INFLUENCE OF SILVER THIOSULPHATE AND FUNGICIDES ON PLANT MORTALITY CAUSED BY *PYTHIUM ULTIMUM* IN THE SEED PROPAGATED GERANIUM (*PELARGONIUM* x *HORTORUM*)

By

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To Jane, my sister and childhood companion.

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ABSTRACT

INFLUENCE OF SILVER THIOSULPHATE AND FUNGICIDES ON PLANT MORTALITY CAUSED BY PYTHIUM ULTIMUM IN THE SEED PROPAGATED GERANIUM (PELARGONIUM X HORTORUM)

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Crown and root rot symptoms caused by Pythium ultimum were described for the first time on the seed propagated geranium. 'Ringo Scarlet' geraniums transplanted into low, medium or high levels (0.75, 1.50, or 3.0 g inoculum liter^{-1} medium) of P. ultimum-infested medium and sprayed with 0.25 mM silver thiosulphate 0, 7 or 14 days following transplant showed greater mortality than geraniums not treated with silver thiosulphate. Geraniums not treated with silver thiosulphate but grown in P. ultimum-infested medium often appeared healthy except for reduced plant size. Fenaminosulf, ethazol or metalaxyl applied as soil drenches at selected times reduced crown and root rot disease caused by P. ultimum in geraniums not treated with silver thiosulphate. Only metalaxyl consistently controlled the increased incidence of crown and root rot in geraniums sprayed with silver thiosulphate. Genetic resistance to P. ultimum was not identified in the 37 cultivars screened.

LITERATURE REVIEW

The seed propagated hybrid pelargonium (*Pelargonium* x *hortorum*) belongs to the *Geraniaceae* family. Family members are characterized by the long-beaked fruit or 'Cranesbill' from which the Greek word *geranos* is derived (32,39,68,82). *Geraniaciae* was first published in *Materia Medica*, a book of herbal remedies written by Dioscorides about 50 A.D. (32,68). The simple, irregular (zygomorphic) flower shape and necter tube are responsible for the separation of *Pelargonium* from the other 10 genera of *Geraniaceae*.

The Dutch of the Cape Colony of South Africa discovered the pelargonium in the opening years of the seventeenth century. Its natural habitat is the arid semi-desert of southern Africa. With few exceptions, all members of the genus *Pelargonium* are of African origin (32,39,68,82). By the 1650's several species were under greenhouse cultivation in Europe (39). Approximately 300 spp. of pelargoniums exist today varying in habit, leaf form and flower color (82). Hybridization has changed the flower form from irregular to rounded, single, semi-double, double, and the quilled types currently available.

Pelargonium x *hortorum* originally arose from a cross between *P. inquinans* and *P. zonale* with subsequent

characteristics incorporated from other species (39,82). This garden or bedding plant is best known as "geranium", a name more correctly describing its hardy, European native cousin of the Geranium genus. However, further use of the term geranium in this thesis will be in reference to the hybrid geranium Pelargonium x hortorum.

Until the 1960's geraniums were almost exclusively propagated by cuttings. Erratic germination, non-uniformity and a flowering time of 12-15 months made seed propagation undesirable (39). Extensive breeding and development in the 1960's made growing geraniums from seed commercially feasible. The open-pollinated 'Nittany Lion Red' developed by Dr. Richard Craig at Pennsylvania State University was the first true breeding hybrid geranium produced by seed (96). Subsequent improvements followed with the introduction of the 'New Era' and 'Carefree' F_1 Hybrids from the Harris Seed Co. and Pan-American Seed Co. (37). Through the joint effort of Goldsmith Seeds, Inc. and Sluis and Groot, a group of cultivars called the Sprinters were released in 1973 and were the first seed propagated geranium to successfully flower in the pack. Subsequently, cultivars referred to as the Ringos were introduced by Sluis and Groot in 1978 which flowered earlier and were more compact for pack production (Personal communication, Dr. L. Ewart; Michigan State University).

In 1983, approximately 10 seed companies were developing improved hybrid seed cultivars. More than 100

cultivars have been introduced, bringing annual production in 1983 to 90-100 million seeds (37). The development and availability of early flowering cultivars makes the production cost of the seed propagated hybrid geranium competitive with the traditional cutting propagated geranium.

Petal shatter has been a problem in transporting and marketing the seed propagated hybrid geranium (10). The degree of shattering varies among cultivars (11). Double or semi-double flowers lacking nectaries do not shatter easily (120). However, the "low shatter" cultivar may not have the most desirable or aesthetic characteristics.

Petal abscission in the seed-propagated hybrid geranium is increased by exogenous ethylene (11,120). Premature petal abscission in the geranium can be reduced by preventing ethylene accumulation and transporting under cool temperatures (1-5 ^{o}C) (11). However, cool storage in combination with frequent irrigation was found to increase ethylene sensitivity and decrease flower life after storage removal in studies on cut carnations (71).

In addition to promoting petal abscission in seed propagated geraniums, ethylene also plays in important role in the keeping quality of several floricultural crops (46). Crocker and Knight (38) first suggested exogenous ethylene as the deleterious component in illuminating gas causing cut carnation "sleepiness". Naturally emanating ethylene from cut flowers measured under contolled conditions was believed

to have been produced by fungus which became contaminants during investigations. Nichols (88), however, showed an ethylene surge accompanies wilting in carnation independent of fungal infection. This confirmed Smith's (106) proposal that the ethylene surge after fungal attack was due to the breakdown of the host tissue and was not generated by the fungus.

Ethylene production has been correlated with flower longevity in cut carnations (40). During a low steady-state ethylene production phase, carnation flowers remained turgid. This ethylene level was followed by a high log linear phase which resulted in flower wilting and senescence. Kende and Hanson (58) concluded from studies with morning glory tissue that this ethylene-induced senescence is an acceleration of natural senescence.

The silver ion is effective in blocking ethylene actions such as senescence and petal abscission (16,17). Silver ion appears to inhibit ethylene effects at a very early stage in the events leading to abscission (94). Precisely how silver inhibits ethylene action is not known. Yang (123) recently presented many of the current hypotheses.

Beyer (18,19) proposed that a small fraction of ethylene is metabolized and incorporated into tissue or converted to CO_2. Burg and Burg (24) first suggested that that ethylene binds to a metal-containing site. Sisler and Goren (102) support this theory. Copper (Cu^+) is the

suggested metal because of its affinity to ethylene (18,26). Sisler (104) showed that ethylene binding is prevented by reagents containing copper enzymes. Ethylene can form mono and diligand complexes with silver (57) however, the bond is not irreversible (16).

It is the conclusion of many investigators that ethylene biosynthesis is not inhibited by silver (6,16,18). Silver appears to counter the effect of ethylene by blocking ethylene action at its receptor sites (6,16,18). Studies in which silver lowered ethylene binding by a plant extract support this theory (102). Sisler and Goren (103) propose that this ethylene/receptor complex triggers a series of metabolic events and then diffuses out or is degraded.

The binding of ethylene to its receptor increased the pool size of the ethylene precursor aminocyclopropane-1-carboxylic (ACC) as well as ethylene production in studies with cut carnation flowers (25). Exogenous ACC caused wilting and increased ethylene levels. Veen and Kwakkenbos (117) showed increased ethylene levels but no flower wilting in cut carnations when a STS treatment was followed by ACC. The blocking of ethylene to the receptor site may inhibit the autocatalytic ethylene increase and the accompanying ACC content increase. Similar studies substantiate this conclusion. Veen (114) blocked the ethylene surge preceding the wilting of cut carnation by the anionic silver thiosulphate (STS) solution. In preclimacteric fruit STS inhibited ethylene-induced ethylene production (55).

The receptacle tissue may be an important factor in the silver inhibition of ethylene action as silver accumulates in receptacle tissue (20,35,116,119). Veen (114) showed that this tissue is also capable of producing ethylene in large quantities.

Although the primary response of silver is considered to be ethylene action inhibition, other physiological plant processes are also affected. Abscisic acid (ABA) influences senescence by affecting ethylene production (98). With ethylene treatment, ABA levels rose during senescence but Nowak and Veen (90) blocked this increase with STS.

STS also prevented endogenous cytokinin levels from rising in cut flower pistils (113). It is postulated that high cytokinin levels in reproductive organs create a sink enhancing flower senescence. STS pretreatment prevents gynaceium enlargement due to carbohydrate accumulation and allows continued transport and utilization of carbohydrates in the petals (41,118).

Silver is also recognized for its germicidal effect. In postharvest physiology studies, Kofranek and Paul (61) immersed the basal end of cut carnations in 1200 ppm $AgNO_3$ for varying time periods. The vascular and pith tissues absorbed silver which moved upward with time. The surface and cut end tissue were impregnated with silver which functioned to inhibit bacterial plugging. Nichols (89) concluded that the silver nitrate prevented bacterial stem blockage, thereby allowing absorption of sucrose-containing

preservative. Kofranek (60) pulsed cut chrysanthemums with basal treatments of silver nitrate plus 5% sucrose and increased flower longevity under a range of shipping temperatures. Silver alone had a much smaller effect than the combination of silver and sucrose in cut carnation longevity.

Dilley and Carpenter (40) attributed the delayed senescence benefits of sucrose to the delay but not inhibition of the autocatalytic production of ethylene. They postulated that sucrose could stimulate respiration creating higher CO_2 levels which could delay autostimulation of ethylene production by endogenous ethylene.

Halevy and Kofranek (45) compared basal and foliar silver treatments on cut carnations to determine if longevity is due to bacteria action or by countering ethylene. They found the benefits of a stem treatment were due to bactericidal properties whereas senescence delay of directly treated flowers was due to anti-ethylene properties of silver.

Because of its ability to block ethylene action, and thereby delay senescence, silver has become an important tool in commercial floriculture. The anionic STS complex is most commonly used because this negatively charged complex is not as likely to be involved in absorption and exchange processes and moves freely within the plant (35). The silver ion formulated as silver nitrate ($AgNO_3$) has low mobility in the plant (61,62). STS reduces phytotoxicity

from silver oxidation which often occurs with silver nitrate application (44,45), yet the inhibitory effect of silver on ethylene action is preserved.

STS is effective in preventing premature senescence and petal abscission in a variety of floricultural crops (7,29,42,43). STS inhibited senescence even in detached petals (86) STS does not, however, produce uniform results in all horticultural crops (115). Cut carnations differed in response to STS with 'standard' flowers more responsive than spray carnations (110).

STS has also been shown to remain effective over an extended time period. Swart (109) immersed lily bulbs in STS prior to planting. The flowers eventually produced from these bulbs were of higher quality and not as sensitive to exogenous ethylene than those not treated with STS at pre-plant. A variety of potted plants treated with STS 2-3 weeks prior to harvest with STS were protected from premature flower abscission under simulated harvest, transit and retail conditions (28).

STS is effective in controlling petal shatter in the seed propagated hybrid geranium (27,79). In geranium production, a STS foliar application is commonly applied just prior to transit. A molar ratio of 1:8 (silver nitrate ($AgNO_3$) to sodium thiosulphate ($Na_2S_2O_3.5H_2O$)) has been suggested by Veen and Van de Geyn (119). Reid et al. (95) recommended a 1:4 ratio. STS mixing procedures have been simplified by Heins et al. (49).

However, during STS formulation trials a higher incidence of crown and root rot symptoms on STS treated geraniums was observed (49). Pythium ultimum was identified as the causal agent. Commercial growers reported similar findings (Personal communication, Dr. Royal Heins Michigan State University, 1983).

Pythium is a large genus with members found worldwide including saprophytes in water or soil and parasites on algae, other fungi, or higher plants (75). The damping-off and crown rot soil pathogens belong to the Oomycete class. They are characterized by coenocytic, elongated mycelium, zoospore production in zoosporangia and resting spores called oospores produced by the union of two morphologically different gametes.

Pythium spp. cause disease problems in greenhouse grown crops (92,100). Pythium spp. are ubiquitious pathogens. Stephens et al. (108) showed that Pythium spp. may be recovered from dust and soil mix particle samples collected from walkways, floors and greenhouse beds and flats. Pythium spp. also infect a wide variety of ornamental vegetable and fruit crops in production, storage or transit (30,36,50,52,53,59,91). Diseases caused by Pythium spp. include seedling damping off, rotting of unrooted cuttings, and root rot of established plants.

Seedling damping off caused by Pythium spp. can develop quickly killing large numbers of seedlings in local areas (66,67,97). Prior to damping off, Campbell and Sleeth (30)

noted purplish or reddish cotyledon color in Pythium infected guayule cotyledons.

Pythium disease symptoms for rooted and unrooted cutting propagated geraniums are well documented and are generally referred to as "blackleg" (87). On cutting propagated geraniums, brown watersoaked lesions originate at the cut base or wounds on young plants. The rooted area enlarges and turns black progressing up 3-4" from the base (22,23,87). On the seed propagated geranium, Pythium disease symptoms have not been thoroughly described although the disease is commonly referred to as blackleg (92). Plant stunting is a typical symptom of root rot due to Pythium infection (30,59,74). Stunted, yellow Pythium infected pineapple showed reduced fruit yields (59). Pythium disease on woody ornamentals resulted in greatly reduced feeder roots and necrotic lesions on existing roots. Root rot symptoms include leaf chlorosis, partial defoliation, reduced growth and vigor and frequent iron deficiency problems (50,54). The amount of stunting depends on on the degree of Pythium injury to the root system (30).

Pythium ultimum enters a plant through the root system (51). On young peach roots, P. ultimum penetrated within 5-8 hours of contact, primarily at epidermal cell junctions (76). Young sweet potato rootlets showed decay within 36 hours after Pythium infection occurred (91). Established infections continued to develop even under drying conditions. Although considered to be primarily a root

pathogen, Pythium spp. can infect stems and foliage of some plants provided environmental conditions are favorable for the pathogen. Braun (24) showed increased disease of stems due to P. complectans on succulent geranium cuttings that were crowded, well-fertilized and well-watered.

Environmental factors also play a role in root disease development and infection potential (1,36,83). Powell et al. (93) noticed increased severity of peach decline following excessive rainfall. Pythium ultimum was one of several Pythium species isolated from affected peach root systems. Mircetich (80) correlated high soil moisture with increased P. ultimum saprophytic activity. Loblolly pine decline was associated with trees on poorly drained, fine-textured soils (69). Saprophytic colonization by Phytophthora and Pythium spp. appeared to weaken the trees allowing brooding and subsequent destruction by bark beetles.

Increasing the moisture holding capacity (MHC) to approximately 30 to 40% did not greatly increase disease severity, although at 70% MHC P. ultimum became a serious problem. However, Hanan et al. (48) determined deficient aeration was not a prerequisite for Pythium infection based on symptom severity on snapdragons in well-aerated medium. To control disease they reduced irrigation but found this method ineffective and to be further detrimental to plant growth.

Sleeth (105) attributed Winter Haven citrus decline to recurring periods of high and low soil moisture and large P. ultimum populations. Biesbrock and Hendrix (21) correlated P. vexans severity with water excess allowing zoospore production. Since P. irregulare forms germ tubes from sporangia it was unaffected by soil water.

Specific temperature ranges are an important requirement for many Pythium spp. Pythium irregulare, P. spinosum Sawada, P. ultimum and related species are most damaging at lower temperatures while P. myriotylum, P. aphanidermatum, P. arrhenomanes, P. polytylum Drechs., P. carolinianum Matthews and P. volutum Vanterpool & Truscolt are damaging at higher temperatures (51). Although P. ultimum is reported to produce more damping-off at lower temperatures (18°C-21°C) with little disease at 30°C (12,67), Halpin el al. showed P. ultimum to be more pathogenic on red clover seedlings at 24-28°C than 16-20°C. (47).

Fertilization also influences disease development. Kraft and Erwin (64) showed favorable nitrogen sources necessary for P. aphanidermatum infection of mung bean seedlings at low inoculum densities. Moore et al. (84) showed calcium deficiency to have the most pronounced influence on susceptilbilty of Highland bentgrass to P. ultimum. Nitrate nitrogen and potassium reduced damping off in moist soil, whereas ammonium nitrogen and phosphate did not (122). Similar results were not obtained in drier soil.

It was proposed that fertilizer influences microbial antagonistic activity in moist soil and corrects plant mineral deficiencies. However, Agnihotri and Vaartaja (3) concluded from their investigations that added nutrients may disrupt a delicate biological balance in the soil which under natural conditions prevents germination of P. ultimum sporangium. A suggested mechanism for increased disease incidence following herbicide application is the inhibition of microflora competing with potential pathogens (9).

Plant exudations into the surrounding environment may play a role in stimulating or preventing root rot fungal growth. Seed or root exudates have been shown to stimulate oospore germination of P. afertile (3), P. aphanidermatum (31,64), P. mamillatum (14), and P. irregulare (4). High numbers of P. ultimum sporangia germinated when parts of different plants were incorporated into the soil (5). Zoospores of P. aphanidermatum supplemented with mung bean exudates showed greater virulence than zoospores not supplemented with exudates (65). Royle and Hickman (99) showed specific substances present in root exudates served as a nutrient source for P. aphanidermatum. They identified sugar or amino acids as the most common promoting factors. A drench of 1000 ppm glucose, fructose, maltose or sucrose induced high germination of P. ultimum sporangia in the soil (5). Mixtures of sugars and amino acids also stimulated germination. Specific herbicides have been shown to affect plant exudation and stimulate pathogen growth (9).

Herbicide application has been correlated with increased disease incidence.

