ISSN 1808-3765

TRIFLURALIN LEACHING IN SOILS CULTIVATED WITH SUGARCANE IRRIGATED BY SUB-SURFACE DRIP SYSTEM

Pedro Luiz Terra Lima[1]; Ciro Augusto de Souza Magalhães[2]; Renato Fráguas de Carvalho[3]; Luiz Antonio Lima[4]; José Maria de Lima[1]; Luiz Antônio de Bastos Andrade[5]

[1] Department of Soil Science, Universidade Federal de Lavras/UFLA, Post Office Box 3037 – 37200-000 – Lavras, MG, Brazil.
[2] Empresa Brasileira de Pesquisa Agropecuária, Embrapa Roraima - Boa Vista, RR, Brazil.
[3] Sandoz o Brasil Ind. Farmaceutica - Cambé, PR, Brazil.
[4] Department of Engineering, Universidade Federal de Lavras/UFLA - Lavras, MG, Brazil.
[5] Department of Agricultural, Universidade Federal de Lavras/UFLA - Lavras, MG, Brazil.

1 ABSTRACT

In order to assess the movement of trifluralin in soils, used as root intrusion inhibitor in sub-surface drip irrigation system (SDI), its concentration at effluent from lysimeters was measured. The lysimeters with sugarcane (*Sacharum officinarum L.*) under natural weather conditions and supplementary irrigation were filled with two Oxisols and an Ultisol. Three lysimeters with undisturbed soil were used as replicates for each treatment; the columns were one meter in diameter and 45cm deep. The SDI system consisted of drippers installed at 20cm depth, with 10.5mm internal diameter tubing with 6 emitters per lysimeter spaced 50cm between them. A moisture sensor was installed in each lysimeter to monitor the soil water tension. A weather station was installed besides the lysimeters, in order to supply weather information. Precipitation, volume of leachate, and trifluralin concentration in the effluent were measured during 65 days. There was no change on the SDI system flow rate. The LVA presented the highest amounts of leached compound, which was above the EPA limit and lower than the allowed by Brazilian law.

Keywords: Sub-surface drip irrigation system, contamination, percolation, leaching, herbicide.

2 INTRODUCTION

Sugarcane (*Sacharum officinarum L.*) can be used in agriculture in different ways, as animal food, forage, raw material for sugarcane spirit, and mainly for sugar and ethanol production. During 2009, sugarcane plantation in Brazil occupied nearly 9 million hectares and the 2008/2009 production was 571.4 million metric tons (CONAB, 2009. The ethanol production in 2008/2009 was 26.7 billion liters.

In order to increase sugarcane yield and avoid increasing cropped areas, irrigation has become an important input. Two irrigation systems are widely used in sugarcane crops: center pivot and drip irrigation. The first requires larger amounts of water, provides smaller irrigated area (corners are not irrigated) and causes soil erosion.

For this reason, drip irrigation has been very common for sugarcane since it requires less water and causes lower evaporation, wind drift and runoff losses (Bernardo et al., 2005). Besides, fertilizers can be applied along with irrigation water directly at the wet bulb. Subsurface drip irrigation has been very common in sugarcane crops, with drip tubing buried from 15 to 40 cm deep, as recommended by Dalri (2006), providing water at the root zone

Recebido em 22/06/2011 e aprovado para publicação em 03/02/2012

with low moisture at soil surface, which decreases weed infestation, reduces evaporation and increases irrigation efficiency. Furthermore, buried tubes provide protection against ultraviolet radiation that can reduce tube life.

Burying depth depends on root system which is related to sugarcane variety, soil porosity, soil moisture, soil bulk density, and nutrient availability. Accordingly to Casagrande (1991), at the first 90 days, the root system is restricted to 30 cm depth, increasing to 60cm depth. Therefore, at the depth of dripping tubes, sugarcane roots are very numerous and can clog drip emitters.

To avoid this root intrusion, trifluralin herbicide has been used (Andrade & Júnior, 2008). Its solubility in water is low (0.22 mg/L) and the molecule can be highly lipophilic. Like other pesticides, it can be degraded, volatilized, and adsorbed by soil particles. Its vapor pressure is 1.1×10^{-4} mm Hg at 25°C, comparatively higher than many other pesticides. Its Octanol Water Partition Coefficient is also high (Christoffoleti and Ovejero, 2009); the amount of trifluralin that can be adsorbed by soil organic fraction is about 7000 times larger than the amount that remains in solution, at equilibrium condition. The high sorption and low water solubility indicates very low mobility in soils.

Trifluralin inhibit cell division at the meristematic issues, reducing seed germination and new cell formation. Pizarro (1996), recommended doses of trifluralin at drip irrigation system ranged from 0.20 to 0.25 cm^3/dripper applied each 5 to 6 months.

Even with low mobility in soils, repeated applications or high doses during trifluralin injection, might cause deep leaching in soil and groundwater contamination. By the American regulations (EPA, 1988), the concentration limit in drink water is 2.0 $\mu g\ L^{-1}$ while in Brazil, this limit is 20.0 $\mu g\ L^{-1}$ for human consumption, 45.0 $\mu g\ L^{-1}$ to animal consumption and 500.0 $\mu g\ L^{-1}$ for recreation use of water (CONAMA, 2008), above its solubility in water, possibly considering its occurrence in suspended forms.

