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SOLARIZATION AS A POTENTIAL APPROACH FOR RECYCLING WASTES OF POTTING MEDIA AND AS AN ALTERNATIVE TO METHYL BROMIDE FOR FIELD-GROWN BEDDING PLANTS

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Abstract. **A field experiment was conducted to evaluate solarization as a recycling method for spent potting media and as an alternative approach to methyl bromide for field-grown bedding plants in south Florida. Spent potting media was collected, spread on raised beds of gravelly calcareous soil, covered with clear polyethylene plastic sheet and solarized for 8 weeks. Other beds were left fallow for the same period and two weeks before transplanting the bedding plants to the field, spent media were spread on these fallow beds and were either treated with methyl bromide: chloropicrin (MB:CC) or were not fumigated. All beds were then covered with white on black polyethylene plastic mulch. Solarization plus humic acid amendment increased: 1) impatiens plant dry weights and were similar to those of MB:CC treatment, 2) petunias plant widths in contrast to those in non-fumigated plots as well as plant dry weights but were not significantly different from fumigated ones. However, solarization increased periwinkle plant height, width and dry weight on average by 15, 17, 41%, respectively, in comparison to those in non-fumigated treatment. Solarization and the addition of humic acid increased petunias plant width, and dry weight, dianthus plant height and width compared to those grown in non-fumigated plots with humic acid. Although solarization increased Mexican heather plant height, width and dry weight, solarization was not as effective as MB:CC. The addition of humic acid to plants in MB:CC plots increased significantly all these parameters. The results of this study show that solarization provides a successful avenue for recycling piles of spent potting media, and with addition of humic acid can be used as a potential non-chemical alternative to methyl bromide for growing field bedding plants in south Florida.**

Florida ranks second in annual bedding and garden plant production in the U.S. with crop sales of about $47 million (USDA-National Agric. Stat. Ser., 1999). For the production of these plants a potting mix that contains peat as the organic component has been the traditional method. Peat is not a quickly renewable resource in the short term and the demand and use of peat is much greater than its production rate (Klock-Moore and Fitzpatrick, 2000). In addition, production of high quality plants is expensive and stock piling of non-saleable planting media from disease infected containerized plants not only makes this material a candidate for landfills but also adds extra costs to large-scale nurseries to dispose the material.

Solarization is one of many techniques used worldwide and known to be a cost-effective technique among horticultural growers for controlling soil-borne pests. It reduces toxic residues, eliminates the need for fumigation, increases levels of available mineral nutrients in soils (Chen and Katan, 1980; Grunzweig et al., 1998; Kaewruang et al., 1989) and favors beneficial organisms (Stapleton and Devay, 1984, 1986; Gamliel and Katan, 1991), controls *Fusarium wilt* of watermelon (Martyn and Hartz, 1986) and tomato (Overman and Jones, 1986), soil nematodes (McSorley and Parrado, 1986), and soilborne pests in field grown flower crops (Elmore, 1999). Also, it has been investigated as a non-chemical alternative to methyl bromide for pepper production (Ozores-Hampton et al., 2000), pest management for organic vegetable production (McSorley et al., 1999), and recommended in pest management programs during transition from conventional to organic farming systems (Zinati, 2002).

Results of a study conducted by Zinati et al. (2001a) showed that solarization of spent media in clear plastic bags for 2-4 weeks for the production of containerized bedding plants such as impatiens, petunia, and periwinkle, was an inexpensive and fast technique to recycle stockpiled media and provided comparable results to those grown in new potting media.

Recycling in Florida has increased from 0.6 to 24.7 million tons between 1988 and 1996 during which municipal solid wastes that include the "Big 5" materials (aluminum, glass, newspaper, plastic and steel) were the main waste streams (Zinati and Emino, 2002). In the last few years, the idea of recycling organic wastes for Florida became an attractive alternative to disposing wastes into landfills. More programs are addressing recycling organic waste streams, which include yard wastes, food wastes, manures and biosolids to produce composts, mulches, organic amendments, and growing media. However, the adopted recycling approaches require state of art equipment, labor and energy to dispose of the material and to produce products free of pests. There is a pressing need to investigate low-cost and an effective approaches for recycling high volumes of disease-infected organic wastes, produced at ornamental nurseries, and for replacing soil fumigants such as methyl bromide: chloropicrin (MB:CC).

