# Effect of Plant Growth Retardants on Stem Elongation of Hibiscus Species

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**Additional index words.** chlormequat chloride, daminozide, paclobutrazol, uniconazole, *Hibiscus coccineus, Hibiscus radiatus, Hibiscus trionum*

**Summary.** One-time spray applications [about 6 mL (0.2 fl oz)] of chlormequat chloride [1000 or 2000 mg·L$^{-1}$ (ppm)], daminozide (2500 or 5000 mg·L$^{-1}$), paclobutrazol (20 or 40 mg·L$^{-1}$) and uniconazole (5 or 10 mg·L$^{-1}$) varied in efficacy in reducing *Hibiscus coccineus* (Medic.) Walt., *H. radiatus* Cav., and *H. trionum* L. (flower-of-an-hour) stem elongation. Chlormequat chloride inhibited stem elongation of all species, with a 2000 mg·L$^{-1}$ application reducing stem length of *H. coccineus*, *H. radiatus*, and *H. trionum* by 87%, 42%, and 52%, respectively, compared to untreated plants, 28 d after application. Paclobutrazol also inhibited stem elongation of all species. Uniconazole reduced stem elongation of *H. coccineus* and *H. radiatus*, but not *H. trionum*. Daminozide applied at 5000 mg·L$^{-1}$ reduced *H. radiatus* stem elongation only. Growth retardants examined in this study did not delay flowering of *H. trionum*, the only species that flowered during the experiment. (Chemical names used: ancymidol (α-cyclopropyl-α-(4-methoxyphenol)-5-pyrimidinemethonol), chlormequat chloride(2-chloroethyltrimethylammonium chloride), paclobutrazol ((+)-(R*,R*)-beta((4-chlorophenyl)methyl)-alpha-(1,1-dimethyl)-1H-1,2,4-triazol-1-ethanol), daminozide ([butanedioic acid mono(2,2-dimethylhydrazide)], uniconazol-P ((E)-(+)-(s)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)pent-1-ene-3-ol)).

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Plant growth retardants (PGRs) are commonly used to inhibit stem elongation of many ornamental plants. PGRs act by inhibiting cell division in the subapical meristem of the shoot (Gianfaga, 1995; Sachs et al., 1960), or by inhibiting cell elongation (Grossman, 1992). The type of growth inhibition is, in part, dependent on the concentration of growth retardant applied (Grossman, 1988) and species. At low concentrations, growth retardants typically reduce cell elongation, whereas at high concentrations the reduction is increasingly due to a reduced cell division (Grossman, 1992). Although traditional plant breeding and advances in greenhouse environment control have reduced the amount of growth retardants applied to many crops, growth retardants are still commercially used to inhibit stem elongation, enhance foliage color and decrease time to flower (Dole and Wilkins, 1999).

The mode of action of plant growth retarding chemicals varies. Ancymidol (A-Rest; SePRO Corp., Carmel, Ind.), paclobutrazol (Bonzi; Uniroyal Chemical Co., Middlebury, Conn.), and uniconazole (Sumagic; Valent USA Corp., Walnut Creek, Calif.) reduce stem elongation by inhibiting the kaurene oxidation sequence of reactions in the gibberellin biosynthesis pathway (Gianfaga, 1995). Daminozide (B-Nine; Uniroyal Chemical Co.) is reported to act by inhibiting translocation of gibberellins (Menhennet, 1980) and by increasing gibberellin degradation (Takeno et al., 1981). Chlormequat chloride (CCC) (Cycocel; Olympic Horticultural Products Co., Mainland, Pa.) reduces elongation by interfering with the biosynthetic steps directly before ent-kaurene, a precursor in the gibberellin biosynthesis pathway (Rademacher, 1991).

