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Nitrogen Source Affects Growth and Quality of Bougainvillea

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Bougainvillea is a popular flowering landscape and container plant in mild climates, but can be difficult to grow in containers. Iron deficiency chlorosis is a common disorder in container-grown plants, and may have multiple causes. High soil pH, root rots, soluble salt injury, or poor soil aeration are usually associated with Fe deficiency symptoms in bougainvillea (Broschat, unpubl. data). Fertilizer N form can also affect Fe deficiency in some plants (Colgrave and Roberts, 1956; Conover and Poole, 1982; Nelson and Selby, 1974; Sideris and Young, 1956). The purpose of this study was to determine the effects of N source on the growth, quality, and flowering of container-grown bougainvillea.

Materials and methods

Experiment 1*.* Liners of *Bougainvillea* 'Brasiliensis' were planted into three-liter plastic pots containing a 5 pine bark: 4 sedge peat: 1 sand substrate (by volume) amended with 4.9 kg dolomite and 880 $g \cdot m^{-3}$ of Micromax micronutrient blend (Scotts Co., Marysville, OH). Plants were fertilized every 2 weeks with 30, 60, or 90 ml/container of a solution containing P at 0.38 $mg \cdot ml^{-1}$, K at 1.66 $mg \cdot ml^{-1}$, and Mg at 0.55 $mg \cdot ml^{-1}$ from monosodium phosphate, potassium sulfate, and magnesium sulfate, plus N at 1.70 $mg \cdot ml^{-1}$ from either ammonium sulfate, sodium nitrate, or half ammonium sulfate and half sodium nitrate. This resulted in N application rates of 50, 100, and 150 mg N/ pot. This experiment was set up on 28 June 1995. Twenty replicate plants were assigned to each fertilizer rate X N-source treatment and were arranged in a completely randomized design in an open-sided greenhouse (max. photosynthetic photon flux=1890 $mE \cdot m^{-2} \cdot sec^{-1}$). Plants were irrigated daily with about 1.5 cm of water from overhead irrigation. Temperature in this greenhouse ranged from a min of 15C to a max of 37C.

Plants were rated subjectively for chlorosis severity on 4 Jan. 1996. A rating scale of 0 to 5 was used (0=dark green, no chlorosis, 3=moderate chlorosis, 5=dead from severe chlorosis). Plant dry mass, number of flowers, and substrate pH were also determined on that date. Fertilizer source effects were determined by analysis of variance. Fertilizer rate effects were determined by regression analysis.

Experiment 2*.* Liners of *Bougainvillea* "Brasiliensis' were potted on 13 Nov. 1996 using the same substrate and containers as in Experiment 1. Phosphorus and K were provided by 3.9 g of superphosphate (0N-8.7P-0K) and 6.9 g of sulfur-coated potassium sulfate (Lesco, Inc., Rocky River, OH) per container every 3 months. Fertilizer treatments consisted of biweekly per pot applications of 50 ml of a solution containing N at 6.3 $mg \cdot ml^{-1}$ from urea, ammonium sulfate, diammonium phosphate, ammonium chloride, ammonium nitrate, sodium nitrate, potassium nitrate, or calcium nitrate. Four other materials, sulfur-coated urea (Lesco, Inc.), two resin-coated ureas (Osmocote 38N-0P-0K, Scotts Co., Marysville, OH and Polycoated urea, Lesco, Inc.), and resin-coated potassium nitrate (Haifa Chemicals, Haifa, Israel) were applied once at rates of 3.8 g N/pot. The total amounts of N applied over a 6-month period by liquid and controlled-release fertilizer were equivalent. Ten replicate containers per treatment were arranged in a completely randomized design as in Experiment 1.

