Growth and Flowering of Greenhouse-grown Tomato Transplants in Response to Uniconazole

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KEYWORDS. **controlled-environment agriculture, growth retardant, plant growth regulator, *Solanum lycopersicum*, vegetable**

ABSTRACT. **Uniconazole is approved for use as a chemical option on tomato (*Solanum lycopersicum*) for height control, but research is limited. In this study, 12 tomato cultivars were chosen with three cultivars each of indeterminate, determinate, heirloom, and container types. Plants were sprayed with a one-time application of 0, 2.5, 5, 7.5, or 10 mg·L^{-1} of uniconazole during the two- to four-leaf stage to evaluate height control. Results indicated no significant difference between concentrations for plant height, stem caliper, and plant dry weight. The greatest soil plant analysis development (SPAD) values were observed with the 10-mg·L^{-1} treatment. Flower response in 'Brandywine' to a single application of 0, 2.5, or 5 mg·L^{-1} of uniconazole demonstrated a greater number of flowers per plant at 5 mg·L^{-1}, whereas no significant difference was shown for the number of flower clusters or the number of flowers per cluster at other treatment levels. Using 2.5 mg·L^{-1} uniconazole was effective for reducing plant height across all cultivars of greenhouse-grown tomato seedlings compared with the control, whereas addition of 5 mg·L^{-1} was shown to increase the number of flowers in the heirloom cultivar Brandywine.**

In Apr 2009, uniconazole-P [(E)-1-(4-chlorophenyl)-4, -4-dimethyl-2-(1,2,4-trizol-1-yl) pentin-3-ol] acquired minor use labeling under the name Sumagic® (Valent BioSciences, Libertyville, IL, USA) and is now available for vegetable crops, including tomato (*Solanum lycopersicum*), pepper (*Capsicum annuum*), and eggplant (*Solanum melongena*). Uniconazole is the first and only plant growth regulator approved that can be used legally on greenhouse-grown fruiting vegetable crops (Runkle 2009). According to the supplement label, the total amount of uniconazole applied to vegetable transplants may not exceed a single spray application of 10 mg·L^{-1} at 2 qt/100 ft^2, and the final application may not occur later than 14 d after the two- to four-leaf stage (Runkle 2009).

The mode of action of uniconazole as a gibberellin biosynthesis inhibitor limits stem elongation between internodes and overall shoot growth (Rademacher 2000). The triazole-type chemical is translocated acropetally via the xylem of plants and is absorbed by the leaves, but is not transported readily out of the leaves to other parts of the plant (Whipker and Latimer 2013). Commercially, the primary purpose of a triazole-type growth regulator is to retard internode elongation and reduce overall stature (Bailey and Miller 1989). With reduced stature, other morphological changes can result, such as reductions in leaf area, dry weight, and number of leaves; increases and decreases in stem diameter; and increased formation of lateral shoots (Wang and Gregg 1989).

Vegetable transplants produced in commercial high-density trays can quickly outgrow their optimal size (Agehara and Leskovar 2015). Overmature transplants generally have thinner, elongated stems and excessive leaf growth with limited root growth as a result of the small rooting volume of high-density plug trays (Marr and Jirak 1990; Nishizawa and Saito 1998). In addition, a limited root-to-shoot ratio can create an imbalance between transpiration demand and water uptake capacity resulting in severe transplant shock and poor stand establishment (Agehara and Leskovar 2015). Producers of high-quality plants realize the need for an efficient and economic production regime to maximize productivity per unit area, make effective use of transportation capacity, and minimize transportation damage loss while fulfilling market demand. The application of low-dose plant growth regulators can provide an economical way to limit growth and achieve those goals (Sparké et al. 2021; Whipker and Latimer 2013).

Research on tomato transplants is abundant because this vegetable is perhaps the most widely grown from transplants (Vavrina 2002). An ideal transplant is young (6–8 inches tall with a stem ∼0.2–0.4 inch in diameter, with no fruit, flowers, or flower buds), does not exhibit rapid vegetative growth, and is slightly hardened off at transplanting time (Kelley and Boyhan 2017). Commercial production goals are to produce transplants of a size that can be handled by mechanical transplanters and transplanting crews without damage and are wind tolerant (Johnson 2020).

