THE POTENTIAL OF VEGETATIVE FILTER STRIPS AT VARYING WIDTHS ON THE REDUCTION OF HERBICIDES IN SURFACE RUNOFF WATER

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INTRODUCTION

Soil erosion and off-site movement of pesticides and suspended solids have become primary issues for agriculture in the last 20 years. Government impediment, such as the Federal Food Security Act of 1985, compelled producers to consider these problems and execute plans by 1995 to control erosion. However, little research is available to forecast how some of these plans will affect off-site movement of pesticides.

From 1985 to 1988, 86% of the soybean acreage in Mississippi were produced under some form of conventional tillage practice (Spurlock and Misra 1989). Many of these acres are produced under a monocrop, conventionally-tilled system, which often allows the largest amount of soil loss and possibly off-site movement of pesticides in surface water. Vegetated buffer strips, or filter strips, have been recommend as one of the many Best Management Practices for the prevention or reduction of nonpoint-source contamination (Baker and Mickelson 1994). Vegetative filter strips may offer producers an alternative to reduce these losses with minimal changes in tillage and planting practices. These strips are typically 2 to 10 m in width and are composed primarily of tall fescue in the Southern United States. Water movement is slowed substantially as it moves across these grass strips, reducing the sediment load.

Tillage has been proven to increase (Felsot et al. 1990; Shaw et al. 1992) or decrease (Baker et al. 1983; Webster and Shaw 1996) herbicide loss in surface runoff. Variations in herbicide losses from conventional tillage and no-till plots also occur between years (Baughman et al. 1995). These differences have been attributed to many factors, including rainfall severity, soil type, and antecedent soil moisture. The presence of plant residues on the soil surface has been attributed to increased alachlor loss (Felsot et al. 1990) due to extensive washoff of herbicide from the crop residue. Straw residues on the soil surface decreased soil reception of metribuzin (Banks and Robinson 1982), oryzalin (Banks and Robinson 1984), and alachlor (Banks and Robinson 1986). A major portion of these herbicides were retained on the straw after as much as 13 mm of rainfall, which increases the potential for ensuing herbicide removal during later runoff events. Therefore, the impact of reduced tillage on herbicide loss are often vague, and many times reduced tillage actually increases herbicide loss in runoff.

Vegetative filter strips reduce sediment and other suspended solids, nitrogen and phosphorus, and colliform organisms (Dilaha et al. 1989; Young et al. 1980). Vegetative filter strips 4.6 and 9.1 m wide with shallow uniform flow removed an average of 84 and 74% of incoming suspended solids, 79 and 61% of incoming phosphorus, and 73 and 54% of incoming nitrogen (Dilaha et al. 1989). Stiff grass hedges of Miscanthus sinesis Anderss. reduced soil loss from conventionally-tilled cotton as much as 50% (McGregor and Dabney 1993). Vegetative filter strips reduce pollution from feedlot runoff (Young et al. 1980). These strips, which were comprised of orchardgrass (Dactylis flomerata L.) and a mixture of sorghum (Sorghum vulgare L.) and sudangrass (Sorghum sudanense L.), reduced off-site movement of runoff and total solids 67 and 79%, respectively. Tall fescue strips 0.5 and 1 m wide reduced herbicide loss at least 48% from conventionally tilled cotton (Gossypium hirsutum L.) (Murphy 1996). Tall fescue filter strips 2 m wide can effectively reduce herbicide concentrations and total losses in soybean planted with conventional tillage or no-till. Metribuzin and metolachlor concentrations were reduced as much as 50% when a vegetative filter strip was used in a tilled monocrop soybean production system (Webster and Shaw 1996). While these data show that vegetative filter strips may effectively reduce herbicide concentrations and sediment, the next reasonable question that arises is the applicable filter strip width to maximize reductions in sediment and contaminants while reducing the amount of land taken out of production by these filter strips. Other researchers have recognized the deficiency of information currently available pertaining to filter strips and their impact on agricultural production systems (Aull 1980). The objective of this research was to evaluate varying tall fescue filter strip widths and their effects on metolachlor and metribuzin loss in surface runoff from conventionally-tilled soybean.

MATERIALS AND METHODS

This experiment was conducted at the Black Belt Branch Experiment Station near Brooksville, Mississippi, in 1994, 1995, and 1996. Soil erosion plots (4 m by 22 m) equipped with a 15 cm H-type flume were located on a Brooksville silty clay (fine, montmorillonic, thermic Typic Chromudert). The high montmorillonitic content of this soil causes shrinking and cracking during dry periods which can temporarily facilitate infiltration through macropore flow. Plots were disked with a tandem disk harrow perpendicular to the slope in the fall of each year. Tall fescue filter strips were established by transplanting native stands from an area adjacent to the runoff plots. The filter strips were placed at the base of the plots just prior to entry into the H-type flume, forcing the runoff through the strips prior to entering the flume. All filter strips were 4 m in length, and widths evaluated were 0, 0.5, 1, 2, 3, and 4 m. The experimental design was a completely randomized design. This research was conducted three consecutive years and years were used as replications.

Plot Establishment

Prior to planting each year, tall fescue was clipped to 10 cm and allowed to grow without further maintenance throughout each year. Spring seedbed preparation involved one pass with a tandem disk harrow followed by two passes with a two-way bed conditioner equipped with rolling baskets and s-tine harrows. Seedbed preparation was conducted no later than 2 d prior to planting each year. "Terra-Vig 515" soybean was planted in 76-cm rows parallel to the slope, with 5 rows per plot. Planting dates were May 31, 1994, June 20, 1995, and July 9, 1996. After planting, plots were bordered with metal flashing to exclude outside runoff. Metolachlor and metribuzin were applied preemergence at 2.8 and 0.42 kg ai ha^{-1}, respectively, using a CO_2-pressurized backpack sprayer delivering a spray volume of 190 L ha^{-1}. Plots were maintained weed-free throughout the growing season by hand weeding.

