Bioavailable Herbicide Residues in Turfgrass Clippings Used for Mulch Adversely Affect Plant Growth

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Abstract. Grass clippings may comprise a minimum of 35% of yard waste. We investigated whether bioavailable herbicide residues in grass clippings used as mulch would be toxic to desirable plants. In each of three experiments, tall fescue (*Festuca arundinacea* Schreb.) was treated with a mixture of 2,4-D + dicamba + MCPP at 0.5 g total a.i./m². Clippings were collected at 1-, 5-, 10-, and 15-day postspray intervals. Clippings at gram equivalent weights relative to desired mulching depths were applied to tomato (*Lycopersicon esculentum* L.), cucumber (*Cucumis sativus* L.), salvia (*Salvia splendens* F.), and marigold (*Tagetes tenuifolia* Cav.) grown in pots. Plant dry-weight comparisons were made at two destructive harvest intervals, from 2 to 5 weeks after mulching. No mulch and nontreated mulch treatments were used as controls. Growth of tomato and marigold was enhanced when nontreated grass mulch was used compared to no mulch, but growth of cucumber and salvia was not enhanced. The bioavailable residues relative to the postspray interval (1 to 15 days) influenced growth of all species. Mulching depth affected growth of all species, except salvia. Herbicide-treated mulch reduced dry weight by ≤80% for cucumber, 73% for tomato, 65% for marigold, and 34% for salvia compared to controls. Herbicide residues apparently increased with mulching depth, resulting in a cumulative effect inhibiting plant growth. Chemical names used: 2,4-dichlorophenoxyacetic acid (2,4-D); 2-(2-methyl-4-chlorophenoxy) propionic acid (MCPP); and 3,6-dichloro-o-anisic acid (dicamba).

Forty-one U.S. states have established waste reduction goals, including 17 states that have placed legislative bans on the disposal of yard waste in public landfills (Glenn, 1989; Goldstein and Riggle, 1990). Composting, grasscycling, and mulching are three alternative methods of disposing of turfgrass clippings. Although not all turf maintenance programs involve regular collection of clippings, in 1984, the U.S. Environmental Protection Agency estimated that 21.6 million tonnes of yard waste were generated annually with a minimum of 7.6 million tonnes consisting of turfgrass clippings alone (Glenn, 1989). The high moisture and N content would seem to make grass clippings ideally suited for use as a mulch by horticulturists, nursery workers, and landscape professionals. However, clippings may be contaminated with herbicides that were applied recently. Information is needed on the potential inhibitory effects of surface-available and bioavailable residues in clippings that may affect plants mulched with such clippings.

Our objectives were to investigate the effect of nontreated and herbicide-treated turfgrass clipping mulch and of mulch depth on growth of two vegetable and two floral crops.

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Materials and Methods

Tall fescue was grown on a nonirrigated field site at the North Carolina State Univ. Turfgrass Field Research site in Raleigh. The fescue was treated with a herbicide mixture of 2,4-D (21.54%) + dicamba (11.45%) + MCPP (2.29%) with total active ingredients at 0.5 g total a.i./m². Clippings for use as a mulch were harvested at 1, 5, 10, and 15 days after spraying (I-1, I-5, I-10, and I-15) and were collected

using a rotary bagging mower set at a 5-cm mowing height.

Two vegetable (tomato and cucumber) and two flower (salvia and marigold) species were bioassayed under controlled growth conditions. Vegetables were propagated in the greenhouse from Nov. 1991 to Jan. 1992, and the flowers were grown in an outdoor rainshelter from May to Sept. 1992. All plants were grown in pots containing a steam-sterilized 5 loam : 2 sand mixture (v/v). Vegetables were grown in 25-cm-diameter pots containing 8 kg of soil; flowers were grown in 20-cm-diameter pots containing 3 kg of soil. Each pot was watered to field capacity before transplanting.

Irrigation was applied at ≥25 mm water weekly, in split applications, throughout the experiment. Although the water was surface-applied, the mulch did not interfere with irrigation or N availability from fertilizer applications. All plants received an initial application of 1.2 g N/cm² using 20N–4.4P–16K peat light fertilizer (Peters Fertilizer Products, Fogelsville, Pa.). A second fertilizer application was made at 2-week intervals to those plants retained for harvest interval two.

