Response of 'Moonbeam' Coreopsis and 'Goldsturm' Rudbeckia to B-Nine and Cycocel[1]

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Abstract

Coreopsis verticillata 'Moonbeam' and *Rudbeckia fulgida* 'Goldsturm' were sprayed with tank mixes of B-Nine and Cycocel in all combinations of 0, 2500, 5000 or 7500 ppm B-Nine and 0, 1000, 1500 or 2000 ppm Cycocel. B-Nine was more effective in controlling height of both cultivars than Cycocel or B-Nine/Cycocel tank mixes. B-Nine alone suppressed height of coreopsis 26–52% (over all concentrations and all data collection dates), in contrast to a 17–41% height suppression when B-Nine was combined with Cycocel. Cycocel alone suppressed height of coreopsis 6–16% over all concentrations and data collection dates. B-Nine suppressed height of rudbeckia 20–40% over all data collection dates, while Cycocel suppressed height of rudbeckia only in the last two weeks of data collection (10 and 12% at weeks 8 and 9, respectively). Tank mixes applied to rudbeckia were not as effective as B-Nine alone for height suppression. Flowering of coreopsis was delayed 6 days by B-Nine and 12–14 days by tank mixes of B-Nine and Cycocel; Cycocel accelerated flowering up to 5 days when used alone. Flowering of rudbeckia was delayed up to 9 days with increasing B-Nine concentrations but was unaffected by Cycocel alone or tank mixes of B-Nine/Cycocel. No phytotoxicity was observed at the concentrations used.

Index words: plant growth regulator, plant growth retardant, herbaceous perennial.

Growth regulators used in this study: B-Nine (daminozide) [butanedioic acid mono (2,2-dimethylhydrazide)]; Cycocel (chlormequat chloride), (2-chlorethyl) trimethylammonium chloride.

Species used in this study: 'Moonbeam' coreopsis or tickseed (*Coreopsis verticillata* L. 'Moonbeam'), 'Goldsturm' black-eyed Susan or orange coneflower (*Rudbeckia fulgida* L. var. sullivantii (Beadle & Boynton) Cronquist 'Goldsturm').

Significance to the Nursery Industry

Coreopsis and rudbeckia are fast growing herbaceous perennials, making them desirable to homeowners. This rapid growth can be problematic for perennial plant growers, leading to excessively tall, leggy plants that are often unmarketable and difficult to ship. To control height, growers prune or pinch plants, which is costly in both time and labor. Plant growth retardants (PGRs) help growers by achieving similar results to pruning or pinching without the labor and time costs of mechanical control. B-Nine and Cycocel, while not labeled for either coreopsis or rudbeckia, have been effective in controlling the heights of many herbaceous perennials and in combination have been reported to be synergistic. This synergy has been used as a 'blanket approach' by growers in controlling heights of plants when the effectiveness of either chemical was unknown or the plant was new to large scale production. While this approach greatly enhances the probability of height suppression, it adds cost to production if either B-Nine or Cycocel is effective alone. Applications of B-Nine alone at 2500 to 7500 ppm were effective in suppressing height of 'Moonbeam' coreopsis and 'Goldsturm' rudbeckia. Flowering of coreopsis was delayed by 6 days and rudbeckia by 9 days, but with no noticeable phytotoxicity. B-Nine/Cycocel tank mixes were less effective than B-Nine alone in controlling height, while Cycocel alone had minimal effect on plant height. Use of B-Nine alone on rudbeckia and coreopsis may save growers chemical costs by reducing or eliminating the need for tank mixing with Cycocel.

