SHORT COMMUNICATION

SOLARIZATION AND BIOFUMIGATION REDUCE *PYTHIUM APHANIDERMATUM* INDUCED DAMPING-OFF AND ENHANCE VEGETATIVE GROWTH OF GREENHOUSE CUCUMBER IN OMAN

M. Deadman[1], H. Al Hasani[2] and A. Al Sa'di[1]

[1] *Department of Crop Sciences, Sultan Qaboos University, P.O. Box 34, Al Khod 123, Sultanate of Oman*
[2] *Ministry of Agriculture and Fisheries, P.O. Box 50, Rumais 121, Sultanate of Oman*

SUMMARY

Damping-off disease, caused by *Pythium aphanidermatum* is a major constraint in the greenhouse crop sector in Oman. Current commercial management practice relies almost exclusively on excessive chemical fungicide inputs. Under commercial conditions solarization and biofumigation (solarization following organic amendment of soil) both reduced *P. aphanidermatum* inoculum levels in soil relative to untreated controls. Both treatments also reduced the level of damping-off disease in greenhouse seedlings.

Biofumigation and solarization both enhanced crop growth as measured by stem height and stem diameter. Effects on pathogen population levels, disease incidence and plant growth were greater during summer growing seasons than during the winter.

Key words: Biofumigation, solarization, damping-off, *Pythium aphanidermatum*, cucumber, greenhouse.

Greenhouse cucumber production in Oman has increased dramatically over the last 5 years with growers cultivating 3 cucumber crops per year. Monocropping has resulted in the evolution of serious constraints to increased production, especially soil-borne diseases (Al Hasani, 2004). With the removal of methyl bromide and some other fungicides, growers need to evaluate alternative methods to control these diseases. Solarization and biofumigation (the use of solarization following soil amendment with organic matter) both have potential in the hot, arid climate of the Arabian Peninsula, but neither has been evaluated under commercial conditions. Fields trials were therefore designed to appraise their effectiveness in reducing *Pythium aphanidermatum* inoculum levels and damping-off disease, and enhancing crop growth.

Two separate trials were conducted in the summer and winter seasons in two commercial greenhouses in Muscat, both of which had previously been used to produce cucumber. Each greenhouse was divided lengthwise into 4 blocks, each containing biofumigation, solarization and control (no) treatments. Each replicate (7 × 3 m) accommodated two rows of 64 plants (summer) or 32 plants (winter). For biofumigation, cabbage residue (*Brassica oleracea*, Capitata group) was incorporated into the top 20 cm of soil at the rate of 5 kg m^{-2}. This material, consisting of stems and basal leaves, had been obtained from an adjacent field following harvest of the marketable portion of the crop. Biofumigation and solarization treatments were irrigated to field capacity before being covered with clear polythene (0.2 mm thickness) for 21 days (mid July to early August 2002 or early to mid December 2002). Control plots remained untreated and uncovered but were similarly irrigated to field capacity. Soil temperatures in all plots were monitored using probes placed at a depth of 10 cm. Before and after treatment three soil samples were taken at random positions from each plot at a depth of 20 cm and *P. aphanidermatum* inoculum density (cfu g^{-1}) was estimated using dilution series on potato dextrose agar amended with rose Bengal (35 mg l^{-1}) and streptomycin (100 mg l^{-1}).

Cucumber seed (cv Luna in summer and cv Salalah in winter) was sown directly following cover removal, with 0.3 m between seeds and 1 m between rows. At 7-day intervals between 7 and 35 days after planting, overall disease incidence was assessed by counting the number of diseased plants in each plot, expressed as a percent of the total number of plants in that plot. Stem height and diameter was also measured at 7-day intervals for 10 randomly selected plants per plot.

P. aphanidermatum colony counts (Table 1) showed no significant differences between treatments at the start of each season. After treatments, colony counts were significantly lower in both solarized and biofumigated soils, being reduced to approximately 20% and 50% of pretreatments levels in the summer and winter experiments respectively. During treatment, maximum soil temperatures in summer were 46.6, 48.1 and 40.3°C for the solarized, biofumigated and control plots respectively; in winter, the corresponding temperature maxima were 36.6, 34.6 and 30.2°C.

Disease incidence levels for each treatment during

Corresponding author: M. Deadman
Fax: +968.24413418
E-mail: mikedead@squ.edu.om

Table 1. Mean population densities of *P. aphanidermatum* before and after solarization and biofumigation soil treatments.

Treatment	*P. aphanidermatum* inoculum density (cfu g^{-1} soil)*			
	Summer		Winter	
	Before treatment	After treatment	Before treatment	After treatment
Solarization	$0.32x10^3$ a	$0.08x10^3$ a	$0.50x10^3$ a	$0.18x10^3$ a
Biofumigation	$0.40x10^3$ a	$0.07x10^3$ a	$0.50x10^3$ a	$0.18x10^3$ a
Control	$0.39x10^3$ a	$0.36x10^3$ b	$0.53x10^3$ a	$0.37x10^3$ b

* Values in the same column followed by different letters are significantly different at (P<0.05) according to Duncan's multiple range test.

the summer and winter seasons are shown in Table 2. In the summer season, there were significant differences in disease incidence between treated and non-treated plots up to 35 days after planting; differences between solarized and biofumigated plots were not significant. During the winter season, disease was higher than during the summer, but as with the summer season, solarized and biofumigated plots had significantly less damping-off than control plots (P<0.05). Disease was significantly lower in biofumigated than in solarized plots at the final assessment, 35 days after planting.

