HORTSCIENCE 30(5):1070–1073. 1995.

Ethylene-induced Abscission of Easter Cactus Phylloclades for Vegetative Propagation

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Additional index words. Rhipsalidopsis gaertneri, ethephon, phytotoxicity

Abstract. **The study was conducted to determine if ethylene or ethephon, an ethylene-releasing compound, can be used to induce abscission of phylloclades of four cultivars of Easter cactus [*Rhipsalidopsis gaertneri* (Regel) Moran] to increase efficiency in vegetative propagation. Abscission occurred within 24 hours after commencement of the ethylene treatments. Phytotoxicity, as exhibited by water soaking, transparency, and darkening of the phylloclades, as well as percent abscission, increased with increasing concentrations of ethephon (0 to 10,000 µl·liter^{-1}). Ethylene released from ethephon, not the acidity of the solution, was determined to be the cause of the phytotoxicity. In three out of the four cultivars, vegetative and root growth from propagated phylloclades was significantly restricted by treatments with ethephon. In comparison, vegetative growth from phylloclades treated with ethylene at 20 µl·liter^{-1} was the same as from those treated with air. Root growth of the ethylene-treated phylloclades was not studied. The acidity of the ethephon solutions likely affected the growing regions, resulting in a reduction in growth. The study shows that treatment with ethylene gas or the use of pH-adjusted ethephon solutions may be an alternative to the labor-intensive procedures associated with vegetative propagation of Easter cactus. Chemical name used: 2-chloroethylphosphonic acid (ethephon).**

Easter cactus is a flowering potted plant produced mainly for winter and spring sales (Boyle, 1991b). Plants consist of a series of phylloclades (jointed stem segments) and terminate with flowers on the apical phylloclades. Vegetative propagation of this plant requires manual removal of individual phylloclades from stock plants (Nell, 1988). It is, thus, of practical interest to determine if abscission of phylloclades can be chemically induced, thus eliminating the labor-intensive procedures involved in the current means of propagating Easter cactus.

Ethephon, an ethylene-releasing compound, has been approved for a variety of applications (Kays and Beaudry, 1987). The effectiveness of the chemical depends on factors such as pH of the solution, temperature and relative humidity of the environment, and the type and age of the plant tissue (Kays and Beaudry, 1987). The effects of ethephon on flowering of Christmas cactus (*Schlumbergera* spp.) and Easter cactus have been evaluated (Kaukovirta, 1979; Yonemura, 1979). In Easter cactus, the percentage of flowering and the number of flower buds were severely restricted when plants were drenched with 10 mg ethephon per plant (Kaukovirta, 1979). In Christmas cactus, Yonemura (1979) reported that application of ethephon at 1000 µl·liter^{-1} to vegetative plants had no effect on the growth of new phylloclades and the number of flower buds formed. However, 10,000 µl·liter^{-1} resulted in abscission of phylloclades, which became necrotic soon after they had abscised. Commercially, ethephon is used to induce abscission of unnecessary floral buds and in the harvesting of fruit (Ben-Tal and Lavee, 1976; Daniell and Wilkinson, 1972; Edgerton and Greenhalgh, 1969; Woolf et al., 1992). We know of no reports on the use of ethephon for inducing abscission of organs for vegetative propagation. The objectives of this study were to determine if ethylene or ethephon could be used to induce abscission of phylloclades and to investigate the effects of the chemicals on the subsequent rooting and growth of propagules.

Materials and Methods

General procedures. One-year-old plants were grown in the glasshouse at the Univ. of Massachusetts under conditions required to maintain vegetative growth (Boyle, 1991a). Plants were grown in 0.5-liter (10 cm square) pots and had three to five tiers of mature phylloclades at the commencement of the experiment. The thermostat in the glasshouse was set at 18/21C (heat/vent). The average light intensity and air temperature, both monitored with a LI-COR 1000 datalogger (Lincoln, Neb.), were 353 µmol·m^{-2}·s^{-1} and 19.0C; the temperatures ranged from 15.0 to 32.3C.

