# Ornamentals Section

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## IMPACT OF SOILBORNE PEST PROBLEMS ON FIELD-GROWN SNAPDRAGON

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*Abstract.* **Effect of several soil fumigants on snapdragon (*Antirrhinum majus* L.) production were evaluated in a commercial site in southeast Florida in 2003-04. Treatments consisted of methyl bromide (98%) + chloropicrin (2%), metam sodium, metam sodium + chloropicrin, solarization, and a nontreated control. All fumigant treatments and solarization initially reduced (P < 0.05) weed populations compared to the nontreated control. Stubby-root nematode (*Paratrichodorus* spp.) numbers were reduced initially by methyl bromide + chloropicrin and by metam sodium + chloropicrin, but numbers resurged in solarized and fumigated plots after 4 months. Plant heights and flower yields were greater (P < 0.05) in fumigated or solarized plots than in control plots. Early in the experiment, rain washed soil from an untreated border area into the experimental plots, and as a result, many plants became infected by a pathogen tentatively identified as *Fusarium* spp., which caused crown and stem rot symptoms. Losses in fumigated or solarized plots averaged 34.1%, whereas losses in nontreated control plots averaged 67.3%. These results illustrate the magnitude at losses that can occur if soilborne problems are not managed in cut flower production, as well as the potential for crop infection from untreated areas bordering the production site.**

Florida ranks second among U.S. states in production of cut flowers, with a production value of $24.7 million in 2002 (Florida Agricultural Statistics Service, 2003). Floral crops may be produced in containers, but many cut flowers are grown in the field (McSorley and Wang, 2002). While field production is economical, crops may be exposed to nematodes, weeds, and soilborne plant pathogens. As with other crops, soilborne pest problems on cut flowers are currently managed by fumigation with methyl bromide, a material that is facing restrictions and phase-out (McMillan and Bryan, 2001; Obenauf, 2002). Much work on chemical alternatives to methyl bromide has been conducted on vegetable crops (Obenauf, 2002), but the need for alternatives on cut flowers and other ornamental crops is critical as well (Gilreath et al., 1999; McSorley and Wang, 2002).

In 2002-03, a field experiment was conducted to compare the performance of several soil fumigants in commercial snapdragon (*Antirrhinum majus* L.) production (McSorley et al., 2004). Metam sodium alone and metam sodium + chloropicrin compared favorably with methyl bromide + chloropicrin, with respect to flower yield and management of weeds and plant-parasitic nematodes. However, pest pressure at the site was relatively light, and so further evaluation under more severe soilborne pest pressure was desirable. In addition, we hypothesized that the clear plastic tarp used to seal in soil fumigants may provide pest management benefits on its own, through the process of solarization. Soil solarization is the heating of soil beneath a layer of clear plastic to temperatures lethal to soilborne pests, a process that has been widely used against plant-parasitic nematodes, soilborne plant pathogens, and weeds (McGovern and McSorley, 1997). The method has been used successfully in Florida for managing soilborne pest and disease problems on ornamentals such as impatiens (*Impatiens* × *wallerana*) and vinca (*Catharanthus roseus* (L.) Don) (McGovern et al., 2002; McSorley and McGovern, 2000). The objective of the research presented here was to evaluate the efficacy of solarization and several common soil fumigant alternatives to methyl bromide for managing plant-parasitic nematodes and weeds in commercial production of snapdragon.

### Materials and Methods

A field experiment was conducted at a commercial cut flower production site in Martin County, Fla., during 2003-04. Soil at this site consisted of 96% sand, 1% silt, and 3% clay. Five treatments were established in a randomized complete block design with four replications: methyl bromide + chloropicrin, metam sodium, metam sodium + chloropicrin, solarization, and nontreated control. The field was the site of a similar experiment in 2002-03 (McSorley et al., 2004), so each of the treatments (except solarization) was established in a plot that received an identical treatment in the previous year. Plots that were solarized had been treated with methyl bromide + chloropicrin in the 2002-03 season. Individual plots were 3.2 m wide × 13.7 m long (10.5 ft × 45 ft). Methyl bromide (98%) + chloropicrin (2%) was injected over each appropriate plot at a broadcast rate of 504 kg $ha^{-1}$ (450 lbs/acre). Metam sodium was drenched on the soil surface at 701 L $ha^{-1}$ (75 gal/acre) and rototilled to a depth of 20-30 cm (8-12 in). In plots with the metam + chloropicrin treatment, chloropicrin was injected at a broadcast rate of 168 kg $ha^{-1}$ (150 lbs/acre) immediately after the metam sodium was rototilled. All treatments were applied by a commercial applicator (Hendrix and Dail, Inc., Palmetto, Fla.) on 20 Aug. 2003. Immediately after treatment applications, all plots (except controls) were covered with clear plastic sheeting, which