Rainfall Simulation

Using an irrigation system, a simulated rainfall event was initiated within 2 days after treatment (DAT) each year. This system applied water through individual cycling irrigation sprinkler heads mounted on 3 m risers spaced 3 m apart. All plots received simulated rainfall at an intensity of 25 mm h^{-1} simultaneously. Other rainfall simulations were employed later in the growing season each year to provide adequate runoff events at timely intervals. Rainfall simulation for a given event was continued until runoff had occurred on all plots for 10 min. Each year runoff was monitored for at least 84 d following herbicide application. Metolachlor and metribuzin have high water solubilities at 530 ppm and 1,220 ppm, respectively (Weed Science Society of America Herbicide Handbook Committee 1994). Half-lives in soil range from 15-25 days for metolachlor and 7-60 days for metribuzin. The relatively short half-lives combined with high solubilities favored increased losses early in the growing season and, by 84 DAT, no detectable levels were present in runoff.

In 1994, all runoff from each plot was collected in individual 550-L catch basins. Runoff effluent was quantified, agitated, and a 1-L composite sample was obtained from each runoff plot and stored at 2 C until analysis. In 1995 and 1996, automated flow meters and water samplers were installed in place of the catch basins. The flow meters were programmed to determine flow rates and total runoff at the outlet of the flume. The automated water samplers were programmed to collect a 0.64-L sample from runoff passing through the flume at 200-L intervals during runoff events occurring from natural and simulated rainfall events. Samples were recovered within 24 h of the runoff event and stored at 2 C until analysis.

Herbicide Analysis

Water samples were filtered under vacuum through a Buchner funnel containing a 9 cm diam filter paper. Filtered sediment was oven-dried at 66 C for 24 h and quantified. These values were combined with total runoff to establish sediment loss on a per ha basis and, subsequently, cumulative sediment loss. Only the runoff water was subjected to herbicide analysis, since the high solubility and low adsorption of these compounds result in minimal amounts on sediment. A 500 ml aliquot of the runoff water was placed in liquid-liquid extractor with 250 ml of methylene chloride. The extractor was then placed on a 500 ml flat-bottom flask containing 300 ml methylene chloride and heated at 215 C for 16 h. Samples were subjected to rotary evaporation to just dryness and brought to a volume of 10 ml with hexane. The samples were analyzed by gas chromatography. Residues were determined with a lower detection limit of 250 and 100 ng L^{-1} for metolachlor and metribuzin, respectively.

Herbicide concentration values were combined with total runoff to determine total loss of each herbicide per runoff event on a per ha basis and, subsequently, cumulative off-site movement in runoff. Attempts were made to regress herbicide losses, runoff amounts, and sediment amounts, both within events and cumulative, in linear, quadratic, and exponential form against filter strip width. However, these regression forms were unable to accurately predict actual values for the unfiltered because of the dramatic difference compared to all filter strip widths; therefore, regression results are not reported. Total runoff, sediment loss, and metolachlor losses and metribuzin losses, along with cumulative losses, were subjected to analysis of variance. Total runoff, sediment, and herbicide loss were separated using Fisher's protected LSD at $P \leq 0.05$.

RESULTS AND DISCUSSION

Total rainfall amounts during the sampling period for 1994 through 1996 were 1411, 726, and 744 mm, respectively. The first runoff event was a simulated event and occurred 2 DAT all years.

Surface Runoff

At 2 DAT, the highest runoff came from the unfiltered treatment, at 137000 L ha^{-1} (Figure 1). Runoff from fi strips was 10000-23000 L ha^{-1}. The addition of a filter strip reduced surface runoff by 83-93%, with no differences in filter strip widths. Total runoff losses at the end of season were again highest from the unfiltered, at 658000 L ha^{-1} (Figure 2), and the addition of a filter strip reduced cumulative runoff to 350000-207000 L ha^{-1}, or a 47-68% reduction. The presence of a filter strip substantially reduced runoff velocity, allowing increased infiltration and reducing the total amount of off-site movement. This is consistent with previous research when a 2-m wide tall fescue filter strip reduced runoff amounts regardless of tillage system (Webster and Shaw 1996). However, other researchers have found that 0.5 and 1 m filter strips do not reduce runoff in conventional-tilled cotton (Murphy 1996). Discrepancy between these results could be attributed to differences in rainfall patterns or antecedent soil moisture. Narrower tall fescue filter strip widths could be subject to innudation during runoff events, rendering them ineffective to runoff reduction.

Herbicide Loss

At 2 DAT, metribuzin concentration from the unfiltered treatment was 231 ng ml^{-1} (Figure 3). Filter strips reduced metribuzin concentrations to 74-119 ng ml^{-1}, or a reduction of 48-68%, regardless of width. Metolachlor concentrations were higher, but the same trends were observed (Figure 4). The highest concentration was from the unfiltered, at 1009 ng ml^{-1}. The addition of a filter strip reduced metolachlor concentration to 313-523 ng ml^{-1}, or a reduction of 48-69%.

When total runoff is combined with herbicide concentrations, losses per ha can be determined. The unfiltered treatment resulted in a metribuzin loss of 32 g ha^{-1} 2 DAT (Figure 5). This loss is equivalent to 7% of the applied metribuzin. Filter strips reduced metribuzin concentrations to 0.8-2.7 g ha^{-1}, regardless of width. The presence of a filter strip reduced metribuzin loss 91-98% on this date, with no differences between widths. The highest metolachlor loss 2 DAT was from the unfiltered, at 141 g ha^{-1}, or 5% of the amount applied (Figure 6). Filter strips reduced metolachlor losses to 3.5-13 g ha^{-1}. The presence of a filter strip of any width effectively reduced metolachlor concentrations by 91-98%. When considering total herbicide loss for the unfiltered treatment, 78% of the total metribuzin loss was accounted for in the first runoff event, and 77% for metolachlor. This supports previous herbicide loss patterns with differing tillage systems and vegetative filter strips (Baughman et al. 1995; Murphy 1996).

