



Potential Risk of Commercial Geranium to Infection by *Puccinia pelargonii-zonalis*

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Abstract

Outbreaks of rust caused by the fungus *Puccinia pelargonii-zonalis* on geraniums can result in large losses due to the plants' reduced aesthetic value and eradication efforts. To assess the potential risk of a rust outbreak in geranium production facilities, 77 commercial varieties of geranium were inoculated with a mixture of two isolates of *P. pelargonii-zonalis*. All but one variety (98.7%) developed at least one sporulating lesion and 72.7% developed rust lesions on more than 20% of the leaves. Six varieties had lesions on fewer than 10% of the leaves and one variety did not develop visible lesions. These data indicate that the potential for geranium rust to spread throughout commercial greenhouses is very high if an accidental introduction should occur. While fungicides are available to manage the disease, including products with curative properties, minimizing risk by using disease-free cuttings, maintaining clean stock plants, and avoiding leaf wetness is essential to limit losses to geranium rust.

Introduction

Floriculture commodities include bedding/garden plants, cut cultivated greens, cut flowers, flowering potted plants, and foliage plants. In 2005, the production of floriculture crops in the US was valued at \$5.36 billion wholesale with California and Florida accounting for 37% of the total (9). A wide variety of crops are produced including *Begonia*, *Calendula* (pot-marigold), *Dendranthema* (chrysanthemum), *Gerbera* (daisy), *Gladiolus*, *Hosta*, *Impatiens*, *Iris*, *Pelargonium* (geranium), *Petunia*, *Viola* (pansy), and many others. Geranium is the most valuable bedding plant in the US valued at \$162 million in 2005 (9). Geranium production as a bedding/garden plant can either be from seed or vegetative cuttings and plants are shipped as flats, pots, or hanging baskets.

Greenhouse production of floriculture crops requires an integrated management plan to reduce losses due to plant diseases that includes cultural practices (e.g., sanitation, water management) and judicious use of fungicides (1). Specific disease-resistant varieties are not widely available for many floriculture crops which are typically only bred for horticultural characteristics such as plant habit or flower color. Many diseases including gray mold (*Botrytis cinerea*) and root rots (*Pythium* spp., *Phytophthora* spp., *Rhizoctonia* spp.) are widespread problems on many floriculture hosts. Other diseases such as rusts, have narrow host ranges and are not a constant threat to production but can cause substantial losses should facilities become infested. Certain rust diseases such as gladiolus rust (*Uromyces transversalis*), chrysanthemum white rust (*Puccinia horiana*), and geranium rust (*Puccinia pelargonii-zonalis*) are quarantine-significant pests and infestation can result in the implementation of federal and/or state quarantine measures (11).

Geranium rust is caused by *P. pelargonii-zonalis* Doidge and the fungus completes its entire life cycle on geranium (*Pelargonium* × *hortorum* L. H. Bailey) (2). Fungicides are available to manage the disease (4,5) but infected plants are not marketable. The pathogen was introduced into Europe from South Africa in the 1960s and by the early 1970s it had been introduced into greenhouses throughout the US (6,10). Attempts to eliminate the rust through sanitation and with quarantine restrictions were unsuccessful and led to the

lifting of most quarantines by the 1980s (8). Restrictions on state-to-state movement of geraniums still exist. For example, Ohio will not accept geraniums from California that are not certified pest-free from *P. pelargonii-zonalis* (7). Geranium rust can be found on landscape plantings of geranium in California but is not endemic to Ohio. Occasional outbreaks of geranium rust occur resulting in substantial financial losses to producers (3). Variable susceptibility of thirteen varieties of geranium to *P. pelargonii-zonalis* was observed by Harwood and Raabe in the 1970s (2). This research was conducted to assess the relative risk of modern commercial geranium varieties (zonal or tetraploid, clonal geranium and diploid seed geranium) to infection by *P. pelargonii-zonalis* and to better assess the potential consequences of contamination of a production facility by the fungus.

