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Losses of pesticides in runoff from cotton crops under different management systems

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In this study the concentrations of the atrazine, desethylatrazine (DEA), desisopropylatrazine (DIA), azoxistrobin, carbendazim, carbofuran, chlorpyrifos, diuron, endosulfan alpha and beta endosulfan sulfate, malathion, metolachlor, methomyl, monocrotofos, permethrin, profenofos, teflubenzuron, thiacloprid, tiametoxan and triflumuron were assessed in runoff water from cotton plantations under different management systems in Central-Western Brazil. The runoff water was collected from plots delimited by steel plates, where cotton was sown under no-tillage (direct seeding) and conventional soil management systems in one farm; and no-tillage soil management systems with and without a vegetated filter strip (buffer filter) planted with *Bracchiaria* grass in a second farm. In general terms, there was a 51% reduction in the total mass of off-site transport of pesticides in the no-tillage system compared to the conventional tillage. In addition, when comparing the no-tillage system with conventional tillage, the pesticides: metolachlor and alfa endosulfan as well as endosulfan sulfate, its metabolite, showed the lowest reduction in relation to the other pesticides transported by runoff. Thus, these pesticides showed broad risk of contamination of surface waters. Besides, the buffer filter reduced the off-site transport of pesticides by runoff in 92%, confirming the efficiency of a *Bracchiaria* filter strip in the retention of pesticides carried by runoff.

Key words: Runoff water, buffer filter, direct seeding, conventional plantation system.

INTRODUCTION

The agricultural sector is the primary user of pesticides in the world, consuming more than three billion kilograms of pesticides annually (Barrett and Jaward, 2012). Agricultural production is closely related to the maintaining areas in appropriate conditions for cultivation. The use of the pesticides within a management system of

the soil aims to improve the productivity of the crop.

Despite this positive effect in the improvement of productivity, pesticides can be dispersed in the environment. The main mechanisms that determine the distribution of pesticides in the environment are leaching, runoff, volatilization, retention, and transformation (Mariot

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et al., 2009).

Kennedy et al. (2001) emphasized that research teams from several universities, government departments of agriculture, land, and water, and the commonwealth scientific, made a cooperative research effort to measure aerial and surface runoff transport of pesticides, and dissipation of their residues from cotton farms. In this context, Dores and De-Lamonica-Freire (2001) made a study in cotton crops in the region of Primavera do Leste, in the state of the Mato Grosso, Brazil. It was observed that the pesticides used in cotton crops in this region are very likely to disperse in water, through the runoff, mainly, organochlorine pesticides (OCPs) such as α -endosulfan, β -endosulfan and endosulfan sulphate. Weaver et al. (2012) reported that the persistence in soil of OCP's applied to cotton crops grown more than two decades ago suggests that they could enter the food chain. Their presence at depths of 1.2 m suggests that they could move into groundwater that may eventually be used for domestic and stock consumption.

Others authors report that in the tropical regions, there is high risk of contamination of the groundwater and surface water by pesticides, therefore, it is necessary to study the influence of the management systems in the dynamic of the pesticides in soil (Carbo et al., 2008; CASARA et al., 2012).

The different systems of the soil tillage significantly influence the dynamics of pesticides in soil, because they provide different physico-hydric behavior. For example, the presence of the crop residues on the surface soil after planting provide the dissipation of impact energy from the rain drops on the soil surface, which consequently minimizes the breakdown of soil particles. Moreover, crop residues in direct contact with the soil surface are effective on the load reduction of sediments in the runoff (Bertol et al., 2007).

Several studies report that in the no-tillage system (direct seeding), in which there is conservation of the crop residues, the losses of water is smaller than the conventional tillage, where there is use of the moldboard plow, which promotes an over spray of top soil, favouring the surface crusting of the soil. In other words, formation of compacted layer, consequently, higher losses of the soil, water, and pesticides (Bernardi et al., 2003; Bertol et al., 2004; Locke et al., 2008).

According to Pinho et al. (2008), the buffer filters, represented by vegetation strips disposed crosswise in the direction of runoff, this management systems, is also a way to mitigate the flow of the pollutants, mainly by runoff. In general, the buffer filters decrease the velocity of runoff, thus, reduce the capacity of the solute transport and provide deposition of particles in suspension; filtering particulate material in suspension by vegetation and increasing of the water infiltration in the soil with consequent reduction capacity of the runoff.

