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Minimizing Stem Elongation During Spray Applications of Gibberellin$_{4+7}$ and Benzyladenine to Prevent Leaf Chlorosis in Easter Lilies

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Abstract. **Several experiments were conducted to find effective ways of utilizing gibberellin$_{4+7}$ (GA_{4+7}) and benzyladenine (BA) to prevent leaf chlorosis during greenhouse production of Easter lilies (*Lilium longiflorum* Thunb.) while minimizing the undesirable side effects on stem elongation. On an absolute concentration basis, GA_{4+7} was much more effective than BA in preventing leaf chlorosis. Excessive levels of GA_{4+7}, however, tended to cause stem elongation. When applied at around the visible bud stage, if the foliage was well covered with the spray solution, 25 mg·L^{-1} of GA_{4+7} was adequate for maximum protection against leaf chlorosis. Increasing the GA_{4+7} concentration above 25 mg·L^{-1} gave no additional benefit on leaf chlorosis. Two possible modes of GA_{4+7} uptake during a foliar spray application (absorption through leaves and stems, and root uptake of the extra run-off) were studied in terms of their relative contribution to leaf chlorosis and stem elongation. Although both modes of uptake prevented leaf chlorosis, foliar uptake was much more effective than root uptake. However, GA_{4+7} taken up by the roots contributed mainly to stem elongation. When sprayed to leaves on only the lower half of the plant, a 10-mL spray of either 25 or 50 mg·L^{-1} of each GA_{4+7} and BA was enough for complete protection against leaf chlorosis. Increasing volumes had no additional benefit on leaf chlorosis, but increased the chances of unwanted stem elongation.**

Leaf chlorosis is a major production problem encountered by many Easter lily growers in North America. Gradual yellowing of basal leaves in Easter lilies often begins before visible bud stage and progresses upward causing significant reduction in market value of the crop. Several factors, such as root rot diseases (Han, 2000), close spacing (Han, 2000; Whitman et al., 2001), growth retardants (Jiao et al., 1986; Prince and Cunningham, 1989; Ranwala et al., 2000), negative DIF forcing (Ranwala et al., 2000), and low phosphorus nutrition (Tsujita et al., 1978), are thought to contribute to this disorder.

Research conducted in recent years has shown that growth regulators containing GA_{4+7} and BA reduce leaf chlorosis in lilies during both production and postproduction phases. Foliar sprays of gibberellin$_{4+7}$ (GA_{4+7}) and benzyladenine (BA) prevented or reduced leaf chlorosis during the production phase of Easter lilies (Han, 2000; Ranwala and Miller, 1999; Whitman et al., 2001), and during postproduction phase of Easter lilies (Han, 1997; Ranwala et al., 2000) and hybrid lilies (Funnell and Heins, 1998; Ranwala and Miller, 1998). Although both GA_{4+7} and BA are effective in preventing leaf chlorosis, GA_{4+7} is the key ingredient that prevents the leaf chlorosis, and is much more effective than BA on a concentration basis (Han, 1997, 2000; Ranwala and Miller, 1998).

While GA_{4+7} is very effective in preventing leaf chlorosis, it also causes stem elongation, an undesirable effect for pot Easter lilies (Han, 2000; Ranwala and Miller, 1999; Whitman et al., 2001). The concentration of GA_{4+7} in the spray solution and the growth stage at the time of the spray are the two major factors that affect the degree of stem elongation. Concentrations of GA_{4+7} as low as 25 mg·L^{-1} (Han, 2000) and as high as 400 mg·L^{-1} (Whitman et al., 2001) have been reported to reduce leaf chlorosis during the production phase of Easter lilies, and significant levels of stem elongation have occurred in all these instances. Treatment with GA_{4+7} at early stages of growth causes greater stem elongation than treatments at later stages of growth (Ranwala and Miller, 1999).

