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Phytotoxicity of Compost Treated with Lawn Herbicides Containing 2,4-D, Dicamba, and MCPP

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Yard waste often contains large quantities of lawn clippings and makes up about 20% of the refuse dumped in landfills (Glenn 1989). As landfills reach capacities, composting has become a popular method of turning yard waste into a soil amendment (Glenn 1990). Compost is usually either incorporated into the soil to improve fertility or applied as a mulch to prevent weeds.

Many lawns are treated with herbicides containing various combinations of 2,4-D, dicamba and MCPP to control broadleaf weeds. Compost made with clippings from treated lawns could damage vegetables and other sensitive plants. Although research on the residue of lawn herbicides in compost is limited, a study by Richard and Chadsey (1990) found concentrations of 2,4-D averaged .0025 mg/kg in compost from Croton Point, NY. Similar research by Gurkewitz (1989) suggested that composted yard waste from Portland, OR contained negligible 2,4-D, dicamba and MCPP, however, specific concentrations were not reported. Low levels of lawn herbicides are probably common in composted yard waste because the herbicides are probably in low concentrations in the starting materials and degraded during composting. Degradation studies on 2,4-D and MCPP in culture (Oh and Tuovinen 1991), dicamba in soil (Smith 1974), and pendimethalin in compost (Lemmon and Pylypiw 1992) suggest that a significant portion of these lawn herbicides will degrade during composting.

Information on what concentrations of lawn herbicides can be present in compost without sensitive plants being injured would make the concentrations found by laboratory analyses more meaningful. The objectives of this study are to; 1) determine how tomatoes respond to being grown in compost containing various concentrations of lawn herbicides and 2) propose maximum acceptable levels of lawn herbicides in compost.

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MATERIALS AND METHODS

A herbicide-free compost was made with clippings and leaves from a lawn known not to have been treated with herbicides for over ten years. Clippings and leaves were ground in a Wiley mill, sieved through a 1 cm screen and mixed in a ratio of 3:1 (v/v). Leaves were mixed with the clippings to improve aeration during composting and provide an optimal C:N ratio of approximately 30:1. Water was added to obtain a moisture content of 60% (by wt). The mixture of grass clippings and leaves was composted in a 114 L cement mixer for four weeks in a greenhouse. The compost was turned once a week and monitored for temperature daily. Compost temperatures ranged from 30 to 60^{o}C for the first three weeks. During the fourth week the temperature declined to approximately that of the ambient air. Composting was considered complete because the compost would no longer generate heat and was not limited by moisture. Finished compost was sieved through a screen with 7 x 8.5 mm openings, spread on a greenhouse bench to a depth of 15 cm, and allowed to cure for two weeks.

Three common lawn herbicide formulations were used in this study: (1) Trimec (PBI/Gordon Corp.), dimethylamine salts of 2,4-D (2,4-dichlorophenoxy acetic acid) 25.9% (by wt), MCPP (2-(4-chloro-2-methylphenoxy)propionic acid) 13.9% and dicamba (2-methoxy-3,6-dichlorobenzoic acid) 2.8%, (2) Agway Lawn Weed Killer (Agway Inc. Chemical Division), diethanolamine salts of 2,4-D 18.2% and dicamba 1.9%, and (3) Ortho Weed-B-Gon (Chevron Chemical Co.), dimethylamine salts of 2,4-D 10.8% and MCPP 11.6%.

A preliminary experiment was performed to determine the approximate amount of a lawn herbicide formulation remaining in grass clippings one day after application. Because the clippings were not composted and the associated losses of herbicide did not occur, this concentration will be considered to represent the most herbicide possible in composted grass. Three 4.3 x 2.1 m plots containing perennial ryegrass (*Lolium perenne* L. `Pennfine'), were sprayed with Trimec at the manufacturer's suggested rate of 1 L/ha. After 24 hours, each plot was cut with a rotary lawn mower and grass samples were obtained. Samples were dried in an oven at 75^{o}C for one day, weighed and placed in 250 mL Erlenmeyer flasks. For each 1 g of grass, 10 mL of a methylene chloride:acetone (3:1, v/v) extracting solution was added. Samples were placed on an orbital shaker for 1 hr. The extracting solution was then filtered through a glass wool plug and a 0.5 Mm membrane filter. 2,4-D was isolated by passing 2.0 mL of filtrate through a silica solid phase extraction tube. A wash step of 2 X 2 mL of methylene chloride was followed with an eluting solution of 50% methanol/distilled water to remove the 2,4-D. The eluent was diluted to 10 mL with 50% methanol/distilled water and assayed by HPLC. A Spherisorb ODS-2 column (250 x 4.6 mm, 5 Mm particles) was used with a mobile phase of 60% methanol/distilled water containing trifluoroacetic acid (0.08%, v) at a flow rate of 1.5 mL/min. 2,4-D was determined with UV detection at 230 nm and compared to standards for quantification. All solvents were HPLC grade. 2,4-D was chosen as an indicator of the amount of lawn herbicide formulation in grass clippings because it is common to the three products used in this study and it is applied at similar rate. dicamba and MCPP were not determined but were considered to be present at levels relative to the 2,4-D in each herbicide formulation.