In view of what has been exposed here, the objective of the present study was to assess the water losses and

mass of pesticides, atrazine and our metabolites desetilatraxina (DEA) and desisopropilatrazina (DIA), azoxystrobin, carbendazin, carbofuran, chlorpyrifos, diurom, alpha and beta endosulfan and our metabolite endosulfan sulfate, malathion, metolachloro, methomyl, monocrotophos, permethrine, prophenofos, teflubenzuron, thiachloprid, thiamethoxan, and triflumuron by runoff in experimental plots under field conditions, in cotton groups cultivated under different management systems: conventional soil preparation, no-tillage (direct seeding), and no-tillage with and without a vegetated filter strip (buffer filter) planted with *Bracchiaria* grass, in the micro-region of Primavera do Leste, localized in Mato Grosso State, Central-Western Brazil.

MATERIALS AND METHODS

Experimental sites and water sampling

The experiment consisted of installing four monitoring units on two farms located in the micro-region of Primavera do Leste, localized in Mato Grosso State, Central-Western Brazil, in one farm situated on the banks of the Chico Nunes stream and another on the banks of the Ilha stream, both tributaries of the Mortes River (Deaths Rivers) (Table 1).

On the first farms, two units were installed to monitor runoff in cotton cultivated areas. In one of them, one filter strip was set up planted with *Bracchiaria* grass. On the second farm, two units were also installed monitoring runoff in areas cultivated with cotton. In one, the monitoring units used the conventional tillage and another, the no-tillage system, both with one system collector of the runoff at its end. This collector was formed from collector gutter linked to the pipe of the polyvinyl chloride. The structure of the collector was directed on the lower end in the experimental plot, consisting of one rectangular box, built from galvanized sheet, with a filtering system (geotextile blanket). This box was made with one divisor type Geib, made on the nine openings, and the central opening was linked to a water tank that stored the volume of runoff that passed by fraction of 1/9 on the Geib (Figure 1).

According to data, pesticide applications were selected and analyzed for the following active ingredients: atrazine and our metabolites desethylatraxine (DEA) and desisopropylatraxine (DIA), azoxystrobin, carbendazin, carbofuran, clorpyrifos, diuron, endosulfan alfa and beta and your metabolite endosulfan sulfate, malathion, metolachlor, methomyl, monocrotophos, permethrine, profenofos, teflubenzuron, tiachlopridthiamethoxan, and triflumuron.

Tables 2 and 3 show the application data of pesticides during the monitoring period on the farms with cotton crops, with no-tillage system (direct seeding), conventional plantation, and a system with and without a vegetated filter strip planted with *Bracchiaria decumbens* grass.

Water samples were collected in amber glass bottles, filtered and conserved under ice immediately after collection, and transferred to the laboratory refrigerator. After the arrival of the samples in the laboratory, the analysis was started in the shortest possible time, with a period not exceeding 15 days.

Analysis of pesticides residues by gaseous chromatographic

The residues of the atrazine, DIA, DEA, clorpyrifos, endosulfan alfa and beta and endosulfan sulfate, malation, metolachlor, monocrotophos, permethrine and profenofos in the water, used in the method reported by Laabs et al. (2002), in general consisted of

Table 1. Description of the chemical and physical characteristics of the monitoring units.

Localization	Soil	Soil management systems	S% ¹	DP ² (m)	Clay	Silt	Sand	OC ³
					g kg ⁻¹			
Chico Nunes small watershed	Yellow latosol	No-tillage with filter strip of the <i>Brachiaria decumbens</i> with width of 10 m (MUS).	3.9	10 × 40	372	108	520	20.0
		No-tillage without strip filters <i>Brachiaria decumbens</i> (MWS)	4.1	10 × 40	461	107	432	30.0
Ilha small watershed	Yellow redoxisol	Conventional tillage (MUC)	3.4	3.5 × 11	457	65	478	30.0
		No-tillage (MUT)	2.9	3.5 × 11	414	95	491	42.7

¹Slope of the monitoring units. ²Dimensions of the monitoring units (width × length) willing toward upright the watercourse. ³Percentage of the organic carbon in the surface layer of the soil (0 to 20 cm).

