Soil Tillage Systems and Herbicide Leaching in Brazil.

A. L. Cerdeira,[1] M. Dornelas-DeSouza,[1] D. Bolonhesi,[2] S. C. N. Queiroz,[1] V. L. Ferracini,[1] M. A. V. Ligo,[1] M. C. P. Y. Pessoa,[1] S. Smith Jr[3].

[1]Embrapa, Meio-Ambiente, Research Division of the Brazilian Ministry of Agriculture, C.P. 69, Jaguariuna, SP, 13820-000, Brazil.
[2]Agronomic Institute of Campinas, Alta Mogiana Experiment Station, C.P. 271, Ribeirao Preto, SP, 14001-970, Brazil.
[3]USDA-ARS- National Sedimentation Laboratory, P.O. Box 1157, Oxford MS, 38655, USA.

ABSTRACT

The Guarany aquifer located in South America has a dimension of approximately 1,200,000 Km^2 and spreads to areas of eight Brazilian states plus parts of Argentina, Uruguay and Paraguay. The region of Ribeirao Preto City, located in Southeast of Brazil, Sao Paulo State, is a sugarcane, soybean, peanuts, and corn producing area. This region is also an important recharge area to the aquifer. Intensive farming on the area has demanded constant use of herbicides and fertilizers. Triazine herbicides such as atrazine, ametryn, and simazine are used on the area and are known to have potential for groundwater contamination. Currently most of the sugar cane crop is mechanically harvested without burning. This practice allows the straw to decompose in soil, maintain a better soil structure, and interferes with the movement and leaching of solutes. It is a common practice to sow peanuts after sugarcane harvest using no-tillage or conventional planting systems. To evaluate the effects of herbicide leaching into groundwater during no-tillage planting of peanut after mechanically harvested sugarcane, a soil leaching study using soil columns has been conducted. The results showed a general trend of higher density and lower porosity in soils under no-tillage, mainly at the top layer. The Hydraulic Conductivity determined in soil columns was higher for soils under conventional system than no-tillage, 10.82 and 4.59 cm/h respectively, indicating higher leaching potential for conventional system.

Keywords: Groundwater, Nonpoint Source Pollution, Hydrology, Agriculture, Solute Transport.

INTRODUCTION

The state of Sao Paulo, located in Southeast of Brazil, is an important sugarcane, soybean and corn producing area with high use of chemicals in agriculture with potential risk of environmental contamination (Pessoa et al. 1998). This region is also an important recharge area for groundwater of the Guarany aquifer. Several studies have demonstrated the possibility of pesticides leaching to groundwater

(Smith et al., 2001; Bouwer, 1990). Among them, triazine herbicides such as atrazine, (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) ametryn, (2-(ethylamino)-4-isopropylamino-6-methyl-thio-s-triazine), and simazine[2-chloro-4,6-bis(ethylamino)-1,3,5-triazine] are used in Brazil and are known to have potential of groundwater contamination (Cerdeira et al., 2000). The Brazilian Health Ministry has set the maximum amount of atrazine and simazine in drinking water to 2 ug/L, or ppb, (Pessoa, 1998).

Since we have different cropping systems, literature indicates that there is a relationship of tillage systems and leaching, the region is located on an aquifer recharge area and herbicides are heavily used, this research was conduct to evaluate the effect of harvesting and soil preparation systems on triazine leaching. A field experiment was set and a soil leaching study was conducted in columns to determine the movement of triazines where mechanical sugarcane harvesting has been followed by No-tillage (NT) and Conventional Tillage (CT) peanuts production. Although not all the triazines are necessarily used at same level on all crops, we have used the three, atrazine, simazine and ametryn as models to study the effect of soil preparation systems on leaching on those soils.

MATERIALS AND METHODS

Field research was conducted at the Alta Mogina Sao Paulo State Experiment Station, Ribeirao Preto, SP, Brazil, and laboratory studies were conducted at the Research Division of the Brazilian Department of Agriculture, Embrapa/Environment, Jaguariuna, SP, Brazil. The experimental design consisted of mechanically harvested sugarcane followed by NT and CT peanuts in a RCB, Randomized Complete Block with four replications and plots of 10X30 m.

Sugar cane was planted in 1977 and mechanically harvested until the last cutting in October 2002. After sugar cane last mechanical harvesting in October, soil samples were collected from trenches before and after peanuts sowing under NT and CT systems. Samples were collected from 0 to 100 cm depths, for every 10 cm. in November and March of years 2002/2003 and taken to the laboratory. Soil density ($g.cm^{-3}$), the relation of soil mass and volume was measured using the Kopeck ring method described by Black, (1965). Total porosity was measured based on percentage of saturation in volume (Vomocil, 1965). Microporosity was determined by the tension table method at 0,006 Mega Pascal (Mpa). After saturation and drying under tension, the samples were dried in oven at 105^0C to obtain the volume of micropores $\leq$ 0.05 mm. Macroporosity was obtained by the difference of micro and total porosity. It were also evaluated the % Organic Matter and physical properties of the soils for each depth (Klute 1986). The soil saturated hydraulic conductivity and the leaching potential of the herbicides were accomplished with leaching experiments conducted in PVC columns of 20 cm diameter. The soil samples were collected from the field experiment and placed in the column at the same depths and density as in the field with a vacuum extractor for collecting solutes.