Chlorosis ratings, plant dry mass, and number of flowers were recorded after 3 months, as in Experiment 1. Leaf samples consisting of the youngest fully-expanded leaves were collected from all plants and analyzed for total Fe and N content. Pour-through substrate solution samples were collected 5 days after a liquid fertilizer application during the final week of the experiment. These leachate samples were analyzed for ammonium-N, nitrate-N, Fe, EC, and pH. Since small (1-2 mm) necrotic lesions appeared on the older leaves of some plants shortly after the initial treatment, the number of leaves with lesions per plant were counted on 6 Dec. 1996. Data were analyzed by regression analysis or by analysis of variance, with mean separations by the Waller-Duncan k-ratio method.

Results and discussion

In the first experiment *Bougainvillea* 'Brasiliensis' fertilized with only sodium nitrate as a N source exhibited more severe chlorosis symptoms than those receiving only ammonium sulfate (Table 1). Plants receiving ammonium sulfate plus sodium nitrate had intermediate chlorosis ratings. Bougainvilleas fertilized with ammonium sulfate had an average of 47.9 flowers/plant vs. 4.4 for those receiving sodium nitrate (Table 1). Plant dry mass was also much larger for bougainvilleas fertilized only with ammonium sulfate.

The fertilizer source by rate interaction was highly significant for plant dry mass, but was not significant for chlorosis severity and number of flowers (Table 1). When fertilization rate effects were analyzed within each N source treatment, the following trends were evident: Increasing fertilization rate within the ammonium sulfate treatments had no effect on chlorosis severity, but increased the number of flowers and plant dry mass (Table 1). Increasing fertilization rate within the sodium nitrate treatments increased chlorosis severity, but had no effect on number of flowers or dry mass. Increasing the overall fertilization rate (data from both fertilizer sources combined) slightly increased plant chlorosis severity, but also significantly increased flower number and plant dry mass (data not shown).

The first experiment suggests that bougainvilleas respond positively in terms of growth (as measured by dry mass) and flowering to increasing amounts of ammonium sulfate, but ammonium sulfate had little or no effect on chlorosis severity. On the other hand, chlorosis increased with increasing amounts of sodium nitrate, but increasing sodium nitrate had no effect on flowering or growth. Although flower production was much greater for plants fertilized with ammonium sulfate than with sodium nitrate, the number of flowers appeared to be related to plant size and vigor. Still, ammonium sulfate-fertilized plants averaged about 5 flowers, ammonium sulfate plus sodium nitrate about 4, and sodium nitrate about 3 flowers per g of dry mass. Both plant size and vigor were greatly reduced in chlorotic plants.

Fertilization with only nitrate-N fertilizer has been associated with Fe deficiency and reduced growth in *Calathea* (Conover and Poole, 1982), conifers (Nelson and Selby, 1974), azaleas (Colgrave and Roberts, 1956) and pineapple (Sideris and Young, 1956). Nitrate fertilizers are known to increase soil and plant tissue pH, whereas ammonium fertilizers have the opposite effect (Kirkby and Mengel, 1967). Container substrate pH in the first experiment averaged 6.43 for the ammonium sulfate-treated plants, 6.46 for ammonium sulfate plus sodium nitrate, and 6.82 for sodium nitrate. Although flower number and plant dry mass had significant negative correlations with substrate pH (r=0.60, P=0.019 and r=0.58, P=0.022, respectively), the negative correlation of chlorosis rating with substrate pH was only marginally significant (r=0.47, P=0.076).

The positive effects of ammonium sulfate fertilization are believed to be due to the NH4+ ion, rather than SO4=, since all plants received adequate amounts of SO4= in the form of K2SO4. Although the increased chlorosis severity associated with sodium nitrate fertilization could be due to the Na+ ion, there is no support in the literature for such an interaction. The second experiment was set up to eliminate the possibility of Na+ or SO4 = affecting these results.

