Soil Conditioners and Pesticide Mobility in the Environment

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ABSTRACT

New soil management practices are needed to develop and expand our knowledge and technical means of agricultural production related to the fate and transport of agricultural chemicals. A field study was conducted on a Lowell silty loam soil at Kentucky State University Research Farm. Eighteen plots (22 × 3.7 m each) were established on a 10% slope. Runoff water was collected and quantified at the lower end of each plot using tipping-bucket runoff metering apparatus. Pan-lysimeters were installed to collect infiltration water from the vadose zone. Three soil management practices were used 1) municipal sewage sludge, 2) yard waste compost, and 3) a no-mulch control to study the impact of soil amendments on pesticide movement into runoff and infiltration water. Devrinol 50-DF "Napropamide" was applied as a pre-emergent herbicide, and the plots were planted with 60 d broccoli seedlings. Surface runoff water and napropamide residues in surface water were significantly reduced ($p < 0.05$) by the sewage sludge treatments. Yard waste compost treatments significantly increased water infiltration and napropamide residues in the vadose zone. Addition of sewage sludge to soil may reduce napropamide contamination of groundwater, especially in areas with a high water table or heavy rainfall events. A substantial amount of runoff was being retarded by the two soil amendments that would otherwise have been transported down hill into streams and rivers.

INTRODUCTION

New soil management practices are needed to expand our knowledge of agricultural production related to the fate and transport of agricultural chemicals and to meet the challenge of conservation, remediation, and environmental quality. The EPA estimates that 15 million tons of biosolids and 31 million tons of yard waste (USEPA, 1991) are discarded annually in the U.S. Recycled wastes have unique properties that should be thoroughly investigated in the soil/water/plant ecosystem. Adsorption of two herbicides, imidazolinone and imazethapyr, to sewage sludge amended soils indicated that imazethapyr interacts with organic matter in sludge through multiple-binding mechanisms including ionic and hydrogen bonds (Senesi et al. 1997). The organic matter applied as sludge or yard compost to soil can modify the mechanism of pesticide adsorption to soil, and can play a prominent role in the pesticide availability and removal process. The organic matter in compost helps improve soil fertility, and provides an organic amendment useful for improving soil structure and nutrient status for stimulating soil microbial activity (Barriuso et al. 1997; Antonious 2003).

The objectives of this study were 1) to study movement of napropamide (an herbicide) into runoff and infiltration water from a broccoli field that has been treated with two soil amendments (yard waste and sewage sludge compost) and 2) to study the impact of these two soil amendments on spring and fall broccoli yield and head quality.

Materials and Methods

Eighteen (18) plots (22 × 3.7m each) were separated using metal borders 20 cm above the ground level to prevent cross contamination between plots. Three soil management practices, replicated six times, were used: 1) municipal sewage sludge treated with lime and pasteurized for land farming (class-A biosolids obtained from Nicholasville Wastewater Treatment Plant, Nicholasville, KY) was mixed with native soil at 50 t acre^{-1} on dry weight basis, 2) yard waste compost made from yard and lawn trimmings, and vegetable remains (produced at Kentucky State University Research Farm, Franklin County, KY) was also mixed with native soil at 50 t acre^{-1} on dry weight basis with a plowing depth of 15 cm, and 3) no-mulch (NM) treatment (roto-tilled bare soil) was used for comparison purposes. Devrinol 50-DF also known as Napropamide [N, N-diethyl-2-(1-naphthyloxy) propionamide] (Figure 1) was sprayed and incorporated into the soil surface as a pre-emergent herbicide at the rate of 4 lb of formulated product acre^{-1}. Broccoli (*Brassica oleracea* L. cv. Packman F1) seedlings of 45 d old were planted on April 15, 2003 (spring broccoli) and August 13, 2003 (fall broccoli) at 10 rows plot^{-1} along the contour of the land slope at 10 plants row.$^{-1}$ During the growing season, runoff water from irrigation and/or rain was collected and quantified at the lower end of each plot using a tipping-bucket runoff metering apparatus. Pan-lysimeters were installed at the lower end of the plots down the land slope at a depth of 1.5 m. Infiltration water was also collected for napropamide residue analysis. Napropamide residues were quantified using a Hewlett Packard model 5890A Series II gas chromatograph equipped with a NP detector. Samples were injected onto a DB-5 high resolution column (15 m × 0.53 mm i.d.) with 0.5 µm film thickness. Napropamide residues also were confirmed using GC/MS that showed spectral data with a molecular ion peak (M+) at m/z 271, along with other characteristic fragment ion peaks. At harvest, broccoli head weight and diameter, stalk diameter and length were recorded. Spring and fall broccoli heads were quartered and examined for small and large instars of *Pieris rapae* L. larvae (Pieridae: Lepidoptera). Data were statistically analyzed using ANOVA procedure.

