

# Conditioning Treatments Affect Insect and Mite Populations on Bedding Plants in the Greenhouse

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*Additional index words.* columbine (*Aquilegia ×hybrida*), New Guinea impatiens (*Impatiens ×hybrida*), marigold (*Tagetes erecta*), ageratum (*Ageratum houstonianum*), two-spotted spider mite (*Tetranychus urticae*), green peach aphid (*Myzus persicae*), western flower thrips (*Frankliniella occidentalis*), stress, nutrition, irrigation, plant growth regulators

**Abstract.** During greenhouse production in Spring 1995, conditioning treatments were applied to columbine (*Aquilegia ×hybrida* Sims ‘McKana Giants’), New Guinea impatiens (*Impatiens hawkeri* Bull. ‘Antares’), marigold (*Tagetes erecta* L. ‘Little Devil Mix’) and ageratum (*Ageratum houstonianum* Mill. ‘Blue Puffs’) plants. Treatments included: mechanical conditioning (brushing 40 strokes twice daily); moisture stress conditioning (MSC) (wilting for ≈2 hours per day); undisturbed ebb-and-flow irrigation; overhead irrigation; high (500 mg·L<sup>-1</sup> N) or low (50 mg·L<sup>-1</sup> N) 3×/week N fertilizer regimes; daminozide (5000 mg·L<sup>-1</sup>); or paclobutrazol (30, 45, or 180 mg·L<sup>-1</sup>). One week after initiation of treatments, individual plants in separate greenhouses were inoculated with two adult green peach aphids (*Myzus persicae* Sulzer) or five two-spotted spider mites (*Tetranychus urticae* Koch). A natural infestation of western flower thrips (*Frankliniella occidentalis* Pergande) in the mite-inoculated greenhouse provided an additional insect treatment. Brushing was the only treatment that consistently reduced thrips and mite populations. Aphid populations were lower on low-N than on high-N plants, but thrips and mite populations were not consistently affected by plant fertilization. Moisture stress conditioning tended to increase aphid populations on New Guinea impatiens and marigold, but had little effect on spider mite or thrips populations. Ebb-and-flow irrigation reduced the mite population on ageratum relative to that on overhead irrigated (control) plants. Plant growth regulators did not consistently affect pest populations. Chemical names used: butane-dioic acid mono(2,2-dimethylhydrazide) (daminozide); β-[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol (paclobutrazol).

Horticultural practices used in greenhouse production are designed to control plant growth, form, and condition to produce a healthy, attractive, and marketable plant. Growth regulation and conditioning of greenhouse-grown bedding plants can be accomplished chemically with plant growth regulators (PGRs), or nonchemically by mechanical conditioning (brushing), and irrigation or nutrient management. Herbaceous ornamentals are commonly treated with PGRs, such as daminozide, paclobutrazol, or uniconazole [(E)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)-penten-3-ol]. Mechanical conditioning via brushing or shaking of plant shoots affects the growth and condition of a variety of vegetable transplants (Latimer, 1991) and ornamental bedding plants (Autio et al., 1994). Moisture stress conditioning (MSC), the controlled exposure of plants to nonlethal water

deficits, also reduces growth and improves plant resistance to additional stresses (Eakes et al., 1991).

The effect of growth regulation or conditioning treatments on population dynamics of greenhouse pests has received little attention. However, management factors can increase or reduce plant resistance to insect pests and affect pest populations (Tingey and Singh, 1980). For example, sterol-inhibiting fungicides (triazole chemicals similar to paclobutrazol or uniconazole) can alter the population structure of both pest and beneficial arthropods. They reportedly increase populations of European red mites (*Panonychus ulmi* Koch) and green apple aphids (*Aphis pomi* Degeer) in apple (*Malus ×domestica* Borkh.) orchards (Biggs and Hagley, 1988). Aphid population growth was reduced on black currants (*Ribes nigrum* L.) by treatment with chlormequat chloride (2-chloro-*N,N,N*-trimethylethanaminium chloride), but was unaffected by daminozide (Smith, 1969). Daminozide reduced green peach aphid and two-spotted spider mite populations on chrysanthemum (*Dendranthema ×grandiflora* Kitam.), presumably indirectly by reducing the survival rate of the immatures, as the chemical showed no direct toxicity to the adults (Worthing, 1969).

