pleted, the crop coefficients used in the USDA irrigation scheduling program were revised. This was done by trial and error, until resimulations with 1987 weather data showed that the program would predict an irrigation regime similar to that applied to T, in 1987. An equation for computing these revised coefficients is given in Table 4 and the revised coefficients are shown in Figs. 1 and 2. Note that the revised coefficients would indicate early season K_{co} values < 0.30. However, a statement in the scheduling program specifies 0.30 as the minimum value of K_{co} . With the revised coefficients, it is also necessary to assume that the root-zone depth increases linearly from 30 cm at planting to 60 cm at effective cover and it is necessary to specify irrigations when 40% of the available soil water in the root zone is depleted.

Use of the revised coefficients in 1986 would have closely duplicated T₂, the treatment that produced a high yield and the best WUE. In 1985, the revised coefficients would have given an irrigation regime similar to T₄, which produced the highest, although not statistically significant, yield and WUE. Table 5 lists the number of irrigations and depth of water applied to the best treatment in each of the 3 years, and, for comparison, the same data if the revised crop coefficients and rooting assumptions had been used. We can conclude that the revised coefficients would have produced the best irrigation scheduling results for all 3 years of our study.

We recommend an irrigation scheduling program based on the revised coefficients (Table 4) for carrots in northern Colorado and similar climates to obtain the best combination of high yields and water use efficiency with a minimal number of irrigations. The irrigation scheduling program is available from E. G. K., J. E. E., and A.E.M. for use on IBM-compatible microcomputers.

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Size and Flowering of Seed-propagated Geraniums in Response to Fungicide Drenching Schedules

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Abstract. Two fungicides registered for the control of *Pythium* spp. were evaluated for their effects on size and time to flowering of seed-propagated geraniums (*Pelargonium × hortorum* L.H. Bailey). Fungicide drenches of fenaminosulf and metalaxyl were applied to geraniums grown in soilless root medium: 1) at seeding (S); 2) at seeding and transplanting (ST); 3) at seeding, transplanting, and 1 week after transplanting (ST + 1); 4) at transplanting (T); and 5) 1 week after transplanting (T + 1). Metalaxyl drenching schedules did not significantly influence plant size or time to flowering. Fenaminosulf drenching schedules 3 and 4 significantly reduced plant size, and drenching schedule 3 significantly increased days to flowering in comparison to control plants. Although fenaminosulf is used infrequently because of limited availability, the detrimental effects of this fungicide on plant size and time to flowering warrant similar investigations with additional fungicides and crops. Chemical names used: sodium[4-(dimethylamino) phenyl]diazenesulfonate (fenaminosulf); N-(2,6-dimethylphenyl) -N-(methoxyacetyl) -DL-alanine methyl ester (metalaxyl).

Pythium spp. are important and often devastating pathogens of seed-propagated geraniums. Root rot and lower stem rot of young and mature geraniums caused by *Pythium ultimum* Trow can be a common occurrence among certain cultivars, causing considerable plant loss (Hausbeck et al., 1987; Powell, 1982). Less severe root rot may result in plant stunting and delay of flowering that may go unnoticed if silver thiosulfate (STS), a petal-shattering preventative, is not applied (Hausbeck et al., 1989a). Silver thiosulfate application to seed-propagated geraniums infected with even low levels of *P. ultimum* increases the incidence of plant death caused by pythium lower stem rot (Hausbeck et al., 1989b).

Current control practices for pythium root rot and lower stem rot of seed-propagated geraniums include sanitation and application of fungicides. *Pythium* spp. have been reduced or eliminated before planting by heating or fumigating of soil. Reintroduction of the pathogen into greenhouses may occur through water supply sources or irrigation ponds (Bewley and Buddin, 1921; Gill, 1970). Also, *Pythium*-infested soil particles from greenhouse walkways, floors, and beds

serve as inoculum that may be unknowingly transported throughout production areas by greenhouse personnel (Stephens et al., 1983; Stephens and Powell, 1982).

