Effects of Magnesium-Sulfate on Leaf Chlorosis, Plant Growth and Nutrient Uptake in *Camellia sasanqua* 'Shishi Gashira'[1]

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Abstract

A 'V'-patterned chlorosis of older leaves is frequently observed on specific cultivars of container-grown *Camellia sasanqua*. Symptoms are expressed during the flowering period and as the first vegetative flush of the season develops in early spring. Symptomatic leaves eventually senesce and subsequent vegetative flushes appear healthy. In the following study, container-grown *Camellia sasanqua* 'Shishi Gashira' were fertilized with 500 ml of nutrient solution containing one of five treatments: 0.0, 4.0, 10, 20, or 40 g/liter magnesium sulfate heptahydrate ($MgSO_4$•$7H_2O$) per 19-liter container every two weeks for nine months to determine if chlorosis could be prevented. Nutrient analyses were conducted on all plant organs to determine if there was a correlation between nutrient partitioning to different organs and the expression of leaf chlorosis. Supplemental $MgSO_4$•$7H_2O$ fertilization increased the Mg concentration in the roots, stems, leaves and flowers, and increased the sulfur concentration only in the leaves and stems. Calcium concentration in all organs decreased and potassium concentration in the leaves and stems decreased with increased fertilization rates. Fertilization with $MgSO_4$•$7H_2O$ prevented the development of 'V'-patterned chlorosis but did not affect plant dry weight.

Index words: flowering, potassium, calcium, nitrogen, phosphorus, interveinal chlorosis, Epsom salts.

Significance to the Nursery Industry

Camellias (*Camellia spp.*) are popular flowering woody nursery crops that are commonly grown in the warmer regions of the United States. With the introduction of hardier varieties (1, 2) that can be grown as far north as zone 5b (USDA Plant Hardiness Zone Map), the demand and subsequent production of camellias has increased. While cultural recommendations for camellia production exist, certain cultivars appear to be susceptible to 'V'-patterned chlorosis that develops on the oldest leaves.

Magnesium (Mg) deficiency symptoms on camellia are expressed during a specific plant developmental stage. The characteristic chlorosis of older leaves only occurs towards the end of the flowering period as the first vegetative flush emerges in early spring. Affected leaves eventually senesce and the vegetative flushes that subsequently develop during the spring and summer appear healthy. Since most camellias are sold when flowering, the development of leaf chlorosis at this time reduces the marketability of afflicted plants. In some cases, nurseries have discontinued the production of specific cultivars, such as *C. sasanqua* 'Hana Jiman' due to the severity of chlorotic symptoms. Based on the results of the following study, 'V'-patterned chlorosis of camellia is likely to occur if Mg concentration of leaf tissue is less than 0.20%.

Introduction

In certain cultivars of camellia, symptoms of magnesium (Mg) deficiency are expressed. A 'V'-pattern chlorosis develops on the older leaves during flowering in late fall and winter, a time of the year when camellia plants are shipped and displayed for sale in retail stores. Like most members of the *Ericaceae* and *Theaceae* families, camellias require media and irrigation sources that are acidic and lower in soluble salts than planting media and irrigation waters commonly used for other nursery crops (11). Because of these unique cultural requirements, camellia, rhododendron, and other calcifuges are often grown in a separate region of the nursery where media and irrigation waters are formulated to meet their specific needs. However, even when these cultural requirements are done, symptoms of Mg deficiency occur in several camellia cultivars, especially those cultivars with *C. sasanqua* in their parentage. Symptomatic leaves eventually senesce in the spring when vegetative growth commences. While information exists regarding the nutritional requirements for leaf quality for the tea of commerce (*Camellia sinensis*) (12, 13, 14), limited information is available on the nutrient requirements for camellias (*C. sasanqua*, *C. japonica*, and hybrids) grown for landscape use where more importance is placed on aesthetic traits, such as leaf color and flower quantity and quality. While the significance of nutrient demand by developing flowers has not been observed in camellia, there is evidence in other crops that reproductive organs may be significant sinks for nutrients such as Mg (3, 4, 6, 7). In grape, leaf chlorosis has been correlated with higher Mg deposition into fruit clusters (4). While attempts have been made to correlate nutrient concentrations in flowers and leaves with potential fruit yield (9, 15), no studies have been conducted to determine if such correlations exist between leaves and flowers of camellia. In the following study we wanted to determine if the development of Mg deficiency symptoms could be prevented with supplemental $MgSO_4$•$7H_2O$ fertilization. At the end of a nine-month growth cycle, the accumulation and allocation of nutrients were quantified in the roots, stems, leaves, and flowers.