the extraction by solid phase extraction with octadecylsilyl (C18) (1000 mg) BakerbondTM, Mallinckrodt Baker, USA, previously conditioned with 10 ml of methanol and 10 ml of water, followed by elution with subsequent portions 10 ml of the ethyl, 10 ml de hexane: ethyl acetate (1:1) and 5 ml of the hexane. The extract was concentrated in a rotary evaporator to near dryness and transferred to an autosampler vial with toluene. A gas chromatograph HP-6890 with mass selective detector HP-5973 (Agilent GmbH, Germany), split/splitless injector, automatic sampler and a HP-5MS (5% phenylmethylsiloxane) column (30 m × 250 µm id × 0.25 µm phase thickness) was used for pesticide analysis. Pesticide residues were quantified by GC-MS operated in the selected ion monitoring mode at the following conditions: injector block temperature of 250°C; carrier gas of helium (99,999% pure), gas flow of 1 ml/min; split/splitless injector operated in splitless mode; injection volume of 1 ml; oven temperature program of initial temperature of 92°C held for 2.5 min, heating up to 175°C at 15°C min⁻¹; 175°C held for 13 min, heating up to 280°C at 20°C min⁻¹, 280°C held for 9 min; and transfer-line temperature of 290°C. Pesticides were identified by retention time and by relative abundance of three major ions from mass spectra of each substance (Table 4). Maximum tolerance for confirmation was specified as 20% of relative ion intensity response.

Analysis of pesticides residues by liquid chromatographic

The pesticides residues: azoxystrobin, carbendazin, carbofuran, diuron, methomyl, teflubenzuron, thiacloprid,

thiamethoxan and triflumuron in water, was performed according to the method described by Carbo et al. (2008), before pesticides extraction it was concentrated with 500 ml of the samples in a SDVB cartridge (Envi-Chrom P, Supelco) previously conditioned with methanol. The cartridge was dried, leaving the vacuum pump on for 30 min.

The pesticides were eluted with 3 × 5 ml of methanol: acetonitrile 7:3 (v/v) at a flow-rate of about 1 ml min⁻¹. The combined fractions were concentrated in a rotary evaporator (45°C) and the residue was redissolved in 1 ml of acetonitrile, followed by the addition of 50 µl of standard terbuthylazine solution (100 µg ml⁻¹) to the vial and the injection of 10 µl into the HPLC/DAD.

The analysis was performed with a Varian HPLC system equipped with a 410 autosampler, a 240 quaternary pump and 330 UV diode-array detector linked to a personal computer running the software program Varian ProStar, version 5.5 (Varian, USA). The analytical column (250 mm × 4.6 mm I.D.) used here was an Omnisphere 5 µm C₁₈, and the guard column (20 mm × 4.6 mm I.D.) was also an Omnisphere 5 µm C₁₈. For the HPLC analysis, an aliquot (10 µl) was injected into the column and eluted at room temperature at a constant flow-rate of 1 ml min⁻¹ under the following conditions. The analytes were eluted with acetonitrile:water with initial composition of 18% acetonitrile, increasing to 40% at 6 min, 80% at 35 min, 90% at 40 min, and 100% acetonitrile at 45 min, where it was kept constant for 3 min and then linearly decreased to the initial analysis conditions in 10 min. The detection and quantification were performed at 230 nm. Analytes were identified by their retention time and identification was confirmed by comparison of their UV spectra to that of standard solutions.

RESULTS

Analysis overview

The runoff coefficients - RC (Table 5) of the monitoring unit with strip filter of the *B. decumbens* - MUS observed values less than the value monitoring units without a buffer filter -MWS. The magnitudes ranged from 0.005 to 0.035 and 0.011 to 0.402 for MUS and MWS, respectively. The runoff coefficients (Table 5) observed on the monitoring unit with no-tillage system -MUT were less than the monitoring unit with a conventional tillage -MUC, the coefficients ranged from 0.00 to 0.528 and 0.00 to 0.94 in the MUT and MUC, respectively.

In general, the increasing or decreasing of the pesticides concentration on the runoff was not observed, due to the presence or absence of the *B. decumbens* strips (Table 6), it can be observed that pesticide concentrations, malathion, metolachlor and atrazine were high with strips of the *B. decumbens* (MUS) compared with strips without the *B. decumbens* (MWS), while for pesticides alfaendosulfan, endosulfan sulfate and diuron the concentrations were the smallest on MWS, already for pesticides methomyl and permethrin the concentrations were very similar between these two monitoring units. Similar