Information on the uptake and mobility of GA_{4+7} in Easter lilies will be useful to develop spraying protocols that prevent leaf chlorosis while minimizing the stem elongation effect. In mature Easter lilies, Han (1997) showed that GA_{4+7} prevented chlorosis only on leaves that had been treated, indicating that it was not mobilized out of mature leaves. If the same holds true for young (growing) plants, the source of gibberellin that causes the stem elongation after a foliar spray could be the extra solution that runs off to the growing media during the spray application, which could then be taken up through the roots. Therefore, investigations of the effects of different spray volumes (which results in different volumes of run-off), and the relative contribution of run-off GA_{4+7} (that will be taken up through the roots) to the leaf chlorosis and stem elongation are needed.

We conducted several experiments with the objective of finding effective ways of utilizing GA_{4+7} and BA to prevent leaf chlorosis during greenhouse production of Easter lilies while minimizing stem elongation. Specific objectives were to investigate the effects of: 1) different concentrations and combinations of GA_{4+7} and BA; 2) spray volume of growth regulator and the elimination of spray run-off to the media; and 3) direct application of the growth regulator solutions to the media on leaf chlorosis and stem elongation.

Materials and Methods

1999 experiment. Easter lily (cv. Nellie White) plants, grown in 1.4-L plastic containers, were obtained from a commercial grower. Plants had been grown from 23–25 cm (circumference) bulbs. Plants were received 60 d after planting (DAP), and were slightly past the visible bud stage. Average height of the plants at the time of receipt was 20 cm (pot rim to the top of the plant).

After receipt, plants were grown in a glass greenhouse at Cornell Univ. Plants were spaced 20 × 20 cm and were fertilized at each watering with a mixture containing 20N–4.4P–16.6K at 200 mg·L^{-1} of N, alternated with calcium nitrate plus potassium nitrate at a concentration of 200 mg·L^{-1} each of N and K. All plants received full natural sunlight in the greenhouse. A set point temperature of 22/18 °C (vent/heat) was used during the experiment.

Two days after receipt (62 DAP), plants were sprayed to runoff with growth regulator solutions containing GA_{4+7} and/or BA (see Table 1 for complete details of the products and concentrations of each component in each treatment). In all the treatments, spray solutions contained 0.1% Tween 20 (polyoxyethylene sorbitan monolaurate) as a surfactant, and only leaves on the lower half of the stem were sprayed. Control plants were sprayed with water plus surfactant.

At the puffy bud stage, plant height (pot rim to the top of the plant), the number of chlorotic or senescent leaves, and the number of flower buds were recorded. Plants were then stored in the dark at 3 ± 0.5 °C for 2 weeks, followed by transfer to a postharvest evaluation room [22 °C, 50% to 80% relative humidity (RH), 15 μmol·m^{-2}·s^{-1} light 12 h/d]. The number of chlorotic or senescent leaves was recorded at weekly intervals. A leaf was considered chlorotic if more than 20% of the leaf area was yellow.

2000 experiments. Easter lily (cv. Nellie White) bulbs (20 to 23 cm in circumference), precooled at 4 °C for 6 weeks were planted into 1.4-L plastic containers using a commercial potting mix (MetroMix 360; Scotts Co., Marysville, Ohio). Plants were grown

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in a glass greenhouse at Cornell Univ. under similar conditions described in the previous experiment. On 35 DAP (when plants were about 10 cm tall), 0.5 mg ancymidol (A-Rest; SePRO Corp., Carmel, Ind.) was applied to each pot as a 300-mL substrate drench. A second ancymidol drench at the same rate was applied 14 d later.

