ELSEVIER

Chemosphere 61 (2005) 717–725

CHEMOSPHERE

www.elsevier.com/locate/chemosphere

Herbicide losses in runoff events from a field with a low slope: Role of a vegetative filter strip

Monica Vianello [a,*], Costantino Vischetti [b], Luciano Scarponi [c], Giuseppe Zanin [d]

[a] *Dipartimento di Agronomia Ambientale e Produzioni Vegetali, Università di Padova, Agripolis, Viale dell'Universitá 16, 35020 Legnaro (PD), Italy*

[b] *Dipartimento di Scienze Ambientali e delle Produzioni Vegetali, Università Politecnica delle Marche, via Brecce Bianche, 60131 Ancona, Italy*

[c] *Dipartimento di Scienze Agroambientali e Produzione Vegetale, Università degli Studi, Borgo XX Giugno 72, 06121 Perugia, Italy*

[d] *CNR—Istituto di Biologia Agroambientale e Forestale, Sezione di Legnaro—Malerbologia, Agripolis, Viale dell'Università 16, 35020 Legnaro (PD), Italy*

Received 26 July 2004; received in revised form 12 March 2005; accepted 19 March 2005
Available online 28 April 2005

Abstract

Herbicide runoff and the effects of a narrow vegetative filter strip (VFS) were studied on an arable field in the low-lying plains of the Veneto Region (north-east Italy). Cultivated plots were compared with and without a 6 m wide VFS composed of trees, shrubs and grass. Natural and simulated runoff were monitored during 2000 and 2001. Herbicides applied on the field were: metolachlor (2184–2254 $g\,ha^{-1}$), terbuthylazine (1000–1127 $g\,ha^{-1}$) and isoproturon (1000 $g\,ha^{-1}$). The VFS reduced both runoff depth (10.2–91.2%) and herbicide losses (85.7–97.9%) in the monitored rainfall events. Total herbicide loss with runoff was low (0.69–3.98 $g\,ha^{-1}$ without VFS, less than 0.27 $g\,ha^{-1}$ with VFS), but concentrations were sometimes very high, especially of terbuthylazine and isoproturon during the first events after treatment. In these events there was a high probability of exceeding the ecotoxicological endpoint for algae, but the VFS helped to reduce the potential risk. Two VFS effectiveness mechanisms were identified: (i) dilution, and (ii) a "sponge-like" effect, which temporarily trapped chemicals inside the VFS before releasing them.

Keywords: Agricultural non-point pollution; Ecotoxicology; Metolachlor; Terbuthylazine; Isoproturon

1. Introduction

Relatively small herbicide loads are carried by surface runoff water in relation to the amount applied to a cropped field (from less than 0.5% up to 5%) (Wauchope, 1978), yet they can be a potential environmental risk. The main pathway for herbicide losses is surface runoff, and a rainstorm shortly after application can determine high chemical concentrations in the runoff (Brown et al., 1995; Ng and Clegg, 1997), which can lead to serious consequences for water quality and wildlife habitats.

A vegetative filter strip (VFS) is proposed as a means to reduce surface water contamination caused by

* Corresponding author. Tel.: +39 0498272822; fax: +39 0498272839.
E-mail address: monica.vianello@unipd.it (M. Vianello).

0045-6535/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.chemosphere.2005.03.043

agricultural non-point pollution (Gilliam, 1994; Daniels and Gilliam, 1996; Lee et al., 2000; Rankins and Shaw, 2001). VFS acts as a natural dam or terrace and, by reducing runoff, the water has more time to penetrate and incorporate the pollutants in the soil and thus prevent off-site movement (Webster and Shaw, 1996). VFS alters flow hydraulics, reducing runoff speed and increasing water infiltration (Misra et al., 1996). The filter thus enhances sediment deposition and filtration by vegetation, pollutant adsorption onto the soil and dead and living plant materials, and uptake of soluble pollutants by plants (Misra et al., 1996; Blanche et al., 2003).