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Units To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
28.3495	oz	g	0.0353
1	ppm	mg·L^{-1}	1
0.1019	qt/100 ft^2	L·m^{-2}	9.8170
(°F − 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

Tomato plants are sensitive to uniconazole, and responses can vary depending on application timing, rate, and cultivar (Dunlap et al. 1991; Runkle and Blanchard 2012). Studies conducted at the University of Guelph, (Ridgetown, ON, Canada) demonstrated late applications (after 21 d postseeding) of uniconazole were less effective than higher rates, and minor differences occurred between 2.5- and 5.0-mg·L^{-1} rates (Zandastra et al. 2007). A study at the University of Florida (Gainesville, FL, USA) evaluated eight different tomato cultivars and their response to an application of uniconazole 1 d after seeding, with rates of 0.25 to 1 mg·L^{-1} being sufficient to reduce stem elongation, except for 'Supersweet 100', which required four times as much to achieve the desired height control (Anderson et al. 2016). In a separate study at the University of Florida, 'Early Girl', 'Big Boy', and 'Champion II' seedlings with application rates of 0, 2.5, 5 or 10 mg·L^{-1} uniconazole at 14, 21, and 28 d after sowing responded similarly in height reduction compared with the control plants for most cultivars and produced plants of comparable size at the market-ready stage (Schnelle 2009). Findings in a greenhouse trial at Michigan State University (East Lansing, MI, USA) concluded that rates of 1.25 to 5 mg·L^{-1} at seed sowing suppressed stem elongation of 'Beefmaster' tomato for 4 weeks and were more effective than 1.25 or 2.5 mg·L^{-1} applied at seeding and again at the two-leaf stage (Runkle and Blanchard 2012). According to Schnelle and Ruberg (2010) and Villavicencio et al. (2015), more cultivars of tomato need to be studied for conclusive application rates to be determined. The objective of this study was to evaluate 12 cultivars and four types of tomatoes to a range of label rates of uniconazole to control plant growth and to determine whether flowering is increased in 'Brandywine'.

Materials and methods

Expt. 1. A greenhouse experiment was conducted at the Horticulture and Landscape Architecture research greenhouses at Oklahoma State University (Stillwater, OK, USA). Seeds of determinate ('Big Boy', 'Beefsteak', and 'Jet Star'), indeterminate ('Mountain Fresh', 'Mountain Pride', and 'Roma'), heirloom ('Brandywine', 'Mortgage Lifter', and 'Cherokee Purple'), and container ('Patio', 'Bush Early Girl', and 'Better Bush') tomato plants were purchased from Totally Tomatoes (Randolph, WI, USA). Popular cultivars were chosen to represent different growth habit types, and all are considered slicers except 'Roma', which is a processing type, and 'Patio', which is a medium tomato. Two seeds per cultivar were planted into standard inserts [2 1/3 × 2 1/2 × 2 1/3 inches (606; American Plant Products, Oklahoma City, OK, USA)] filled with soilless medium (Metro-Mix 902; Sun Gro Horticulture, Bellevue, WA, USA) on 13 Jan 2019 and 22 Jan 2021, and later thinned to one seedling per cell. Plants were placed in a heated greenhouse with mean temperatures of 23.9 ± 1.1 and 24.8 ± 3.9 °C under natural irradiance and an average daily light integral of 14.0 ± 10.6 and 16.1 ± 9.4 mol·m^{-2}·d^{-1} for 2019 and 2021, respectively. Plants were watered as needed and fertigated with each watering after planting with 20N–4.4P–16.6K water-soluble fertilizer (Jack's Professional® General Purpose; J.R. Peters Inc., Allentown, PA, USA) at a rate of 200 mg·L^{-1} nitrogen. Treatments of 2.5, 5, 7.5, or 10 mg·L^{-1} uniconazole plus a control (0 mg·L^{-1}) were applied 28 d after planting to leaves and stems after all seedlings reached the two- to four-leaf stage. A spray volume of 20 mL was applied to each insert using a spray bottle (Great Value; Wal-Mart, Bentonville, AR, USA) without restricting soil coverage until point of glisten. Data were collected 19 Mar 2019 [37 d after treatment (DAT)] and 20 Mar 2021 (29 DAT) on plant height (from top of insert), soil plant analysis development [SPAD; average of six leaves from the middle of the leaf (Konica–Minolta, Inc., Osaka, Japan)], stem caliper (from top of insert), and shoot dry weight (cut at soil surface) that was dried at 80 °C for 4 d.