At 68 DAP (when average plant height was 20 cm), plants with uniform height were selected for three sets of experiments:

1) Plants were treated with growth regulator solutions containing various concentrations of GA_{4+7} and/or BA as foliar sprays (see Table 2 for complete details of the products and concentrations of each component in each treatment). In all the treatments, spray solutions contained 0.1% Tween 20 (polyoxyethylene sorbitan monolaurate) as a surfactant. Leaves of only the lower half of the stem were sprayed to run-off. Control plants were sprayed with water plus surfactant.
2) To investigate the effect of spray volume, each plant was sprayed with 5, 10, or 25 mL of Promalin (50 mg·L^{-1} each GA_{4+7} and BA). The given volume was sprayed uniformly to the leaves of the lower half of the stem, allowing any excess solution to drain into the planting media.
3) This experiment was designed to investigate the effect of excess spray solution draining into the media. Each plant was supplied with 10, 25, or 50 mL of Promalin (50 mg·L^{-1} each GA_{4+7} and BA) as a drench at the base of the stem.

At the puffy bud stage, plant height, the number of chlorotic or senescent leaves, and the number of flower buds were recorded in all experiments. Plants were cold-stored, followed by transfer to a postharvest evaluation room as described in the1999 experiment.

2001 experiments. Easter lily (cv. Nellie White) bulbs (20 to 23 cm in circumference), precooled at 4 °C for 6 weeks were planted into 1.4-L plastic containers using a commercial potting mix (MetroMix 360). Plants were grown in a glass greenhouse at Cornell Univ. under similar conditions described in the previous experiments. On 40 DAP (when plants were ≈12 cm tall), 0.5 mg ancymidol (A-Rest, SePRO Corp.) was applied to each pot as a 300-mL substrate drench. A second ancymidol drench at the same rate was applied 14 d later.

At 75 DAP (when average plant height was 20 cm), plants with uniform height were selected for two sets of experiments:

1) Plants were sprayed with 10, 25, or 50 mL of Promalin (25 mg·L^{-1} each GA_{4+7} and BA). In one set of plants, the given volume was sprayed uniformly to the leaves of the lower half of the stem, allowing the any excess solution to drain to the media. In the other set, the pot media was covered with aluminum foil to prevent excess spray solution draining into the media. In all the treatments, spray solutions contained 0.1% Tween 20 as a surfactant. Control plants were sprayed with water plus surfactant.
2) Plants were treated with 10, 25, or 50 mL of Promalin (25 mg·L^{-1} each GA_{4+7} and BA) as a drench at the base of the stem.

Measurements at the puffy bud stage, and postharvest evaluation after cold storage were done as described in previous experiments.

Statistical analysis. In all experiments, treatments were arranged in a completely randomized design with eight replicates (plants) per treatment. Data were subjected to analysis of variance (ANOVA) to determine treatment effects, and treatment means were compared using Duncan's multiple range test (General Linear Models Procedure, SAS software, SAS Inst., Cary, N.C.) Percentage data were arcsin transformed before ANOVA. Linear regression analysis was performed on the spray or drench volume vs. plant height, in the 2000 and 2001 experiments (Regression Procedure, SAS software).

Results

1999 experiment At the puffy bud stage, 22% of the leaves were either chlorotic or senescent in control (untreated) plants (Table 1). Foliar sprays of solutions containing at least 25 mg·L^{-1} of GA_{4+7} significantly reduced leaf chlorosis. Above 25 mg·L^{-1}, GA_{4+7} was equally effective alone or as a 1:1 mixture with BA (Promalin), or a 1:10 mixture with BA (Accel). At lower concentrations (e.g., 2.5 or 5 mg·L^{-1}), GA_{4+7} alone did not prevent leaf chlorosis; however, in a mixture with BA, it slightly reduced leaf chlorosis (Accel treatments). BA alone also reduced leaf chlorosis but only at a higher concentration than needed for GA_{4+7} (250 or 500 mg·L^{-1}).

During the 2 weeks of cold storage at 4 °C, no further leaf chlorosis occurred in any treatment. However, after transfer to the 22 °C evaluation room, rapid leaf chlorosis developed in all treatments. The rate of the development of leaf chlorosis during the poststorage phase was slightly lower in plants that had been treated with solutions containing 25 mg·L^{-1} or higher GA_{4+7}.