The herbicide-free compost was treated (spiked) with Trimec, Agway Lawn Weed Killer and Ortho Weed-B-Gon to obtain compost with 0, 0.1, 0.4, 1, 4, 10, 100, and 400% (dry wt) of the herbicide found in grass by the preliminary experiment. Tomatoes are known to be sensitive to 2,4-D (Loran and Maynard 1980) and a similar sensitivity to dicamba and MCPP is likely. Phytotoxicity was evaluated by growing tomato seedlings (*Lycopersicum esculentum* L. `Roma') directly in compost and in potting soil (Pro-Mix Bx, Premier Brands Inc.) covered with 1.5 cm of treated compost. The former method simulated the most compost which can be incorporated into the soil and the latter simulated soil mulched with compost. Six week old tomatoes were transplanted into 11.5 cm white plastic pots containing all treatments within 1 hr of adding each herbicide formulation to the compost. Plants were irrigated with 250 mL of tap water once a week for the first three weeks and twice a week for the last four weeks. Greenhouse temperatures ranged from 15 to 30^{o}C. Plant growth was determined after seven weeks by harvesting the aerial plant parts and obtaining their dry weights.

Although the forms of 2,4-D, dicamba and MCPP present in the lawn herbicide products are not considered volatile (Klingman and Ashton, 1975), the following precautions were taken to minimize the exposure of plants grown with low herbicide treatments to plants grown with high herbicide treatments. Six 2.5 x 0.9 m greenhouse benches were equally divided into eight rows with 40 cm tall, clear polyethylene barriers. Each compost treatment was replicated six times. The benches created a split block design with each row made up two replicates of each of the three herbicide formulations. Plants grown directly in compost and plants grown in potting soil mulched with compost were placed in separate rows. Border pots, containing herbicide-free potting soil were placed at the ends of each row.

RESULTS AND DISCUSSION

Grass clippings collected in the preliminary experiment were found to contain approximately 500 mg/kg of 2,4-D (dry wt). Based on the 100% compost treatment containing 500 mg/kg 2,4-D, the concentrations of 2,4-D, dicamba and MCPP added to each compost treatment, via the addition of each herbicide formulation, are shown in Table 1. While the compost treatments do not address the rate of herbicide degradation during composting, it does provide a means for obtaining compost containing the absolute amounts of herbicides needed for the bioassay with tomatoes. The effect of the herbicide treated compost on the growth of tomatoes is shown in Figure 1. Regardless of whether the tomatoes were grown directly in compost or potting soil mulched with compost, all plants died within seven days in the 100% and 400% treatments. Except for the plants grown in potting soil mulched with the 10% Ortho Weed-B-Gon treatment, all tomatoes

Table 1. Concentrations of herbicides in compost treatments (mg/kg)[z].

Compost Treatment	Trimec			Agway Lawn Weed Killer		Ortho Weed-B-Gon	
	2,4-D	MCPP	Dicamba	2,4-D	Dicamba	2,4-D	MCPP
0%[y]	0	0	0	0	0	0	0
0.1%	0.5	0.3	0.01	0.5	0.01	0.5	0.5
0.4%	2.0	1.1	0.2	2.0	0.2	2.0	2.1
1%	5.0	2.6	0.5	5.0	0.6	5.0	5.4
4%	20	11	2.0	20	2.0	20	21
10%	50	26	5.0	50	5.0	50	53
100%	500	265	51	500	55	500	535
400%	2000	1060	206	2000	220	2000	2140

[z]Dry weight basis, as the acid-equivalent form.

[y]Percent (dry wt) of herbicide in grass clippings one day after application.

died within three weeks in the 10% treatments. Tomatoes grown directly in compost containing the 4% Trimec and 4% Agway Lawn Weed Killer treatments, also died within three weeks. Distorted foliage was observed on tomatoes growing directly in compost containing the 1% treatments and on the tomatoes mulched with the 4% treatments. No other plants showed visible effects of the herbicides.

Compost containing Trimec and Agway Lawn Weed Killer was more phytotoxic than compost containing Ortho Weed-B-Gon possibly because of the relatively high sensitivity of the plants to dicamba. Trimec may have been phytotoxic at the lowest concentrations because of the synergistic effects of the combination of 2,4-D, MCPP and dicamba. Because dicamba (Engel and Ilnicki 1969) and MCPP (Oh and Tuovinen 1991) are more slowly degraded by microbes, they may represent the active ingredients most likely to be the greatest threat to plants grown in compost containing lawn herbicides.