Plant growth retardants are currently used to reduce stem elongation of commercially available hibiscus species (*Hibiscus* L.) (Dole and Wilkins, 1999). CCC and ancymidol reduce *Hibiscus rosa-sinensis* L. (chinese hibiscus) stem elongation (Shanks, 1972). Foliar application of CCC (1000 mg·L$^{-1}$) reduced shoot length of cultivars *H. rosa-sinensis* 'Brilliantissima' and 'Kona' by 51% and 69%, respectively (Shanks, 1972). CCC application to *H. rosa-sinensis* also results in darker green leaf color (Wilkins and Kotecki, 1982). Soaking *H. rosa-sinensis* 'Seminole Pink' unrooted cuttings in 25 mg·L$^{-1}$ paclobutrazol or uniconazole for 5 s reduced plant height 25% and 75%, respectively, after 24 weeks compared to untreated plants (Wang and Gregg, 1991). CCC also reduced height of *H. syriacus* L. (rose-of-sharon), *H. mutabilis* L. (cotton rose), and *H. sabdariffa* L. (roselle) (Bose et al., 1968). Spray applications of either 1000 mg·L$^{-1}$ CCC or 15 mg·L$^{-1}$ uniconazole reduced *H. moscheutos* L. (common rose mallow) 'Disco Belle Mixed' stem elongation, although multiple applications appeared to be necessary to produce a commercially acceptable crop (Wang et al., 1998).

We examined numerous hibiscus species for potential commercial use (Warner and Erwin, 2001). Of these, *H. radiatus* and *H. trionum* were identified as being potentially commercially important. Although *H. coccineus* did not flower in the previous study, plants observed in flower (R. Warner, personal observation) suggest this species may also have commercial potential. However, height of each species at flowering was excessive [>20 cm (8 inches)] in a 10-cm (4-inch) pot. Therefore, plant height must be reduced in order to make shipping economically feasible and to produce an attractive plant for the consumer. The objective of this experiment was to determine the efficacy of four PGRs in inhibiting stem elongation of the potential new commercial hibiscus species, *H. coccineus*, *H. radiatus*, and *H. trionum*.

## Materials and methods

On 7 and 23 Mar. 1998, *H. coccineus*, *H. radiatus*, and *H. trionum* seeds were soaked for 12 h in about 75 °C (167 °F) water that was allowed to cool to about 22 °C (72 °F). Seeds were then sown in 128-cell trays in a soilless medium (Germination Mix; Strong-Lite Horticultural Products, Pine Bluff, Ark.), covered with vermiculite (Premium Grade Medium Vermiculite; Strong-Lite Horticultural Products) to a depth about 1.5 times the diameter of the seed and placed under intermittent mist (6 s of mist every 10 min, from 0700 to 1900 HR)

**Table 1. Effect of plant growth retardant spray application on increase in plant height from day zero to day 14 (Inc 1), day 14 to day 28 (Inc 2), day zero to day 28 (Inc total), and the per cent reduction (%) in height compared to untreated plants of three hibiscus species.**