Compounds produced by host plants have also been identified which are toxic to fungi and bacteria. An extensive review has been written on this topic (63). Phytoalexins have been shown to be promoted by ethylene production stimulated by host tissue breakdown due to pathogen infection. However, compound identification and host pathogen relationships are not conclusive.

Physiological plant changes may be involved in resistance to Pythium disease. McCarter and Littrel (73) showed oats, wheat and cucumber were more susceptible in the early stages of germination than in late growth stages. Root rot severity in cotton seedlings decreased as the plants grew older (97). Peach tree seedlings escaping pre-emergence and early postemergence mortality in infested soil grew to a size comparable to those in non-infested soil (81). Differences in P. ultimum blackleg resistance in cutting geraniums were attributed to the time required for the cut surface to heal (33). A decrease in disease caused by P. ultimum in cutting geraniums was correlated to the suberization of wound periderm (34).

Susceptibility of two safflower cultivars (Carthamus tinctorius) differed, according to the period in which elongation of the hypocotyl first internode ocurred (112). This resistance was not correlated to age alone but rather

the physiological processes which occur at the time of internode development.

Genetic resistance to P. ultimum has been demonstrated for a variety of crops (51) including bean cultivars (Phaseolus vulgaris) (2). Schroth and Cook (101) found resistance to Pythium disease in three bean varieties to be correlated with the amount of seed exudation; the greatest exudation occurred in the more susceptible variety. Alicbusan et al. (8) showed that P. ultimum grew more abundantly in the rhizophere of susceptible plants than in that of resistant plants.

Mathre and Otta (70) were unable to find genetic resistance to R. solani or P. ultimum among species and varieties of cotton. McCarter and Littrell (72) screened crops for genetic resistance to Pythium spp. Tomato, bean and rye were more susceptible to disease caused by Pythium spp. than cotton and corn.

Resistance to P. ultimum has not been thoroughly investigated for seed propagated geranium cultivars. Stephens and Powell (Personal communication, Dr. Christine T. Stephens; Michigan State University) screened many bedding plant crops including two hybrid geranium cultivars for resistance to P. ultimum. Although neither cultivar showed disease resistance, there was a difference in damping-off susceptibilty between them. Powell (92) observed apparent cultivars differ to P. ultimum in naturally occurring disease instances.

In the absence of identified Pythium-resistant geranium cultivars, primary control of the pathogen is achieved through sanitation and/or fungicides. Powell (92) and Stephens (107) recommended the fungicides ethazol (Truban), fenaminosulf (Lesan), metalaxyl (Subdue) and ethazol plus dimethyl 4,4-O-O phenylenbis (Banrot) for Pythium control on seedling geraniums. Moorman (85) recommended heat or fumigant soil treatments as the preferred control method due to the adverse effects of some fungicides on various plant species.

In many reported cases, fenaminosulf controlled disease due to Pythium spp. resulting in reduced mortality and increased plant growth (56,97,111). However, Miller and Sauve (78) found fenaminosulf to be less effective than other fungicides for control of Pythium stem rot of cutting geranium. This substantiates earlier work by Wheeler et al. (121).

Miller and DeNeve (77) found ethazol superior to fenaminosulf in controlling Pythium crown and root rot on bedding plants. Baker and Harman (13) showed ethazol drenches more effective than soil steaming in controlling Pythium spp. on chrysanthemums. Metalaxyl produced varying results. They also determined that a combination soil steaming plus a Pythium controlling fungicide was more effective in increasing chrysanthemum growth and flower production than either treatment used alone. This effect

was attributed to disease eradication through steaming and subsequent fungicide protection from recontamination.

SUMMARY

The seed propagated hybrid geranium (Pelargonium x hortorum) has become a popular bedding plant in recent years. Breeding programs have produced bright colors, consistent germination and compact growth habits (37). New, early flowering cultivars make the production cost of the seed propagated geranium competitive with the traditional cutting propagated geranium.

Petal shatter is a problem in transporting and marketing seed propagated hybrid geraniums (10). STS prevents petal abscission in seed propagated geraniums and is commercially important in seed propagated geranium production (27,43,79).

Michigan State University researchers observed P. ultimum crown and root rot symptoms on geraniums treated with STS during STS formulation trials (49). Pythium spp. are often pathogens of greenhouse crops (92,100).

Objectives of this study were threefold: 1) To verify the interaction of silver thiosulphate and P. ultimum crown and root rot; 2) To test fungicides and application times for control of mortality due to P. ultimum of geraniums grown in P. ultimum-infested medium and treated with or without STS; 3) To screen geranium cultivars for P. ultimum and P. ultimum/STS resistance.

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Section I:

Verification of induced *Pythium ultimum* mortality in 'Ringo Scarlet' geraniums treated with silver thiosulphate

Verification of Induced *Pythium ultimum* Mortality in 'Ringo Scarlet' Geraniums Treated with Silver Thiosulphate

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ABSTRACT

Hausbeck, M.K., C.T. Stephens and R.D. Heins. 1985. Verification of induced *Pythium ultimum* mortality in 'Ringo Scarlet' geraniums when treated with silver thiosulphate. Plant Disease 0:0.

Pythium ultimum crown and root rot symptoms on the seed propagated geranium are described. Root rot caused by *P. ultimum* often resulted in plant stunting, otherwise plants appeared healthy unless compared to an uninfected plant. Severe root rot symptoms frequently resulted in plant mortality. Stem blackening or crown rot commonly occurred on plants which initially showed only plant stunting or a reduced root system. Geraniums transplanted into a *P. ultimum*-infested medium and sprayed with silver thiosulphate (STS) had a higher mortality incidence than geraniums transplanted into *P. ultimum*-infested medium and not treated with STS. Increasing inoculum level resulted in increased mortality when seedlings were transplanted into the *P. ultimum*-infested medium 35 days after seeding but not when seedlings were transplanted 49 days after seeding.

Additional key words: Pelargonium hortorum, Pythium ultimum, silver thiosulphate.

INTRODUCTION

Premature flower petal shatter has been a severe problem in marketing the seed propagated geranium (4). Foliar application of silver thiosulphate (STS) solution prevents petal abscission in seed propagated hybrid geraniums (6,11,23). Heins, et al. (13) observed crown and root rot symptoms on geraniums treated with STS during STS formulation trials. Commercial growers reported similar findings (Personal communication, Dr. Royal Heins; Michigan State University). The symptoms of this root rot were dark, water-soaked stem lesions and death. Isolations from plants with these symptoms confirmed the identity of the pathogen as Pythium ultimum Trow.

The objective of this study was to determine if a relationship existed between plant mortality incidence due to P. ultimum crown and root rot and application of STS on geraniums grown in P. ultimum-infested medium. Information is also presented on the relationship between plant mortality and inoculum levels of P. ultimum.

MATERIALS AND METHODS

'Ringo Scarlet' geranium seeds (Sluis & Groot B.V., Enkhuizen, Holland) were individually sown in round 2.0 cm in diameter cells, covered with fine vermiculite and placed under intermittant mist at 24 °C in a glass greenhouse.

After germination (7 days), the seedlings were removed from the mist and grown at 22°C day and 20°C night temperatures under natural light in the greenhouse. They were fertilized at each watering with 200 mg liter^{-1} each of nitrogen and potassium.

Preliminary investigations using a P. ultimum isolate cultured from rotted geranium roots and a highly virulent P. ultimum isolate (#248) used in previous studies (28) showed both isolates to cause crown and root rot symptoms (Results not shown). The #248 P. ultimum isolate was used throughout the remainder of this study.

Pythium ultimum inoculum was prepared using the potato media procedure first developed for culture of Rhizoctonia solani Kuhn by Ko and Hora (17). Fifty grams of finely chopped potato was added to 500 ml of a commercial soilless mix (Sunshine Media Mix, Blend 1, Fisons-Western Corp., Vancouver, B.C., Canada) containing 2 parts vermiculite, 2 parts peat moss and 1 part perlite. After mixing, the potato media-mixture was autoclaved twice for one hour, 24 hours apart.

Cultures of P. ultimum were maintained on 20 ml of water agar (Difco Laboratories, Detroit, MI 48232) and grown in 10 cm petri plates for 2 days at 24°C. Six mycelial discs 12 mm in diameter were selected from the perimeter of the growing culture and used to infest 1.5 liters of sterilized potato soil medium. The inoculum was grown in 2.0 liter closed flasks for 2 weeks and shaken daily. The

inoculum mixture was air dried for 1-2 days and sieved through a #10 (2mm) screen.

The inoculum was then mixed with the soilless medium at three infestation levels; 0.75 g $liter^{-1}$ (low), 1.5 g $liter^{-1}$ (medium) and 3.0 g $liter^{-1}$ (high). The low inoculum level was chosen as a level sufficient to induce P. ultimum disease symptoms (Personal communication, Dr. H. Hoitink; Ohio State University). After thoroughly mixing, the infested soil was placed into single cells (8 x 8 cm) of 18 pack flats (25 x 53 cm). Eight single cells (replicates) were used per treatment.

Seedlings were transplanted 35 and 49 days after seeding into the P. ultimum-infested medium or into a non-infested medium. The P. ultimum-infested and non-infested treatments were randomized in a growth chamber. Temperatures were maintained at 21°C day and 18°C night. Irradiance was controlled at 135 μmols m^{-2} s^{-1} for 12 hours per day using VHO cool white fluorescent lamps. The medium pH varied between 5.5 and 6.5 during the experiment. Plants were fertilized at each watering with 200 mg $liter^{-1}$ each of nitrogen and potassium. Foliar applications of 750 ppm chlormequat chlorine (American Cyanamide Co., Wayne, N.J. 07470) (CCC) were applied to control height as growth necessitated (8).

A freshly prepared 0.25 mM STS solution (silver to thiosulphate ratio of 1:4) (13,25) was sprayed on the foliage the day of transplant into P. ultimum-infested

medium (0 days), 7 or 14 days following transplant. A second STS application was applied 30 days after each original STS treatment. The control received no STS.

Plants were observed for symptoms of Pythium crown and root rot. The number of days following transplant into P. ultimum-infested medium at which death occurred was recorded. Percent mortality was calculated. Plant height and width were recorded at 36,41, and 56 days or 27,36,42 and 49 days following tranplant into P. ultimum infested-medium on seedlings transplanted at 35 and 49 days respectively. Plant volume (size) was calculated from height and width measurements by assuming the plant to be a cylinder.

Reisolation of P. ultimum was conducted on geraniums that died during the study. At the termination of the experiment, surviving geraniums in P. ultimum-infested medium and non-infested controls were randomly sampled. One half inch sections of roots, stem and petioles were surface sterilized in 10% sodium hypochlorite for approximately 20 seconds and plated on water agar. The plates were observed for a minimum of seven days for Pythium hyphal growth. The agar plates with hyphal growth were allowed to dry at room temperature for three weeks to promote encysted sporangia development. The fungus was identified as P. ultimum.

RESULTS

Disease Symptoms

Geraniums grown in P. ultimum-infested medium showed two different types of disease symptoms. The root rot phase

was characterized by a number of foliar and root rot symptoms. Lower leaves became chlorotic and also showed a reddish cast associated with anthocyanin due to an apparent breakdown of chlorophyll. Affected leaves eventually wilted (Figure 1). Plants with severe foliar symptoms also showed considerable growth reduction. Root systems of affected plants were often minimal with extensive necrosis and rotting of feeder roots. Geraniums either remained in this condition with no further apparent disease progression or rotted at the soil line resulting in death. Geraniums which showed many root rot symptoms generally did not progress into the stem blackening associated with the crown rot phase.

Other geraniums showed stunted growth but otherwise appeared healthy (Figure 2). Root systems of these plants were reduced in size but did not show extensive necrosis or rotting. These plants often developed crown rot symptoms. The first symptoms of the crown rot phase were black, watersoaked stem lesions at the base of the plant just above the soil line (Figure 3). Plants remained green and turgid until stem blackening progressed up the stem to the base of the petioles. Total stem blackening usually occurred during a 24 to 48 hour period depending on the size of the plant. Once the disease symptoms had progressed substantially, the plant toppled over and the blackened tissue hardened. White mycelium at the base of the plant was evident approximately five days following plant death if the plant was kept moist.

Figure 1. Symptoms of Pythium ultimum infection on geranium showing chlorotic, reddish and wilted lower leaves.

Figure 2. Size comparision between geraniums grown in non-infested (left) and Pythium ultimum-infested medium (right).

Figure 3. First symptoms of crown rot phase due to Pythium ultimum showing black, watersoaked stem lesions at the base of the plant just above the soil line.

Response of 35 day old plants

When grown in P. ultimum-infested medium but not treated with STS, final plant mortality varied from 0 to 38% (Table 1). Mortality was greater after STS application regardless of P. ultimum infestation level, although total plant mortality increased as P. ultimum inoculum level increased. As the time between transplanting (infestation) and STS application increased (0 to 14 days), plant mortality increased during the first thirty days after transplanting into the P. ultimum-infested medium (Table 1, Figure 4). However, by the termination of the experiment, the number of geraniums that died was similiar within a P. ultimum infestation level.

When surviving plants were retreated with STS four weeks following the initial spray, there was additional mortality. The greatest plant loss occurred when STS was reapplied to plants initially treated with STS at transplant (Figure 4). This was due at least in part to the fact that more plants in these treatments survived for 30 days compared to plants in other treatments.

Plants growing in the P. ultimum-infested medium were smaller than plants grown in the non-infested medium. At days 36 and 41, plant size in the low, medium and high P. ultimum-infested medium did not differ significantly (Figure 5). By 52 days, plants growing in the high level of P. ultimum-infested medium were significantly smaller than

Table 1. Percent mortality of 'Ringo Scarlet' geraniums 30 days after STS application and at experiment termination when transplanted into 4 levels of Pythium ultimum-infested medium at 35 days and treated with .25 mM silver thiosulphate (STS) at 4 timings.

STS Application Times	*Pythium ultimum* infestation levels							
	0.0 g/l[z]		0.75 g/l		1.50 g/l		3.0 g/l	
	30[y]	Final[x]	30	Final	30	Final	30	Final
Control	0	0	0	6	0	0	6	38
0 days[w]	0	25	25	69	31	88	38	100
7 days	0	0	50	75	75	88	81	100
14 days	0	25	50	56	88	88	88	100

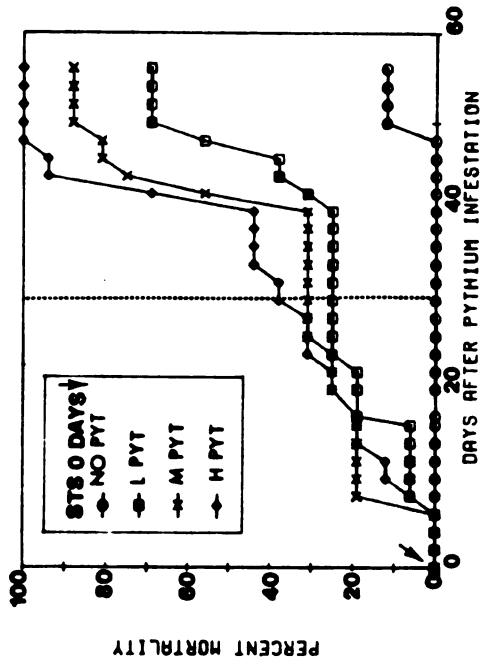
[z]Grams *P. ultimum* inoculum per liter of soilless medium.

[y]Days after initial STS application.

[x]Termination of experiment 60 days after transplant into non-infested or *P. ultimum*-infested medium.

[w]Day after transplanting into non-infested or *P. ultimum*-infested medium at which STS was applied.

