Agriculture, Ecosystems and Environment 253 (2018) 1–10

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Research Paper

Effect of grass hedges on runoff loss of soil surface-applied herbicide under simulated rainfall in Northern China

Qinghai Wang[a,*], Cui Li[a], Zhuo Pang[a], Haifeng Wen[a], Ruilun Zheng[a], Jie Chen[a], Xueju Ma[a], Xiaoe Que[b,**]

[a] *Beijing Research & Development Center for Grass and Environment, Beijing Academy of Agriculture and Forestry Sciences, Beijing, China*
[b] *Institute of Desertification Studies, Chinese Academy of Forestry, Beijing, China*

A R T I C L E I N F O

Keywords:
Grass hedge
Atrazine loss
Surface runoff
Sloping cropland

A B S T R A C T

Pesticide loss triggered by runoff is one of the most important sources of non-point pollution. The effects of grass hedges (*Melilotus albus* and *Pennisetum alopecuroides*) on atrazine runoff under different rain intensities and slope gradients were evaluated. The plot-scale experiments were carried out on a maize (*Zea mays*) field on slopes with 15% and 20% gradients using simulated rainfall (rain intensity of 30 and 45 mm h^{-1}). Atrazine residues were investigated in runoff water and soil taken from three depths (0–5, 5–10, and 10–15 cm) in the middle and base of the slope after runoff events. Total atrazine loss in runoff water ranged from 2.3% to 4.9% of that applied from plots without grass hedges. Grass hedges decreased atrazine loss by 37%-76% and surface runoff by 27%-72%, and Pennisetum showed better efficacy than Melilotus, especially under higher rain intensity. Atrazine loss showed a significant positive linear correlation with surface runoff volume. Grass hedges had a more significant effect on atrazine loss than rain intensity and slope gradient. But they functioned less effectively if used under intense rain or/and steep slope conditions. Atrazine residues remained in the surface 15 cm soil were higher for the plots with grass hedges than the control plots. These results suggest that grass hedges not only significantly reduced atrazine loss by reducing the surface runoff, but also reduced the amount of atrazine leaching to deeper soil layer. *P. alopecuroides* was a suitable grass-hedge species for controlling atrazine losses in northern China and similar regions. Other management practices or control measures should be integrated with grass hedges in strongly sloping cropland in high-rainfall areas to maintain pesticide losses at an acceptable level.

1. Introduction

World pesticide usage at the producer level totaled nearly 2.7×10^9 kg annually in both 2011 and 2012 (Atwood and Paisley-Jones, 2017). Given the magnitude of global pesticide use, widespread pesticide contamination of surface water and groundwater is expected (Rippy et al., 2017). During 1992-2011, the proportion of assessed streams with one or more pesticides that exceeded an aquatic life benchmark was 61% for agricultural streams in USA (Stone et al., 2014). In developing countries, contamination of ground and surface water with pesticides is more prevalent (Schwarzenbach et al., 2010). Because it is biologically active, water pollution caused by pesticides used in agriculture is a major concern worldwide (Juergens et al., 2015; Stehle and Schulz, 2015). It poses a significant health risk to humans and other animals (Hussain et al., 2009). Pesticides deposition in soil is one of the major pollution sources. These pesticides can enter surrounding surface waters mainly through diffuse sources, surface runoff and erosion is one of the most important pathways of pesticide input in aquatic ecosystems among diffuse pollution (Vymazal and Březinová, 2015). Surface runoff water acted as the major mobile carrier of pesticide mobilization from agricultural land to ecosystem, because sediment amount is usually small compared to the runoff volume from a field (Reichenberger et al., 2007). Pesticides losses linked to runoff during the growing season have been reported to account for greater than 60% of the total loss (Potter et al., 2014). Herbicide concentrations in the runoff obtained during the first rainfall events after treatment, had a high probability of exceeding the ecotoxicological endpoint for algae (Vianello et al., 2005). Therefore, adequate control of runoff, and subsequent pesticide loss is very important. Among the various control measures, grass hedges, a special type of vegetative filter strips defined as narrow strips of stiff-stemmed grass used to control runoff and erosion (Vieira and Dabney, 2012), are commonly used in preventing soil and water loss on sloping croplands all over the world due to their low cost, eco-friendliness and efficiency (Xiao et al., 2011).

* Corresponding author at: Beijing Research and Development Center for Grass and Environment, No. 9 Shuguang Garden Road of Haidian District, Beijing, 100097, China.
** Corresponding author.
E-mail addresses: wangqinghai@baafs.net.cn (Q. Wang), quexiaoe@sina.com (X. Que).

http://dx.doi.org/10.1016/j.agee.2017.10.024
Received 6 July 2017; Received in revised form 14 October 2017; Accepted 27 October 2017
0167-8809/

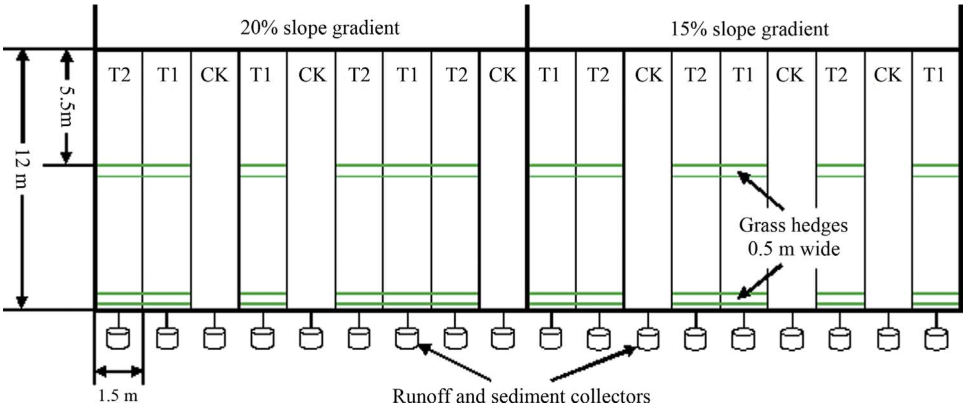

Fig. 1. Schematic diagram of experimental plot, T1 = Melilotus hedge, T2 = Pennisetum hedge, and CK = control.