Materials and Methods

Plant material and substrate. Two-year-old cutting-grown *Camellia sasanqua* 'Shishi Gashira' were transplanted from 3.8 liter (#1) to 19 liter (#5) black polyethylene containers. Substrate consisted of composted 19 mm (0.75 in) pine bark and sphagnum peat (2:1 by vol), which was amended with

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1008 g/m^3 (1.70 lb/yd^3) calcium (Ca), 89.0 g/m^3 (0.15 lb/yd^3) magnesium (Mg) and other essential nutrients. Additional nutrients were supplied through the irrigation water to provide 85, 100, 68, and 17 mg/liter (ppm) of potassium (K), N, Ca, and Mg, respectively. Plants were grown in unshaded nursery beds in Glendora, CA. Average minimum and maximum temperatures were 7C (45F) and 19C (67F) during winter months, and 19C (66F) and 31C (88F) during summer months. Plants were watered to runoff with overhead irrigation twice a week from January through April, and daily from May through October.

Fertilizer treatments. Treatments began on January 4, 1999. Every two weeks, each plant was fertilized with 500 ml (0.13 gal) of tap water containing one of five concentrations of magnesium sulfate ($MgSO_4$•$7H_2O$): 0.0, 4,000, 10,000, 20,000, or 40,000 mg/liter (0.0, 0.54, 1.38, 2.69, or 5.46 oz/gal). This is equivalent to a $MgSO_4$•$7H_2O$ fertilization rate of: 0.0 2.0, 5.0, 10.0, or 20.0 g (0.0, 0.07, 0.18, 0.35, or 0.71 oz). There were five replications of each treatment, with plants organized in a randomized complete block design.

Plant harvest. Flower bud development began in late August for all treatments and plants began to flower during the first week of November. During the next eight weeks, flowers buds were harvested as they opened. At the end of December 1999, entire plants were harvested, divided into roots, leaves with 'V'-patterned chlorosis, green leaves, flowers and stems. Leaves were considered chlorotic when relative chlorophyll values were less than 70 using a Minolta Chlorophyll meter (model SPAD502, Spectrum Technologies, Inc., Plainfield, IL). Plant material was dried at 60C, weighed, and then ground with a Wiley Mill (Thomas Scientific, Swedesboro, NJ) to pass through a 40-mesh (0.425 mm) screen.

Tissue analyses. All plant material was analyzed for Ca, K, Mg, N, P, and S. However, due to insufficient material, chlorotic leaves were combined with green leaves to determine nutrient concentration of all leaves. Tissue N concentrations were determined by combustion on a LECO-FP528 Nitrogen Gas Analyzer (Leco Corp., St. Joseph, MI), utilizing induction furnace and thermal conductivity. Potassium was analyzed by atomic absorption spectrophotometry. Calcium, Mg, P, and S were determined using an Inductively Coupled Plasma-Atomic Emission Spectrophotometer.

