Olivine: A Potential Magnesium Source for Container Production[1]

Stuart L. Warren[2] and James E. Shelton[3]
Department of Horticultural Science
North Carolina State University
Raleigh, NC 27695-7609

Abstract

Fraser photinia, 'Plumosa Compacta Youngstown' juniper and 'Hino-Crimson' azalea were grown in pine bark amended with a factorial combination of five rates (0, 0.9, 1.8, 3.6 and 7.2 kg/m^3) (0, 1.5, 3, 6 and 12 lbs/yd^3) of olivine, a magnesium ortho silicate containing 27% Mg and four particle sizes of olivine. Calcium carbonate (38% Ca) at 2.4 kg/m^3 (4 lbs/yd^3) was incorporated into all olivine treatments. A separate treatment utilizing 4.2 kg/m^3 (7 lbs/yd^3) dolomitic limestone (22% Ca, 11% Mg) was also included to serve as a comparison to dolomitic limestone. In general, Mg concentration in the media increased with increasing olivine rate and decreasing particle size. Media P, K and Ca concentration and pH were not affected by olivine rate or particle size, nor were they significantly different from the treatment containing dolomitic limestone. Foliar Mg increased with increasing olivine rate in all species. Foliar K decreased with increasing olivine rate for 'Hino-Crimson' azalea and Fraser photinia. Top dry weight of 'Plumosa Compacta Youngstown' juniper was not affected by olivine rate or particle size while top dry weight of 'Hino-Crimson' azalea and Fraser photinia increased quadratically with increasing olivine rate, with the maximum occurring at 0.9 kg/m^3 (1.5 lbs/yd^3) and 1.8 kg/m^3 (3.0 lbs/yd^3), respectively. These maximum top dry weights were significantly heavier than plants grown with dolomitic limestone.

Index words: dolomitic limestone, calcium carbonate, mineral nutrition, container production.

Species used in this study: Fraser photinia (*Photinia × fraseri* Dress); 'Plumosa Compacta Youngstown' juniper (*Juniperus horizontalis* Moench 'Plumosa Compacta Youngstown'); and 'Hino-Crimson' azalea (*Rhododendron obtusum* Planch. 'Hino-Crimson').

Significance to the Nursery Industry

When using dolomitic limestone as a Mg source, growers cannot adjust Mg level in the media independently of calcium and pH. Data herein suggest that olivine can serve as a source of Mg for container production allowing growers to raise or lower Mg concentrations in the media without affecting Ca supply or pH. However, further research is needed to determine the proper combination of rate and particle size.

Introduction

Preplant incorporation of dolomitic limestone into container potting medium to provide Ca and Mg and adjust pH is common practice. Researchers have evaluated the effects of dolomitic limestone on growth of ornamentals with results varying from inhibition (2, 16, 17), stimulation (7, 14) or no effect (3) depending upon rate, plant species, water quality and medium. Studies have reported that MgO combined with $CaCO_3$, and $MgSO_4$ in combination with $CaSO_4$ resulted in greater plant growth compared to plants grown with dolomitic limestone (1, 4, 11). Thus, these data suggest the possibility of improving growth by replacing dolomitic limestone in container medium. However, since Ca and Mg are essential for maximum plant performance alternative sources of Ca and Mg need to be identified and evaluated before dolomitic limestone can be eliminated.

Olivine, a magnesium ortho silicate (Mg_2SiO_4), is a natural mineral which has shown some potential as a Mg source in field applications (9). Therefore, the objective of this research was to determine the potential of olivine as a Mg source for container production.

Materials and Methods

The study, a 5 × 4 factorial in a randomized complete block design with eight replications, was conducted on a gravel pad located at the Mountain Horticultural Crops Research Station, Fletcher, NC. The two main factors were five rates of olivine (27% Mg): 0, 0.9, 1.8, 3.6 and 7.2 kg/m^3 (0, 1.5, 3, 6 and 12 lbs/yd^3), providing 0, 0.24, 0.49, 0.97 and 1.94 kg/m^3 (0, 0.41, 0.82, 1.62 and 3.24 lbs/yd^3) Mg; and four particle sizes of olivine (Table 1), hereafter referred to as 20, 40, 70 or 200.

