this experiment may also produce compact, uniform *Hypoestes*.

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Chemical Promotion of Axillary Shoot Development of Geranium Stock Plants[1]

James T. Foley and Gary J. Keever[2]

Department of Horticulture and
Alabama Agricultural Experiment Station
Auburn University, AL 36849

Abstract

Foliar applications of Promalin (BA + GA_{4+7}), Pro-Shear (BA), Accel (PBA) or Florel (ethephon) were evaluated for their capacity to increase cutting production of geranium stock plants. After a first harvest of cuttings, the number of terminal cuttings was increased 19% by a single application of Promalin (BA + GA_{4+7}) or Accel (PBA) and 93% with Florel (ethephon) application when compared to an untreated control. However, after a second harvest of cuttings following a second application of the foliar spray treatments, numbers of terminal cuttings did not differ among chemical treatments and single-node cuttings increased 60–73% with the application of Promalin (BA + GA_{4+7}) when compared to the control.

Index words: chemical branching agent, cytokinin, axillary shoot development, stock plants, BA, Pro-Shear, Promalin, BA + GA_{4+7}, Accel, PBA, Florel, ethephon

Growth regulators used in this study: Pro-Shear (BA), *N*-(phenylmethyl)-1*H*-purin-6-amine; Accel (PBA), *N*-(phenylmethyl)-9-(tetrahydro-2*H*-pyran-2-yl)-9*H*-purin-6-amine; Promalin (BA + GA_{4+7}), *N*-(phenylmethyl)-1*H*-purin-6-amine (BA) + (1α,2β,4aα,4bβ,10β)-2,4a,7-trihydroxy-1-methyl-8-methylenegibb-3-ene-1,10-dicarboxylic acid (GA_{4+7}); Florel (ethephon), (2-chloroethyl)phosphonic acid.

Species used in this study: geranium (*Pelargonium* × *hortorum* L.H. Bailey 'Hollywood Star').

Significance to the Nursery Industry

The maintenance of geranium stock plants as a source of vegetatively propagated cultivars requires a continual investment in space and labor. Greater efficiency is possible if the number of cuttings per plant is increased, thus reducing the total number of stock plants maintained. Florel (ethephon) is labeled as a branching compound for use on geranium stock plants, however in our research, calipers of terminal cuttings were less than those of control plants. Two applications of Promalin (BA + GA_{4+7}) at either 75 or 150 ppm increased production of single-node cuttings, without reducing the number or caliper of the terminal cuttings. The use of Promalin (BA + GA_{4+7}) is a viable alternative to the industry standard, Florel (ethephon), for increasing the total number of marketable geranium plants produced from single-node cuttings.

Introduction

Although many types of geraniums are produced from seed, some cultivars continue to be propagated from cuttings

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[2]Graduate Student and Associate Professor, resp.

taken from stock plants. For growers who maintain stock plants, greater efficiency may be attained through increased productivity. Productivity of stock plants can be doubled or tripled by the division of the stem below the terminal cutting into leaf bud or single-node cuttings (8, 9, 10). Shanks (11) suggested that the use of chemical growth regulators could increase the axillary shoot development of vegetatively propagated geranium cultivars resulting in an increase in the number of terminal or single-node cuttings per stock plant, further increasing productivity.

The promotion of axillary shoot development of geranium stock plants by ethephon has been well-documented (1, 11, 12). Ethephon (Florel, Ethrel) is labeled as a branching compound for use on geranium stock plants at a concentration of 500 ppm (1, 7, 9). Other plant growth regulators, such as synthetic cytokinins, reduce apical dominance, thereby promoting the growth of axillary buds. Foliar sprays of Pro-Shear (BA) effectively increased the branching of *Cordyline* at 100, 250 or 500 ppm (6), *Peperomia* at 250, 500 or 1000 ppm (5) and pinched geranium at 1000 ppm (1). Promalin, 1 BA: 1 GA_{4+7}, sprays applied at 500 ppm increased the primary and secondary branching of apple (4, 13), while a 1000 or 2000 ppm concentration increased lateral branching of pear and cherry (2). Accel (PBA) applications of 75 and 250 ppm increased the branching of pinched geranium (1) and *Dracaena* plants (3), respectively. The objective of this study was to determine the effectiveness of several chemical branching agents in inducing the axillary shoot development of 'Hollywood Star' geranium stock plants for the purpose of increasing the production of cuttings.