The objectives of this study were to 1) determine the potential use of solarization as a recycling method of high volumes of spent media in the field, 2) determine the potential use of solarization as an alternative approach to soil fumiga-

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tion by methyl bromide, and 3) determine the effect of solarization on plant height, width and dry weight for bedding and ground cover plant species with and without amendments in comparison to those grown in methyl bromide or control treatments.

Materials and Methods

A field experiment was initiated in 2000 at the University of Florida, Tropical Research Education Center, Homestead, FL (25°30'42"N, 80°30'0"W). The experimental site has an average annual rainfall of 147 cm. and the soil is Krome very gravelly loam (loamy-skeletal, carbonatic, hyperthermic Lithic Udorthents) with 67% pebbles (>2mm) (Zinati et al., 2001b). The spent potting media (mix of ground plant and potting mix) was provided by Lovell Farms, Inc., Miami, FL. Beds of 86m long, 1m wide, and 0.15 m deep were prepared.

After bed preparation, plots that were designated for solarization received spent media that was spread over the top surface of the bed at the rate 101 Mg (dw)·ha^{-1} or 7.5 cm thick layer, covered with a clear polyethylene plastic film of 0.03 mm thick and solarized for eight weeks (September 20, 2000 through November 16, 2000). Soon after that, the clear plastic mulch was removed and plots that were left fallow during the solarization period were topped with spent media at the above-mentioned rate. Dry fertilizer of 6-2.6-10 of NPK at the rate of 2100 kg·ha^{-1} was applied and incorporated into soil-media surface and a single drip tube was laid over the surface of the beds at the center of each bed before they were covered with a polyethylene white on black plastic mulch. The plots that were not solarized were either fumigated with methyl bromide: chloropicrin (MB:CC) mixture at a 67:33 ratio at the rate of 253 kg·ha^{-1} of crop area or left non-fumigated (control).

Two weeks after fumigation, impatiens (*Impatiens wallerana*) 'Super Elfin Violet', periwinkle (*Catharanthus roseus* L) 'Pacific Punch', petunia (*Petunia* × *hybrida*) 'Ultra Pink', dianthus (*Dianthus chinensis*) 'Princess Scarlet', 'Princess White' and 'Raspberry Parfait' and Mexican heather (*Cuphea hyssopifolia*) 'Allyson' were planted on two rows per bed with 30.5 cm × 30.5 cm spacing into all beds and were drip irrigated 1.5 h twice a day during the growing season. All treatments received either humic acid or SC-27, as organic amendments and were compared to those amended with water. Humic acid ESP-50, a black powder provided by Earthgreen Production Inc., was drenched at rate of 1.27 kg·ha^{-1} and a dilution rate of 28 g·40 L^{-1} water. SC-27 is a liquid mix of multiple beneficial microorganisms provided by Martin Marietta Aggregates, Columbus, OH, applied at the rate of 1000 mL·ha^{-1}. Each plant received 50 mL of dissolved solution of either amendment.

Four plants of each species per treatment per amendment were evaluated for plants height, width and dry weight eight weeks after transplanting. Variances and separations of means were analyzed using Duncan's Multiple Range Test at the 0.05, 0.01 and 0.001 probability levels of the Statistical Analysis System (SAS Institute, 1985).

Results and Discussion

The pH and the electrical conductivity of the soil-media ranged from 7.1-7.3 and EC 1.2 to 1.97 mS·cm^{-1}, respectively. Soil temperatures measured at 8 cm deep in the solarized plots ranged from 56 to 63 °C during the day during the eight weeks of solarization.