Each olivine treatment was combined with 2.4 kg/m^3 (4 lbs/yd^3) calcium carbonate (38% Ca) providing 0.91 kg/m^3 (1.52 lbs/yd^3) Ca and was incorporated into a milled pine bark medium [(<13 mm) (0.5 in)]. For comparison to dolomitic limestone, an additional treatment of 4.2 kg/m^3 (7 lbs/yd^3) dolomitic limestone (22% Ca, 11% Mg), providing 0.92 kg/m^3 (1.54 lbs/yd^3) Ca and 0.46 kg/m^3 (0.77 lbs/yd^3) Mg (no olivine), was included. Micro-Start (Parker Fertilizer Co., Inc., Sylacauga, AL) was incorporated into all treatments at 3.0 kg/m^3 (5.0 lbs/yd^3).

Rooted stem cuttings of Fraser photinia, 'Plumosa Compacta Youngstown' juniper and 'Hino-Crimson' azalea were transplanted into 3.8 liter (#1) containers on May 11, 1987. Nine g (0.3 oz) of Super Nursery Special 20N-2.2P-8.3K

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[2]Associate Professor.

[3]Associate Professor, Dept. of Soil Science.

Table 1. **Particle size distribution of four particle sizes of olivine.**

Particle size range (mm)	Olivine particle size 20	40	70	200
		(% wt)		
>6.3	11.5	0	0	0
6.3–4.0	67.6	0	0	0
4.0–2.8	17.1	0	0	0
2.8–2.0	2.2	0	0	0
2.0–1.4	1.5	0	0	0
1.4–1.0	0	0	0	0
1.0–0.7	0	7.5	0	0
0.7–0.5	0	72.2	18.8	0
0.5–0.3	0	12.6	49.5	0
0.3–0.2	0	3.8	24.3	0.7
0.2–0.1	0	2.4	5.9	5.4
<0.1	0	1.5	1.5	93.9

(20-5-10) (Parker Fertilizer Co., Inc, Sylacauga, AL) was surface applied to all containers on May 15, 1987 (Day 0). Media soluble salts were monitored weekly via the Virginia Tech. extraction method (13). When soluble salt levels dropped below 0.50 mMhos on July 14 and Aug. 28, 1987, Super Nursery Special was reapplied at the above rate. Plants received 1.3 cm (1/2 in) of water daily via overhead irrigation. Plants were visually evaluated for Mg deficiency every 30 days. On Oct. 13, 1987, tops (aerial tissue) were removed, dried at 70°C (160°F) for 96 hr and weighed. Since Mg deficiency occurs in the oldest leaves first, leaves from the bottom 1/3 of each plant were removed and ground in a Wiley mill to pass a 40 mesh (0.425 mm) screen. Each tissue sample (1.25 g) was combusted at 490°C for 6 hr. The resulting ash was dissolved in 10 ml 6 N HCl and diluted to 50 ml with distilled deionized water. Potassium, Ca and Mg concentrations were determined by inductively coupled plasma emission spectroscopy. Nitrogen was determined using 10 mg samples utilizing a Perkin Elmer 2400 CHN elemental analyzer. All foliar analyses were conducted at the Analytical Service Laboratory, Dept. of Soil Science, N. C. State Univ.

Medium solution from 'Plumosa Compacta Youngstown' juniper containers were sampled by the Virginia Tech. extraction method (13) every 15 days for 135 days after initiation of the study (DAI). A pour-through sample was obtained by pouring 150 ml (5 oz) of distilled water on the medium surface 2 hr after irrigation and collecting the leachate. Samples were filtered through Whatman #1 filter paper and frozen until analysis. Phosphorus, K, Ca and Mg concentrations were determined by inductively coupled plasma emission spectroscopy. Irrigation water sampled at each collection date, averaged in mg/liter: 1.3 P, 2.8 K, 4.9 Ca and 1.6 Mg. All media solution analyses were conducted at the Analytical Service Laboratory, Dept. of Soil Science, N. C. State Univ.