The tomatoes were started from seed in flats filled with Metromix 220 potting soil (W.R. Grace Co., Traveler's Rest, S.C.) and transplanted when plants were between 9 and 12 cm tall. The cucumbers were seeded directly into the pots used for the bioassay. The flowers were purchased from a nursery in flats and transplanted when in the second to third week of growth. Air in the greenhouse ranged from 20 to 38C as determined with a minimum–maximum thermometer and an outdoor thermometer located near the rainshelter measuring daily air temperatures. No supplemental lighting was provided.

Mulch was applied to the transplants and to the soil surface of the cucumbers immediately after seeding. The five treatments were mulch depths of 12, 25, and 37 mm with herbicide (M12+H, M25+H, M37+H); 37 mm with no herbicide (M37–H), and a control of no mulch (–M–H). Therefore, cucumbers emerged

Table 1. Analysis of variance for tomato, cucumber, marigold, and salvia dry-weight means over four post-herbicide-application, clipping-collection day intervals, two harvest dates after mulch application. Five replications were used at each harvest.

Source	df	Tomato	Cucumber	Marigold	Salvia
Herbicide treatment (Trt)	1	***	***	NS	**
Clipping collection interval (CCI)	3	NS	NS	***	**
Harvest	1	NA	***	***	**
Trt × harvest	1	NA	NS	NS	***
CCI × harvest	3	NA	***	***	***
Trt × CCI	3	***	***	***	***
Trt × CCI × harvest	3	NA	**	*	***

NS, *, **, ***Nonsignificant or significant at $P < 0.05$, 0.01, or 0.001; NA = not applicable for this source.

Table 2. Tomato dry-weight means 3 weeks after mulching with herbicide-treated clippings.

Mulch and depth (mm)	Plant dry wt (g)			
	Interval between spraying and clipping collection (days)			
	1 (I-1)	5 (I-5)	10 (I-10)	15 (I-15)
None, 0 (–M–H)	5.7 b ^c	5.0 a	5.4 b	5.4 b
No herbicide, 37 (M37+H)	7.1 a	5.9 a	6.5 a	6.7 a
With herbicide, 12 (M12+H)	2.5 c	5.1 a	6.1 ab	3.7 c
25 (M25+H)	2.9 c	4.8 a	5.7 ab	3.4 c
37 (M37+H)	3.0 c	5.8 a	5.2 b	1.8 d

^cMean separation within columns at $P \leq 0.05$.

through mulch, whereas only stems of tomato, marigolds, and salvia were in contact with mulch. A dust of 1-naphthyl *N*-methylcarbamate (carbaryl) was applied to tomato, and 2-propynyl (E,E)-3,7,11-trimethyl-2,4-dodecadienoate (kinoprene) and *O*,*S*-dimethyl acetylphosphoramidothioate (acephate) were applied to flower species as needed to control flea beetle (Coleoptera: Chrysomelidae) and whitefly (Homoptera: Aleyrodidae) infestation.

A completely randomized design was used with a total of 200 plants per species, except for tomato for which 100 plants were used. Two destructive harvest dates were 14 and 28 days after mulching for the vegetables and 21 and 35 days after mulching for the flowers. Harvested plants were dried at least 24 h in an Isotemp drying oven (Fisher Scientific Corp., Pittsburgh) at 80°C. Plant dry weights were taken at each harvest interval, and significance was tested using a mean separation least significant difference at $P \leq 0.05$. A generalized linear model was used to provide an analysis of variance of the data. Comparisons of treatments, postspray harvest intervals, and destructive sampling harvest dates were made using contrast statements. Statistical analyses were performed using Statistical Analysis Systems software (SAS Institute, 1985).

