Effect of Nitrogen and Potassium Fertilizer Rates on Severity of Xanthomonas Blight of *Syngonium podophyllum*

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ABSTRACT

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Syngonium podophyllum 'White Butterfly' plants were grown under various nutritional regimes before inoculation with *Xanthomonas campestris* pv. *syngonii*. Percentage of blighted leaf area decreased linearly as the rate of complete fertilizer (liquid 20:20:20 or slow-release 19:6:12) increased. Increased rates of either nitrogen or potassium were equally effective in reducing symptom expression. Plant response (number of leaves, height, and top quality) to increasing rates of complete fertilizer was generally described by a quadratic function, and good plant growth occurred over a wide range of fertilizer rates. Plant height and leaf number were not affected by N-K ratio, and fresh top weight showed a quadratic response to nitrogen rate only. Severity of Xanthomonas blight of *S. podophyllum* 'White Butterfly' can be minimized with moderate increases in application rates of complete fertilizer, nitrogen, or potassium.

Bacterial diseases cause severe losses in commercial production of some foliage plants. Control of these diseases has been based on use of bactericides that provide a limited degree of control (1,12). Some foliar diseases caused by pathovars of *Xanthomonas campestris* and species of *Pseudomonas* can be controlled by rigorous sanitation and preventive bactericide applications. Systemic diseases caused by *Erwinia* spp., *X. c.* pv. *dieffenbachiae* (Pammel) Dowson, and *X. c.* pv. *syngonii* Dickey & Zumoff can be controlled only if pathogen-free plantlets are available from tissue culture. Cultural conditions are especially important for systemic bacterial diseases, since bactericides rarely give adequate control. The effect of host nutrition on severity of several bacterial diseases of foliage plants has been examined during the past few years (2,3,5,6,10).

Xanthomonas blight is a serious disease of most species and cultivars of *Syngonium*, including the most widely grown cultivar for the potted plant market, *S. podophyllum* Schott 'White Butterfly.' The pathogen has been identified as *X. c.* pv. *syngonii* (9) and is closely related to *X. c.* pv. *dieffenbachiae*, which attacks many other members of the aroid family (7). Cultural control of Xanthomonas blight of White Butterfly has been investigated because chemical controls have proved inadequate. Although production temperature affects disease severity, preinoculation light levels do not (4). This paper reports effects of fertilizer rate and N-K ratio on growth of *S. podophyllum* and subsequent development of Xanthomonas blight. A preliminary report has been published (2).

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MATERIALS AND METHODS

Preparation of plant materials. White Butterfly plantlets derived from tissue culture and approximately 4–6 cm tall were obtained from producers in central Florida. Plantlets were established in flats containing a 1:1 mixture of Canadian peat and pine bark that had been steam-treated for 1.5 hr at 90 C, then amended with 2.7 kg/m^3 of dolomite and 0.5 kg/m^3 of Micromax (Sierra Chemical Co., Milpitas, CA). Plants were fertilized every other week with a 200 ppm solution of Miller 20:20:20 until they were approximately 8–12 cm tall with four or five leaves. Nutrient content of the soluble fertilizer is 6.22% nitrate nitrogen, 3.88% ammoniacal nitrogen, 9.90% urea, 20% phosphorous acid, and 20% soluble potash. The N compounds were primarily derived from urea, ammonium phosphate, and potassium nitrate.

Preparation of inoculum and inoculation method. *X. c.* pv. *syngonii* (7) was grown on Difco nutrient agar amended with 0.5% sucrose at 27 C for 3 days. Bacteria were removed from the medium surface by flooding it with 0.01 M $MgSO_4$ and gently rubbing it with a sterilized cotton swab. Suspensions were collected and adjusted to 1×10^8 cfu per milliliter using a spectrophotometric method. Bacterial suspensions were applied to plants within 30 min of preparation.

Plants were placed in intermittent mist (5 sec every 30 min from 0800 to 2000 hours each day) starting 24 hr before inoculation. Inoculum was misted onto leaf surfaces to drip with a pulp-action hand sprayer; plants were placed in polyethylene bags for 24 hr while misting continued. After approximately 14–21 days, disease severity was estimated as the percentage of the leaf surface with blight symptoms (water-soaking, chlorosis, and/or necrosis). Data were transformed using the arcsine transformation before analysis because differences were too great for direct analysis (13).