Expt. 2. Seeds of 'Brandywine' tomato, a popular heirloom cultivar that does not produce a high fruit yield and appeared to have increased flowering from Expt. 1, were purchased from Totally Tomatoes on 1 Aug 2019. Seeds were planted 5 Aug 2019 in tray inserts [5 × 12 1/3 × 2 1/3 inches (801, American Plant Products)] filled with soilless medium (Fafard® Germinating Mix, Sun Gro Horticulture) and placed indoors under fluorescent grow lights (Harris Seed, Rochester, NY, USA) at 64.8 ± 0.4 μmol·m^{-2}·d^{-1} and a temperature at 24 ± 2 °C. Trays were watered twice daily with tap water until seeds emerged. Bare root seedlings were transplanted 19 Aug 2019 into standard inserts [2 1/3 × 2 2/5 × 3 1/3 inches (606 deep jumbo, American Plant Products)] filled with soilless growing medium (Metro-Mix 360, Sun Gro Horticulture) and placed in the Horticulture and Landscape Architecture research greenhouses in Stillwater, OK, USA. Plants were placed in a heated greenhouse with a mean temperature of 28.2 ± 1.8 °C under natural irradiance and an average daily light integral of 20.5 ± 4.9 mol·m^{-2}·d^{-1}. Uniconazole was applied on 27 Aug 2019, when seedlings were at the two-leaf stage, at rates of 0, 2.5, or 5 mg·L^{-1}. A spray volume of 20 mL was applied to each insert as described previously Expt. 1. On 9 Sep 2019, seedlings were transplanted into 5-gal fabric pots [12 inches in diameter × 10 inches in height (247Garden, Montebello, CA, USA)] filled with soilless growing medium (Metro-Mix 360). Each pot had three 2-gal/h drip emitters (Netafim, Tel Aviv, Israel) and were watered daily and fertilized with 20N–4.4P–16.6K water-soluble fertilizer (Jack's Professional® General Purpose) at a rate of 200 mg·L^{-1} nitrogen. Data collection began on 3 Sep 2019 (7 DAT) with plant height and stem caliper. Height measurements were taken at 2-week intervals for 14 weeks, from the soil to the shoot tip. Stem caliper measurements were acquired in weeks 1 and 14. Data on flowering began 1 Oct 2019, and all flowers and buds were counted then removed from the plants every 2 weeks for the following 6 weeks.

Experimental design and data analysis. The data analysis for Expt. 1 was performed using statistical software (SAS/STAT® version 9.4 for Windows; SAS Institute, Cary, NC, USA). Expt. 1 was a randomized complete block arranged as a 5 × 12 × 4 factorial consisting of five uniconazole rates, 12 cultivars, and four tomato types. The mean response of 12 plants was computed and the study was repeated over time to serve as the replication. The data were analyzed using linear mixed model methods, with years being pooled together. Post hoc analyses consisted of Tukey adjusted pairwise comparisons. Contrast methods were used to analyze group effects among the 12 cultivars. All tests were conducted at the nominal 0.05 level.

Expt. 2 was conducted in two different but similar greenhouses. Each of the three treatments had 12 plants assigned randomly per replication. The experimental design was a randomized complete block design in which greenhouse was the replication factor. Data were analyzed using generalized linear mixed model methods for repeated measures. Post hoc pairwise comparisons were made using Tukey methods. All tests were conducted at the nominal 0.05 level.