Infiltration was found to be the most important herbicide removal mechanism associated with VFS, especially for soluble or weakly adsorbed pesticides (Klöppel et al., 1997). Watanabe and Grismer (2001), investigating diazinon transport within a VFS, found that the pesticide was trapped on its surface and in the root-zone, where further adsorption, attenuation and presumably degradation may occur. Nevertheless, enhanced infiltration could cause more leaching and the herbicide reach the water table, changing the ecotoxicological impact from surface to subsurface water.

Delphin and Chapot (2001) evaluated the leaching and investigated the fate of atrazine and de-ethylatrazine transported in runoff effluents and trapped by a grass filter strip.

The plants in the VFS confer a higher organic matter content to the filter zone than in the adjacent cultivated field. This organic matter accumulation should increase adsorption capacity and microbial activity for herbicide degradation, so reducing the amount of herbicide in surface runoff and leaching (Staddon et al., 2001). Higher herbicide dissipation in the VFS soil is due both to enhanced degradation and the formation of non-extractable (bound) residues, which can become a long-term store inside the filter (Benoit et al., 2001).

The north-east of Italy is mainly formed by the alluvial Po Valley, a flat, intensively-farmed plain. The most common arable crops are maize, winter wheat, soybean and sugarbeet.

In these conditions, narrow VFS have demonstrated their effectiveness in reducing sediment, N and P runoff (Borin et al., 2005), and in a preliminary study (Borin et al., 2004), also in reducing pesticides in subsurface water coming from cropland. The objectives of this study were to assess: (i) the importance of herbicide runoff in low slope conditions; (ii) the effects of a narrow VFS on herbicide loss in surface runoff from an arable field.

2. Materials and methods

2.1. Experimental site

The study was done during 2000 and 2001 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.).

The soil 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), good 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 in the area is sub-humid (De Martonne, 1926): annual rainfall is about 805 mm, mainly during spring and autumn. Weather data were collected at the weather station on the farm.

The experimental site consisted of 20 m × 35 m plots with a 1.8% slope downwards to a ditch. Two treatments were compared: plots cultivated to the edge of the ditch and plots with a 6 m wide VFS between the cropland and ditch. Each treatment (with or without VFS) had two replicates.

The VFS was composed of grass and two shrub-tree rows. The grass was *Festuca arundinacea* Schreber, with regularly alternating shrubs *Viburnum opulus* L. and trees *Platanus hybrida* Brot in the rows. The two rows were 1.5 m and 4.5 m from the ditch, planted 2 m apart in the centre of 1.2 m wide ethylene–vinyl acetate (EVA) film. The grass was sown (at a density of 30 kg ha^{-1}), and shrubs and trees planted in 1997. The grass was cut at least twice a year during the growing season.

In 2000, plots were cropped with maize and two herbicide treatments applied: metolachlor and terbuthylazine at pre-emergence and terbuthylazine at post-emergence. After maize harvesting, the plots were cropped with winter wheat and sprayed with isoproturon, and then (summer 2001) cropped with soybean and sprayed with metolachlor. The soybean was sod-seeded on the winter wheat stubble. Herbicides were applied using a tractor-mounted Hardy LY–HY sprayer equipped with a 12 m boom and 4110-16 fan nozzles. Standard agronomic practices were followed (Table 1). Weather conditions were optimal during herbicide treatments, assuring good distribution uniformity. The physico-chemical properties and ecotoxicological endpoints of the herbicides are reported in Table 2.

Simulated rainfalls using a sprinkler irrigation system were applied to all plots 1 day after the second terbuthylazine treatment on 25 May 2000 (52 mm rainfall at 43 mm h^{-1} intensity) and 28 days after the metolachlor application on 31 July 2001 (87 mm rainfall at 82 mm h^{-1} intensity).

2.2. Runoff monitoring and water samples collection

A collector system with multi-pipe divisor (Morari et al., 2001) was designed and built to measure runoff volumes and collect water samples. There was a sampler for each plot, located in the ditch. The system allowed