The recycled spent media before solarization was examined for plant parasitic nematodes at the Entomology and Nematology laboratory in Gainesville and results showed that there were no nematodes. However, the spent media were infected with rhizoctonia (*Rhizoctonia solani) and* phytophthora (*Phytophthora nicotianae*).

Impatiens (Impatiens wallerana). Average plant height of impatiens was highest and significantly different at $P < 0.001$ level in treatments that were fumigated with MB:CC than those that were either grown in solarized or non-fumigated treatments, irrespective of the organic amendment applied (Table 1).

Table 1. Horticultural parameters of impatiens plants as affected by treatment and organic amendments 8 weeks after transplanting.

Treatment[z]	Amendment: Water	Humic acid	SC-27	Significance level
	Plant height (cm)			
Control (no fumigation)	30.25 b[y]	31.12 b	32.25 b	NS
Solarization	30.00 b	32.00 b	33.00 b	NS
MB:CC (67:33)	39.62 a	42.87 a	38.87 a	NS
Significance level[x]	***	***	***	
	Plant width (cm)			
Control (no fumigation)	53.02	49.50 b	51.00 b	NS
Solarization	52.25	52.00 b	50.25 b	NS
MB:CC (67:33)	62.62	65.87 a	64.25 a	NS
Significance level[x]	NS	***	**	
	Plant dry wt (g/plant)			
Control (no fumigation)	28.85	24.20 b	28.02	NS
Solarization	27.26	38.74 a	28.03	NS
MB:CC (67:33)	29.33	38.84 a	36.48	NS
Significance level[x]	NS	*	NS	

[z]Treatment: MB:CC: Methyl bromide with chloropicrin.
[y]Means within same column followed by the same letters are not significantly different at $P < 0.05$, using Duncan's Multiple Range Test.
[x]Significance level: NS: no significance; **$P < 0.01$% and ***$P < 0.001$%.

Significant differences in average plant width were observed between treatments that either received humic acid or SC-27. There was no significant difference in average plant height, width and dry weight within same treatment with various amendments. Only plants amended with humic acid showed a significant increase in average dry weight when grown in solarized plots and the values were comparable to those grown in the MB:CC treated plots.

Periwinkle (*Catharanthus roseus L.*). There were significant differences in average plant height, width, and dry weight of periwinkle between treatments (Table 2).

Plants grown in solarized plots had higher average plant height, width, and dry weight, irrespective of the amendment, than those grown in non-fumigated plots. Plants grown in MB:CC had 15-30% increase in average height, width and dry weight than those grown in solarized plots.

Solarization increased average periwinkle height, width and dry weight by 15, 17, and 41%, respectively, in comparison to those in non-fumigated treatment. There was no significant difference in the values of periwinkle growth parameters between amendments within same treatment.

Petunia (*Petunia × hybrida*). There was no significant difference in average petunia heights between treatments and within treatments irrespective of the amendment (Table 3). Petunias grown in solarized plots and amended with humic acid had significantly ($P < 0.001$) higher average width than those grown in non-fumigated plots but lower than those grown in MB:CC treated plots. The addition of SC-27 to plants grown in non-solarized plots significantly increased average plant width in comparison to those amended with either water or humic acid. However, there was no significant difference in average plant width when grown in either solarized or fumigated plots with any amendment.

There was no significant difference in average plant dry weight between amendments within same treatment. Solarization and the addition of humic acid to petunia plants increased average plant width, and dry weight than those grown in non-fumigated plots with the same amendment. In non-fumigated beds, rhizoctonia (*Rhizoctonia solani*) *and* phytophthora (*Phytophthora nicotianae*) infected petunia plants and caused the death of some plants. Whereas, solarization of spent media suppressed these pathogens and increased petunias average width and dry weight. These results are in agreement with those reported by Gamliel et al. (1993) where they showed an increase in *Gypsophila paniculata* plant yield using solarized container media. The increase in these horticultural parameters in solarized media could be attributed to the reduction of pathogens during solarization that has been ascribed not only to high temperatures under the plastic but also to the production of some of the volatiles such as carbon dioxide, ethylene and other substances that are toxic to fungi as reported by Kaewrung et al. (1989) and to shift in biological activity in the soil (Gamliel et al., 1999).