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Introduction

Most plant growth retardants (PGRs) suppress growth by inhibiting one or more stages of gibberellin synthesis. One group of PGRs, the onium compounds, inhibit gibberellin synthesis early in the process during the cyclization of geranylgeranylphosphate to *ent*-kaurene (13). One of the oldest and most widely used chemicals from this group is chlormequat chloride (CCC, Cycocel). Cycocel is labeled for ornamentals and has been used to control height in a number of crops (12, 18, 20, 21, 22). Cycocel suppressed height in raspberries (*Rubus idaeus*) and dianthus (*Dianthus barbatus*), but was phytotoxic at 1000 ppm on *R. idaeus* 'Autumn Bliss' (12) and 3000 ppm on *D. barbatus* 'Indian Carpet' (19). Daminozide (Alar, B-Nine, B-995), also inhibits gibberellin synthesis and has been widely used on fruit crops and ornamentals since 1975 (3, 4, 6, 16, 18, 21). Similar to prohexadione-Ca, daminozide is a structural mimic to 2-oxoglutaric acid that is required in processes which oxidize GA_{12}-aldehyde into other gibberellins. Daminozide specifically inhibits the process when GA_{20}, an inactive form of GA, is converted to GA_1 (6, 10, 23).

Although these two PGRs inhibit production of gibberellin, some plant species are more effectively controlled than others (24). Ornamental crop producers have been using both B-Nine and Cycocel for many years, and it has been shown that these two chemicals can be tank mixed to gain additional height control in some crops (4, 5, 7, 9, 11, 17, 20). Lewis et al. (17) reported that a tank mix of B-Nine/Cycocel is more effective than either chemical alone, yet not as overpowering to some crops as other PGRs might be. If crop sensitivity was unknown, tank mixing B-Nine and Cycocel may help growers enhance their chances for effective height control. Certain crops that are unresponsive to one PGR may be highly responsive to another with a different mode of action (16, 27). A species that is not responsive to either chemical should not be responsive to a tank mix (5, 11, 17).

Table 1. **Height of 'Moonbeam' coreopsis 1 week after initial treatment with B-Nine, Cycocel, or combinations of the two.**

B-Nine (ppm)	Cycocel (ppm) 0	1,000	1,500	2,000	Significance[z]
0	22.6[y]	20.7	21.1	18.9	L**
2,500	16.2	15.1	16.5	16.8	NS
5,000	14.0	13.6	16.9	15.9	L*
7,500	16.6	14.4	14.5	15.7	Q*
Significance	Q***	Q***	L***	L**	

[z]Significant B-Nine/Cycocel interaction ($P = 0.011$); trend analysis non-significant (NS), linear (L) or quadratic (Q) at $P \leq 0.05$ (*), 0.01 (**) or 0.001 (***).

[y]Plant height in centimeters.

Table 2. **Height of 'Moonbeam' coreopsis 3 weeks after initial treatment with B-Nine, Cycocel, or combinations of the two.**

B-Nine (ppm)	Cycocel (ppm) 0	1,000	1,500	2,000	Significance[z]
0	32.1[y]	27.9	27.5	27.5	Q**
2,500	17.7	16.6	17.4	18.4	NS
5,000	15.5	14.8	17.3	17.2	L*
7,500	17.4	14.9	15.3	16.3	Q*
Significance	Q***	Q***	L***	L***	

[z]Significant B-Nine/Cycocel interaction ($P = 0.004$); trend analysis non-significant (NS), linear (L) or quadratic (Q) at $P \leq 0.05$ (*), 0.01 (**) or 0.001 (***).

[y]Plant height in centimeters.

Concentrations and ratios given for the tank mixes of B-Nine/Cycocel are based on Cycocel concentrations that cause phytotoxicity at higher rates (1000–1500 ppm) and use of B-Nine according to labeling and desired activity level (800–7500 ppm). These concentrations and ratios are meant to be adjusted for different crop species (9, 20). With inconsistent crop sensitivity to these two chemicals, determining the proper ratio for tank mixes may require an inefficient trial and error method. Research would be needed on almost every crop until the proper B-Nine/Cycocel ratios were demonstrated. In some cases, tank mixing may be unnecessary if research showed no benefit of adding either B-Nine or Cycocel.