Cumulative metribuzin and metolachlor losses through the growing season followed previous trends. The highest cumulative metribuzin loss was again observed from the unfiltered (Figure 7). Cumulative metribuzin loss was 41.5 g ha^{-1}, or 9.8% of the applied metribuzin. Filter strips reduced cumulative metribuzin losses to 1.7-11 g ha^{-1}, or 0.4-2.6% of the applied. Cumulative metolachlor losses were higher for the unfiltered treatment, resulting in 183 g ha^{-1} or 6.5% of the amount applied (Figure 8). The addition of a filter strip also reduced cumulative metolachlor losses to only 19-60 g ha^{-1}, or 0.7-2.1% of the applied. Since herbicide loss patterns were the focus of this study, each year the experiment was terminated 84 DAT. By this time, metribuzin and metolachlor concentrations were below the detection limit of 100 and 250 ng L^{-1}, respectively. By doing this, cumulative loss patterns accurately reflect annual loss patterns for both compounds. Increasing filter strip width did not affect reductions of cumulative metribuzin or cumulative metolachlor loss, and all filter strips reduced herbicide losses compared to the unfiltered treatment. The higher metribuzin and metolachlor loss from the unfiltered is related to a combination of higher runoff amounts and higher concentrations in the early events. The presence of a filter strip reduced total runoff and consequently reduced cumulative metribuzin and metolachlor loss. This relates to previous research where a 2-m-wide tall fescue filter strip reduced runoff and herbicide loss, regardless of tillage system (Webster and Shaw 1996). This research indicates that filter strip widths from 0.5 to 4.0 m can effectively reduce metribuzin and metolachlor losses when compared to the unfiltered, and provide a viable management tool for the reduction of herbicide losses.

Sediment Loss

At 2 DAT, sediment loss was highest from the unfiltered area, at 90 kg ha^{-1} (Figure 9). By providing a filter strip, sediment losses were reduced to 2-11 kg ha^{-1}, or a 99-98% reduction. Total sediment loss for the season was 442 kg ha^{-1} from the unfiltered treatment (Figure 10). Filter strips continued to reduce cumulative sediment loss, with losses of only 25-78 kg ha^{-1}. Filter strips reduced runoff amounts, and consequently sediment losses, by increasing backwater depths prior to entry of the filter strips thus increasing deposition of suspended solids. Although there were no differences in filter strip widths in reducing sediment losses, all widths reduced the off-site movement of sediment. This meshes well with previous research in which 0.5 and 1 m wide tall fescue filter strips reduced the amount of sediment transported off-site in cotton production systems (Murphy 1996). This research further validates those results and provides additional insight that filter strips up to 4 m do not significantly reduce the amount of sediment lost compared to a 0.5 m filter strip, but are more appropriate than unfiltered systems.

No differences were detected among filter strip widths on the reduction of runoff water, metolachlor, metribuzin, and sediment loss but, when compared to the unfilterd, reductions were observed. Further research is now needed to determine how these data can be transfered to watershed level to best optimize filter strip width for maximum filtering effects with minimal land allocations.

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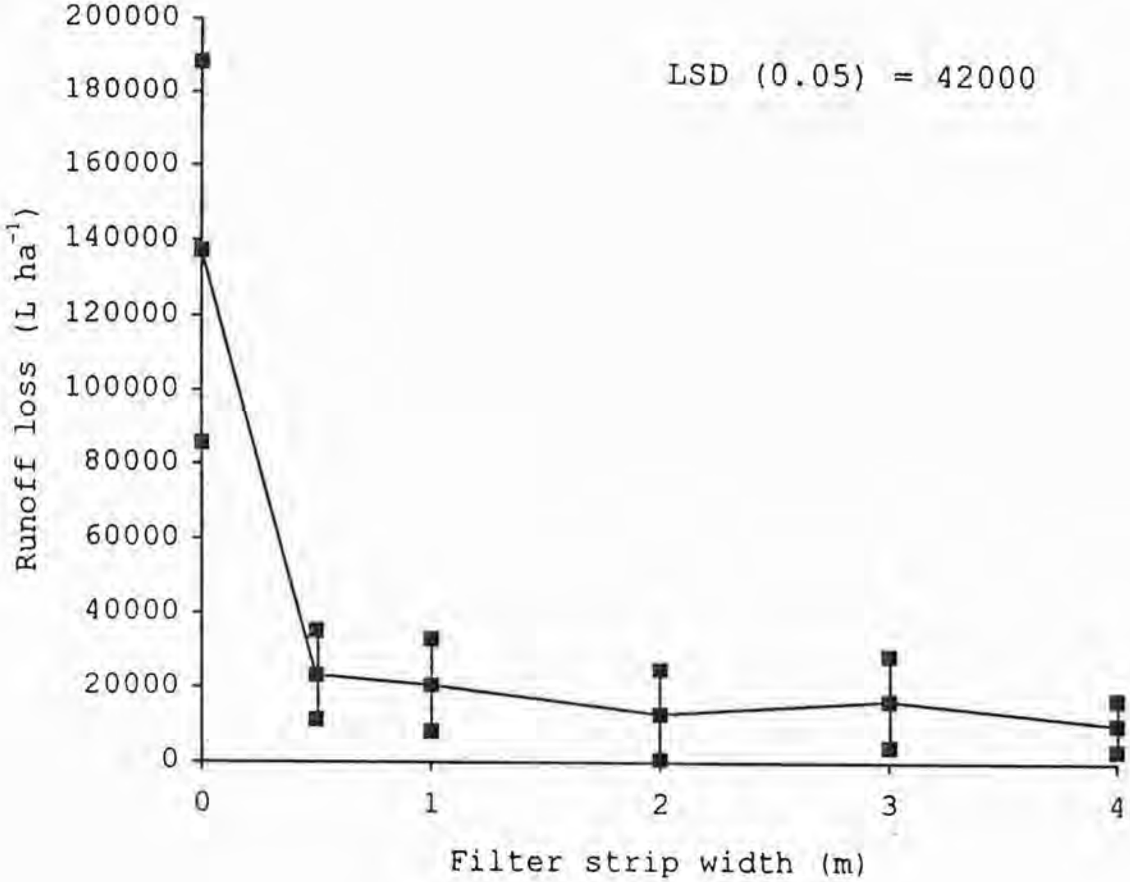

Figure 1. The effect of filter strip width on runoff loss 2 days after initiation of study. Means are shown with standard deviations.