Figure 4. Percent mortality over time of 'Ringo Scarlet' geraniums transplanted into control, low, medium or high levels (0.0, 0.75, 1.5 or 3.0 g inoculum liter^{-1} medium) of Pythium ultimum-infested medium 35 days after seeding. Plants were treated with 0.25 mM silver thiosulphate (STS) at 0, 7 or 14 days following infestation or not at all. The arrow (⟶) indicates the first STS application. A second application (----) was made thirty days after the initial STS treatment.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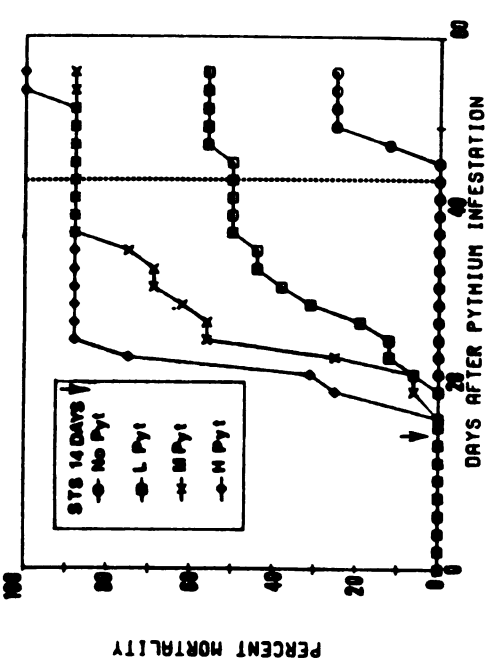
PERCENT MORTALITY
DAYS AFTER PYTHIUM INFESTATION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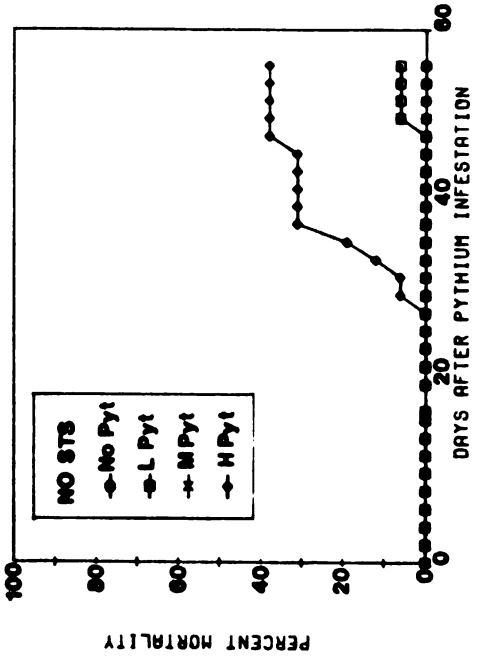
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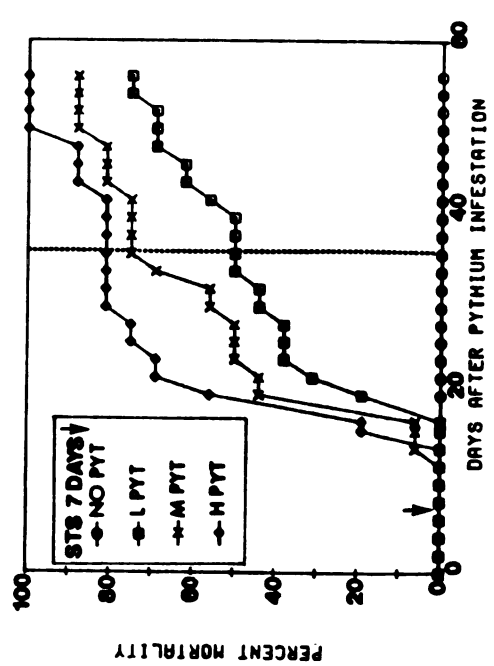
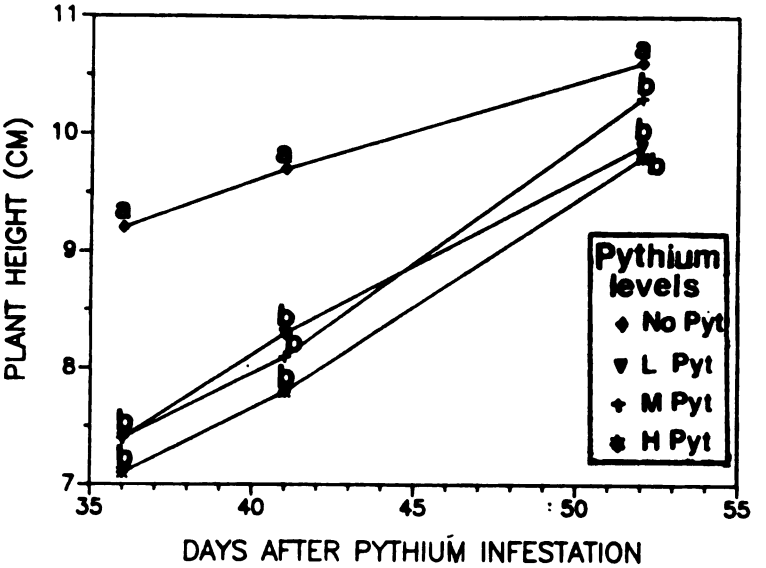

STS 7 DAYS
NO PYT
L PYT
M PYT
H PYT
PERCENT MORTALITY
DAYS AFTER PYTHIUM INFESTATION

Figure 5. Average plant height, width and volume of 'Ringo' Scarlet' geraniums over time transplanted into control, low, medium or high levels (0.0, 0.75, 1.5 or 3.0 g inoculum liter^{-1} medium) of Pythium ultimum-infested medium at 35 days. Letters indicate significant differences in treatment means based on Tukey's test.


PLANT HEIGHT (CM)
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DAYS AFTER PYTHIUM INFESTATION
Pythium levels
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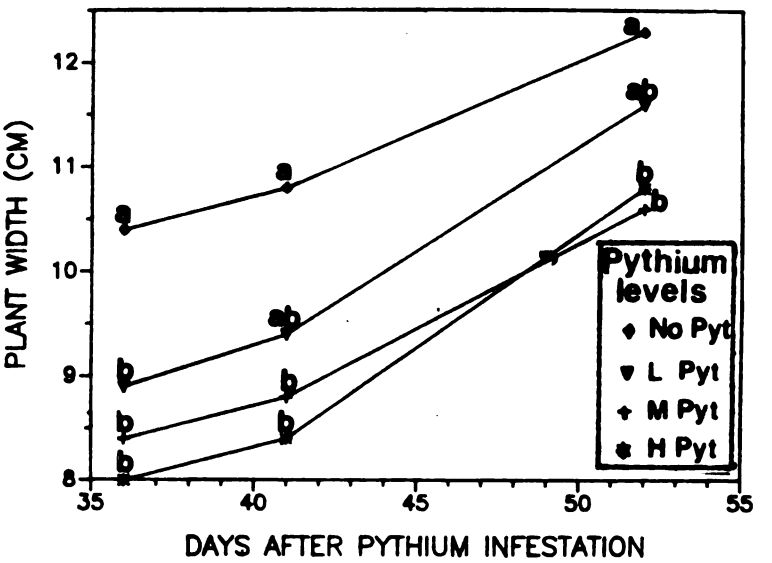
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DAYS AFTER PYTHIUM INFESTATION
Pythium levels
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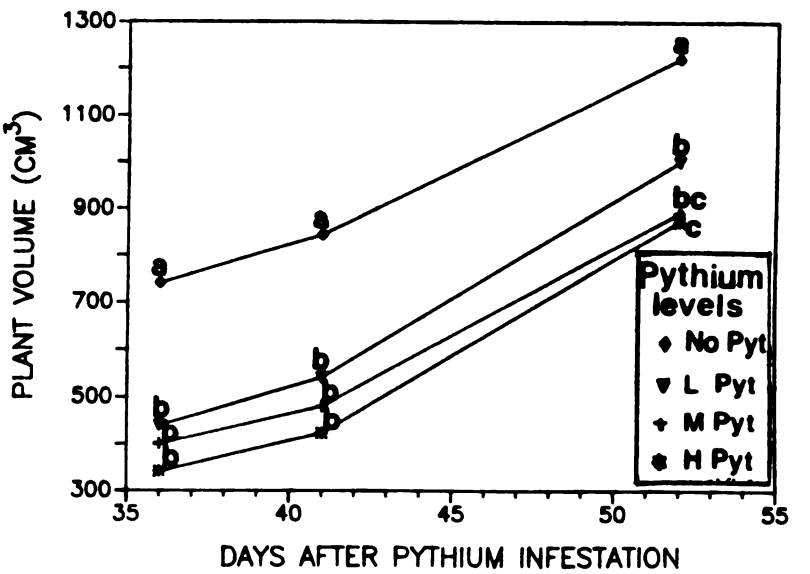
M Pyt
H Pyt


PLANT VOLUME (CM3)
1300
1100
900
700
500
300
35
40
45
50
55
DAYS AFTER PYTHIUM INFESTATION
Pythium levels
No Pyt
L Pyt
M Pyt
H Pyt

those growing in the low level of P. ultimum-infested medium.

Response of 49 day old plants

Plant mortality due to P. ultimum was low in the non-STS treated plants regardless of P. ultimum infestation level (Table 2).

STS application increased percent mortality due to P. ultimum at all levels of P. ultimum infestation. Plant mortality incidence was 63% or greater in treatments combining both P. ultimum and STS (Table 2). No trends were observed as inoculum level increased. However, 30 days after transplant into P. ultimum-infested medium, plant mortality was at least 63% greater when STS was applied 14 days after infestation compared with STS application 0 or 7 days after infestation (Table 2).

STS timing influenced rate of plant loss. During the 30 days following initial spraying, STS application at 0 or 7 days after transplanting into the P. ultimum-infested medium resulted in plant mortality similar to that of the control treatments (Figure 6). Application of STS 14 days after transplanting into the P. ultimum-infested medium, however, resulted in up to 90% plant death during a similar 30 day period.

A second STS application 30 days after the first STS application to plants originally sprayed 0 or 7 days after transplant into P. ultimum-infested medium resulted in up to

Table 2. Percent mortality of 'Ringo Scarlet' geraniums 30 days after STS application and at experiment termination when transplanted into 4 levels of Pythium ultimum-infested medium at 49 days and treated with .25 mM silver thiosulphate (STS) at 4 timings.

STS Application Times	Pythium ultimum infestation levels							
	0.0 g/l[z]		0.75 g/l		1.50 g/l		3.0 g/l	
	30[y]	Final[x]	30	Final	30	Final	30	Final
Control	0	12	6	19	0	19	6	6
0 days[w]	12	12	12	75	12	100	0	69
7 days	0	12	6	88	6	63	0	69
14 days	12	25	75	88	90	94	90	94

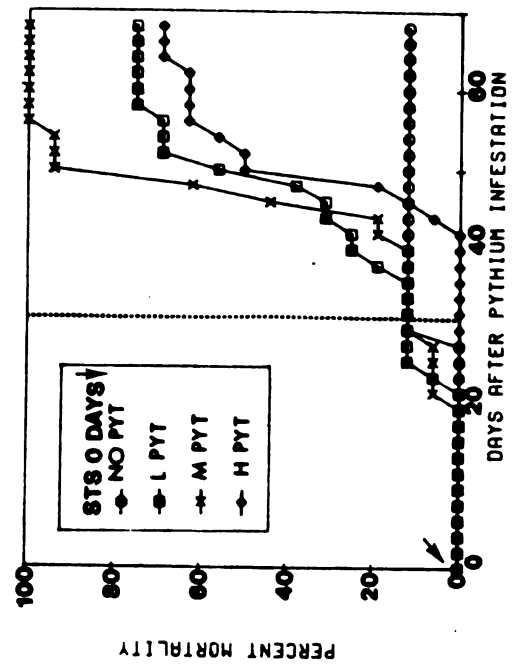
[z]Grams P. ultimum inoculum per liter of soilless medium.

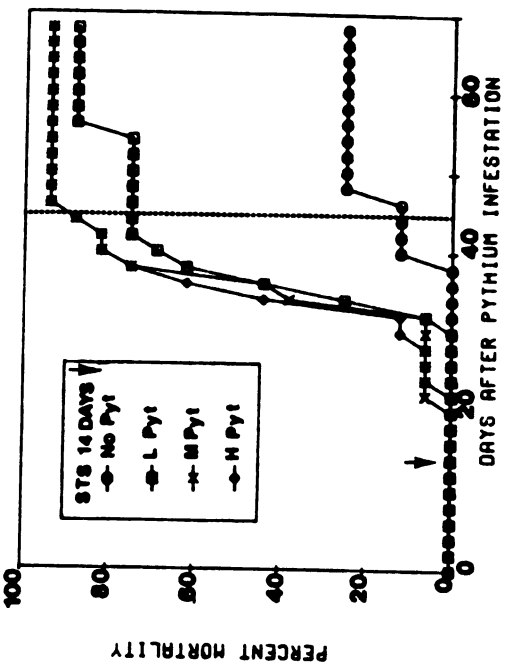
[y]Days after initial STS application.

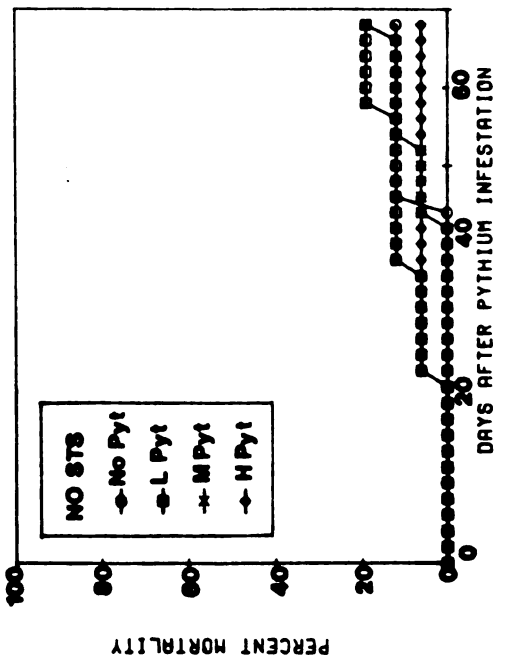
[x]Termination of experiment 70 days after transplant into non-infested or P. ultimum-infested medium.

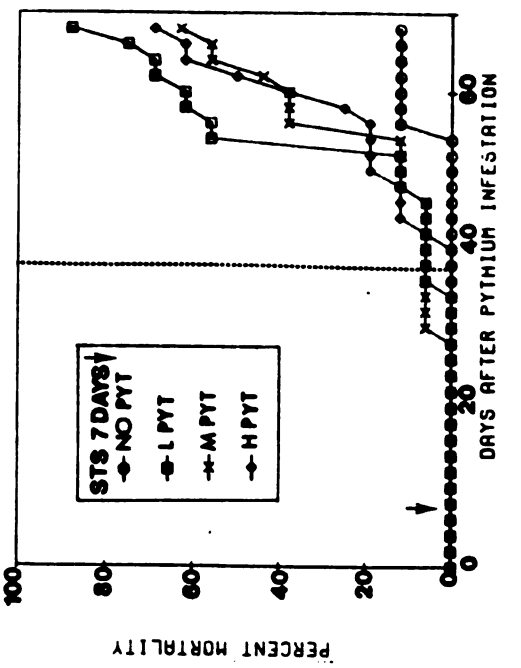
[w]Day after transplanting into non-infested or P. ultimum-infested medium at which STS was applied.

Figure 6. Percent mortality over time of 'Ringo Scarlet' geraniums transplanted into control, low, medium or high levels (0.0, 0.75, 1.5 or 3.0 g inoculum liter^{-1} medium) of Pythium ultimum-infested medium 49 days after seeding. Plants were treated with 0.25 mM silver thiosulphate (STS) at 0, 7 or 14 days following infestation or not at all. The arrow (⟶) indicates the first STS application. A second application (----) was made thirty days after the initial STS treatment.


STS 0 DAYS
NO PYT
L PYT
M PYT
H PYT
PERCENT MORTALITY
DAYS AFTER PYTHIUM INFESTATION


STS 14 DAYS
No Pyt
L Pyt
M Pyt
H Pyt
PERCENT MORTALITY
DAYS AFTER PYTHIUM INFESTATION


NO STS
No Pyt
L Pyt
M Pyt
H Pyt
PERCENT MORTALITY
DAYS AFTER PYTHIUM INFESTATION


STS 7 DAYS
NO PYT
L PYT
M PYT
H PYT
PERCENT MORTALITY
DAYS AFTER PYTHIUM INFESTATION

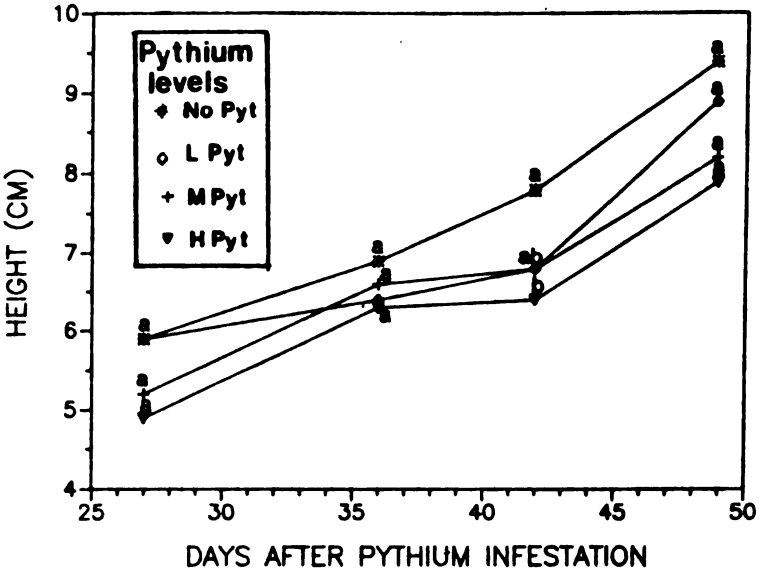
100% plant mortality by the termination of the experiment (Table 2, Figure 6).

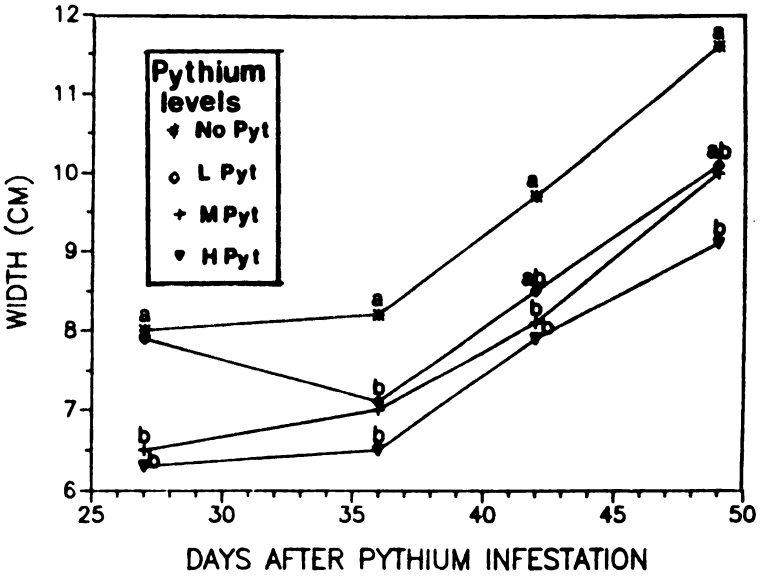
Twenty-seven days after tranplanting, plants growing in the non-infested and low level of P. ultimum-infested medium were significantly larger than those plants growing in medium and high levels of P. ultimum-infested medium (Figure 7). At day 36, the plants grown in non-infested medium were significantly larger than those plants grown in P. ultimum-infested medium. By day 42 and 49, however, plants grown in low levels of P. ultimum-infested medium were not statistically smaller than the non-infested control.