Several fungicides are recommended for control of diseases caused by *Pythium* spp. on seed-propagated geraniums (Powell, 1982; Stephens, 1984). Preventive fungicide treatment is warranted for production systems using STS but invariably involves fungicide applications to plants not infected with the targeted pathogen. The effects of such drenches on plant growth and time to flowering are seldom considered in disease management strategies, primarily due to lack of information. The objective of this study was to determine the effects of two fungicides registered to control *Pythium* spp. on the size and time to flowering of seed-propagated geraniums.

The fungicides fenaminosulf, 0.43 g a.i./liter (Lesan 35% WP, Mobay Chemical Corp., Kansas City, Me.), and metalaxyl, 0.101 g a.i./liter (Subdue 2E, 25% emulsifiable concentrate, Ciba-Geigy, Greensboro, N. C.) were used in this study. Fungicide drenches were applied to plants grown in soilless root medium according to the following drenching schedules: 1) at seeding (S); 2) at seeding and transplanting (ST); 3) at seeding, transplanting, and 1 week after transplanting (ST + 1); 4) at transplanting (T); and 5) 1 week after transplanting (T + 1). These drenching schedules encompass preventive control strategies that might be used by greenhouse operators and include those effective in controlling root rot and lower stem rot caused by *P. ultimum* (Hausbeck et al., 1988).

Geranium seeds (cultivar Ringo Scarlet) obtained from Sluis and Groot B. V., Enkhuizen, The Netherlands, were individually sown in round 2.0-cm-diameter cells (6.3 cm³)

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Table 1. Relative plant size of geraniums treated with fungicide drenches.

Drenching schedule	Plant size relative to control (%) ^a			
	Expt. 1		Expt. 2	
	Fenaminosulf	Metalaxyl	Fenaminosulf	Metalaxyl
Seeding	106	142	82	113
Seeding and transplanting	84	74	77	97
Seeding, transplanting, and 1 week after transplanting	35*	115	71*	118
Transplanting 1 week after transplanting	27*	118	70*	102
Control ^b	125	80	85	110
HSD (0.05)	46	100	25	

^aControl plants receiving no fungicide were 281 cm³ in size (HSD = 130) 21 days after transplanting and 1706 cm³ (HSD = 427) 47 days after transplanting for Expt. 1 and 2, respectively.

*Treatments significantly different at $P = 0.05$ according to HSD comparison between plants treated with fungicide and the control.

Table 2. Difference in days to flowering between geraniums treated with fungicide drenches and the control.

Drenching schedule	Difference in time of flowering (days)			
	Expt. 1		Expt. 2	
	Fenaminosulf	Metalaxyl	Fenaminosulf	Metalaxyl
Seeding	+ 9.4	+ 6.1	+1.4	+ 0.4
Seeding and transplanting	+ 7.1	+3.4	+4.9	-1.1
Seeding, transplanting, and 1 week after transplanting	+ 17.8*	+ 4.2	+7.6*	-0.7
Transplanting 1 week after transplanting	+13.1*	+ 3.3	+2.2	0
Control ^b	+3.4	+ 6.4	-4.7	+1.1
HSD (0.05)	12.1	0	5.1	

^aControl plants flowered in 123 days and 94.4 days for Expts. 1 and 2, respectively.

*Treatments significantly different at $P = 0.05$ according to HSD comparison between plants treated with fungicide and the control.

containing soilless root medium (Sunshine Media Mix, Blend 1, Fisons-Western Corp., Vancouver, B. C., Canada) containing 2 vermiculite : 2 sphagnum peat : 1 perlite (by volume). The seeds were then covered with ≈ 0.5 cm fine vermiculite and placed under intermittent mist at $24 \pm 2^\circ\text{C}$ in a glass greenhouse. Seedlings were removed from the mist after germination (7 days) and grown at $21/24/26^\circ\text{C}$ (night/day/vent temperatures) under natural light in a glass greenhouse until transplanting (30 days).