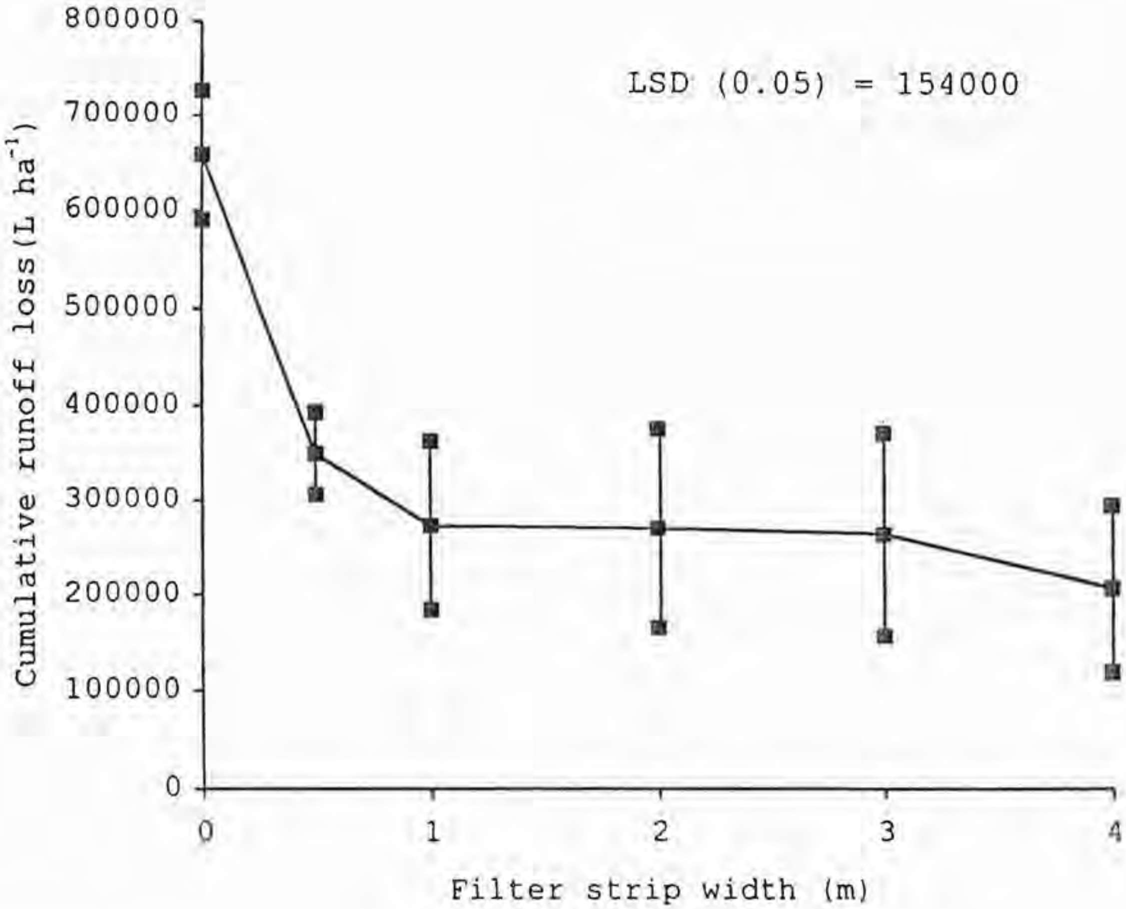

Figure 2. The effect of filter strip width on cumulative runoff loss through 84 days after initiation of the study. Means are shown with standard deviations.

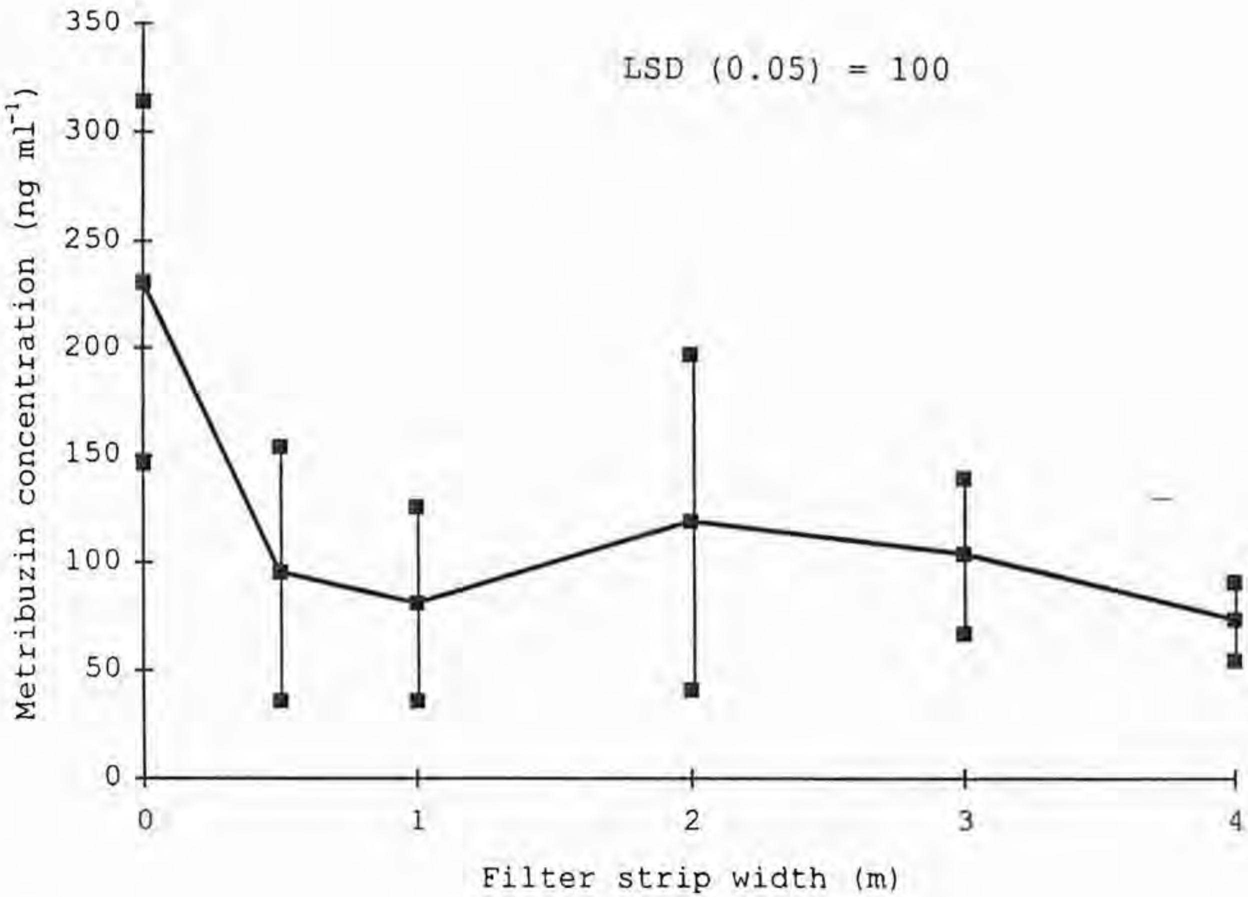

Figure 3. The effect of filter strip width on metribuzin concentration 2 days after initiation of study. Means are shown with standard deviations.