Aphids and other sucking insects generally respond more positively to host stress than do other foliar feeding insects, presumably because stress increases the soluble nitrogen available to these insects (Larsson, 1989; Larsson and Bjorkman, 1993). Leafminer (*Lyriomyza trifolii* Burgess) populations increased linearly with increasing leaf nitrogen content of chrysanthemum (Harbaugh et al., 1983) and tomato (*Lycopersicon esculentum* Mill.) (Minkenberg and Ottenheim, 1990).

Overhead irrigation resulted in higher green peach aphid infestations on chrysanthemum than did capillary watering (Wyatt, 1969). In greenhouse experiments, drought stress increased two-spotted spider mite populations on chrysanthemum (Price et al., 1982), but reduced aphid (*Aphis varians* Patch) populations on fireweed (*Epilobium angustifolium* L.) (Morris, 1992). Moderate to severe drought generally reduces insect pest population development, but intermittent drought stress can increase aphid fecundity (Tingey and Singh, 1980). Brushing vegetable transplants reduced thrips feeding damage and aphid populations (Latimer and Oetting, 1994).

In preliminary experiments (unpublished) on the effect of conditioning treatments on insect pest infestations of bedding plants, we found that treatment with paclobutrazol (45 mg·L<sup>-1</sup>) or brushing (40 strokes twice daily) reduced the number of two-spotted spider mites per marigold plant after 4 weeks of treatment. In the same test, spider mite populations were reduced when ageratum plants were grown under ebb-and-flow irrigation as opposed to overhead irrigation or were conditioned by brushing.

The objective of the tests reported here was to evaluate the effects of several greenhouse management practices on insect populations on herbaceous perennial and annual bedding plants.

## Materials and Methods

Plugs for ‘Little Devil Mix’ marigold, ‘Blue Puffs’ ageratum, ‘McKana Giants’ columbine, and ‘Antares’ New Guinea impatiens were obtained from a commercial grower in Mar. 1995, and planted in 10 × 10-cm plastic pots (soil volume 580 cm<sup>3</sup>) filled with Metro-Mix 300 (Grace Horticultural Products, Cambridge, Mass.). Marigold, ageratum, and columbine plugs were planted on 3 Mar. and the New Guinea impatiens on 14 Mar.

Conditioning treatments were initiated on each crop 7 d after planting, when the plants had resumed active growth. The control plants were well-watered with overhead irrigation, and fertilized with N at 250 mg·L<sup>-1</sup> three times per week using a 20N-4.4P-16.6K water-soluble fertilizer (Peters peatlite special 20-10-20; The Scotts Co., Marysville, Ohio). Two fertilization rates were selected to represent extreme ends of the normal range. The water soluble fertilizer was applied three times per week with N at 50 mg·L<sup>-1</sup> (“low N”) or at 500 mg·L<sup>-1</sup> (“high N”). All plants not assigned to specific N treatments were fertilized with N at 250 mg·L<sup>-1</sup> three times per week.

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Two irrigation treatments were included. Ebb-and-flow irrigation was used to maintain plants well-watered but undisturbed. Moisture stress conditioning (MSC) was imposed by withholding water daily until the plants exhibited visible wilt symptoms for up to 2 h each day, measured from initial flagging of leaves. The treatment was imposed as soon as the plants were large enough to deplete the water in the media between the fertilizer applications. The intensity of the MSC treatment increased with increasing plant size.