Results and discussion

Expt. 1. There was no interaction between rate and cultivar. Application rates were likely too high in relation to a rate–response curve to see interactions. Plant growth inhibitors at low rates are often only slightly shorter than control plants; but, with increasing rates, increasingly shorter heights result, until plateauing at the highest rates for plant height. If the treatment rates applied are all high and in the last portion of the response curve, there is often little or no differences in the height of the treated plants although all are considerably shorter than control plants. Main effects for plant height, SPAD, and shoot dry weight were significant among application rates (Table 1). For plant height, 2.5 mg·L^{-1} produced plants with the smallest height, but was not different from any other application rate except the control. Lack of significant height difference among spray concentrations is consistent with data reported from a study using 'Champion II', 'Big Boy', and 'Early Girl' tomato (Schnelle and Barrett 2009; Schnelle and Ruberg 2010). A 25% to 35% height suppression in the ornamental plant market is considered ideal, plants more than 35% shorter than untreated plants may make plants appear stunted (Hamrick 2003). Sprays at 2.5 mg·L^{-1} in our study provided an ~35% reduction in growth rate compared with the untreated tomato plants. For stem caliper and dry weight, the 0-mg·L^{-1} treatment was the greatest. In contrast, data from a study using 'Mountain Fresh' tomato transplants did find stem diameter to be greater with uniconazole treatment, but a fertilization program in conjunction with the foliar spray was used to provide an inch of growth per week that may have influenced the difference (Zandastra et al. 2007). In addition, dry weight of 'Summer Flavor' tomato was found to decline progressively with increasing rates of uniconazole (Wang and Gregg 1990). At high rates, uniconazole has also been shown to reduce total leaf area and dry weight (Bailey and Miller 1989; Wang and Blessington 1990). SPAD value was greatest at 10 mg·L^{-1}, with no difference among other rates except for 0 mg·L^{-1} (Table 1). Previous studies have shown uniconazole commonly produces plants with darker leaves as a result of an increased chlorophyll concentration, which occurs because of an altered rate of chlorophyll degradation in plant tissue creating the appearance of greater chlorophyll levels (Davis and Curry 1991; Wang and Gregg 1989).

Main effects for cultivars were significant for height, SPAD, and shoot dry weight (Table 2). 'Beefsteak' and 'Mortgage Lifter' were greater in height than 'Patio', but were not significantly different from the remaining cultivars. 'Big Boy' had the greatest stem caliper, but varied only from 'Patio'. 'Patio' is a container tomato bred for compactness; it averaged a 42% reduction in growth rate compared with 'Beefsteak'. SPAD was lower for 'Beefsteak' than 'Better Bush'; all other cultivars did not differ significantly. Soval-Villa et al. (2002) reported cultivar-specific differences among tomato cultivars as chlorophyll readings for 'Max' tomato were significantly greater than 'Caruso', 'Jumbo', 'Match', and 'Trust'. For shoot dry weight, 'Beefsteak'

Table 1. Main effects of five different foliar uniconazole application rates applied at the two- to four-leaf stage 28 d after planting on 12 different tomato seedling cultivars grown in a greenhouse in Stillwater, OK, USA.

Rates (mg·L^{-1})[i]	Plant ht (cm)[i]	Stem caliper (mm)[i]	SPAD	Dry wt (g)[i]
0	20.6 a[ii]	5.1 a	37.6 b	2.6 a
2.5	13.1 b	4.3 b	42.9 a	2.1 b
5	12.1 b	4.4 b	42.3 a	2.1 b
7.5	11.3 b	4.4 b	42.2 a	1.9 b
10	11.3 b	4.2 b	43.9 a	1.9 b
P value	<0.001	<0.05	<0.001	<0.001

[i] 1 mg·L^{-1} = 1 ppm, 1 cm = 0.3937 inch, 1 mm = 0.0394 inch, 1 g = 0.0353 oz.
[ii] Means within a column followed by the same letter are not significantly different based upon the Tukey-Kramer method at α = 0.05.
SPAD = soil plant analysis development chlorophyll meter.

Table 2. Main effects of tomato cultivars on plant growth and quality after five different rates of foliar uniconazole applications applied to seedlings at the two- to four-leaf stage 28 d after planting in a greenhouse in Stillwater, OK, USA.

Cultivar	Plant ht (cm)[i]	Stem caliper (mm)[i]	SPAD	Dry wt (g)[i]
Beefsteak	15.6 a[ii]	4.5 ab	39.2 b	2.4 a
Mortgage Lifter	15.0 a	4.4 ab	39.9 ab	2.3 a
Big Boy	14.2 ab	5.0 a	40.0 ab	2.2 a
Jet Star	13.6 ab	4.6 ab	39.7 ab	2.2 a
Brandywine	14.1 ab	4.5 ab	41.2 ab	2.2 a
Bush Early Girl	13.5 ab	4.4 ab	43.4 ab	2.0 a
Better Bush	13.4 ab	4.5 ab	43.5 a	2.0 ab
Roma	13.1 ab	4.5 ab	40.0 ab	2.0 ab
Mt. Pride	12.4 ab	4.4 ab	41.2 ab	2.0 ab
Cherokee Purple	13.6 ab	4.4 ab	41.4 ab	2.0 ab
Mountain Fresh	12.4 ab	4.2 ab	42.9 ab	1.9 ab
Patio	8.9 b	4.1 b	41.1 ab	1.4 b
P value	<0.05	<0.05	<0.05	<0.01

[i] 1 cm = 0.3937 inch, 1 mm = 0.0394 inch, 1 g = 0.0353 oz.
[ii] Means within a column followed by the same letter are not significantly different based upon the Tukey-Kramer method at α = 0.05.
SPAD = soil plant analysis development chlorophyll meter.

