# Ethylene and Defoliation of Ornamental Lime Plants in Transit[1]

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*Abstract.* **Ethylene concentration greater than 1 ppm added to ornamental lime plants (*Citrus latifolia* Tan. cv. Persian), held in air-tight containers caused serious defoliation of intact plants. No $C_2H_4$ was detectable in cartons of lime plants shipped from Florida to Ohio although defoliation occurred.**

Lime trees grown in pots have shown encouraging prospects for use as house plants but, during 3 to 5 days in transit, many leaves and fruits abscise. The marketing of these plants in areas removed from the growing area is not feasible unless this can be prevented. Ethylene is a natural plant product (6) and has caused similar problems with many plants (5). This study was initiated to determine what concn of $C_2H_4$ would cause leaf abscission and whether $C_2H_4$ would accumulate to effective levels around plants during transit to cause abscission.

There have been differing reports on the production of $C_2H_4$ by citrus fruit and leaves and its effect on abscission of plant parts. Biale (2) suggested that citrus fruit only produce $C_2H_4$ under stress and this was confirmed by Vines et al. (7). Burg and Burg (3) reported $C_2H_4$ production by fruit of sweet orange (*Citrus sinensis* (L.) Osbeck) and calamondin (*C. madurensis* Lour). Ben-Yehoshua and Eaks (1) found that both leaves and fruit of *C. sinensis* produced $C_2H_4$, and a level as low as 0.1 ppm caused leaf abscission in this species.

'Persian' lime plants used in the study were provided by a Florida grower. Softwood cuttings were taken on May 1, 1972, and potted into 10 cm pots July 1. These were shipped to Columbus in the early fall, repotted into 15 cm clay pots, and grown in the greenhouse until the following summer when laboratory experiments began.

Plants were placed in air-tight polyethylene containers fitted with septa for the introduction and extraction of gas samples to determine the $C_2H_4$ concn necessary to induce leaf abscission. A sheet of glass was sealed to the top of each container with lanolin paste. Pure $C_2H_4$ was injected into the containers to give concn ranging from 0.1 to 10 ppm. Plants were confined in the dark for 4 days, the average shipping time from Miami, Florida to Columbus, Ohio and kept for observation several additional days under continuous light after removal from the containers.

Treatments were in triplicate. Sampling started the day after $C_2H_4$ was added to allow for complete diffusion of the gas. One-ml gas samples were used to measure $C_2H_4$ on a Packard 602 flame ionization gas chromatograph, Model 409, using a 120 cm × 3 mm stainless steel column packed with alumina. Gas flow rates were air (300 ml/min), $H_2$ (25 ml/min), and $N_2$ (25 ml/min) with the injector, detector, and column at 110°, 150°, and 85°C, respectively. Three-ml samples were used to measure $CO_2$ on an Aerograph thermal conductivity gas chromatograph, Model A 350 B, fitted with a 90 cm × 6 mm copper column packed with silica gel with injector, detector, and column at 120°, 180°, and 75°C, respectively.

Substantial defoliation occurred on plants exposed to $C_2H_4$ (Table 1); 14% of the leaves dropped from plants exposed to approx 0.2 ppm $C_2H_4$ while 58% or more leaves dropped when the concn exceeded 1 ppm. Control plants that were enclosed in air-tight containers without added $C_2H_4$ had an average leaf drop of 4%. The environment around control plants showed increasing concn of $C_2H_4$ but the accumulated level was less than 0.1 ppm even on the 4th day.

Ben-Yehoshua and Eaks, working with explants, found that 0.1 ppm $C_2H_4$, a level lower than that which they found occurring naturally in many fruit attached to the tree, caused abscission of leaves and fruit (1). The study reported here was done on intact plants, which might explain the higher concn needed to induce abscission.

$CO_2$ concn ranged from 0.6 to 3% during the period of measurement with no correlation to $C_2H_4$ concn. Even at the highest concn, which occurred in the control plants, $CO_2$ was not present in sufficient amounts to account for inhibition of ethylene action. The $K_A$ for $CO_2$, relative to $C_2H_4$, is approx $1 \times 10^6$ (3).