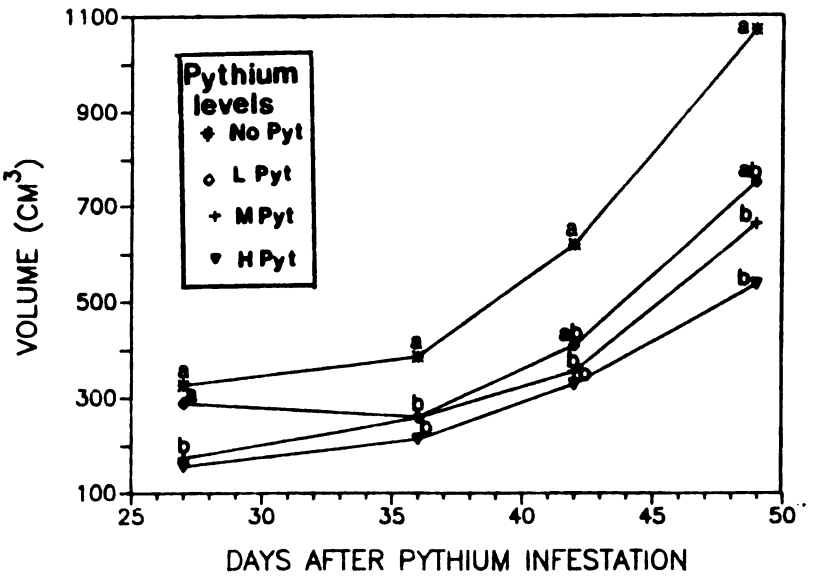
DISCUSSION

Pythium ultimum disease symptoms on the seed propagated geranium were documented by this study. Geraniums in the P. ultimum-infested medium may not exhibit all of the typical root rot symptoms commonly associated with infection of Pythium spp. This study showed that symptoms present may be limited to stunted plants and a reduced root system. Pythium ultimum was isolated from plants with these symptoms. Abscence of chlorotic and wilted lower leaves may be misleading in diagnosing the cause of reduced plant size because several growing conditions may also result in low plant vigor including improper soil pH, high soluble salts and low nutrition levels. It is conceivable that an entire crop could be infested with Pythium spp. without the grower

Figure 7. Average plant height, width and volume of 'Ringo' Scarlet' geraniums over time transplanted into control, low, medium or high levels (0.0, 0.75, 1.5 or 3.0 g inoculum liter^{-1} medium) of *Pythium ultimum*-infested medium at 49 days. Letters indicate significant differences in treatment means based on Tukey's test.


Pythium levels
No Pyt
L Pyt
M Pyt
H Pyt
HEIGHT (CM)
DAYS AFTER PYTHIUM INFESTATION


Pythium levels
No Pyt
L Pyt
M Pyt
H Pyt
WIDTH (CM)
DAYS AFTER PYTHIUM INFESTATION


Pythium levels
No Pyt
L Pyt
M Pyt
H Pyt
VOLUME (CM3)
DAYS AFTER PYTHIUM INFESTATION

being aware of the resulting decrease in plant size if healthy plants were not available for comparision.

Stunting is a typical symptom of root rot due to Pythium infection (7,16,22). Disease symptoms due to Pythium spp. include leaf chlorosis, partial defoliation, reduced growth and vigor on woody ornamentals. Such specimans exhibited a greatly reduced feeder root system and necrotic lesions on existing roots (14,15). Campbell and Sleeth (7) correlated the amount of plant stunting to the degree of Pythium injury to the root system.

This study documented that there was significantly higher plant mortality among STS treated geraniums grown in P. ultimum-infested medium than plants grown in P. ultimum-infested medium without STS. This correlation between STS application and increased disease incidence has not been previously reported.

Other chemicals appear to increase plant mortality incidence due to Pythium spp.. The herbicide glyphosate applied to bean seedlings at levels ineffective in causing mortality in sterilized soil increased disease incidence due to Pythium spp. in non-sterilized soil (12). Altman and Campbell (3) addressed the interaction of increased disease incidence following herbicide application. They summarized three major herbicide effects possibly leading to increased plant disease: 1) reduction of host structural defense; 2) stimulation of host exudation stimulating pathogen growth;

3) inhibition of microflora competing with potential pathogens.

It is conceivable that STS may affect the plant resuling in increased P. ultimum disease incidence in a manner similiar to those proposed for herbicides. Another possibility is that STS may reduce the geranium's natural defense system. Phytoalexins produced by the plant have been shown to be toxic to fungi and bacteria. Phytoalexins have also been shown to be promoted by ethylene production stimulated by host tissue breakdown due to pathogen infection (18). Since the silver can block the action of ethylene (5), phytoalexin production or some other defense system may be reduced by STS application. Another possible mechanism involves exudation of STS through the root system resulting in exudates favorable for pathogen growth. This exudation could inhibit microflora which normally suppress pathogen growth. Studies show that STS is readily tranlocated within the plant (10), however, STS movement in the root system has not been documented. Favorable seed exudates have been shown to increase pathogen growth (2,9,19,20,27). In contrast, it has also been suggested that altering the delicate soil balance may result in increased Pythium disease incidence (1). No specific evidence is available to support one hypothesis over another.

Results of this study suggest that foliar sprays of STS increased the decline in plants already infected with

P. ultimum. The longer the time for possible infection before STS application the quicker the plant death due to P. ultimum (Figure 4,6). Geraniums transplanted into the P. ultimum-infested medium 35 days after seeding required a minimum 7 day infection period to result in increased death during the first 30 days after STS application. However, geraniums transplanted into P. ultimum-infested medium 49 days after seeding required a minimum 14 day infection period to result in increased disease incidence within 30 days after STS application. This may be due to increased resistance of older plants to infection. Volume measurements of geraniums transplanted into P. ultimum-infested medium 35 and 49 days after seeding also support this. Over time, P. ultimum at higher levels continued to significantly affect plant size in geraniums transplanted into the P. ultimum-infested medium at 35 days. However, geraniums tranplanted into the P. ultimum-infested medium at 49 days showed no significant size difference between the non-infested and P. ultimum-infested treatments. This may indicate that geraniums transplanted at 49 days are more resistant or tolerant to invasion by P. ultimum than those geraniums transplanted at 35 days.

Several studies substantiate this hypothesis. For instance, McCarter and Littrel (21) showed oats, wheat and cucumber were more susceptible in the early stages of germination than in late growth stages. Root rot severity in cotton seedlings decreased as the plants grew older (26).

Peach tree seedlings escaping pre-emergence and early postemergence mortality in infested soil grew to a size comparable to those in the non-infested soil (24).

However, delaying transplant of geraniums from the plug tray to suitable growing containers is not recommended as a method of controlling P. ultimum or the interaction of P. ultimum with STS application. A second STS spray to plants transplanted at a later date resulted in a high mortality.

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Section II:

Efficacy of selected fungicides in controlling crown and root rot in 'Ringo Scarlet' geraniums caused by *Pythium ultimum* in the presence or absence of silver thiosulphate

Efficacy of Selected Fungicides in Controlling Crown and Root Rot in 'Ringo Scarlet' Geraniums Caused by *Pythium ultimum* in the Presence or Absence of Silver Thiosulphate

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ABSTRACT

Hausbeck, M.K., C.T. Stephens and R.D. Heins. 1985. Efficacy of selected fungicides in controlling crown and root rot in 'Ringo Scarlet' geraniums caused by *Pythium ultimum* in the presence or absence of silver thiosulphate. Plant Disease 0:0.

Fenaminosulf, ethazol or metalaxyl applied as soil drenches at selected times were effective in reducing crown and root rot disease caused by *Pythium ultimum* in geraniums when plants were not treated with silver thiosulphate (STS). Only metalaxyl consistently controlled the increased levels of disease caused by *P. ultimum* when plants were sprayed with silver thiosulphate. At selected application times, all three fungicides effectively decreased plant stunting symptoms and the delay of flowering associated with root rot caused by *P. ultimum*. However, metalaxyl and ethazol were generally, more effective than fenaminosulf. Fungicides also significantly affected plant size and flowering time of geraniums grown in the non-infested medium.

Additional key words: Pythium ultimum, silver thiosulphate, fenaminosulf, metalaxyl, ethazol.

INTRODUCTION

Unlike the geraniums grown from cuttings, seed propagated geraniums experience premature flower petal abscission (1). This flower shattering generally occurs during transportation and has been a serious problem in marketing. Foliar application of silver thiosulphate (STS) solution prevents petal abscission in seed propagated hybrid geraniums (5,8,18).

A correlation between STS application and increased disease incidence due to Pythium ultimum of plants grown in P. ultimum-infested medium has been documented (9). Plants grown in P. ultimum-infested medium and not treated with STS showed low mortality but exhibited a marked reduction in growth.

Crown and root rot due to Pythium spp. is a common disease of geraniums and other greenhouse plants (11). Infection by Pythium on the seed propagated hybrid geranium may cause plant stunting, chlorotic and wilting of lower leaves, stem blackening, reduced root growth and root rot. One or more of these symptoms may be present. Plants with severe root rot generally will not develop black watersoaked stem lesions, which initiate the stem blackening and plant death phase of the disease. Plants with severe root rot symptoms may rot just below the soil line which ultimately

leads to death. However, apparently healthy plants with reduced root systems and stunted growth may develop a blackened stem and die with little warning to the grower after application of STS. The blackening progresses rapidly up the stem and into the base of the petioles.

Control of Pythium crown and root rot is currently achieved through sanitation and/or preventative fungicides. Moorman (19) recommended heat or fumigant soil treatments as the preferred control method due to the suspected adverse effects of some fungicides on various plant species. Although Pythium spp. can be eliminated by heat or fumigant soil treatments, reintroduction of the pathogen is common in the bedding plant greenhouse (24). The fungicides ethazol (Truban), fenaminosulf (Lesan), metalaxyl (Subdue) and ethazol plus dimethyl 4,4-O-O phenylenbis (Banrot) are recommended for prevention of crown and root rot caused by Pythium spp. (20,22).

The objective of this study was to determine the effectiveness of selected Pythium-controlling fungicides in preventing plant mortality due to crown and root rot disease caused by P. ultimum in geraniums treated with or without STS. Due to the nature of this experiment, it was possible to determine the fungicide effect on geranium plant growth on plants grown in a non-infested medium and not treated with STS.

MATERIALS AND METHODS

'Ringo Scarlet' geranium seeds (Sluis & Groot B.V., Enkhuizen, Holland) were individually sown in round 2.0 cm in diameter cells, covered approximately 0.5 cm with fine vermiculite and placed under intermittent mist at 24°C in a glass greenhouse. The seedlings were removed from the mist after germination (7 days) and grown at 21°C night and 24°C day temperatures under natural light in a glass greenhouse until tranplanting at 35 days from seeding.

Inoculum of Pythium ultimum Trow was prepared using the potato media procedure developed for Rhizoctonia solani Kuhn culture (14). Fifty grams of finely chopped potato was added to 500 ml of growing medium (Sunshine Media Mix, Blend 1, Fisons-Western Corp., Vancouver, B.C., Canada) containing 2 parts vermiculite, 2 parts peat moss and 1 part perlite. After mixing, the potato media-mixture was autoclaved twice, 24 hours apart, for one hour.

Pythium ultimum cultures were maintained on 20 ml of water agar (Difco Laboratories, Detroit, MI 48232) and grown in 10 cm petri plates for two days at 24°C. A highly virulent isolate of P. ultimum shown to cause crown and root rot in preliminary studies was used (25). Six mycelial discs 12 mm in diameter taken from the growing perimeter were used to infest 1.5 liters of sterilized potato soil media. After two weeks growth in 2.0 liter closed flasks,

the inoculum was air dried for 1-2 days and sieved through a #10 (2 mm) screen.

Three grams of inoculum were mixed with a liter of the soilless medium. Previous studies indicate that high levels of P. ultimum crown and root rot occur in geraniums transplanted into this ratio of inoculum and medium (9). After thoroughly mixing, the infested soil was placed into single cells (8 x 8 x 6 cm) of 18 pack flats (25 x 53 cm) for the first experiment and in plastic pots (10 cm) for experiments 2 and 3. Eight single cells or pots were used to replicate each treatment.

Non-infested and P. ultimum-infested treatment containers were randomized on greenhouse benches constructed of 14.0 cm wide wooden planks spaced 4.0 cm apart. To minimize P. ultimum contamination of non-infested plants, non-infested and P. ultimum-infested treatments were placed on alternating wooden planks.

Treatments were maintained at 20°C night and 22°C day temperatures. Medium pH varied between 5.5-6.5 during the expermiment. Plants were fertilized at each watering with a constant liquid feed containing 200 mg $liter^{-1}$ each of N and K. Foliar applications of 750 ppm chlormequat chlorine (American Cyamide Co., Wayne, N.J. 07470) (CCC) were applied for height control as growth necessitated (2,7).

A series of three fungicide screenings were conducted over the greenhouse growing season: Experiment 1-

September through November; Experiment 2- January through April; Experiment 3- April through July.

Fungicide drenches were applied at the following times for each screening:

Experiment 1

1) seeding
2) seeding and transplanting
3) seeding, transplanting and 1 week after transplanting
4) transplanting
5) 1 week after transplanting (1 week before STS application)
6) 2 weeks after transplanting (day of STS application)

Experiment 2

1) seeding
2) seeding and transplanting
3) seeding, transplanting and 1 week after transplanting
4) transplanting
5) 8 weeks after transplanting (1 week before STS application)
6) 9 weeks after transplanting (day of STS application)

Experiment 3

1) seeding
2) seeding and transplanting
3) seeding, transplanting and 1 week after transplanting
4) transplanting
5) 1 week after transplanting
6) seeding, transplanting and 7 weeks after transplanting

7) 7 weeks after transplanting (1 week before STS application)
8) 8 weeks after transplanting (day of STS application)

The following fungicides were used at the label rate: fenaminosulf, 0.43 g ai/liter (Lesan 35% WP, Mobay Chemical Corp., Kansas City, MO 64120); ethazol, 0.11 g ai/liter (Truban 30% WP, Mallinkrodt, Inc., St. Louis, MO 63147); metalaxyl, 0.101 g ai/liter (Subdue 2E, 25% emulsifiable concentrate, Ciba-Geigy, Agricultural Division, Greensboro, NC 27409).

A 0.25 mM silver thiosulphate (STS) solution (10,21) was sprayed to runoff 50, 61 or 52 days following transplant into P. ultimum-infested medium in Experiments 1-3 respectively. A second STS application was applied 14 days after each original STS treatment. Control plants received no treatment.

Plants were observed daily for symptoms of Pythium crown and root rot. The number of days following transplant into P. ultimum-infested medium at which death occurred were recorded from time of transplant (day 0) into P. ultimum-infested medium through day 80 (Experiment 1), day 114 (Experiment 2) and day 75 (Experiment 3). Percent mortality was calculated. Plant height and width were recorded at the following times: 1) Experiment 1- days 51 and 98; 2) Experiment 2- day 135; 3) Experiment 3- days 84 and 105. Plant volume (size) was calculated from the height and width measurements, assuming the plant to be a cylinder. Days from seeding to flower were also recorded for Experiment 1

(non-infested and P. ultimum-infested treatments) and Experiment 3 (non-infested treatments). Plant measurements and flowering time were recorded only for plants that had not been treated with STS because the effect of STS on plant growth was not being investigated. Measurements on plants not treated with STS insures an accurate evaluation of the effects of fungicide and P. ultimum on plant growth.

Reisolation of P. ultimum was conducted on geraniums that died during the study. At the termination of the experiment, surviving geraniums in P. ultimum-infested medium and non-infested controls were randomly sampled to determine if P. ultimum was present. One half inch sections of roots, stem and petioles were surface sterilized in 10% sodium hypochlorite for approximately 20 seconds and plated on water agar. The plates were observed for a minimum of seven days for Pythium hyphal growth. The agar plates with hyphal growth were allowed to dry at room temperature for three weeks to promote encysted sporangia development. The fungus was idenified as P. ultimum.

RESULTS

Experiment 1

No plant death occurred in the non-infested medium with or without STS (Results not shown) or the P. ultimum-infested medium without STS (Table 1). However, 88% mortality was observed on plants growing in the P. ultimum-infested medium and treated with STS.

Table 1. Percent mortality of 'Ringo Scarlet' geraniums 110 days after seeding and 80 days following transplant into Pythium-infested medium. Plants were sprayed with .25 mM silver thiosulphate (STS) on day 80 and treated with Pythium controlling fungicides at selected timings.

Timings of Fungicide Application[z]				Percent Mortality							
				Fungicides							
				Control		Fenaminosulf		Metalaxyl		Ethazol	
Seeding	Transplant	1 week before STS	Days of STS	-STS	+STS	-STS	+STS	-STS	+STS	-STS	+STS
+	-	-	-			0	50	0	38	0	100
+	+	-	-			0	50	0	0	0	0
+	+	+	-			0	25	0	0	0	0
-	+	-	-			0	50	0	0	0	0
-	-	+	-			0	88	0	0	0	0
-	-	-	+			0	0	12	0	12	12
-	-	-	-	0	88						

[z]0, 30, 37 or 44 days after seeding for each respective treatment time.

