Science of the Total Environment 490 (2014) 1–10

Contents lists available at ScienceDirect

Science of the Total Environment

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

Comparative assessment of herbicide and fungicide runoff risk: A case study for peanut production in the Southern Atlantic Coastal Plain (USA)☆

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HIGHLIGHTS

- Herbicide and fungicide runoff was measured during production of 4 peanut crops.
- Much higher fungicide runoff rates were observed.
- Results were linked to application frequency and timing with respect to runoff.
- Data emphasize need for more fungicide runoff research.
- Findings showed that conservation-tillage may effectively reduce runoff losses.

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 10 March 2014
Received in revised form 8 April 2014
Accepted 8 April 2014
Available online xxxx

Editor: D. Barcelo

Keywords:
Conservation tillage
Erosion
Risk assessment
Peanut
Tebuconazole
Metolachlor

ABSTRACT

Peanut (*Arachis hypogaea*) is produced intensively in the southern Atlantic Coastal Plain of the eastern USA. To effectively protect the region's water quality data are needed which quantify runoff of pesticides used to protect these crops. Fungicides are used intensively yet there is little published data which describe their potential for loss in surface runoff. This study compared runoff of a fungicide, tebuconazole (α-[2-(4-chlorophenyl)ethyl]-α-(1,1-dimethylethyl)-1*H*-1,2,4-triazole-1-ethanol), and an herbicide, metolachlor (2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide) from 0.2 ha fields in strip (ST), a commonly used conservation-tillage practice, and conventional tillage (CT) near Tifton, GA (USA). Following their first application, metolachlor and tebuconazole were detected at high frequency in runoff. Concentrations and their annual losses increased with application frequency and runoff event timing and frequency with respect to applications, and when fields were positioned at the top of the slope and CT was practiced. Runoff one day after treatment (DAT) contributed to high tebuconazole runoff loss, up to 9.8% of the amount applied on an annual basis. In all cases, metolachlor loss was more than 10 times less even though total application was 45% higher. This was linked to the fact that the one metolachlor application to each crop was in May, one of the region's driest months. In sum, studies showed that fungicide runoff rates may be relatively high and emphasize the need to focus on

☆ Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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http://dx.doi.org/10.1016/j.scitotenv.2014.04.034
0048-9697/Published by Elsevier B.V.

these products in future studies on peanut and other crops. The study also showed that peanut farmers should be encouraged to use conservation tillage practices like ST which can substantially reduce pesticide runoff.

1. Introduction

Worldwide an estimated 3 million metric tons of pesticide active ingredients are applied to crop-land annually at a cost of more than 40 billion dollars (Popp et al., 2013). Compelling arguments can be made that use of these products substantially increases economic returns to farmers while lowering consumer food costs and increasing food security (Oerke, 2006; Popp et al., 2013). However pesticides also have well documented potential for adverse impact on human health and the environment (Gilliom et al., 2006). A primary concern is water quality impairment when residues are transported from farm fields to streams and rivers in surface runoff.

There are three broad categories of pesticides in common use: herbicides, insecticides, and fungicides. Products are applied at different times, rates, and frequency depending on pest pressure, economics, climatic conditions, regulatory limits, and other factors. Typically multiple applications are made. Using simulation models, Haith (2010) and Verro et al. (2009) effectively demonstrated that evaluating potential water quality impact due to runoff requires examining relative risk associated with each application of each active ingredient. Key findings were that runoff from farm fields and other treated areas likely contains mixtures of pesticides with potential for interactive ecotoxicological impact and that fungicides when used had high runoff risk. This was explained by the high frequency with which these products are applied to some crops thus increasing potential for runoff to occur close to the time of application. Numerous studies have demonstrated that the highest pesticide runoff losses occur in events soon after they were applied (Southwick et al., 1993; Wauchope, 1978; Wauchope et al., 1995; Sadler et al., 2014).

Water quality monitoring studies in the USA, Europe, and Australia that have targeted fungicides appear to confirm their high runoff potential (Battaglin et al, 2011; Berenzen et al., 2005; Gregoire et al., 2010; Herrero-Hernández et al., 2013; Kahle et al., 2008; Knäbel et al., 2014; Montuelle et al., 2010; Polard et al., 2011; Rabiet et al., 2010; Rasmussen et al., 2011; Reilly et al., 2012; Smalling et al., 2012; Wightwick et al., 2012). In some studies residues were detected in >50% of all samples with the highest concentrations correlated with storm events that generated surface runoff during growing seasons. Generally, concentrations of compounds detected in these studies did not indicate that human and or ecological risks were high. However data did not provide the basis for comprehensive risk assessments since sampling campaigns and analytical schedules were limited in scale and scope. There are also uncertainties about levels that may have adverse impact (Battaglin et al., 2011; Rodrigues et al., 2013; Verro et al., 2009).