Chemical growth regulation treatments included daminozide (B-Nine; Uniroyal Chemical Co., Middlebury, Conn.) at 5000 mg·L<sup>-1</sup> for all crops, or paclobutrazol (Bonzi; Uniroyal Chemical) at 45 mg·L<sup>-1</sup> (marigold and ageratum), 180 mg·L<sup>-1</sup> (columbine), or 30 mg·L<sup>-1</sup> (New Guinea impatiens). Rates were based on preliminary experiments with these crops. Growth regulators were applied once to actively growing plants as a foliar spray, using a hand-held compressed air sprayer with a 1-mm hollowcone nozzle at a pressure of 2.1 kg·cm<sup>-2</sup>. Sprays were evenly applied at a volume of 210 mL·m<sup>-2</sup> (label recommended rate for paclobutrazol) over a 1-m<sup>2</sup> area containing 10 plants. Each plant species was treated individually.

Brushed plants were removed from the bench for treatment, placed on a table where the plants were brushed back and forth with a wooden pole for a total of 40 strokes twice daily, and then returned to the greenhouse bench. The height of the bar was adjusted to strike only the upper one-third of the shoots.

The experiment was conducted in two separate 49-m<sup>2</sup> polyethylene greenhouses to introduce two specific insect pests 1 week after conditioning treatments were initiated. In the aphid-inoculated greenhouse, two adult green peach aphids were placed on each plant using a camel's hair brush to transfer them from chrysanthemum host plants. In the mite-inoculated greenhouse, five adult two-spotted spider mites were removed from New Guinea impatiens host plants and placed on each test plant. A natural infestation of western flower thrips in the mite-inoculated greenhouse provided the opportunity to assess treatment effects on plant response to thrips infestation. The thrips population was not high enough to interfere with the development of the spider mite population.

Within each pest-infested greenhouse, each plant species was arranged in a randomized complete-block design with three plants per experimental unit and five replications (n = 15). Each plant species/pest combination constituted an individual experiment. Plant height and width (average of width at widest point and perpendicular to the widest point) were measured 4 and 6 weeks after treatment (WAT). Populations of aphids or spider mites (number per plant) were counted at 2, 4, and 6 WAT. Thrips populations are difficult to evaluate because the adults are reclusive and rarely seen on plants, but immature thrips can usually be found on the leaves (Higgins, 1992). However, the number of feeding scars per plant (Broadbent et al., 1990) was used to estimate

the thrips population on the treated plants at 2, 4, and 6 WAT.

*Statistical analysis.* All data were subjected to analysis of variance using SAS's general linear models procedure (SAS Institute, Cary, N.C.), and mean separation was by protected least significant difference test (LSD),  $P \leq 0.05$ .

**Results**

*Columbine.* Height of columbine plants was increased by high N, ebb-and-flow irrigation, or paclobutrazol application at 4 and 6 WAT (Table 1). Although the plugs appeared to be uniform, the uniformity of subsequent growth was very poor, resulting in very high coefficients of variation. However, spider mites did become established. At 4 WAT, only brushing significantly reduced spider mite populations relative to untreated controls, ebb-and-flow irrigation, MSC, or daminozide treatment. Thrips did not become established on columbine in this greenhouse.

*New Guinea impatiens.* Plant height of New Guinea impatiens was not affected by N level, but plant width was reduced by low N relative to controls (Table 2). Ebb-and-flow irrigation increased plant height, but decreased plant width at 6 WAT, whereas MSC had no effect on plant growth relative to controls. Both plant height and width were reduced by

brushing at 4 and 6 WAT. Paclobutrazol reduced plant height at 4 WAT. Neither spider mites nor thrips had become established at 2 WAT. Spider mite populations were reduced by low N at 4 WAT or by brushing at 4 and 6 WAT. The number of thrips feeding scars per plant was reduced on low N plants at 6 WAT and on brushed plants at 4 and 6 WAT. However, MSC increased the number of feeding scars, but only at 4 WAT.