While GA_{4+7} treatments at a rate of 25 mg·L^{-1} or higher reduced leaf chlorosis, it also caused significant stem elongation. This effect could be seen in individual GA_{4+7} treatments as well as in a mixture with BA. Stem elongation of as much as 5–6 cm occurred in 25 to 50 mg·L^{-1} GA_{4+7} treatments.

2000 experiments The results of the experiments on growth regulator type and concentrations were similar to the experiments conducted in 1999, except that GA_{4+7} alone at 5 mg·L^{-1} significantly reduced leaf chlorosis at the puffy bud stage (Table 2). Benzyladenine alone also reduced leaf chlorosis at higher concentrations, and increasing the BA concentration up to 1000 mg·L^{-1} did not give any further effect compared to 100 mg·L^{-1}. While all the treatments reduced leaf chlorosis during the post-storage phase, only Promalin (50 mg·L^{-1} each GA_{4+7} and BA) caused considerable prevention. Increases in plant height with high concentrations of GA_{4+7} were also observed in this experiment. For example, 50 mg·L^{-1} GA_{4+7} caused more than 10 cm increase in height at puffy bud stage, compared to the control plants.

The effect of spray volume was investigated using a solution of 50 mg·L^{-1} each GA_{4+7} and BA. A 5-mL spray was not enough to completely cover all the leaves of the lower half of the stem, while 10 mL were adequate. Substantial run-off occurred with a 25-mL spray. Leaf chlorosis was only partially prevented by a 5-mL spray, whereas better prevention was obtained with 10- or 25-mL sprays (Table 3). A 25-mL spray did not further reduce leaf chlorosis compared to 10 mL. A linear regression model fitted for spray volume vs. plant height (Table 3) was significant ($P \leq 0.05$) indicating that increasing spray volumes increased plant height.

Applying growth regulator solutions directly to the growing media was done to assess the effects of excess run-off that could occur during a foliar spray application. Although increasing drench volumes reduced leaf chlorosis, the extent of this prevention was less than a foliar spray of identical volume

Table 1. Effects of growth regulator (GA_{4+7} and/or BA) treatments on plant height and leaf chlorosis in 'Nellie White' Easter lilies (1999 experiment). Growth regulators were applied 62 DAP as a spray to leaves of the lower half of the stem. Plant height was measured at the puffy bud stage, and leaf chlorosis was determined at the puffy bud stage, and during a postharvest evaluation phase (22 °C) following 2 weeks of dark storage at 3 °C. Each value is the mean of eight replicate plants.

Growth regulator treatment			Plant height	% Chlorotic or senescent leaves			
Product	GA_{4+7} (mg·L^{-1})	BA (mg·L^{-1})	at puffy bud (cm)	At puffy bud	At the end of cold storage	1 week poststorage	2 weeks poststorage
Water	---	---	39.4 cd	22 a[z]	25 a	38 a	52 a
ProVide	2.5	---	39.3 cd	17 a–c	21 ab	33 ab	46 ab
	5.0	---	40.6 b–d	21 ab	23 ab	32 a–c	44 a–c
	25	---	45.8 a	7 ef	9 cd	23 c–e	36 b–e
	50	---	44.7 ab	5 ef	6 cd	21 d–f	33 c–e
BAP-10	---	25	38.8 cd	17 bc	18 b	27 b–d	44 a–c
	---	50	36.9 d	19 a–c	20 ab	35 ab	52 a
	---	250	40.9 b–d	8 ef	9 cd	23 c–e	41 a–d
	---	500	38.1 d	8 ef	9 cd	21 d–f	38 b–e
Promalin	25	25	44.4 ab	7 ef	8 cd	26 b–d	41 a–d
	50	50	45.8 a	4 ef	4 d	14 ef	29 de
Accel	2.5	25	38.6 cd	14 cd	17 b	28 b–d	43 a–c
	5.0	50	40.9 b–d	9 de	11 c	28 b–d	40 a–e
	25	250	43.1 a–c	5 ef	5 cd	20 d–f	33 c–e
	50	500	45.1 ab	3 f	4 d	11 f	26 e

[z]Mean separation within columns by Duncan's multiple range test ($P \leq 0.05$).