Coreopsis and rudbeckia have been two of the most popular perennials on the market since their introduction. In 1992, 'Moonbeam' coreopsis was the Perennial Plant of the Year and is still the most popular cultivar of this species. 'Goldsturm' rudbeckia was the 1999 Perennial Plant of the Year and its popularity reached such levels that, at times, demand could not be met by vegetative propagation (1, 2).

Growth regulation of these two perennials using B-Nine has shown inconsistent results. A nursery setting as opposed to a greenhouse setting negatively impacted PGR efficacy (8, 16). Hayashi (15) showed ethephon to be ineffective in controlling height of 'Moonbeam' coreopsis. Cycocel was shown to be so effective in controlling height of *Rudbeckia bicolor*, a long day species, that plants resembled those kept under short day length (14). Yuan (26) reported that A-Rest, B-Nine, Bonzi and Cycocel only slightly reduced plant height of 'Goldsturm' rudbeckia. Neither B-Nine nor Cycocel are labeled for coreopsis or rudbeckia, thus effectiveness and optimal concentrations are unknown. The objective of this study was to determine the response of coreopsis and rudbeckia to B-Nine and Cycocel concentrations and tank mix ratios of the two.

Materials and Methods

Cuttings of coreopsis were stuck in 806 cell packs on April 4, 2001, and placed under intermittent mist (5 sec on every 10 min from 9:00 am to 4:00 pm). Cuttings were removed from mist on May 9, 2001, and placed in an unshaded greenhouse [heat set point: 18.3C (65F), ventilation set point: 25.5C (78F)]. Rooted cuttings of coreopsis were potted into 10 cm (4 in) pots containing Fafard 3B growing medium (Fafard, Anderson, SC) on June 1 and pruned to a uniform height of 6.4 cm (2.5 in) three days later. On April 20, 2001, uniform rooted offsets of rudbeckia were dug from a landscape planting and potted into 15.3 cm (6 in) pots containing Fafard 3B growing medium and placed in the same greenhouse as the coreopsis.

B-Nine/Cycocel tank mixes were applied at four concentrations of each PGR (0, 2500, 5000 or 7500 ppm and 0, 1000, 1500 or 2000 ppm, respectively) in a 4 × 4 factorial experiment. Treatments were completely randomized within species and replicated with 10 single plants of each species. Treatments were applied to rudbeckia on May 14 [33.3C (92F) and 38% relative humidity (RH)] and 2 weeks after initial application on May 30 [34.5C (94F) and 50% RH], and to coreopsis on June 13 [32.8C (91F) and 72% RH] and 1 week after initial treatment on June 20 [34.5C (94F) and 70% RH]. Treatments were applied uniformly with a hand-held spray bottle at 0.2 liter/m^2 (equivalent to 2 qt/100 ft^2). Plant height was recorded weekly following first treatments for five weeks on coreopsis and nine weeks on rudbeckia. Days to first flower were recorded, as well as flower diameter (largest flower on the plant when at least three flowers were fully opened). Data were analyzed using one way analysis of variance (ANOVA) and two-way ANOVA to test the interaction of the two PGRs. Trend analyses were determined by the general linear models procedure using orthogonal contrasts (SAS Institute, Cary, NC).

Results and Discussion

Coreopsis. No treatment caused phytotoxicity during the study. Interactions between B-Nine and Cycocel occurred for plant height at all observation dates (Tables 1–3), days to

Table 3. **Height of 'Moonbeam' coreopsis 5 weeks after initial treatment with B-Nine, Cycocel, or combinations of the two.**

B-Nine (ppm)	Cycocel (ppm) 0	1,000	1,500	2,000	Significance[z]
0	29.4[y]	26.7	26.8	26.2	L*
2,500	19.6	18.5	17.6	19.3	NS
5,000	16.9	15.6	16.5	16.3	NS
7,500	16.8	16.2	16.7	18.0	NS
Significance	Q***	Q***	Q***	Q***	

[z]Significant B-Nine/Cycocel interaction ($P = 0.05$); trend analysis non-significant (NS), linear (L) or quadratic (Q) at $P \leq 0.05$ (*) or 0.001 (***).