Data were subjected to analysis of variance and regression analysis (8). Where appropriate, means were separated using LSD. Means from the dolomitic limestone treatment were compared to the olivine treatments using Dunnett's T test at the 5% level.

Results and Discussion

Media P, K and Ca concentration and pH were not affected by olivine rate or particle size at any sample time nor were they significantly different from the treatment containing dolomitic limestone (data not presented). Magnesium concentration in the media was affected by olivine rate and particle size at all sample times except 120 DAI (Table 2). Magnesium concentration in the media maintained by the 3.6 (6.0) and 7.2 kg/m^2 (12 lbs/yd^3) rate of olivine 200 was similar to media Mg concentration maintained by dolomitic limestone (Fig. 1A). Magnesium concentrations in the media at 0 kg/m^3 (no Mg source) were less than 1.5 mg/liter at all sample times (data not presented). Magnesium concentrations in the media increased up to 75 DAI then decreased throughout the remainder of the study for all rates of olivine 200. Olivine 40 followed a similar trend but at a much lower concentration (Fig. 1B). Magnesium concentrations of olivine 20 and 70 displayed the same patterns as 40 with the quantitative values less than and greater than olivine 40, respectively (data not presented). In general, Mg concentration increased with increasing olivine rate and decreasing particle size. These data suggest that by combining the proper rate and particle size, it would be possible to provide a specific range of Mg concentration in the media solution, providing the grower the ability to independently adjust Mg concentration in the media compared to dolomitic limestone.

Table 2. **Container media Mg concentration and top dry weight of 'Hino-Crimson' azalea, 'Plumosa Compacta Youngstown' juniper and Fraser photinia as influence by olivine rate and particle size (PS).**

Source of variation	Container media Mg concentration (mg/liter) — Days after initiation of study 15	30	45	60	75	90	105	120	135
Olivine rate (R)	**[z]	**	**	**	**	**	*	NS	*
Olivine PS	**	**	**	**	**	**	**	**	**
R × PS	**	**	**	*	**	**	NS	NS	*

	Top dry weight (g) — 'Plumosa Compacta Youngstown' juniper	'Hino-Crimson' azalea	Fraser photinia
Olivine rate	NS[z]	**	*
Olivine PS	NS	**	**
R × PS	NS	NS	NS

[z]NS,*,**Nonsignificant or significant at $p \le 0.05$ or $p \le 0.01$, respectively.

