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Effect of a full-grown vegetative filter strip on herbicide runoff: Maintaining of filter capacity over time

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Abstract

Narrow vegetative filter strips (VFS) proved to effectively reduce herbicide runoff from cultivated fields mainly due to the ability of vegetation to delay surface runoff, promote infiltration and adsorb herbicides. Since VFS are dynamic systems, their performance would not remain constant over the years indicating the need to define suitable buffer management. In order to evaluate the performance of different five and six year-old VFS, the runoff of the herbicides metolachlor and terbuthylazine was monitored in 2002 and 2003 in an experimental site in northern Italy. The structure of the herbaceous cover in the buffers changes over time. When rows of trees are present, the grass cover is decreased by the shading action of the trees, but the leaf litter gains importance. In VFS with grass cover only, the cover composition changes because of the substitution of grass by broadleaf species. Six metres wide VFS are very effective in reducing runoff volume and concentration during both wet and dry years. Classification analysis showed that runoff concentration and volume are linked to the characteristics of the rainfall event, buffer, source of herbicides and time after application. Regression analysis showed that the significant predictors for runoff volume are rainfall amount and intensity, total vegetal cover in the VFS, crop leaf area index and time after treatment; for concentration they are rainfall intensity, crop leaf area index and total vegetal cover in the VFS. The role of VFS is complex, so appropriate management is required to maintain its increasing filtering capacity over time.

Keywords: Vegetation management; Buffer strips; Metolachlor; Terbuthylazine

1. Introduction

The migration of pesticides and related metabolites from farmland, by runoff to surface water and by leaching to groundwater, can lead to toxic effects on non-target organisms and contamination of drinking and irrigation water. To reduce diffuse pollutant transport and improve water quality, various in-field and off-site best management practices have been suggested depending on the type and mechanism of pollutant loss (Misra et al., 1996).

Many in-field methods and levels of action can help to reduce this loss: for example, new or improved cropping practices, such as integrated pest management, selecting more environmentally-friendly pesticides, choosing the best application method, rate and period or the use of non-chemical methods. However, diffuse pollution cannot be totally prevented once pesticides have been introduced in a field (Margoum et al., 2006).

Narrow vegetative filter strips (VFS), or buffer strips, represent a potential low-input technique to reduce pesticide transport in water runoff from cropland to adjacent water bodies (Rankins and Shaw, 2001; Borin et al., 2004). VFS can improve water quality and produce additional environmental benefits when used along with other best management practices.

In recent years, many studies have evaluated VFS effectiveness in removing pesticides from water runoff, and the

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mechanisms relating to VFS performance have been described, such as infiltration rate, sedimentation, adsorption and dilution (USDA, 2000; Lacas et al., 2005).

Based on the review by Krutz et al. (2005), parameters affecting herbicide retention in VFS include: VFS width (Barfield et al., 1998; Schmitt et al., 1999; Mickelson et al., 2003), antecedent moisture content (Asmussen et al., 1977; Rhode et al., 1980) and herbicide properties (Arora et al., 1996; Webster and Shaw, 1996; Rankins and Shaw, 2001; Blanche et al., 2003; Krutz et al., 2004).

Many studies have also evaluated the effect of vegetation type on herbicide retention in VFS. Differences have been described in the ability of vegetation to delay surface runoff, promote infiltration and adsorb herbicides (Schmitt et al., 1999; Rankins and Shaw, 2001): generally, tall, stiff grasses with high stem density form deeper ponds and reduce flow better. Other criteria must be met for a species to form an effective VFS, such as tolerance to herbicide drift and accidental over-sprays, longevity, competitiveness, tolerance to shading from the cultivated crop and tree rows. While some authors (Benoit et al., 1999; Blanche et al., 2003; Krutz et al., 2003) have studied the evolution of VFS performances in relation to time after establishment, emphasizing the effect of increase in organic matter content, size and stability of soil aggregates, soil porosity and infiltration capacity, few have described the effect of the dynamics of herbaceous vegetation over time.

