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Thidiazuron Increases Shoot Formation in Nandina[1]

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Abstract

A study conducted from 1997 to 2000 determined the effects of thidiazuron (TDZ) on shoot formation, whole plant size, and phytotoxicity in *Nandina domestica* Thunb. 'Harbour Dwarf' and 'Compacta' (2000 only). Single foliar applications of up to 4000 ppm TDZ increased shoot formation in both cultivars, with minimal effect on plant size or appearance. Single substrate drenches of up to 2500 ppm TDZ increased shoot formation in 'Harbour Dwarf' nandina but were severely phytotoxic, often resulting in foliar distortion and necrosis, or plant death.

Index words: plant growth regulator, branching, phytotoxicity.

Growth regulator used in this study: Dropp 50WP (thidiazuron or TDZ), N-phenyl-N'-(1, 2, 3-thiadiazol-5-yl) urea.

Species used in this study: 'Harbour Dwarf' and 'Compacta' nandina (*Nandina domestica* Thunb. 'Harbour Dwarf' and 'Compacta').

Significance to the Nursery Industry

Although exceptionally popular landscape plants in the South, nandina cultivars form new shoots slowly during container production, often limiting the availability of cuttings and increasing production time, even when plants are pruned. Single foliar sprays of Dropp (thidiazuron or TDZ), a cotton defoliant with cytokinin properties, applied at up to 4000 ppm promote shoot formation and fuller appearing plants of 'Harbour Dwarf' and 'Compacta' nandinas within 30 days of application with minimal phytotoxicity or effects on plant size. Substrate drenches, while effective in stimulating branching, resulted in foliar distortion, necrosis, and in many cases plant death, thus are not recommended.

Introduction

Nandina domestica 'Harbour Dwarf', with its compact growth habit and finely textured foliage, is one of the most widely used broadleaf evergreen shrubs in Southern gardens. Rhizomatous in nature and forming cane-type shoots from the ground, it eventually forms a dense mound (1). However, during container production 'Harbour Dwarf' nandina develops few basal or lateral shoots and does not readily respond to mechanical pruning with multiple shoot formation. These characteristics often limit cuttage for propagation and extend production time to reach a marketable stage.

Exogenously applied cytokinins, including the adenine cytokinins, benzyladenine (BA) and PBA, promote axillary bud growth and branching of woody and herbaceous plants (2, 5, 6). 'Harbour Dwarf' nandina responded positively to foliar applications of 1000 to 2500 ppm BA and to 2000 to 5000 ppm Promalin, a mixture of equal parts by weight of BA and GA_{4+7} (6). However, in subsequent unpublished tests branching was frequently inconsistent.

Structurally unrelated to the complex adenine cytokinins, the phenylurea cytokinins are simple in chemical structure. Thidiazuron (TDZ), a phenylurea cytokinin, is a commercially available cotton defoliant (Dropp 50WP, Aventis CropScience, Research Triangle Park, NC) that promotes premature formation of abscission layers in petioles, thus causing green leaf drop. TDZ is one of the most potent cytokinins known, with activity at 10^{-13} to 10^{-8}M in the standard tobacco callus bioassay compared to 3×10^{-8}M for BA (7).

More than 100 reports have been published over the past six years on TDZ-mediated micropropagation of plants. However, limited research on the effects of TDZ *in vivo* on shoot multiplication have been published. Henny and Fooshee (4) observed large increases in basal bud and shoot development of small *Alocasia* plants treated seven days after potting; however, root growth was inhibited and most shoots failed to develop fully when drenches were applied at concentrations as low as 1 to 5 ppm. In a later study, Henny (3) reported more than double the number of basal shoots in *Spathiphyllum* 'Petite' drenched with 2 to 10 ppm TDZ with no inhibition of plant height, leaf size or shoot and root fresh weights compared to untreated plants. The objective of the following study was to determine the effects of TDZ on shoot formation, plant size and appearance of 'Harbour Dwarf'and 'Compacta' nandina.

Materials and Methods

Four experiments were conducted between 1997 and 2000 using similar methodology unless otherwise noted. In all experiments with 'Harbour Dwarf' nandina, stem cuttings were rooted in late spring of the year prior to treatment. Liners were repotted in September into 2.8 liter (#1 trade) containers of a 6:1 pinebark:sand substrate amended per m^3 (yd^3) with 5.4 kg (9 lb) 20N–3.3P–6K (PolyOn 22–4–14, Pursell Industries, Sylacauga, AL), 0.9 kg (1.5 lb) Micromax (The Scotts Company, Marysville, OH) and 3.0 kg (5 lb) dolomitic limestone. Plants were placed pot-to-pot outdoors in full sun under overhead irrigation until the following spring.