Dianthus (*Dianthus chinensis*). There was a consistent significant difference between treatments in average height, width and dry weight of dianthus in the plots amended with humic acid (Table 4). In non-fumigated plots, average dianthus height and width were highest when amended with SC-27 and not significantly different from those amended with humic acids but significantly different from than those amended with water.

Dianthus grown in solarized beds and amended with humic acid increased in average height, width and dry weight in comparison to those in non-fumigated plots but were less than those grown in MB:CC with humic acid plots.

Mexican Heather (*Cuphea hyssopifolia*). There was a significant difference in average height, width and dry weight between treatments when plants were amended with either water or humic acid (Table 5). There was no significant difference within same treatment when any of the amendments were added except in MB:CC plots where they had the highest average plant height, width and dry weight, especially when amended with humic acid. Solarization was not as effective as MB:CC in increasing Mexican heather plant height, width and dry weight.

Table 2. Horticultural parameters of periwinkle plants as affected by treatment and organic amendments 8 weeks after transplanting.

Treatment[z]	Amendment			Significance level
	Water	Humic acid	SC-27	
	Plant height (cm)			
Control (no fumigation)	19.25 b[y]	18.37 c	19.75 c	NS
Solarization	22.12 ab	22.37 b	22.75 b	NS
MB:CC (67:33)	24.12 a	24.37 a	25.00 a	NS
Significance level[x]	**	***	***	
	Plant width (cm)			
Control (no fumigation)	22.62 b	23.50 c	20.12 c	NS
Solarization	29.00 a	25.75 b	25.12 b	NS
MB:CC (67:33)	32.50 a	37.12 a	38.50 a	NS
Significance level[x]	NS	***	**	
	Plant dry wt (g/plant)			
Control (no fumigation)	15.83 c	17.14 c	14.75 c	NS
Solarization	25.84 b	30.10 b	24.55 b	NS
MB:CC (67:33)	38.28 a	45.15 a	43.28 a	NS
Significance level[x]	***	***	***	

[z]Treatment: MB:CC: Methyl bromide with chloropicrin.
[y]Means within same column followed by the same letters are not significantly different at $P < 0.05$, using Duncan's Multiple Range Test.
[x]Significance level: NS: no significance; $^{**}P < 0.01\%$ and $^{***}P < 0.001\%$.

Table 3. Horticultural parameters of petunia plants as affected by treatment and organic amendments 8 weeks after transplanting.

Treatment[z]	Amendment			Significance level
	Water	Humic acid	SC-27	
	Plant height (cm)			
Control (no fumigation)	33.87	34.37	29.00	NS
Solarization	33.87	31.75	29.50	NS
MB:CC (67:33)	31.00	31.00	31.62	NS
Significance level[x]	NS	NS	NS	
	Plant width (cm)			
Control (no fumigation)	58.37 b[y] B[w]	46.37 c B	65.62 A	**
Solarization	61.12 ab	55.87 b	57.75	NS
MB:CC (67:33)	68.00 a	66.00 a	64.62	NS
Significance level	*	***	NS	
	Plant dry wt (g/plant)			
Control (no fumigation)	46.30	35.60 b	45.70	NS
Solarization	49.10	39.80 ab	35.20	NS
MB:CC (67:33)	51.38	60.25 a	43.60	NS
Significance level	NS	*	NS	

[z]Treatment: MB:CC: Methyl bromide with chloropicrin.
[y]Means within same column followed by the same letters are not significantly different at $P < 0.05$, using Duncan's Multiple Range Test.
[x]Significance level: NS: no significance; $**P < 0.01\%$ and $***P < 0.001\%$.
[w]Means within same row followed by the same letters are not significantly different at $P < 0.05$, using Duncan's Multiple Range Test.

