Metolachlor and Simazine Leaching through Horticultural Substrates[1]

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Abstract

This study was designed to determine whether differences existed in the amount of Derby (metolachlor and simazine) leached through four substrates used in container production. Substrate compositions (by vol) used in this study were 3:1 redwood bark:sand, 2:1:1 redwood bark:Yolo loam:sand, 3:1 pine bark:sand, and 1:1 composted hardwood bark:pine bark. Substrates were packed into #3 containers, and 4.5 kg ai/ha (4 lb ai/A) of metolachlor and 1.1 kg ai/ha (1 lb ai/A) of simazine were applied to the containers as a granular formulation. Containers were leached with 2.7 cm (1.06 in) of water per day, and leachate samples were collected 0, 1, 2, 4, 8, and 16 days after herbicide application. Both herbicides were detected in the redwood bark:sand leachate on the day of herbicide application, and concentrations increased over time but appeared to level off between day 8 and day 16. Metolachlor and simazine were detected in the redwood bark:Yolo loam:sand leachate 4 days after application, and concentrations of both herbicides increased over time. Metolachlor and simazine were detected in a few leachate samples from the hardwood bark:pine bark and pine bark:sand substrates. Substrate ranking based on the amount of herbicide lost was 3:1 redwood bark:sand > 2:1:1 redwood bark:Yolo loam:sand > 1:1 hardwood bark:pine bark > 3:1 pine bark:sand.

Index words: herbicide mobility, pine bark, redwood bark, hardwood bark.

Herbicides used in this study: Derby, (metolachlor), 2-chloro-*N*-(2-ethyl-6-methylphenyl-*N*-(2-methoxy-1-methylethyl)acetamide + (simazine), 6-chloro-*N*,*N'*-diethyl-1,3,5-triazine-2,4-diamine.

Significance to the Nursery Industry

This study indicated that substrate composition influences the amount of herbicide present in leachate from containers. The highest concentrations of metolachlor and simazine were detected in leachate from the 3:1 redwood bark:sand substrate while the lowest herbicide concentrations were detected in leachate from the 3:1 pine bark:sand substrate. This information indicates that the amount of herbicide movement within containers can vary greatly due to differences in substrate materials. If a large portion of the herbicide leaches through the substrate and out of the container, less herbicide will remain at the surface of the container and the period of effective weed control could be shortened. In addition, the leaching of a herbicide into a large part of the rooting zone of a plant may increase the potential for herbicide injury to container grown plants. Further research on herbicide interactions with substrate components could indicate which substrate components are most likely to reduce leaching and might indicate methods for minimizing herbicide leaching through substrates.

Introduction

Operators of container plant nurseries face increased regulation regarding the quality of surface runoff leaving nursery sites (4, 17). Some nursery operators recapture runoff water in containment ponds and reuse it for irrigation (15), but concerns exist about the possible accumulation of herbicide residues in containment pond water. If the water is reused for irrigation, the herbicides could damage sensitive plants within the nursery.

Herbicides have been found in containment pond water on nursery sites (9) and in water leaving nursery property (5). A broadcast herbicide application could lead to residues in surface runoff because herbicide which falls between containers can be easily removed in runoff water. In addition, herbicides falling on the substrate in the container might leach through the substrate and enter runoff water.

Previous research indicates that some herbicides are mobile in container substrates. Elmore et al. (3) studied leaching of several herbicides in a 1:1 (by vol) peat:sand substrate under daily irrigation. Herbicide ranking in terms of leaching depth was dichlobenil > simazine > trifluralin ≈ nitralin ≈ DCPA. Koncal et al. (10) applied 10 kg/ha (9 lb/A) of metolachlor, alachlor, or EPTC to containers filled with 4:1 (by vol) sphagnum peat moss:sand substrate and irrigated the containers for 10 weeks. After 7 weeks, EPTC had leached to 12.5 cm (5 in), and after 10 weeks alachlor and metolachlor had leached to 10 cm (4 in).

Substrate composition also influences herbicide movement. Horowitz and Elmore (7) examined oxyfluorfen leaching in two container substrates. Oxyfluorfen leached much further in a 3:1 (by vol) redwood bark:sand substrate than in a 1:1 (by vol) peat:sand substrate. Wehtje, et al. (19) studied the leaching of oxadiazon in several substrates and found that substrate composition influenced the depth of oxadiazon leaching.

Materials used in container substrates vary significantly among regions of the United States depending upon the availability and the suitability of materials for the production practices used. The materials selected for a substrate could influence herbicide mobility through the substrate. The objectives of this study were to determine whether metolachlor and simazine leached through container substrates and to

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determine whether substrate composition affected the amount of herbicide leached through the substrates.