*Marigold.* Marigold plants treated with paclobutrazol were shorter than controls at 4 WAT, but the effect did not persist through 6 WAT (Table 3). Plant width was reduced by low N, brushing, and paclobutrazol throughout the study. Spider mite counts were not significantly affected by conditioning treatments at any measurement date. Ebb-and-flow irrigation increased the numbers of thrips feeding scars per plant counted at 2 WAT, while brushing reduced them. Values for control, ebb-and-flow, and brushing were 13.9, 58.6, and 1.7, respectively, all being significantly different from one another at  $P \leq 0.05$ . At 4 WAT, brushing reduced thrips populations relative to values for undisturbed plants grown under ebb-and-flow irrigation, the treatment with the highest thrips population (Table 3). Low N and brushing reduced thrips populations at 6 WAT relative to controls, MSC, daminozide, and paclobutrazol.

*Ageratum.* Ageratum height and width were

Table 1. Effect of conditioning treatments on height and width of 'McKana Giants' columbine, and the number of two-spotted spider mites per plant at 4 and 6 weeks after treatment (WAT) in the greenhouse in 1995. Thrips did not become established on this species in this greenhouse.

Treatment	4 WAT			6 WAT		
	Height (cm)	Width (cm)	Spider mites	Height (cm)	Width (cm)	Spider mites
Control	12.6 de <sup>z</sup>	20.1 b	72 ab	15.2 c	27.9 bc	101
Low N	15.9 b-d	20.2 b	40 a-c	19.6 bc	30.8 ab	63
High N	16.8 a-c	20.7 ab	31 bc	29.9 a	30.3 b	83
Ebb/flow	20.2 a	23.9 a	93 ab	29.0 a	35.7 a	146
MSC <sup>y</sup>	15.3 cd	21.2 ab	93 ab	18.0 c	29.4 b	168
Brushed	12.9 de	20.0 b	4 c	20.0 bc	30.0 b	18
Daminozide	10.4 e	15.8 c	96 a	14.5 c	23.6 c	118
Paclobutrazol	19.6 ab	22.0 ab	43 a-c	25.2 ab	32.7 ab	111
LSD	3.8	3.3	65	6.3	5.4	---
F test	***	**	*	***	**	NS

<sup>z</sup>Mean separation by protected LSD,  $P \leq 0.05$ .

<sup>y</sup>Moisture stress conditioning.

ns, \*, \*\*, \*\*\*Nonsignificant or significant at  $P \leq 0.05, 0.01, \text{ or } 0.001$ , respectively.

Table 2. Effect of conditioning treatments on height and width of 'Antares' New Guinea impatiens, the number of two-spotted spider mites per plant, and the number of western flower thrips feeding scars per plant at 4 and 6 weeks after treatment (WAT) in the greenhouse in 1995.

Treatment	4 WAT				6 WAT			
	Height (cm)	Width (cm)	Spider mites	Thrips scars	Height (cm)	Width (cm)	Spider mites	Thrips scars
Control	10.0 a <sup>z</sup>	21.9 a	16.1 a	27.8 bc	12.5 b-d	24.9 b	14.4 a-c	9.9 a
Low N	9.3 a-c	18.2 d	5.7 bc	26.7 bc	11.4 de	21.5 e	7.3 cd	5.1 c
High N	9.4 a-c	22.2 a	14.1 ab	33.1 ab	13.5 ab	26.7 a	18.0 ab	8.1 a-c
Ebb/flow	10.0 a	20.3 bc	10.3 a-c	32.7 ab	14.5 a	23.1 cd	15.6 a-c	7.5 a-c
MSC <sup>y</sup>	9.6 ab	21.0 ab	18.7 a	43.6 a	13.1 bc	24.1 bc	21.3 a	9.5 ab
Brushed	8.5 c	19.4 cd	2.9 c	6.1 d	10.8 e	22.2 de	4.4 d	4.3 c
Daminozide	9.4 a-c	22.4 a	10.5 a-c	30.3 a-c	12.4 b-d	25.3 ab	10.5 b-d	10.3 a
Paclobutrazol	8.7 bc	19.9 bc	13.5 ab	17.9 cd	12.1 cd	24.5 bc	18.3 ab	11.3 a
LSD	1.0	1.4	8.9	13.9	1.2	1.6	9.8	4.6
F test	*	***	*	***	***	***	**	*

<sup>z</sup>Mean separation by protected LSD,  $P \leq 0.05$ .