1997. On May 27, 1997, 'Harbour Dwarf' plants were repotted into 11.4 liter (#3) containers of the same amended substrate except 10.7 kg (18 lb) per m^3 (yd^3) of 20N–3.3P–6K (PolyOn 22–4–14) was added instead of 5.4 kg (9 lb). On July 30, plants uniform in size with a single, unbranched shoot were selected for treatment and moved into a polyethylene greenhouse. TDZ (Dropp 50WP, Aventis CropScience) was applied at 100, 250, 500, 1000, 1500, 2000 or 2500 ppm as either single foliar sprays or substrate drenches. A non-treated control was also included. Foliar sprays were applied

[1]Received for publication August 27, 2001; in revised form November 12, 2001.

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Table 1. TDZ effects on shoot counts and growth index of 'Harbour Dwarf' nandina, 1997.

TDZ rate (ppm)	Shoot counts[z]		Growth index[y] (cm)
	45 DAT[x]	90 DAT	45 DAT
0	1.8	3.8	42.1
100	1.6	3.0	41.8
250	2.3	3.7	42.3
500	2.3	4.3	42.4
1000	3.8	5.9	42.0
1500	5.5	7.4	43.2
2000	6.2	8.3	38.3
2500	6.4	8.9	43.0
Significance[w]	L***	L***	NS
Control	1.8b[v]	3.8b	42.1a
Foliar spray	3.9a	5.9a	42.9a
Drench	3.7a	5.4a	40.6b

[z]Total number of lateral and basal shoots.

[y]Growth index = (height + $width_1$ + width 90° to $width_1$) ÷ 3.

[x]DAT = days after treatment.

[w]Values are the means of the two application methods because of nonsignificant interactions. Nonsignificant (NS) or significant linear (L) regression response at $P = 0.001$ (***); control included in regression analysis.

[v]Values are the means for all rates for a given application method. Mean separation by single degree of freedom orthogonal contrasts, $P = 0.05$.

in a volume of 0.2 liter/m^2 (2 qt/100 ft^2) using a CO_2 sprayer with a flat spray nozzle (TeeJet 8004VS, Bellspray, Inc., Opelousas, LA) at 1.4 kg/cm^2 (20 psi). Tween 20 (Mallinckrodt Baker, Phillipsburg, NJ), a nonionic surfactant, was added to all spray solutions at 1 ml/liter (0.1%). Drenches were applied in 100 ml (3.4 oz) per pot. Temperature and relative humidity at treatment were 33C (91F) and 56%, respectively. Treated plants were returned to the nursery container area the following day. Treatments in this 2 × 7 factorial experiment plus a control were completely randomized, with 9 single plant replications.

In all experiments, unless otherwise noted, at 45 and 90 days after treatment (DAT) new basal and lateral shoots were counted, a growth index [(height + widest width + width 90° to widest width) ÷ 3] was determined, and plants were rated for phytotoxicity (1 = normal, healthy; 2 = chlorotic immature foliage; 3 = chlorotic, distorted immature foliage; 4 = necrotic immature and/or mature foliage; 5 = dead).

An analysis of variance was used to test the significance of main effects and interactions. When interactions were not significant, single degree of freedom orthogonal contrasts, which included the control, were used to test rate responses across methods of application (MOA). Orthogonal contrast also were used to make comparisons among MOA and the control treatment across all rates. When interactions were significant, rates responses were determined within MOA, and comparisons between MOA were made within rate.

1998. 'Harbour Dwarf' nandina in 2.8 liter (#1 trade) containers were repotted into 11.4 liter (#3) containers on February 18, 1998. On July 8, 1998, TDZ was applied at 1000, 1500, 2000, 2500, or 3000 ppm as foliar sprays, and at 500, 750, 1000, 1250, or 1500 ppm as substrate drenches. Temperature at treatment was 38C (100F) and relative humidity was 62%. There were 10 single plant replications.

