Damping-Off, Root Rot, and Lower Stem Rot of Seed-Propagated Geraniums Caused by *Pythium ultimum*

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ABSTRACT

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Symptoms caused by *Pythium ultimum* on seed-propagated geraniums (*Pelargonium* ×*hortorum*) are described and include damping-off, root rot, and lower stem rot. Geranium seedlings were transplanted into a soilless root medium artificially infested with low, medium, and high levels of inoculum of *P. ultimum*. Plant stunting caused by root rot and plant death caused by damping-off and lower stem rot were greatest when seedlings were grown in the highly infested medium.

Diploid ($2N = 18$) geraniums (*Pelargonium* ×*hortorum* L. H. Bailey) are used exclusively for the development of seed-propagated cultivars and constitute a small portion of asexually reproduced cultivars (7). Tetraploid ($2N = 36$) cultivars are asexually reproduced and constitute the majority of commercially produced geraniums in both the United States and Europe (7). However, seed-propagated geraniums are increasing in popularity because of low production costs and the introduction of cultivars with increased diversity, improved horticultural characteristics, and more satisfactory garden performance (2).

Diseases of seed-propagated geraniums have not commanded much attention in the literature. Overall, disease losses are considered generally low in seed-propagated geraniums grown under a good sanitation program, because soilborne or systemic pathogens are only rarely carried on or in seed (11). Recently, however, the commercial use of silver thiosulfate (STS) to prevent petal abscission on seed-propagated geraniums (5,15) has focused attention on diseases caused by *Pythium ultimum* Trow. Foliar applications of STS to asymptomatic seed-propagated geraniums infected with *P. ultimum* can result in premature plant death caused by Pythium lower stem rot (9).

Pythium disease symptoms on seed-propagated geraniums are reported to be similar to those occurring during the propagation of asexually reproduced geraniums (16,17). These include brown water-soaked lesions that originate at the wounded base of cuttings or wounds on young plants. These lesions enlarge, turn coal black, and progress upward 75–100 mm from the base, causing plant death (4,16). The term *blackleg* has been used to describe the disease in asexually reproduced geraniums as well as seed-propagated geraniums. Damping-off caused by *P. ultimum* is reported to be an occasional problem of seed-propagated geraniums, resulting in stunted, wilted, or dead seedlings with blackened roots (11,17).

Current descriptions of disease symptoms caused by *P. ultimum* on seed-propagated geraniums seem to be incomplete. Studies investigating the influence of STS on premature plant death caused by *P. ultimum* suggest that STS increases the decline of plants already infected with the pathogen, although foliar disease symptoms are often absent (9). The objective of this study was to document disease symptoms caused by *P. ultimum* on seed-propagated geraniums.

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MATERIALS AND METHODS

Geranium seeds (cv. Ringo Scarlet) obtained from Sluis and Groot B.V., Enkhuizen, The Netherlands, were individually sown in a soilless root medium (Sunshine Media Mix, Blend 1, Fisons-Western Corp., Vancouver, B.C., Canada) containing 2:2:1 (v/v) vermiculite, sphagnum peat, and perlite, in round cells 2 cm in diameter. The seeds were covered with approximately 0.5 cm of fine vermiculite and placed under intermittent mist at 24 ± 2 C in a glass greenhouse. Seedlings were removed from the mist after germination (7 days) and grown under natural light at 24 C during the day and 21 C at night until transplanting.

Inoculum of *P. ultimum* was prepared by a procedure developed for culturing *Rhizoctonia solani* Kühn (12). Finely chopped potatoes (50 g) were mixed with 500 ml of the soilless root medium. The mixture was autoclaved for 1 hr on each of two consecutive days. A pathogenic isolate of *P. ultimum* used in previous studies (18) was grown on 20 ml of water agar in petri plates 10 cm in diameter for 2 days at 24 C. Six mycelial disks (12 mm in diameter) taken from the perimeters of colonies were used to infest 1.5 L of the sterilized potato-medium mixture in 2-L flasks plugged with cotton. After 2 wk the inoculum was air-dried for 1–2 days and sieved through a number 10 (2-mm) screen.

