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# Response of Potted Plants and Vegetable Seedlings to Chlorinated Water

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*Additional index words.* chlorine, foliage plants, flowering plants, vegetable crops, seed germination, irrigation, soilless media

*Abstract.* **Eleven species of potted foliage plants, eight species of potted flowering plants, and four species of vegetable seedlings were tested for their response to irrigation with chlorinated water containing 0, 2, 8, 18, 37, or 77 mg·liter$^{-1}$ residual chlorine. Growth and appearance were determined after 12 weeks for potted plants and after 6 weeks for seedlings. When compared with the control, growth of geranium and begonia declined at 2 mg·liter$^{-1}$; pepper and tomato at 8 mg·liter$^{-1}$; kalanchoe, lettuce, and tradescantia at 18 mg·liter$^{-1}$; broccoli, marigold, and petunia at 37 mg·liter$^{-1}$; and swedish ivy, impatiens, madagascar palm, and english ivy at 77 mg·liter$^{-1}$. The appearance of the plants followed a similar pattern. Germination of vegetable seeds was not affected by any of the chlorine treatments. Thus, current water chlorination practices with residual chlorine concentrations <1 mg·liter$^{-1}$ should not adversely affect either the growth or appearance of most potted plants and vegetable seedlings grown in soilless media.**

Chlorination of drinking water generally produces residual chlorine concentrations ≤1 mg·liter$^{-1}$. Occasionally, concentrations may be increased to 5 to 10 mg·liter$^{-1}$ to control persistent slime bacteria in distribution systems (4, 5, 8, 9). Little research on the response of plants to chlorinated water has been reported. Buxton (3) stated that many plants grown in soil-based media would be killed by chlorine at concentrations typical of tap water but cites no experimental data. Krone and Weinard (6) found an average decline of 90% in height and 67% in weight of seven species of potted plants irrigated with water containing 5 mg·liter$^{-1}$ residual chlorine. Others (2, 12) suggested that various plants would not be harmed when the residual chlorine concentration was <10 mg·liter$^{-1}$. Because of the sparsity of evidence and differences of opinion, we undertook the present study to evaluate the effects of chlorine on 23 different plant species grown in soilless media.

Eleven species of potted foliage plants, eight species of potted flowering plants, and four species of vegetable seedlings (Table 1) were tested for their response to irrigation water containing residual chlorine at concentrations of 0, 2, 8, 18, 37, or 77 mg·liter$^{-1}$. Potted plants were started from seed or cuttings and, after becoming well-established, were transplanted into 10-cm standard plastic pots. The potting medium contained 2 Canadian sphagnum peat : 1 perlite : 1 vermiculite (by volume) and had a pH of 5.5. Pots were placed in 10-cm-diameter vinyl saucers with ridges that raised the pot 0.75 cm off the base. Four replicates of each of the six chlorine treatments were arranged in the greenhouse with each plant species in a randomized block design.

Vegetable seedlings were germinated and grown in cavity trays placed in saucers and arranged in the greenhouse in the same design as the potted plants. Each tray contained six 4 × 3 × 6-cm cavities filled with the same medium as the potted plants. Two seeds were placed in each cavity. The trays were covered with clear plastic for 1 week and irrigated by placing the appropriate chlorinated water in the saucer and allowing it to be absorbed into the medium. Following germination, the plastic was removed, the number of germinated seeds was noted, and seedlings were thinned to one per cavity. The vegetables then were treated in the same manner as the potted plants.

Potted plants and vegetable seedlings were grown in the greenhouse for 12 and 6 weeks, respectively, during the winter. Temperatures ranged from 20° to 30°C during the day to 17° to 22° at night. Plants were fertilized, as found necessary by soil tests (10) performed every 2 weeks, with a 20N–8.8P–16.6K water-soluble fertilizer, which was added to the chlorinated water for each treatment at a concentration of 300 mg·liter$^{-1}$ of N. Each pot was irrigated from above with ≈300 ml of chlorinated water once to twice a week, with much of the water contacting the foliage.