Materials and Methods

Substrate compositions (by vol) and sources were 3:1 pine bark:sand (P/S) from North Carolina, 1:1 composted hardwood bark:pine bark (H/P) from Ohio, 3:1 redwood bark:sand (R/S) from California, and 2:1:1 redwood bark:Yolo loam (fine-sandy, mixed, nonacid, thermic Typic Xeroorthent):sand (R/Y/S) from California. Selected chemical and physical properties of the substrates are listed in Table 1. Blow-molded number three containers with 25.4 cm (10 in) top inner diameter, 21.6 cm (8.5 in) bottom inner diameter, and 25.4 cm (10 in) deep were used in the study. Containers were filled with substrate and leached with 10 l (10.6 qt) of water prior to herbicide application to settle the substrates and remove some of the fine particulate matter.

Derby 5G was applied with a shaker jar. Application rates were 4.5 kg/ha (4 lb/A) of metolachlor and 1.1 kg/ha (1 lb/A) of simazine equivalent to 22.8 mg of metolachlor and 5.7 mg of simazine per container. Four containers of each substrate were treated with Derby 5G, and each container was considered a replication for a total of 4 replications per substrate. Another container of each substrate was included as an untreated control.

Water was applied with a CO_2 pressurized, four nozzle spray boom mounted on a wooden frame in order to maintain the same boom height above all containers. The boom was fitted with solid cone TeeJet TG2 nozzles (Spraying Systems, Wheaton, IL) on a 28.6 cm (11.3 in) spacing. Boom pressure was 138 kPa (20 psi), and the water delivery rate was 736 ml/minute (24.9 fl oz/min). Water was delivered in five, 22 second increments for a total volume of 1350 ml/container/day equivalent to 2.7 cm (1.06 in). Leachate was collected from each individual container by funneling leachate from the container into a glass jar. Leachate volumes were measured daily. Five hundred milliliter leachate subsamples were taken from each container 0, 1, 2, 4, 8, and 16 days after treatment (DAT) and stored at 4°C until extractions could be completed.

Both metolachlor and simazine were extracted from the leachate samples with the same method. Samples were partitioned three times with 75 ml of methylene chloride, the organic fractions were combined and dried with anhydrous Na_2SO_4, and the volume was reduced to about 2 ml on a rotary evaporator. The remaining volume was transferred to a dilution tube, evaporated to about 0.1 ml under a stream of nitrogen, and 1 ml of methanol was added. The sample was again evaporated under nitrogen to about 0.1 ml and brought to a final volume of 1 ml with ethyl acetate (G. Mahnken and R.B. Leidy–unpublished data).

The presence of metolachlor and simazine was determined with a Hewlett Packard 5880 gas chromatograph (Hewlett-Packard, Avondale, PA) equipped with a nitrogen/phosphorus detector, and residues were quantified against external standards of known concentration. The column (Supelco, Inc., Bellefonte, PA) was 15 m × 0.24 mm (i.d.) fused silica coated with 0.20 µm SP-2250. Helium carrier gas flow rate was 1.7 ml/minute. Detector gas flow rates were 95 ml/min of air and 4.8 ml/min of hydrogen. Temperature settings were oven, 170°C; injection port, 200°C; and detector port, 300°C. Detection limits were 0.005 mg/L (ppm) of metolachlor and 0.0005 mg/L (ppm) of simazine. Retention times were 9.3 minutes for metolachlor and 4.7 minutes for simazine. The entire experiment was completed twice, and fresh substrate was used for both runs of the experiment.

Herbicide concentrations were converted to logarithm (base 10) values, and the data were subjected to analysis of variance procedures (14) to determine if herbicide concentrations in leachate differed among substrates or among sampling dates and to determine if an interaction existed between substrate and number of days after application.

To determine whether the amount of herbicide leached through the containers was the same, subtotal losses of metolachlor and simazine from each container were calculated by multiplying the herbicide concentration by the leachate volume for each of the six sampling dates. For each container, the amounts lost on the six sampling dates were totaled, the totals were subjected to analysis of variance procedures, and the mean subtotals were separated using Fisher's LSD procedure at the 0.05 probability level (14).