Stem diameter and stem height measurements for cucumber seedlings are shown in Table 3. During the summer season there were consistent and significant differences in stem diameter between plants in solarized or biofumigated plots and plants from control plots. These differences were reflected in the stem height measurements for the summer season; at the final assessment the plants in solarized plots (141.0 cm) and biofumigated plots (134.2 cm) were substantially taller than those in the control (89.4 cm). The increases in plant height and stem diameter during the winter season are also shown in Table 3. Differences in plant growth were generally less than for the summer season; by day 35 there were no significant differences in either stem height or stem diameter between the three treatments.

In Oman many greenhouse crop producers fallow the soil during the summer period. This is done primarily because yields are lower and energy costs are high. This period between crops could be used to reduce soil-borne pathogen population densities.

Data from the current experiment shows that solarization and biofumigation both increase the soil temperature at a depth of 10 cm sufficiently to reduce the population density of *P. aphanidermatum*. In Florida, Coelho *et al.* (1999) found that solarization raised the soil temperature at 10 cm to a comparable 47°C, this being sufficient to reduce disease caused by *Phytophthora* species to a level similar to that achieved by methyl bromide. Coelho *et al.* (1999) failed to achieve enhanced control when cabbage residue was incorporated into the soil prior to solarization. In the current work biofumigation and solarization achieved equivalent reductions in disease incidence, although disease levels were lower in the summer treatment, presumably a reflection of the lower pathogen population density in the soil, caused by higher temperatures causing greater pathogen mortality. The observation that solarization and biofumigation reduced disease levels even following winter treatment is important and would appear to indicate that soil temperatures were sufficiently high to reduce the pathogen's ability to cause disease.

Biofumigation has been reported to be as effective as methyl bromide when applied during warm weather

Table 2. Effect of solarization and biofumigation on percent damping-off disease incidence expressed as percentage of diseased plants, in summer and winter seasons.

Treatment	Damping-off disease incidence (%)*			
	14 days	21 days	28 days	35 days
Summer				
Solarization	1.2 a	1.6 a	1.6 a	1.6 a
Biofumigation	2.8 a	3.1 a	3.5 a	3.5 a
Control	5.5 b	6.3 b	6.3 b	7.0 b
Winter				
Solarization	3.9 a	4.7 a	6.3 a	11.7 b
Biofumigation	6.3 b	7.0 b	7.0 a	7.0 a
Control	9.4 c	10.2 c	13.3 b	16.4 c

* Values in the same column followed by different letters are significantly different at (P<0.05) according to Duncan's multiple range test.

Table 3. Effect of solarization and biofumigation on cucumber seedling stem diameter and stem height in summer and winter seasons.

	Days after planting (season)									
	Stem diameter (cm)*					Stem height (cm)*				
summer	7	14	21	28	35	7	14	21	28	35
Solarization	0.28b	0.52b	0.91b	1.19b	1.26b	2.7b	5.9b	14.0b	48.9a	141.0b
Biofumigation	0.27b	0.53b	0.89b	1.17b	1.25b	2.9a	6.2b	13.3b	52.1a	134.2b
Control	0.22a	0.43a	0.73a	0.92a	0.94a	2.3a	4.5a	9.4a	45.4a	89.4a
winter										
Solarization	0.26a	0.39a	0.66a	0.75a	0.79a	3.2a	7.6b	17.2b	37.0b	79.2a
Biofumigation	0.31a	0.40a	0.67a	0.85a	0.91a	3.3a	7.6b	13.9a	31.8a	89.6a
Control	0.25a	0.38a	0.67a	0.90a	0.98a	2.9a	6.6a	12.8a	29.4a	87.4a

* Values in the same column followed by different letters are significantly different at ($P<0.05$) according to Duncan's multiple range test.

(Bello *et al.*, 2000) and may enhance the performance of solarization (Ramirez-Villapudua and Munnecke, 1987; Gamliel and Stapleton, 1993). Percolation through the soil of toxic isothiocyanate (ITC) volatiles produced during the breakdown of brassica residue is thought to be the principal mechanism by which pathogen population levels are reduced during biofumigation (Warton *et al.*, 2001). However, Cohen *et al.* (2005) have suggested that the beneficial effects of soil amendment with brassica residue is through an enhancement of soil saprophytic activity, with microorganisms such as species of *Streptomyces* acting as agents for the induction of plant resistance to diseases such as those caused by *Rhizoctonia*.

Soil solarization has previously been shown to improve plant growth and yield, probably through the release of nutrients induced by high temperature (Stapleton and DeVay, 1984; Abdel-Rahim *et al.*, 1988). Results from the current experiment also showed that solarization and biofumigation not only reduced disease, but also significantly enhanced vegetative growth in the summer season, although not in the winter. Additional trials are required, especially to examine the potential for further disease reductions when the solarization and biofumigation treatments are applied over a longer period of time and cover an increased soil area. However, the results do suggest that incorporation of brassica residue into the soil, in combination with solarization, can decrease damping-off incidence in greenhouses in Oman, and could provide a step towards reduced fungicide dependency.

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