<sup>y</sup>Moisture stress conditioning.

ns, \*, \*\*, \*\*\*Nonsignificant or significant at  $P \leq 0.05, 0.01, \text{ or } 0.001$ , respectively.

reduced by low N and MSC relative to controls at 4 WAT (Table 4). At 6 WAT, ebb-and-flow irrigation had the greatest effect on growth; both height and width were greater than those of the controls. Although height was not affected by the other conditioning treatments, width was reduced by brushing (4 WAT only), daminozide, or paclobutrazol at 4 and 6 WAT. High N increased plant width at 4 and 6 WAT. Spider mite populations were not affected by conditioning treatments at 2 WAT (data not presented), but were significantly reduced by high N (4 WAT), low N (6 WAT), ebb-and-flow (4 and 6 WAT), brushing (4 and 6 WAT), or paclobutrazol (4 WAT). Relative to controls (9.7 scars/plant), thrips injury was increased by ebb-and-flow (34.1 scars/plant) at 2 WAT ( $P \leq 0.05$ ), but the effect did not persist. At 6 WAT, thrips injury was reduced by low N, MSC, or brushing.

**Effect of conditioning treatments on aphid populations.** The growth effects of the conditioning treatments applied in the aphid-inoculated greenhouse were not significantly different from those applied in the mite-infested greenhouse (data not presented). Aphid populations were negligible on columbine (data not presented), very low on New Guinea impatiens, high on marigold, and relatively low on ageratum (Table 5). High N or ebb-and-flow irrigation increased aphid counts on New Guinea impatiens at 6 WAT. Populations were reduced by low N (4 and 6 WAT) and ebb-and-flow irrigation (4 WAT) on marigolds, whereas control plants and those treated with high N or MSC had the highest populations. Aphids were slow to establish on ageratum, but high N increased the populations at 6 WAT relative to all other treatments.

## Discussion

Ebb-and-flow or high N tended to increase plant size, especially for ageratum and New Guinea impatiens. In contrast, low N, MSC, and brushing tended to reduce plant growth, although columbine was the least affected. Brushing caused minor leaf damage and significant flower damage on New Guinea impatiens. Brushing also caused minor leaf damage on ageratum, but did not significantly reduce plant height. The PGRs, daminozide and paclobutrazol, had moderate, generally nonpersistent effects on plant growth in the greenhouse at the rates used in these experiments.

Insect pest populations have been related to leaf soluble nitrogen levels, which are affected by fertilization and plant stress (Larsson, 1989). In our study, fertilization rate had little effect on spider mite or thrips populations, but consistently affected aphid populations. New Guinea impatiens, marigolds, and ageratum plants subjected to low N consistently had lower levels of aphids than those subjected to high N. This suggests that aphids, which are phloem-feeding insects, are more responsive to overall plant nutritional status than are two-spotted spider mites or thrips, which feed on cell contents. Mites and thrips are able to select nutritionally acceptable leaves from the plant. The short period of these experiments (6 weeks)

Table 3. Effect of conditioning treatments on height and width of 'Little Devil' marigold, the number of two-spotted spider mites per plant, and the number of western flower thrips feeding scars per plant at 4 and 6 weeks after treatment (WAT) in the greenhouse in 1995.