Table 3. Group effects of tomato types on plant growth and quality after five different rates (0, 2.5, 5, 7.5, and 10 mg·L^{-1}) of foliar uniconazole applications applied to seedlings at the two- to four-leaf stage 28 d after planting in Stillwater, OK, USA.

Type[i]	Plant ht (cm)[ii]	Stem caliper (mm)[ii]	SPAD	Dry wt (g)[ii]
Indeterminant	14.5 a[iii]	4.7 a	39.7 b	2.3 a
Determinant	12.6 ab	4.4 b	41.3 ab	2.0 bc
Heirloom	14.2 a	4.5 ab	40.8 b	2.1 ab
Container	11.9 b	4.3 b	42. 7a	1.8 bc
P value	<0.05	<0.05	<0.01	<0.001

[i] Indeterminant = 'Mountain Fresh', 'Mountain Pride', and 'Roma'; determinate = 'Big Boy', 'Beefsteak', and 'Jet Star'; heirloom = 'Brandywine', 'Mortgage Lifter', and 'Cherokee Purple'; and container = 'Patio', 'Bush Early Girl', 'Better Bush'.
[ii] 1 mg·L^{-1} = 1 ppm, 1 cm = 0.3937 inch, 1 mm = 0.0394 inch, 1 g = 0.0353 oz.
[iii] Means within a column followed by the same letter are not significantly different based upon the Tukey-Kramer method at α = 0.05.
SPAD = soil plant analysis development chlorophyll meter.

had the greatest weight but was different only from 'Patio'.

The effect of tomato type on height was greatest for the indeterminant type, but was not different from all others except container types (Table 3). Stem caliper was greatest for the indeterminant types, and was significantly different from the determinant and container types. Container tomatoes had significantly greater SPAD readings compared with heirlooms and indeterminants. Dry weight was greatest for the indeterminant types, and only different from the determinant and container types. Visually, the heirloom types were noted as having greater flowering among treatments than the control (data not shown).

EXPT. 2. There was a significant rate × time interaction for plant height and stem caliper (Table 4). The smallest plant height was 7 DAT with 2.5 mg·L^{-1} and was not different from 5 mg·L^{-1} uniconazole. At 21 DAT, plant height was still restricted for the 2.5-mg·L^{-1} treatment, but on all future dates, no difference was reported among treatments within a day. This indicates that plants outgrew the treatment by day 35. Runkle and Blanchard (2012) reported only the two 2.5-mg·L^{-1} applications (one at sowing and the other 27 d after sowing) reduced plant height at 2 weeks after transplant for tomato 'Beefmaster', and restrictions were diminished by week 3, whereas for 'Early Girl', restrictions were still seen. Whitman et al. (2005) demonstrated a single 1- to 2.5-mg·L^{-1} application of uniconazole 8 DAT produced moderate height control on 'Apricot Brandy' celosia (*Celosia plumosa*), 'Vista Red' scarlet sage (*Salvia splendens*), 'Wave Rose' petunia (*Petunia multiflora*), and 'Inca II Orange' marigold (*Tagetes erecta*), and height control was still seen at 27 DAT in 'Vista Red', 22 DAT in 'Wave Rose', and 35 DAT in 'Inca II Orange'. Depending on application rate and growing conditions, the effects of uniconazole on stem elongation may last 3 to 5 weeks (Whitman et al. 2005). Plant height was greater for 'Brandywine' in the second study and was not different from the control at 5 weeks compared with the first study, which could have been the result of transplanting into larger inserts or environmental conditions. Stem caliper means were similarly small at 7 DAT with either 2.5 or 5 mg·L^{-1} uniconazole. No rate differences were observed 106 DAT for stem caliper.