Statistical analyses of the dry weights of the tomatoes, using the Tukey HSD multiple comparisons test ($P = 0.01$), showed tomatoes grown directly in compost containing the 0.1% Trimec, 0.4% Ortho Weed-B-Gon and 0.4% Agway Lawn Weed Killer treatments, grew no differently than plants grown directly in compost containing no herbicides. Growth of tomatoes in potting soil mulched with compost containing the 1% or less treatments was no different than plants mulched with untreated compost.

Chemical analysis of compost for the active ingredients used in lawn herbicides could be a valuable tool for rapidly assessing the potential for a compost to be

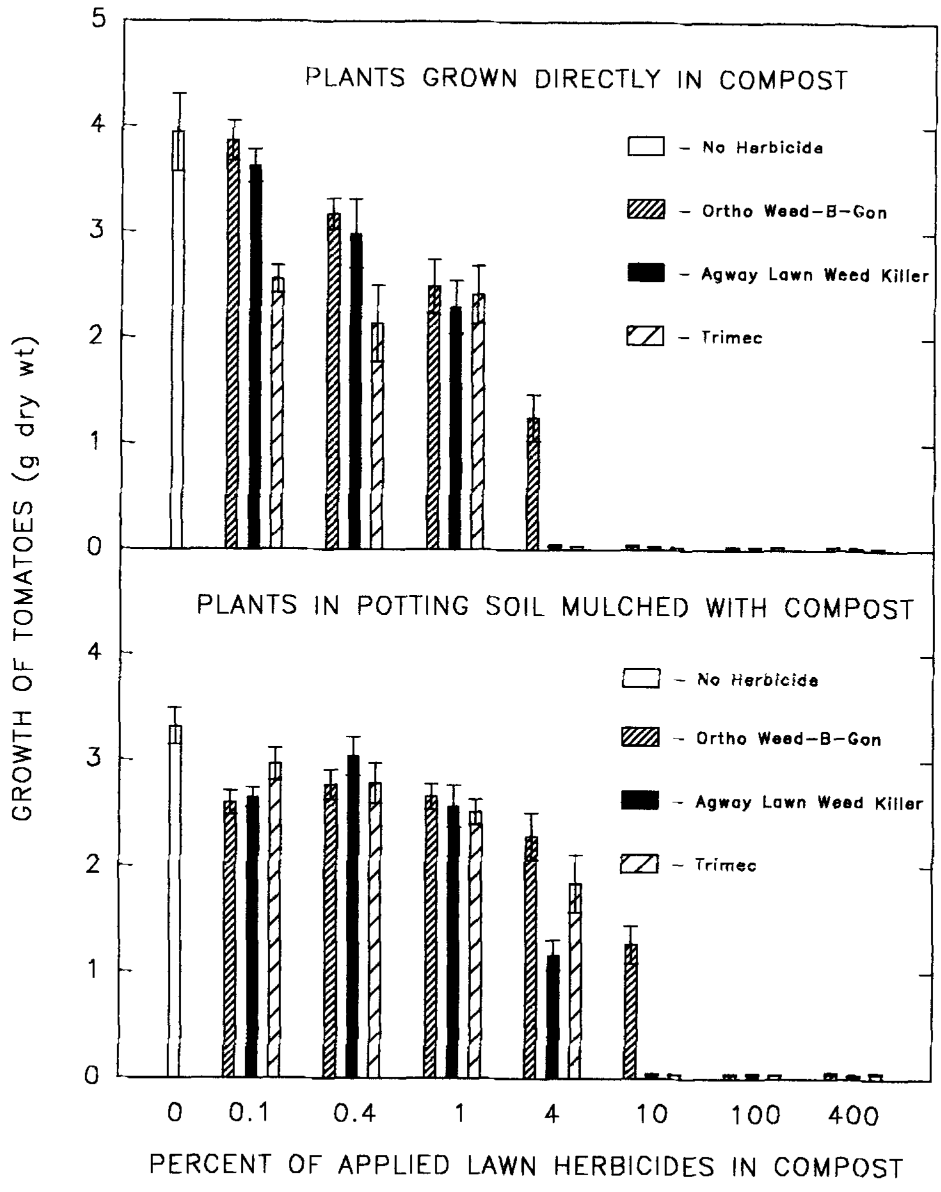

Figure 1. Growth of tomato in compost containing various percentages of the lawn herbicides found in freshly treated grass. Error bars equal +/- one standard error of the mean.

toxic to plants. The determination of maximum acceptable concentrations of lawn herbicides in compost should be based on the worst-case scenario of sensitive plants being grown directly in compost. Based on the 0.1% treatment causing no growth declines under this scenario and the data for the 0.1% treatment in Table 1, the maximum acceptable concentrations of lawn herbicides in compost can be considered to be approximately 0.5 mg/kg 2,4-D, 0.6 mg/kg MCPP and 0.05 mg/kg dicamba.

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