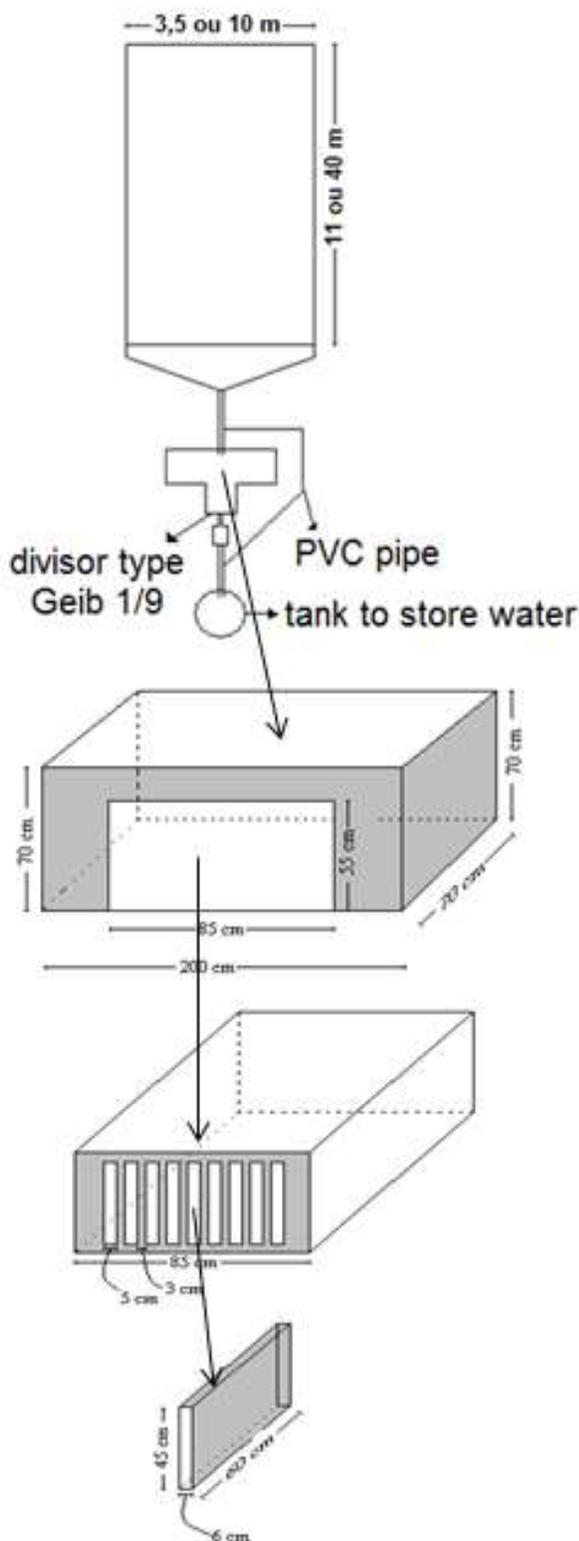


Figure 1. Schematic representation of the experimental plot and collector structure runoff.

of pesticides on the monitoring with MUT and MUC (Table 6).

Analyzing quantitatively the total mass of the pesticides transported by runoff, it was observed that the total mass of the pesticides detected in the MWS was higher than the mass observed in the MUS (Figure 2). It can also be verified that total mass of pesticides transported by runoff in the MUT was smaller than MUC, the only exception was methomyl pesticide (Figure 2).

Figure 3 shows the percentages of the reduction mass of pesticides carried by runoff in the monitoring units with filter stripes of the *B. decumbens* compared to those without filter stripes of the *B. decumbens* (MUS and MWS, respectively); and no-tillage system compared to the conventional tillage (MUT and MUC, respectively).

DISCUSSION

Runoff water

The smallest runoff in the monitoring unit with no tillage system is probably because this system provides high stable infiltration compared to the conventional tillage (Barcelos et al., 1999; CASTRO, 1995; Sobrinho et al., 2003; Brandão, 2006; Brandão et al., 2007). The high efficiency of the *B. decumbens* strips to reduce the runoff also was observed by Syversen and Bechmann (2004).

Pesticides residues in runoff water

The isomers α and β -endosulfan were broadly detected on the monitoring units studies (Table 6). Pesticides proportion detected increased during the collections after several pesticide applications on the field of study. Already, endosulfansulphate was detected broadly, because endosulfan in soil rapidly forming significant concentrations of endosulfan sulfate, which persists for several months, means that a cotton field can act as a strong source of pesticide residues in runoff water for several months after applications (Kennedy et al., 2001).

The metabolites of the atrazine, DEA and DIA, were detected in increasing concentrations, besides which the frequency of the detection of DEA was larger than DIA. Higher concentrations were detected on the last sampling (Table 6). This fact shows high solubility of DIA and DE, as well as easy transportation by runoff, as well as reported by Correia et al. (2007).