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remained in place until 30 Sept. Plots that received a clear plastic cover but no soil fumigant were considered to be solarized. Control plots received no fumigants or plastic.

Following removal of plastic, two beds, with centers 1.5 m (5 ft) apart, were formed within each plot. Plugs with small (1-2 cm tall) snapdragon seedlings were planted at a rate of 120 plants per 1.0 m of bed on 15-16 Oct. (replications 1-2) and 17-20 Oct. (replications 3-4). Several different cultivars of snapdragon were used, typical of commercial production practices to provide a range of colors and maturity. Replication 1 was planted with 'Pot Ivory', replication 2 with 'Pot Rose' and 'Pot Light Rose', replication 3 with 'Pot Pink', and replication 4 with 'Pot Rose' and 'Pot Dark Orange'. The crop was fertilized, irrigated, and maintained according to standard grower practices. Snapdragons were harvested as cut flowers during December and January by cutting stems at about 3-5 cm (1-2 in) above ground level at peak bloom.

A section of one bed, 7.6 m (25 ft) long, was used for data collected within each plot. Soil samples for nematode analysis were collected prior to treatment and four times during the growing season. On each sampling date, a single soil sample consisting of 6 soil cores (2.5 cm [1 in] diameter × 20 cm [8 in] deep) was collected from each plot. In the laboratory, nematodes were extracted from a 100-$cm^3$ (0.2 pt) soil subsample using a standard sieving and centrifugal flotation procedure (Jenkins, 1964). Plant-parasitic nematodes extracted were identified and counted. On 2 Oct. and 20 Nov., all weeds were counted in a 1-$m^2$ quadrat from each plot. The percent of ground covered by weeds within the quadrant was estimated using the rating scale of Horsfall and Barratt (1945) where 1 = 0%, 2 = 0-3%, 3 = 3-6%, 4 = 6-12%, 5 = 12-25%, 6 = 25-50%, 7 = 50-75%, 8 = 75-88%, 9 = 88-94%, 10 = 94-97%, 11 = 97-100%, 12 = 100% of ground covered. Weeds were removed by the grower following each evaluation date. On 20 Nov., the percent of dead plants in each plot was rated using the Horsfall and Barratt (1945) scale. Data on heights of 10 plants per plot were collected on 17 Dec. On 13 Jan., the amount of flowers harvested per 1.0 m of bed from each plot was determined by summing the number of plants cut for harvest, the number of plants blooming, and the number of plants with mature flower buds.

Nematode data, weed data, and yield data were assessed by analysis of variance (ANOVA) followed by mean separation using Duncan's new multiple range test (Freed et al., 1991). Nematode data were transformed by $\log_{10}(x+1)$ prior to ANOVA, but only untransformed data are presented. Because different cultivars were used, it was not possible to directly analyze plant height data across the entire experiment. Heights of 10 plants from each treatment with the same cultivar and replication were compared directly by ANOVA. In this way, some limited but direct comparisons were possible among heights of plants in control plots and those in plots with various treatments. To analyze plant height data across the entire experiment, plant heights in treated plots were standardized relative to nontreated controls of the same cultivar by the formula:

(Height in treated - height in control) / (height in control) × 100 = % growth relative to control (control is 100%)

Data for these standardized plant heights were then compared among treatments by ANOVA.

Table 1. Effect of soil fumigation treatments and solarization on weeds in snapdragon test, 2 October 2003.

| | Weeds per $m^2$ | | | |
|---|---|---|---|---|
| Treatment | Pigweed | Goosegrass | Crabgrass | Total weeds |
| Methyl bromide + CP[z] | 0.0 b[y] | 0.0 b | 0.0 b | 0.0 b |
| Metam sodium | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Metam sodium + CP | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Solarization | 0.0 b | 0.0 b | 0.0 b | 0.0 b |
| Control | 20.2 a | 54.5 a | 5.0 a | 79.8 a |

[z]CP = chloropicrin.
[y]Data are means of 4 replications. Means in columns followed by the same letter are not different (P < 0.05) according to Duncan's new multiple range test.