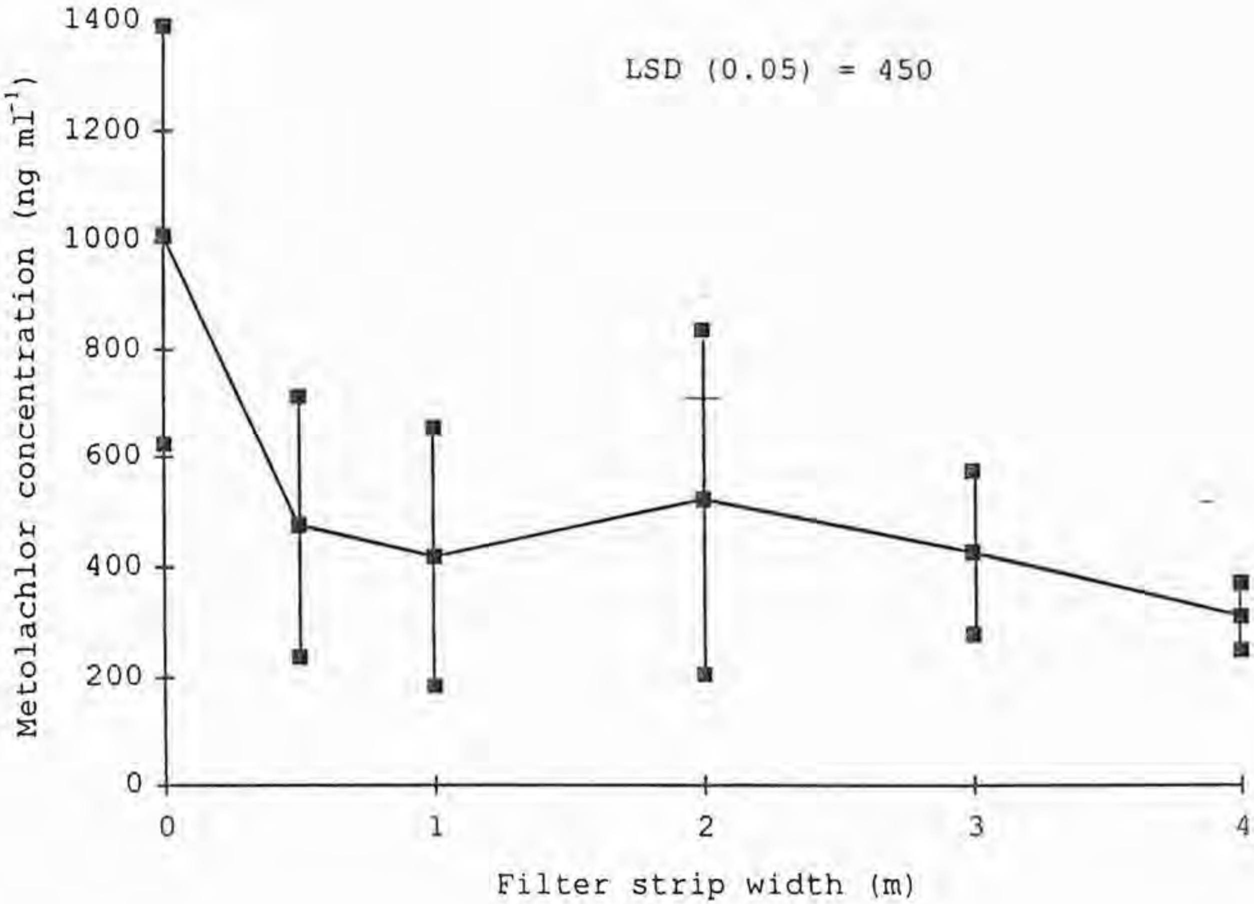

Figure 4. The effect of filter strip width on metolachlor concentration 2 days after initiation of study. Means are shown with standard deviations.