Fungicide drench(es) reduced mortality on STS-treated plants grown in P. ultimum-infested medium. Metalaxyl and ethazol were more effective than fenaminosulf in preventing mortality of geraniums grown in the P. ultimum-infested medium and treated with STS. A fenaminosulf drench one week before STS or an ethazol drench at seeding did not reduce mortality in STS treated geraniums grown in the P. ultimum-infested medium compared to those without fungicide.

Fifty-one day old geraniums grown in P. ultimum-infested medium with no fungicide treatment were 75% smaller than plants grown in the non-infested medium and not treated with fungicide (Table 2) (See Appendix A, Tables A1, A2 for corresponding height and width measurements). After 98 days, the plants were still 53% smaller (Table 3) (See Appendix A, Tables A3, A4 for corresponding height and width measurements). Fungicide drenches at 1) seeding or 2) one week after transplanting did not reduce plant stunting due to P. ultimum. Further, fenaminosulf drenches, regardless of application timing, did not reduce plant stunting in comparision to plants grown in the P. ultimum-infested medium without fungicide.

The fungicide drenches affected size of plants grown in the non-infested medium (Table 2). On day 51, geraniums grown in the non-infested medium and treated with fenaminosulf drench(es) at 1) seeding, transplanting and 1 week after transplanting or 2) at transplanting only were significantly smaller than plants not drenched with

Table 2. Average size of 'Ringo Scarlet' geraniums 51 days after seeding and 21 days following transplant into non-infested or *Pythium*-infested medium when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]				Non-infested Plant Volume (cm^3)				*Pythium*-infested Plant Volume (cm^3)			
Seed	Transplant	1 wk after Transplant	2 wks after Transplant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-		285	296	203		82	130	110
+	+	-	-		221	177	188		77	262	264
+	+	+	-		92	237	205		52	176	323
-	+	-	-		82	298	212		98	146	227
-	-	+	-		356	216	105		98	81	81
-	-	-	+		183	128	273		58	170	103
-	-	-	-	252				67.3			
					HSD (5%) = 108[y]				HSD (5%) = 72		

Source	D.F.	M.S.	F
Fungicide	2	20888.32	2.04
Application	5	43117.76	4.21**[x]
FxA	10	129938.98	12.69**

Source	D.F.	M.S.	F
Fungicide	2	309547.92	67.75**
Application	5	100703.20	22.04**
FxA	10	59881.01	13.11**

[z]0, 30, 37 or 44 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) significance level.

Table 3. Average size of 'Ringo Scarlet' geraniums 98 days after seeding and 68 days following transplant into non-infested or Pythium-infested medium when treated with Pythium controlling fungicides at selected timings

Timings of Fungicide Application[z]				Non-infested Plant Volume (cm^3)				Pythium-infested Plant Volume (cm^3)			
Seed	Transplant	1 wk after Transplant	2 wks after Transplant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethanol
+	-	-	-		650	684	495		462	526	507
+	+	-	-		927	698	635		497	732	1127
+	+	+	-		486	864	679		338	651	965
-	+	-	-		538	659	760		458	818	924
-	-	+	-		1140	742	528		372	398	403
-	-	-	+		926	479	774		275	970	617
-	-	-	-	631.				285.			
				HSD (5%) = 430[y]				HSD (5%) = 296			

Source	D.F.	M.S.	F
Fungicide	2	220565.17	2.83
Application	5	120704.30	1.55
FxA	10	323912.31	4.15**[x]

Source		M.S.	F
Fungicide	2	1694248.85	46.02**
Application	5	509380.38	13.84**
FxA	10	256747.08	6.97**

[z]0,30, 37 or 44 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) significance level.

fungicide. Ethazol applied 1 week after transplanting or metalaxyl 2 weeks after transplanting also resulted in significant growth reduction in comparision to the no fungicide control. By day 98, no significant size difference existed between plants treated or not treated with fungicide (Table 3). Plants drenched with fenaminosulf one week after transplant were, however, larger than plants not drenched with fungicide.

Geraniums without fungicide and grown in the P. ultimum-infested medium showed a flowering delay in comparision to plants without fungicide and grown in non-infested medium (Table 4,5). Flowering delay due to P. ultimum of geraniums grown in P. ultimum-infested medium was prevented by a metalaxyl drench at transplanting or a combination of ethazol drenches at seeding and transplanting (Table 4).

Time to flower of geraniums grown in non-infested medium was affected by application timings of fungicides (Table 5). Fenaminosulf drench(es) at 1) seeding, transplanting and 1 week after transplanting or 2) transplanting resulted in delayed flowering. An ethazol drench at seeding also delayed flowering.

Experiment 2

Twelve percent mortality occurred due to P. ultimum in geraniums grown in the P. ultimum-infested medium and not treated with either STS or fungicide drenches (Table 6) and 75% mortality when treated with STS. Metalaxyl, regardless

Table 4. Average days to flower of 'Ringo Scarlet' geraniums transplanted into *Pythium*-infested medium on day 30 when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]				Days to Flower			
				Fungicides			
Seeding	Transplant	1 wk after Transplant	2 wks after Transplant	Control	Fenaminosulf	Metalaxyl	Ethazol
+	-	-	-		156.0	140.1	138.2
+	+	-	-		139.0	127.2	124.3
+	+	+	-		149.0	131.7	126.9
-	+	-	-		139.2	123.8	133.4
-	-	+	-		no sample[y]	135.8	149.3
-	-	-	+		137.6	134.0	138.2
-	-	-	-	140.3	HSD (5%) = 13.8[x]		

Source	D.F.	M.S.	F
Fungicide	2	756.14	8.43**[w]
Application	5	532.28	5.93**
F x A	9	135.26	1.51

[z] 0, 30, 37 or 44 days after seeding for each respective treatment time.
[y] Insufficient plant material available for evaluation due to physiological damage.
[x] Application comparison within each fungicide.
[w] 1% (**) significant level.

Table 5. Average days to flower of 'Ringo Scarlet' geraniums when treated with Pythium controlling fungicides at selected timings.

Timings of Fungicide Application[z]				Days to Flower			
				Fungicides			
Seeding	Transplant	1 wk after Transplant	2 wks after Transplant	Control	Fenaminosulf	Metalaxyl	Ethazol
+	-	-	-		132.3	129.3	136.3
+	+	-	-		123.8	126.3	131.3
+	+	+	-		140.7	127.1	134.9
-	+	-	-		136.0	126.2	128.2
-	-	+	-		126.3	129.3	129.3
-	-	-	+		121.3	132.0	124.1
-	-	-	-	122.8			

HSD (5%) = 12.6[y]

Source	D.F.	M.S.	F.
Fungicide	2	105.39	1.44
Application	5	226.77	3.11*[x]
F x A	10	129.09	1.77

[z]0, 30, 37 or 44 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]5% (*) significance level.

Table 6. Percent mortality of 'Ringo Scarlet' geranium 135 days after seeding and 114 days following transplant into Pythium-infested medium. Plants were sprayed with .25 mM silver thiosulphate (STS) on day 89 and treated with Pythium controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Percent Mortality							
					Fungicides							
					Control		Fenaminosulf		Metalaxyl		Ethazol	
Seeding	Transplant	1 wk after Transplant	1 wk before STS	Days of STS	-STS	+STS	-STS	+STS	-STS	+STS	-STS	+STS
+	-	-	-	-			0	25	0	38	12	12
+	+	-	-	-			12	38	0	0	0	75
+	+	+	-	-			0	50	0	0	0	38
-	+	-	-	-			0	25	0	12	12	38
-	-	-	+	-			0	25	0	0	0	25
-	-	-	-	+			0	25	0	12	12	12
-	-	-	-	-	12	62						

[z]0, 21, 28, 77 or 84 days after seeding for each respective treatment time.

of application time, decreased plant mortality due to crown and root rot of geranium grown in the P. ultimum-infested medium. Specific drenches of fenaminosulf or ethazol were also effective.

Metalaxyl drenches were more effective in preventing plant mortality on plants grown in the P. ultimum-infested medium treated with STS than either fenaminosulf or ethazol drenches (Table 6). However, 38% mortality still occurred when metalaxyl was applied at seeding.

Plants grown in non-infested medium for 135 days and drenched with metalxyl were similar in size to plants not treated with a fungicide drench (Table 7) (See Appendix A, Tables A5, A6 for corresponding height and width measurements). However, plants grown in the non-infested medium and treated with a fenaminosulf drench at transplant or an ethazol drench 9 weeks after transplanting were larger than plants not treated with fungicide.

Experiment 3

There was 14% plant mortality due to P. ultimum in STS treated plants grown in the non-infested medium (Results not shown). Thirty-eight percent mortality occurred in STS treated plants grown in the P. ultimum-infested medium without fungicide (Table 8). Drenches of fenaminosulf or metalaxyl were more effective than ethazol in preventing death due to P. ultimum in plants not treated with STS and grown in P. ultimum-infested medium. However, a metalaxyl

Table 7. Average size of 'Ringo Scarlet' geraniums 135 days after seeding and 114 days following transplant into non-infested or *Pythium*-infested medium when treated with *Pythium* controlling fungicides at selected timings

Timings of Fungicide Application[z]					Non-infested Plant Volume (cm^3)				*Pythium*-infested Plant Volume (cm^3)			
Seed	Transplant	1 wk after Transplant	8 wks after Transplant	9 wks after Transplant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-	-		1847	2225	2087		1599	1877	1916
+	+	-	-	-		1778	2410	1993		1595	2081	1687
+	+	+	-	-		1768	2449	2400			no sample	
-	+	-	-	-		2959	2126	2328		1962	2117	1839
-	-	-	+	-		1802	2262	2382		2481	2532	1919
-	-	-	-	+		1938	2543	2649		1862	2505	2040
-	-	-	-	-	1733				2130			
						HSD (5%) = 828[y]				HSD (5%) = 809		

Source	D.F.	M.S.	F
Fungicide	2	1270639.36	3.76*[x]
Application	5	588974.62	1.74
FxA	10	799243.95	2.37*

Source	D.F.	M.S.	F
Fungicide	2	1455436.40	4.14*
Application	4	1184052.47	3.36*
FxA	8	312322.41	.89

[z]0, 21, 28, 77 or 84 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) or 5% (*) significance level.

Table 8. Percent mortality of 'Ringo Scarlet' geraniums 112 days after seeding and 75 days following transplant into *Pythium*-infested medium. Plants were sprayed with .25 mM silver thiosulphate (STS) on day 89 and treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Percent Mortality							
					Fungicides							
					Control		Fenaminosulf		Metalaxyl		Ethazol	
Seed	Transplant	1 wk after Transplant	1 wk before STS	Days of STS	-STS	+STS	-STS	+STS	-STS	+STS	-STS	+STS
+	-	-	-	-			12	100	12	100(25)[y]	88	100
+	+	-	-	-			0	100	0	0	62	100(12)
+	+	+	-	-			0	100	0	0	25	75
-	+	-	-	-			0	88	0	0	12	100(50)
-	-	+	-	-			0	80(38)	12	0	62	75
+	+	-	+	-			0	50	0	0	25	100
-	-	-	+	-			12	88	38	17(25)	12	80(38)
-	-	-	-	+			12	100	0	12	0	86(12)
-	-	-	-	-	38	100(12)						

[z]0, 37, 44, 86 or 93 days after seeding for each respective treatment time.
[y]Percent mortality due to *Pythium* which occurred before STS application.

drench 1 week before STS application to plants grown in the P. ultimum- infested medium resulted in the same mortality as the no fungicide control.

Foliar STS sprays applied to geraniums grown in the P. ultimum-infested medium resulted in up to 100% mortality due to P. ultimum (Table 8). Properly timed metalaxyl drenches controlled mortality due to P. ultimum on plants grown in the P. ultimum-infested medium and treated with STS with the exception of plants treated with a drench at seeding. Fenaminosulf and ethazol were ineffective in preventing mortality.

Geraniums grown in the non-infested medium without fungicide treatment were 75% larger on day 84 than geraniums not treated with fungicide and grown in the P. ultimum-infested medium (Table 9) (See Appendix A, Tables A7, A8 for corresponding height and width measurements). On day 84, any fungicide drench applied at 1) seeding or 2) one week after transplant did not reduce plant stunting. Fenaminosulf drenches, regardless of timing, did not reduce plant stunting. Drenches at 7 or 8 weeks following transplant into P. ultimum-infested medium had not been applied at this measurement.

Eighty-four days after seeding, plants grown in the non-infested medium and treated with fungicide were similar in size to those plants without fungicide (Table 9). However, plants treated with a metalaxyl drench one week after transplanting were significantly smaller compared to

Table 9. Average size of 'Ringo Scarlet' geraniums 84 days after seeding and 47 days following transplant into non-infested or *Pythium*-infested medium when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Non-infested Plant Volume (cm^3)				*Pythium*-infested Plant Volume (cm^3)			
Seed	Trans-plant	1 wk after Trans-plant	7 wks after Trans-plant	8 wks after Trans-plant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-	-		1345	1756	1218		390	357	322
+	+	-	-	-		1250	1883	1637		485	1340	728
+	+	+	-	-		1291	2085	1473		620	1213	1029
-	+	-	-	-		1376	1556	1524		463	1494	985
-	-	+	-	-		1632	1136	1371		357	336	296
+	+	-	+	-		1431	1913	1801		517	1341	956
-	-	-	+	-		1444	1431	1650		360	297	530
-	-	-	-	+		1494	1610	1831		372	262	506
-	-	-	-	-	1596				434			

HSD (5%) = 676[y]

Source	D.F.	M.S.	F
Fungicide	2	4340118.37	11.28**[x]
Application	7	387776.00	1.00
FxA	14	1069895.78	2.78**

HSD (5%) = 414

Source	D.F.	M.S.	F
Fungicide	2	5941152.05	41.12**
Application	7	4070081.22	28.21**
FxA	14	1256979.81	8.71**

[z]0, 37, 44, 86 or 93 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) significance level.

plants drenched with metalaxyl at 1) seeding and transplanting, 2) seeding, transplanting and 1 week after transplanting or 3) seeding, transplanting and 7 week after transplanting.

On day 105, geraniums grown in the non-infested medium without fungicides were 83% larger than plants grown in the P. ultimum-infested medium without fungicides (Table 10) (See Appendix A, Tables A9, A10 for corresponding height and width measuremnts). Regardless of fungicide, drenches at 1) seeding, 2) 1 week after transplant or 3) 8 weeks after transplanting did not reduce plant stunting.

Some fungicide applications to plants grown in the non-infested medium resulted in reduced plant size on day 105 in comparision to plants without fungicide drenches (Table 10). The fenaminosulf treatment consisting of drenches at seeding, transplanting and 7 weeks after transplanting reduced plant growth significantly compared to plants not treated with fungicide (Table 10). A delay in flowering occurred in plants treated with drenches of fenaminosulf at seeding, transplanting and 1 week after transplanting (Table 11).

DISCUSSION

Fungicides at specific application times were effective in reducing crown and root rot disease caused by P. ultimum without STS treatment (Table 6,8). Other studies show fenaminosulf, ethazol and metalaxyl effectively control

Table 10. Average size of 'Ringo Scarlet' geraniums 105 days after seeding and 68 days following transplant into non-infested or *Pythium*-infested medium when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Non-infested Plant Volume (cm^3)				*Pythium*-infested Plant Volume (cm^3)			
Seed	Trans-plant	1 wk after Trans-plant	7 wks after Trans-plant	8 wks after Trans-plant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-	-						960	500	299
+	+	-	-	-		2315	3158	2002		1189	1449	1017
+	+	+	-	-		2190	2523	2569		1201	1546	1579
-	+	-	-	-		2137	2919	2385		883	2384	1295
-	-	+	-	-		1964	2651	2261		835	611	632
+	+	-	+	-		2459	2104	2169		1055	2016	1193
-	-	-	+	-		1810	2542	2458		1194	1022	1263
-	-	-	-	+		2109	2360	2407		563	no sample	967
-	-	-	-	-		2553	2920	2746				
					2886				487			
						HSD (5%) = 1003[y]				HSD (5%) = 515		

Source	D.F.	M.S.	F
Fungicide	2	3244780.54	7.66**[x]
Application	7	640322.17	1.51
FxA	14	546367.64	1.29

Source	D.F.	M.S.	F
Fungicide	2	2594048.51	23.22**
Application	7	2181592.79	19.52**
FxA	13	979984.06	8.77**

[z] 0, 37, 44, 86 or 93 days after seeding for each respective treatment time.
[y] Application comparison within each fungicide.
[x] 1% (**) significance level.

Table 11. Average days to flowers of 'Ringo Scarlet' geraniums when treated with Pythium controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Days to Flower			
					Fungicides			
Seeding	Transplant	1 wk after Transplant	7 weeks after Transplant	8 wks after Transplant	Control	Fenaminosulf	Metalaxyl	Ethazol
+	-	-	-	-		95.8	94.0	94.0
+	+	-	-	-		99.2	93.3	95.9
+	+	+	-	-		102.0	95.1	97.2
-	+	-	-	-		96.6	94.4	96.0
-	-	+	-	-		94.3	96.9	98.1
+	+	-	+	-		89.7	95.5	93.0
-	-	-	+	-		95.9	101.1	94.6
-	-	-	-	-		93.5	95.6	94.6
					94.4	HSD (5%) = 7.0[y]		

Source	D.F.	M.S.	
Fungicide	2	8.45	.41
Application	7	60.44	2.93**[x]
FxA	14	52.63	2.55**

[z]0, 37, 44, 86 or 93 days after seeding each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) significance level.

death due to Pythium spp. on a variety of crops (4,12,16,17,26,27).