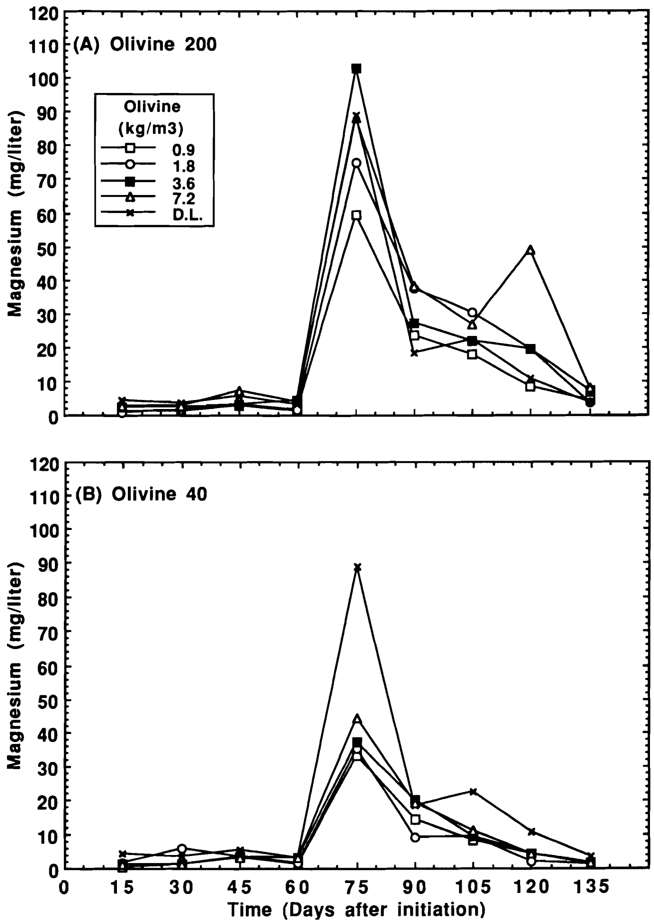

Fig. 1. Effect of olivine rate and olivine particle size (A) 200 and (B) 40 on media Mg concentration. D.L. = dolomitic limestone at 4.2 kg/m³ (7 lbs/yd³).

Top dry weight of 'Plumosa Compacta Youngstown' juniper was not affected by olivine rate or particle size (Table 2). In addition, top dry weight produced with olivine was not different from top dry weight produced with dolomitic limestone (data not presented). This suggests that 'Plumosa Compacta Youngstown' juniper can tolerate a wide range of Mg concentrations before top growth is inhibited. During the study, 'Plumosa Compacta Youngstown' juniper did not display any symptoms of magnesium deficiency.

Top dry weight of 'Hino-Crimson' azalea and Fraser photinia were significantly affected by olivine rate and particle size (Table 2). Fraser photinia top dry weight increased quadratically with increasing olivine rate, with the maximum occurring at 1.8 kg/m³ (3.0 lbs/yd³) (Table 3). Surprisingly, top weight of Fraser photinia produced with dolomitic limestone (161.4 g) was not different from Fraser photinia grown with no magnesium source (162.4 g) other than the Mg supplied by the irrigation water. Olivine 70 produced the greatest top dry weight although it was not significantly greater than olivine 40 (Table 3). Fraser photinia grown with 0 kg/m³ olivine displayed symptoms of magnesium deficiency by 60 DAI.

Top dry weight of azalea increased quadratically with increasing olivine rate, with the maximum occurring at 0.9 kg/m³ (1.5 lbs/yd³) (Table 3). Maximum top dry weight was 16% greater than plants grown with dolomitic limestone (27.3 g). As with photinia, azalea top dry weight produced with no magnesium source (0 kg/m³) was similar to top dry weight produced with the dolomitic limestone. Olivine 40 produced the greatest azalea top dry weight. However, it was not significantly different from olivine 20 or 70 (Table 3). Olivine 200, which had the highest Mg concentration in the media, produced the smallest top dry weight. 'Hino-Crimson' azalea never displayed any symptoms of magnesium deficiency.

Foliar Ca of 'Hino-Crimson' azalea and Fraser photinia, and foliar N, K and Ca in 'Plumosa Compact Youngstown' juniper, were not affected by olivine rate or particle size (Table 4). This is in contrast to Starr and Wright (10) who reported that increased media Mg levels decreased foliar Ca in 'Helleri' holly (*Ilex crenata* 'Helleri'). Foliar N and K in 'Hino-Crimson' azalea and foliar K in Fraser photinia decreased linearly with increasing olivine rate (Table 5). Magnesium has been shown to affect NH_4 and K uptake (6). Hicklenton and Cairns (5), Starr and Wright (10), and Therios and Sakellariadis (12) reported a reduction in K uptake with increasing media Mg levels for 'Coral Beauty' cotoneaster (*Cotoneaster dammeri* 'Coral Beauty'), 'Chondrolia Chalkidikis' olive (*Olea europaea* 'Chondrolia Chalkidikis'), and 'Helleri' holly, respectively. In addition, foliar K was influenced by olivine particle size (Table 4).

Table 3. Effect of olivine rate and particle size (PS) on top dry weight of 'Hino-Crimson' azalea and Fraser photinia.