Materials and Methods

Experiment 1. On November 13, 1987, seeds of 'Hollywood Star' geranium were sown in 36-cell flats of Pro-Mix BX drenched with benomyl fungicide. Flats were placed under intermittent mist (10 sec/5 min) in a double layer polyethylene greenhouse with minimum day/night temperatures of 21°C (70°F) day/16°C (60°F) night until cotyledons had fully emerged. Seedlings were transplanted to 15.3 cm (6 in) pots of identical growth medium on January 6, 1988, and after 2 days the following foliar spray treatments were applied to the plants just prior to runoff: Pro-Shear (BA) at 75, 150, 300 or 600 ppm; Accel (PBA) at 75, 150, 300, 600 ppm; and Promalin (BA + GA_{4+7}) at 150, 300, 600 or 1200 ppm. An untreated control was included for comparison. Buffer-X was added as a surfactant at 0.2% to all chemical solutions in each experiment. Plants were fertilized weekly with 200 ppm N from 20N-4.3P-16.6K (20-10-20) Peter's Peatlite Special. At the termination of the experiment, 8 weeks after plant treatment, data collected included the number of axillary shoots, the mean length of three randomly selected axillary shoots, and a growth index ((height + width_1 + width_2) /3). Plants were measured at their widest point (width_1) and perpendicular to width_1 (width_2). There were 5 single-plant replications in a completely randomized design. Statistical analysis included a Fisher's least significance test for comparison among growth regulators and a regression analysis which included the control.

Experiment 2. A second study was initiated to determine appropriate concentrations and numbers of applications of the branching compounds, Accel (PBA), Promalin (BA + GA_{4+7}) and Florel (ethephon) on geranium stock plants. Seeds were sown on April 4, 1988, and the seedlings were grown as in the first experiment. The following foliar spray treatments were applied on June 27, 1988, Accel (PBA) at 37.5 or 75 ppm, Promalin (BA + GA_{4+7}) at 75 or 150 ppm, and Florel (ethephon) at 500 ppm. A control treatment was included for comparison. Four weeks after initial treatment, terminal and single-node cuttings were taken and a second application was applied to half of the plants in each treatment group. Plants were then allowed to produce a second crop of cuttings. All side branches were cut from the main leader of each plant and divided into terminal cuttings (about 10 cm long) and single-node cuttings (with leaf attached). Data collected at the first and second removal of cuttings consisted of lengths and calipers of axillary shoots and numbers of terminal and single-node cuttings. The caliper of each side shoot was taken at the point of detachment from the main leader and the lengths of side branches were also measured from this point to the vegetative shoot apex. Initial sprays were applied to 14 single-plant replicates in a completely randomized design.

Experiment 3. A third experiment compared the effects of one, two or four foliar sprays of Promalin (BA + GA_{4+7}) at 75, 150 or 300 ppm and Florel (ethephon) at 500 ppm. An untreated control was included for comparison. Seeds were sown on March 2, 1989, and seedlings were grown as in the first two experiments. The first foliar spray application was on May 4, 1989; additional applications were made at 2-week intervals. At time of cutting, the number of terminal and single-node cuttings and lengths and calipers of axillary shoots were recorded. Treatments were completely randomized with 10 single-plant replicates.

Results and Discussion

Experiment 1. As the concentration of Pro-Shear (BA) increased, the numbers of axillary shoots decreased (Table 1). When Pro-Shear (BA) was applied at 600 ppm, axillary shoot formation was suppressed; there was no effect at lower concentrations. Axillary shoot length increased linearly as concentration of Pro-Shear (BA) increased, however the growth index was not affected by application of Pro-Shear (BA). These results are the reverse of those reported by Henny (5). Pro-Shear (BA) was not studied further since axillary shoot number was not increased following its application.