Malathion was detected only once (Table 6). The concentrations observed were lower and similar in the monitoring units with no-tillage and conventional tillages and there was high concentration of this pesticide already in the systems with buffer filters.

Pesticides metolachlor and diuron were detected in almost all samples of the water. Besides, these pesticides were also detected in all monitoring units (Table 6). Metolachlor has been classified as an easily

behavior can be observed relative to the concentrations

Table 2. Pesticides applied on the cotton farms where the monitoring units were installed with conventional tillage and no-tillage soil management systems.

Active principle	Average concentration applied (L/ha ou*kg/ha)	Active principle	Average concentration applied (L/ha ou *kg/ha)
Prophenophos	0.51	lambdacialotrine	0.06
Alphaand beta endosulfan	7.50	Cipermetrine	0.30
Azoxystrobin	0.25	Deltametrine	0.10
Carbosulfan	1.92	Thiophanate-methyl	0.58
Teflubenzuron	0.10	Triazophos	1.02
Parathion	1.02	Parathion	1.02
Zeta-cipermetrine	0.30	Acetamiprid	0.13 *
Diafenthiuron	0.33*	Tetroconazol	0.40
Chlormequat chloride	0.20	Gamma-cyhalothrine	0.09
Bifenthrin	0.60	Fenitrothion	0.60
Luphenuron	0.30	Triflumuron	0.06

Table 3. Pesticides applied on the cotton farms with no-tillage soil management systems where the monitoring units were installed with and without a vegetated filter strip planted with *Brachiaria decumbens* grass.

Active principle	Average concentration (L/ha or*kg/ha)	Active principle	Average concentration (L/ha or*kg/ha)
Metolachlor	0.60	Novalurom	0.15
Diuron	1.0 *	Malathion	1.0
Diuron	0.80	Diafentiuron	0.28*
Carbosulfan	0.80	Tetraconazole	0.4
Acetamiprid	0.23*	Trifloxisulfuron	0.002*
Methomyl	2.9	Propiconazol	0.50
Carbosulfan	2.0	Carbendazim	1.5
α and β endosulfan	4.0	-	-

Table 4. Monitoring ions for identification and quantification of the pesticides by GC/EM.

Pesticides	Target ion	Fisrt ion	Second ion
Atrazine	200	215	202
DIA	173	258	145
DEA	172	174	187
Alphaendosulfan	241	238	195
Betaendosulfam	207	195	237
Endosulfam sulfat	272	274	387
Malathion	173	125	127
Metolachlor	162	238	240
Permetrine	183	163	165
Prophenophos	208	139	339

soluble and mobile pesticide (FAO, 2000), because our solubility is 530 mg ml⁻¹ (Rivard, 2003) and adsorption coefficient to organic carbon is 200 g ml⁻¹ (Rivard, 2003). Diuron is classified as easily soluble and moderately mobile (FAO, 2000), because our solubility and

adsorption coefficient to organic carbon is 36.4 mg ml⁻¹ and 418 to 560 g ml⁻¹ (Moncada, 2004), respectively. Moreover, Dores et al. (2005) reported that the half-life of diuron and metolachlor is 15 and 34 days. These properties of diuron and metolachlor explain the high

Table 5. Runoff and runoff coefficients of the monitoring unit with and without buffer filter; unit with system conventional tillage and no-tillage .

Sampling date	⁵ CP	MUB ¹		MUW ²		Sampling date	CP	MUC ³		MUT ⁴	
		⁶ RF	⁷ RC	RF	RC			RF	RC		
		mm						mm			
03/1/2007	60	2.11	0.035	24.1	0.402	05/1/2007	78	19.96	0.260	12.25	0.157
19/01/2007	138	2.11	0.015	1.49	0.011	18/01/2007	59	55.57	0.940	31.13	0.528
01/02/2007	108	1.05	0.010	21.65	0.200	2/2/2007	160	42.23	0.260	17.65	0.110
23/02/2007	396	2.11	0.005	12.56	0.032	22/02/2007	231	109.73	0.480	61.46	0.266
14/03/2007	313	2.11	0.007	30.83	0.098	14/03/2007	104	0.000	0.000	0.000	0.000
5/4/2007	218	2.11	0.010	30.72	0.141	4/4/2007	425	47.79	0.110	35.85	0.112
21/04/2007	122	4.16	0.034	33.8	0.277	20/04/2007	92	44.14	0.480	24.73	0.269
Total	1247	8.38	-	133.5	-		1045	319.42	-	183.07	-
Average	193,571	2.251	0.010	22.164	0.160	-	149.286	45.631	0.422	26.152	0.206
SD ⁸	-	-	0.013	-	0.152		-	-	0.292	-	0.170

¹Monitoring units with strip filter of the *Brachiaria decumbens*; ²Monitoring units without strip filter of the *Brachiaria decumbens*; ³Monitoring units with conventional tillage; ⁴Monitoring units No-tillage system; ⁵Cumulative precipitation, mm; ⁶Runoff ; ⁷Runoff coefficient; ⁸Standard deviation.