Results and Discussion

Plant growth. Total plant dry weight was unaffected by the $MgSO_4$•$7H_2O$ fertilization rates (Table 1). However, $MgSO_4$•$7H_2O$ fertilizer treatments inhibited the development of chlorosis since the total dry weight of chlorotic leaves was reduced with increased fertilization rates (Table 1). The lack of a plant growth response may be attributed to the duration (12 months) of the study; a second season of treatment applications and growth may have resulted in the manifestation plant dry mass differences. However, the nutrient deficiency, while severe enough to cause expression of leaf chlorosis, was not physiologically significant to inhibit plant growth.

Nutrient uptake and partitioning. On a whole plant basis, increased rates of $MgSO_4$•$7H_2O$ fertilization resulted in de-

Table 1. Effects of magnesium sulfate fertilization on plant dry weight of *Camellia sasanqua* 'Shishi Gashira'. Flowers were harvested during an eight-week period as buds began to open. At the end of flowering, entire plants were harvested, divided into roots, yellow leaves (SPAD value < 70), green leaves (SPAD value ≥ 70), and stems.

	Dry weight (g)					
Treatment (g) $MgSO_4$•$7H_2O$	Roots	Yellow leaves	Leaves	Stems	Flowers	Whole plant
0.00	180	20.1	144	122	76.9	543
2.00	156	8.5	166	120	67.2	518
5.00	180	3.5	162	116	76.1	537
10.0	171	0.5	168	127	86.5	552
20.0	171	0.3	171	129	75.6	547
	NS[z]	***	NS	NS	NS	NS

[z]NS, *** = Not significant, P ≤ 0.001 respectively.

creased concentrations of Ca and increased concentrations of Mg and S (Table 2). Whole plant concentration of N increased quadratically. There were no significant changes in K and P concentrations (Table 2). The increased concentrations of Mg and S can be explained by an increased uptake of these elements derived from the $MgSO_4$•$7H_2O$ fertilizer. The decreased uptake of Ca may be associated with the competition between Mg and Ca for plant uptake. Since these ions have similar atomic properties (positively charged ions with molecular weights of 24 [Mg] and 39 [Ca] atomic mass units), they effectively compete with each other for similar uptake sites at the plant root surface (5, 8).

Accumulation of Ca, K, Mg, N, P, and S into the plant organs was variable (Table 2). Magnesium concentrations increased and Ca concentrations decreased in all plant organs as $MgSO_4$•$7H_2O$ fertilization rates increased (Table 2). Potassium concentrations decreased and S concentrations increased in the stems and leaves with higher $MgSO_4$•$7H_2O$ fertilization levels. Nitrogen concentrations increased quadratically only in the stems and there were no significant effects of $MgSO_4$•$7H_2O$ fertilization rates on P partitioning.

The 'V'-patterned chlorosis on mature leaves of *C. sasanqua* 'Shishi Gashira' appears to be associated with insufficient soil Mg, since increased fertilization rates with $MgSO_4$•$7H_2O$ prevented chlorosis and Mg was the only plant-mobile element that increased in leaves with increased fertilization rates (Table 2). In addition, Mg concentrations in leaves of the first two fertilizer treatments were below the sufficiency ranges (0.14–0.33%) reported for other camellia species (10, 14). Considering this relatively low concentration of Mg in the leaves along with the fact that the Mg concentration in the flowers was higher in the higher versus the lower fertilizer treatments, the Mg sources (leaves) of the low fertilizer treatments probably did not have sufficient Mg or were unable to physiologically reallocate enough Mg to the sinks (developing flowers). While this type of correlation between nutrient demand and flowering have not been observed in camellia, there is evidence in other crops that reproductive organs may be significant sinks for nutrients such as Mg (3, 4, 7). Zhao and Oosterhuis (15) found that both Mg and Ca concentrations increased in developing cotton flower buds. In grape, leaf chlorosis has been correlated with higher Mg deposition into fruit clusters (4). Attempts have been made to correlate nutrient concentrations in flow-

Table 2. **Effects of magnesium sulfate fertilization rate on the nutrient concentrations in flowers, leaves, stems, roots and whole plant of *Camellia sasanqua* 'Shishi Gashira'. Flowers were harvested during an eight-week period as buds began to open. At the end of flowering, entire plants were harvested, divided into roots, stems and leaves.**