| Treatment | Inc 1 | | Inc 2 | | Inc total | |
|---|---|---|---|---|---|---|
| | | | Concn | | | |
| (mg·L$^{-1}$) | (mm)[z] | (%) | (mm) | (%) | (mm) | (%) |
| *Hibiscus coccineus* | | | | | | |
| Untreated | 31.3b[y] | 0.0 | 86.9c | 0.0 | 118.2d | 0.0 |
| CCC[x], 1000 | 5.9 | 81.1 | 17.8 | 79.5 | 23.7 | 79.9 |
| 2000 | 5.2a | 81.2 | 9.1a | 89.5 | 14.8a | 87.5 |
| Linear | *** | | *** | | *** | |
| Quadratic | *** | | *** | | *** | |
| Daminozide, 2500 | 27.1 | 13.4 | 64.5 | 25.8 | 91.6 | 22.5 |
| 5000 | 31.2b | 0.3 | 73.7bc | 15.2 | 104.9cd | 11.2 |
| Linear | NS | | N | | NS | |
| Quadratic | NS | | NS | | NS | |
| Paclobutrazol, 20 | 15.1 | 48.2 | 89.8 | –3.3 | 104.9 | 11.2 |
| 40 | 9.8a | 68.7 | 54.0b | 37.9 | 63.8b | 46.1 |
| Linear | *** | | NS | | * | |
| Quadratic | *** | | NS | | * | |
| Uniconazole, 5 | 18.0 | 42.5 | 76.6 | 11.8 | 94.6 | 20.0 |
| 10 | 11.8a | 62.3 | 62.5bc | 28.1 | 74.3bc | 38.1 |
| Linear | *** | | NS | | * | |
| Quadratic | *** | | NS | | NS | |
| *Hibiscus radiatus* | | | | | | |
| Untreated | 61.1c | 0.0 | 173.1b | 0.0 | 234.2c | 0.0 |
| CCC, 1000 | 26.2 | 57.1 | 123.5 | 28.6 | 149.7 | 36.1 |
| 2000 | 20.6a | 66.3 | 114.1a | 34.1 | 134.7a | 42.5 |
| Linear | *** | | *** | | *** | |
| Quadratic | *** | | *** | | *** | |
| Daminozide, 2500 | 49.3 | 19.3 | 151.1 | 12.7 | 200.4 | 14.4 |
| 5000 | 57.1c | 6.5 | 121.9a | 29.6 | 179.0b | 23.6 |
| Linear | NS | | *** | | *** | |
| Quadratic | NS | | *** | | *** | |
| Paclobutrazol, 20 | 57.4 | 6.1 | 153.3 | 11.4 | 210.7 | 10.0 |
| 40 | 39.5b | 35.3 | 140.4a | 18.9 | 164.6ab | 29.7 |
| Linear | *** | | * | | *** | |
| Quadratic | *** | | NS | | *** | |
| Uniconazole, 5 | 49.5 | 19.0 | 135.4 | 21.8 | 184.9 | 21.1 |
| 10 | 38.8b | 36.5 | 145.4a | 16.0 | 184.2b | 21.3 |
| Linear | NS | | *** | | *** | |
| Quadratic | ** | | *** | | *** | |
| *Hibiscus trionum* | | | | | | |
| Untreated | 133.3bc | 0.0 | 302.6b | 0.0 | 435.9bc | 0.0 |
| CCC, 1000 | 70.1 | 47.4 | 169.0 | 44.4 | 239.1 | 45.1 |
| 2000 | 60.6a | 54.5 | 148.9a | 51.8 | 209.5a | 51.9 |
| Linear | *** | | *** | | *** | |
| Quadratic | *** | | *** | | *** | |
| Daminozide, 2500 | 134.4 | 0.8 | 284.8 | 5.9 | 419.2 | 3.8 |
| 5000 | 151.5c | –13.7 | 328.9b | –8.7 | 480.4c | –10.2 |
| Linear | NS | | NS | | NS | |
| Quadratic | NS | | * | | NS | |
| Paclobutrazol, 20 | 98.8 | 25.9 | 249.7 | 17.5 | 348.5 | 21.1 |
| 40 | 74.8a | 43.9 | 195.0a | 35.6 | 269.8a | 38.8 |
| Linear | *** | | *** | | *** | |
| Quadratic | *** | | *** | | *** | |
| Uniconazole, 5 | 113.3 | 15.0 | 283.8 | 6.2 | 397.1 | 8.9 |
| 10 | 88.4b | 33.7 | 260.6b | 13.9 | 349.0b | 20.0 |
| Linear | NS | | NS | | NS | |
| Quadratic | ** | | NS | | NS | |

[z]1.0 mm = 0.039 inches.
[y]Lowercase letters represent means separation test (Tukey's HSD, $P = 0.05$.) comparing growth retardant at the highest rate to untreated plants within species and time point.
[x]CCC = chlormequat chloride.
[NS,*,**,***]Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

at 25 ± 1 °C (77 ± 2 °F; 24-h mean ± SE) air temperature. Seedlings were transplanted into 10-cm pots in a soilless medium (Universal Mix, Strong-Lite Horticultural Products) when cotyledons were parallel to the media surface, and placed in a greenhouse maintained at 20 ± 1 °C (68 ± 2 °F) air temperature under ambient light conditions for 3 d (St. Paul, Minn.). Transplanting dates were 18 Mar. and 3 Apr. 1998 for *H. radiatus* and *H. trionum*, and 25 Mar. and 10 Apr. 1998 for *H. coccineus*. Plants were then grown at 22 ± 2 °C (72 ± 3 °F) under ambient light plus night interruption lighting [2 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (10 f.-c.)], provided using incandescent lamps (Sylvania Directlite 100W; GTE Products Corp., Salem, Mass.), from 2200 to 0200 HR daily. Treatments were initiated when the second true leaf unfolded (i.e., was parallel to the media surface).