STS application to plants grown in P. ultimum-infested medium increased mortality due to P. ultimum as observed previously (9).

Metalaxyl drenches at specific application timings consistently prevented increased incidence of plant death due to P. ultimum when plants were grown in P. ultimum-infested medium and treated with STS (Table 1,6,8). In contrast, fenaminosulf was ineffective in controlling increased death due to P. ultimum in response to foliar treatment with STS. Ethazol treatments gave inconsistent responses. In two of the three trials, ethazol treatments did not reduce mortality due to P. ultimum when plants were grown in P. ultimum-infested medium and treated with STS.

This investigation concluded that metalaxyl was superior in preventing mortality due to P. ultimum in STS-treated geraniums grown in P. ultimum-infested medium. The inability of fenaminosulf and ethazol to control P. ultimum after STS application when these same fungicides were effective against P. ultimum without STS is a matter of concern to the grower. It is proposed that STS application favors the pathogen (9) requiring stronger control fungicides. Apparently, metalaxyl is able to control P. ultimum under these conditions.

Results from this study suggest that plant size may be significantly affected by fungicides meant to control

Pythium spp. when the pathogen is not present. Whether a decrease or an increase of plant size occurs depends on the fungicide used and when it is applied. Plant size data were not consistent enough among the three screenings to determine at which developmental stage a geranium is most sensitive to a particular fungicide.

Fungicide phytotoxicity has been suggested in other bedding plant studies. Stephens (23) showed that phytotoxicity of fenaminosulf and ethazol was dependent on the rate of application and growing medium used. Bolton (3) found geraniums to be very sensitive to fungicides applied as drenches. For instance, transplant into fenaminosulf treated medium resulted in plant chlorosis and stunting. Bolton's work is supported by the plant measurements taken on day 51 in the first screening. Plants grown in non-infested medium with a fenaminosulf drench at transplant were 68% smaller than the no fungicide control (Table 3).

Significant stunting has been shown on the geranium 'Ringo Scarlet' when grown in P. ultimum-infested medium compared to plants grown in a non-infested medium (9). In the first and third screenings, geraniums grown in the P. ultimum infested medium showed severe plant stunting typical of that caused by Pythium spp. (6,13,15). This was not the case in the second screening. However, the high mortality (62%) of STS-treated plants grown in non-infested medium suggests that these controls were contaminated with P. ultimum and do not constitute a control for comparision.

Metalaxyl or ethazol treatments at specific application timings to plants grown in P. ultimum-infested medium effectively reduced time to flower in comparision to the control. Fungicide application also affected time to flower when applied to geraniums grown in non-infested medium. In the first and third screenings, drenches of fenaminosulf at seed, transplant, and 1 week after transplant consistently delayed flowering (Table 7,10).

Fungicide screening for effectiveness in controlling Pythium spp. has been investigated on several crops (4,12,16,17,26,27). However, recommendations from these studies may not be effective in situations where STS is utilized. Growers planning to use STS should consider a fungicide program which will provide the added control.

Fungicide testing is important in formulating grower recommendations. Frequently, percent mortality is the only parameter evaluated in these studies. This particular study has attempted to define fungicide effectiveness through a variety of plant parameters. Data from this study are helpful in emphasizing that fungicide recommendations for control of P. ultimum on seed propagated geraniums should involve several factors; 1) the increased disease incidence due to STS if P. ultimum is present, 2) the subtle symptoms of P. ultimum infection including growth stunting and delay of flowering that may occur without fungicidal control, and 3) the possible fungicide effects of geraniums without a pathogen.

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Section III:

Variation in sensitivity to *Pythium ultimum* of selected seed propagated hybrid geranium cultivars

Variation in Sensitivity to *Pythium ultimum* of Selected Seed Propagated Hybrid Geranium Cultivars

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ABSTRACT

Hausbeck, M.K., C.T. Stephens and R.D. Heins. 1985. Variation insensitivity to *Pythium ultimum* of selected seed propagated hybrid geranium cultivars. Plant Disease 0:0. While genetic resistance to *Pythium ultimum* was not identified in 37 cultivars screened, tolerance appeared to be present. Cultivars varied in the amount of plant stunting and flowering delay caused by *P. ultimum*. Silver thiosulphate increased plant mortality due to *P. ultimum* when plants were grown in a *P. ultimum*-infested medium.

Additional key words: *Pythium ultimum*, geranium (*Pelargonium* x *hortorum*), silver thiosulphate

INTRODUCTON

The seed propagated hybrid geranium (Pelargonium x hortorum) is commanding significant attention as an important crop in the bedding bedding plant industry. In 1983, approximately ten seed companies were developing hybrid geranium seed cultivars. More than 100 cultivars have been introduced, bringing annual production in 1983 to 90-100 million seeds (7).

However, flower petal shatter is a severe problem in marketing the seed propagated geranium (2). This premature abscission occurs primarily during transportation. Foliar application of silver thiosulphate (STS) solution prevents petal abscission in seed propagated hybrid geraniums (6,8,17).

Foliar sprays of STS increase disease incidence due to Pythium ultimum Trow in geraniums grown in P. ultimum-infested medium (10). Geraniums not treated with STS but grown in Pythium-infested medium may not show typical black stem lesions commonly associated with P. ultimum crown and root rot, but may have stunted plant growth, reduced root systems and chlorotic, wilted lower leaves indicative of Pythium root rot (10).

The objectives of this experiment were: 1) to screen geranium cultivars for possible resistance to crown and root rot disease caused by P. ultimum in plants treated with or without STS and 2) to screen geranium cultivars not treated

with STS for possible tolerance to plant stunting due to root rot disease caused by P. ultimum.

MATERIALS AND METHODS

Forty-one seed propagated geranium (Pelargonium x hortorum) cultivars were chosen, encompassing a variety of colors, leaf types and seed sources (Table 1). The cultivars were grouped into four separate experiments due to variable seed and greenhouse space availability. Seeds were individually sown in round 2.0 cm in diameter cells, covered with fine vermiculite and placed under intermittant mist at 24°C in a glass greenhouse. After germination (7 days), the seedlings were removed from the mist and grown at 22°C day and 20°C night temperatures under natural light in the greenhouse. They were fertilized at each watering with 200 mg liter^{-1} of N and K throughout the experiment.

Pythium ultimum inoculum was prepared using the potato media procedure originally developed for culture of Rhizoctonia solani Kuhn (13). Fifty grams of finely chopped potato were added to 500 ml of a commercial soilless mix (Sunshine Media Mix, Blend 1, Fisons-Western Corp., Vancouver, B.C., Canada) containing 2 parts vermiculite, 2 parts peat moss and 1 part perlite. The potato media mixture was autoclaved twice for one hour, 24 hours apart.

Table 1. Selected seed propagated hybrid geranium cultivars, seed sources, flower colors and foliage characteristics grouped into 4 experiments. Each cultivar was screened for sensitivity to crown and root rot when grown in Pythium ultimum-infested medium and treated with or without silver thiosulphate.

Cultivar	Seed Source	Flower Color	Foliage
Experiment 1			
Jackpot	S&G[z]	Scarlet	Zoned
Rosita Improved	S&G	Rose-pink	Green
Smash Hit Rose Pink	Ball[y]	Br. rose-pink	Zoned
Smash Hit Salmon	Ball	Deep salmon	Zoned
Experiment 2			
Cameo	Ball	Deep salmon	Zoned
Cheri Improved	Gold[x]	Soft salmon	Zoned
Encounter Salmon	Ball	Midsalmon	Zoned
Marathon	Ball	Deep scarlet	Green
Red Orbit	Gold	Bright red	Zoned
Showgirl	Ball	Rose-pink	Green
Smash Hit	Ball	Scarlet	Zoned
Snowdon	Ball	White	Green
White Orbit	Gold	White	Green
Experiment 3			
Capri Deep Red	PA[w]	Dark red	Zoned
Jackpot	S&G	Scarlet	Zoned
Mustang	S&G	Red	Zoned
Picasso	S&G	Violet-cerise	Zoned
Red Elite	Gold	Red	Green
Red Pimpernel	S&G	Red	Green
Ringo Dolly	S&G	Bicolor	Green
Ringo Salmon	S&G	Deep salmon	Zoned
Ringo Scarlet	S&G	Bright scarlet	Zoned
Rosita Improved	S&G	Rose-pink	Zoned

Table 1. (Cont.)

Cultivar	Seed Source	Flower Color	Foliage
Experiment 4			
Appleblossom Orbit Imp	Gold	Soft-pink	Zoned
Cherry Diamond	Walz[v]	Cherry-red	Zoned
Expermental Rose	Walz	Soft-pink	Zoned
Heidi	S&G	Bicolor	Green
Hollywood Red	Ball	Red	Zoned
Hollywood Salmon	Ball	Deep salmon	Zoned
PAC Adretta	Walz	Coral red	Zoned
Pink Orbit	Gold	Rose-pink	Zoned
Pinwheel Salmon	Harris[u]	Medium salmon	Zoned
Quix	Walz	Orange scarlet	Green
Ringleader Light Pink	VJ[t]	Light pink	Zoned
Ringleader Red	VJ	Red	Zoned
Ringleader Salmon	VJ	Salmon	Zoned
Ringo Dolly	SG	Bicolor	Green
Ringo Scarlet	SG	Bright scarlet	Zoned
Scarlet Diamond	Walz	Bright scarlet	Zoned
Sitta	Walz	Salmon pink	Zoned
Sprinter Scarlet	Gold	Bright scarlet	Green

[z]Sluis & Groot B.V., Enkhuizen, Holland
[y]Ball Seed Co., West Chicago, IL 60185
[x]Goldsmith Seeds, Gilroy, CA 95020
[w]Pan-America Seed Co., West Chicago, IL 60185
[v]Walz, Germany
[u]Harris Seeds, Rochester, NY 14624
[t]Vaughan-Jacklin, Downers Grove, IL 60515

Cultures of P. ultimum (#248) (20) were maintained on 20 ml of water agar (Difco Laboratories, Detroit, MI 48232) and grown in 10 cm petri plates for two days at 24°C. Six mycelial discs 12 mm in diameter from the growing perimeter were used to infest 1.5 liters of sterilized potato soil media. The inoculum was grown in 2.0 liter closed flasks for approximately two weeks and shaken daily. The inoculum was air dried for 1-2 days and sieved through a #10 (2mm) screen.

Three grams of inoculum (prepared as described above) were added to each liter of non-infested medium. This rate had been shown to incite a high level of disease due to P. ultimum (10). After thoroughly mixing, the infested medium was placed into 10 cm plastic pots. There were 12 replications for each treatment. Non-infested and P. ultimum-infested treatment containers were randomized on greenhouse benches comprised of 14.0 cm wooden planks 4.0 cm apart. To minimize P. ultimum contamination of non-infested plants, non-infested and P. ultimum-infested treatments were placed on alternating wooden planks. Benches were sterilized between experiments with a 10% sodium hypochlorite solution.

Treatments were maintained at 20°C night and 22°C day temperatures. Medium pH varied between 5.5-6.5 during the experiment. Foliar applications of 750 ppm chlormequat chlorine (American Cyanamid Co., Wayne, N.J. 0747) (CCC) were applied for height control as growth necessitated (5).

A 0.25 mM foliar silver thiosulphate (STS) treatment (11,18) is commonly applied at flower bud color. STS was applied 100, 105, 102 or 95 days after seeding for Experiments 1 to 4 respectively. Each plant was individually sprayed. A second STS spray was applied two weeks after the original application. The control plants received no treatment.

Plants were observed daily for symptoms of P. ultimum crown and root rot. The number of days following transplant into P. ultimum-infested medium at which death occurred were recorded, from time of transplant (day 0) into P. ultimum-infested medium through day 94, 93, 93 or 100 after transplanting for Experiments 1 to 4 respectively. Percent mortality was calculated. Plant height and width were recorded 83, 90 or 100 days after seeding for Experiments 1-3 and 67 and 103 days after seeding for Experiment 4. Plant volume (size) was calculated from the height and width measurements, assuming the plants to be a cylinder. Days from seeding to flower were also recorded.

Reisolation of P. ultimum was conducted on geraniums that died during the study. At the termination of the experiment, surviving geraniums in the P. ultimum-infested medium and non-infested controls were randomly sampled. One half inch sections of roots, stem and petioles were surface sterilized in 10% sodium hypochlorite for approximately 20 seconds and plated on water agar. The plates were observed for a minimum of seven days for Pythium hyphal growth. The agar plates with hyphal growth were allowed to dry at room

temperature for three weeks to promote encysted sporangia development. The fungus was identified as P. ultimum.

RESULTS

Cultivar Set 1

Mortality prior to application of STS ranged from 9-34% (Table 2). STS application increased mortality due to P. ultimum with mortality following STS application ranging from 27 to 53% The cultivar 'Smash Hit Rose Pink' showed the greatest loss throughout the experiment.

All tested cultivars showed a significant reduction in plant size when transplanted into P. ultimum-infested medium (Table 3) (See Appendix B, Table B1 for corresponding height and width measurements). This was accompanied by a delay in flowering. Surviving 'Smash Hit Rose Pink' geraniums in P. ultimum-infested medium showed the greatest volume reduction in comparision to control plants as well as the greatest flowering delay.

Cultivar Set 2

The nine cultivars investigated had lower mortality overall than the previous cultivar set (Table 4). The overall low mortality was also reflected in a smaller plant volume reduction due to P. ultimum-infestation (Table 5) (See Appendix B, Table B2 for corresponding height and width measurements. The cultivar 'Cheri Improved' showed a significant size reduction in P. ultimum-infested medium as well as a significant 5% delay in flowering.

Table 2. Percent mortality of selected geranium cultivars grown in non-infested (-P) or Pythium-infested (+P) medium and treated with 0.25 mM silver thiosulphate (STS).

Cultivar	PERCENT MORTALITY[z]					
	Before STS Treatment		After STS Treatment[y]			
			-STS		+STS	
	-P	+P	-P	+P	-P	+P
Rosita Improved	3	9	0	0	0	53
Smash Hit Salmon	9	9	0	0	0	50
Jackpot	9	28	0	0	0	27
Smash Hit Rose Pink	3	34	0	0	0	50

[z]120 days after seeding and 94 days following Pythium infestation.
[y]Percent mortality based on surviving plants at STS application on day 100.

Table 3. Average size and days to flower of selected geranium cultivars grown in non-infested (-P) or *Pythium*-infested (+P) medium.

Cultivar	Plant volume (cm^3)[z]		% volume reduction	Days to flower		% flower delay
	-P	+P		-P	+P	
Jackpot	1753	1354**[y]	23	96.7	103.7**	7
Rosita Improved	1721	1270**	26	98.1	106.3**	8
Smash Hit Salmon	1607	1028**	26	96.1	99.8*	4
Smash Hit Rose Pink	3311	1572**	53	95.2	106.9**	11

Source	D.F.	M.S.	F	Source	D.F.	M.S.	F
Cv.	3	18771495.20	105.90**[x]	Cv.	3	79.57	4.20**
Pyt.	1	32570337.45	183.75**	Pyt.	1	1627.69	85.92**
Cxp	3	5242096.88	29.57**	Cxp	3	73.23	3.86*

[z]Measurements taken 83 days after seeding and 51 days following *Pythium* infestation.
[y]Differences between -P and +P significant at 1% (**) or 5% (*) level based on t-test.
[x]1% (**) or 5% (*) significance level.

Table 4. Percent mortality of selected geranium cultivars grown in non-infested (-P) or Pythium-infested (+P) medium and treated with 0.25 mM silver thiosulphate (STS).

Cultivar	PERCENT MORTALITY[z]					
	Before STS Treatment		After STS Treatment[y]			
			-STS		+STS	
	-P	+P	-P	+P	-P	+P
Showgirl	0	0	0	31	9	0
Cheri Improved	0	0	0	0	0	7
Red Orbit	0	0	0	0	8	8
White Orbit	0	0	0	7	13	8
Encounter Salmon	0	0	0	0	0	9
Snowdon	0	0	0	0	0	9
Marathon	0	0	0	0	10	13
Cameo	0	0	0	0	9	15
Smash Hit	0	4	0	0	9	0

[z]140 days after seeding and 93 days following Pythium infestation.
[y]Percent mortality based on surviving plants at STS application on day 105.

Table 5. Average size and days to flower of selected geranium cultivars grown in non-infested (-P) or Pythium-infested (+P) medium.

Cultivar	Plant volume (cm^3)[z] -P	Plant volume (cm^3)[z] +P	% volume reduction	Days to flower -P	Days to flower +P	% flower delay
White Orbit	1161	1262		103.5	104.5	1
Marathon	2676	2591	3	110.7	116.8*[y]	5
Snowdon	1778	1661	7	103.1	100.6	
Showgirl	2140	1964	8	102.7	104.3	2
Red Orbit	1809	1646	9	99.3	98.6	
Cheri Improved	1648	1415	14	107.9	113.2**	5
Encounter Salmon	2099	1788	15	93.9	95.7	2
Cameo	1394	1183	15	96.3	98.1	2
Smash Hit	1723	1438	17	96.3	104.4*	

Source	D.F.	M.S.	F	Source	D.F.	M.S.	F
Cv.	8	9277263.18	24.60**[x]	Cv.	8	873.32	28.67**
Pyt.	1	2846307.23	7.55**	Pyt.	1	292.32	9.60**
Cxp	8	173117.75	.46	Cxp	8	61.36	2.01*

[z]Measurements taken 90 days after seeding and 62 days following Pythium infestation.
[y]Differences between -P and +P significant at 1% (**) or 5% (*) level based on T-test.
[x]1% (**) or 5% (*) significance level.