Plant Inoculations and Rating of Disease

Two isolates of *P. pelargonii-zonalis* obtained from infected stock in Georgia were maintained on *Pelargonium × hortorum* cv. Elite White grown from seed in a greenhouse. For plant inoculations, urediniospores of each rust isolate were collected by vacuum from actively sporulating lesions, combined and suspended in 0.001% Tween 20 (J. T. Baker, Phillipsburg, NJ), and filtered through sterile cheesecloth to remove debris. Spores were then diluted to 1×10^5 spores/ml in 0.001% Tween 20. Plants were watered immediately prior to inoculation, sprayed with the urediniospore suspension until run-off, bagged to maintain high relative humidity, and stored in the dark at room temperature (4,5). Plastic bags were removed after 24 h and geraniums were maintained in a greenhouse. Lesions were typically observed in 10 to 14 days.

Thirty-one varieties of vegetatively-propagated geranium (Table 1) in 10.2 × 10.2 cm containers were obtained from Oglevee Ltd. (McDonough, GA) and maintained in a rust-free greenhouse for 6 weeks to minimize the effects of any potential pesticide applied by the producer. Plants were transplanted into Metro-Mix 360 (Sun Gro Horticulture, Bellevue, WA) in 3.78 liter containers one week prior to the experiment. Seed from 46 varieties (Goldsmith Seeds, Gilroy, CA) (Table 2) were sown in 72-cell plug trays containing Metro-Mix 360. Seedlings were irrigated as needed and all plants were fertilized weekly with 100 ppm N (Peters Geranium Special, The Scotts Company, Marysville, OH). Five-month old plants transplanted into Metro-Mix 360 in 3.78 liter containers were used in the experiment. Seedling and vegetative geraniums were inoculated with *P. pelargonii-zonalis* in separate experiments. Plant size was similar in the two trials with an average of 46.5 leaves (vegetative varieties) and 42.8 leaves (seed varieties). For each trial, eighteen 11.4-liter pots containing three Elite White geraniums with sporulating lesions of *P. pelargonii-zonalis* (approximately 120 to 140 infected leaves per pot) were dispersed among the test varieties. Three single plant replicates of each variety were used and non-infected Elite White plants were included in each trial as a control. Trials were conducted in a 3.6 × 7.9 m air-conditioned greenhouse with day/night temperature settings of 17 and 21°C. Plants were subjected to overhead misting for 3 h (10 sec every 15 min) each morning to facilitate further infection by the fungus. After three weeks all plants were scored for total number of leaves, number of infected leaves, and leaves with greater than 10 lesions (measure of severity). Data were converted to percent infection and analyzed by ANOVA at $P = 0.05$.

Table 1. Infection of vegetatively-propagated geranium varieties by *P. pelargonii-zonalis*.

Variety	% infected leaves	% leaves > 10 lesions
Stardom Pink and White	56.0	22.7
Maestro Red	46.9	23.3
Patriot Bright Red	46.8	13.4
Patriot Bright Violet	38.4	5.9
Patriot Salmon	37.1	6.1
PAC Veronica	36.9	13.5
PAC Melody	36.9	10.5
Elite White ^z	36.0	7.3
Patriot Cranberry Red	33.6	0.7
Wilhelm Langguth	31.9	2.1
PAC Pink X2	30.5	5.3
Stardom Salmon (Lucille)	29.5	2.1
PAC Melody Blue	28.7	3.4
PAC Shocking Violet	26.2	4.1
PAC Patriot White	21.7	0.0
Catalina	21.5	1.1
Candy Bright Red (Fireball)	19.0	0.7
PAC Candy Lavender	17.3	3.5
PAC Evening Glow	15.0	1.2
Candy White (White Truffles)	14.4	0.0
PAC Kim	14.4	1.3
PAC Victor	13.5	2.8
Sincerely Yours	12.6	0.0
Maestro Salmon	12.4	0.0
PAC Sassy Dark Red	12.3	0.5
Stardom Deep Lavender (Natalie)	10.0	0.0
Stardom Red	8.6	0.0
Candy Rose Splash	6.6	0.0
Patriot Bright Pink	4.4	0.0
Candy White Splash (Raspberry) Ice	3.0	0.0
Patriot Cherry Rose	0.9	0.0
PAC Fox	0.0	0.0
LSD	15.7	7.8
P-value	<0.0001	<0.0001

^z seed-propagated Elite White included for comparison.

Table 2. Infection of seed-propagated geranium varieties by *P. pelargonii-zonalis*.