This study was designed to evaluate relative runoff risks of an herbicide, metolachlor, and a fungicide, tebuconazole, commonly used for peanut production and to determine the potential for a commonly used conservation tillage practice, strip-tillage (ST), to reduce their runoff losses. Work was conducted in the Southern Atlantic Coastal Plain region of the eastern USA where more than 3/4 of the nation's peanuts are grown.

2. Materials and methods

2.1. Site description

Investigations were conducted in Tift County Georgia, USA (N 31° 26′13″, W 83° 35′17″). In the fall of 1998, a 1.8-ha parcel on a naturally occurring hill-slope was divided into one 0.4-ha and two 0.6-ha blocks (Fig. 1). The two 0.6-ha blocks running up and down the prevailing 2–3% slope were used in the current investigation. These blocks were randomly assigned to either CT or ST management and divided into three 0.2-ha fields running across the slope so that soil, hydrologic, and water quality responses could be compared by both tillage and slope position (Bosch et al., 2012). Crop residues on CT fields were plowed into the soil prior to planting. On ST fields crops were planted into 15-cm wide strips tilled into the desiccated cover crop mulch. These tillage practices were maintained continuously until the end of the study in 2009. Each field was surrounded by a 0.6 m high earthen berm that directed surface runoff to 0.46-m metal H-flumes located at down slope plot corners. Flow was recorded electronically using pressure transducers (Druck Inc., New Fairfield, CT, USA) calibrated to record runoff hydrographs. Rainfall was monitored using a tipping bucket rain gauge. Accuracy of pressure transducers and rain gauges were verified at 6 month intervals. Bosch et al. (2012) summarized results of hydrologic monitoring from 1999 to 2009 and soil characteristics. As noted, Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kanidult) and Carnegie sandy loam (fine, kaolinitic, thermic Plinthic Kanidult) were identified on the study site. Both soil series are characterized by an argillic horizon and plinthite below 50 cm that controls internal drainage and promotes lateral subsurface flow. Across all plots the mean ± standard deviation of sand, silt, clay and organic carbon content of surface soil samples (0–15 cm) collected prior to planting the cotton crop in 1999 was 893 ± 24 g kg^{-1} sand, 63 ± 9.7 g kg^{-1} silt, 43 ± 2.1 g kg^{-1} clay, and 5.1 ± 0.5 g kg^{-1} OC.

2.1.1. Crop and soil management

The rye grain (*Secale cearale*) cover crop used during winter months was killed by glyphosate application in the spring and after desiccation turned into the soil using a disc harrow and or mold-board plow on CT fields (1, 3, and 5). On ST fields (2, 4, and 6), 15-cm wide strips were tilled into the cover crop mulch for planting. Cotton (*Gossypium hirsutum*) was produced in 1999, 2000, 2001, 2003, 2005, 2007, and 2009 and peanut in 2002, 2004, 2006, and 2008. All crops were planted in May of each year and harvested in September through October. As is commonly practiced, one metolachlor and 3 to 5 tebuconazole applications were made to peanut crops at label rates using tractor mounted sprayers (Beasley, 2012). Metolachlor and tebuconazole properties and their number and rate of application are summarized by year in Table 1. Metolachlor was applied at planting and watered-in within 24 h with 12.5 mm sprinkler irrigation. In 2002, 2004, and 2006 the formulation, Dual II Magnum® (Syngenta Crop Protection, Greensboro, NC, USA) was used. This product is enantiomerically enriched with S-metolachlor. In 2008, a generic product Stalwart® (SipcamAgro, Durham, NC, USA) was applied. Metolachlor in this product is a racemic mixture. Tebuconazole was applied at approximately 14 day intervals between 60 and 100 days after planting. The formulation was Folicur® 3.6F (Bayer CropScience, Research Triangle Park, NC, USA).

2.1.2. Runoff sample collection

Flow-proportional composite runoff samples were collected from each 0.2-ha field during runoff events directly into 9-L glass jars using ISCO® (Lincoln, NE, USA) autosamplers with samplers programmed to withdraw 50 mL for every 520 L that passed the flumes (Potter et al., 2004). A minimum of 100 mL was necessary for pesticide analysis, thus 1040 L runoff (0.5 mm) was required for an analyzable sample. The upper bound on the sample collection system, events which would overfill the 9-L glass jar, was 63-mm runoff per event. A total of 21 of the 776 samples collected during the period covered in this study exceeded this amount. Of the samples collected when runoff overfilled sample containers only 3 were collected during peanut