There were nine growth retardant treatments established in a completely randomized statistical design with two replications per treatment and 10 plants per replication. Treatments consisted of a single spray application of about 6 mL (0.2 fl.) of 2500 or 5000 $mg \cdot L^{-1}$ daminozide, 10 or 20 $mg \cdot L^{-1}$ paclobutrazol, 1000 or 2000 $mg \cdot L^{-1}$ chlormequat chloride, 5 or 10 $mg \cdot L^{-1}$ uniconazole or distilled water alone. Seedlings were sprayed until the entire seedling surface was covered.

Data were collected on leaf number and plant height (distance from the media surface to the apical meristem) on day 0, 14 and 28 after spray application. Change in height was calculated. Date of first flower opening was recorded for *H. trionum* only, as this was the only species to flower during the experiment.

## Results and discussion

**RATE OF DEVELOPMENT.** Leaf unfolding rate of all three species did not vary between untreated plants, and plants in any growth retardant treatment. *Hibiscus coccineus*, *H. radiatus*, and *H. trionum* plants had 4, 6, and 6 leaves, respectively, 14 d after treatment, and 8, 10, and 9 leaves, respectively, 28 d after treatment. None of the plant growth retardants at any concentration studied delayed date of first flower opening of *H. trionum*, which flowered 26 ± 1 d after treatment.

**STEM ELONGATION.** Species and growth retardant applied interacted to affect stem elongation of *H. coccineus*, *H. radiatus*, and *H. trionum* (Table 1). CCC applied at 1000 or 2000 $mg \cdot L^{-1}$ effectively inhibited stem elongation of all species at all time points (Table 1). This is consistent with previous reports on the efficacy of CCC on other hibiscus species (Shanks, 1972; Wang et al., 1998). When applied at 1000 and 2000 $mg \cdot L^{-1}$, CCC resulted in excessive inhibition of *H. coccineus* stem elongation, reducing elongation by 80% and 88%, respectively, 28 d after application. Therefore, CCC concentrations less than 1000 $mg \cdot L^{-1}$ may be preferred for commercial production of *H. coccineus*, especially in northern climates.

*Hibiscus coccineus* plants sprayed with 2000 $mg \cdot L^{-1}$ CCC exhibited foliar chlorosis about 3 to 5 d after application. After 28 d, however, leaf color of previously chlorotic leaves was similar to leaves sprayed with water only. Tolbert (1960) reported an increase in chlorophyll content of wheat (*Triticum aestivum* L.) leaves after CCC application. The leaf chlorosis observed on *H. coccineus* after CCC application is consistent with results observed on other species, such as geranium (*Pelargonium ×hortorum* Bailey) (Fonteno, 1992). This chlorosis is apparently due to chloroplast breakdown in expanding leaves (Barrett and Holcomb, 1993; Styer and Koranski, 1998). Cathey (1975) observed that this chlorosis is temporary in a wide range of bedding and vegetable plants. It appears that this temporary damage to chloroplasts is eventually compensated for by the chlormequat chloride-induced increase in leaf chlorophyll content.

In contrast to CCC, daminozide inhibited stem elongation of *H. radiatus*, but did not impact stem elongation of *H. coccineus* or *H. trionum* 28 d after application (Table 1). However, *H. coccineus* plants sprayed with daminozide exhibited reduced, though not statistically significant, stem elongation compared to control plants. Therefore, multiple applications or higher concentrations may be necessary to significantly reduce stem length using daminozide.

