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# Efficiency of Grass Buffer Strips and Cropping System on Off-Site Dacthal Movement

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Soil erosion can be defined as detachment of particles from the soil mass followed by movement and transport by erosive agents such as running water and winds. Erosion pulls valuable topsoil off the land, dragging it into lakes and streams where it becomes a pollutant. Soil erosion is recognized as one of the most serious environmental problems we face today. Rainfall erosivity, soil erodibility, and slope steepness are among the factors that influence the soil erosion process and mostly beyond human control. Soil terraces have been used to reduce slope length, but they are expensive and time-consuming conservation technology. Cover management like grass filter strips has become popular as a management practice to slowdown runoff and minimize soil erosion rate by trapping sediment.

Dacthal (dimethyl 2,3,5,6 tetrachloro-1,4-benzenedicarboxylate), is a pre-emergence non-systemic herbicide active against annual grasses and some broadleaf weeds in turf and in a number of vegetable crops (Ashton and Crafts 1981). It is recommended for use on direct seeded plants or after transplanting of pepper and tomato (Anonymous 1997). The use of herbicides to control weeds on erodible lands may reduce the need for tillage. However, when pesticide application concides with intense spring thunderstorms or heavy rainfall, major surface runoff events may carry substantial amounts of pesticides off-target site and cause soil and water contamination (Antonious and Byers 1997; Antonious et al. 1997). According to a U.S. Environmental Protection Agency survey released in 1997, pollution is a serious problem in 21 percent of the nation's 2000 or so watersheds. Agriculture's part in this pollution problem is substantial (Anonymous 1998).

Information is needed to quantify both horizontal movement of pesticides into surface waters and vertical movement into groundwater. Herbicides such as Dacthal have been used for many years on a broad spectrum of crops and cropping systems without special regard for its horizontal movement into surface water through runoff and vertical movement into the vadose zone through infiltration. A comprehensive understanding of runoff loss is still lacking for most common management situations (Shaw et al. 1992). This research was undertaken 1) to measure the influence of fescue strips intercropped between cropping rows on soil and water conservation, 2) to determine Dacthal residues detected in runoff water following natural rainfall events, and 3) to monitor the movement of Dacthal residues toward the vadose zone (the unsaturated water zone below the plant root) by infiltration as affected by three management practices.

## MATERIALS AND METHODS

Pepper and tomato plants were transplanted to the field at Kentucky State University Research Farm in Franklin County, Kentucky, in a Lowell silty loam soil (pH 6.7, 2% organic matter) of 10% slope. Dacthal W-75 (75% WP) was applied to soil surface using a $CO_2$ hand-held backpack sprayer (NSF Testing Laboratory, Ann Arbor, MI) operated at 35 psi at the recommended rate of 10.1 lb/acre ((3.44 kg AI/acre) (Anonymous 1997). Plots (n=18) were 3.7 m wide and 22 m long each, universal soil loss equation (USLE) standard plots, with metal borders 20 cm high above ground level. The experimental design was a 2 x 3 factorial with main factors including the two crops, pepper and pepper intercropped with tomato, each in row, and three soil management practices. The soil management practices were living fescue (*Festuca sp.*, Kentucky 31) intercropped between every row (turf-1), living fescue every other row (turf-2), and no mulch (NM) treatment (roto-tilled bare soil). Sweet pepper (*Capsicum annuum* cv.Bell Boy Hybrid) and tomato (*Lycopersicon esculentum* cv. Mountain Spring $F_1$ Hybrid) transplants, each in a row, were spaced every 0.37 m with 10 plants per row. Plots contained 10 rows oriented on the contour of the slope and each plot contained one of the three soil management practices. Living fescue strips, 30 cm wide, and vegetable rows (pepper and pepper intercropped with tomato plants) were used as repeated barriers to runoff.