Olivine rate (kg/m³)	Top dry weight (g)		Olivine PS	Top dry weight (g)	
	Fraser photinia	'Hino-Crimson' azalea		Fraser photinia	'Hino-Crimson' azalea
0	162.4	27.0	20	164.5 b[z]	30.9 a
0.9	164.7	31.7	40	167.6 ab	31.0 a
1.8	171.4	30.0	70	171.2 a	30.3 a
3.6	164.8	30.6	200	162.0 b	27.8 b
7.2	168.4	30.6			
D.L.[y]	161.4	27.3			
Significance[x]					
Linear	NS	*			
Quadratic	*	*			

[z]Means followed by the same letter within each species are not significantly different by Fisher's lsd, 5% level.

[y]D.L. = plants grown with dolomitic limestone at 4.2 kg/m³ (7 lbs/yd³) (no olivine). These data were not included in the regression analysis.

[x]NS,*,** Nonsignificant or significant at $p \leq 0.05$ or $p \leq 0.01$, respectively.

Table 4. Foliar nutrient concentrations of 'Hino-Crimson' azalea, Fraser photinia and 'Plumosa Compacta Youngstown' juniper in response to olivine rate and particle size (PS).

Source of variation	Nutrient concentration (% dry weight)											
	'Hino-Crimson' azalea				Fraser photinia				'Plumosa Compacta Youngstown' juniper			
	N	K	Ca	Mg	N	K	Ca	Mg	N	K	Ca	Mg
Olivine rate	**z	**	NS	**	**	**	NS	**	NS	NS	NS	**
Olivine PS	NS	**	NS	**	**	**	NS	**	NS	NS	NS	**
R × G	NS	NS	NS	**	**	NS	NS	**	NS	NS	NS	**

zNS,*,** Nonsignificant or significant at $p \leq 0.05$ or $p \leq 0.01$, respectively.

Olivine 200 decreased foliar K of 'Hino-Crimson' azalea and Fraser photinia compared to the other particle sizes (Table 5).

Olivine rate and particle size affected foliar Mg in all three species (Table 4). Foliar Mg of 'Hino-Crimson' azalea increased with increasing olivine rate (Fig. 2). Similarly, Starr and Wright (10) and Therios and Sakellariadis (12) reported increasing foliar Mg with increasing media Mg concentrations. Olivine 200 produced much higher foliar Mg (excluding 0 kg/m^3), compared to the other olivine particle sizes. 'Hino-Crimson' azalea when grown with dolomitic limestone, had foliar Mg of 0.24. Foliar Mg of 'Plumosa Compact Youngstown' juniper and Fraser photinia responded similarly (data not presented).

In addition to providing all essential nutrients, a fertility program must provide mineral nutrients in the proper balance. An excessive nutrient level can be as deleterious as one which is inadequate. Even though the media Mg concentrations of 0 kg/m^3 olivine (no magnesium source) and dolomitic limestone were very different, there were no growth differences with either Fraser photinia and 'Hino-Crimson' azalea grown in each media. This suggests a high Mg concentration in the media can be just as detrimental as a low concentration. Therios and Sakellariadis (12) reported that growth of 'Chondrolia Chalkidikis' olive was reduced when media Mg concentrations were greater than 50 mg/liter. Maximum top dry weight of Fraser photinia and 'Hino-Crimson' azalea occurred when the Mg levels in the media did not exceed 50 mg/liter. This is in agreement with Starr and Wright (10) who reported that low levels (5 to 10 mg/liter) of Mg produced optimum growth of 'Helleri' holly in a pine bark medium. Media Mg concentration maintained by 4.2 kg/m^3 (7 lbs/yd^3) dolomitic limestone may have been too high for optimum plant growth. A high Mg concentration in the media may cause a nutrient imbalance reducing plant growth (5, 12). However, macronutrient interactions in organic media are complex and not well understood (15).