Table 6. Pesticides concentrations ($\mu\text{g L}^{-1}$) in surface waters of the monitoring units with and without stripe filter; and monitoring units with system conventional and no-tillage.

Pesticide	Sampling dates						
	05/01/07	18/01/07	02/02/07	22/02/07	14/03/07	04/04/07	20/04/07
Monitoring units with stripe filter							
α -Endosulfan	n.d. ¹	0.45	0.25	0.61	0.20	0.09	0.11
β -Endosulfan	n.d.	0.27	0.73	0.90	0.48	0.17	0.28
Endosulfan sulfate alpha and beta endosulfam	0.25	0.23	1.93	1.75	3.22	1.05	1.07
Atrazine	n.d.	0.18	0.11	0.18	0.39	0.62	0.16
Metolachlor	0.60	0.62	0.61	0.16	0.13	0.21	0.12
Malathion	n.d.	n.d.	n.d.	3.15	n.d.	n.d.	0.24
Prophenophos	n.d.	0.15	n.d.	n.d.	0.15	n.d.	n.d.
Permethrin	0.10	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Diuron	0.87	1.17	1.19	0.32	n.d.	n.d.	n.d.
Methomyl	n.d.	n.d.	n.d.	4.65	15.3	11.11	4.22
Monitoring units without stripe filter							
α -Endosulfan	3.85	0.32	0.44	5.0	0.17	0.04	0.05
β -Endosulfan	0.72	0.17	1.06	4.49	0.26	0.10	0.19
Endosulfan Sulfate	0.58	0.22	2.86	3.12	1.93	1.99	1.81
Atrazine	n.d.	n.d.	0.11	0.15	0.65	0.14	0.17
Metolachlor	0.55	0.16	0.31	0.13	0.19	0.11	0.12
Permethrin	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	n.d.
Diuron	0.71	0.91	2.50	n.d.	n.d.	n.d.	n.d.
Methomyl	n.d.	n.d.	n.d.	6.00	4.59	0.10	0.24
Monitoring unit with no-tillage system							
α -Endosulfan	0.39	0.17	0.43	0.53	n.d.	0.04	n.d.
β -Endosulfan	0.07	0.11	1.02	0.83	n.d.	0.11	n.d.
Endosulfan Sulfate	0.46	1.01	2.58	3.32	n.d.	1.93	2.03

Table 6. Contd.

Atrazine	0.05	0.04	0.05	0.16	n.d.	0.32	0.28
DIA	n.d.	n.d.	n.d.	0.06	n.d.	0.1	0.18
DEA	n.d.	0.04	0.04	0.06	n.d.	0.08	0.18
Metolachlor	0.1	0.08	0.08	0.08	n.d.	0.08	0.08
Malathion	n.d.	n.d.	0.12	n.d.	n.d.	n.d.	n.d.
Diuron	20.6	3.98	1.65	1.11	n.d.	n.d.	n.d.
Methomyl	46.34	4.20	n.d.	n.d.	n.d.	n.d.	n.d.
Monitoring unit with conventional tillage							
α -Endosulfan	0.51	0.08	0.31	0.53	n.d.	n.d.	n.d.
β -Endosulfan	0.26	n.d.	0.69	1.04	n.d.	0.21	0.20
Endosulfan Sulfate	0.43	0.45	1.15	2.64	n.d.	1.58	2.02
Atrazine	0.07	0.08	0.06	0.20	n.d.	0.26	0.84
DIA	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	2.56
DEA	0.06	0.04	0.04	0.06	n.d.	0.11	3.46
Metolachlor	0.1	0.1	0.09	0.08	n.d.	0.1	0.1
Malathion	n.d.	n.d.	0.12	n.d.	n.d.	n.d.	n.d.
Diuron	17.37	6.11	2.91	1.61	n.d.	0.20	0.58
Methomyl	18.16	2.11	n.d.	n.d.	n.d.	n.d.	n.d.

n.d.¹: Not detected; detection limit = 0.02 $\mu\text{g L}^{-1}$.

detection of these compounds in water samples of the runoff.