Runoff (soil-water suspension) was collected in 4 L amber borosilicate glass bottles and quantified at the lower end of each plot using tipping-bucket runoff metering apparatus (Department of Agricultural Engineering, University of Kentucky, Lexington, KY 40546, USA). Runoff water and sediment samples were transported to the laboratory on ice in coolers. Sediment loss, dependent on natural rainfall, was determined by weighing the sediments collected from 1 L of runoff water using Whatman No. 1 filter paper. Sediment (g/L) was converted to kg/ha based on total runoff water lost per runoff event, per each 0.008 ha plots. Dacthal concentration, in a 300 mL aliquot of the runoff water sample was transferred quantitatively to a Buchner funnel and passed through a Whatman 934-AH glass microfibre filter (Fisher Scientific, Pittsburgh, PA, USA). The filtered water sample was extracted by solid phase extraction (SPE) using a cartridge column containing $C_{18}$-octadecyl bonded silica (J & W Scientific, Folsom, CA). The SPE cartridges were pre-activated with 10 mL of MeOH followed by 10 mL of distilled water. The runoff water sample was then passed through the SPE cartridges and a vacuum was applied to achieve a flow rate of 8 to 10 mL $min^{-1}$ (Antonious et al. 1997). Dacthal was then eluted from the column with 5 mL of methylene chloride ($CH_2Cl_2$). The solvent was reduced by evaporation using nitrogen ($N_2$) gas to 1 mL final volume for quantification by GC/MSD. Sediment (20 g) samples were refluxed with 200 mL of $CH_2Cl_2$ for 3 h in a Soxhlet apparatus to extract Dacthal. Extracts were then dried over anhydrous $Na_2SO_4$ and concentrated by rotary vacuum (Buchi Rotavapor Model 461, Switzerland) and $N_2$ stream evaporation.

Suction lysimeters (Model 1920, Soil Moisture Equipment Corporation, Santa Barbara, CA, USA) were established in three experimental plots to monitor the presence of Dacthal in the vadose zone. Lysimeters (n=27) were installed according to manufacturer's recommendations using soil coring equipment. Within each plot, lysimeters (n=9) were installed at depths 0.3, 0.6 and 1.5 m, with three lysimeters at the top, middle and bottom of the plot. Prior to sampling, vacuum (30 psi) was applied into each lysimeter using a vacuum/pressure pump (Pressure Pump Model C, Soil Moisture Company, Santa Barbara, CA, USA). Leachate samples were collected from May to July, 1994. Borosilicate amber bottles were used for sample collection. Volumes of water collected were recorded following each rainfall. Dacthal residues were extracted using the same procedure described for runoff water samples.

Dacthal (dimethyl 2,3,5,6 tetrachloro-1,4-benzenedicarboxylate) of >95% purity and its formulated form (Dacthal W-75) were obtained from ISK Biotech Corporation, Mentor, OH, USA. Standards ranging from 0.1 to 1.0 ng/µL were prepared in $CH_2Cl_2$ and were used to spike soil and water samples for evaluating the efficiency of the analytical procedures used. Aliquots of water (100 mL each) were filtered through Whatman No. 1 filter paper and spiked with Dacthal. Sediment samples (20 g) were collected from the control treatments and spiked to evaluate the analytical procedure for recovery of Dacthal residues from sediment samples. The lack of Dacthal residues in the blanks suggested that there was no contamination from sampling, processing, or laboratory procedures. Recovery values (means ± SD) using fortified samples were 90.0 ± 3.2, 81.9 ± 3.9, and 91.9 ± 1.8% for Dacthal in runoff water, runoff sediment, and water collected from tension lysimeters, respectively. All Dacthal residue data have been adjusted for efficiency of recovery.