Results and Discussion

Percent organic material by volume in the substrates ranged from 100% in the H/P substrate to approximately 50% in the R/Y/S substrate. The H/P substrate contained the greatest amounts of humic matter at 1.0% and elemental carbon at 44% (Table 1). The elemental carbon content of the R/Y/S substrate was 5% which reflects the smaller percentage of organic material present in the substrate. Although the R/S substrate contained more organic material by volume than the R/Y/S substrate, the humic matter content of the R/Y/S substrate was higher which could have been due to the presence of soil in the R/Y/S substrate. The R/S and P/S substrates contained 75% organic material by volume, but the materials apparently differed in their chemical composition. The P/S substrate contained almost two times more elemental carbon and had a higher cation exchange capacity of 12.2 meq/100 g.

Extraction efficiencies of metolachlor and simazine from fortified check leachate water ranged from 55.3% to 73.9% (Table 2). Leachate color ranged from yellow to black indi-

Table 1. Selected properties of substrates used in the study[z].

Substrate	Redwood bark:Sand	Redwood bark:Yolo loam:Sand	Hardwood bark: Pine bark	Pine bark: Sand
Composition (by vol)	3:1	2:1:1	1:1	3:1
pH	4.4	6.3	4.9	5.0
Humic matter (% vol)	0.2	0.4	1.0	0.3
Elemental carbon (% wt)	8	5	44	15
CEC (meq/100g)	5.3	11.7	16.3	12.2
Bulk density (g/cm^3)	0.43	0.91	0.22	0.56
Total porosity (% vol)	74	60	84	71
Container capacity (% vol)	62	53	55	59
Air space (% vol)	12	7	28	12
Plant wilting point (% vol)	22	13	28	24
Dry wt./container (kg)	4.0	7.3	2.3	4.9

[z]Values for pH, humic matter, and CEC (cation exchange capacity) were determined by North Carolina Dept. of Agriculture Soil Testing Lab, Raleigh, NC. Elemental carbon was determined by the Analytical Services Lab of the North Carolina State University Soil Science Dept., Raleigh, NC. Bulk density, total porosity, container capacity, air space, and plant wilting point were determined by the North Carolina State University Horticultural Substrates Lab, Raleigh, NC. Values for container capacity and air space were determined using cores 7.6 cm in diameter, 7.6 cm in height, and 347.5 cm^3 volume.

Table 2. Extraction efficiencies, mean daily leachate volumes, and subtotal losses of metolachlor and simazine in substrate leachate.

Substrate (by vol)	Metolachlor extraction efficiency (%)	Simazine extraction efficiency (%)	Mean daily leachate volume	Metolachlor subtotal losses (ug)[z]	Simazine subtotal losses (ug)[z]
Redwood:sand (3:1)	55.3 (11.2)[y]	63.3 (9.8)	1241 (41)	560 (152) a	113 (33) a
Redwood:Yolo loam:sand (2:1:1)	68.4 (10.8)	71.5 (8.4)	1243 (36)	150 (62) b	35 (7) b
Hardwood bark:pine bark (1:1)	57.2 (13.0)	66.1 (12.4)	1233 (58)	4 (8) c	< 1 (1) c
Pine bark:sand (3:1)	73.9 (10.1)	71.8 (11.5)	1233 (45)	2 (5) c	< 1 (0) c
LSD (P = 0.05)				59.0	9.9

[z]Means followed by the same letter within a column are not significantly different (P = 0.05).
[y]The standard deviation of each mean is shown in parenthesis.

cating the presence of organic compounds which could have interfered with extraction efficiency.

Mean daily leachate volume was similar for all substrates, and leachate volumes were approximately 92% of the water volume applied (Table 2).

The analysis of variance procedure indicated that a significant interaction existed between herbicide concentrations in leachate from a particular substrate and sampling date. The concentration data were averaged over both runs of the study. The greatest metolachlor and simazine concentrations were detected in leachate from the R/S substrate (Fig 1). Both herbicides were detected in leachate water on the day of herbicide application, and concentrations increased over time until they leveled off between 8 and 16 DAT. Metolachlor and simazine were detected in leachate from the R/Y/S substrate on 4 DAT, and concentrations increased through 16 DAT. Low concentrations of metolachlor and simazine were detected in a few leachate samples collected from the H/P substrate with the greatest concentrations about twice the detection limit. Simazine was not detected in any leachate samples from the P/S substrate, and metolachlor was detected in only one sample from this substrate.