Methomyl has solubility in water of 58 mg L⁻¹ (Ferracini et al., 2001) and it is classified as easily soluble (FAO, 2000). Besides, methomyl has absorption coefficient of 72 g ml⁻¹ (Ferracini et al., 2001), considered a mobile pesticide. Thus due to these properties of methomyl and also the occurrence of an event of rain after application of methomyl, likely, there was not enough time for it to interact with crop residues in the soil and about the soil, therefore, the straw in the no-tillage system was washed by rainwater, thus one part of the methomyl applied was carried by runoff. In the conventional tillage, due to the absence of the straw, the methomyl entered in direct contact with the soil and, therefore, it was leached from deeper layers of the soil, decreasing the available amount to be carried by runoff. Other authors observed similar behavior for clorimuron-ethyl, that is, also considered to be one pesticide with high solubility in water (Loke et al., 2008).

The MUT has shown an average efficiency of the reduction in pesticides losses ranging from the 24 to 92% in the lost total mass of the pesticide compared to the MUC.

Management system and pesticides residues

The reduction on the concentrations of majority pesticides detected in water samples of the runoff in the

no-tillage monitoring unit system compared with conventional tillage (Figure 2) is due to the fact to no-tillage system, there is higher organic carbon percentage in soil than in conventional tillage (Table 1). This fate provides greater pesticide retention and degradation in the soil, this fact is consistent with results observed by Weaver et al. (2012) that reported strong association between DDE concentrations in soil with organic carbon when compared with the other soil properties.

In addition, Locke et al. (2008) reported that this management system of the soil provides the retention and degradation of the pesticide molecules, as well as better adsorption capacity of soil in relation of the high percentage of the organic matter often observed in this management system which can be observed in Table 1. The reduction ranged for MUS from the 64 to 98% compared to MWS (Figure 3). These observed reductions were due to the smaller capacity of the runoff water, considering that the pesticides concentration was more dependent on the pesticide properties and no soil management. This indicates that conservationist management of soil as well as improving soil properties also provides reduction of the risk of the pesticides being transported by runoff to the water stream.