Axillary shoot number was increased at lower concentrations of Accel (PBA), with no effect thereafter. Increased branching of pinched geranium and *Dracaena* has also been reported at similar concentrations of Accel (PBA) (1, 3). Axillary shoot length was not affected by Accel (PBA) application. The growth index increased with Accel (PBA) up to 300 ppm but declined at higher concentrations.

Axillary shoot number did not differ from the control at the two highest concentrations of Promalin (BA + GA_{4+7}), while numbers increased at the 300 ppm concentration. Although axillary shoot lengths increased linearly as concentration of Promalin (BA + GA_{4+7}) increased, lengths did not differ from the control. The growth index increased linearly with increasing concentration of Promalin (BA + GA_{4+7}) with 1200 ppm producing a growth index that differed from the control.

Experiment 2. The first cuttings were harvested four weeks after initial treatment. More terminal cuttings were produced

Table 1. **Number and length of axillary shoots and growth index of geranium as affected by three plant growth regulators, 8 weeks after treating, Expt. 1.**

Plant growth regulator	Conc. (ppm)	Axillary shoots Number	Axillary shoots Length (cm)	Growth index[z] (cm)
BA	75	16.2	9.5	25.1
	150	15.6	10.9	24.7
	300	14.4	11.1	25.3
	600	6.5 Q[y]	13.3 L	25.6 NS
Accel	75	17.6	10.3	25.8
	150	16.6	11.5	26.5
	300	17.0	11.1	28.1
	600	13.6 Q	10.2 NS	25.7 Q
Promalin	150	10.2	8.7	25.8
	300	17.2	10.8	25.5
	600	14.0	10.2	26.5
	1200	11.4 Q	12.2 L	28.4 L
Control		13.6	9.4	24.2
LSD[x]		3.2	3.7	3.1

[z]Growth index = (height + $width_1$ + $width_2$)/3.

[y]Significance of regression analysis at P = 0.05: L = linear; Q = quadratic; NS = not significant; control included in regression.

[x]Mean separation within columns by a protected Fisher's least significant test, P = 0.05; LSD used for comparisons among growth regulators.

Table 2. **Terminal and single-node cutting numbers and length and caliper of axillary shoots of geranium as affected by three plant growth regulators after first and second harvests, Expt. 2.**

Plant growth regulator	Conc. (ppm)	Applic. no.	Terminal cuttings	Single-node cuttings	Axillary shoots Length (cm)	Axillary shoots Caliper (cm)
			First harvest[z]			
Accel	37.5	1	9.5	11.3	9.8	0.80
	75	1	10.0	10.5	9.6	0.79
Promalin	75	1	9.9	9.6	11.3	0.79
	150	1	10.4	13.6	12.5	0.88
Florel	500	1	16.2	10.8	7.3	0.68
Control			8.4	12.3	10.2	0.82
LSD[z]			1.4	4.3	1.4	0.09
			Second harvest[z]			
Accel	37.5	1	9.4	13.4	9.5	0.79
	37.5	2	8.7	19.3	12.8	0.82
	75	1	9.4	18.1	10.7	0.81
	75	2	7.3	16.8	11.2	0.78
Promalin	75	1	9.9	8.9	8.1	0.74
	75	2	10.9	25.7	12.7	0.79
	150	1	8.7	17.4	11.5	0.80
	150	2	9.0	27.9	13.5	0.82
Florel	500	1	11.0	16.6	9.0	0.68
	500	2	10.2	17.2	9.5	0.69
Control			9.0	16.1	10.1	0.88
LSD[y]			2.4	8.6	2.7	0.10

[z]First harvest made 4 weeks after initial treatment; second harvest taken 9 weeks after second application of treatments.

[y]Mean separation within columns by a protected Fisher's least significant test, P = 0.05; LSD used for comparisons among growth regulators.