Various concentrations of ethephon solution (0 to 10,000 µl·liter^{-1}) containing 0.1% of Tween 20 (ICI America, Wilmington, Del.) (polyoxyethylene sorbitan monolaurate) were sprayed on both sides of the phylloclades. Plants were placed, until the following day, in a 23C room illuminated with 8.2 µmol·m^{-2}·s^{-1} to allow all surfaces to dry. Plants were then returned to the greenhouse where phylloclades were allowed to abscise. One week after the chemical treatment, abscised phylloclades were counted and collected for propagation. The percentage of the total number of phylloclades that abscised and the percentage of abscised phylloclades that developed symptoms of phytotoxicity, characterized by water soaking, transparency, and darkening of the phylloclades, were recorded at that time. Abscised phylloclades that showed no sign of phytotoxicity 1 week after the ethephon treatment were used to examine the effects of ethephon on rooting and new growth. Phylloclades were removed manually from the control plants. We used a randomized block design.

Responses to ethephon. Six replicate plants of four cultivars of Easter cactus ('Andromeda', 'Evita', 'Purple Pride', and 'Thor-Ina') were sprayed with an aqueous solution of ethephon at 0, 1250, 2500, 5000, or 10,000 µl·liter^{-1} on 4 Mar. 1992. Abscised phylloclades were collected and counted.

Six phylloclades from each plant were propagated in 35-cm^3 cell packs filled with potting medium (Pro-Mix BX; Premier Brands, New Rochelle, N.Y.) and rooted in the glasshouse under natural daylength without mist. Plants were fertilized weekly at a rate of 200 mg N/liter, 4 weeks after propagation. The average number and length of roots and the number, length, and dry weight of the new phylloclades were recorded 4 and 12 weeks after the phylloclades had been placed in the propagating medium. In addition, the percentage of total phylloclades that became necrotic during propagation was recorded 4 weeks after propagation.

Responses to ethylene and acidity. Ethephon degrades rapidly into three components: ethylene, a chloride ion, and a phosphate ion (Maynard and Swan, 1963). To examine the cause of phytotoxicity from the ethephon treatment, plants were vented with ethylene gas or sprayed with acid solutions prepared from hydrochloric acid or phosphoric acid.

The pH of the ethephon solutions at 0, 1250, 2500, 5000, and 10,000 µl·liter^{-1} used in the previous experiment was 6.2, 3.1, 2.8, 2.6, and 2.3, respectively. Six replicate plants of 'Evita' and 'Andromeda' were sprayed with deionized water or with a solution adjusted with hydrochloric or phosphoric acid to a pH equivalent to that of the 10,000-µl·liter^{-1} treatment. Surfactant (0.1% Tween 20) was added to all solutions.

Plants of 'Evita' and 'Andromeda' were placed in 30-liter tanks on 22 Apr. 1992 and vented with air (control) or with ethylene gas at 20 µl·liter^{-1} for 7 days. The containers were located in a 20 ± 1C chamber illuminated with 12 h of 17 ± 3 µmol·m^{-2}·s^{-1} photosynthetic photon flux provided by cool-white fluorescent lamps. Abscised phylloclades were re-

Received for publication 24 Apr. 1995. Accepted for publication 11 May 1995. Publication no. 3127 of the Massachusetts Agricultural Experiment Station. We thank Thomas H. Boyle for providing the plant materials used in this study. Use of trade names is to help identify materials used and does not imply endorsement of products named nor criticism of those not mentioned. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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moved daily from the tank and placed in a 23C room. Phylloclades were propagated 7 days after the commencement of the experiment; those from air-treated plants were manually removed for propagation.

Statistical analyses. Data were tested statistically by analysis of variance (SAS Institute, 1990). Before analysis, percent data were transformed to arcsin and data for the variable root count were transformed to . Paired comparisons were used to test for differences between treatments.

Results and Discussion

Exposure of Easter cactus plants to ethephon at ≥1250 µl·liter^{-1} induced abscission of phylloclades and at ≤2500 µl·liter^{-1} caused phytotoxicity (Table 1).