Dacthal residues were detected and quantified by HP 5890A gas chromatograph (GC) equipped with MS (HP 59714, Hewlett Packard Co., Palo Alto, CA, USA) operated in selective ion mode (SIM) and HP 7673 auto-injector. The instrument was autotuned with perfluorotributylamine (PFTBA) at m/z 69, 219 and 502. The operating parameters of the gas chromatograph were as follows: injector and detector temperatures 210 and 275° C, respectively. The oven temperature was programmed from 70 to 230° C at the rate of 10° C/min. A 25 m x 0.20 mm id capillary column containing 5% diphenyl and 95% dimethylpolysiloxane with 0.33 µm film thickness (HP-5) was used. Quantitation was based on average peak areas from two 1 µL consecutive injections obtained from external standards ranging from 0.1 to 1 ppm prepared in $CH_2Cl_2$. Linearity over the range of concentrations was determined using regression analysis. Two ions at m/z 301 and 332 were monitored on the mass spectrum (Monohan et al. 1995). Retention times of the two peaks were 21.1 and 22.0 min, respectively. Residues of Dacthal detected in runoff water, sediment, and water collected by suction lysimeters were analysed using analysis of variance (ANOVA) (SAS 1991); Duncan's LSD test was used to compare means (Snedecor and Cochran 1967).

## RESULTS AND DISCUSSION

Buffer strips intercropped between pepper rows reduced runoff water by 99 and 33% in turf-1 and turf-2 treatments, respectively compared to NM treatments. Buffer strips intercropped between pepper/tomato, each in a row, reduced runoff water by 100% and 24% in turf-1 and turf-2 treatments, respectively (Figure IA). This means that a substantial amount of runoff water is being trapped by the buffer strips along the hillslope that would otherwise have been transported down hill. Similar observation can be also concluded from the amount of runoff sediment collected at the lower end of the experimental plots. Buffer strips planted between every cropping row (turf-1) in both pepper and pepper intercropped with tomato treatments reduced sediment loss by 100% compared to NM treatments. Buffer strips planted every other cropping row (turf-2) reduced sediment loss by only 6% in pepper treatments and 68% in pepper/tomato treatments (Figure 1B).

Ten rows of buffer strips (turf-1) in pepper plots reduced Dacthal residues in runoff water and runoff sediment by 95 and 100%, respectively, compared to NM treatments (Figure 2). This indicates that a substantial amount of Dacthal residues was trapped on sediment by the buffer strips in turf-1 treatments along the hill slope that would otherwise have been transported down hill into surface water. When the number of buffer strips rows was reduced to five rows per plot (turf-2) Dacthal movement from the treated soil into runoff water and runoff sediment was reduced by 65 and 39%, respectively. Results also indicated that NM plots planted with pepper intercropped with tomato as cover crop had 72% less runoff water and 79% less runoff sediment compared to NM plots planted with pepper only. This is likely due to greater soil coverage in the mixed planting associated with the growth habit of tomato plants. Pepper has an erect growth habit and tomato has a prostrate, vining growth habit, resulting in greater soil coverage in the pepper/tomato plots.

The mobility of any pesticide in soil is one of the principal parameters controlling the extent to which a pesticide may represent a risk for surface and groundwater contamination. Dacthal has a low vapor pressure, $2.5 \times 10^{-6}$ mm Hg and very low water solubility, 0.5 ppm (Anonymous 1994; Wauchope et al. 1992). Filter strips can reduce runoff and nonpoint source pollution of surface water. However, mulching improved infiltration (Sherman et al. 1995) into the vadose zone as indicated by volume of water collected in tension lysimeters used in the present study (Figure 3, upper graph). Dacthal with its low water solubility, <0.5 ppm, and stability to u.v. light (Anonymous 1994) could be bound on soil particles. Consequently, low residue levels of Dacthal would be available in the vadose zone at lower depths as indicated in Figure 3, lower graph. This will decrease the likelihood of its transport to surface runoff water or to groundwater following rainfall events or early season irrigation soon after Dacthal application. Lysimeters have been demonstrated to have low recovery values for nonpolar pesticides because they are adsorbed strongly to the interior polyvinyl chloride (PVC) walls of the lysimeter (Angle et al. 1991). However, the presence of Dacthal residues in the water samples collected from the vadose zone (Figure 3, lower graph) provides evidence of its potential leaching. Lysimeters