## Results and Discussion

Pigweed (*Amaranthus* spp.), goosegrass (*Eleusine indica* [L.] Pers.), crabgrass (*Digitaria* spp.), and Carolina geranium (*Geranium carolinianum* L.) were common in this site, but purslane (*Portulaca oleracea* L.), nutsedge (*Cyperus* spp.), nightshade (*Solanum* spp.), bermudagrass (*Cynodon dactylon* [L.] Pers.), and spurge (*Chamaesyce* spp.) were found as well. All of the fumigant treatments and solarization were effective in preventing weed emergence and development on 2 Oct. (Table 1). There were no differences among the fumigant treatments and solarization in weed suppression. However, weed populations in control plots were extremely high, therefore, all weeds were manually removed by the grower after evaluation so that a future crop could be grown in the control plots.

Following removal of the plastic on 30 Sept., but before beds were formed in early October, heavy rains washed surface soil from an untreated border area on to many of the plots. This event likely aided in the distribution of weed seeds across the experimental area, and as a result, weed growth was apparent in all plots, including fumigated plots, in November (Table 2). These weeds had emerged recently, since all older weed growth was removed in October. Carolina geranium was a common winter annual in November that had not emerged in October. Although the percentage of ground area covered by weeds was high in control plots and zero in treated plots in October, moderate levels of weeds had covered all plots by late November (Table 3). Weeds were manually removed from plots after 20 Nov. to reduce interference with crop growth.

Table 2. Effect of soil fumigation and solarization treatments on weeds in snapdragon test, 20 November 2003.

| | Weeds per $m^2$ | | | |
|---|---|---|---|---|
| Treatment | Pigweed | Goosegrass | Carolina Geranium | Total weeds |
| Methyl bromide + CP[z] | 0.8 a[y] | 2.2 b | 4.2 a | 9.0 a |
| Metam sodium | 2.5 a | 0.8 b | 6.0 a | 10.2 a |
| Metam sodium + CP | 3.0 a | 5.5 ab | 3.8 a | 15.0 a |
| Solarization | 6.2 a | 6.8 ab | 4.5 a | 19.2 a |
| Control | 8.2 a | 10.5 a | 3.2 a | 23.5 a |

[z]CP = chloropicrin.
[y]Data are means of 4 replications. Means in columns followed by the same letter are not different (P < 0.10) according to Duncan's new multiple range test.

Table 3. Horsfall-Barratt rating[z] of percent of ground covered by weeds or percent of plants dead.

| Treatment | Weed rating 2 Oct. | Weed rating 20 Nov. | Dead plants 20 Nov. |
|---|---|---|---|
| Methyl bromide + CP[y] | 1.0 b[x] | 3.1 a | 6.4 a |
| Metam sodium | 1.0 b | 3.0 a | 4.8 a |
| Metam sodium + CP | 1.0 b | 3.4 a | 4.9 a |
| Solarization | 1.0 b | 3.6 a | 6.5 a |
| Control | 7.5 a | 4.1 a | 7.4 a |

[z]Rated on 1 to 12 scale for percent ground covered by weeds or percent of plants dead, where 1 = 0%, 2 = 0-3%, 3 = 3-6%, 4 = 6-12%, 5 = 12-25%, 6 = 25-50%, 7 = 50-75%, 8 = 75-88%, 9 = 88-94%, 10 = 94-97%, 11 = 97-100%, 12 = 100% of plants dead (or 100% ground covered).
[y]CP = chloropicrin.
[x]Data are means of 4 replications. Means in columns followed by the same letter are not different (P < 0.05) according to Duncan's new multiple range test.