[y]Plant height in centimeters.

Table 4. **Days to flower for 'Moonbeam' coreopsis treated with B-Nine, Cycocel, or combinations of the two.**

B-Nine (ppm)	Cycocel (ppm)				Significance[z]
	0	1,000	1,500	2,000	
0	28	29	28	23	L*
2,500	28	31	31	34	L*
5,000	34	35	33	33	NS
7,500	34	41	41	37	Q**
Significance	L**	L***	L***	L***	

[z]Significant B-Nine/Cycocel interaction ($P = 0.05$); trend analysis non-significant (NS), linear (L) or quadratic (Q) at $P \le 0.05$ (*), 0.01 (**) or 0.001 (***).

Table 5. **Inflorescence diameter of 'Moonbeam' coreopsis treated with B-Nine, Cycocel, or combinations of the two.**

B-Nine (ppm)	Cycocel (ppm)				Significance[z]
	0	1,000	1,500	2,000	
0	3.3[y]	3.3	3.5	3.8	L*
2,500	3.3	3.6	3.4	3.2	NS
5,000	3.6	3.0	3.2	2.8	L**
7,500	3.3	2.7	2.9	2.9	NS
Significance	NS	L***	L**	Q*	

[z]Significant B-Nine/Cycocel interaction ($P = 0.05$); trend analysis non-significant (NS), linear (L) or quadratic (Q) at $P \le 0.05$ (*), 0.01 (**) or 0.001 (***).

[y]Inflorescence diameter in centimeters.

flower (Table 4), and inflorescence diameter (Table 5). Increasing concentrations of B-Nine, in the absence of Cycocel, suppressed height quadratically on all dates. Height suppression with B-Nine alone was relatively constant over the duration of the study ranging from 26–38%, 44–51%, and 33–43% at 1, 3 and 5 weeks after initial treatment (WAT), respectively. The greatest change in plant height was between the untreated control and plants treated with 2500 ppm B-Nine, with minimal additional suppression using higher concentrations.

Height of coreopsis was suppressed linearly or quadratically at all sampling dates with increasing B-Nine concentration and the addition of Cycocel (Tables 1–3). Plant height was suppressed 39% at week one, 54% at week 3 and 46% at week 5 using 5000 ppm B-Nine and 1000 ppm Cycocel. Adding Cycocel to 5000 ppm B-Nine suppressed coreopsis height only slightly more than 5000 ppm B-Nine alone (3, 6 or 8% increase at 1, 3 or 5 WAT, respectively).

Increasing the concentration of Cycocel alone suppressed heights linearly and quadratically at all dates, but to a lesser extent than B-Nine. Height was suppressed by Cycocel alone 7–16%, 13–15% or 9–10% at weeks 1, 3 or 5, respectively. Increasing the concentration of Cycocel mixed with B-Nine had varied results depending on the number of weeks after treatment and the concentration of B-Nine. Increasing the concentration of Cycocel in combination with 2500 ppm B-Nine had no effect on height at 1, 2, 3 or 5 WAT, while at 4 WAT height suppression ranged from 2 to 14% more than with 2500 ppm B-Nine alone. Increasing the concentration of Cycocel combined with 5000 ppm B-Nine resulted in linear increases in plant height from 1.7 to 2.9 cm at 1, 2, or 3 WAT. In contrast, increasing the concentration of Cycocel combined with 7500 ppm B-Nine suppressed height quadratically by 5–13%, 7–17% or 6–14% at 1, 2 or 3 WAT compared to 7500 ppm B-Nine alone. None of these changes was considered to be of horticultural significance. At 4 and 5 WAT, height response to Cycocel concentration when combined with 5000 or 7500 ppm B-Nine was not significant indicating no additional height suppression from tank mixing B-Nine and Cycocel than was achieved over B-Nine alone. This result was similar to those of Banko et al. (4), where combinations of PGRs with B-Nine were not more effective at height control than B-Nine used alone in *Salvia* x *sylvestris* 'May Night'.