Table 2. Effects of growth regulator (GA_{4+7} and/or BA) treatments on plant height and leaf chlorosis in 'Nellie White' Easter lilies (2000 experiments). Growth regulators were applied 68 DAP as a spray to leaves of the lower half of the stem. Plant height was measured at the puffy bud stage, and leaf chlorosis was determined at the puffy bud stage, and during a postharvest evaluation phase (22 °C) following 2 weeks of dark storage at 3 °C. Each value is the mean of eight replicate plants.

Growth regulator treatment			Plant height	% Chlorotic or senescent leaves			
Product	GA_{4+7} ($mg·L^{-1}$)	BA ($mg·L^{-1}$)	at puffy bud (cm)	At puffy bud	At the end of cold storage	1 week poststorage	2 weeks poststorage
Water	---	---	45.4 c	27 a[z]	28 a	41 a	50 a
ProVide	5	---	47.8 bc	8 cd	10 cd	26 b	36 b
Accel	5	50	48.9 b	8 bcd	10 cd	22 b	33 b
Promalin	50	50	56.1 a	5 d	6 d	8 c	10 c
BAP-10	---	100	45.1 c	12 bc	15 bc	25 b	32 b
	---	500	44.4 c	11 bc	12 bc	21 b	29 b
	---	1000	41.1 d	13 b	15 b	28 b	37 b
Provide & BAP-10	5	500	46.8 bc	7 cd	10 cd	24 b	31 b

[z]Mean separation within columns by Duncan's multiple range test ($P \leq 0.05$).

Table 3. Effects of spray volume of the growth regulator solutions on plant height and leaf chlorosis in 'Nellie White' Easter lilies. The whole volume was sprayed to the leaves of the lower half of the stem (68 DAP in 2000; 75 DAP in 2001) allowing any excess solution to run-off. Plant height was measured at the puffy bud stage, and leaf chlorosis was determined at the puffy bud stage, and during a postharvest evaluation phase (22 °C) following 2 weeks of storage at 3 °C. Each value is the mean of eight replicate plants.

		% Chlorotic or senescent leaves			
Spray vol.	Plant height at puffy bud (cm)	At puffy bud	At the end of cold storage	1 week poststorage	2 weeks poststorage
2000 experiments (50 $mg·L^{-1}$ each GA_{4+7} and BA)					
Control	44.7[z]	29 a[y]	30 a	39 a	48 a
5 mL	47.8	15 b	16 b	32 a	43 a
10 mL	51.0	6 c	7 c	16 b	24 b
25 mL	54.7	6 c	7 c	11 b	13 b
2001 experiments (25 $mg·L^{-1}$ each GA_{4+7} and BA)					
Control	38.5	17 a	18 a	35 a	47 a
10 mL	42.3	4 b	4 b	14 bcd	21 bc
10 mL (covered)	40.1	5 b	6 b	23 b	31 b
25 mL	44.3	4 b	4 b	10 cd	14 c
25 mL (covered)	40.7	6 b	7 b	17 bc	23 bc
50 mL	45.3	3 b	3 b	4 d	8 c
50 mL (covered)	39.6	5 b	5 b	11 c	15 c

[z]Linear regression equation for spray volume vs. plant height for 2000 experiment: Y = 45.70 + 0.386x, significant at $P \leq 0.05$; for 2001 experiment: Y = 39.96 + 0.122x, significant at $P \leq 0.05$ (when pots were not covered), and Y = 39.38 + 0.015x, nonsignificant at $P \leq 0.05$ (when pots were covered).
[y]Mean separation within columns by Duncan's multiple range test ($P \leq 0.05$).