Effect of slow-release fertilizer rate on disease severity. White Butterfly plants were transplanted into 12.5-cm plastic pots containing the potting medium described and topdressed with Osmocote 19:6:12 (19N-3P-10K) fertilizer at 0.8, 3.4, 5.9, 8.4, 10.9, 13.5, 15.9, and 18.4 g per pot; the recommended rate for this plant is about 2.8 g per 12.5-cm pot (8). Osmocote 19:6:12 has a 3- to 4-mo release schedule when soil temperatures are 21 C. Nutrient content is 10% ammoniacal nitrogen, 9% nitrate nitrogen, 6% phosphorous acid, and 12% soluble potash from ammonium nitrate, ammonium phosphates, calcium phosphates, and potassium sulfate. Ten single-pot replicates were included for each treatment. Plants were irrigated by hand two or three times per week as needed. Electrical conductivity (EC) of

the leachate was determined monthly using a Hach Conductivity Meter 2511 (Hach Chemical Company, Ames, IA) (15). Leaf number and plant height also were recorded monthly, with plant top quality or fresh weight of tops (representative plants, not those to be inoculated) recorded just before inoculation. Top quality was rated visually on the following scale: 1 = dead; 2 = poor, unsalable; 3 = moderate, salable; 4 = good, salable; and 5 = excellent, salable. This experiment was performed three times. Test 1 was performed from 21 March to 9 June 1986 with a maximum light level of 230 $\mu mol \cdot m^2 \cdot s$ (recorded at 1200 hours) and temperatures between 18 and 32 C. Test 2 was performed from 11 June to 21 August 1986 with a maximum light level of 250 $\mu mol \cdot m^2 \cdot s$ and temperatures between 21 and 37 C. Test 3 was performed from 29 August to 13 November 1986 with a maximum light level of 270 $\mu mol \cdot m^2 \cdot s$ and temperatures between 18 and 35 C.

Effect of liquid fertilizer rate on disease severity. Plants were established as described previously except that 10-cm pots were used. Plants were fertilized with each irrigation using a soluble fertilizer (Miller 20:20:20) at rates of 0.03, 0.21, 0.38, 0.56, 0.75, and 0.93 g per pot per week. Plants were irrigated two or three times per week, depending on need, with fertilizer rate adjusted accordingly. Plant measurements and leachate EC were recorded as described above. Ten replicate pots per treatment were included in test 1 and 15 pots per treatment in test 2. Test 1 was conducted from 4 November 1986 to 2 March 1987 with a maximum light level of 190 $\mu mol \cdot m^2 \cdot s$ and temperatures between 15 and 27 C. Test 2 was conducted from 13 March to 5 June 1987 with a maximum light level of 340 $\mu mol \cdot m^2 \cdot s$ and temperatures from 20 to 35 C. Five of the replicate plants for each treatment in test 2 were harvested for tissue elemental analysis. Mature leaves were removed from plants, dried at 60 C, and ground. Elemental content was determined by A & L Southern Agricultural Laboratories in Pompano Beach, FL (14).

Effect of variable rates of nitrogen and potassium on disease severity. The effect of various rates of nitrogen and potassium on disease severity was tested using White Butterfly plants in 10-cm pots. Three rates each of nitrogen (from NH_4NO_3) and potassium (from KCl) were used in a factorial experiment. The rate of phosphorus (from H_3PO_4) was maintained constant at 10 mg per pot per week. The rates of nitrogen were 50, 150, and 250 mg per pot per week and those of potassium were 30, 90, and 150 mg per pot week. Fertilizer was applied with each irrigation two or three times per week. As plant water use changed, rates were adjusted accordingly. Ten replicate pots were used for each treatment in tests 1 and 2, and 15 pots were used per treatment in test 3. Test 1 was conducted from 2 December 1986 to 2 March 1987 with a maximum light level of 190 $\mu mol \cdot m^2 \cdot s$ and temperatures from 15 to 27 C. Test 2 was conducted from 13 February to 4 June 1987 with a maximum light level of 280 $\mu mol \cdot m^2 \cdot s$ and temperatures between 15 and 35 C. Test 3 was conducted from 27 April to 25 June 1987 with a maximum light level of 320 $\mu mol \cdot m^2 \cdot s$ and temperatures from 20 to 35 C. Five replicate plants per treatment were harvested for tissue nutrient content evaluations as described above.