The inoculum was thoroughly mixed with soilless root medium at three infestation levels: 0.75 g/L (low), 1.5 g/L (medium), and 3.0 g/L (high). The base infestation level of 0.75 g/L was determined from cucumber seedling bioassays conducted by Chen et al (6). The medium was then placed into single plastic cells (8 × 8 × 6 cm) of 18-cell flats (25 × 53 cm). Geranium seedlings 35 or 49 days old were transplanted into the infested and the uninfested medium. Entire plugs of soilless root medium containing individual seedlings were transplanted, with one plant per cell. Eight single cells were used per treatment, arranged in a completely randomized block design in a walk-in plant growth chamber. These experiments were repeated twice.

Temperature set points in the growth chamber following transplanting were 21 C during the day and 18 C at night. The irradiance was 135 μmol·sec^{-1}·m^{-2} for 12 hr per day, from VHO cool white fluorescent lamps. During the experiment, the pH of the medium varied between 5.5 and 6.5. The plants were fertilized at each watering with N and K, each at 200 mg/L. Foliar applications of chlormequat (2-chloroethyltrimethylammonium chloride) at 750 ppm were used in all treatments, including the control, to regulate plant height.

Disease symptoms were noted and dead plants counted daily following transplanting. Plant height and canopy width were recorded 36, 41, and 56 days and 27, 36, 42, and 49 days after transplanting 35- and 49-day-old seedlings, respectively. Plant volume (size) was calculated from plant height and canopy width on the assumption that the volume occupied by the plant approximates a cylinder. As the results from the two experiments were similar, only the results from the experiment with seedlings transplanted at 35 days are reported.

Geraniums that died during the study were sampled to detect colonization by *P. ultimum*. Surviving geraniums in the infested and the uninfested medium were sampled randomly (a minimum of three plants per treatment). Three 2-cm segments of root, stem, and petiole tissues were surface-disinfested in 0.5% sodium hypochlorite for approximately 20 sec, rinsed in sterile distilled water, and then plated on water agar. *Pythium* spp. isolated from the plant tissue were identified according to Middleton's key (14).

RESULTS AND DISCUSSION

Plant death 55 days after transplanting 35-day-old seedlings into the medium infested with *P. ultimum* at low, medium, and high inoculum levels was 6, 0, and 38%, respectively. Surviving plants grown in the infested medium were smaller than plants grown in the uninfested medium (Fig. 1). *P. ultimum* was consistently isolated from surface-disinfested root tissue of dead and surviving plants grown in the infested medium. Plants grown in the uninfested medium remained symptomless, and *P. ultimum* was never isolated from them.

Geraniums grown in the infested medium commonly showed one of three disease patterns: damping-off, root rot, or lower stem rot. The first disease pattern, observed immediately after transplanting into the infested medium, was seedling damping-off. In affected seedlings, stem rot developed at the surface of the soilless medium, causing plant collapse and death. The stem rot symptoms noted were similar to those discussed by Hendrix and Campbell (10), who showed that *Pythium* spp. generally attack newly emerged seedlings at ground level, causing them to collapse.

Seedlings and young plants surviving transplanting showed other damping-off disease symptoms, including lower stem girdling and root necrosis, which resulted in severe plant stunting. An overall grayish green coloration of leaves was commonly observed, with lower leaves becoming chlorotic and often developing a reddish cast. These same leaves were the first to wilt and eventually become totally necrotic. Geraniums either remained in this condition with no further apparent disease progression or developed a soft, brown stem necrosis, which normally remained localized, just below the soil line. Deterioration of the lower stem tissue resulted in plant collapse and death within several days. Symptoms of stem girdling usually resulting from infection by *R. solani* have typically been described as "wire stem" (1). In such instances, the seedling is resistant enough or grows in an environment favorable enough that only the cortical tissue is invaded, and dysfunction of the vascular system is minimal (1). Observations from this study indicate that similar symptoms on seed-propagated geraniums result from infection by *P. ultimum*.