1999. 'Harbour Dwarf' nandina were repotted on April 4, 1999, into 11.4 liter (#3) containers of the same substrate, except 7.1 kg/m^3 (12 lb/yd^3) of 17N–3P–10K (Osmocote 17–7–12, The Scotts Company) was incorporated as the complete fertilizer. TDZ was applied as foliar sprays only at 0, 1000, 1500, 2000, 2500, 3000, 3500 and 4000 ppm on June 2, 1999, to 10 single plant replications. Temperature and relative humidity at treatment were 33C (91F) and 59%, respectively. Data were collected at 30, 60, and 90 DAT.

2000. On April 21, 2000, 'Harbour Dwarf' nandina in 2.8 liter (#1 trade) containers and 'Compacta' nandina in 32-cell flats were transplanted into 11.4 liter (#3) containers of the same substrate amended as in 1999. On June 14, 2000, single foliar sprays of 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, and 4000 ppm TDZ were applied to 10 single plant replications. Buffer-X (Kalo Agr. Chemicals, Overland, KS) was added at 2 ml/liter (0.2%) as a nonionic surfactant. Temperature and relative humidity during treatment were 31.7C (89F) and 50%, respectively. Plants in this 2 × 9 (cultivar × TDZ rate) factorial experiment were completely randomized. New shoots were counted and plants were rated for phytotoxicity only at 30, 60, and 90 DAT.

Results and Discussion

1997. Shoot counts increased linearly by 255% at 45 DAT and 134% at 90 DAT as TDZ rate increased (Table 1). Foliar

Table 2. TDZ effects on phytotoxicity ratings and growth index of 'Harbour Dwarf' nandina, 1997.

TDZ		Growth index[z] (cm)	Phytotoxicity rating[y]	
Application method	Rate (ppm)	90 DAT[x]	45 DAT	90 DAT
Control	0	43.9	1.6	1.2
Foliar spray	100	43.7	1.2	1.8
	250	45.1	2.0	1.6
	500	42.4	1.7	2.2
	1000	45.5	1.7	2.1
	1500	43.0	1.7	1.9a[w]
	2000	42.8a	1.6a	2.1a
	2500	42.4	1.9a	2.1a
Significance[v]		NS	NS	L*
Drench	100	42.0	2.0	1.9
	250	45.2	1.4	1.7
	500	45.0	1.4	1.7
	1000	44.2	2.0	1.9
	1500	44.2	2.4	2.6
	2000	34.7	3.4	3.4
	2500	47.3	4.2	4.3
Significance		Q***	L***Q**	L***Q**

[z]Growth index = (height + $width_1$ + width 90° to $width_1$) ÷ 3.

[y]Phytotoxicity rating: 1 = normal, healthy; 2 = chlorotic immature foliage; 3 = chlorotic, distorted immature foliage; 4 = necrotic immature and/or mature foliage; 5 = dead.

[x]DAT = days after treatment.

[v]Significant application method × rate interaction for all parameters. Nonsignificant (NS), linear (L) or quadratic (Q) regression response at $P = 0.05$ (*), 0.01 (**), or 0.001 (***); control included in regression analysis.

[w]Foliar spray means followed by an 'a' are significantly different from corresponding drench means, $P = 0.05$.

Table 3. TDZ effects on shoot counts, phytotoxicity ratings, and growth index of 'Harbour Dwarf' nandina, 1998.

TDZ		Shoot counts[z]		Growth index[y]		Phytotoxicity rating[x]	
Application method	Rate (ppm)	45 DAT[w]	90 DAT	45 DAT	90 DAT	45 DAT	90 DAT
Control	0	0.2	0.7	36.3a[v]	36.4ab	1.8	1.5
Foliar spray	1000	0.7	2.3	36.8	37.2	2.1	2.0
	1500	1.6	2.0	39.2	39.0	2.2	1.7
	2000	0.8	1.8	40.3	39.9	2.2	2.0
	2500	1.6	2.4	38.0	39.1	2.6	2.0
	3000	2.2	3.1	38.4	38.9	1.8	1.7
Significance[u]		L**	L**	NS	NS	NS	NS
Drench	500	0.4	1.1	33.6ab	34.8ab	3.1	3.0
	750	0.4	1.4	38.0a	38.8a	3.9	3.9
	1000	0.0	0.5	27.0b	27.3b	4.7	4.6
	1250	0.0	0.0	—[t]	—	5.0	5.0
	1500	0.2	1.1	32.3ab	27.7b	4.2	4.2
Significance		NS	NS			L***Q**	L***Q**
Control		0.2b[s]	0.7b	36.3ab	36.4ab	1.8b	1.5b
Spray		1.4a	2.3a	38.5a	38.8a	2.2b	1.9a
Drench		0.2b	0.8b	32.7b	32.2b	4.2a	4.1a

[z]Total number of lateral and basal shoots.