Variety	% infected leaves	% leaves > 10 lesions
Elite Scarlet	74.9	32.8
Maverick Salmon	71.0	44.2
Maverick Star	68.2	33.6
Maverick Red	64.0	37.4
Maverick Scarlet	63.9	31.8
Maverick Pink	62.2	38.8
Elite White	61.4	29.1
Elite Salmon	60.0	7.5
Orbit Scarlet Eye	59.9	33.5
Orbit Red	58.0	7.5
Maverick Quicksilver	57.5	19.5
Orbit White	57.5	22.7
Orbit Coral	57.5	20.0
Multibloom Bright Rose	56.0	25.8
Maverick White	53.9	18.1
Bull's Eye Salmon	53.6	14.6
Maverick Violet	53.2	23.0
Orbit Cardinal	46.5	28.3
Multibloom Red	45.4	19.7
Multibloom White	44.7	28.3
Orbit Violet	44.6	8.4
Orbit Pink	44.6	5.8
OrbitDeep Salmon	43.9	13.0
Bull's Eye Light Pink	43.4	6.5
Multibloom Pink	42.7	20.9
Bull's Eye Cherry	38.6	18.9
Orbit Salmon	38.5	5.5
Orbit Orchid	38.2	11.2
Maverick Coral	36.8	16.3
Maverick Light Salmon	35.8	8.2
Multibloom Capri	34.8	18.0
Multibloom Light Salmon	31.8	17.6
Multibloom Salmon	29.0	11.9
Orbit Cherry	26.2	11.5
Maverick Lavender	25.5	4.4
Orbit Scarlet	25.1	4.2
Bull's Eye Scarlet	24.4	0.0
Orbit Appleblossom	23.7	3.7

(continued)

Table 2. (continued).

Variety	% infected leaves	% leaves > 10 lesions
Orbit Light Salmon	21.9	1.1
Elite Cherry	21.6	7.6
Elite Pink	21.4	5.6
Orbit Rose	18.2	0.0
Elite Red	14.5	5.9
Orbit Hot Pink	12.2	0.0
Multibloom Scarlet	12.2	0.0
Orbit Glow	4.6	0.7
LSD	15.6	13.2
<i>P</i> -value	<0.0001	<0.0001

Disease Development

The vast majority (76 out of 77) of the geranium varieties supported lesion formation by a mixture of two isolates of *P. pelargonii-zonalis* (Tables 1 and 2). A total of 48.4% of the vegetative geraniums had lesions on > 20% of the total leaves. Five varieties had more than 10% of the leaves with 10 or more lesions per leaf (Table 1). A total of 89.1% of the seed geraniums had lesions on > 20% of the total leaves and 58.7% of the varieties had more than 10% of the leaves with 10 or more lesions per leaf (Table 2). Five vegetative and one seed geranium had less than 10% infected leaves. One vegetative variety (PAC Fox) did not become infected. Disease was more severe on the seed-propagated geranium with 57.8% of the varieties with more than ten lesions on > 10% of the leaves compared to 16.1% of the vegetative varieties.

Conclusion

The potential risk of widespread contamination from an accidental introduction of *P. pelargonii-zonalis* within a commercial operation is large. Lesions developed on the majority of the commercial varieties propagated by two major US geranium producers in 2004-2005. The geraniums tested in the present study represented approximately 72% and 88% of the total available in the 2005 or 2004-2005 catalogs of Oglevee Ltd. and Goldsmith Seeds, respectively. The potential for contamination within a greenhouse is very high even with the presence of few sporulating lesions (Fig. 1). Urediniospore production of a related rust, *Puccinia hemerocallidis* on daylily, can range from 1,000 to 2,000 urediniospores per lesion in a 24-h period (Buck, *unpublished*). Urediniospores can be easily spread on workers, by watering, or by air movement from infected plants to non-contaminated stock. Compounding this is the time frame between infestation/infection to the development of discernable symptoms on the host. Yellow spots at the infection points were often not observed until 7 to 9 days post-infection and this varied with variety (Fig. 2). Until breeding programs for floriculture crops incorporate disease resistance as a desirable phenotype in variety selections disease problems will continue in commercial operations. The best defense against geranium rust continues to be avoidance of the pathogen by utilizing disease-free cuttings, minimizing leaf wetness, and maintaining clean stock.



Fig. 1. Sporulating lesions of *P. pelargonii-zonalis* on the abaxial surface of a leaf. Note the formation of a whitish ring (arrow) around the initial central infection point that will form additional lesions as the disease progresses.



Fig. 2. Yellow lesions (YL) and sporulating lesions (SL) of *P. pelargonii-zonalis* on geranium.

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