RESULTS

Effects of slow-release and liquid fertilizer rate on disease severity. Plant growth responses to fertilizer rate were similar regardless of source (liquid or slow-release) or test, and only data from the second test employing liquid fertilizer are presented (Table 1). Leachate EC increased linearly from 260 to 4,450 μmhos/cm as fertilizer rate increased. Plant height decreased as fertilizer rate increased, but both number of leaves and top quality responded curvilinearly with a significant quadratic component. Best plants were produced with intermediate rates of liquid fertilizer (0.21–0.38 g per pot per week) (Table 1). Elemental nutrient content showed a predominantly linear response to fertilizer rate. As fertilizer rate increased, nitrogen, potassium, and sulfur increased and phosphorus, magnesium, and calcium decreased (Table 2). Optimal ranges for the following elements on a percentage dry weight basis were chosen on the basis of plant growth: nitrogen, 4.52–4.90%; phosphorus, 0.56–0.57%; potassium, 3.91–4.87%; sulfur, 0.27–0.29%; magnesium, 0.38–0.52%; and calcium, 1.40–1.46%.

Disease severity, as indicated by the percentage of the plant foliage with blight symptoms, decreased linearly as fertilizer rate increased at rates of 20:20:20 of 0.21 or higher (Table 1). Disease severity peaked at 0.21 g of fertilizer and was lowest at the highest rate of fertilizer used (0.93 g). Response of disease severity (y) to fertilizer rate (x) in test 2 was $y = 77.55 - 7.92x$, $R^2 = 0.93$**. The response to increases in slow-release

Table 1. Effect of liquid fertilizer (Miller 20:20:20) level on growth of *Syngonium podophyllum* 'White Butterfly' and electrical conductivity (EC) of leachate before inoculation with *Xanthomonas campestris* pv. *syngonii*[a]

Fertilizer (g/10-cm pot/wk)	Leachate EC (μmhos/cm) 14 May	Height (cm) 6 May	Leaf number 6 May	Plant top quality[b] 30 April	Mean % disease 5 June
0.03	260	10.0	17.9	3.0	63.0
0.21	745	10.6	27.5	3.7	74.0
0.38	1,645	10.5	28.9	3.7	66.5
0.56	4,050	10.4	25.2	3.4	59.5
0.75	4,300	9.7	26.3	3.4	59.5
0.93	4,450	9.5	24.0	3.3	53.5
Significance[c]					
Linear	**	**	NS	NS	**
Quadratic	**	**	**	**	**
Residual	NS	NS	NS	NS	NS

[a]Means are for 10 plants per treatment (except leachate EC, where means are for four pots per treatment), test 2 (13 March to 5 June 1987).
[b]Rated visually: 1 = dead; 2 = poor, unsalable; 3 = moderate, salable; 4 = good, salable; and 5 = excellent, salable.
[c]Regression analyses were performed for tests in which a significant difference between treatments was indicated by an F test. NS = not significant, * = $P = 0.05$, ** = $P = 0.01$.

Table 2. Nutrient content for mature *Syngonium podophyllum* 'White Butterfly' fertilized with different rates of Miller's 20:20:20

Fertilizer (g/10-cm pot/wk)	Percent dry weight[a]					
	N	P	K	S	Mg	Ca
0.03	1.78	0.59	1.49	0.21	0.59	1.70
0.21	4.52	0.57	3.91	0.27	0.52	1.46
0.38	4.90	0.56	4.87	0.29	0.38	1.40
0.56	4.74	0.54	4.53	0.30	0.29	1.19
0.75	4.08	0.57	4.55	0.34	0.29	1.16
0.93	4.40	0.51	4.48	0.33	0.27	0.99
Significance[b]						
Linear	**	**	**	**	**	**
Quadratic	**	NS	*	NS	NS	NS
Residual	NS	NS	NS	NS	NS	NS

[a]Means are for five plants per treatment, test 2.
[b]Regression analyses were performed for tests in which a significant difference between treatments was indicated by an F test. NS = not significant, * = $P = 0.05$, ** = $P = 0.01$.

fertilizer was similar with lowest disease severity at highest fertilizer rates. The slopes of the lines for tests 2 and 3 were similar (Fig. 1). Overall, disease severity ratings were lower in tests performed when temperatures were not optimal. Previous research established that temperatures between 26 and 30 C are optimum for disease development (4).