In the second experiment, where bougainvilleas were grown with a variety of ammonium or nitrate sources, the largest plants were those receiving controlled-release ureas (Table 2). Plant size was intermediate for the soluble urea and ammonium sources and smallest for nitrate-fertilized plants. Number of flowers was highest for plants receiving controlled-release ureas, but all soluble ammonium and nitrate salts produced equally low numbers of flowers. Chlorosis severity also was lowest for plants receiving controlled-release ureas, intermediate for most of the soluble urea and ammonium sources, and highest for nitrate-fertilized plants. The number of leaves with small necrotic lesions was highest for sodium, potassium, and calcium nitrate-fertilized plants and lowest for those receiving urea or ammonium salts, or controlled-release potassium nitrate. Thus, plant quality, as measured by these four variables, was generally poorest for plants receiving nitrate-N, best for those receiving controlled-release urea, and intermediate for those receiving soluble urea or ammonium fertilizers.

The physiological basis for this association of chlorosis and leafspotting with nitrate fertilization is less clear. The chlorosis symptoms observed appeared to be classical Fe deficiency symptoms, with sharply delimited green veins on otherwise yellow or whitish new leaves. New leaf size was also greatly reduced in more severe cases. Leaf Fe concentrations were not correlated with fertilizer treatments, chlorosis severity, or with any of the other plant quality variables (data not shown). However, the role of Fe deficiency in this disorder cannot be completely ruled out since leaf Fe concentrations often are not correlated with plant quality or chlorosis severity (Mills and Jones, 1996).

Nitrate fertilizers increased substrate pH to a greater extent in Experiment 2 (x = 7.21 for nitrate versus 6.28 for ammonium) than in Experiment 1. Although the lowest substrate pH values were those from ammonium chloride and diammonium phosphate treatments, these treatments did not result in the best quality plants. Substrate nitrate concentrations were equivalent for containers fertilized with soluble ammonium and nitrate fertilizers, suggesting that nitrification of ammonium was occurring during this study. The very low substrate nitrate and ammonium levels for S-coated urea can be attributed to its having released most of its N during the 3-month study. On the other hand, Osmocote 38N-0P-0K is claimed to have a 12 to 14 month life at 21C. It apparently released N at a very slow rate due to its heavy coating.

There were no significant correlations of any plant quality variables with substrate EC. Leafspot severity was negatively correlated only with substrate ammonium-N levels ($r = -0.25$, $P=0.006$). Substrate pH was strongly affected by N form ($P < 0.0001$) in Experiment 2, but was less strongly correlated with plant dry mass ($r = -0.20$, $P = 0.025$) and with chlorosis severity ($r = 0.23$, $P = 0.011$). Leafspot severity was significantly affected by N form ($P< 0.0001$) and was positively correlated with substrate pH ($r = 0.39$, $P < 0.0001$). Leafspot severity was only marginally related to substrate nitrate-N concentrations ($r = 0.16$, $P = 0.076$). Although pH-induced Fe deficiency associated with nitrate fertilization appears to be the primary cause of the chlorosis in bougainvillea, it is possible that factors other than substrate pH, nitrate-N, ammonium-N, or EC may also be involved in this problem. The leafspotting disorder appears to be a phytotoxic response associated more with a lack of ammonium-N than the presence of nitrate-N.

Conclusions

These studies showed that N source strongly affects the growth and quality of bougainvillea. Although the physiological reasons are unclear, plants fertilized with controlled-release ureas were the largest, had the most flowers, and the least chlorosis and leafspotting. Those receiving only nitrate N were severely stunted, extremely chlorotic, had a high incidence of leafspotting and leafdrop, and produced few flowers. Water-soluble urea and ammonium salts produced plants of intermediate quality. Thus, bougainvillea growers should use controlled-release urea fertilizers and avoid the use of nitrate fertilizers for optimum plant growth and quality .

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Table 1. Response of *Bougainvillea* 'Brasiliensis' to fertilizer source and rate. Experiment 1.