The control irrigation water (0 mg·liter$^{-1}$) was obtained by aging tap water in sunlight for at least 48 hr. Water directly from the tap contained ≈2 mg·liter$^{-1}$ residual chlorine. Mixing 114 ml of 5.25% sodium hypochlorite (commercial bleach) with 20 liters of tap water produced a stock solution containing 77 mg·liter$^{-1}$ residual chlorine. Other treatments were obtained by dilution of the stock solution. Because sodium hypochlorite raised the pH of the stock solution to near 11, 65 ml of 1:10 hydrochloric acid was added to lower the pH to 6.5–7.0. Thus, this water was chemically equivalent to chlorinated tap water, where added chlorine gas lowers the pH, which is subsequently adjusted with so-

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Table 1. Plant species studied for sensitivity to chlorinated water.

| Common name | Scientific and cultivar name |
|---|---|
| Asparagus Fern | *Asparagus densiflorus* (Kunth) Jessop cv. Sprengeri |
| Begonia | *Begonia* ×*semperflorens-cultorum* Hort. cv. Viva |
| Boston Fern | *Nephrolepsis exaltata* (L.) Schott. cv. Bostoniensis |
| Broccoli | *Brassic oleracea* var. italica Plenck cv. Calabrese |
| English Ivy | *Hedera helix* L. cv. Ralf |
| Fuchsia | *Fuchsia* ×*hybrida* Hort. ex Vilm. cv. Madame Corneiliessen |
| Geranium | *Pelargonium* ×*hortorum* L. H. Bailey cv. Ringo |
| Grape Ivy | *Cissus rhombifolia* Vahl cv. Ellen |
| Impatiens | *Impatiens wallerana* Hook. f. cv. Tel Star |
| Jade Plant | *Crassula argenta* Thumb. |
| Kalanchoe | *Kalanchoe blossfeldiana* Poelln cv. Tetra Vulcan |
| Lettuce | *Lactuca sativa* L. cv. Salad Bowl |
| Madagascar Palm | *Chrysalidocarpus lutescens* Wendl |
| Marigold | *Tagetes erecta* L. cv. Aztec |
| Peperomia | *Peperomia caperata* Yunck. |
| Pepper | *Capsicum annuum* L. cv. California Wonder |
| Petunia | *Petunia* ×*hybrida* Hort. cv. Snowdrop |
| Spathiphyllum | *Spathiphyllum* cv. Clevelandii |
| Spider Plant | *Chlorophytum comosum* (Thumb.) Jacques cv. Variegatum |
| Streptocarpus | *Streptocarpus* ×*hybridus* Voss cv. Baby Blue |
| Swedish Ivy | *Plectranthus coleoides* Benth. |
| Tomato | *Lycopersicum esculentum* L. cv. Rutgers |
| Tradescantia | *Tradescantia albiflora* Kunth |

dium hydroxide to about pH 7.0. Water obtained by either method contains chlorine predominantly in the form of hypochlorous acid (1), which is the form of chlorine responsible for its bleaching and disinfectant properties. If the pH had not been adjusted, the plants could have been damaged by the alkaline reaction of the bleach, which may be responsible for some of the conflicting reports in the literature. Concentrations of sodium and chloride in the stock solution (77 mg·liter$^{-1}$ chlorine) were less than those said to be toxic to sensitive plants (7). Chlorine in the tap water was monitored at each irrigation with a Hach test kit. The bleach containing 5.25% sodium hypochlorite was standardized with the arsenious oxide titration method (11).

Plants were slow to show effects from any of the chlorine treatments. Germination of the vegetable seeds was not affected; however, residual chlorine of 37 and 77 mg·liter$^{-1}$ had visibly damaged the seedlings 3 weeks after seeding. Symptoms included a general lack of vigor and chlorosis of the foliage. Of the potted plants, only geranium, kalanchoe, marigold, and petunia appeared damaged after 6 weeks of irrigation with water containing 37 and 77 mg·liter$^{-1}$ residual chlorine. As with the vegetable seedlings, chlorotic foliage and decreased vigor were the most obvious symptoms. Kalanchoe also exhibited premature abscission of its older foliage.

At the end of the growing period, all plants were ranked for overall appearance on a 1 (poor) to 10 (excellent) scale. Dry weight was determined by drying aerial plant parts at 75°C for 1 week and then weighing them.

Analysis of variance was performed on both the growth and appearance data, and single degree of freedom contrasts were used to determine whether growth and appearance differed significantly from the control. The mean growth of each species as a function of treatment is shown in Table 2, where significant differences from the control are indicated. The data also were subjected to analysis of covariance, and the level of significance of the linear and quadratic terms is shown in Table 2. The appearance data are not shown because they provided essentially the same information as did plant weights, with the exceptions noted below.