In a parallel transit study, 18 plants in 4 liter containers were shipped from Florida to Ohio on Aug. 29, 1973, Nov. 7, 1973, and Feb. 2, 1974. Each shipment consisted of 2 cartons each with 9 plants. Several treatments were used to attempt to control defoliation in the shipped cartons: one carton was sent with ventilating holes and 1 without in the Aug. shipment; plants in 1 carton were sleeved and in the other were not in the Nov. shipment; and plants in 1 carton were watered and the others were not in the Feb. shipment. Samples of gas were removed before shipments arriving from Florida were opened to determine if $C_2H_4$ and $CO_2$ had accumulated around the plants during transit.

Gas samples tested from unopened cartons shipped from Florida had no detectable levels of $C_2H_4$ present regardless of treatments imposed prior to shipment, using a chromatograph that could detect concns as low as 0.01 ppm. However, while no $C_2H_4$ was detected, substantial defoliation occurred equally in all treatments.

Defoliation might be due to other factors since no $C_2H_4$ could be detected inside shipped cartons, and the level needed to cause abscission, from exogenous applications, was greater than 1 ppm. According to these data, even though levels below that detectable by this method may have been accumulating around the plant they may not have been responsible for abscission. Air-tight containers holding lime plants for 4 days did show an increase in concn of $C_2H_4$ but nothing approaching the level needed to induce leaf abscission in intact plants. Burg and Burg (4) found that $C_2H_4$ acts endogenously and does not have to accumulate in the ambient air to be effective. Thus, endogenous $C_2H_4$ may indeed be accumulating in these plants during transit to sufficient levels to promote abscission.

Table 1. The effect of exogenous applications of ethylene on defoliation of ornamental lime plants.

| $C_2H_4$ (ppm) | | Defoliation |
|---|---|---|
| First day | Fourth day | (%) |
| 9.4 | 6.1 | 100 |
| 4.5 | 2.3 | 93 |
| 2.7 | 1.9 | 92 |
| 1.1 | 1.1 | 58 |
| 0.17 | 0.09 | 14 |
| 0.0 (control) | 0.09 | 4 |

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# Optimizing Phosphoric Acid and Chlormequat Concentrations for Growing 'Sincerity' Geranium under Alkaline Water Conditions[1]


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*Abstract.* **Food grade phosphoric acid (75%) was found to be a suitable P source for *Pelargonium* x *hortorum* cv. Sincerity and was effective as a soil and water acidifier. The best P level for overall plant development was 100 ppm P at every irrigation for plants receiving no chlormequat, and 50 ppm P for chlormequat-treated plants. Lowest soluble salts levels were at 50-100 ppm P. As P in the fertilizer solution increased, leaf concentrations of P increased. Other leaf nutrient concentrations were usually higher in chlormequat-treated plants than in untreated plants. Chlormequat-treated plants were shorter with smaller leaves and had slightly more flowering branches than untreated plants.**


Liquid phosphoric acid has been utilized as a P fertilizer (5, 7, 9, 10) and was shown to reduce soil crusting and increase sugar beet seedling emergence by increasing aggregate stability in the soil surface (9). Food grade phosphoric acid (75%) is recommended as a satisfactory source of phosphorus for greenhouse crops and is used to neutralize bicarbonates in irrigation water (4, 11, 12). Chlormequat (Cycocel) is utilized to prevent excessive plant height in geraniums, and in some cases has caused increased basal branching and earlier flowering (15). Carpenter and Carlson (2) reported that a 2950 ppm soil drench of chlormequat reduced plant height and branching, and advanced flowering 7 days in 'Carefree Scarlet' geranium.

The objectives of this study were to determine effects of various rates of phosphoric acid and chlormequat applications on plant development and macronutrient content of 'Sincerity' geraniums, and to study effects of these treatments on soil pH and soluble salt levels.