Soil columns were saturated with water from bottom to top to extract the remaining air, the soil saturated hydraulic conductivity was measured and it was left to dry for three days to reach field capacity water level according to Klute, (1965). After that, the soil was drained by gravity for three days and then it was applied the volume of 1570 ml of solution with 8 Kg/ha a.i. of each of the herbicides.

The herbicides were applied at the top of the columns. Water was applied until it reached 5cm; equivalent to a 50 mm rain. The time interval for the solution to reach the bottom was measured. The solutes were collected at 20 cm depths using vacuum extractors for each 10 cm depth and analyzed for residues by HPLC.

RESULTS AND DISCUSSION

Samples collected from different depths, from 0 to 100 cm have shown a high percentage of clay and no effect of the depths on the physical properties of the soils under NT or CT system was observed. Organic carbon content was higher at top layer 0 to 10 cm. for NT soils. There was also a trend of increasing the moisture content and decreasing organic carbon to deeper depths under both cultivation systems.

Our results have shown a general trend of higher density in soils under NT, mainly at the top layer (Table 1). Roscoe and Buurman (2003) studying the Brazilian cerrados (savannas) following cultivation on a Dark Red Latosol (Oxisol) also found that cultivation led to compaction, which significantly increased soil bulk density and that using (CT) or (NT) system did not alter the total C and N stocks in the first 45 cm depth at the end of 30 years of cultivation.

Table 1. Soil density ($g.cm^{-3}$) under No-tillage (NT) and conventional tillage (CT) peanuts at various depths.

Depth (cm)	NT	CT	F Value
0-10	1.24	1.12	23.27*
10-20	1.22	1.14	5.53
20-30	1.30	1.19	1.82
30-40	1.20	1.20	0.00
40-50	1.16	1.14	1.27
50-60	1.09	1.09	0.37
60-70	1.06	1.04	0.29
70-80	1.05	1.04	0.02
80-90	1.03	1.06	NA*

* Significant different at $p \leq 0.005$ NA: Not available

Most of literature is also contradictory on the effects of tillage systems on micro, macro, and total porosity of soils submitted to these tillage systems. Our data have shown no effect on these parameters when under the CT or NT systems.

Some authors found reduction in runoff and increasing in leaching of atrazine and simazine in NT as opposed to CT, (Triplett et al., 1978; Edwards et al., 1980), which is contradictory to our findings (Figure 1, Table 2). Others have found the opposite, NT runoff was higher and leaching was lower, Baker and Johnson, (1979), results similar to those found in our study (Figure 1). There were also reports of no effect of the cropping systems, CT or NT on runoff of pesticides (Logan, 1990). Wauchope, (1987) considered that the results and conclusions of effects of tillage on runoff and leaching losses of pesticides are generally inconsistent and often contradictory.

There were also great differences in literature regarding the tillage effects on hydraulic conductivity. In our study, there was a higher conductivity for soils submitted to CT than NT but this did not reflect on the movement of the triazines (Figure 1, Table 2).

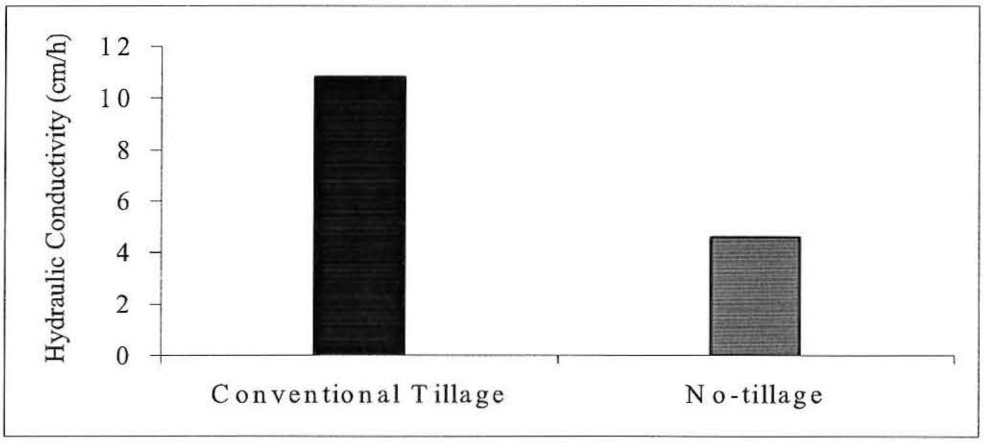

Figure 1. Hydraulic conductivity (cm/h) of soils under No-tillage (4.59*) and conventional tillage systems (10.82). *Statistically different F=0.0034

The soil columns studies have shown the leaching of the herbicides atrazine and simazine down to the maximum of 20 cm. No herbicide was detected under 20 cm for the conditions of the experiment indicating less mobility under the experimental conditions than in mathematical modeling simulations, (Pessoa et al., 1998). Ametryn was not detected in any depths (Table 2).