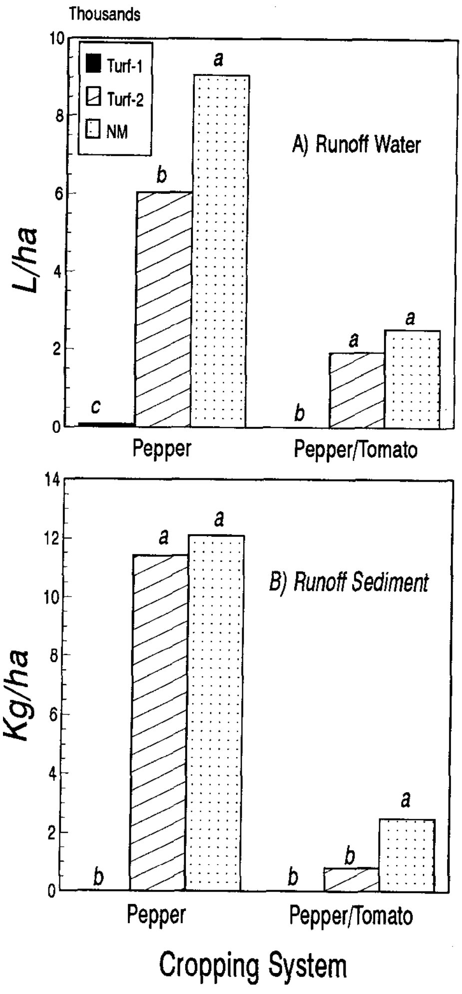


*Figure 1. Runoff water (upper graph) and runoff sediment (lower graph) collected at the lower end of USLE standard plots under two cropping systems and three soil management strategies: turf-1, living fescue mulch between every cropping row; turf-2, living mulch every other row; and NM, a bare soil. Statistical comparisons were done between the three soil treatments for each cropping system. Bars accompanied by the same letter are not significantly different (P>0.05 Duncan's multiple range test).*

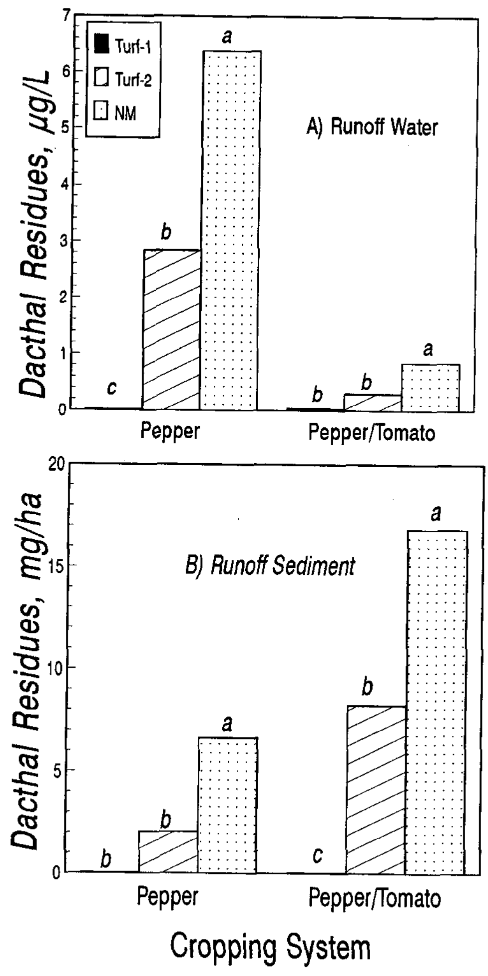


*Figure 2. Dacthal concentrations in runoff water (upper graph) and runoff sediment (lower graph) following soil application of Dacthal 50 WP under two cropping systems and three soil management strategies: turf-1, living fescue mulch between every cropping row; turf-2, living mulch every other row; and NM, a bare soil. Statistical comparisons were done between the three soil treatments for each cropping system. Bars accompanied by the same letter are not significantly different (P>0.05; Duncan's multiple range test).*