Table 3. Terminal and single-node cutting numbers and length and caliper of axillary shoots of geranium as affected by two plant growth regulators, 7 weeks after treatment, Expt. 3.

Plant growth regulator	Conc. (ppm)	Applic. no.[z]	Terminal cuttings	Single-node cuttings	Axillary shoots	
					Length (cm)	Caliper (cm)
Promalin	75	4	11.4	24.4	17.6	0.72
	75	2	12.5	27.4	15.6	0.83
	75	1	12.5	20.5	12.2	0.79
Promalin	150	4	10.3	15.7	14.6	0.62
	150	2	11.8	23.1	15.5	0.79
	150	1	13.7	23.6	14.4	0.80
Promalin	300	4	9.6	6.2	10.0	0.60
	300	2	11.0	16.9	13.1	0.70
	300	1	10.8	19.5	14.3	0.90
Florel	500	1	14.3	14.3	5.7	0.68
Control			12.6	16.5	10.7	0.87
LSD[y]			1.6	8.0	2.6	0.12

[z]Application number: 1 = monthly; 2 = biweekly; 4 = weekly.

[y]Mean separation within columns by a protected Fisher's least significant test, P = 0.05; LSD used for comparisons among growth regulators.

following Florel (ethephon) application than with the other treatments (Table 2). Treatment with Accel (PBA) at 75 ppm or Promalin (BA + GA_{4+7}) at 75 or 150 ppm increased the numbers of terminal cuttings, but the increase was not as great as with Florel (ethephon). The number of single-node cuttings was not affected by applications of Florel (ethephon), Accel (PBA), or Promalin (BA + GA_{4+7}) after the first cuttings had been harvested. Axillary shoot length and caliper of plants treated with Florel (ethephon) was less than all other treated and control plants; this effect has been noted in previous experiments with Florel (ethephon) (7, 11). When Promalin (BA + GA_{4+7}) was applied at 150 ppm, axillary shoot length was increased. Applications of Accel (PBA) did not affect axillary shoot length. Axillary shoot caliper was not affected by treatment with Promalin (BA + GA_{4+7}) or Accel (PBA).

After harvesting a second crop of cuttings, number of terminal cuttings did not differ among treatments. The numbers of single-node cuttings increased after a second application of 75 or 150 ppm Promalin (BA + GA_{4+7}). The number of single-node cuttings did not differ from that of control plants with a second application of Accel (PBA) or Florel (ethephon). The lengths of axillary shoots were increased with a second application of Promalin (BA + GA_{4+7}) at 150 ppm; axillary shoot lengths of plants in other treatments were similar to those of control plants. Calipers of cuttings from plants treated with Florel (ethephon) or one application of Promalin (BA + GA_{4+7}) at 75 ppm were reduced; calipers of plants given other treatments did not differ from those of control plants.

Experiment 3. Application of Florel (ethephon) increased the number of terminal cuttings (Table 3). Foliage of plants receiving four applications of Promalin (BA + GA_{4+7}) at 150 or 300 ppm was chlorotic; isolated marginal necrosis was also present. Phytotoxicity possibly contributed to reduced numbers of terminal cuttings. Numbers of terminal cuttings were also decreased by a single application of Promalin (BA + GA_{4+7}) at 300 ppm, indicating an excessive concentration.

The numbers of terminal cuttings from plants receiving other concentrations of Promalin (BA + GA_{4+7}) were similar to those of control plants. The number of single-node cuttings was increased by two applications of Promalin (BA + GA_{4+7}) at 75 ppm, while numbers decreased from four applications at 300 ppm. The other application numbers and concentrations of Promalin (BA + GA_{4+7}) and Florel (ethephon) had no affect on single-node cutting number.

The lengths of axillary shoots were reduced by application of Florel (ethephon). One application of Promalin (BA + GA_{4+7}) at 150 or 300 ppm or two or four applications at 75 or 150 ppm increased axillary shoot length. Axillary shoot caliper decreased when plants were treated with four applications of Promalin (BA + GA_{4+7}), two applications of 300 ppm Promalin (BA + GA_{4+7}) or with Florel (ethephon).