Table 2. Mean shoot dry weight of each species irrigated with six levels of chlorine.

| | Covariance | | Chlorine (mg·liter$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Linear | Quadratic | 0 | 2 | 8 | 18 | 37 | 77 |
| Geranium | ** | NS | 6.16 | 5.45** | 5.33** | 5.17** | 4.14** | 3.13** |
| Begonia | ** | NS | 3.28 | 2.65** | 3.37 | 2.80* | 2.39** | 1.90** |
| Pepper | ** | ** | 0.54 | 0.48 | 0.41** | 0.36** | 0.16** | 0.10** |
| Tomato | ** | ** | 2.04 | 1.93 | 1.72** | 1.55** | 0.59** | 0.13** |
| Kalanchoe | ** | ** | 5.26 | 4.99 | 5.05 | 3.82** | 1.00** | 0.54** |
| Lettuce | ** | ** | 2.04 | 2.38 | 1.88 | 1.51* | 0.82** | 0.58** |
| Tradescantia | * | ** | 3.92 | 2.97 | 3.24 | 2.36** | 2.21** | 2.36* |
| Broccoli | ** | NS | 2.14 | 1.91 | 1.87 | 1.87 | 1.50** | 0.80** |
| Marigold | ** | NS | 4.46 | 4.50 | 4.17 | 3.86 | 2.73** | 1.74** |
| Petunia | ** | NS | 4.39 | 4.18 | 3.93 | 3.82 | 2.95** | 1.56** |
| Swedish Ivy | ** | ** | 6.44 | 7.61 | 7.07 | 6.77 | 6.14 | 3.11** |
| Impatiens | ** | * | 2.22 | 1.94 | 2.29 | 2.34 | 2.31 | 1.41* |
| Madagascar Palm | ** | NS | 5.82 | 6.57 | 5.15 | 5.46 | 4.86 | 3.06** |
| English Ivy | * | NS | 7.33 | 7.21 | 7.71 | 6.64 | 7.16 | 6.29* |
| Fuchsia | ** | NS | 2.84 | 3.42 | 3.42 | 3.05 | 2.06 | 2.18 |
| Streptocarpus | ** | NS | 2.84 | 3.15 | 2.71 | 2.81 | 2.94 | 1.91 |
| Boston Fern | * | NS | 5.52 | 4.81 | 4.89 | 5.69 | 4.89 | 3.36 |
| Jade Plant | * | NS | 7.45 | 7.40 | 7.00 | 7.37 | 6.26 | 6.36 |
| Asparagus Fern | NS | NS | 4.68 | 5.62 | 5.88 | 5.67 | 4.95 | 4.36 |
| Grape Ivy | NS | NS | 3.63 | 4.91 | 4.77 | 4.31 | 4.83 | 4.11 |
| Peperomia | NS | NS | 2.22 | 1.81 | 1.54 | 1.64 | 1.89 | 1.44 |
| Spathiphyllum | NS | NS | 2.69 | 1.98 | 3.09 | 2.45 | 2.44 | 2.01 |
| Spider Plant | NS | NS | 4.49 | 4.79 | 4.32 | 5.57 | 4.51 | 4.47 |

NS,*,**Nonsignificant and significant at 5% or 1% levels, respectively. Mean separation by 1 df contrasts with the control.

The plant species are grouped (Table 2) according to the chlorine concentration that caused a significant decline in growth when compared to the control. Geranium and begonia declined in growth and appearance when chlorine was 2 mg·liter$^{-1}$. Growth and appearance of pepper and tomato seedlings declined at chlorine concentrations of 8 mg·liter$^{-1}$, and kalanchoe, lettuce, and tradescantia declined at 18 mg·liter$^{-1}$. Growth of broccoli, marigold, and petunia declined at 37 mg·liter$^{-1}$, and swedish ivy, impatiens, madagascar palm, and english ivy at 77 mg·liter$^{-1}$. Although single degree of freedom contrasts did not reveal any other significant decreases in growth when compared with the control, analysis of covariance showed a significant linear decline in growth of fuchsia, streptocarpus, boston fern, and jade plant. The remaining five species showed no effects of chlorine at concentration of 77 mg·liter$^{-1}$.

Plant species differed somewhat in the chlorine concentration necessary to cause declines in appearance compared to declines in growth. Marigold, petunia, swedish ivy, impatiens, madagascar plam, fuchsia, and streptocarpus declined in appearance at a chlorine concentration next lower than that causing a decline in growth. The reverse was evident for tradescantia. Petunia showed the most extreme foliar chlorosis, which became noticeable at 18 mg·liter$^{-1}$ and progressed as concentrations increased until necrotic areas at the leaf margins were noticed at 77 mg·liter$^{-1}$ chlorine. Most other plants that declined in appearance also exhibited a general, but less obvious, chlorosis at the higher chlorine treatments. Since chlorosis was general and not more pronounced where water remained on the foliage, the effects of chlorine were likely systemic in nature.

Current water chlorination practices with residual chlorine concentrations of <1 mg·liter$^{-1}$ should not adversely affect either the growth or appearance of most potted plants and vegetable seedlings grown in soilless media.