Rate effects for the number of flower clusters and the number of flowers per plant were significant (Table 5). The greatest number of flower clusters occurred in the 5-mg·L^{-1} treatment, but was not different from the control. The number of flowers per plant was greatest for the 5-mg·L^{-1} treatment. Villavicencio et al. (2015) reported no difference in flower number for 'Early Girl' tomato, but did report more flowers across rates of 5, 8, and 10 mg·L^{-1} , and number of fruits for 'Sun Sugar' tomato at rates of 5 and 8 mg·L^{-1}. Wang and Gregg (1990) reported fruit number of 'Summer Flavor' tomato was reduced regardless of the rate and stage of uniconazole application.

The main effect of time was significant for number of flower clusters, number of flowers per cluster, and number of flowers per plant (Table 6). The number of flowers per plant maximized at 49 and 69 DAT. Number of flowers per cluster was greatest at 35 DAT, but not different from 69 and 82 DAT. Number of flower clusters was greatest at 69 DAT, but was not different from 49 DAT. No delay in flowering was observed among treatments.

Table 4. Height and caliper response to different rates of foliar uniconazole application 22 d after planting to 'Brandywine' tomato seedlings grown in a greenhouse in Stillwater, OK, USA.

DAT[i]	Rate (mg·L^{-1})[ii]	Plant ht (cm)[ii]	Stem caliper (mm)[ii]
7	0	3.9 f[iii]	2.8 b
7	2.5	3.3 g	2.5 c
7	5	3.6 gf	2.6 bc
21	0	7.1 d	—
21	2.5	5.8 e	—
21	5	6.6 d	—
35	0	24.6 c	—
35	2.5	24.8 c	—
35	5	25.1 c	—
69	0	52.3 b	—
69	2.5	50.2 b	—
69	5	51.8 b	—
106	0	72.6 a	8.0 a
106	2.5	70.2 a	8.3 a
106	5	73.1 a	8.3 a
P value	—	<0.001	<0.05

[i] Days after initial treatment.
[ii] 1 mg·L^{-1} = 1 ppm, 1 cm = 0.3937 inch, 1 mm = 0.0394 inch.
[iii] Means within a column followed by the same letter are not significantly different based upon the Tukey-Kramer method at α = 0.05.

Table 5. Main effects of flower response to three different rates of foliar uniconazole applications 22 d after planting to 'Brandywine' tomato seedlings grown in a greenhouse in Stillwater, OK, USA.

Rate (mg·L^{-1})[i]	Flower clusters (no.)	Flowers (no./cluster)	Flowers (no./plant)
0	2.2 ab[ii]	5.9 a	13.6 b
2.5	2.1 b	6.2 a	13.2 b
5	2.3 a	6.6 a	16.3 a
P value	<0.05	NS	<0.05

[i] 1 mg·L^{-1} = 1 ppm.
[ii] Means within a column followed by the same letter are not significantly different based upon the Tukey-Kramer method at α = 0.05.

Table 6. Main effects of flower response over five different dates to foliar uniconazole applications 22 d after planting to ‘Brandywine’ tomato seedlings grown in a greenhouse in Stillwater, OK, USA.

DAT[i]	Flower clusters (no.)	Flowers (no./cluster)	Flowers (no./plant)
35	1.6 bc[ii]	7.4 a	11.2 b
49	3.4 a	5.7 b	19.7 a
69	3.5 a	6.5 ab	22.7 a
82	1.5 c	6.7 a	10.1 bc
106	1.8 b	4.7 c	8.1 c
P value	<0.001	<0.001	<0.001

[i] Days after initial treatment.

[ii] Means (n = 12) within a column followed by the same letter are not significantly different based upon the Tukey-Kramer method at α = 0.05.

Conclusion

For height control, the 2.5-mg·L^{-1} foliar applications were not different from greater applications, and no one tomato cultivar responded differently when evaluated across the high label rates. Lower incremental application rates at different application times could confirm whether 2.5 mg·L^{-1} is the lowest rate that can maintain height control among different tomato types and whether cultivar-specific effects can be seen as hypothesized initially. Based on the two studies, height measurements should be recorded earlier than 35 DAT and more frequently (daily) to delineate rate effects fully initially, because in the second study, rate differences were seen at 21 d but not at 35 d as in Expt. 1. An increased number of flowers with 5 mg·L^{-1} in ‘Brandywine’ could lead to increased flowering and fruiting in other heirloom cultivars, but this will need to be explored more in future research to determine whether greater flower numbers correlate with greater fruit yield. As with any plant growth regulator, growers should trial under their specific conditions, because plant growth can be affected by a combination of environmental conditions, timing, and application methods.

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