Two experiments were conducted for this study. An entire 2-cm soilless medium plug was transplanted into $8 \times 8 \times 6$ cm (384 cm³) single cells of 18 pack flats for the first experiment or 10-cm (0.450-liter) plastic pots for the second experiment. Eight single cells or pots were used per treatment with one plant per cell or pot. Treatments were completely randomized on greenhouse benches constructed of 14.0-cm-wide wooden planks spaced 4.0 cm apart. During the experiments, 'medium pH varied between 5.5 to 6.5. Plants were fertilized at each watering with 14.3 mM N and 5.1 mM K. Foliar applications of 4.7 mM (2-chloroethyl)-trimethylammonium chloride (chlormequat) were applied to all treatments, including the control, for height control as growth necessitated.

Greenhouse setpoints following transplanting were $20/22/24^\circ\text{C}$. Environmental information collected with a computerized greenhouse environmental control system showed that, during Expt. 1 (initiated 20 Sept.), natural irradiance levels decreased rapidly as Michigan experienced extended periods of cloudy weather. Greenhouse temperatures were easily controlled during the day and typically fluctuated less than 3°C above the 22°C setpoint within and among days. In contrast, plants in Expt. 2 (initiated 3 Apr.) were exposed to rising natural irradiance levels and rising outside temperatures. Plants were exposed to more-widely fluctuating temperatures (up to 15°C) within and among days.

Plant height and width were recorded 21 days after transplanting for Expt. 1. Due to small containers and pot-to-pot spacing in Expt. 1, plant size measurements were taken before possible effects of overcrowding on plant size. Measurements for Expt. 2 were taken 47 days after transplanting. Plant volume (size) was calculated from plant height and canopy width measurements by assuming the volume occupied by the plant was a cylinder. Number of days from seeding to first floret opening also was recorded. Data were tested via analysis of variance with a protocol of the Statistical Analysis System

(SAS, 1985). An honestly significant difference (HSD) test was used to establish significance on the plant size and days to flowering data (Steel and Torrie, 1980).

Results from both experiments demonstrated that plant size (Table 1) and days to flowering (Table 2) of plants treated with metalaxyl were not significantly different from plants not treated with a fungicide (control). In contrast, fenaminosulf drenching schedules ST + 1 and T significantly reduced plant growth, compared to control plants in both experiments (Table 1). A significant delay in flowering resulted from fenaminosulf drenching schedule ST + 1 in both experiments (Table 2). A significant delay in flowering was also observed in Expt. 1 among plants treated with fenaminosulf drenching schedule T.

Results suggest fenaminosulf maybe phytotoxic during specific plant growth stages. Fenaminosulf drenching schedule ST + 1 consistently reduced plant size and increased the number of days to flowering. In contrast, Manning et al. (1969) showed that three drenches of fenaminosulf made at 10-day intervals to established poinsettia plants did not result in phytotoxicity. The fungicide drenching schedules used in this study coincided with expected root initiation and root growth following seed germination and seedling transplanting. An application of fenaminosulf at transplanting only resulted in significantly reduced plant growth in both experiments and delayed flowering in Expt. 1. A fenaminosulf drench applied at transplanting was the common denominator in the two fenaminosulf drenching schedules that adversely affected plant size and time to flowering in both experiments.

Previous reports on the effects of fungicides on plant rooting are conflicting. Boodley (1968) reported that fresh weight, root length, and root grade were all reduced when fenaminosulf was applied at recommended rates to poinsettia cultivars Barbara Ecker Supreme and Paul Mikkelsen 2 days following cutting propagation in 2 peat : 1 vermiculite : 1 perlite. Lee et al. (1983) observed that metalaxyl and fenaminosulf applied as dips to polyurethane propagation cubes before propagation of poinsettia cultivar Annette Hegg Lady cuttings decreased rooting. Treatments containing fenaminosulf decreased rooting most, while treatments containing metalaxyl decreased rooting least. Moorman (1983), however, found that these same fungicides used as a pretreatment neither enhanced nor decreased root initiation of florists, zonal, or ivy geranium cuttings propagated in 1 peat : 1 perlite. Kuack et al. (1981) also reported no phytotoxicity when five fungicides, including fenaminosulf, were applied to poinsettia (cultivar Annette Hegg Dark Red) cuttings immediately after placement in 2 soil : 1 sphagnum peat : 1 perlite.