Treatment	4 WAT				6 WAT			
	Height (cm)	Width (cm)	Spider mites	Thrips scars	Height (cm)	Width (cm)	Spider mites	Thrips scars
Control	12.3 ab <sup>2</sup>	19.8 ab	5.5	3.7 b-d	14.0 ab	21.0 a	38.7	47.8 a
Low N	10.2 d	14.2 e	5.7	1.1 cd	10.4 d	16.6 e	34.0	14.1 bc
High N	11.8 a-c	20.0 a	2.5	2.4 cd	13.0 a-c	20.3 ab	28.6	36.6 ab
Ebb/flow	12.9 a	19.2 a-c	4.7	10.5 a	14.2 a	19.4 bc	32.3	32.9 a-c
MSC <sup>3</sup>	11.7 a-c	18.8 bc	2.9	5.9 b	13.3 a-c	19.4 bc	22.9	54.7 a
Brushed	10.5 cd	17.6 d	1.1	0.7 d	12.1 cd	17.3 de	10.3	9.4 c
Daminozide	11.1 b-d	18.8 a-c	6.9	4.1 bc	12.4 bc	19.7 a-c	44.5	49.1 a
Paclobutrazol	10.9 cd	18.3 cd	5.6	3.0 b-d	12.5 a-c	18.6 cd	35.9	48.7 a
LSD	1.3	1.2	---	3.1	1.8	1.6	---	25.6
F test	**	***	NS	***	**	***	NS	**

<sup>2</sup>Mean separation by protected LSD,  $P \leq 0.05$ .

<sup>3</sup>Moisture stress conditioning.

ns, \*, \*\*, \*\*\*Nonsignificant or significant at  $P \leq 0.05$ , 0.01, or 0.001, respectively.

Table 4. Effect of conditioning treatments on height and width of 'Blue Puffs' ageratum, the number of two-spotted spider mites per plant, and the number of western flower thrips feeding scars per plant at 4 and 6 weeks after treatment (WAT) in the greenhouse in 1995.

Treatment	4 WAT				6 WAT			
	Height (cm)	Width (cm)	Spider mites	Thrips scars	Height (cm)	Width (cm)	Spider mites	Thrips scars
Control	13.8 ab <sup>2</sup>	25.9 b	24.2 ab	6.7	16.0 bc	28.6 c	40.3 a	15.3 a
Low N	11.3 d	18.5 e	17.8 a-c	4.6	13.5 c	21.6 e	22.7 b-d	4.6 c
High N	13.9 ab	29.7 a	13.3 cd	6.9	18.6 ab	35.3 a	29.5 a-c	12.9 ab
Ebb/flow	14.9 a	22.8 cd	5.7 d	4.3	19.0 a	31.6 b	14.7 cd	8.9 a-c
MSC <sup>3</sup>	11.4 cd	24.0 c	24.6 a	10.5	14.2 c	27.3 cd	34.6 ab	8.7 bc
Brushed	12.9 b	23.9 c	8.2 d	2.9	14.8 c	26.9 cd	10.5 d	3.3 c
Daminozide	12.6 b-d	22.2 d	16.3 bc	12.7	13.9 c	25.5 d	28.4 a-c	11.6 ab
Paclobutrazol	12.9 bc	23.0 cd	12.9 cd	12.1	14.2 c	26.1 d	26.2 a-d	11.3 ab
LSD	1.5	1.5	8.0	---	2.6	2.0	17.2	6.6
F test	***	***	***	NS	***	***	*	**

<sup>2</sup>Mean separation by protected LSD,  $P \leq 0.05$ .

<sup>3</sup>Moisture stress conditioning.

ns, \*, \*\*, \*\*\*Nonsignificant or significant at  $P \leq 0.05$ , 0.01, or 0.001, respectively.

Table 5. Effect of conditioning treatments on the number of green peach aphids per plant on three bedding plants at 4 and 6 weeks after treatment (WAT) in the greenhouse in 1995. Aphids did not become established on columbine.