Florel (ethephon) produced more terminal cuttings than the other plant growth regulators, but plants had shorter axillary shoots of smaller calipers when compared to the control and Promalin (BA + GA_{4+7}) treated plants. The increased numbers of terminal cuttings with shorter axillary shoots of smaller caliper is supported by other research with Florel (ethephon) on geranium (1, 11, 12). Plants treated with Promalin (BA + GA_{4+7}) produced longer axillary shoots of increased caliper, resulting in an increased number of single-node cuttings when compared to plants treated with Florel (ethephon). In addition to an unaltered number of terminal cuttings, the increased number of single-node cuttings produced from stock plants treated with two applications of Promalin (BA + GA_{4+7}) at 75 ppm biweekly, doubled or tripled the total number of cuttings produced, as Rogers suggested (10). This effect would potentially result in an substantial increase in the total number of marketable plants produced.

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Consequences of Water and Nitrogen Management on Growth and Aesthetic Quality of Drought-Tolerant Woody Landscape Plants[1]

T.D. Paine,[2] C.C. Hanlon,[3] D.R. Pittenger,[4] D.M. Ferrin,[5] and M.K. Malinoski[6]
Department of Entomology
University of California
Riverside, CA 92521

Abstract

Two drought-tolerant California native plant species (a nonselected form of *Ceanothus griseus* var. *horizontalis*, *C. griseus* var. *horizontalis* 'Santa Ana', a nonselected form of *Rhamnus californica*, and *R. californica* 'Eve Case') and a widely planted non-native landscape species (*Photinia fraseri*) received the same total volume of water (63.8% ET_0) over a 14 week period in one of four irrigation treatments (water applied daily, every three days, every five days, or every seven days). Each irrigation treatment also received one of three rates of nitrogen application (0, 20 g N/m^2, and 40 g N/m^2 [0, 180, and 360 lb. N/A]). The irrigation frequencies or fertilization rates had few significant effects on plant growth and survival. Selection of a cultivar of *R. californica* has resulted in increased growth rates and aesthetic quality, but has also increased susceptibility to root pathogenic fungi.

Index words: drought tolerance, water stress, irrigation frequency

Species used: Carmel Creeper (*Ceanothus griseus* var. *horizontalis*); Santa Ana (*Ceanothus griseus* var. *horizontalis* 'Santa Ana'); California Coffeeberry (*Rhamnus californica*); Eve Case (*Rhamnus californica* 'Eve Case'); Fraser photinia (*Photinia fraseri*).

Significance to the Nursery Industry

Xerophytic plants have been adapted to landscape use in a limited way. Although the interest in using these plants is continuing to grow, the production and sale of the plants have been relatively minor parts of the landscape plant industry. Traditional attitudes towards the form and appearance of landscape plants, as well as misperceptions of the shape and color of drought-tolerant plants, have slowed acceptance of the xerophytic species. Consequently, plant breeders have selected new cultivars of the drought tolerant species to conform to more traditional views. Also, there is a conventional wisdom suggesting that the xerophytic species are either hard to maintain or short-lived in the landscape because of their sensitivity to irrigation schedules. The study presented here demonstrates that the frequency of irrigation (total water applied at 63.8% ET_0) and fertilization of the nonselected form of *Ceanothus griseus* var. *horizontalis*, *C. griseus* var. *horizontalis* 'Santa Ana', the nonselected form of *Rhamnus californica, R. californica* 'Eve Case', or *Photinia fraseri* have only minor impacts on plant growth and survival. The results suggest that if the

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[2]Assistant Professor.

[3]Staff Research Associate.

[4]Extension Urban Horticulturist, Department of Botany and Plant Sciences, University of California, Riverside, CA 92521.

[5]Assistant Professor, Department of Plant Pathology, University of California, Riverside, CA 92521.

[6]Staff Research Associate, Current Address: Department of Entomology, University of Maryland, College Park, MD 20742.