Rooted cuttings of 'Sincerity' geraniums were planted, one per 10 cm clay pot, on March 16, 1973 in sterilized soil mixture of 1 part low fertility sandy loam soil:1 part sphagnum peat moss:1 part horticultural perlite. Hydrated lime was added (1.5 kg/m$^3$) and pH adjusted to an average of 6.6. No phosphorus was added to the soil prior to planting. Fertilizer treatments were started March 26. $Ca(NO_3)_2$ and $KNO_3$, selected for their alkaline and neutral reactions, respectively, were used to supply 150 ppm each of N and K at every irrigation to plants in all treatments. These rates are considered the minimum N and K rates for satisfactory geranium growth (13, 14). Phosphoric acid was used to supply P at 0, 25, 50, 100, 200, and 400 ppm at every irrigation with 150 cc of solution applied per pot at each irrigation; thus some leaching occurred at every watering.

The water supply was alkaline (pH 7.8) and contained 2.2 me/liter $HCO_3$ (Table 1). Phosphoric acid at the rate of 455 cc/3785 liter water (15.4 oz/1000 gal), or approx 41 ppm P, would have been sufficient to neutralize the 2.2 me/liter $HCO_3$ (4), but I wanted to investigate the effects of applying higher rates of the acid.

The pH of the various fertilizer solutions varied from 7.90 to 2.25 (Table 2). Chlormequat was applied at 0, 1500 ppm (133.5 mg/pot) and 3000 ppm (267 mg/pot) as an 89 cc per pot soil drench March 31 to plants at each of the above P levels. There were 18 experimental treatments with 6 levels of P and 3 levels of chlormequat. A randomized complete block design was used with 12 plants per treatment, 3 replications of 4 plants each. The plants were spaced 17.7 x 20.3 cm on a N-S bench in a fiberglass greenhouse maintained at 14.4°C (night) with 17-20° (cloudy days) and 20-24°C (sunny days). Flower buds appearing in late March and early April were removed.

Table 1. Irrigation water analysis.[z]

| Constitutent | ppm | me/liter |
|---|---|---|
| Ca | 42.0 | 2.1 |
| Mg | 14.0 | 1.1 |
| Na | 30.0 | 1.3 |
| B | 00.06 | – |
| Cl | 36.0 | 1.0 |
| $SO_4$ | 54.0 | 1.1 |
| $CO_3$ | 0.0 | – |
| $HCO_3$ | 134.0 | 2.2 |

[z]Conductivity (Ec x 10$^6$ micromhos/cm) = 430.0, pH = 7.8.

Table 2. pH ranges of fertilizer solutions applied on each irrigation to 'Sincerity' geraniums.

| Fertilizer treatment[z] | pH range[y] |
|---|---|
| No P | 7.40–7.90 |
| 25 ppm | 6.60–7.25 |
| 50 ppm | 5.70–5.85 |
| 100 ppm | 3.10–3.20 |
| 200 ppm | 2.55–2.60 |
| 400 ppm | 2.25–2.30 |

[z]P was supplied from 75% food grade phosphoric acid; N and K rates were uniform for all treatments (150 ppm of each) and were supplied from $Ca(NO_3)_2$ and $KNO_3$.

[y]Solutions were prepared in 53 liter lots as needed. Slight changes in pH occurred with time.

At flowering, data were recorded on vegetative height (uppermost leaf), total flowering height, leaf diameter at the fourth node down from the tip of the plant, days to flower from planting, soil pH, and soluble salts (solubridge 1:5) at the end of the experiment.

Leaves, with petioles, which were 3/4 to recently fully expanded and located at the 4th or 5th node down from the tip of the plant were taken for macronutrient analysis. Two leaves were removed from each plant.

Analytical procedures were: $NO_3$, Orion specific ion electrode (8), % N, Micro-Kjeldahl; % P, wet digestion in nitroperchloric acid and determined by hydrazine sulfate method with a Spectronic 20 colorimeter; % K, wet digestion and flame photometry; and % Ca and Mg, wet digestion and atomic absorption spectrophotometry. On June 7, the total no. of flowering branches on each plant was recorded.

The acidifying action of the phosphoric acid resulted in average soil


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