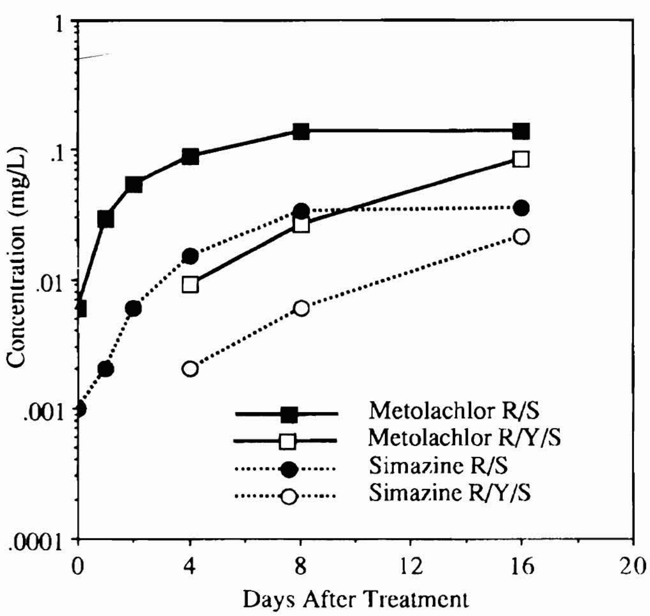

Fig. 1. Concentrations of metolachlor and simazine in 3:1 redwood:sand (R/S) and 2:1:1 redwood:Yolo loam:sand (R/Y/S) substrate leachates. The metolachlor detection limit was 0.005 mg/L, and the simazine detection limit was 0.0005 mg/L.

Subtotal losses of metolachlor and simazine in leachate reflect the concentration versus time curves with the largest amounts of metolachlor and simazine lost from the R/S substrate (Table 2). The amounts of herbicide lost from the R/S substrate were significantly larger than the amounts lost from the R/Y/S substrate. The small losses from the H/P and P/S substrates reflect the few detections of herbicide in leachate from these substrates.

Elemental carbon content is the total amount of carbon present in a substrate and reflects substrate organic matter content. The P/S and H/P substrates contained the greatest amounts of elemental carbon (Table 1), and less metolachlor and simazine leached through these substrates (Table 2). These results are consistent with research done on the mobility of metolachlor and simazine in soils. In general, more adsorption and less leaching of these herbicides occurred in soils containing greater amounts of organic matter (1, 2, 8, 13, 18, 20). Although greater amounts of metolachlor and simazine leached through the R/S and R/Y/S substrates, more herbicide leached through the R/S substrate which contained more elemental carbon than the R/Y/S substrate. The R/Y/S substrate contained soil as part of the mix in contrast to the R/S substrate which contained only redwood bark and sand. The organic matter fraction of soil can vary greatly in chemical composition depending on the material from which the organic matter forms, and organic matter composition can influence herbicide adsorption (16). The same could be true for bark since the chemical composition of bark varies both among and within species according to the age and the environment of the tree (12). The soil organic matter fraction in the R/Y/S substrate could have been more effective in adsorbing the herbicides and may have compensated for the smaller amount of total organic material. Hodges and Talbert (6) noted differences in simazine adsorption on soil and mulch material made from wood products. They reported over three times as much simazine was adsorbed by the mulch compared to the soil, but the mulch contained 10 times more organic matter which indicated that the organic matter of the mulch was less effective in adsorbing simazine.

The greater humic matter content of the R/Y/S substrate may also have been a factor in the smaller amount of leaching through the R/Y/S substrate compared with the R/S substrate (Table 1). Kozak et al. (11) reported that the humic matter fraction of organic matter was more effective in adsorbing prometryn and metolachlor than the other fractions. Although humic matter may influence herbicide leaching through substrates, other substrate properties may also influence herbicide movement. The humic matter contents of the P/S, R/S, and R/Y/S substrates are similar, but much less metolachlor and simazine leached through the P/S substrate. The cation exchange capacity of the P/S substrate was 2.3 times greater than the R/S substrate indicating the chemical composition of the two substrates was different, and the pine bark components could have been more effective in adsorbing herbicides. Although the cation exchange capacities of the P/S and the R/Y/S substrates were similar, the P/S substrate contained more elemental carbon which may also have been a factor in the amount of herbicide found in leachate.

Substrate composition affects herbicide leaching through substrates. Research by Elmore et al. (3) and Koncal et al. (10) indicates that herbicide properties influence herbicide movement through containers. Although herbicide properties can be useful in ranking relative herbicide mobility within a given substrate, the results of this study indicate that generalizations about herbicide movement cannot be made across substrates. Herbicides that are mobile within one substrate can be less mobile in a different substrate. If herbicide mobility in a substrate is a criterion for herbicide selection, the effect of substrate composition on herbicide movement will have to be considered. Substrate composition in the future could become even more complex if composted yard waste or other solid waste materials are introduced for use in container substrates. How these components interact with herbicides could be important in determining how herbicides are used within container nurseries.

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