N Source	Biweekly fertilizer rate (mg N/pot)	Chlorosis rating[z]	No. of flowers	Dry mass (g)
Ammonium sulfate	50	0.8	25.2	4.9
	100	0.8	63.6	10.8
	150	1.2	55.4	12.5
Mean		0.9	47.9	9.3
Fertilizer rate		NS	*	***
Ammonium nitrate +				
Sodium nitrate	50	1.4	9.2	3.2
	100	1.8	20.9	5.8
	150	1.4	30.6	7.2
Mean		1.5	20.2	5.4
Fertilizer rate		NS	*	***
Sodium nitrate	50	1.9	3.6	1.5
	100	2.1	6.3	1.9
	150	2.9	3.3	1.3
Mean		2.3	4.4	1.5
Fertilizer rate		*	NS	NS
Overall effects				
N Source		***	***	***
N Rate (L)		*	**	***
N Rate (Q)		NS	NS	NS
N Source X Rate (L)		NS	NS	***

[z]0=dark green, no chlorosis, 3=moderate chlorosis, 5=dead from severe chlorosis

*,**, ***, and NS indicate significance at .05, .01, .001, and non-significant, respectively.

Table 2. Effects of N source on dry mass, number of flowers, chlorosis severity, and number of leaves with necrotic lesions in *Bougainvillea* 'Brasiliensis'.

N Source	Dry mass (g)	Number of	Chlorosis	No. leaves	Leaf Fe (µg ·	Substrate pH	Substrate	Substrate	EC (dS ·

		flowers	severity[z]	with lesions	g^{-1})		NO_3-N (µg · ml^{-1})	NH_4-N (µg· ml^{-1})	m^{-1})
S-coated urea	12.1 ab[v]	41.9 b	0.8 c	1.4 c	217 b	6.89 cd	3.3 c	0.1 c	3.32
Resin-coated urea[y]	13.6 a	54.6 a	1.1 c	0.3 c	158 cd	6.70 de	7.8 c	0.3 c	2.40
Urea	8.0 cd	4.6 d	1.7 b	0.0 c	439 a	6.35 f	165.3 a	5.0 c	1.93
Resin-coated urea[x]	11.3 abc	22.8 c	1.9 b	0.2 c	160 cd	6.66 f	119.7 ab	5.9 c	2.56
Ammonium sulfate	8.8 bcd	3.7 d	1.9 b	0.1 c	165 cd	5.99 g	110.0 ab	27.5 b	2.32
Diammonium phosphate	5.6 def	1.2 d	2.5 a	0.2 c	129 d	5.59 h	117.3 ab	31.5 b	2.37
Ammonium chloride	7.0 de	0.9 d	2.1 b	0.3 c	144 cd	5.76 h	129.9 a	39.4 a	3.25
Ammonium nitrate	7.9 d	3.3 d	1.8 b	0.1 c	185 bc	6.25 f	158.8 a	6.6 c	2.18
Sodium nitrate	3.6 f	2.3 d	2.7 a	8.3 a	129 d	7.31 ab	154.1 a	0.0 c	2.80
Potassium nitrate	3.2 f	2.5 d	2.8 a	5.5 b	143 cd	7.20 b	190.9 a	0.1 c	2.87
Calcium nitrate	2.8 f	3.3 d	2.8 a	6.0 ab	133 d	6.93 c	138.6 a	0.1 c	2.67
Resin-coated potassium nitrate[w]	4.5 ef	8.8 d	2.7 a	1.4 c	165 cd	7.45 a	23.1 bc	0.1 c	2.55
N Source	***	***	***	***	***	***	***	***	NS

[z]0 = dark green, no chlorosis, 3 = moderate chlorosis, 5 = dead from severe chlorosis

[y]Osmocote 38N-0P-0K

[x]Lesco Poly-coated urea

[w]Haifa Multicote

[v]Mean separation by the Waller-Duncan k-ratio method, k = 100

*****indicates significance at P<.001**

Control of Royal Palm Bug with Imidacloprid

F. W. Howard and Alan Stopek

(adapted from *Principes* 42: 80-84 (1998))

The royal palm bug, *Xylastodoris luteolus* Barber (Hemiptera: Thaumastocoridae), feeds exclusively on royal palms (*Roystonea regia* (H. B. K.) O.F.Cook. It has been reported from Cuba and Florida. Extremely small piercing-sucking insects, the adults of *X. luteolus* are elongate, 2-2.5 mm long and of a pale yellow-green (luteous) color (Baranowski, 1958).