Effect of variable rates of nitrogen and potassium on disease severity. Data obtained in the three nitrogen-potassium (N-K) tests were similar, and only data from test 3 are presented (Table 3). Leachate EC was affected by rates of both nitrogen and potassium, with higher readings occurring as either element was increased (Table 3). The ranges were higher than those seen for the complete fertilizer rate trials, with a low mean of about 190 and a high at 10,250 μmhos/cm. There was no interaction between N and K rate for leachate EC. Height and leaf number were unaffected by rates of N and K in the ranges tested (Table 3). Because the rates used for the complete fertilizer trials were not exactly those used for these N-K trials, direct comparisons cannot be made. However, the range tested in the complete fertilizer trials included both lower and higher rates than those for the N-K trials, with the plant growth responses reflecting the greater range. Top quality was similar for all plants and therefore was not recorded for this series of trials. Fresh weight of tops was affected by nitrogen only, with highest growth at the intermediate rate of 150 mg of N per pot per week (Table 3). There were no statistically significant interactions between nitrogen and potassium for plant growth responses. Elemental nutrient content for five of the six elements was affected by N or K rate, with only nitrogen unaffected (Table 4).

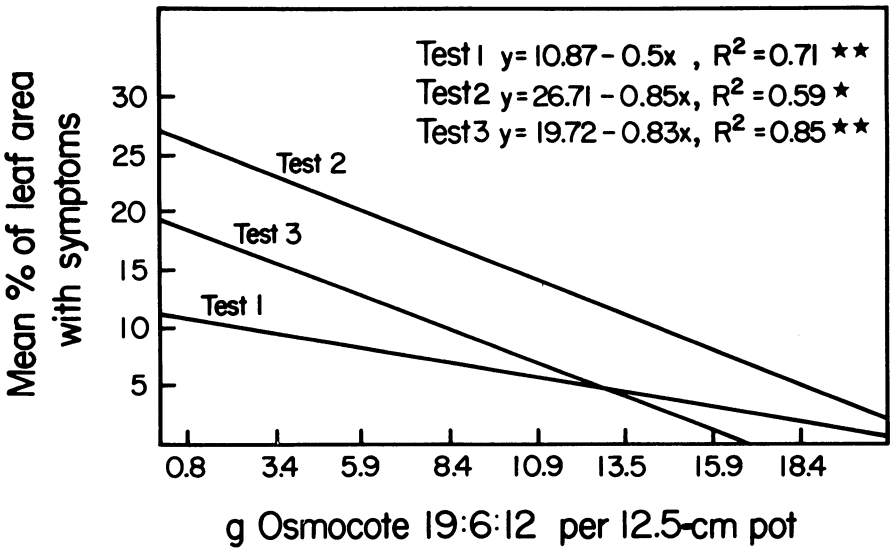

Fig. 1. Effect of rate of Osmocote 19:6:12 slow-release fertilizer on severity of Xanthomonas blight of *Syngonium podophyllum* 'White Butterfly' caused by *Xanthomonas campestris* pv. *syngonii*. R^2 values indicate goodness-of-fit and asterisks indicate level of significance (* = 5%, ** = 1%) of the F value for the regression.

Table 3. Effect of variable nitrogen and potassium rates on growth of *Syngonium podophyllum* 'White Butterfly' and on electrical conductivity (EC) of leachate before inoculation with *Xanthomonas campestris* pv. *syngonii*[a]

Nitrogen (mg/pot/wk)	Potassium (mg/pot/wk)	Leachate EC (μmhos/cm) 25 June	Height (cm) 22 June	Leaf number 22 June	Top weight (g) 25 June	Mean % disease 14 July
50	30	193	12.2	42.2	38.9	61.0
50	90	850	13.4	40.6	38.2	45.5
50	150	2,192	13.8	45.6	45.4	59.5
150	30	4,417	13.8	44.8	42.8	54.5
150	90	5,750	13.2	46.6	49.3	53.5
150	150	7,417	14.0	32.0	39.0	34.0
250	30	8,000	11.0	45.0	35.3	42.7
250	90	8,917	13.6	39.4	39.1	36.5
250	150	10,250	12.6	32.6	30.5	32.5
Significance[b]						
Nitrogen (N)		**	NS	NS	*	**
Potassium (K)		**	NS	NS	NS	*
N × K		NS	NS	NS	NS	**

[a]Means are for 10 plants per treatment (except leachate EC, where means are for four pots per treatment), test 3 (27 April to 25 June 1987).
[b]Regression analyses were performed for tests in which a significant difference between treatments was indicated by an F test. NS = not significant, * = $P = 0.05$, ** = $P = 0.01$.