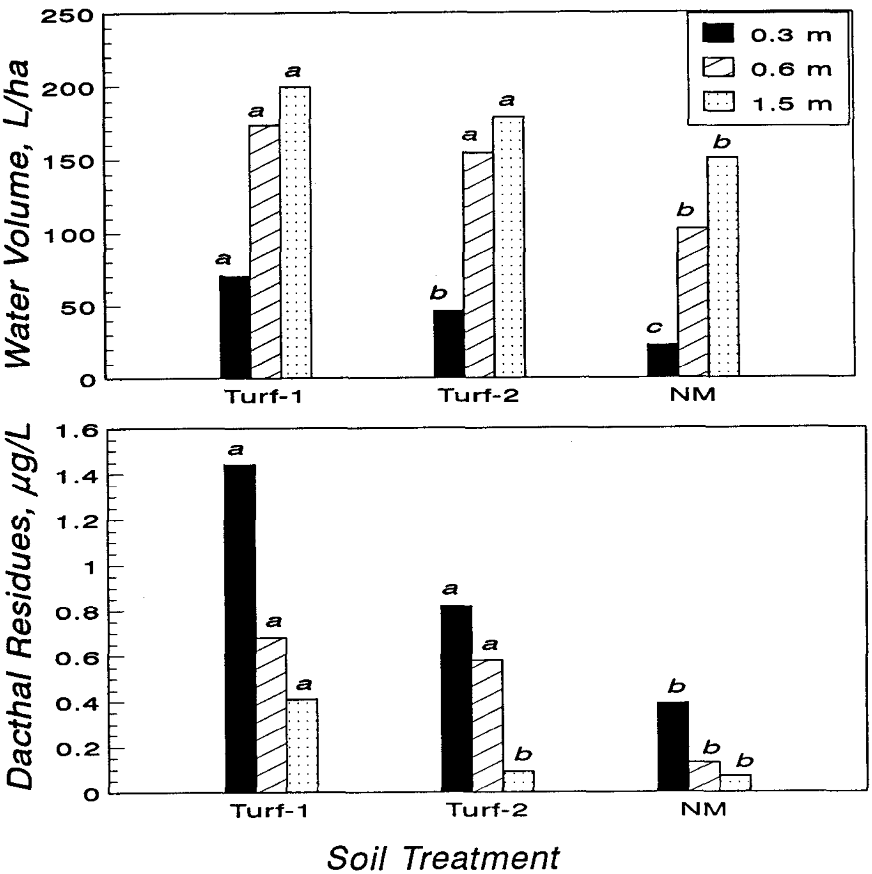


***Figure 3.*** *Leachate water volume (upper graph) and residue levels of Dacthal (lower graph) in water samples collected during a three month period from the vadose zone under three management strategies: turf-1, living fescue mulch between every cropping row; turf-2, living mulch every other row; and NM, a bare soil. Statistical comparisons were done among the three cropping systems for each lysimeter depth used to collect leachate water samples. Bars accompanied by the same letter are not significantly different (P>0.05; Duncan's multiple range test).*

therefore can be used to test for significant differences in Dacthal concentrations among the tested treatments.

In NM plots, water infiltration rates varied between 22 and 150 L/ha, infiltration ranged between 70 and 200 L/ha in turf-1 and between 46 and 179 L/ha in turf-2 treatments. Water solubility is one of the pesticide characteristics that controls mobility (Lichtenstein 1980; Cohen et al. 1984). Previous results have indicated that cultivation of turf reduced runoff but did not reduce leaching of the water soluble isomer of endosulfan (an insecticide) to the vadose zone (Antonious and Byers 1997). In spite of its low water solubility, Dacthal residues were detectable in runoff water (Figure 2) and in the vadose zone (Figure 3, lower graph) indicating that its residues in soil are subject to surface runoff as well as subsurface flow. Figure 3 also indicates that when the depth of water sampling from the vadose zone was increased, more water was collected from the vadose zone. However, Dacthal residues detected at 1.5m were less than that residues detected at 0.3 or 0.6m depth. This may be explained by the nonpolar properties of Dacthal which increases its adsorption to the soil particles thereby decreasing its availability in water at lower soil depths. A significant portion of pesticides applied to agriculture remain associated with soils in the form of bound residues (Bollag and Myers 1992; Printz et al. 1995). The boundaries of a pesticide are the bottom of the root zone and the edge of the field. A pesticide movement is assumed to have occurred if the pesticide is leached below the root zone, or leaves the field boundary in runoff waters.

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