Increasing concentrations of ethephon increased abscission of phylloclades. Most of the abscission occurred within 72 h after the ethephon treatment. Cultivars respond significantly different to the treatments. The degree of the response to the increasing concentrations also varies between cultivars, resulting in a cultivar × treatment interaction. With the cultivars tested, 1250 and 2500 µl·liter^{-1} resulted in abscission of 1% to 5% and of 33% to 45% of the phylloclades, respectively. Concentrations of ethephon >2500 µl·liter^{-1} increased abscission of phylloclades to close to 100%. The concentrations required to induce abscission of phylloclades were higher than those needed for the abscission of fruit and flower buds of other crops (Ben-Tal and Lavee, 1976; Edgerton and Greenhalgh, 1969; Woolf et al., 1992).

Symptoms of phytotoxicity, including water soaking, transparency, and darkening of the phylloclades, began to develop 4 days after the treatment. The percentage of abscised phylloclades with phytotoxic symptoms and the severity of the symptoms, rated 1 week after the treatment, increased with increasing concentrations of ethephon (Table 1).

'Evita' and 'Andromeda' Easter cactus sprayed with solutions of deionized water adjusted with HCl or H_3PO_4 to a pH of 2.3 showed no abscission or phytotoxicity. However, between ≈40% and 70% of phylloclades abscised from plants that had been treated with ethylene gas at 20 µl·liter^{-1} for 7 days (Fig. 1).

Within 24 h after the commencement of the ethylene treatment, 13.9% ± 1.0% and 16.3% ± 3.4% of the phylloclades abscised from 'Evita' and 'Andromeda', respectively. About half of the eventual abscission occurred within the first 48 h. Symptoms of phytotoxicity, identical to those observed on ethephon-treated phylloclades, were first visible 3 days after the commencement of the treatment. At the termination of the 7-day ethylene treatment, 25.0% ± 2.2% and 11.7% ± 0.9% of phylloclades of 'Evita' and 'Andromeda', respectively, had developed phytotoxic symptoms. Phylloclades were examined by transmitting light through them, allowing for detection of minor damage that would otherwise be obscured by the thickness of the phylloclades. This view indicated

Table 1. Percent abscission and percent phytotoxicity of phylloclades of four cultivars of *Rhipsalidopsis* following treatment with various concentrations of ethephon.

Cultivar	Ethephon concn (µl·liter^{-1})	Abscission[z, y] (%)	Phytotoxicity[x] (%)
Andromeda	0	0	0
	1,250	1.1 ± 0.5	0
	2,500	37.3 ± 5.0	7.2 ± 4.5
	5,000	83.7 ± 5.3	22.5 ± 4.7
	10,000	99.1 ± 0.4	55.0 ± 2.2
Evita	0	0	0
	1,250	1.8 ± 0.4	0
	2,500	33.4 ± 5.3	2.2 ± 1.3
	5,000	66.9 ± 5.2	24.8 ± 7.7
	10,000	89.8 ± 2.9	47.3 ± 2.3
Purple Pride	0	0	0
	1,250	1.1 ± 0.5	0
	2,500	45.3 ± 3.7	0
	5,000	89.1 ± 3.3	28.4 ± 2.6
	10,000	98.2 ± 0.9	72.2 ± 4.0
Thor-Ina	0	0	0
	1,250	4.7 ± 2.0	0
	2,500	34.8 ± 2.2	2.6 ± 2.3
	5,000	86.5 ± 1.5	41.0 ± 2.3
	10,000	96.7 ± 0.6	77.8 ± 6.2
Significance			
Cultivar (C)		***	*
Treatment (T)		***	***
C × T		***	***
Contrast (df = 1)			
Control vs. 2,500 µl·liter^{-1}			
Andromeda		***	***
Evita		***	NS
Purple Pride		***	NS
Thor-Ina		***	NS

[z]Data are the means ±SE of six replicate plants and were collected 1 week after the ethephon treatment.
[y]Expressed as the total number of phylloclades on plants.
[x]Expressed as percentage of the abscised phylloclades with phytotoxicity symptoms.
NS, *, ***Nonsignificant or significant at $0.01 < P \leq 0.05$ or $P \leq 0.001$, respectively.