(Tables 3 and 4). Plant height increased with increasing volumes of drench (Table 4) indicating that GA_{4+7} was taken up through roots and caused stem elongation.

2001 experiments. The results of experiments on spray volume and direct application on the media were similar to the previous year experiments. Overall, plants were slightly shorter and had fewer chlorotic or senescent leaves compared to the 2000 experiment (Table 3). A 10-mL spray of 25 $mg·L^{-1}$ each GA_{4+7} and BA was sufficient to reduce leaf chlorosis. Increasing the spray volume up to 50 mL caused no additional reduction of leaf chlorosis. A linear regression model fitted for spray volume vs. plant height was significant ($P \leq 0.05$) when the surface of the planting media was not covered, but the model was not significant (that is, no relationship) when the pot was covered to prevent spray solution from entering the substrate (Table 3). The results indicate that GA_{4+7} runoff that enters into the media when excessive spray volumes are used can be absorbed through the roots and contribute to lily height increase.

Similar to the previous year experiments, applying growth regulator solution to growing media decreased leaf chlorosis, but to a lesser degree compared to foliar spray of identical volumes. Again, plant height significantly increased with these growth regulator drenches.

Discussion

This study demonstrates the relationships of concentration of each growth regulator, spray volume and spray coverage during applications of gibberellins and BA for preventing leaf chlorosis during the greenhouse forcing of Easter lilies. We tested various combinations and concentrations of GA_{4+7} and BA to find out effective doses for preventing leaf chlorosis while minimizing stem elongation. On an absolute concentration basis, GA_{4+7} was much more effective than BA in preventing leaf chlorosis. Excessive levels of GA_{4+7}, however, caused undesired stem elongation. In previous studies reporting on the use of GA_{4+7} for preventing leaf chlorosis during the production phase of Easter lilies, the spray solution concentration of GA_{4+7} ranged from 10 to 400 $mg·L^{-1}$ (Han, 2000; Ranwala and Miller, 1999; Whitman et al., 2001). The general trend in these studies was that higher concentrations of GA_{4+7} tended to reduce the development of leaf chlorosis but also increased plant height. Our results indicate that a thorough coverage of the lower foliage with 25 $mg·L^{-1}$ of GA_{4+7} applied around the visible bud stage, provides adequate protection against leaf chlorosis. Increasing the GA_{4+7} concentration above 25 $mg·L^{-1}$ gives no additional benefit on leaf chlorosis, but increases the likelihood of undesired postspray elongation. Han (2000) reported similar observations where 25 $mg·L^{-1}$ each of GA_{4+7} and BA adequately prevented leaf chlorosis caused by root rot and close spacing in Easter lilies; however, significant increases in plant height were also observed.

While BA alone inhibits leaf chlorosis in Easter lilies to some degree, it is unclear that BA alone can always adequately prevent leaf chlorosis without the presence of GA_{4+7}. We observed slightly different results with treatments of BA alone between 2 years of experiments. In 1999 experiments, 250 $mg·L^{-1}$ BA reduced leaf chlorosis comparable to 25 $mg·L^{-1}$ of GA_{4+7} treatment, whereas in 2000 experiments even 1000 $mg·L^{-1}$ BA was not able to provide prevention of leaf chlorosis comparable to 50 $mg·L^{-1}$ of GA_{4+7}. Han (2000) observed that 25 $mg·L^{-1}$ of BA prevented leaf chlorosis to some degree in Easter lilies, but effects were less than that of 25 $mg·L^{-1}$ of GA_{4+7} alone or GA_{4+7} in combination of BA. The BA alone treatments were particularly ineffective in plants where leaf chlorosis was induced by root rot. An additional advantage of GA_{4+7} over BA is that its preventive effects on leaf chlorosis are carried over to the postharvest stage. This effect was especially clear in our 2000 experiments. If plants are cold-stored after harvest, GA_{4+7} has been shown to be much more effective than BA during the postharvest phase (Han, 1997; Ranwala and Miller, 1998).