When using dolomitic limestone as a Mg source, growers cannot adjust Mg level in the media independently of Ca and pH. Data herein suggest that olivine can serve as a

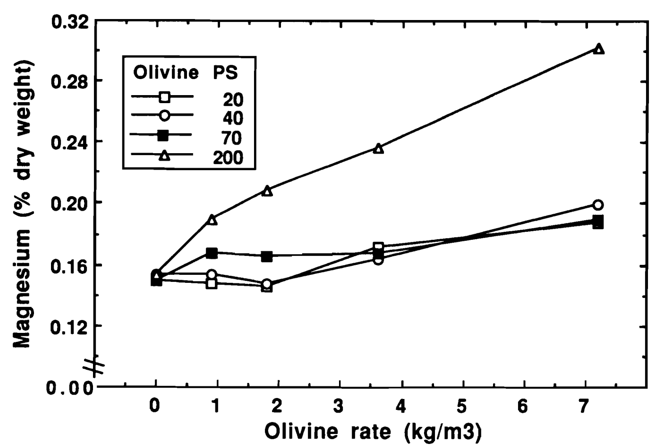

Fig. 2. Effect of olivine rate and particle size (PS) on foliar Mg in 'Hino-Crimson' azalea.

Table 5. Influence of olivine rate and particle size (PS) on foliar N and K concentrations of 'Hino-Crimson' azalea and Fraser photinia.

Olivine rate (kg/m^3)	'Hino-Crimson' azalea N	'Hino-Crimson' azalea K	Fraser photinia K	Olivine PS	'Hino-Crimson' azalea K	Fraser photinia K
0	2.56	1.30	1.97	20	1.27 b	1.86 a
0.9	2.34	1.29	1.85	40	1.34 a	1.86 a
1.8	2.33	1.28	1.81	70	1.29 ab	1.94 a
3.6	2.28	1.23	1.82	200	1.12 c	1.76 b
7.2	2.27	1.18	1.75			
D.L.y	2.21	0.94	1.70			
*Significance*x						
Linear	**	**	*			
Quadratic	NS	*	*			

Column heads span "Nutrient concentrations (% dry weight)".

zMeans followed by the same letter within each species are not significantly different by Fisher's lsd, 5% level.

yD.L. = plants grown with dolomitic limestone at 4.2 kg/m^2 (7 lbs/yd^3) (no olivine). These data were not included in the regression analysis.

xNS,*,** Nonsignificant or significant at $p \leq 0.05$ or $p \leq 0.01$, respectively.

source of Mg for container production allowing growers to raise or lower Mg concentrations in the media without affecting Ca supply or pH. However, further research is needed to determine the proper combination of rate and particle size.

Literature Cited

1. Brosh. D.L., C.E. Whitcomb, S.W. Akers, and P.L. Claypool. 1987. Water quality and calcium plus magnesium fertilization effects on container-grown gardenia and Japanese holly. J. Environ. Hort. 5:49–52.

2. Chrustic, G.A., and R.D. Wright. 1983. Influence of liming rate on holly, azalea, and juniper growth in pine bark. J. Amer. Soc. Hort. Sci. 108:791–795.

3. Cobb, G.S. and M.L. Zarko. 1983. Medium pH and growth of two woody ornamentals as influenced by liming rate. Proc. Southern Nurserymen's Assoc. Res. Conf., 28th Annu. Rpt. pp. 46–47.

4. Fuller, D.L. and W.A. Meadows. 1983. Effects of powdered vs. pelletized dolomite and two fertilizer regimes on pH of growth medium and quality of eight woody species in containers. Southern Nurserymen's Assoc. Nursery Res. J. 9:1–7.

5. Hicklenton, P.R. and K.G. Cairns. 1992. Calcium and magnesium nutrition of containerized *Cotoneaster dammeri* 'Coral Beauty'. J. Environ. Hort. 10:104–107.

6. Mengel, K. and E.A. Kirkby. 1982. Principles of plant nutrition. 3rd ed. Intl. Potash Inst., Worflaufen-Bern, Switzerland.

7. Nash, V.E., A.J. Laiche, Jr., and F.P. Rasberry. 1983. Effects of amending container growing media with dolomitic limestone on the growth of *Photina* 'Fraseri'. Comm. Soil Sci. Plant Anal. 14:497–506.