Cultivar Set 3

In the ten cultivars screened in Experiment 3, mortality ranged from 0 to 33% before STS application (Table 6). STS greatly increased the mortality of geraniums grown in P. ultimum-infested medium. The largest difference was seen in the cultivar 'Mustang' with a mortality increase of 55%. 'Ringo Dolly' showed no mortality either before or after STS.

While 'Ringo Dolly' geraniums grown in P. ultimum-infested medium showed no mortality, plants were significantly smaller in comparision to the control (Table 7) (See Appedix B, Table B3 for corresponding height and width measurements). All the cultivars grown in P. ultimum-infested soil also showed reduced plant size in comparision to control plants. Flowering was delayed in 'Picasso' and 'Capri Deep Red' grown in P. ultimum-infested medium.

Cultivar Set 4

Eighteen geranium cultivars were screened in this experiment. Overall, there was more P. ultimum mortality in this group (Table 8) than in the previous three screenings. Percent mortality before STS treatment ranged from 0 to 63%. STS application to geraniums grown in the P. ultimum-infested medium resulted in increased mortality due to P. ultimum. The cultivar 'Sprinter Scarlet' showed no plant loss prior to STS but 69% mortality after application.

Table 6. Percent mortality of selected geranium cultivars grown in non-infested (-P) or *Pythium*-infested (+P) medium and treated with 0.25 mM silver thiosulphate (STS).

Cultivar	PERCENT MORTALITY[z]					
	Before STS Treatment		After STS Treatment[y]			
			-STS		+STS	
	-P	+P	-P	+P	-P	+P
Ringo Dolly	0	0	0	0	0	0
Ringo Scarlet	0	0	0	0	8	0
Red Elite	0	0	0	0	0	7
Red Pimpernel	0	0	0	0	0	8
Ringo Salmon	0	0	0	0	0	17
Rosita Improved	0	0	0	0	0	42
Picasso	0	4	0	0	8	42
Mustang	0	8	0	8	0	55
Jackpot	0	10	0	0	0	11
Capri Deep Red	6	33	0	13	11	20

[z]120 days after seeding and 93 days following *Pythium* infestation.
[y]Percent mortality based on surviving plants at STS application on day 102.

Table 7. Average size and days to flower of selected geranium cultivars grown in non-infested (-P) or Pythium-infested (+P) medium.

Cultivar	Plant volume (cm^3)[z] -P	+P	% volume reduction	Days to flower -P	+P	% flower delay
Ringo Scarlet	1983	1664**[y]	16	97.9	99.3	1
Picasso	1849	1420**	23	99.9	108.3*	8
Red Elite	1448	1059**	27	99.3	102.4	3
Ringo Dolly	1518	1070**	30	100.1	101.9	2
Red Pimpernel	1897	1331**	30	98.5	101.4	3
Mustang	2390	1520**	36	100.5	101.7	1
Ringo Salmon	1542	948**	39	99.3	102.8	3
Capri Deep Red	1938	1001**	48	104.8	116.8*	10
Rosita Improved	2065	1060**	49	92.6	96.9	4
Jackpot	2261	1133**	50	92.9	96.9	4

Source	D.F.	M.S.	F	Source	D.F.	M.S.	F
Cv.	9	2805388.00	13.12**[x]	Cv.	9	303.92	12.48**
Pyt.	1	46397214.11	217.08**	Pyt.	1	803.84	33.01**
Cxp	9	905612.23	4.24**	Cxp	9	50.24	2.06*

[z]Measurements taken 100 days after seeding and 73 days following Pythium infestation.
[y]Differences between -P and +P significant at 1% (**) or 5 (*) level based on t-test.
[x]1% (**) or 5% (*) significance level.

Table 8. Percent mortality of selected geranium cultivars grown in non-infested (-P) or *Pythium* infested (+P) medium and treated with 0.25 mM silver thiosulphate (STS).

Cultivar	PERCENT MORTALITY[z]					
	Before STS Treatment		After STS Treatment[y]			
			-STS		+STS	
	-P	+P	-P	+P	-P	+P
Sprinter Scarlet	0	0	0	0	8	69
Ringo Scarlet	0	4	0	0	0	64
Ringo Dolly	8	8	0	0	0	69
Quix	8	12	0	0	27	89
Hollywood Salmon	0	12	0	0	0	75
Ringleader Salmon	0	13	0	0	0	57
Ringleader Red	0	15	0	0	8	85
Heidi	4	20	0	11	17	91
Sitta	0	24	0	0	0	27
Pinwheel Salmon	0	26	0	0	0	75
Hollywood Red	0	26	0	0	0	88
Pink Orbit	4	29	8	0	0	100
Scarlet Diamond	15	30	0	0	9	50
Cherry Diamond	4	33	0	20	8	50
Ringleader Pink	4	35	0	11	20	88
PAC Adretta	8	36	0	25	0	63
Experimental Rose	13	50	0	33	9	29
Appleblossom Orbit Improved	0	63	0	50	27	83

[z]130 days after seedling and 100 days following *Pythium* infestation.
[y]Percent mortality based on surviving plants at STS application on day 95.

'Pink Orbit' showed 29% and 100% mortality before and after STS respectively.

Mortality before STS was not a reliable indicator of subsequent response to STS. For example, 'Quix' showed only 12% mortality before STS but 89% after STS while 'Appleblossom Orbit Improved' showed 63% loss before STS treatment and 83% after application.

Pythium ultimum infestation resulted in a significant size reduction in all cultivars at day 67 (Table 9) (See Appendix B, Table B4 for corresponding height and width meausurements). Plants growing in the P. ultimum-infested medium were still smaller at day 103 but not statistically in the three cultivars, 'Hollywood Salmon','Quix', and 'Sitta' (Table 10) (See Appendix B, Table B5 for corresponding height and width measurements). There was, however, significant delay in flowering of these cultivars.

DISCUSSION

While each cultivar set was screened by the same procedure, comparisions between the screenings are not valid since each screening was conducted at a different time. The apparently increased plant mortality due to disease caused by P. ultimum in cultivar set 4 may be due to environmental factors. For example, cultivar set 4 experienced temperatures ranging from 20°C to 32°C whereas the previous 3 screenings were conducted in temperatures of 16°C-22°C. Greenhouse environments are more precisely controlled during

Table 9. Average size of selected geranium cultivars grown in non-infested (-P) or *Pythium*-infested (+P) medium.

Cultivar	Plant volume (cm^3)[z]		
	-P	+P	% Reduction
Sprinter Scarlet	697	505	28 *[y]
Heidi	1086	607	44 **
Quix	585	311	47 **
Experimental Rose	1059	476	55 **
Ringleader Red	754	307	59 **
Hollywood Salmon	751	290	61 **
PAC Adretta	1393	508	64 **
Ringo Scarlet	1679	605	64 **
Sitta	868	300	65 **
Pinwheel Salmon	1316	424	68 **
Scarlet Diamond	1361	408	70 **
Pink Orbit	616	178	71 **
Ringo Dolly	1356	381	72 **
Cherry Diamond	1136	300	74 **
Hollywood Red	717	175	76 **
Ringleader Pink	698	130	81 **
Ringleader Salmon	694	129	81 **
Appleblossom Orbit Improved	642	103	84 **

Source	D.F.	M.S.	F
Cv.	17	2312483.60	30.92 **[x]
Pyt.	1	71179843.82	951.61 **
Cxp	17	713857.37	9.54 **

[z]Measurements taken 67 days after seeding and 37 days following *Pythium* infestation.

[y]Differences between -P and +P significant at 1% (**) or 5% (*) level based on T-test.

[x]1% (**) or 5% (*) significance level.

Table 10. Average size and days to flower of selected geranium cultivars grown in non-infested (-P) or *Pythium*-infested (+P) medium.

Cultivar	Plant Volume (cm^3)[z]			Days to Flower		
	-P	+P	% volume reduction	-P	+P	% flower delay
Hollywood Salmon	1080	946	12	92.5	107.0**[y]	14
Sprinter Scarlet	1493	1092**	27	102.9	106.5	3
Quix	1002	692	31	99.7	111.2*	10
Sitta	835	558	33	88.8	85.8	
Heidi	1962	1314**	33	92.4	100.5*	8
Pinwheel Salmon	2060	1297**	37	89.0	100.4**	11
Ringo Scarlet	2297	1397**	39	85.9	105.5**	19
PAC Adretta	2523	1538**	39	96.5	98.8	2
Ringleader Salmon	1217	656*	46	99.3	117.2**	15
Cherry Diamond	1840	976*	47	86.1	88.5	3
Pink Orbit	1092	570**	48	96.2	110.6**	13
Scarlet Diamond	1662	839**	50	77.4	78.1	1
Experimental Rose	1932	805*	58	90.9	94.2	4
Ringo Dolly	2238	834**	63	83.1	96.2**	14
Ringleader Pink	1540	494**	68	98.3	115.5**	15
Hollywood Red	1530	485**	68	93.8	103.0	9
Appleblossom Orbit Improved	1616	382*	76	92.1	120.0	23
Ringleader Red	2215	427**	81	96.8	106.4**	9

Source	D.F.	M.S.	F	Source	D.F.	M.S.	F
Cv.	17	3109174.38	15.23**[x]	Cv.	17	1170.09	14.50**
Pyt.	1	47958451.08	234.95**	Pyt.	1	7562.86	93.69**
Cxp	17	833127.30	4.08**	Cxp	17	225.20	2.79**

[z]Measurements taken 103 days after seeding and 73 days following *Pythium* infestation.
[y]Differences between -P and +P significant at 1% (**) or 5% (*) level based on t-test.
[x]1% (**) or 5% (*) significance level.

the winter (experiments 1-3) than during spring and early summer (experiment 4).

Pythium ultimum Trow has historically been considered a cool season pathogen (3,12,14), although some evidence indicates otherwise (9). Greater water fluctuations would naturally accompany the higher temperatures experienced during the fourth screening. Periods of high water moisture followed by a very dry period has been connected to increased disease due to Pythium spp. (19).

Results show a cultivar difference in mortality response to crown and root rot disease caused by P. ultimum. Surviving geraniums in P. ultimum-infested medium were significantly stunted in comparision to control plants but did not show any other root rot symptoms.

Cultivar set 2, showed insignificant growth differences between geraniums grown in non-infested or P. ultimum-infested medium. Plant mortality was minimal. This substantiates previous studies which suggested that stunted geranium growth is often a symptom of root rot preceding the black stem lesions of crown rot leading to subsequent mortality (10).

Resistance to P. ultimum was not identified within selected cultivars screened. However, tolerance to disease caused by P. ultimum appeared to be present in varying degrees as measured by plant growth and time to flower. It is possible that a cultivar grown in P. ultimum-infested medium which shows decreased mortality yet has greatly

stunted growth may be showing more tolerance than a cultivar which has high mortality but shows size reduction.

STS treatment increased mortality due to P. ultimum crown and root rot. Geranium cultivars resistant to disease caused by this P. ultimum/STS interaction cannot be confidently identified. The geraniums 'Showgirl' and 'Smash Hit' in cultivar set 2 showed 0% mortality when grown in P. ultimum-infested medium and treated with STS. treatments. The overall low mortality in this group, however, suggests factors other than resistance to disease caused by P. ultimum are involved. In cultivar set 3, 'Ringo Dolly' and 'Ringo Scarlet' show no plant loss when grown in P. ultimum-infested medium and sprayed with STS. However, in cultivar set 4, these same cultivars showed 69 and 64% mortality respectively.

A variety of crops have been shown to have genetic resistance to disease caused by P. ultimum (12) including bean cultivars (Phaseolus vulgaris) (1). However, resistance to P. ultimum was not found among species and varieties of cotton (15). Another study showed cotton and corn to be more resistant to Pythium spp. than tomato, bean and rye (16).

Genetic resistance to disease caused by Pythium spp. has not been thoroughly investigated in the seed propagated hybrid geranium. Stephens et al. incuded two geranium cultivars in their search for P. ultimum disease resistance in bedding plant crops. Neither cultivar showed resistance

(Personal communication, Dr. Christine T. Stephens; Department of Botany and Plant Pathology, Michigan State University). The genetic recombination possible in the seed propagated geranium offers an opportunity for possible identification and subsequent development of Pythium resistance.

Baker and Linderman (4) address the special problems involved with breeding for disease resistance in ornamentals. They point out that the success of newly introduced cultivars is often dependent on horticultural qualities rather than disease resistance. A disease tolerant cultivar will not be grown if the cultivar is not also horticulturally advantageous. They conclude that disease loss must be great enough to make breeding and subsequent development of disease resistant or tolerant cultivars that are also horticulturally acceptable cost effective.

The large plant losses due to P. ultimum of geraniums grown in P. ultimum-infested medium and treated with STS may make this a worthwhile situation to explore for disease resistance or tolerance. Findings show that plant stunting may be the only symptom of P. ultimum root rot disease in otherwise healthy appearing geraniums. This provides little warning for the grower who may be unaware of plant stunting symptoms unless non-infected plants are available for comparision. It also emphasizes the importance of identifying cultivars which show tolerance to P. ultimum.

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APPENDIX A

Table A1. Average size of 'Ringo Scarlet' geraniums 51 days after seeding when treated with Pythium controlling fungicides at selected timings.

Timings of Fungicide Application[z]				Plant Height (cm)				Plant Width (cm)			
Seed	Transplant	1 wk after Transplant	2 wks after Transplant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-		5.9	5.6	5.4		7.7	7.9	6.6
+	+	-	-		5.4	4.9	5.1		6.9	6.6	6.7
+	+	+	-		4.1	5.2	5.1		5.1	7.3	7.0
-	+	-	-		4.0	5.8	5.0		5.1	8.0	7.1
-	-	+	-		6.0	5.6	4.2		8.4	6.9	5.5
-	-	-	+		4.8	4.2	5.5		6.7	6.0	7.7
-	-	-	-	5.2				7.7			

HSD (5%) = .9[y]

Source	D.F.	M.S.	F
Fungicide	2	1.06	1.70
Application	5	4.60	7.32**
FxA	10	7.78	12.38**

HSD (5%) = 1.3

Source	D.F.	M.S.	F
Fungicide	2	5.16	3.80*[y]
Application	5	4.80	3.53**
FxA	10	21.28	15.66**

[z]0, 30, 37 or 44 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]5% (**) significance level.

Table A2. Average size of 'Ringo Scarlet' geraniums 51 days after seeding and 21 days following transplant into *Pythium*-infested medium when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]				Plant Height (cm)				Plant Width (cm)			
Seed	Transplant	1 wk after Transplant	2 wks after Transplant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-		4.2	4.2	4.3		4.8	6.1	5.4
+	+	-	-		4.1	5.5	5.5		4.8	7.6	7.6
+	+	+	-		3.6	4.7	5.9		4.2	6.8	8.2
-	+	-	-		4.3	4.7	5.4		5.2	6.2	7.2
-	-	+	-		4.2	4.0	4.2		5.3	4.7	4.8
-	-	-	+		3.6	5.0	4.0		4.3	6.4	5.5
-	-	-	-	3.8				4.7			
					HSD (5%) = .7[y]				HSD (5%) = 1.1		

Source	D.F.	M.S.	F
Fungicide	2	20.89	46.11**[x]
Application	5	7.14	15.76**
FxA	10	4.68	10.32**

Source	D.F.	M.S.	F
Fungicide	2	85.48	82.63**
Application	5	20.85	20.16**
FxA	10	12.86	12.43**

[z]0, 30, 37 or 44 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) significance level.

Table A3. Average size of 'Ringo Scarlet' geraniums 98 days after seeding when treated with Pythium specific fungicides at selected timings.

Timings of Fungicide Application[z]				Plant Height (cm)				Plant Width (cm)			
Seed	Transplant	1 wk after Transplant	2 wks after Transplant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-		9.0	9.4	7.6		9.4	9.6	8.9
+	+	-	-		9.9	9.1	8.8		10.7	9.8	9.5
+	+	+	-		7.8	10.2	9.1		8.9	10.3	9.6
-	+	-	-		8.4	9.0	8.6		8.9	9.6	9.8
-	-	+	-		11.6	9.4	7.8		11.0	9.8	9.1
-	-	-	+		9.1	7.5	9.2		11.1	8.8	9.9
-	-	-	-	8.5				9.6			

HSD (5%) = 1.9[y]

Source	D.F.	M.S.	F
Fungicide	2	7.63	5.10**[x]
Application	5	3.84	2.56*
FxA	10	10.36	6.93**

HSD (5%) = 2.0

Source	D.F.	M.S.	F
Fungicide	2	3.54	2.07
Application	5	2.19	1.28
FxA	10	4.97	2.90**

[z]0, 30, 37, or 44 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) significance level.

Table A4. Average size of 'Ringo Scarlet' geraniums 98 days after seeding and 68 days following transplant into *Pythium*-infested medium when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]				Plant Height (cm)				Plant Width (cm)			
Seed	Transplant	1 wk after Transplant	2 wks after Transplant	Control	Fenamino-sulf	Metalaxyl	Ethanol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-		7.6	8.3	8.0		8.7	8.9	8.8
+	+	-	-		7.8	8.9	10.9		8.8	10.1	11.4
+	+	+	-		6.4	9.1	10.5		8.0	9.5	10.8
-	+	-	-		8.0	9.2	10.6		8.4	10.4	10.5
-	-	+	-		7.0	7.0	7.4		8.1	7.7	8.2
-	-	-	+		6.0	10.0	8.5		7.4	10.9	9.5
-	-	-	-	6.2	HSD (5%) = 1.6[y]			7.5	HSD (5%) = 1.8		

Source	D.F.	M.S.	F
Fungicide	2	62.82	56.80**[x]
Application	5	15.59	14.10**
FxA	10	7.76	7.01**

Source	D.F.	M.S.	F
Fungicide	2	36.30	26.63**
Application	5	13.32	9.77**
FxA	10	5.47	4.01**

[z]0,30, 37 or 44 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) significance level.