Effects of exogenous gibberellins on the growth and development of Easter lilies were reported several decades ago (De Hertogh and Blakely, 1972; Kays et al., 1971; Laiche and Box, 1970). The modes of application of gibberellin in these studies were either soil drench or bulb soak, and both modes were effective in causing gibberellin-induced changes, indicating that gibberellins were taken up by the roots and mobilized within the plant. The effects of gibberellins observed in those studies included increased plant height, reduced number of flower buds, and accelerated flowering. Effects on leaf chlorosis, however, were not reported. De Hertogh and Blakely (1972) observed that soil drenches of GA_{4+7} caused significant height increase in young Easter lily plants, and that GA_{4+7} was more effective in causing stem elongation than GA_3.

Our present study illustrates different modes of uptake of GA_{4+7} by Easter lilies during a spray application, and the relative contribution of each uptake mode in preventing leaf chlorosis and stem elongation. During a foliar spray application, GA_{4+7} can be absorbed through the lower leaves or the roots (as a result of run-off into the media). Although both modes of uptake can prevent leaf chlorosis, foliar uptake is much more effective than root uptake. In contrast, GA_{4+7} taken up by the roots

Table 4. Effects of growth regulator drenches on plant height and leaf chlorosis in 'Nellie White' Easter lilies. Different volumes of growth regulator solution was applied to the media at the base of the stem (68 DAP in 2000; 75 DAP in 2001). Plant height was measured at the puffy bud stage, and leaf chlorosis was determined at the puffy bud stage, and during a postharvest evaluation phase (22 °C) following 2 weeks of storage at 3 °C. Each value is the mean of eight replicate plants.

		% Chlorotic or senescent leaves			
Drench vol.	Plant height at puffy bud (cm)	At puffy bud	At the end of cold storage	1 week poststorage	2 weeks poststorage
2000 experiments (50 mg·L^{-1} each GA_{4+7} and BA)					
Control (no drench)	44.7[z]	31 a[y]	33 a	44 a	53 a
10 mL	50.3	24 ab	25 b	38 ab	45 ab
25 mL	53.8	21 bc	22 bc	33 bc	42 b
50 mL	58.1	13 c	14 c	23 c	32 c
2001 experiments (25 mg·L^{-1} each GA_{4+7} and BA)					
Control (no drench)	38.3	18 a	19 a	34 a	47 a
10 ml	42.0	13 b	14 b	20 b	27 b
25 ml	45.4	9 c	9 c	17 bc	23 b
50 ml	47.2	8 c	8 c	10 c	14 c

[z]Linear regression equation for drench volume vs. plant height for 2000 experiment: Y = 46.43 + 0.250x, significant at $P \leq 0.05$; for 2001 experiment: Y = 39.59 + 0.170x, significant at $P \leq 0.05$.
[y]Mean separation within columns by Duncan's multiple range test ($P \leq 0.05$).

contributes substantially to stem elongation. Therefore, the best strategy in spray application would be to use a volume that is sufficient to cover the foliage while minimizing runoff.

These results could help explain lily grower observations of occasional excessive stem elongation while using products containing GA_{4+7}. Current recommendations stress complete coverage of lower leaves to give uniform protection against lower leaf chlorosis since the GA_{4+7} is "not mobilized" between mature leaves. Over-exuberant spraying of GA_{4+7} by growers could lead to substantial runoff into the substrate. While there may be very little GA_{4+7} movement out of the mature leaves to other leaves or apically to the shoot apex, there is substantial GA_{4+7} movement within the plant as a result of root uptake, presumably by xylem transport. Such GA_{4+7} transport to the shoot apex can result in unexpected and unwanted stem elongation.

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