Data from this study indicate that early grower reports (C. T. S., personal observation) of metalaxyl toxicity are unfounded if the fungicide is used at the correct rate. Although repeated drenches of metalaxyl did

not adversely affect plant size or time to flowering, applications of this fungicide should be made in rotation with other fungicides to avoid selection and build-up of fungicide-resistant pathogen populations.

In addition, this study effectively identified fenaminosulf fungicide drenching schedules that consistently reduced plant size and delayed time to flowering among seed-propagated geraniums. Although only existing supplies of fenaminosulf are still available to growers, it is important for them to recognize that an alternate product, such as metalaxyl, can not only be more effective (Hausbeck et al., 1988) but also less phytotoxic. Further, the inclusion of fenaminosulf in this study has shown that fungicide drenches applied to healthy geraniums may "cost" a grower in terms of reduced plant size and delayed time to flowering. Also, results suggest specific plant growth stages may be particularly sensitive to fungicide drenches. Based on this study, similar investigations conducted with additional fungicides and crops appear to be warranted. This information is necessary to make recommendations concerning fungicide usage complete.

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Influence of Photoperiod and Temperature on the Growth and Flowering of *Heliconia aurantiaca*

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Abstract. The effect of photoperiod (8, 12, or 16 hr) and temperature (15, 18, or 21C) on *Heliconia aurantiaca* Ghiesbr. ex. Lemaire was investigated. By exposing plants to a photoperiod of 8 hr, flowering was more advanced and more abundant, fewer leaves subtended the inflorescence, and the length of the flowering stems was shorter than at 16 hr. Raising the temperature from 15 to 21C increased the flowering percentage by $\approx 20\%$; the flowering stems were 40 cm longer and the number of leaves subtending the inflorescence was increased by 2.5.

There is an increasing interest in *Heliconias* as cut flowers, landscaping plants for tropical regions, interior plants, and pot plants. Many species are very showy and have colorful inflorescences, but most are seasonal bloomers and produce few flowers.

Until now, very little has been known about manipulation of flowering in *Heliconia*. In *H. psittacorum* it has been reported that the main factors influencing flowering are irradiance and temperature (Broschat et al., 1984), but photoperiod also appears to have a slight influence (Geertsen, 1989).

In *H. stricta*, a seasonal pattern of flowering has been recorded. Yields were greater for plants grown at 8-hr photoperiods than under natural daylength (Criley and Kawabata, 1986). No flowering occurred in long days.

For *H. aurantiaca* it has been observed that under glasshouse conditions in Denmark flowering only occurs during November to February. This pattern suggests that flowering might be influenced by photoperiod. Since *H. aurantiaca* is an attractive plant

that shows potential as a cut flower, particularly if flowering could be extended to a greater part of the year, the present experiment was set up to examine how photoperiod and temperature affect growth and flowering.

The experiment was carried out with *H. aurantiaca* that originally was obtained from the Botanical Garden in Edinburgh. Rhizome clumps with about three shoots (shoot length < 10 cm, no unfolded leaves) were planted in 10-liter containers in February 1986. The potting medium was a well-drained Danish peat (Pindstrup 3). Until the start of the experiment on 10 Apr., plants were receiving natural daylength that varied from 10.5 to 14.5 hr, including civil twilight. The temperature was maintained at 20C.

The experiment was carried out in the phytotron at the Institute of Glasshouse Crops. Plants were exposed to photoperiods of 8, 12, or 16 hr combined with a minimum air temperature of 15, 18, or 21C (ventilation at + 3C). The photoperiod treatments consisted of an 8-hr natural day in the glasshouse compartment plus day continuation by incandescent light in the dark chamber at a photon flux density of $3.5 \pm 1.9 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ to equal 12 or 16 hr. The actual average day temperatures in the glasshouse compartment were 20, 22, and 23C, respectively.

Each treatment consisted of nine plants that were spaced 14 plants/m². Treatments were terminated on 23 Oct.; from then on, plants were placed under natural daylength, which, in Denmark, is ≈ 12 hr at the end of October, dropping to 8.5 hr in midwinter, including