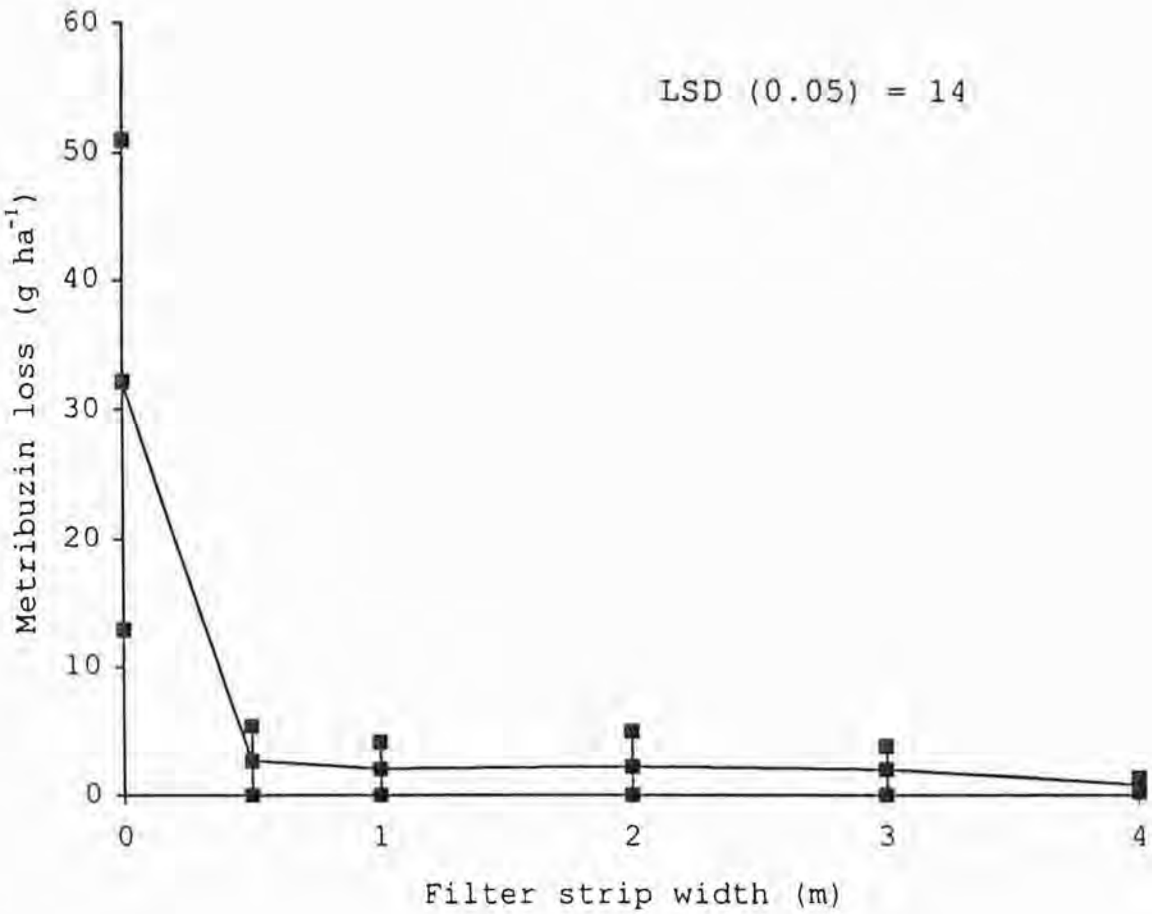

Figure 5. The effect of filter strip width on metribuzin loss 2 days after initiation of study. Means are shown with standard deviations.

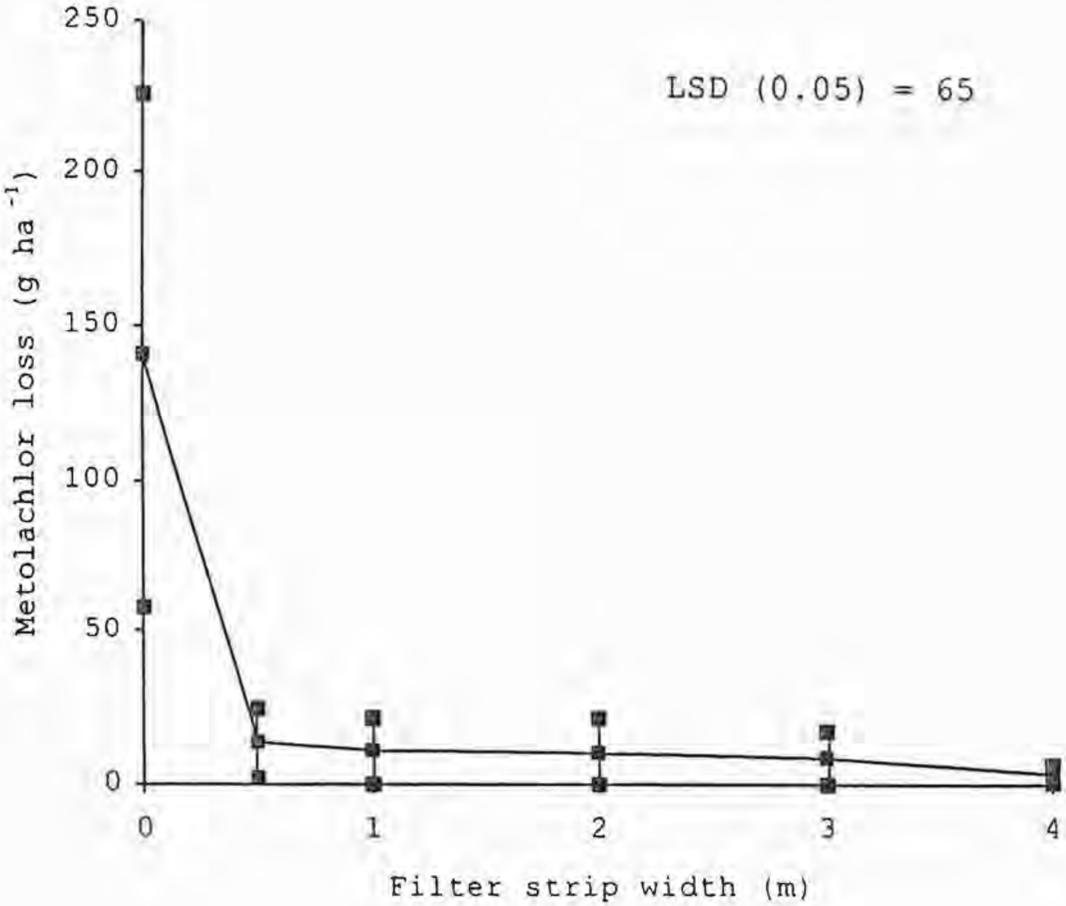

Figure 6. The effect of filter strip width on metolachlor loss 2 days after initiation of study. Means are shown with standard deviations.