VFS are dynamic systems with characteristics (tree height, shading, root extension, floral composition of herbaceous cover, litter accumulation, organic matter content, grass thatch) that change over time: all these factors could be relevant to VFS performance, which is never constant over the years. It is therefore necessary to define specific management methods, as maintenance is critical.

The Po Valley (north-east Italy) is an area where fields have a low slope and the landscape is characterized by small fields, due to highly-fragmented land ownership. In this situation, a narrow VFS is the most suitable type of buffer. To evaluate the effectiveness of narrow VFS in an area with low slope, a research programme began in 1997 with the planting of multipurpose buffers of different composition and width.

The effects of VFS in removing nutrients and herbicides at mid-point of the coppicing cycle have been reported in Borin et al. (2005) and Vianello et al. (2005). The latter highlights that herbicide concentrations in runoff may depend on adsorption on organic matter, but this factor changes quickly because of the evolution in the herbaceous cover.

The aims of this paper are: (1) to assess the performances of different VFS in reducing herbicide concentrations and losses 5 and 6 years after their establishment, i.e., in the last phase of the first coppicing cycle; (2) compare their effectiveness over time in relation to growth; and (3) identify VFS and field properties that characterize the ability to reduce pesticide runoff.

2. Material and methods

2.1. Site information

The study was done at the Padova University Experimental Farm in the Po Valley, north-east Italy (45°12′N, 11°58′E, altitude 6 m.a.s.l.). Soil type is classified as Fulvi-Calcaric Cambisol (FAO-UNESCO, 1990). It is silty-loam textured (11.8% clay, 44.9% silt, 43.3% sand), rich in limestone, with sub-basic pH (pH 8.11), relatively low organic carbon content (0.92%) and medium–low hydraulic conductivity (4.7×10^{-4} cm s^{-1}). According to the De Martonne classification, the climate is sub-humid (De Martonne, 1926): annual rainfall is about 805 mm and mainly falls during spring and autumn.

The buffer zone was created in 1997, on the basis of the Veneto Region Directive, to obtain multifunctional effects: wood production, landscape improvement, reduction of non-point source pollution from nutrient and pesticide runoff, and increased biodiversity. The VFS were formed by two elements: herbaceous cover and rows of alternating shrubs and trees. The shrub function was to fill the soil layer near the row and separate the tree roots to avoid the spread of fungal diseases. According to the protocol, coppicing was done every 6 years (the first was in November 2003).

The experimental site is a rectangular field of 200 m × 35 m, with a 1.8% slope down towards a ditch. Four types of VFS, between cropland and ditch, are compared with a plot without VFS (NoVFS) cultivated to the edge of the ditch. The VFS differ in width and composition: (a) 3 m wide buffer formed by grass cover only (3G), (b) 3 m wide buffer with grass cover and a shrub and tree row (3G1R), (c) 6 m wide buffer with a shrub and tree row (6G1R) and (d) 6 m wide buffer with two rows of trees and shrubs (6G2R). The rows are 1.5 and 4.5 from the ditch. The herbaceous cover is *Festuca arundinacea* Schreber and the rows are of regularly alternating *Viburnum opulus* L. shrubs and *Platanus hybrida* Brot. trees. The plots are 20 × 35 m and the five treatments have two replicates.

This paper reports the data from 5 (2002) and 6 (2003) years after VFS creation.

2.2. Buffer management and measurement of vegetal cover

The grass was sown (30 kg ha^{-1} seeds), and shrubs and trees planted in November 1997. VFS management involved mowing the herbaceous cover and thinning the plane tree offshoots. The grass was mown at least twice a year during the growing season leaving the vegetation *in situ*, according to low cost maintenance management.

Observations and measurement of the herbaceous cover and litter were done in August each year on all the VFS. The percentage of herbaceous cover and leaf litter layer was first estimated for the total buffer area, delineating two or more homogeneous sub-areas and then calculating