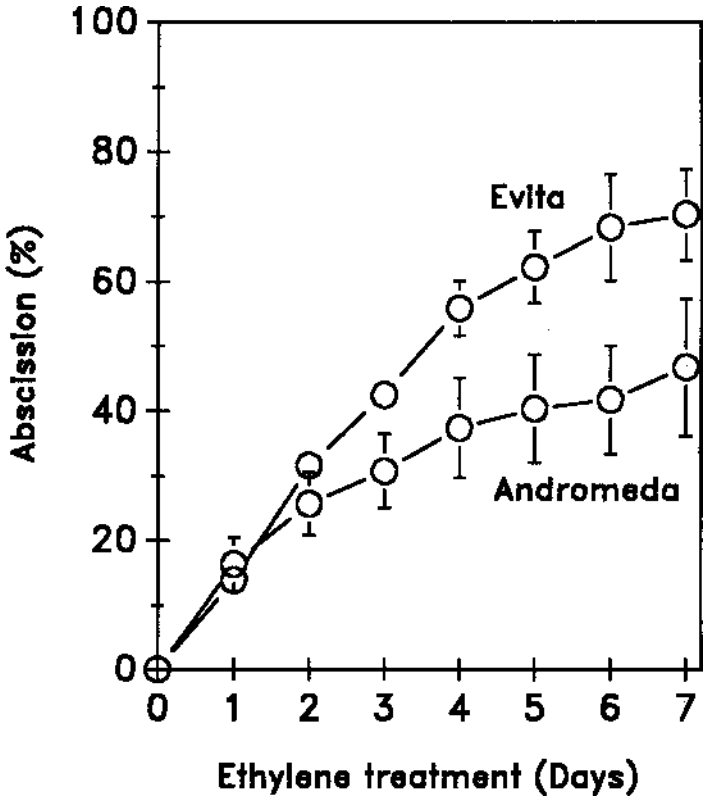

Fig. 1. Percent abscission of phylloclades of two cultivars of *Rhipsalidopsis* treated with ethylene gas at 20 µl·liter^{-1}. Vertical bars represent SE.

that ethylene released from the ethephon solutions contributed to the abscission and phytotoxicity of phylloclades, just as had ethylene gas.

To determine the effects of ethephon and ethylene on new growth, abscised phylloclades that did not develop phytotoxic symptoms were propagated. During the propagation period, necrosis of phylloclades occurred on >40% of those treated with ethephon at 10,000 µl·liter^{-1} and on a lower percentage of those sprayed at 2500 or 5000 µl·liter^{-1} (Table 2). With all cultivars, results recorded 4 weeks after propagation revealed fewer and shorter roots on propagated phylloclades treated with ethephon than on those treated with water, although the degree of responses to the treatments varied significantly between cultivars. The number and length of the roots was restricted by increasing concentrations of ethephon, suggesting that ethephon treatment delayed the formation of roots. Our results are in contrast to those from geraniums (*Pelargonium ×hortorum* L.H. Bailey) and chrysanthemums [*Dendranthema ×grandiflorum* (Ramat.) Kitamura] where root counts on cuttings collected from ethephon-treated stock plants were higher than from nontreated plants (Samananda et al., 1972; Tsujita and Harney, 1978). The contradicting results may be explained by differences in the concentrations of ethephon and on the target of the application. In our study, ethephon concentrations of ≥1250 µl·liter^{-1} were applied directly to the propagules to induce their abscission. With chrysanthemums, ethephon at 1 µl·liter^{-1} was applied to the cuttings to increase rooting of difficult-to-root cultivars (Samananda et al., 1972). With geraniums, ethephon at 500 µl·liter^{-1} was applied to the stock plants to increase the number of axillary shoots and thus the number of cuttings (Tsujita and Harney, 1978).