Table 4. Effect of location in field (replication) on weeds and dead plants, 20 November, 2003.

| Replication number[z] | Total weeds per m$^2$ | Horsfall-Barratt rating (1-12 scale)[y] | |
|---|---|---|---|
| | | Weed coverage | Dead plants |
| 1 | 6.0 c[x] | 2.1 c | 4.6 b |
| 2 | 10.8 bc | 2.2 c | 2.4 b |
| 3 | 18.6 ab | 4.2 b | 8.2 a |
| 4 | 26.2 a | 5.2 a | 8.8 a |

[z]Replication number represents location in field.
[y]Rated on 1 to 12 scale for percent ground covered by weeds or percent plants dead, where 1 = 0%, 2 = 0-3%, 3 = 3-6%, 4 = 6-12%, 5 = 12-25%, 6 = 25-50%, 7 = 50-75%, 8 = 75-88%, 9 = 88-94%, 10 = 94-97%, 11 = 97-100%, 12 = 100% of ground covered (or plants dead).
[x]Data are means of 5 observations (treatment values) for each replication. Means in columns followed by the same letter are not different (P < 0.01) according to Duncan's new multiple range test.

By 20 Nov., many snapdragon plants were dead or showing symptoms of a severe disease affecting vascular tissue in the crown and lower stem region of the plants. Plant samples were collected and plated on potato dextrose agar at the U.S. Horticultural Research Laboratory. Fungal cultures were then transferred to Komada's media and tentatively identified as *Fusarium* spp. Dead plants occurred in all plots, with no differences among treatments (Table 3). The flooding that occurred in early October appeared to be more severe in the area of the site that contained replications 3-4 than in the area that contained replications 1-2. Analysis of weed and crop loss data by replication revealed greater (P < 0.05) levels of weeds and dead plants in replications 3-4 than in replications 1-2 (Table 4). These data are consistent with observations on water movement and support the hypothesis that contaminants such as weed seeds and plant pathogens were washed on to the site from an untreated border area. The incidence of dead plants in replications 3-4 was very high, approaching 90% (Table 4), therefore plots in these replications were destroyed in November. Incidence of dead plants in replications 1-2 was ca. 15-20% in November (Table 4) and did not change during December and January.

Initially (19 Aug.), stubby-root nematodes (*Paratrichodorus* spp.) were present in the site at a mean density of 40.5/100 cm$^3$ soil. In October, numbers of stubby-root nematodes in plots treated with methyl bromide + chloropicrin or metam + chloropicrin were lower (P < 0.05) than those in solarized plots (Table 5). However by late November, stubby-root nematodes had resurged in many of the treated plots, with lowest numbers in untreated control plots (Table 5). The rapid resurgence of stubby-root nematodes following soil fumigation has been well-known for some time (Weingartner et al., 1983), and resurgence of this nematode after solarization has occurred consistently as well (McSorley et al., 1999; McSorley and McGovern, 2000). High population levels of stubby-root nematodes remained through December and January (Table 5), although no differences among treatments were evident at these times (only two replications remained). Root-knot nematode (*Meloidogyne* spp.) juveniles were found in soil in December, but not in January.

Overall, heights of plants in treated plots ranged from 22 to 41% greater than in control plots, but did not differ among fumigant and solarization treatments (Table 6). When plant height data were examined by cultivar, plants from untreated control plots were always the smallest (P < 0.05) among treatments (Table 6). Plants from solarized plots were shorter than those from the best fumigant treatment (Table 6).

Despite the fact that only two replications were harvested, cut flower yield was significantly (P < 0.05) affected by treatment (Table 7). Three of the four treatments resulted in flower yields that were more than twice the level obtained in untreated control plots. Yield in plots treated with methyl bromide + chloropicrin was intermediate, not because the fumigation was ineffective (see Table 1), but because plots became infested after fumigation with a *Fusarium* spp. that caused severe crown and stem rot. Losses at harvest resulted from

Table 5. Effect of soil fumigation and solarization on nematodes in snapdragon test, 2003-04.

| Treatment | Nematodes per 100 cm$^3$ soil | | | | |
|---|---|---|---|---|---|
| | Stubby-root | | | | Root-knot |
| | 2 Oct. | 20 Nov. | 17 Dec. | 13 Jan. | 17 Dec. |
| Methyl bromide + CP[z] | 0.0 b[y] | 12.8 a | 133.0 a | 112.0 a | 3.0 a |
| Metam sodium | 3.5 ab | 23.0 a | 69.0 a | 66.0 a | 0.0 a |
| Metam sodium + CP | 1.8 b | 12.2 ab | 5.5 a | 38.0 a | 0.0 a |
| Solarization | 16.8 a | 40.2 a | 131.5 a | 17.0 a | 0.0 a |
| Control | 9.2 ab | 0.5 b | 6.0 a | 63.5 a | 140.5 a |

[z]CP = chloropicrin.
[y]Data are untransformed arithmetic means of 4 (Oct., Nov.) or 2 (Dec., Jan.) replications. Means in columns followed by the same letter are not different (P < 0.05) according to Duncan's new multiple range test performed on log-transformed data.