Results and Discussion

Analysis of dry weight means for tomato and cucumber indicated there was a treatment $\times$ day of clipping removal interaction (Table 1). Visual observations of leaf curling indicated that deleterious effects of phenoxy herbicides in clippings occurred on tomato within 7 to 10 days after mulching. The most obvious effects resulted from M37+H at I-1 and I-5. Mulch plus herbicide applications for all other postspray intervals did not produce symptoms before harvest. At the 3-week harvest, following mulching, the dry weights revealed that an increase in tissue weight of 25% for tomato occurred with M37+H over -M-H for all of the postspray intervals (Table 2). M12+H, M25+H, and M37+H reduced growth relative to controls (-M-H and M37+H) when clippings were obtained at I-1. Treatment M12+H reduced tomato wet weight by >60% compared to M37+H and -M-H (data not shown). At I-10, the M37+H plants had higher dry weights than the -M-H plants. Tomato plants grown with treatment M37+H had lower dry weights at I-10 than those grown with M37-H and -M-H (Table 2). Apparently, enough herbicide residue was present in or on clippings 10 days after spraying to affect growth of mulched tomatoes. Results were similar at I-15.

The dry weight means for cucumber indicated distinct treatment effects for I-1 and I-15 (Table 3). Within the first 2 weeks of growth (harvest 1), plants harvested from -M-H had higher dry weights than those from M37-H, M12+H, M25+H, and M37+H across all four postspray clipping-collection intervals. Over the next 2 weeks (harvest 2), plants with M37-H mulch had lower dry weights at I-1 and I-15 than those grown with -M-H. Little difference in dry weights existed at I-5 and

I-10 for the M12+H, M25+H, M37+H, and M37-H treatments. At harvest 2, significant reductions in dry weights were evident for M12+H, M25+H, and M37+H compared to -M-H and M37-H at I-1 and I-15.

The dry weights for the marigold and salvia revealed a clipping collection delay $\times$ treatment interaction (Table 1). Marigold dry weights in harvest 1 were reduced for M12+H, M25+H, and M37+H compared to M37-H at

Table 3. Treatment dry-weight means for cucumber as affected by mulching treatments, harvest interval 1 (2 weeks) and 2 (4 weeks) after mulching, and postspray clipping collection as days after herbicide application.

Mulch and depth (mm)	Plant dry wt (g)			
	Interval between spraying and clipping collection (days)			
	1 (I-1)	5 (I-5)	10 (I-10)	15 (I-15)
<i>Harvest 1</i>				
None, 0 (-M-H)	0.43 a ^z	0.68 a	0.48 a	0.60 a
No herbicide, 37 (M37-H)	0.25 b	0.32 c	0.30 b	0.42 b
With herbicide				
12 (M12+H)	0.22 b	0.52 ab	0.57 a	0.35 b
25 (M25+H)	0.14 bc	0.49 bc	0.48 a	0.30 bc
37 (M37+H)	0.07 c	0.34 bc	0.34 b	0.21 c
<i>Harvest 2</i>				
None, 0 (-M-H)	2.5 a	3.5 ac	2.5 a	3.8 a
No herbicide, 37 (M37-H)	1.4 b	2.7 a-c	2.0 a	1.8 b
With herbicide				
12 (M12+H)	0.15 c	3.2 ab	2.6 a	1.1 bc
25 (M25+H)	0.37 c	2.1 b	2.4 a	0.25 c
37 (M37+H)	0.28 c	1.6 bc	2.2 a	0.75 bc

^zMean separation within columns at $P \leq 0.05$.

Table 4. Treatment dry-weight means in grams for marigolds as affected by mulching treatments, harvest interval 1 (2 weeks) and 2 (5 weeks) after mulching, and postspray clipping collection as days after herbicide application.