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# Synergistic Defoliation in Rutabaga with Mixtures of Ethephon and Ammonium Peroxydisulfate

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*Additional index words.* *Brassica napus*, Group *Napobrassica*, preharvest spray, abscission, ammonium persulfate

***Abstract.*** **The addition of 1.0% (wt/vol) ammonium peroxydisulfate to 0.125%, 0.25%, and 0.50% (wt/vol) ethephon sprays, applied before harvest to rutabaga (*Brassica napus*, Group *Napobrassica* Mill. cv. Laurentian) nearing commercial size, defoliated a greater percentage of leaves than would be anticipated from the effects of the individual components. Defoliation expressed on the logit scale was a linear function of the square root of the ethephon concentration, if ethephon was applied with or without ammonium peroxydisulfate. Chemical name used: (2-chloroethyl) phosphonic acid (ethephon).**

Preharvest chemical defoliation of rutabaga has been demonstrated using large amounts of ethephon (9), but was considered economically prohibitive. A subsequent experiment (8) revealed that satisfactory rutabaga defoliation could be accomplished with ammonium peroxidisulfate applied within a critically narrow concentration range. Also, if ethephon and the persulfate were combined in a single spray, the ethephon requirement was reduced substantially. Although the data in the second experiment (8) were not ideally comparable, greater than additive effects were suspected in the combined defoliant applications. This finding was strengthened after further testing (unpublished data) and the following experiment was implemented to assess synergistic effects.

Three blocks of nine plots, consisting of 11 roots each, were delineated in a large single-field planting at Kentville Research Station, Kentville, N.S. All combinations of ethephon at 0%, 0.125%, 0.25%, and 0.5% (wt/vol) and ammonium peroxydisulfate at 0% and 1.0% (wt/vol) were applied in 0.40% (wt/vol) aqueous emulsions of a wetting agent (Atplus 526, Atkemix, Brantford, Ont.) to randomized plots. The ninth plot in each block was an untreated check. Laboratory-prepared concentrates were diluted in the field and were applied to the leaves with a hand-held sprayer to the point of runoff on 29 Aug. 1984. There were 371 to 417 leaves per treatment, averaging 401. Leaves on each root were counted at spraying and at several times thereafter. The number of defoliated leaves was calculated as the initial leaf count minus the final count of attached leaves (11 Sept.).

The number of defoliated leaves and the final count of attached leaves for each treatment were analyzed as binomial variates, using the approach of generalized linear models (5). Binomial variates can be modeled directly without first having to transform them to angles to stabilize their variance, and the factorial effects can be assessed in the same way as regression. Using the regression module of Genstat 4.04 (1), a nested series of statistical models was calculated, from the simplest to the full model, accounting for the effects of blocks, applied levels of ethephon, addition of ammonium peroxydisulfate, and their interactions. Effects that were nonsignificant were excluded, and a simple descriptive model was deduced. Response to ethephon seemed linear on the logit scale ($\log[p/1-p]$, where p is a proportion) if regressed on the square root of the ethephon concentrations for the applications with or without added ammonium peroxydisulfate.

There was no defoliation on the unsprayed check plots. Block effects were nonsignificant and did not interact ($P > 0.05$) with other factors. The resultant statistical model

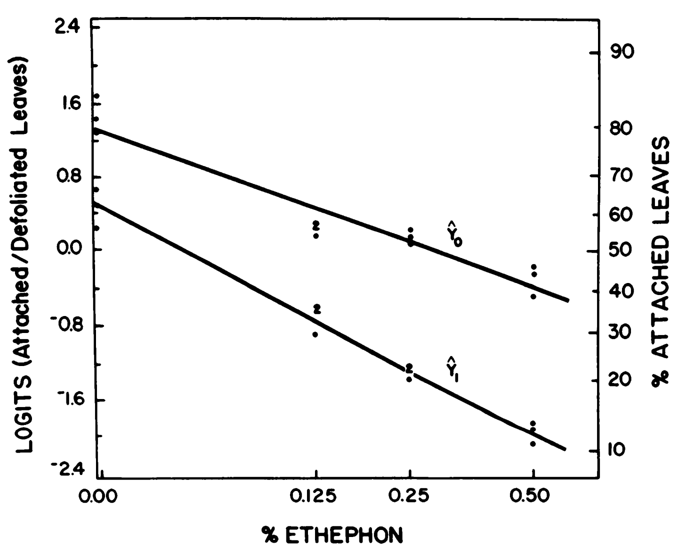


Fig. 1 Leaf populations after spraying with ethephon ($\hat{Y}_0 = 1.30 - 2.40\sqrt{x}$) and ethephon plus ammonium peroxydisulfate ($\hat{Y}_1 = 0.47 - 3.47\sqrt{x}$), where $\hat{Y}$ is in logits. The plotting character 2 denotes two observations.

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