Table 6. Effect of soil fumigation and solarization on plant heights of snapdragon cultivars, 17 December 2003.

| Treatment | Plant height (cm)[z] | | | Height as % of Control[y] |
|---|---|---|---|---|
| | Pot Ivory | Pot Rose | Pot Light Rose | |
| Methyl bromide + CP[x] | 67.4 ab | —[w] | 69.7 a | 134 a |
| Metam sodium | 75.0 a | 83.2 a | — | 141 a |
| Metam sodium + CP | 73.7 ab | 71.4 b | — | 130 a |
| Solarization | 65.7 b | — | 60.5 b | 122 a |
| Control | 54.1 c | 58.2 c | 48.8 c | — |

[z]Data are means of 10 plant measurements. Means in columns followed by the same letter are not different ($P < 0.05$) according to Duncan's new multiple range test.
[y]Computed as (height of plants in treated plot - height of plants in control plot) / (height of plants in control plot) × 100%. Data are means of 2 replications.
[x]CP = chloropicrin.
[w]— indicates no data.

plants that had died and plants that were too small and stunted to provide flowers in December and January. These losses were substantial, averaging 67.3% in control plots and 34.1% across all fumigated and solarized plots (Table 7). In contrast, losses from fumigated plots in the previous season (2002-03), when plants were not affected by *Fusarium* spp., averaged only 2.1% (McSorley et al., 2004).

Results from the current experiment emphasize the need for management of soilborne pest problems in field-grown cut flower production. Two replications in the experiment were lost to the Fusarium crown and stem rot, and in the two remaining replications, only 32.7% of the plants in untreated plots were harvested. This level of yield was achieved only because weeds were manually removed from the control plots. Nevertheless, the data illustrate the magnitude of losses that can occur without soilborne pest management. Furthermore, results indicate that management of the planted site itself is insufficient; untreated border areas that can be sources of pathogens, weeds, and other pests must be managed as well.

Under the conditions of this test, it was difficult to distinguish among the relative performances of the three fumigant and solarization treatments. While heights of snapdragon plants in solarized plots were less than those in some fumigated plots, solarization performed as well as the fumigants in terms of weed suppression and flower yields. This solarization was achieved by leaving a clear plastic tarp (normally used to cover site after fumigation) in place for 6 weeks. Although fumigant treatments were covered by clear plastic tarp during this time period as well, the clear plastic tarp alone (solarization) provided benefits in pest management that were similar to the fumigation treatments. In a previous season, this clear plastic tarp treatment was used as a "control" treatment, and resulted in harvest losses of 8.7% compared to losses of 2.1% from fumigated plots (McSorley et al., 2003). However in that case, the plastic tarp remained in place for only 2 weeks. Results with the 6-week solarization were more encouraging, but further research is needed to more clearly evaluate its performance relative to methyl bromide and other soil fumigants.

Table 7. Effect of soil fumigation and solarization on snapdragon yield, 13 January 2004.

| Treatment | Harvested plants per m of row | Missing plants per m of row | % loss[z] |
|---|---|---|---|
| Methyl bromide + CP[y] | 62.0 bc[x] | 58.0 ab | 48.3 |
| Metam sodium | 84.6 ab | 35.4 bc | 29.5 |
| Metam sodium + CP | 92.3 a | 27.7 c | 23.1 |
| Solarization | 77.4 ab | 42.6 bc | 35.5 |
| Control | 39.2 c | 80.8 a | 67.3 |

[z]Based on 120 plants per m.
[y]CP = chloropicrin.
[x]Data are means of 2 replications. Means in columns followed by the same letter are not different ($P < 0.05$) according to Duncan's new multiple range test.


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