The bugs begin to attack fresh leaves as they are unfolding. This results in small, yellow spots scattered on the lower frond surfaces. As the bug populations increase and more bugs feed, fronds become necrotic, turning brown and desiccated. Damaged fronds eventually become tattered due to wind action, and sunlight bleaches them to a lighter grey color. As each new leaf is produced about monthly, the bugs attack them so by the end of the summer a large portion of the crown may be damaged (Baranowski, 1958). Most observers would agree that the bugs do more damage to royal palms during some years than others.

Reinert (*op. cit*.) identified three species of spiders that preyed on royal palm bugs, and suggested that they, along with heavy rains, were major factors in the natural control of the species. However, we have observed dense populations of the bugs on palm fronds during very rainy periods, and whether populations of these prolific bugs are regulated by spiders and rain alone is still open to question. Other natural enemies or abiotic factors that may regulate royal palm bug populations in Florida have not been identified.

When royal palm bugs reach damaging populations, chemical control is the only known method of controlling them. But chemical control of *X. luteolus* is difficult because of the tall heights of the palms: Baranowski (*op. cit*.) reported that *X. luteolus* seldom attacks palms of less than 4 m in height. Reinert (1975) found that foliar applications of oxamyl, monocrotophos, and carbofuran reduced royal palm bug populations from more than 68 to less than 3 bugs per 3 leaflets. Unfortunately, because of chemical drift, none of these highly toxic chemicals would be suitable for foliar applications to tall palms, especially in cities.

Root drenches of oxamyl and monocrotophos reduced numbers of bugs per 3 leaflets after 2 weeks, but after 4 weeks the populations were well into recovery (Reinert, 1975). Again, these chemicals were applied in a research study; they may not be suitable for widespread use as root drenches, especially under the edaphic and hydrological conditions of southern Florida (chemicals travel fast in the sandy soil and the water table is relatively high). Dimethoate shares some of the undesirable characteristics of other synthetic pesticides, but used as a drench was probably the safest of the methods tested. This treatment reduced the bug populations from 113.2 to 32.8 bugs per 3 leaflets after four weeks (Reinert *op. cit*.). Because about 1/3 of the population remained, it would have rebounded quickly. In summary, a practical method of controlling royal palm bug has not been available for years.

A relatively new insecticide, imidacloprid, seemed promising for this use. It can be applied without a special use permit. This chemical was discovered and developed as an insecticide by Bayer. It is the active ingredient in several of Bayer's products, including Admire or Gaucho in different countries for use on various food crops, Marathon for use on ornamentals in greenhouses and Merit for use on ornamentals and turf grass out-of-doors. Imidacloprid is considered to be a pesticide of unusually low mammalian toxicity. Animal toxicity data from the Material Safety Data Sheet for this product lists oral LD50 rates as 1858-2591 mg/kg and the dermal LD50 rate as >2000. When applied as a root drench, it remains for long periods in the soil and is taken up slowly. For this reason, there is typically a delay of a few weeks to a few months, depending partly on the size of the plant, before the chemical becomes active against the target pest. Once active, it may remain so for an extended period as long as the plant continues to take up the chemical. These characteristics make it potentially very useful for controlling royal palm bug. The present report communicates results of a test of imidacloprid for effectiveness in controlling royal palm bug.

Methods

The experiment was conducted in the town of Palm Beach, on sandy soil. Field evaluations were conducted at two sites where royal palm bug damage had been severe in previous years. Site #1 was adjacent to Lake Worth. Site #2 was about 1.5 km inland on the island from Lake Worth.

Four palms were treated on each site with 56.7 g (2 oz.) of Merit 75 WP mixed in 9.5 l (2.5 gal) of water, the equivalent of 42.5 g of imidacloprid per palm. Half of this rate was applied to one palm at one of the sites. This mixture was poured from a bucket very slowly into the soil immediately surrounding each palm. Mulch layers, if present, were scraped back, then returned after the drench treatment. At both sites, every other palm was treated, leaving alternate palms as controls. The treatments were applied on 21 January 1997.