8. SAS Institute. 1985. SAS User's Guide: Statistics. Version 5. Edition. SAS Inst., Cary, N.C.

9. Shelton, J.E. and R.E. Bir. 1986. Olivine: a slow release magnesium source for the nursery industry. Proc. Southern Nurserymen's. Assoc. Res. Conf. 31st Ann. Rpt. pp. 106–108.

10. Starr, K.D. and R.D. Wright. 1984. Calcium and magnesium requirements of *Ilex crenata* 'Helleri'. J. Amer. Soc. Hort. Sci. 109:857–860.

11. Tayrien, R.C. and C.E. Whitcomb. 1984. An evaluation of calcium and magnesium sources and water quality on container grown nandina. Okla. State Univ. (Stillwater) Res. Rpt. 855 pp. 41–43.

12. Therios, I.N. and S.D. Sakellariadis. 1982. Some effects of varied magnesium nutrition on the growth and composition of olive plants (cultivar Chondrolia Chalkidikis). Scientia Hort. 17:33–41.

13. Wright, R.D. 1986. The pour-through nutrient extraction procedure. HortScience 21:227–229.

14. Wright, R.D. and L.E. Hinesley. 1991. Growth of containerized eastern redcedar amended with dolomitic limestone and micronutrients. HortScience 26:49–51.

15. Wright, R.D. and A.X. Niemiera. 1987. Nutrition of container-grown woody nursery crops, pp. 76–101. *In*: J. Janick (ed.). Horticultural Reviews. AVI Publishing Co., Inc. Westport, Conn.

16. Yeager, T.H. and D.L. Ingram. 1983. Influence of dolomitic limestone rate on growth of holly, juniper, and azalea. Proc. Southern Nurserymen's Assoc. Res. Conf. 28th Ann. Rpt. pp. 49–51.

17. Yeager, T.H. and D.L. Ingram. 1986. Growth response of azaleas to fertilizer tablets, superphosphate, and dolomitic limestone. HortScience 21:101–103.

Flower Bud Hardiness of Forsythia Cultivars[1]

Steve McNamara and Harold Pellett[2]
University of Minnesota Landscape Arboretum
P.O. Box 39,
Chanhassen, MN 55317

Abstract

Winter hardiness profiles were developed for six *Forsythia* cultivars introduced in the last 10–15 years for superior flower bud hardiness. The cultivars 'Meadowlark', 'Northern Gold', 'Northern Sun', 'New Hampshire Gold', 'Sunrise', and 'Vermont Sun' were at least 2–4°C (4–7°F) more hardy than *F.* × *intermedia* and *F. ovata* cultivars on most sampling dates. All cultivars acclimated sufficiently to withstand early-season minimum temperatures in most years. By mid-winter, five of the six new introductions obtained maximum hardiness levels of −36°C (−33°F). 'Sunrise' was 2–4°C (4–7°F) less hardy than the other cultivars in mid-winter but was one of the most hardy cultivars in late-winter. With the exception of 'Vermont Sun', there was little difference among the new cultivars in timing of deacclimation. 'Vermont Sun' deacclimated earliest and was less hardy than the other cultivars by mid-March. While these new introductions have experienced little flower-bud injury in field trials over the past decade, nearly 100% of the flower buds of these cultivars were killed in two of three winters encompassed by this study. The climatic conditions that resulted in injury were distinctly different for the two years.

Index Words: Cold acclimation, winter injury

Significance to the Nursery Industry

The limited flower-bud hardiness of Forsythia precludes more wide-spread use of this landscape shrub in northern landscapes. Many cultivars presently available in the nursery trade often experience winter injury in the northern United States. This study characterized the cold hardiness of six recent Forsythia introductions that have exhibited flower-bud hardiness in the field. Our findings indicate that improvements in flower-bud hardiness and plant form might be realized by hybridization of several of the cultivars tested.

Introduction

Many Forsythia cultivars lack sufficient flower bud hardiness for use in northern climates. Flower buds of popular *F.* × *intermedia* cultivars are completely killed above the

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[2]Scientist and Professor, respectively.