Atrazine is a photosynthesis inhibiting triazine herbicide that has been used for approximately 50 years and has become one of the most heavily applied agricultural herbicides in the world (Jablonowski et al., 2011). Furthermore, it exhibits relatively high water solubility (32 mg L^{-1}) and moderate environmental persistence (half-life in soil: 146 d) with adsorption coefficient (logKoc) of 1.97 (Bouldin et al., 2006), and is frequently detected in surface water and shallow groundwater (Bradley et al., 2017). It has become the subject of continuous concern due to its potential endocrine and carcinogenic activity (Jablonowski et al., 2011; Richter et al., 2016).

Atrazine has been widely accepted as an important tool in controlling weeds in summer maize, a main crop in the predominant cropping system in Northern China where there is severe soil and water loss (Mao and Ren, 2004; Xiao et al., 2011). Atrazine application period is just in the rainy season, and frequent strong thunderstorms with such features as high intensity and short duration typically occur in this region, thus atrazine has huge potential of losses in surface runoff with water and sediment in this region. In terms of runoff-producing rainfall events after herbicide application, the first few storms are often responsible for the largest herbicide losses (Baker and Mickelson, 1994). These extreme events dominate herbicide transport and are critical for devising management practices or control measures, and monitoring total pesticide loss (Shipitalo and Owens, 2006). It is, therefore, of great significance and broadness to evaluate the effectiveness of grass hedges in reducing herbicide loss, as well as to quantify atrazine loss from sloping agricultural fields in runoff events, especially rainstorms shortly after its application.

Melilotus (Melilotus albus) and Pennisetum (Pennisetum alopecuroides) are promising grass hedge candidates due to their native and non-invasive characteristics, tolerance to the climate extremes, as well as sufficient stem strength for blocking water flow, and provide an efficient way to prevent soil and water loss on sloping croplands (Wu et al., 2010; Xiao et al., 2011). However, little is known about their effectiveness on herbicide loss and their influences on herbicide distribution in soil at different rain intensities and slope gradients. Achieving such information may help to seek for suitable grass species to develop grass hedges for the temperate regions, and to explore the potential of grass hedges alone for reducing pesticide loss to an acceptable level under extreme conditions (such as heavy rainfall, steep slope). Consequently, the main objectives of this research were to (1) estimated runoff loss of atrazine for storms of high intensity and short duration occurring shortly (4 h) following application to soil surface, (2) determine the efficacy of the two types of hedges (Melilotus and Pennisetum) in decreasing atrazine loss and their influences on atrazine distribution in soil, and (3) analyze the relative importance of grass hedges, rain intensity and slope gradient for atrazine losses. This research extends previous work of Wu et al. (2010) and Xiao et al. (2011) by focusing on herbicide loss rather than water and soil loss, and quantifying the correlations between herbicide loss and surface runoff. This study also gains data for future use in predicting potential pesticide loss due to runoff and evaluating the risk to water quality.

2. Materials and methods

2.1. Study site

The study was carried out at the National Experimental Station for Precision Agriculture (116°26′ E, 40°10′ N) in Beijing, China. The experimental station is located in North China and is characterized by a continental, semi-humid, and monsoon climate. The mean precipitation is 640 mm y^{-1}, 80% of which occurs between June and August. The mean annual temperature is 11.5 °C. Rotation of winter wheat and summer maize dominates agricultural activities in the region. The soil is brown fluvo aquic soil in type and loamy clay in texture (41% sand, 24% silt and 35% clay) with a pH of 7.6. The bulk density is 1.37 g cm^{-3}, The soil organic matter content and the total nitrogen and phosphorus are 14.0, 2.46 and 0.63 g kg^{-1}.

2.2. Experimental design and herbicide application

The experiment was based on three independent variables: grass hedges (Melilotus hedges, Pennisetum hedges, and without grass hedges as control), slope gradients (15% and 20%), and rainfall intensities (30 and 45 mm h^{-1}). Eighteen 1.5 m by 12 m plots (3 hedge levels × 2 slope gradients × 3 replications) were established. Plots were separated by 2-mm-wide sheet metal frames driven approximately 30 cm into the soil in two sides of the plots (but not the top and bottom). The grass hedges were located at the middle and bottom positions of selected test plots. They were established in June 2012 in two parallel rows perpendicular to the slope direction (Fig. 1). The grass hedges were thick enough (densities of Melilotus and Pennisetum was 684 and 125 stems m^{-2}) when the experiments were conducted.

Summer maize was sown manually in all plots of every treatment after the harvest of winter wheat without tillage in both years (27 June 2013 and 20 June 2014, respectively). Afterwards, atrazine (38% Suspension concentrates) was applied on the soil surface using a hand sprayer at recommended field dosage [1282.5 g ha^{-1} (ai)]. All sprays were applied on the day that the summer maize was sown.

2.3. Rainfall Simulation and Runoff Collection

Rainfall simulation has been used extensively as a cost-effective method to evaluate the effects of managements on infiltration, surface runoff, soil erosion, and contaminant transport in overland flow (Humphry et al., 2002; Sharpley and Kleinman, 2003). It exhibits advantages in expediting data collection, as well as creating controlled and reproducible artificial rainfall for comparison among locations (Humphry et al., 2002). In this study, precipitation was simulated using