[y]Growth index = (height + $width_1$ + width 90° to $width_1$) ÷ 3.

[x]Phytotoxicity rating: 1 = normal, healthy; 2 = chlorotic immature foliage; 3 = chlorotic, distorted immature foliage; 4 necrotic immature and/or mature foliage; 5 = dead.

[w]DAT = days after treatment.

[v]Insufficient replications for regression analysis; mean separation among control and drench treatments by Duncan's multiple range test, $P = 0.05$.

[u]Nonsignificant (NS) or significant linear (L) or quadratic (Q) regression response at $P = 0.01$(**) or 0.001 (***).

[t]All plants in this treatment dead.

[s]Means separation among application methods and control by single degree of freedom orthogonal contrasts, $P = 0.05$.

spray and drench applications were equally effective in promoting shoot formation, and plants treated with both MOA formed more shoots than non-treated control plants, 106% to 117% more at 45 DAT and 42% to 55% more at 90 DAT. The increased shoot counts in TDZ-treated plants resulted in visibly fuller plants. Growth index was not affected by TDZ rate, however growth index of drench-treated plants was 4% to 5% less than those of controls and spray-treated plants at 45 DAT (Table1). At 90 DAT the only treatment effect on growth index was a 19% reduction in drench-treated plants, compared to plants sprayed with 2000 ppm TDZ (Table 2).

Phytotoxicity rating of sprayed plants was unaffected by TDZ at 45 DAT but increased linearly with increasing TDZ rate at 90 DAT (Table 2). The primary symptom was chlorosis of the immature foliage, which would not likely affect marketability. Plants were overwintered and new growth the following spring exhibited no adverse symptoms. Phytotoxicity ratings of drenched plants increased quadratically with increasing TDZ rate, up to 163% at 45 DAT and 258% at 90 DAT. Phytotoxicity ratings were also higher for drench-treated plants than for spray-treated plants at the higher TDZ rates (2000 and 2500 ppm at 45 DAT; 1500, 2000 and 2500 ppm at 90 DAT). In addition, by 90 DAT 11%, 22% and 78% of plants drenched with 1500, 2000 and 2500 ppm TDZ, respectively, had died.

Results of the 1997 test showed a stimulation in shoot formation in 'Harbour Dwarf' nandina, regardless of MOA, minimal effects on growth index, and slight phytotoxicity with spray applications up to 2500 ppm, but more severe phytotoxicity, including death, with drench application of 1500, 2000 and 2500 ppm TDZ.

1998. Based on 1997 results, the highest spray and drench rates were changed to 3000 ppm and 1500 ppm, respectively. As in 1997, shoot counts increased linearly with increasing spray rates of TDZ, by 1000% at 45 DAT and 343% at 90 DAT (Table 3). Across all rates, shoot counts of spray-treated plants were 600% higher than those of drenched plants and controls at 45 DAT, and 188% and 229% higher, respectively, at 90 DAT. Growth index was unaffected by spray rate but was about 19% higher than that of drench-treated plants. In contrast to 1997, the phytotoxicity rating was unaffected by TDZ foliar sprays. Shoot counts of drench-treated plants were not affected by TDZ rate, probably due to severe phytotoxicity. The phytotoxicity rating increased quadratically at 45 and 90 DAT. The lowest rating 3, was for plants drenched with the lowest rate of TDZ, and increased to 5 for plants drenched with 1250 ppm TDZ. Phytotoxicity ratings of drench-treated plants were about twice as high as those of sprayed plants or controls at both sampling dates. Phytotoxicity of TDZ drenches was reflected in the death of plants in all treatments: 500 ppm (20%), 750 ppm (60%), 1000 ppm (80%), 1250 ppm (100%), and 1500 ppm (70%). Due to the severe phytotoxicity from TDZ drenches and the lack of phy-

Table 4. Shoot counts and growth index of 'Harbour Dwarf' nandina treated with TDZ, 1999.