Established geraniums also showed symptoms of root rot and lower stem rot diseases. Root rot symptoms on established plants often did not have associated foliar symptoms but included varying degrees of plant stunting and root necrosis. These plants appeared healthy and would not be suspect unless compared with an uninfected plant, although *P. ultimum* was consistently isolated from surface-disinfested root tissue. Plants with this type of root rot either continued to grow with only apparently minor disease symptoms or eventually developed a lower stem rot.

The primary symptom of lower stem rot disease (blackleg) on established young and mature plants was a black, water-soaked stem lesion originating at the stem base just below the surface of the soilless medium. Prior to the development of black lesions, affected plants appeared healthy and remained green and usually turgid until the black lesion progressed up the stem into the petioles. Total stem blackening usually occurred during a 24- to 72-hr period. Eventually the plant toppled over and died, and the blackened tissue hardened. Lower stem rot always resulted in plant death in these studies. The term *lower stem rot* is proposed to more adequately describe this disease, occurring on established seed-propagated geraniums, than the term *blackleg*, which describes a disease occurring during the propagation of asexually reproduced cuttings.

In summary, this study clarifies diseases and associated symptoms caused by *P. ultimum* on seed-propagated geraniums throughout the production cycle, including seedlings and young and mature plants. Damping-off of seedlings and young, unestablished plants normally occurs during an early, discrete production phase and is usually readily identified by the grower. However, *P. ultimum* can infect the roots of established plants at any point in the production cycle, causing a root rot, which may go unnoticed unless progression into lower stem rot disease occurs.

Pythium spp. are ubiquitous and may be introduced into a greenhouse at virtually any stage in the production cycle through water supply sources or

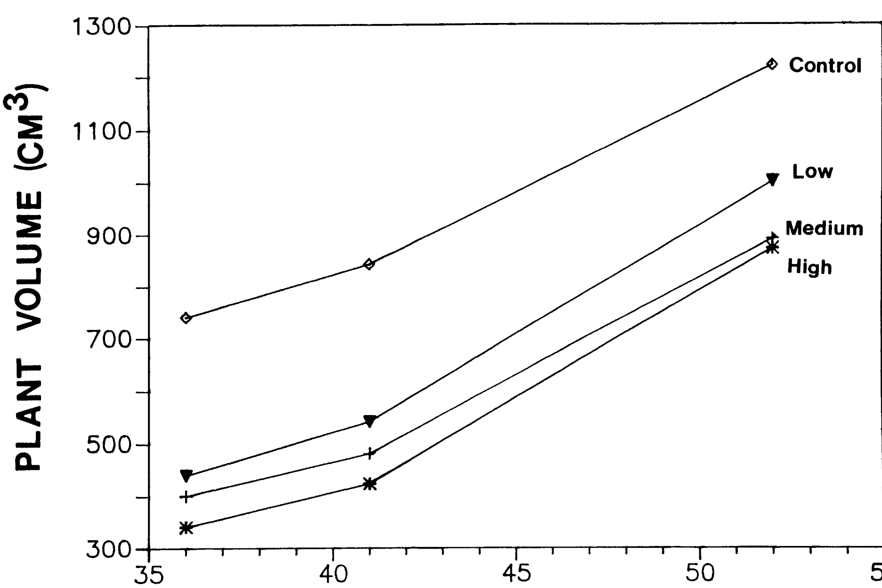

Fig. 1. Average plant volume of geraniums (cv. Ringo Scarlet) transplanted at 35 days into an uninfested soilless root medium (control) and a soilless root medium infested with *Pythium ultimum* at low, medium, and high levels (0.75, 1.5, and 3.0 g of inoculum per liter of medium, respectively).

irrigation ponds (3,8) and by *Pythium*-infested soil particles from greenhouse walkways, floors, and beds (18,19). Although foliar symptoms may be absent, root rot causes crop delay and lowered plant quality (9). Infected plants generally fail to recover even when conditions become unfavorable for disease development (10) and may decline and die after shipping or after placement in the landscape (13). Growers of seed-propagated geraniums, especially growers using STS, need to recognize symptoms of disease caused by *P. ultimum* or, more importantly, realize that infection may occur without causing foliar symptoms. STS applied to such infected plants could result in massive crop losses (9).

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