Table A5. Average size of 'Ringo Scarlet' geraniums 135 days after seeding when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Plant Height (cm)				Plant Width (cm)			
Seed	Trans-plant	1 wk after Trans-plant	8 wks after Trans-plant	9 wks after Trans-plant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-	-		16.4	16.8	16.0		13.1	14.1	13.7
+	+	-	-	-		15.9	16.8	15.6		13.0	14.5	13.4
+	+	+	-	-		15.6	17.0	17.0		13.0	14.6	14.4
-	+	-	-	-		18.0	17.1	16.1		15.5	13.9	14.2
-	-	-	+	-		16.2	16.4	16.2		13.1	14.1	14.4
-	-	-	-	+		16.6	16.8	15.0		13.3	14.8	15.0
-	-	-	-	-	16.6				13.0			

HSD (5%) = 2.1[y]

Source	D.F.	M.S.	F
Fungicide	2	4.80	2.30
Application	5	2.66	1.27
FxA	10	1.22	1.22

HSD (5%) = 1.8

Source	D.F.	M.S.	F
Fungicide	2	7.87	4.82**[x]
Application	5	2.77	1.70
FxA	10	3.63	2.22*

[z]0, 21, 28, 77 or 84 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) or 5% (*) significance level.

Table A6. Average size of 'Ringo Scarlet' geraniums 135 days after seeding, 114 days following transplant into *Pythium*-infested medium when treated with *Pythium* specific fungicides at selected timings.

Timings of Fungicide Application[z]					Plant Height (cm)				Plant Width (cm)			
Seed	Trans-plant	1 wk after Trans-plant	8 wks after Trans-plant	9 wks after Trans-plant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-	-		15.4	15.8	16.1		12.5	13.1	13.4
+	+	-	-	-		15.6	18.7	15.4		12.5	13.8	12.6
+	+	+	-	-			no sample				no sample	
-	+	-	-	-		16.2	16.9	15.4		13.4	13.9	13.1
-	-	-	+	-		16.1	17.4	16.1		14.6	14.6	13.4
-	-	-	-	+		15.7	16.6	18.2		13.2	14.6	13.6
-	-	-	-	-	15.9				13.9			

HSD (5%) = 2.3[y]

Source	D.F.	M.S.	F
Fungicide	2	16.22	5.62**[x]
Application	4	3.56	1.23
FxA	8	8.16	2.83**

HSD (5%) = 1.9

Source	D.F.	M.S.	F
Fungicide	2	7.84	3.86*
Application	4	6.98	3.44*
FxA	8	1.75	.86

[z]0, 21, 28, 77 or 84 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide
[x]1% (**) or 5% (*) significance level.

Table A7. Average size of 'Ringo Scarlet' geraniums 84 days after seeding when treated with Pythium controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Plant Height (cm)				Plant Width (cm)			
Seed	Trans-plant	1 wk after Trans-plant	7 wks after Trans-plant	8 wks after Trans-plant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-	-		9.2	10.8	8.9		13.1	14.1	12.8
+	+	-	-	-		8.8	10.6	9.9		13.4	14.9	14.4
+	+	+	-	-		9.1	11.2	9.6		13.3	15.4	13.9
-	+	-	-	-		9.5	10.3	10.0		13.4	13.8	13.9
-	-	+	-	-		10.2	8.8	9.6		14.3	12.6	13.3
+	+	-	+	-		9.7	10.9	10.9		13.6	14.9	14.4
-	-	-	+	-		9.6	9.6	10.0		13.6	13.5	14.1
-	-	-	-	+		10.0	10.1	10.6		13.4	13.9	14.5
-	-	-	-	-	9.9				14.2			

HSD (5%) = 1.7[y]

Source	D.F.	M.S.	F
Fungicide	2	29.76	12.19**[x]
Application	7	3.76	1.54
FxA	14	5.76	2.37*

HSD (5%) = 1.6

Source	D.F.	M.S.	F
Fungicide	2	13.29	6.08**
Application	7	1.90	.87
FxA	14	5.36	2.45**

[z]0, 37, 44, 86 or 93 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) or 5% (*) significance level.

Table A8. Average size of 'Ringo Scarlet' geraniums 84 days after seeding, 47 days following transplant into *Pythium*-infested medium when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Plant Height (cm)				Plant Width (cm)			
Seed	Trans-plant	1 wk after Trans-plant	7 wks after Trans-plant	8 wks after Trans-plant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-	-		6.0	6.1	5.6		9.0	8.4	8.2
+	+	-	-	-		6.6	9.4	7.1		9.5	13.2	10.6
+	+	+	-	-		7.2	9.2	8.6		10.0	12.8	12.1
-	+	-	-	-		6.3	10.4	8.7		9.6	13.4	11.4
-	-	+	-	-		5.5	6.1	5.5		8.9	8.2	7.9
+	+	-	+	-		7.1	9.9	8.8		9.4	13.0	11.6
-	-	-	+	-		5.7	6.0	6.8		8.7	7.8	9.8
-	-	-	-	+		6.1	5.4	6.8		8.7	7.7	9.3
-	-	-	-	-	6.3	HSD (5%) = 1.5[y]			9.0	HSD (5%) = 1.6		

Source	D.F.	M.S.	F
Fungicide	2	49.25	26.53**[x]
Application	7	47.55	25.61**
FxA	14	13.15	7.08**

Source	D.F.	M.S.	F
Fungicide	2	43.75	21.41**
Application	7	50.70	24.81**
FxA	14	13.65	6.68**

[z]0, 37, 44, 86 or 93 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) significance level.

Table A9. Average size of 'Ringo Scarlet' geraniums 105 days after seeding when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Plant Height (cm)				Plant Width (cm)			
Seed	Trans-plant	1 wk after Trans-plant	7 wks after Trans-plant	8 wks after Trans-plant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-	-		11.0	13.8	10.7		15.4	16.9	15.1
+	+	-	-	-		11.5	12.4	12.4		15.5	16.0	16.1
+	+	+	-	-		11.6	13.4	12.0		15.3	16.5	15.8
-	+	-	-	-		11.5	12.8	11.9		14.6	16.1	15.5
-	-	+	-	-		12.4	12.5	12.0		15.9	14.5	15.1
+	+	-	+	-		10.8	13.0	12.5		14.2	15.8	15.8
-	-	-	+	-		11.5	12.0	12.1		15.0	15.4	15.6
-	-	-	-	+		12.7	13.5	13.5		16.0	16.5	16.0
-	-	-	-	-	12.9				16.8			

HSD (5%) = 2.5[y]

Source	D.F.	M.S.	F
Fungicide	2	25.96	9.84**[x]
Application	7	4.10	1.55
FxA	14	2.90	1.10

HSD (5%) = 2.3

Source	D.F.	M.S.	F
Fungicide	2	7.86	3.62*
Application	7	3.06	1.41
FxA	14	2.43	1.43

[z]0, 37, 44, 86 or 93 days after seeding for each respective treatment time.
[y]Application comparison within each fungicide.
[x]1% (**) or 5% (*) significance level.

Table A10. Average size of 'Ringo Scarlet' geraniums 105 days after seeding, 68 days following transplant into *Pythium*-infested medium when treated with *Pythium* controlling fungicides at selected timings.

Timings of Fungicide Application[z]					Plant Height (cm)				Plant Width (cm)			
Seed	Trans-plant	1 wk after Trans-plant	7 wks after Trans-plant	8 wks after Trans-plant	Control	Fenamino-sulf	Metalaxyl	Ethazol	Control	Fenamino-sulf	Metalaxyl	Ethazol
+	-	-	-	-		8.4	6.6	5.5		12.0	9.4	8.0
+	+	-	-	-		9.0	10.0	9.0		12.8	13.5	12.0
+	+	+	-	-		9.4	10.5	10.0		12.6	13.6	14.2
-	+	-	-	-		8.4	13.0	10.1		11.5	15.1	12.6
-	-	+	-	-		8.4	7.3	7.0		11.1	10.3	10.7
+	+	-	+	-		8.9	12.1	9.8		12.1	14.5	12.4
-	-	-	+	-		9.1	8.3	9.5		12.7	12.5	12.7
-	-	-	-	+		7.0	no sample	8.3		10.0	no sample	11.2
-	-	-	-	-	6.2	HSD (5%) = 1.9[y]			9.8	HSD (5%) = 2.0		

Source	D.F.	M.S.	F
Fungicide	2	25.36	16.67**[x]
Application	7	29.47	19.36**
FxA	13	11.11	7.30**

Source	D.F.	M.S.	F
Fungicide	2	13.44	7.80**
Application	7	28.50	16.53**
FxA	13	9.37	5.43**

[z] 0, 37, 44, 86 or 93 days after seeding for each respective treatment time.
[y] Application comparison within each fungicide.
[x] 1% (**) singificance level.

APPENDIX B

Table B1. Average size of selected geranium cultivars grown in non-infested (-P) or Pythium-infested (+P) medium.

Cultivar	Plant height (cm)[z] -P	+P	% height reduction	Plant width (cm) -P	+P	% width reduction
Jackpot	10.6	9.3**[y]	13	14.4	13.5**	6
Rosita Improved	10.9	9.2**	16	14.0	13.1**	6
Smash Hit Salmon	10.5	8.6**	18	13.9	12.0**	14
Smash Hit Rose Pink	14.2	10.5**	26	17.2	13.8**	20

Source	D.F.	M.S.	F	Source	D.F.	M.S.	F
Cv.	3	110.01	86.06**[x]	Cv.	3	85.64	55.90**
Pyt.	1	241.70	189.09*	Pyt.	1	173.19	113.06**
Cxp	3	15.64	12.23**	Cxp	3	16.16	10.55**

[z]Measurements taken 83 days after seeding and 51 days following Pythium infestation.
[y]Differences between -P and +P significant at 1% (**) or 5% (*) level based on t-test.
[x]1% (**) or 5% (*) significance level.

Table B2. Average size of selected geranium cultivars grown in non-infested (-P) or Pythium-infested (+P) medium.

Cultivar	Plant height (cm)[z] -P	+P	% height reduction	Plant width (cm) -P	+P	% width reduction
White Orbit	9.3	9.4	1	12.2	12.8	
Marathon	13.0	12.5	4	16.0	16.0	0
Snowdon	11.0	10.5	5	14.2	13.5	5
Showgirl	11.4	11.1	3	15.2	14.7	3
Red Orbit	10.5	11.0		14.7	13.7*[y]	7
Cheri Improved	10.7	9.8**	8	13.8	13.2	4
Encounter Salmon	11.5	10.8	6	15.0	14.3	5
Cameo	9.8	9.0**	8	13.3	12.6	5
Smash Hit	10.3	10.1	2	14.3	13.2	8

Source	D.F.	M.S.	F
Cv.	8	52.51	29.14**[x]
Pyt.	1	13.02	7.23**
Cxp	8	2.64	1.46

Source	D.F.	M.S.	F
Cv.	8	56.34	14.56**
Pyt.	1	29.32	7.58**
Cxp	8	2.49	.64

[z]Measurements taken 90 days after seeding and 62 days following Pythium infestation.
[y]Differences between -P and +P significant at 1% (**) or 5% (*) level based on T-test.
[x]1% (**) or 5% (*) significance level.

Table B3. Average size of selected geranium cultivars grown in non-infested (-P) or *Pythium*-infested (+P) medium.

Cultivar	Plant height (cm)[z] -P	Plant height (cm)[z] +P	% height reduction	Plant width (cm) -P	Plant width (cm) +P	% width reduction
Ringo Scarlet	10.7	10.5	2	15.3	14.1**[y]	8
Picasso	10.9	10.1	7	14.6	13.1**	10
Red Elite	9.4	8.6*	9	13.9	12.3**	12
Ringo Dolly	9.8	8.7**	11	14.0	12.2**	13
Red Pimpernel	10.3	9.3*	10	15.3	13.1**	14
Mustang	11.5	9.7**	16	16.1	13.7**	15
Ringo Salmon	9.5	8.3**	13	14.1	11.5**	18
Capri Deep Red	10.2	8.2**	20	15.4	12.0**	22
Rosita Improved	10.4	8.5**	18	15.8	12.0**	24
Jackpot	11.0	8.4**	24	16.1	12.5**	22

Source	D.F.	M.S.	F	Source	D.F.	M.S.	F
Cv.	9	22.30	12.68***[x]	Cv.	9	23.01	7.59**
Pyt.	1	181.93	103.48**	Pyt.	1	605.86	199.86**
Cxp	9	5.66	3.22**	Cxp	9	9.15	3.02**

[z]Measurements taken 100 days after seeding and 73 days following *Pythium* infestation.
[y]Differences between -P and +P significant at 1% (**) or 5 (*) level based on t-test.
[x]1% (**) or 5% (*) significance level.

Table B4. Average size of selected geranium cultivars grown in non-infested (-P) and *Pythium*-infested (+P) medium.

Cultivar	Plant height (cm)[z]			Plant width (cm)		
	-P	+P	% Reduction	-P	+P	% Reduction
Sprinter Scarlet	7.6	6.7	12 *[y]	10.3	9.3	10 NS
Heidi	8.8	7.2	18 **	12.3	10.1	18 **
Quix	6.8	5.3	22 **	10.1	8.3	18 **
Experimental Rose	8.4	6.4	24 **	12.5	9.3	26 **
Ringleader Red	7.3	5.2	29 **	11.4	8.5	25 **
Hollywood Salmon	7.5	5.5	27 **	11.1	7.8	30 **
PAC Adretta	9.6	6.9	28 **	13.5	9.4	30 **
Ringo Scarlet	10.8	7.5	31 **	14.0	9.8	30 **
Sitta	7.9	5.1	35 **	11.5	7.9	31 **
Pinwheel Salmon	9.6	6.7	30 **	13.0	8.8	32 **
Scarlet Diamong	9.1	6.0	34 **	13.7	8.6	37 **
Pink Orbit	7.0	4.9	30 **	10.4	6.5	37 **
Ringo Dolly	9.9	6.3	36 **	13.1	8.7	34 **
Cherry Diamond	8.5	5.8	32 **	12.7	7.8	39 **
Hollywood Red	7.7	4.9	36 **	10.7	6.4	40 **
Ringleader Pink	7.5	4.0	47 **	10.7	5.7	47 **
Ringleader Salmon	7.3	4.1	44 **	10.9	6.1	44 **
Appleblossom Orbit Improved	7.0	4.0	43 **	10.6	5.4	49 **

Source	D.F.	M.S.	F	Source	D.F.	M.S.	F
Cv.	17	45.76	30.92 **[x]	Cv.	17	55.21	23.77 **
Pyt.	1	1116.68	754.57 **	Pyt.	1	2431.42	1046.91 **
Cxp	17	6.19	4.19 **	Cxp	17	14.94	6.43 **

[z]Measurements taken 67 days after seeding and 37 days following *Pythium* infestation.
[y]Differences between -P and +P significant at 1% (**) or 5% (*) level based on T-test.
[x]1% (**)

Table B5. Average size of selected geranium cultivars grown in non-infested (-P) or *Pythium*-infested (+P) medium.

Cultivar	Plant Height (cm)[z]			Plant Width (cm)		
	-P	+P	% height reduction	-P	+P	% height reduction
Hollywood Salmon	8.8	7.9	10	12.4	12.1	2
Sprinter Scarlet	9.9	8.8**[y]	11	13.8	12.4**	10
Quix	7.9	7.0	11	12.0	10.8	10
Sitta	7.7	6.8	12	11.5	10.0	13
Heidi	11.2	9.6*	14	14.8	13.0*	12
Pinwheel Salmon	11.3	8.9**	21	15.2	13.6**	11
Ringo Scarlet	11.6	9.6**	17	15.7	13.5**	14
PAC Adretta	11.8	10.4	12	16.4	13.6**	17
Ringleader Salmon	9.0	6.7**	26	12.9	11.2*	13
Cherry Diamond	10.3	7.7**	25	14.8	12.3*	17
Pink Orbit	8.5	6.4**	25	12.7	10.2**	20
Scarlet Diamond	9.5	7.3**	23	14.7	11.4*	22
Experimental Rose	10.3	6.5*	37	15.0	12.0*	20
Ringo Dolly	10.9	8.0**	27	16.0	11.4**	29
Ringleader Pink	9.7	6.0**	38	14.2	9.3**	35
Hollywood Red	9.6	6.6**	31	14.0	9.6**	31
Appleblossom Orbit Improved	10.1	6.0*	41	14.1	9.0*	36
Ringleader Red	10.9	6.2**	43	16.0	8.2**	49

Source	D.F.	M.S.	F[x]
Cv.	17	27.57	15.77**
Pyt.	1	382.03	218.58**
Cxp	17	5.56	3.18**

Source	D.F.	M.S.	F
Cv.	17	31.51	10.52**
Pyt.	1	591.56	197.48**
Cxp	17	15.29	5.11**

[z] Measurements taken 103 days after seeding and 73 days following *Pythium* infestation.
[y] Differences between -P and +P significant at 1% (**) or 5% (*) level based on t-test.
[x] 1% (**) or 5% (*) significance level.