Phosphorus was highest when nitrogen rate was 150 mg per pot per week, regardless of potassium rate. Potassium and magnesium levels were affected by both nitrogen and potassium rates, with sulfur affected by nitrogen rate only and calcium affected by potassium rate only. Significant interactions between nitrogen and potassium were found for magnesium and potassium only. Potassium levels in tissue were similar when either 90 or 150 mg of K per pot per week was applied but decreased as N rate increased. Highest levels of magnesium occurred with the lowest application rates of N and K. The results are especially interesting because plant top quality and other growth measurements were not affected by nitrogen or potassium rate. This indicates the wide range of tissue element content that corresponds to good-quality plants. Levels of the elements for plants in N-K trials were similar to those found in the highest quality plants in complete fertilizer trials: nitrogen, 3.68–4.88%; phosphorus, 0.45–0.51%; potassium, 2.15–4.96%; sulfur, 0.14–0.27%; magnesium, 0.26–0.60%; and calcium, 1.26–1.58%.

Mean percentage of leaf area showing symptoms of Xanthomonas blight was affected by both nitrogen and potassium rates (Table 3). Increases in either element resulted in a similar degree of reduction in symptom expression. An interaction between N and K occurred, and the intermediate or high rate of nitrogen combined with the high rate of potassium resulted in the lowest disease severity rating (Table 3). The N-K ratio was not involved in disease severity expression, although rate of each element did affect disease severity expression.

DISCUSSION

Environmental differences between tests affected disease severity. Preinoculation light intensity has not been found to affect severity of Xanthomonas blight (4), so differences in light level among tests reported here would not be expected to influence disease severity. In contrast, temperature has a significant impact on disease severity, with optimal development occurring between 26 and 30 C. Temperatures in this range were present for all complete fertilizer trials with slow-release fertilizer, test 2 for liquid fertilizer, and tests 2 and 3 for N-K ratio. Differences in severity did occur among tests, as evidenced by the three slow-release fertilizer tests (Fig. 1). Despite these differences, the response to fertilizer treatment was similar regardless of overall disease severity.

Nitrogen source and rate are important factors in development of many plant diseases, with the exact role depending on both the host and the pathogen involved (11). Xanthomonas blight is affected by the rate of fertilizer supplied to the host but not by the ratio

Table 4. Nutrient content for mature *Syngonium podophyllum* 'White Butterfly' fertilized with different rates of nitrogen and potassium

Nitrogen (mg/pot/wk)	Potassium (mg/pot/wk)	Percent dry weight[a]					
		N	P	K	S	Mg	Ca
50	30	4.12	0.49	2.29	0.14	0.60	1.51
50	90	3.44	0.45	4.96	0.17	0.43	1.26
50	150	3.84	0.46	4.80	0.17	0.33	1.42
150	30	3.68	0.51	2.15	0.22	0.39	1.56
150	90	3.98	0.49	4.59	0.23	0.31	1.58
150	150	4.30	0.49	4.48	0.25	0.27	1.34
250	30	3.68	0.48	2.44	0.23	0.31	1.50
250	90	4.44	0.45	4.09	0.24	0.29	1.57
250	150	4.88	0.40	4.25	0.27	0.26	1.38
Significance[b]							
Nitrogen (N)		NS	*	**	**	**	NS
Potassium (K)		NS	NS	**	NS	**	**
N × K		NS	NS	**	NS	**	NS

[a]Means are for five plants per treatment, test 3.
[b]Regression analyses were performed for tests in which a significant difference between treatments was indicated by an *F* test. NS = not significant, * = $P = 0.05$, ** = $P = 0.01$.

of nitrogen to potassium. An earlier report also showed that nitrogen source (nitrate vs. ammonium) did not influence the development of Xanthomonas blight (3).

In general, increasing the amount of nitrogen, potassium, or complete fertilizer reduced the severity of subsequent symptoms caused by *X. c.* pv. *syngonii*. This response has been consistent for some other pathovars of *X. campestris* that infect foliage plants. Leaf spot of scheffleras caused by *X. c.* pv. *hederae* Young et al (6) and red-edge disease of heart-leaf philodendron caused by *X. c.* pv. *dieffenbachiae* (10) showed the same response. The sensitivity of the host plant to fertilizer level determines the usefulness of fertilizer rate as a control method. For plants that respond adversely to a twofold or threefold increase in fertilizer level (over the optimum rate), it is unlikely that any benefit could be obtained from applying more than the optimum rate for bacterial disease reduction. Some plants, such as schefflera and syngonium, are very tolerant of as much as a sixfold increase in fertilizer level, and minimizing severity of *Xanthomonas* diseases of these plants with increased fertilizer rate has good potential (2,6). Even a 25% decrease in disease severity can be meaningful when bactericides are phytotoxic and relatively ineffective because of development of pesticide-resistant bacterial strains. To minimize fertilizer costs and potential for groundwater contamination, the lowest rate of fertilizer that results in a significant reduction of disease severity should be used.

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