Damage assessment was conducted 51 days later (March 13) and 108 days later (May 8). The first and second youngest leaves of treated and control palms were observed from the ground for evidence of royal palm bug damage. Because we couldn't reach the fronds of all the palms, we didn't obtain statistically analyzable data to compare populations on treated palms and controls. However, we examined many fronds closely to confirm the association between bugs and their damage, and counted the numbers of bugs per leaflet on several fronds as an indication of the severity of the infestations at the study sites.

Results and Discussion

Damage assessment. Prior to application of treatments on 21 January, at site #1 there was only minor damage due to royal palm bugs, but some fronds had necrotic areas that we attributed to wind damage of a storm in November. At Site #2, there were brown necrotic streaks typical of royal palm bug damage on some younger fronds of some palms. Royal palm bug damage had been especially severe at this site in past years (Richard Horne, Parks Foreman, Palm Beach Public Works Department, Personal Communication).

When the palms at both sites were examined 51 days after application of treatments, bug damage had progressed since January on some of the untreated palms, but there was no conclusive difference between treatment and controls.

When the palms were examined 108 days after application of treatments, the fronds of the seven palms treated with 56.7 g of imidacloprid were virtually free of royal palm bug damage, except for damage on older fronds which may have been caused by either bugs, wind or cold spells prior to the treatment. The single palm treated with 28.35 g of imidacloprid was similarly free of damage. In contrast, the first and second fronds of the eight untreated palms previously selected as controls had extensive damage typical of royal palm bugs. The tissue of these leaves was mostly brown with some small green areas remaining. The damage was very conspicuous from the ground.

As a further observation, a total of 15 royal palms in a row at Site #1, including the 4 treated palms and 11 untreated palms, were examined 108 days after treatment. The 4 undamaged (treated) palms contrasted dramatically with the 11 untreated palms, which were all severely damaged by royal palm bug.

Observations on royal palm bugs. On 21 January, we counted a mean of 3.0 (range: 2-5) royal palm bugs per leaflet on 10 leaflets randomly selected from palms at Site #1. At Site #2, where there was typical royal palm bug damage on younger fronds of some palms, a mean of 59.1 (range: 8-17) royal palm bugs per leaflet were counted on 7 leaflets from one of these palms.

When examined 108 days after treatments, there were abundant royal palm bugs on young damaged fronds of three of the untreated palms that we could reach. On a leaflet that we selected as harboring a typical infestation, we determined that there were about 300 of the bugs, including adults and nymphs. There were only about 15 bugs per leaflet on the fourth untreated palm that we examined. Bug damage was as severe on this palm as on the other untreated palms, suggesting that the population had been higher and was now declining. On the treated palms, 0-5 royal palm bugs per leaflet were observed.

We observed no evidence of important natural enemies of royal palm bugs on any of the palms.

These preliminary data on bug populations show that royal palm bugs occurred at levels of up to 300 bugs per leaflet in association with severe damage. More frequent observations on a larger number of palms would be required for conclusive data on population dynamics of this bug. However, the results of damage assessment clearly showed that the treatments prevented damage by royal palm bugs.

The delayed period before imidacloprid treatments become effective and the period during which they remain effective in controlling royal palm bug remains unknown. Since it protected the youngest two leaves, and in royal palm a new leaf is produced about monthly (Baranowski, 1958), it was apparently effective for at least 2 months.

A disadvantage of this product for this use is its cost. At current prices the cost of treatment at the lowest rate used in this evaluation (28.4 g) is $19 per palm. However, it may be applicable to limited areas, e. g. around tourist hotels. Imidacloprid has been applied to royal palms on Fisher Island, an affluent development in Miami, for control of royal palm bugs (Eric Messersmith, Pest Control Specialist, Montgomery Foundation, Miami, FL, Personal communications).

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