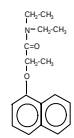

Figure 1. Chemical structure of napropamide [Devrinol, (N,N-diethyl-2-(1-naphthyloxy) propionamide)]

RESULTS AND DISCUSSION

Runoff water collected from plots treated with sewage sludge was significantly lower than plots treated with yard waste compost. Napropamide residues were significantly higher in runoff water from NM soil compared to yard waste and sewage sludge treatments (Figure 2, upper graph). The organic matter content was significantly higher in soil mixed with sewage sludge (5.95±0.17%) and soil mixed with yard waste compost (5.72±20%) compared to NM soil (2.8±0.77%). These results confirm the notion that the sorption of pesticides was highest in soils with the greatest organic matter content (Zbytniewski and Buszewski 2002; Antonious et al. 2004). Application of compost to soil has increased the retention or removal of hydrophobic compounds like trifluralin (an herbicide) from runoff water (Antonious 2004) and retention of pyrethrins (natural insecticides) on soil solids (Antonious et al. 2004). Concentration of napropamide in infiltration water from soil treated with sewage sludge was lower than napropamide in infiltration water from yard waste compost treatment.

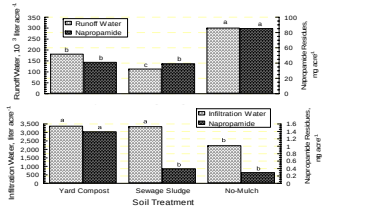

Figure 2. Volume of spring runoff water and napropamide residues in runoff water (upper graph) and infiltration water and napropamide residues in infiltration water (lower graph) collected under three soil management practices. Bars accompanied by different letter are significantly different ($P< 0.05$) using Waller LSD test.

Yard waste compost was associated with increased napropamide residue in the vadose zone (Figure 2, lower graph). Napropamide residues in the vadose zone were 0.3 mg acre^{-1} in the NM treatment compared to 1.4 mg acre^{-1} in yard waste compost treatment. Previous results have indicated that the complexation of pesticides with a water-soluble carrier such as dissolved organic matter (DOM) may facilitate chemical movement through the soil. The increased napropamide movement through the soil mixed with yard waste compost into the vadose zone could be attributed to the formation of napropamide-DOM complexes that lack adsorption affinity for the solid phase (Nelson et al. 2000) or due to reduced bulk density and increased soil particle interspaces after addition of yard compost. No napropamide residues were collected during the fall season (data not shown) due to reduced rainfall.

Addition of sewage sludge to soil increased broccoli head weight and diameter as well as stalk diameter and length compared to the NM treatment (Table 1). Broccoli marketable yield (tight, uniform heads with fine beading) is important in establishing and maintaining marketing opportunities (Sterrett et al. 1990). The use of any soil amendment in vegetable production must provide the growers with acceptable and marketable yield in order for them to use this agricultural practice. Organic substances and nutrients in sewage sludge and yard waste support a vast population of soil organisms that "mine" for soil minerals. Evidence of enhanced microbial activity in the rhizosphere of plants grown with soil amendments has been reported (Antonious 2003). The minimum average head weight should be 195 g to meet the marketing opportunities. This requirement can be achieved when using sludge for spring broccoli production (Table 1).

Table 1. Quality of spring and fall broccoli grown under three soil management practices at Kentucky State University Research Farm (Franklin County, KY).

Soil Treatment	Head Weight, g	Head Diameter, cm	Stalk Diameter, cm	Stalk length, cm	No. of Cabbage Loopers/ Head
Spring Broccoli					
Sewage Sludge	196.3 a	12.7 a	3.9 a	3.5 a	1.1 b
Yard Waste	172.7 a	11.9 b	3.4 b	1.5 b	1.2 b
No Mulch	138.3 b	10.5 c	3.1 c	3.3 a	2.6 a
Fall Broccoli					
Sewage Sludge	186.9 a	10.5 a	4.0 a	5.8 a	0.0 b
Yard Waste	187.5 a	9.7 b	3.6 b	7.1 b	0.2 ab
No Mulch	189.3 a	10.2 ab	3.9 ab	2.7 c	0.3 a

Each value in the table is an average of 6 replicates. Values within a column for each broccoli season having different letter(s) are significantly different ($P< 0.05$) using Waller LSD test.

CONCLUSION

Further studies are needed to reduce DOM content of municipal waste before land application. This will protect water quality from off-site movement of pesticides.

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Class-A Biosolids (Nicholasville Wastewater Treatment Plant, Nicholasville, KY)

A tipping bucket runoff metering apparatus used for collecting runoff (Kentucky State University Research Farm, Frankfort, KY).

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