Vegetative growth of all cultivars was significantly affected by the ethephon treatment. With the exception of the average length of new phylloclades, the response of individual cultivars to the treatments was significantly different. Increasing concentrations of ethephon restricted the number, length, and dry weight of the phylloclades (Table 2). Paired comparisons were conducted for 0 (control) vs. 2500 µl·liter^{-1}, because this concentration of ethephon resulted in moderate abscission of the phylloclades with a low incidence of phytotoxicity (Table 1). Of the four cultivars tested, vegetative growth of 'Thor-Ina' was not affected by the 2500-µl·liter^{-1} spray, whereas growth of 'Andromeda', 'Evita', and 'Purple Pride' was significantly restricted by the treatment. The restricted growth of ethephon-treated phylloclades may be explained, in part, by the data on the longest phylloclades. These indicated that, except for 'Thor-Ina', ethephon delayed the initiation of new growth and thus restricted overall vegetative growth.

With the exception of the length of the largest new phylloclades for 'Andromeda' and dry weight for 'Evita', treatment with ethylene gas did not affect the number, average length, and dry weight of new phylloclades compared to those of the controls (Table 3). The acidity of the ethephon solutions, then, may affect the growing regions of the phylloclades and explain the differences in growth of the ethephon- and ethylene-treated phylloclades. The abscission rate of plants treated with ethephon at 1250 µl·liter^{-1} was very low in comparison to that for ethylene-treated plants (Table 1, Fig. 1). At the same time, a marked reduction in vegetative growth was noted on ethephon-treated phylloclades, although there were not enough abscised ones (replicates) to perform statistical analysis (data not shown). The data, thus, substantiated the conclusion that it was the acidity and not the amount of ethylene released from the ethephon solutions that restricted new growth. Evaluation of new growth on phylloclades that are manually removed and treated with acid solutions of various pH levels is needed to confirm the conclusion that the differences in new growth from phylloclades treated with ethephon and ethylene was due to the acidity of the former treatment.

The study reported here demonstrated that the use of ethylene may be a viable alternative to the labor-intensive procedures of propagating Easter cactus. Vegetative growth of rooted phylloclades, evaluated 12 weeks after propagation, indicated no detrimental effects of ethylene on subsequent growth. However, to minimize the development of phytotoxicity, lower concentrations (<20 µl·liter^{-1}) of ethylene gas and shorter treatment times should be tested. Spray applications of ethephon, with the solutions adjusted to a pH that would have no affect on subsequent growth, may be a feasible method for propagation of Easter cactus.

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Table 2. Root and vegetative growth from abscised ethephon-treated Easter cactus phylloclades following propagation.