Paclobutrazol inhibited stem elongation of *H. radiatus* and *H. trionum*, but only marginally inhibited *H. coccineus* stem elongation 28 d after application (Table 1). Stem elongation of both *H. coccineus* and *H. radiatus* was strongly inhibited by paclobutrazol 14 d after application, but was similar to untreated plants from 14 to 28 d after application (Table 1). Therefore, multiple applications may be necessary for long-term height control.

Uniconazole inhibited stem elongation of *H. radiatus*, but did not impact *H. trionum* stem elongation and only marginally impacted stem elongation of *H. coccineus* 28 d after application (Table 1). However, uniconazole inhibited stem elongation of *H. trionum* 14 d after application (Table 1). Therefore, multiple applications, or higher concentrations, of uniconazole may be necessary for adequate height control of both *H. coccineus* and *H. trionum*.

At the highest concentrations applied, CCC (2000 $mg \cdot L^{-1}$), paclobutrazol (40 $mg \cdot L^{-1}$) and uniconazole (10 $mg \cdot L^{-1}$) were equally effective (based on means separation test) in inhibiting stem elongation of *H. coccineus* 14 d after application (Table 1). However, by 28 d after application CCC applied at 2000 $mg \cdot L^{-1}$ was the most effective in inhibiting *H. coccineus* stem elongation (Table 1). CCC applied at 2000 $mg \cdot L^{-1}$ and paclobutrazol applied at 40 $mg \cdot L^{-1}$ were equally effective in inhibiting *H. radiatus* stem elongation 28 d after application. Daminozide applied at 5000 $mg \cdot L^{-1}$ and uniconazole applied at 10 $mg \cdot L^{-1}$ also inhibited stem elongation of *H. radiatus* 28 d after application, but were less effective than CCC and paclobutrazol. Similar to *H. radiatus*, CCC applied at 2000 $mg \cdot L^{-1}$ and paclobutrazol applied at 40 $mg \cdot L^{-1}$ were equally effective in inhibiting *H. trionum* stem elongation 28 d after application.

This experiment employed a long photoperiod provided using low intensity incandescent lights in the middle of the night. It should be noted that stem elongation is promoted under lighting regimes with a low ratio of red (R) to far-red (FR) light (R:FR) (Smith, 1994). The R:FR of the incandescent lamps employed in this experiment was 0.73. Low R:FR (i.e., <1) can reduce growth regulator efficacy through promotion of stem elongation. Therefore, using natural photoperiod or using a lamp type with higher R:FR to provide the night-interruption would likely have resulted in less stem elongation.

PGRs successfully inhibited stem elongation of the three Hibiscus spp. This information, combined with previously identified impacts of photoperiod and temperature on floral initiation of *H. radiatus* and *H. trionum* (Warner and Erwin, 2001) provide a basis for developing production schedules for these species. Further work is needed to understand floral inductive requirements of *H. coccineus.*

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# Yield and Quality of Machine Harvested Red Chile Peppers


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**ADDITIONAL INDEX WORDS.** ***Capsicum annuum*, mechanical harvest, ethephon, paprika, vegetable crops.**



**SUMMARY. In the southwestern U.S. growing region, which includes southern New Mexico, west Texas, and southeastern Arizona, mechanical harvest of chile peppers (*Capsicum annuum*) is increasing because of the high cost of hand labor. Mechanical harvesters have been developed, but there is limited information on the performance of chile cultivars when machine harvested. Four red chile pepper cultivars (New Mexico 6-4, Sonora, B-18, and B-58) were grown in a farmer's field near Las Cruces, N.M., and harvested in October 2000 using a double-helix-type harvester. Ethephon was applied 3 weeks before harvest at 1.5 pt/acre (1.75 L·ha$^{-1}$) to promote uniform ripening. Ethephon caused fruit of 'B-18' and 'B-58' to drop before harvest, thereby affecting yield results. Treatment with ethylene-releasing compounds is not recommended for these cultivars. 'Sonora' and 'New Mexico 6-4'**



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