Atrazine and simazine were just found at the top layer from 0 to 20cm in the soil columns studies. In both systems NT and CT, atrazine has leached more than simazine, what was expected according to studies conducted with mathematical simulation (Pessoa et al., 1998). There was no clear difference on mobility of both herbicides due to the tillage systems (Table 2).

Table 2. Maximum amount of the herbicides measured (ppb) of the herbicides found from zero to 20 cm. in solution extracted from the columns.

Herbicides	**Tillage systems**	
	No-tillage	Conventional tillage
Ametryn	ND[1]	ND
Atrazine	85.8	72.6
Simazine	28.5	31.4

ND[1] = Not detected. Average of three replications.

Since most of the soil properties that affect leaching were similar in both systems at various depths, the lower leaching capacity of soils under NT system could be attributed mainly to the higher density of the top layers of soils under this system, NT (Table 1). Although organic carbon content was not statistically different, those parameters were also higher for soils under NT at top layers and could also play an important role in lower hydraulic conductivity (Figure 1).

Further studies will be conducted with lysimeters in order to understand better the effects of those soil tillage systems and consequent impact on ground water quality.

Acknowledgements. Research funded by FAPESP, The State of Sao Paulo Research Foundation, Brazil. Project Number 2002/05067-1. The authors acknowledge Gustavo Luiz dos Santos for the chromatographic analysis.

REFERENCES

Albarran A, Celis R, Hermosin MC, Lopez-Pineiro A, Cornejo J. 2004. Behaviour of simazine in soil amended with the final residue of the olive-oil extraction process. Chemosphere 6:717-24.

Baker JL, Johnson HP. 1979. The effect of tillage system on pesticides in runoff from small watersheds. Trans American Soc Agric Eng 22:554-559.

Black GR. 1965. Bulk density. In: Black, CA. et al. (ed). Methods of soil analysis, Madison, American Society of Agronomy, pp. 374-390.

Bouwer H. 1990. Agricultural chemicals and groundwater quality. J Soil Water Conserv 42:184-189.

Cerdeira AL, Gomes MA, Pessoa MCPY, Queiroz RC, Bonato PS, Lanchote VL (2000) Tebuthiuron in soil and groundwater in sugarcane area in Brazil. Boll. Chim. Igien. 51: 51-57

Edwards WM, Triplett, GB, Kramer, RM. 1980. A watershed study of glyphosate transport in runoff. J Environ Qual 9:661-665.

EXTOXNET. 1998. Atrazine and alachlor pesticide information profiles. Extension Toxicology Network InfoBase http://ace orst edu/info/extoxnet/ Oregon State University.

Hornsby AG. 1990. Pollution and public health problems related to irrigation. irrigation of agricultural crops. ASA/CSSA/ASSA monograph 30, Madison, WI, pp. 1173-1186.

Klute A. 1965. Laboratory measurement of hydraulic conductivity of saturated soil. In: Black CA. et al. eds. Methods of soil analysis, Madison, American Society of Agronomy,p.210-221

Klute A. 1986. Methods of soil analysis - part 1: Physical and mineralogical methods. 2.ed. Madison: ASA; SSSA. Agronomy Series, 9 pp1188. (

Laabs V, Amelung W, Pinto AA, Wantzen M, da Silva CJ, Zech W. 2002. Pesticides in surface water, sediment, and rainfall of the northeastern Pantanal basin, Brazil. J EnvironQual 5:1636-48.

Logan TJ. 1990. Agricultural best management practices and groundwater protection. J Soil Water Conserv 45:201-206.
Pessoa MCPY, Gomes MAF, DornelasDeSousa M, Cerdeira AL, Nicolella G, Monticelli A. 1998. Simulação do movimento de herbicidas utilizados no monocultivo de cana-de-açúcar em Areia Quartzosa da área de recarga do Aquífero Guarani (antigo Botucatu) em Ribeirão Preto, SP. Rev Cient Rural 2:11-19.
Roscoe R, Buurman P. 2003. Tillage effects on soil organic matter in density fractions of a Cerrado Oxisol. Soil Till Res 70: 107-119.
Smith S, Johnson RM, Pepperman AB. 2001. Formulation and Tillage Effects on Atrazine and Alachlor in Shallow Groundwater in Upland Corn Production. Bull Environm Contam Toxicol 67:113-121.
Triplett GB, Conner BJ, Edwards WM. 1978. Transport of atrazine and simazine in runoff from conventional and no-tillage corn. J Environ Qual 7:77-83.
Vomocil JA. 1965. Porosity. In: Black, CA. et al. eds. Methods of soil analysis, Madison, American Society of Agronomy, pp. 299-314.
Wauchope RD. 1987. Effects of conservation tillage on pesticide loss with water In: Logan TJ, Davidson JM, Baker JL, Overcash MR (eds) Effects of conservation tillage on groundwater quality. Lewis Publishers Inc Chelsea MI. p205-215.
Wauchope RD, Buttler TM, Hornsby AG, Augustijn-Beckers PWM, Burt JP. 1992. Pesticide properties database for environmental decisionmaking. Rev Environ. ContamToxicol 123: 1-157.