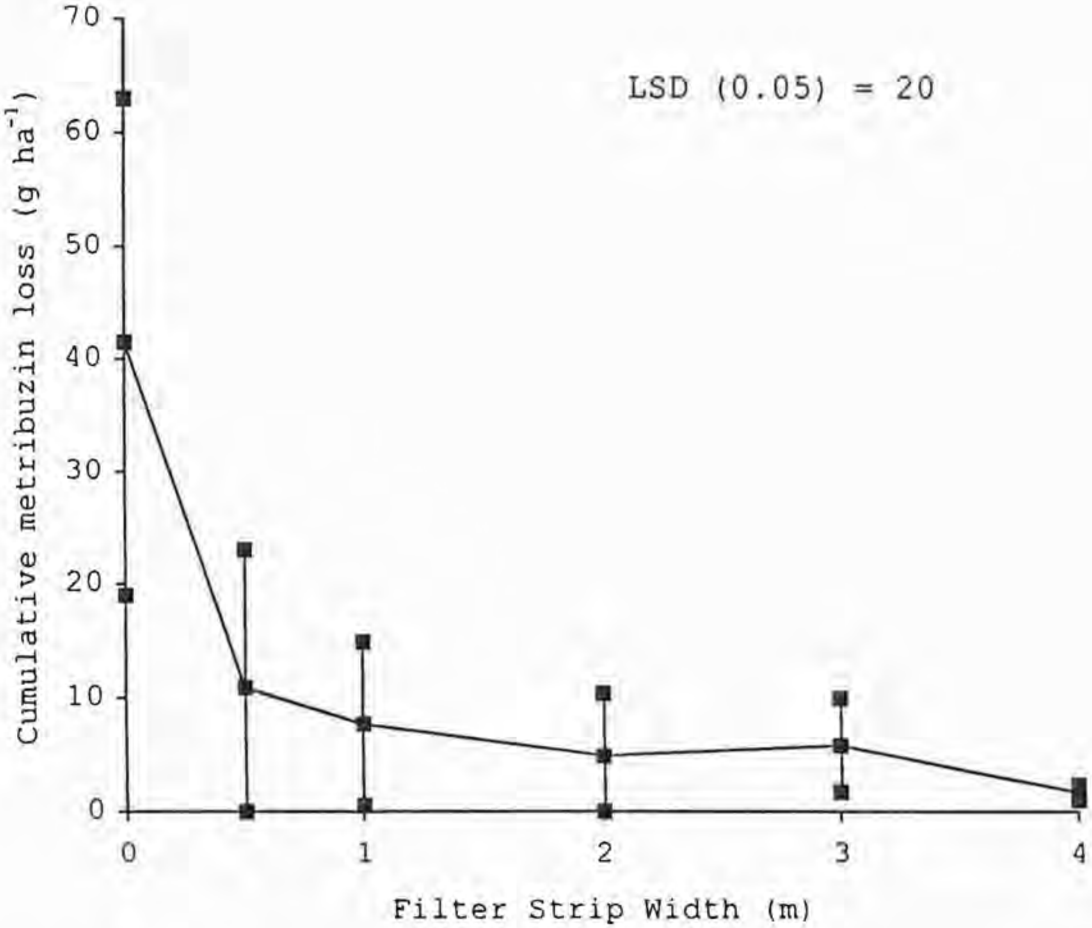

Figure 7. The effect of filter strip width on the reduction of cumulative metribuzin loss through 84 days after initiation of the study.Means are shown with standard deviations.

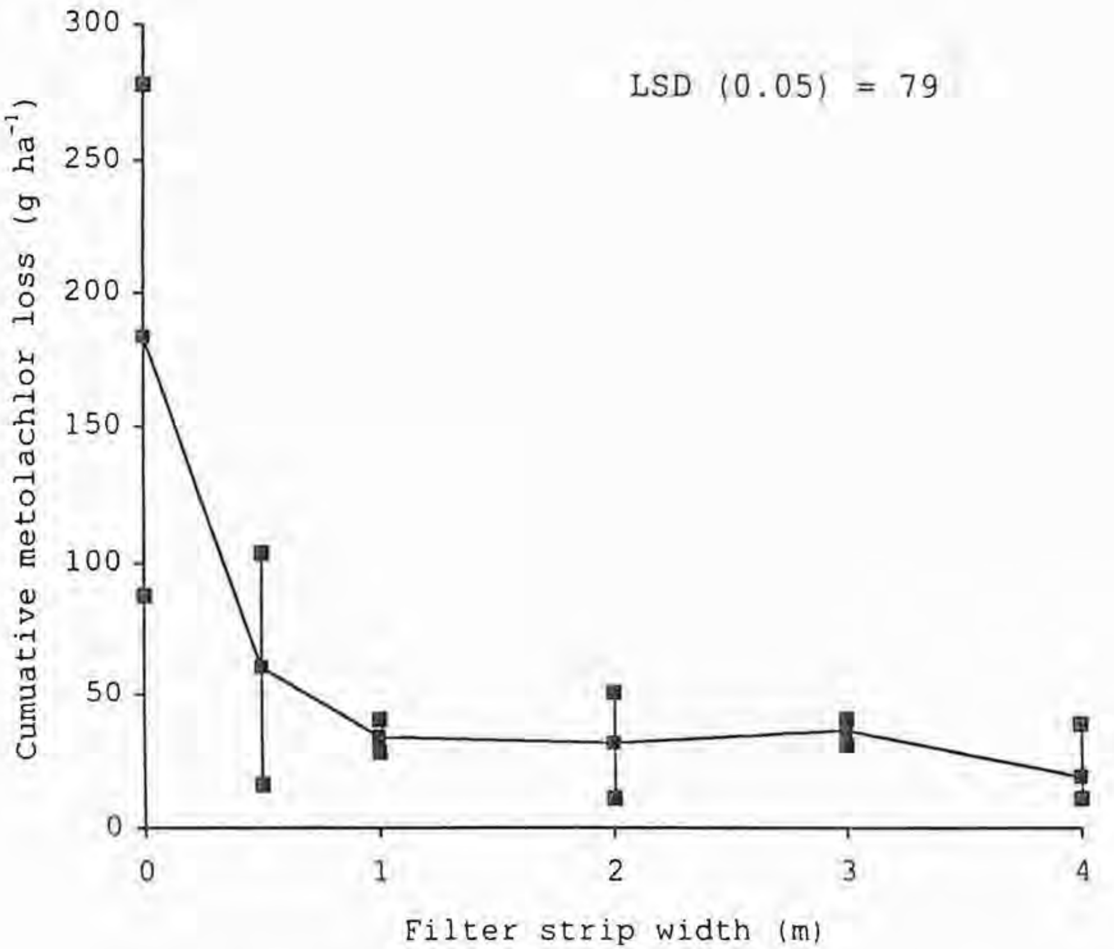

Figure 8. The effect of filter strip width on cumulative metolachlor loss through 84 days after initiation of the study. Means are shown with standard deviations.