	Treatment (g) $MgSO_4 \cdot 7H_2O$	Nutrient concentration (% of dry weight)					
		Ca	K	Mg	N	P	S
Plant	0.00	0.66	0.96	0.15	1.74	0.09	0.24
	2.00	0.66	0.97	0.17	1.79	0.11	0.24
	5.00	0.60	0.95	0.20	1.84	0.09	0.26
	10.0	0.60	0.94	0.22	1.88	0.10	0.26
	20.0	0.55	0.90	0.26	1.83	0.09	0.28
	Linear	[z]***	NS	***	NS	NS	*
	Quadratic	NS	NS	***	*	NS	NS
Roots	0.00	0.45	0.74	0.25	1.66	0.06	0.37
	2.00	0.41	0.74	0.27	1.57	0.07	0.36
	5.00	0.36	0.79	0.28	1.69	0.06	0.39
	10.0	0.38	0.64	0.28	1.66	0.06	0.37
	20.0	0.33	0.71	0.32	1.67	0.06	0.41
	Linear	*	NS	**	NS	NS	NS
	Quadratic	NS	NS	NS	NS	NS	NS
Stems	0.00	0.63	0.27	0.16	1.39	0.06	0.11
	2.00	0.56	0.27	0.16	1.44	0.08	0.11
	5.00	0.66	0.27	0.18	1.49	0.08	0.12
	10.0	0.64	0.25	0.20	1.56	0.07	0.13
	20.0	0.47	0.25	0.21	1.47	0.06	0.12
	Linear	*	*	***	NS	NS	NS
	Quadratic	NS	NS	NS	*	NS	*
Leaves	0.00	1.09	1.29	0.07	1.99	0.09	0.23
	2.00	1.03	1.26	0.10	2.03	0.10	0.24
	5.00	0.91	1.18	0.16	2.12	0.09	0.25
	10.0	0.90	1.24	0.17	2.12	0.09	0.28
	20.0	0.90	1.14	0.23	2.12	0.09	0.29
	Linear	***	**	***	NS	NS	**
	Quadratic	***	NS	***	NS	NS	NS
Flowers	0.00	0.39	1.90	0.14	2.19	0.20	0.19
	2.00	0.40	1.91	0.17	2.37	0.23	0.20
	5.00	0.36	1.85	0.18	2.21	0.20	0.19
	10.0	0.37	1.92	0.21	2.30	0.21	0.20
	20.0	0.36	1.81	0.22	2.17	0.20	0.19
	Linear	*	NS	***	NS	NS	NS
	Quadratic	NS	NS	***	NS	NS	NS

[z]NS, *, **, *** Not significant, $P \leq 0.05$, 0.01, 0.001 respectively

ers and leaves with potential fruit yield (4, 15). However, no studies have been conducted to determine if such a source-sink relationship exists between leaves and flowers of *Camellia sasanqua*.

While other nutrients (S and N) increased in leaf tissue, chlorosis was unlikely caused by the lack of these elements since both were within the range (0.14–0.42% S) and (1.20–3.54% N) considered sufficient for camellia by other investigations (10). In addition, chlorosis of mature leaves could not be attributed to inadequate S since S-related chlorosis is expressed in the youngest leaves. Also, the flowers did not appear to act as a sink for S and N, since concentrations in flowers did not increase with increased fertilization rates.

Based on the results of this study, symptoms of Mg deficiency in *Camellia sasanqua* 'Shishi Gashira', expressed as 'V'-patterned chlorosis in the oldest leaves, may be prevented with increased applications of Epsom salts ($MgSO_4 \cdot 7H_2O$). Supplemental applications of these nutrients will not correct deficiency symptoms of already chlorotic leaves, which emphasizes the importance of providing adequate Mg nutrition throughout crop development.

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