentration to expect during flooding. For each time period, a water soak control was included. The Easter lily roots were adjacent to or exposed through the drainage holes in the pot which ensured root exposure to the glyphosate solution prior to any glyphosate inactivation by the growth medium.

'Ace' and 'Nellie White' plants exposed to glyphosate in simulated flooding studies for up to 48 hr showed no injury symptoms

Table 1. Easter lily plant response to foliar sprays of glyphosate at varying concentrations. Means of 5 replications (one plant/15.2 cm).

Glyphosate (10^{-4}M)	No. days to flower: 'Ace'	No. days to flower: 'Nellie White'	Ht at flowering (cm): 'Ace'	Ht at flowering (cm): 'Nellie White'	No. of flowers: 'Ace'	No. of flowers: 'Nellie White'	Marketable plants[z] (%): 'Ace'	Marketable plants[z] (%): 'Nellie White'
0	115	128	82	74	6.2	6.0	100	100
2.7	116	127	88	69	6.4	5.8	100	100
27	113	129	89	72	6.8	4.8	100	100
270	117	130	93	73	8.2	5.6	100	100
540	119	131	78	75	6.6	6.2	0	20
Significance	NS	NS	NS	NS	NS	NS		

[z]Marketable plants based on flowers. Any flower formed that did not meet standard quality was considered unmarketable.

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Table 2. Effect of glyphosate exposure to the roots of Easter lilies 'Nellie White' and 'Ace' for varying time periods. Means of 5 replications (one plant/15.2 cm pot).

Glyphosate (10^{-5}M)	Time (hr)	No. days to flower 'Ace'	No. days to flower 'Nellie White'	Ht at flowering (cm) 'Ace'	Ht at flowering (cm) 'Nellie White'	No. flowers 'Ace'	No. flowers 'Nellie White'
0	1	117	124	96	66	7.6	3.4
	2	121	128	96	63	6.2	3.8
	4	117	131	92	61	5.6	3.6
	8	123	126	92	66	5.8	4.2
	12	114	128	96	60	7.0	4.4
	24	115	134	84	69	5.6	4.6
	48	122	137	94	67	7.6	4.6
2.0	1	119	128	88	71	7.0	4.4
	2	114	129	86	63	6.6	4.4
	4	115	135	96	72	5.2	5.0
	8	114	127	89	68	6.2	3.8
	12	117	135	81	67	5.0	4.0
	24	118	130	84	64	5.0	4.2
	48	122	132	92	64	6.4	4.4
Significance[z]		NS	NS	NS	NS	NS	NS

[z]Main plot and interaction terms were all nonsignificant.

Table 3. Easter lily plant response following a 2-hr exposure of roots to varying concentrations of glyphosate. Means of 3 replications (one plant/15.2 cm pot).

Glyphosate (10^{-4}M)	Fresh wt (g) tops 'Ace'	Fresh wt (g) tops 'Nellie White'	Height at flowering (cm) 'Ace'	Height at flowering (cm) 'Nellie White'	No. flowers 'Ace'	No. flowers 'Nellie Whtie'
0	313 ± 38[z]	290 ± 68	83 ± 8	74 ± 6	6.3 ± 0.6	5.0 ± 1
2.7	284 ± 56	261 ± 43	96 ± 9	72 ± 2	6.7 ± 1	5.3 ± 0.6
27	0	0	0	0	0	0
270	0	0	0	0	0	0

[z]± SD.

(Table 2). The height at flowering or number of flowers were not affected. No malformed flowers were observed on any of these plants. These results suggest that flooding the floor of the greenhouse after normal glyphosate application would dilute the herbicide to a concentration that would not influence Easter lily growth or flowering.

Results of the previous experiment showed that a realistic flooding concentration of glyphosate did not result in Easter lily plant injury, so a 3rd experiment was designed to determine the glyphosate concentration required to cause Easter lily injury from root uptake of glyphosate. 'Ace' and 'Nellie White' (5–6 weeks old) with root growth as described above were exposed to glyphosate solutions of 270, 27, or 2.7 × 10^{-4}M (1.1 to 0.01 kg/ha) for 2 hr and then placed on a greenhouse bench for observation.

Glyphosate caused severe injury to the Easter lily plants when roots were exposed to concentrations of 270 or 27 × 10^{-4}M concentrations (Table 3). Results were similar for both 'Ace' and 'Nellie White', with complete death occurring above 27 × 10^{-4}M. The concentration of 2.7 × 10^{-4}M (Table 3) did not result in injury. Easter lily root absorption of glyphosate from solution can result in plant injury if the concentration is high enough; this agrees with results of Sprankle et al. (8) for wheat. Calculations showed that an effective concentration of 220 kg/ha glyphosate would have to be applied to the greenhouse floor prior to flooding for subsequent root uptake from the flooding solution to result in plant injury. Misapplication of glyphosate at ×100 normal rate is not likely to occur.

The glyphosate concentration necessary to cause plant injury following root exposure was considerably lower than that required for injury following shoot exposure. Injury from root uptake of glyphosate may occur when pools of water are present in the greenhouse and glyphosate is sprayed on the water. Subsequent placement of plants in these areas would allow root uptake of glyphosate which could result in injury. Injury also could occur after placing plants on moist soil or moist concrete following glyphosate application. The potential for this type of injury to crops under greenhouse conditions would be reduced by use of spot sprays or use of custom applicating equipment (e.g., rope wicks, sponge bars) which minimize the amount of herbicide applied, and restrict the herbicide to specific areas of the greenhouse.

Our results suggest that glyphosate use under normal conditions in a greenhouse should not result in Easter lily injury. Only misapplication to foliage or direct exposure of plant roots to a concentrated glyphosate solution would result in injury. Growers following label recommendations and using specialized application equipment are unlikely to encounter problems with glyphosate injury.

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