TDZ rate (ppm)	Shoot counts			Growth index[z]		
	30 DAT[y]	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
0	1.0	1.1	1.9	44.9	47.1	49.5
1000	1.7	2.3	2.6	52.5	51.6	52.4
1500	4.1	4.2	4.1	52.4	50.9	51.4
2000	3.5	5.1	4.9	49.9	50.7	50.6
2500	4.5	4.3	6.4	51.5	52.8	54.0
3000	3.2	2.9	2.8	50.2	52.5	52.9
3500	4.9	5.4	7.2	48.1	49.0	50.8
4000	4.1	6.2	7.1	47.1	48.5	49.5
Significance[x]	L***Q**	L***Q**	L***	Q***	Q**	Q*

[z]Growth index = (height + $width_1$ + width 90° to $width_1$) ÷ 3.

[y]DAT = days after treatment.

[x]Nonsignificant (NS), linear (L), quadratic (Q) or cubic (C) response at $P = 0.05$ (*), 0.01 (**) or 0.001 (***); control included in regression analysis.

totoxicity from foliar sprays, drenches were not included in subsequent experiments and the highest spray rate was increased to 4000 ppm.

1999. With increasing TDZ rates, shoot counts increased quadratically at 30 DAT (390%) and 60 DAT (464%) and linearly at 90 DAT (279%) (Table 4). At all sampling dates counts were numerically highest in plants receiving a foliar spray of 3500 or 4000 ppm TDZ. Growth index, while quadratically influenced by TDZ rate, increased minimally (9% to 17%) over that of control plants. Phytotoxicity rating was not affected by TDZ rate (data not shown).

2000. There were no significant interactions between TDZ spray rate and cultivar for shoot counts or phytotoxicity rating at any of the sampling dates, hence only main effects are reported. Shoot counts increased linearly with increasing TDZ rate, by 529% at 30 DAT and 218% at 90 DAT, and quadratically at 60 DAT, up to 430% (Table 5). 'Harbour Dwarf' nandina developed more new shoots than 'Compacta' nandina at 30 DAT (35%), 60 DAT (28%) and 90 DAT (18%), possibly due to the smaller size of 'Compacta' nandina at treatment. Phytotoxicity rating increased linearly with increasing TDZ rate at 30 and 60 DAT, and was similar for the two cultivars. Symptoms consisted only of slight chlorosis of immature foliage. At 90 DAT the phytotoxicity rating was unaffected by TDZ rate.

In summary, shoot formation in 'Harbour Dwarf' nandina was stimulated by foliar sprays of TDZ in four experiments and by substrate drenches in two experiments. Foliar sprays also enhanced shoot formation in 'Compacta' nandina in one experiment. Phytotoxicity from foliar TDZ sprays was minimal and transitory. However, drench applications, especially at higher rates, were severely phytotoxic resulting in foliar

Table 5. Effects of TDZ foliar sprays on shoot counts and phytotoxicity ratings of 'Harbour Dwarf' and 'Compacta' nandinas, 2000.

TDZ rate (ppm)	Shoot counts[z]			Phytotoxicity rating[y]		
	30 DAT[x]	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
0	0.7	1.0	1.7	1.2	1.6	1.9
500	2.5	3.6	3.9	1.3	1.9	2.2
1000	2.7	4.4	4.3	1.6	1.9	2.2
1500	2.6	3.4	3.4	1.5	1.8	2.0
2000	3.1	4.3	3.9	1.7	1.8	2.1
2500	4.3	5.3	5.2	2.1	2.1	2.1
3000	3.6	5.1	5.4	2.3	2.3	2.1
3500	3.9	4.7	5.1	2.1	2.1	2.4
4000	4.4	5.3	5.3	2.2	2.0	2.1
Significance[w]	L***	L***Q***	L***	L***	L***	NS
'Harbour Dwarf'	3.5a[v]	4.6a	4.6a	1.7a	2.0a	2.2a
'Compacta'	2.6b	3.6b	3.8b	1.8a	1.9a	2.0a

[z]Total number of lateral and basal shoots.

[y]Phytotoxicity rating: 1 = normal, healthy; 2 = chlorotic immature foliage; 3 = chlorotic, distorted immature foliage; 4 = necrotic immature and/or mature foliage; 5 = dead.

[x]DAT = days after treatment.

[w]Nonsignificant (NS) or significant linear (L) or quadratic (Q) regression response at $P = 0.001$ (***). Rate × cultivar interactions were not significant, hence, only main effects are reported.

[v]Mean separation by single degree of freedom orthogonal contrasts, $P = 0.05$.

distortion, necrosis, and plant death. Based on these results, foliar sprays of up to 4000 ppm TDZ can be used to stimulate shoot formation in nandina with minimal adverse effects. While effective in increasing shoot formation, drenches have limited potential use on nandina due to severe phytotoxicity.

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