Mulch and depth (mm)	Plant dry wt (g)			
	Interval between spraying and clipping collection (days)			
	1 (I-1)	5 (I-5)	10 (I-10)	15 (I-15)
<i>Harvest 1</i>				
None, 0 (-M-H)	2.7 b ^z	2.7 ab	2.7 a	2.7 b
No herbicide, 37 (M37-H)	3.4 a	2.2 b	1.5 b	3.5 a
With herbicide				
12 (M12+H)	2.5 b	3.3 a	2.1 ab	3.7 a
25 (M25+H)	2.3 bc	3.0 ab	1.7 b	3.3 ab
37 (M37+H)	1.9 c	3.0 ab	1.4 b	3.5 a
<i>Harvest 2</i>				
None, 0 (-M-H)	6.2 a	3.3 b	5.5 a	5.9 b
No herbicide, 37 (M37-H)	8.2 b	6.4 a	4.0 ab	7.9 a
With herbicide				
12 (M12+H)	5.7 a	7.3 a	3.3 b	7.8 a
25 (M25+H)	6.6 a	7.1 a	2.5 bc	8.1 a
37 (M37+H)	5.5 a	6.8 a	1.4 c	8.2 a

^zMean separation within columns at $P \leq 0.05$.

Table 5. Treatment dry-weight means in grams for salvia as affected by mulching treatments, harvest interval 1 (2 weeks) and 2 (5 weeks) after mulching, and postspray clipping collection as days after herbicide application.

Mulch and depth (mm)	Plant dry wt (g)			
	Interval between spraying and clipping collection (days)			
	1 (I-1)	5 (I-5)	10 (I-10)	15 (I-15)
<i>Harvest 1</i>				
None, 0 (-M-H)	2.7 a ^z	2.6 a	3.3 a	2.7 a
No herbicide, 37 (M37-H)	1.7 b	1.8 b	2.6 ab	3.1 a
With herbicide				
12 (M12+H)	2.6 a	2.4 a	1.9 b	2.9 a
25 (M25+H)	2.4 ab	2.5 a	3.1 a	6.0 a
37 (M37+H)	2.5 a	2.5 a	2.8 ab	3.0 a
<i>Harvest 2</i>				
None, 0 (-M-H)	4.1 ab	5.0 a	4.3 a	NA
No herbicide, 37 (M37-H)	3.1 b	3.5 ab	4.7 a	NA
With herbicide				
12 (M12+H)	4.6 b	4.7 a	4.4 a	NA
25 (M25+H)	4.4 b	4.4 ab	5.1 a	NA
37 (M37+H)	3.0 b	5.1 a	5.4 a	NA

^zMean separation within columns at $P \leq 0.05$; NA = not applicable for this harvest.

I-1 (Table 4). The extremely low weights within I-10 are unexplained and may be due to random effects. There was little evidence of cumulative herbicide residue effects associated with increases in treated mulch depth across all four postspray collection intervals, regardless of the harvest date.

At no time during the experiment were herbicide-induced injury symptoms visible on salvia. These salvia were mulched at a more mature stage of growth than other plants bioassayed, which may have reduced the risk of injury. The M37-H treatment resulted in either no effect or a negative effect relative to -M-H, as demonstrated by plant dry weights (Table 5). At I-10, harvest 1 dry weights of salvia were reduced as much as 40% with M12+H relative to -M-H and 27% relative to M37-H. Harvest 2 dry weights were not reduced significantly by M12+H and M37+H relative to -M-H, regardless of collection interval. The significance of the response appeared relative to the stage of growth at the time of application. It appears that salvia is as

tolerant to the bioavailable herbicide residues as marigolds, particularly if 2 to 3 weeks of growth have past before mulching. More research regarding herbicide residue tolerance levels relative to stage of growth is needed.

The degree of tolerance exhibited by plants to the phenoxy and benzoic herbicides may not be correlated to morphological characteristics but may be related to the plant's metabolic processes (Audus, 1976; Jensen, 1982). Toxicity to nontolerant plants could result from the release of injurious herbicide metabolites rather than leaf-surface-available herbicide residues, supporting the assumption that such by-products may accumulate in the turfgrass leaf tissue. Growth responses varied after herbicide-treated mulch application. Possible causes warranting further research are the effect(s) of 1) induced metabolic and hormonal activity relative to the stage of plant growth at the time mulch is applied, 2) organic acids that are released as clippings decompose, and 3) changes in the acidity of the root medium resulting from the production of NH_4^+

by bacteria decomposing the protein fraction of the leaf tissues. Benefits afforded by nontreated turfgrass clippings used as mulch are specific to the growth phase and the plant type, generally enhancing growth when compared to the absence of a mulch.

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