Increasing the concentration of B-Nine alone delayed flowering up to 6 days (Table 4). This agrees with previous studies where B-Nine delayed flowering up to 4 days in *C. rosea* (8) and 2 to 5 days in *C. verticillata* 'Moonbeam' (16) when compared with an untreated control, and almost 3 weeks in *Vitex agnus-castus* (18) when compared to Cycocel. B-Nine at 7500 ppm in combination with Cycocel at 1500 ppm showed a more pronounced delay of 14 days.

Flowering was accelerated up to 5 days with increasing concentrations of Cycocel alone, but when 2500, 5000 or 7500 ppm B-Nine was added, flowering was delayed up to 6 days, not affected by B-Nine concentration, or delayed up to 7 days, respectively.

Inflorescence diameter was not affected by B-Nine alone (Table 5). When Cycocel was combined with increasing concentrations of B-Nine, inflorescence diameter decreased as much as 27%. In contrast, inflorescence diameter increased up to 15% with increasing concentrations of Cycocel alone.

Table 6. **Height, days to flower and inflorescence diameter of 'Goldsturm' rudbeckia treated with B-Nine.**

B-Nine (ppm)	Weeks after initial treatment									Days to flower	Inflorescence diameter (cm)
	1	2	3	4	5	6	7	8	9		
0	20.8[z]	26.5	28.7	31.6	35.0	37.4	39.0	39.9	40.8	37	7.1
2,500	18.3	19.3	20.1	20.8	24.1	25.2	27.0	29.2	30.7	46	4.8
5,000	16.7	18.4	18.7	18.4	19.9	20.7	22.3	26.2	27.4	46	4.8
7,500	16.8	18.7	18.3	18.9	19.4	19.8	20.7	21.8	24.3	45	4.2
Significance[y]	L***	Q***	Q***	Q***	L***	L***	L***	L***	L***	Q***	L***

[z]Plant height in centimeters.

[y]B-Nine × Cycocel interactions not significant; treatment means averaged over Cycocel treatments; significant linear (L) or quadratic (Q) response at $P \le 0.001$ (***).

Whipker and McCall (25) showed sunflower inflorescence diameter decreased when 4000 and 8000 ppm daminozide was applied.

Rudbeckia. There were no interactions between B-Nine and Cycocel for any data taken on rudbeckia, hence main effects only are reported. With increasing concentrations of B-Nine, plant height was suppressed up to 20% at week 1 and 40% at week 9 (Table 6). Cycocel concentration had no effect on plant height, except a linear decrease at weeks 8 and 9 when maximum suppression observed was 10 and 12%, respectively using 1500 ppm Cycocel ($P \leq 0.05$ at week 8 and $P \leq 0.01$ at week 9). Time to flower increased quadratically by 8 days and inflorescence diameter decreased linearly 41% with increasing concentration of B-Nine, but neither was affected by Cycocel concentration (data not shown).

The practice of tank mixing B-Nine and Cycocel for height control in species where chemical effectiveness is unknown is widespread. This 'blanket control' can be very effective for many species, although the control may be attributed to only one chemical. While growers have used B-Nine/Cycocel tank mixes with great success on many species, the synergistic effect of the chemicals may not occur with all species. Our results show B-Nine more effective in controlling height of coreopsis and rudbeckia than B-Nine/Cycocel tank mixes or Cycocel alone. Flowering was delayed up to 6 days with B-Nine, but no noticeable phytotoxicity occurred.

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