Conclusion

The monitoring units with filter stripes of the *B. decumbens*

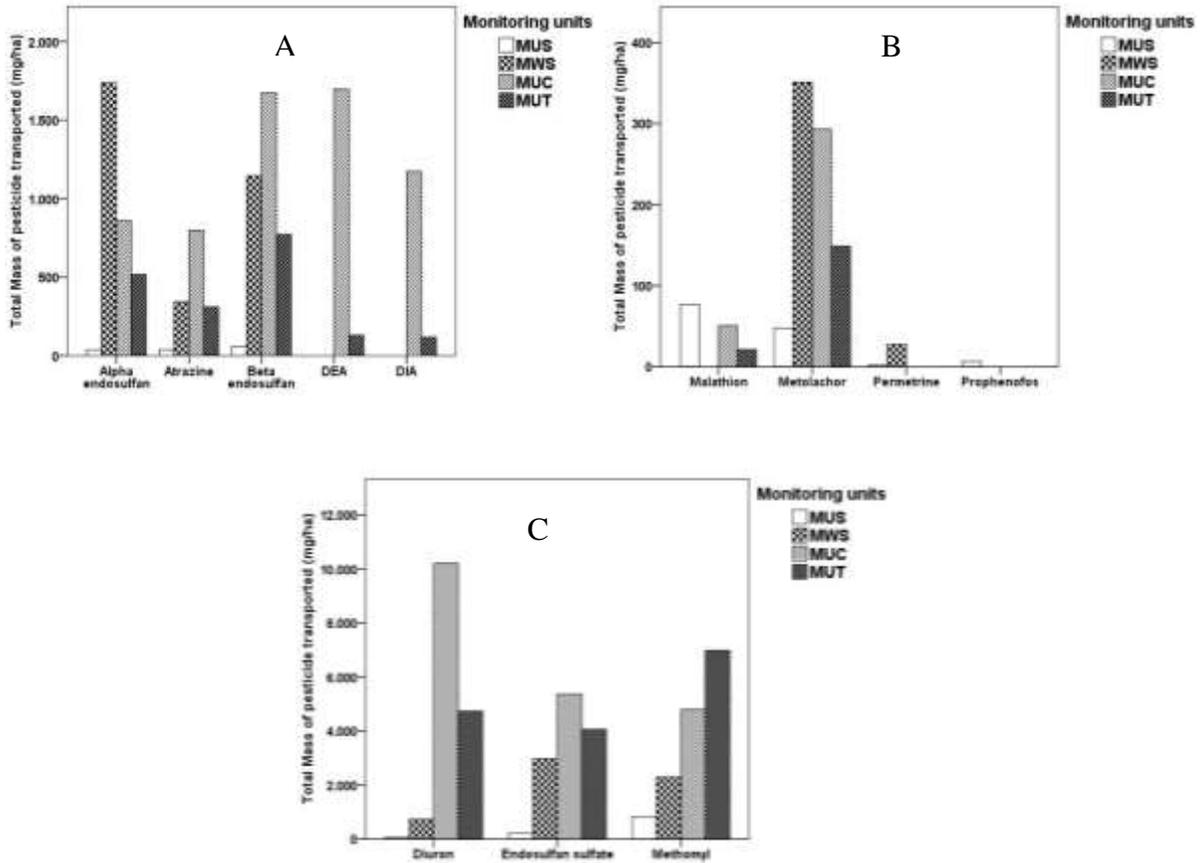


Figure 2. (A, B, C) Total losses of the pesticides (mg ha⁻¹) by runoff in the monitoring units: MUS: Monitoring unit with strip filter of the *Brachiaria decumbens*; MWS: monitoring unit without strip filters *Brachiaria decumbens*; MUT: monitoring unit with no-tillage system; e MUC: monitoring unit with conventional tillage.

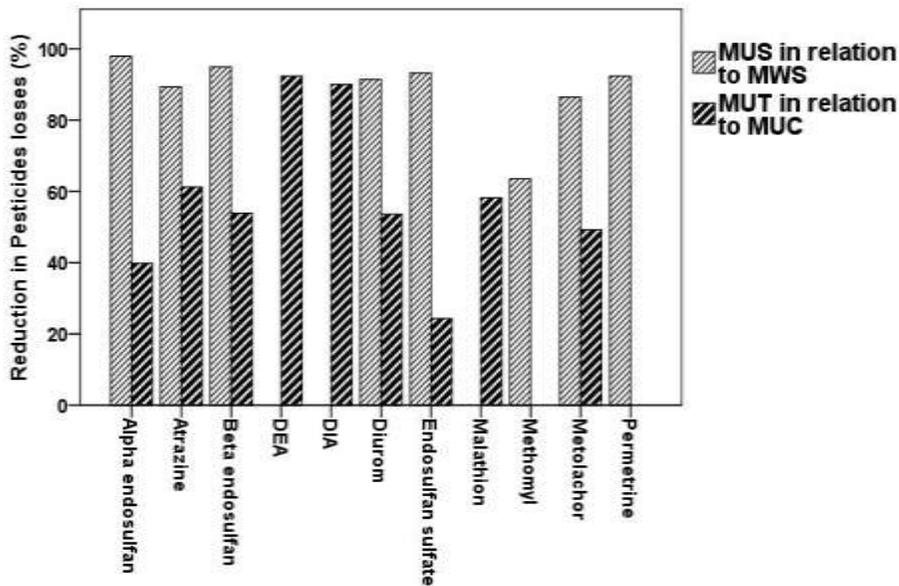


Figure 3. Mass reduction of the pesticides between the monitoring units with strip filter of the *Brachiaria decumbens* (MUS) and without strip filter of the *Brachiaria decumbens* (MWS); e monitoring unit with no-tillage system (MUT) and monitoring unit with Conventional tillage (MUC).

and no-tillage system were the types of the management which reduced more efficiently the total loss pesticides by runoff. The percentage of the decrease was between 24 and 92% in the no-tillage system compared with the conventional tillage. Already, in the monitoring units with strip filters compared with monitoring units without strip filters, the percentage of the decrease was between 64 and 98%.

Furthermore, the type of soil management observed was evaluated in this paper, the risk of the pesticide contamination of surface waters by runoff in tropical regions was reduced more efficiently where there are cotton plantations, because the types of management evaluated decreased the volume of the surface water transported in the soil.

When comparing the no-tillage system with conventional tillage, pesticides, metolachlor and alfa endosulfan as well as endosulfan sulfate, and its metabolite, showed the lowest reduction in relation to other pesticides transported by runoff. Thus, these pesticides can be potentially transported by runoff, therefore, these chemical compounds showed broad risk of surface waters contamination. It is noteworthy that in this paper, only the pesticides transported by runoff were evaluated, thus, it is necessary to evaluate also the pesticides transported by adsorption by sediments.

Conflict of Interests

The authors have not declared any conflict of interests.

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