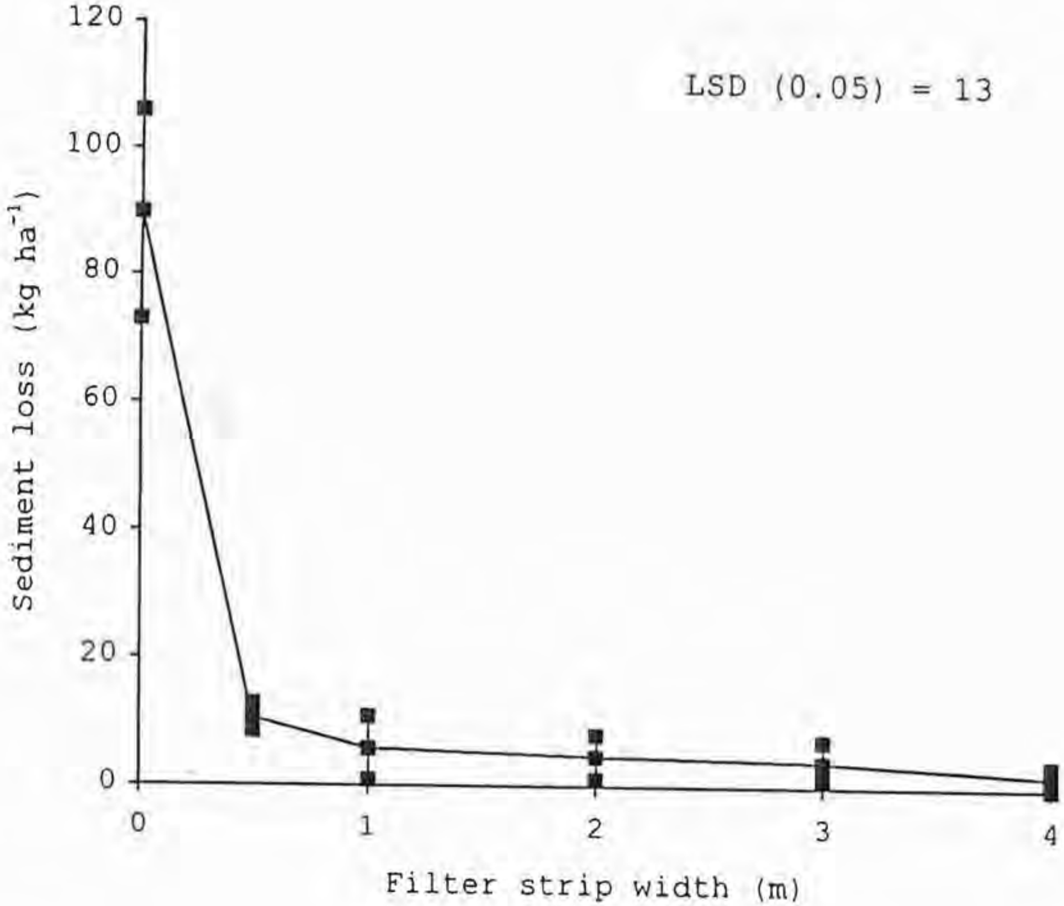

Figure 9. The effect of filter strip width on sediment loss 2 days after initiation of study. Means are shown with standard deviations.

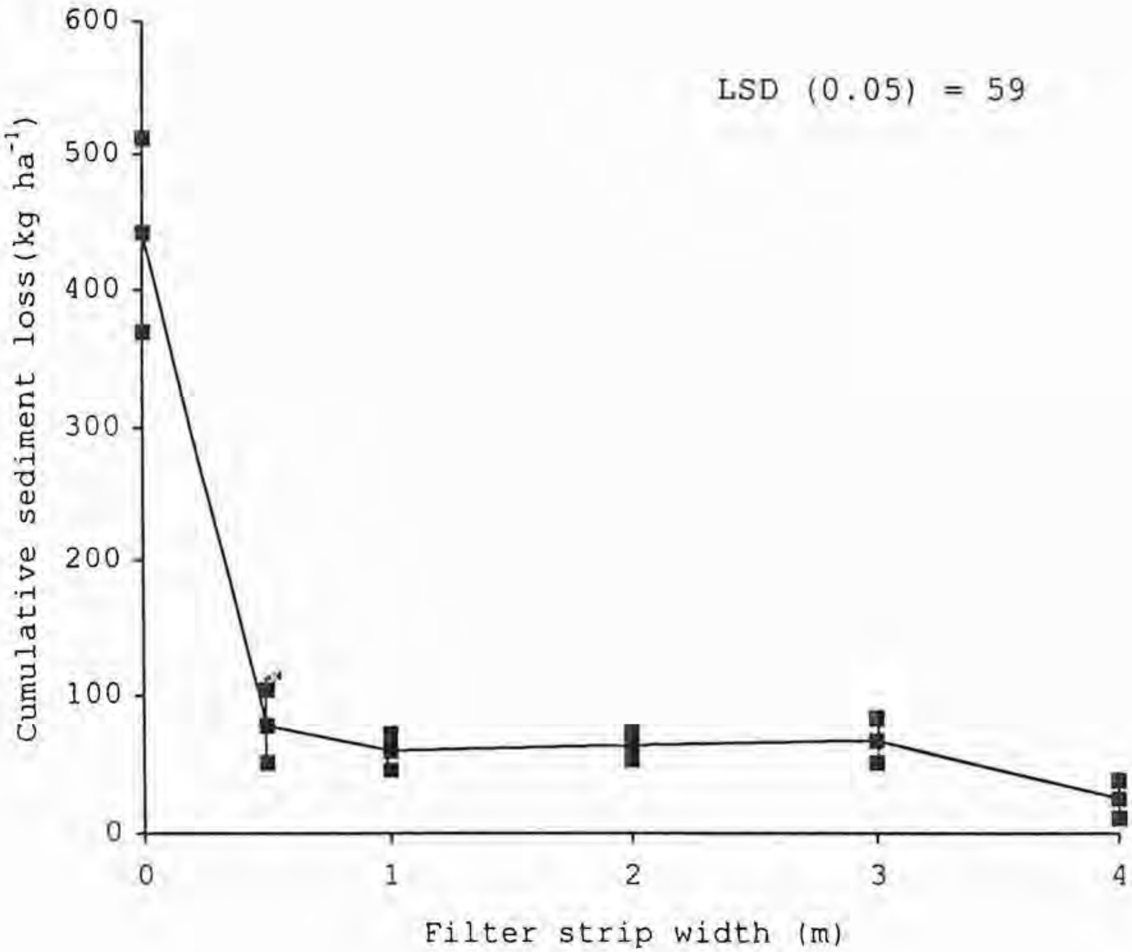

Figure 10. The effect of filter strip width on cumulative sediment loss through 84 days after initiation of the study. Means are shown with standard deviations.