Conclusions

Impatiens amended with humic acid showed a significant increase in plant dry weight when grown in solarized plots and these values were comparable to those of plants grown in plots treated with methyl bromide.

Irrespective of the amendment, solarization provided higher periwinkle plant height, width, and dry weight than those grown in non-fumigated plots. Plants grown in MB:CC had 15-30% increase in height, width and dry weight than those grown in solarized plots.

Solarization and the addition of humic acid increased petunias width, and dry weight, dianthus height and width than those grown in non-fumigated plots with the same amendment.

Although solarization increased Mexican heather plant height, width and dry weight, solarization was not as effective as MB:CC. The addition of humic acid to plants in MB:CC plots increased all these parameters significantly.

This study show that solarization provides a successful avenue for recycling piles of spent potting media; reducing cost of waste disposition and cost of production; and disinfecting spent media thermally rather than chemically.

Table 4. Horticultural parameters of dianthus plants as affected by treatment and organic amendments 8 weeks after transplanting.

Treatment[z]	Amendment			Significance level
	Water	Humic acid	SC-27	
	Plant height (cm)			
Control (no fumigation)	19.50 b[y] B[x]	21.25 b AB	23.37 b A	*
Solarization	20.50 b B	23.37 ab A	22.62 b A	**
MB:CC (67:33)	23.00 a	25.37 a	26.37 a	NS
Significance level[w]	**	**	*	
	Plant width (cm)			
Control (no fumigation)	30.50 b B	31.00 c B	37.75 A	
Solarization	35.62 ab	36.37 b	36.12	**
MB:CC (67:33)	36.62 a	40.25 a	40.62	NS
Significance level[x]	*	***	NS	NS
	Plant dry wt (g/plant)			
Control (no fumigation)	36.96	37.55 b	50.25	NS
Solarization	38.68	47.85 b	50.34	NS
MB:CC (67:33)	42.00 B	60.94 a A	55.60 A	**
Significance level[x]	NS	**	NS	

[z]Treatment: MB:CC: Methyl bromide with chloropicrin.
[y]Means within same column followed by the same letters are not significantly different at $P < 0.05$, using Duncan's Multiple Range Test.
[x]Significance level: NS: no significance; $**P < 0.01\%$ and $***P < 0.001\%$.

Table 5. Horticultural parameters of Mexican heather plants as affected by treatment and organic amendments 8 weeks after transplanting.

	Amendment			
Treatment[z]	Water	Humic acid	SC-27	Significance level
	Plant height (cm)			
Control (no fumigation)	18.75 b[y]	17.75 c	19.62	NS
Solarization	20.00 b	19.87 b	20.00	NS
MB:CC (67:33)	22.25 a AB[x]	23.75 a A	21.00 B	*
Significance level[w]	***	***	NS	
	Plant width (cm)			
Control (no fumigation)	38.00 b	35.25 b	37.00	NS
Solarization	39.50 b	39.75 b	38.00	NS
MB:CC (67:33)	45.50 a AB	48.75 a A	41.12 B	**
Significance level[x]	***	***	NS	
	Plant dry wt (g/plant)			
Control (no fumigation)	45.16 b	39.84 b	43.40	NS
Solarization	47.82 b	47.55 b	45.76	NS
MB:CC (67:33)	63.64 a AB	66.39 a A	53.67 B	*
Significance level[x]	***	**	NS	

[z]Treatment: MB:CC: Methyl bromide with chloropicrin.
[y]Means within same column followed by the same letters are not significantly different at $P < 0.05$, using Duncan's Multiple Range Test.
[x]Means within same row followed by the same letters are not significantly different at $P < 0.05$, using Duncan's Multiple Range Test.
[w]Significance level: NS: no significance; $^{**}P < 0.01\%$ and $^{***}P < 0.001\%$.

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