Cultivar	Ethephon concn (µl·liter^{-1})	Necrosis[x] (%)	Root[z] No.	Root[z] Length (mm)	New phylloclade[y] No.	New phylloclade[y] Avg length (cm)	New phylloclade[y] Longest (cm)	New phylloclade[y] Dry wt (g)
Andromeda	0	0	6.5 ± 0.4	26.1 ± 1.4	6.5 ± 0.5	2.8 ± 0.1	3.9 ± 0.1	0.13 ± 0.05
	2,500	6.1 ± 3.9	5.4 ± 0.4	14.5 ± 0.8	5.3 ± 0.3	2.5 ± 0.1	3.2 ± 0.1	0.09 ± 0.01
	5,000	2.8 ± 2.8	4.4 ± 0.3	16.2 ± 0.9	5.4 ± 0.3	2.7 ± 0.1	3.2 ± 0.2	0.10 ± 0.01
	10,000	47.2 ± 10.0	4.0 ± 0.4	9.2 ± 1.1	2.8 ± 0.4	1.7 ± 0.2	2.1 ± 0.2	0.03 ± 0.01
Evita	0	0	7.9 ± 0.4	26.7 ± 1.2	5.9 ± 0.3	3.0 ± 0.1	4.2 ± 0.1	0.13 ± 0.01
	2,500	0	5.0 ± 0.3	19.4 ± 0.9	3.5 ± 0.2	2.8 ± 0.2	3.4 ± 0.2	0.08 ± 0.01
	5,000	13.9 ± 5.1	5.2 ± 0.3	14.0 ± 1.0	3.4 ± 0.3	2.2 ± 0.2	2.9 ± 0.3	0.05 ± 0.01
	10,000	66.7 ± 9.6	2.8 ± 0.7	8.5 ± 2.0	2.1 ± 0.3	1.6 ± 0.3	1.0 ± 0.3	0.09 ± 0.00
Purple Pride	0	0	6.7 ± 0.4	28.8 ± 1.1	5.2 ± 0.3	3.6 ± 0.1	4.9 ± 0.9	0.17 ± 0.02
	2,500	2.8 ± 2.8	4.6 ± 0.2	13.1 ± 0.9	4.2 ± 0.2	3.0 ± 0.1	4.2 ± 0.2	0.10 ± 0.01
	5,000	11.1 ± 5.5	3.5 ± 0.3	11.3 ± 0.7	3.9 ± 0.9	2.2 ± 0.2	2.9 ± 0.2	0.07 ± 0.01
	10,000	47.2 ± 10.0	2.6 ± 0.6	7.2 ± 1.4	3.2 ± 0.4	1.8 ± 0.3	2.4 ± 0.4	0.06 ± 0.03
Thor-Ina	0	0	6.2 ± 0.4	35.2 ± 1.3	6.8 ± 0.4	2.5 ± 0.2	3.6 ± 0.3	0.11 ± 0.01
	2,500	0	4.8 ± 0.2	18.6 ± 1.0	5.9 ± 0.3	2.8 ± 0.1	3.5 ± 0.1	0.13 ± 0.01
	5,000	5.6 ± 3.5	5.1 ± 0.3	15.2 ± 0.8	4.1 ± 0.3	2.4 ± 0.1	2.8 ± 0.1	0.08 ± 0.01
	10,000	70.6 ± 11.8	4.0 ± 0.7	14.8 ± 2.7	3.0 ± 0.4	2.1 ± 0.3	2.5 ± 0.7	0.05 ± 0.01
Significance								
Cultivar (C)		NS	***	***	***	NS	***	**
Treatment (T)		***	***	***	***	***	***	***
C × T		*	***	***	***	***	***	***
Contrasts (df = 1)								
Control vs. 2500 µl·liter^{-1}								
Andromeda		***	NS	***	*	NS	**	*
Evita		NS	***	***	***	NS	***	***
Purple Pride		NS	***	***	***	***	***	***
Thor-Ina		NS	*	***	NS	NS	NS	NS

[z]Data collected 4 weeks after propagation and are means ±SE of six replications with six phylloclades per replicate.
[y]Data collected 12 weeks after propagation.
[x]Percentage of the propagated phylloclades that had become necrotic 1 month after propagation.
NS, *, **, ***Nonsignificant or significant at $0.01 < P \leq 0.05$, $0.001 < P \leq 0.01$, or $P \leq 0.001$, respectively.

Table 3. Vegetative growth of *Rhipsalidopsis* from abscised phylloclades induced by 20 µl·liter^{-1} ethylene gas.

		New phylloclade[z]			
Cultivar	Treatment	No.	Avg length (cm)	Longest (cm)	Dry wt (g)
Andromeda	Air (control)	6.8 ± 0.3	1.9 ± 0.1	3.8 ± 0.1	0.16 ± 0.01
	Ethylene	6.8 ± 0.4	2.1 ± 0.1	3.3 ± 0.1	0.17 ± 0.01
Evita	Air	4.9 ± 0.4	2.8 ± 0.1	4.4 ± 0.1	0.19 ± 0.01
	Ethylene	5.3 ± 0.3	2.8 ± 0.1	4.5 ± 0.2	0.23 ± 0.02
Contrasts (df = 1)					
Air vs. C_2H_4 in Andromeda		NS	NS	**	NS
Air vs. C_2H_4 in Evita		NS	NS	NS	*

[z]Data were collected 12 weeks after propagation and are means ±SE of three replicate packs with six phylloclades per pack.

NS, *, **Single degree of freedom orthogonal contrast nonsignificant or significant at $0.01 < P \leq 0.05$, $0.001 < P \leq 0.01$, respectively.

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