Treatment	New Guinea impatiens					
	Marigold		Ageratum		Ageratum	
	4 WAT	6 WAT	4 WAT	6 WAT	4 WAT	6 WAT
Control	0.5	1.5 b <sup>2</sup>	231 a-c	295 bc	10.5	14.9 b-d
Low N	0.2	0.7 b	58 d	118 d	4.1	4.7 d
High N	1.4	3.9 a	329 a	470 a	10.7	41.3 a
Ebb/flow	0.5	1.3 b	100 d	162 cd	9.3	15.9 b-d
MSC <sup>3</sup>	0.4	3.8 a	292 ab	450 ab	4.4	19.3 bc
Brushed	0.9	1.4 b	125 cd	184 cd	9.1	18.6 bc
Daminozide	1.9	1.8 b	170 b-d	296 bc	9.1	22.4 b
Paclobutrazol	0.1	1.5 b	150 cd	290 c	11.3	8.2 cd
LSD	---	1.9	127	159	---	11.8
F test	NS	**	***	***	NS	*

<sup>2</sup>Mean separation by protected LSD,  $P \leq 0.05$ .

<sup>3</sup>Moisture stress conditioning.

ns, \*, \*\*, \*\*\*Nonsignificant or significant at  $P \leq 0.05$ , 0.01, or 0.001, respectively.

did not appear to deplete the nutritional reserves of the plants.

Irrigation practices had little effect on insect and mite populations. Spider mite and thrips populations on ebb-and-flow or MSC plants generally did not differ from those on the controls with two exceptions. Spider mite populations on ebb-and-flow irrigated ageratum were less than those on control plants at 4 and 6 WAT (Table 4), and the thrips population on MSC-treated New Guinea impatiens at 4 WAT was higher than that on controls (Table

3). Drought or waterlogging conditions or other stresses that promote leaf senescence also increase aphid populations by increasing the mobilization of nitrogen and other plant constituents (van Emden, 1969; White, 1984). Apparently, the MSC treatment was not severe enough to stimulate the production of feeding enhancers.

Brushing was the only treatment that had a consistent impact on insect and mite populations. Two-spotted spider mite populations on brushed plants were significantly lower than

those on controls for most sampling periods, and were consistently lower than those on plants in most other conditioning treatments. Brushing was equally effective in reducing the feeding damage of thrips, i.e., the fewest feeding scars were counted on brushed plants at most of the sample periods on the three bedding plants on which thrips became established. These results are consistent with those found on greenhouse-grown vegetable transplants (Latimer and Oetting, 1994). Brushing or wounding of the leaves elicits the production of phytochemicals, some of which induce insect resistance in as little as 24 h (Roseland and Grosz, 1997; Smith, 1988). Thrips and mites either feed on the underside of the leaf or are present in hard-to-reach places, such as within the shoot tip. Physically removing these pests by brushing the tops of the plants would be difficult.

On the other hand, aphids are more common on the upper leaves, where they could be removed physically or dislodged. However, aphid populations on brushed plants were not consistently lower than on plants of other treatments. Bailey et al. (1995), who simulated physical distribution of aphids (*Rhopalosiphum padi* L.) by raking the tops of infested oats (*Avena sativa* L.) with a two-pronged hand cultivator, found that the treatment increased the total distance of aphid dispersal but did not affect the population level. Our brushing treatment may have redistributed the aphids within the treated plants (each plant species was treated separately), but did not affect population increase. Furthermore, stressing leaves increases production of soluble N and soluble carbohydrates, which may enhance aphid feeding (van Emden, 1969; White, 1984).

Contrary to previous reports of PGRs affecting insect and mite pest populations (Biggs and Hagley, 1988; Smith, 1969; Worthing, 1969), growth regulators generally had no effect on insect or mite populations in our study.

In summary, of the growth regulation treatments tested, mechanical conditioning via brushing had the greatest impact in reducing spider mite and thrips populations. The use of brushing for plant growth regulation and conditioning of greenhouse-grown bedding plants could provide the added benefit of reducing pest pressure.

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