This research evaluated leaching of trifluralin in lysimeters with Distroferric Oxisol (LVdf), Red-Yellow Oxisol (LVA) and Red-Yellow Argisoil (PVA), cultivated with sugarcane which was irrigated by subsurface drip tubing, using trifluralin to avoid root intrusion in the system.

3 MATERIAL AND METHODS

Soil lysimeters with 1 m diameter and 0.45 m deep has been used since 1983. The soil columns are the same used and described by Castro et al. (2008), who evaluated thiamethoxam leached in lysimeters with LVdf and PVA. The main soil attributes are presented at Table 1.

Table 1. Chemical characterization and soil granulometry

Attribute	LVdf		LVA		PVA	
	0-20cm	20-40cm	0-20cm	20-40cm	0-20cm	20-40cm
pH	5.5	5.2	5.5	5.6	4.8	4.5
P (mg dm^{-3})	2.2	0.6	0.8	0.7	1.1	0.9
K (mg dm^{-3})	43	12	70	44	23	16
Ca ($cmol_c$ dm^{-3})	1.3	0.1	1.8	1.2	0.2	0.1
Mg ($cmol_c$ dm^{-3})	0.3	0.1	0.3	0.2	0.1	0.1
Al ($cmol_c$ dm^{-3})	0.2	0.5	0.2	0.2	1.1	1.2
H + Al ($cmol_c$ dm^{-3})	4.2	5.6	3.2	2.6	7.9	7.4
SB ($cmol_c$ dm^{-3})	1.7	0.2	2.3	1.5	0.4	0.2
t ($cmol_c$ dm^{-3})	1.9	0.5	2.5	1.7	1.5	1.4
T ($cmol_c$ dm^{-3})	5.9	5.8	5.5	4.1	8.3	7.6
V (%)	28.8	3.4	41.8	36.6	4.8	2.6
MO (g kg^{-1})	20.0	18.5	17.5	10.0	20.0	15.0
B (mg dm^{-3})	0.2	0.1	0.2	0.1	0.2	0.2
Cu (mg dm^{-3})	2.7	3.3	1.5	1.6	0.7	0.7
Fe (mg dm^{-3})	47.0	38.9	96.0	102	72.0	72.4
Mn (mg dm^{-3})	9.6	2.6	24.0	13.9	7.6	5.2
Zn (mg dm^{-3})	4.8	0.7	4.0	0.7	4.2	1.7
Sand (g kg^{-1})	232	125	350	360	467	380
Silt (g kg^{-1})	91	175	185	160	203	80
Clay (g kg^{-1})	677	700	465	480	330	540

Analyzed according to Embrapa (1997).

Water retention curves were obtained after saturation of soil samples for 24 hours, using pressure extraction chambers from -10 to -1500 kPa. The water retention values were adjusted to the mathematical model proposed by Van Genuchten (1980).

The outside diameter of the drip tubing used (Hidrogol) is 12.5 mm with drippers spaced 30 cm from each other, with 1.0 L h^{-1} under 100 kPa operating pressure. Tubing was installed in a circular way inside the lysimeter, in order to assure 6 drippers per lysimeter. The flow rate was measured at four different dates, operating under 20 kPa pressures.

Lime was applied to soil 30 days before planting, and irrigation was provided daily to keep soil moisture near field capacity. Nine sugarcane internodes with 2 buds each were planted at each lysimeter, buried at 20 cm depth. The variety planted was SP80-1816. At planting date, fertilizers were supplied accordingly to recommend by CFSEMG (1999).

Water irrigation management was performed based on weather data obtained by an automatic weather station and also by soil moisture sensors (Watermark) linked to dataloggers in each lysimeter.

Drip flow rate was measured using a 12.5 mm internal diameter transparent tube, to provide a 2 m water column (20 kPa). The required time to lower the water level from 2 to 1.8 meters at this tube was measured. Thus, the water volume was calculated and the flow rate was obtained based on the elapsed time. The low pressure value used (20 kPa) turned the method easy to apply rather than using the nominal operating pressure of 100 kPa, as well as possibly more susceptible to root effects on its operating characteristics.

The sugarcane growth was evaluated by measuring plant height up to 65 days after planting. The highest leaf was used for this purpose.

Trifluralin was injected in the drip system 40 days after planting. The applied amount was 0.12 mL of the commercial product (45.5% of active ingredient) per dripper, resulting in 0.72 mL per lysimeter (334 mg of trifluralin). The product used was Trifluralin Milenia (45.5%). It was injected using a syringe and the needle hole was immediately sealed with ductile tape.

Since the lysimeters were exposed to irrigation and eventual natural rainfall, their effluent was collected every time field capacity moisture was exceeded; trifluralin concentration was determined at 4, 12 and 24 days after trifluralin injection.

Trifluralin was analyzed by gas chromatography, in a HP6890 equipment, with HP-5 column (30 m x 0.32 mm x 0.25 µm – 5% phenyl methyl siloxano) and N_2 gas, at the rate of 43 cm s^{-1}. The measurement was taken after temperature stabilization at 90° C during 3 minutes, followed by temperature increased to 200° C, at 25° C min^{-1}, and fixed at 200° C for one minute. The injection volume was 1 µL, using Splitless mode at 220° C. The purging time was one minute. The detector was an ECD at 300° C. The Nitrogen (N_2) make up rate (N_2) was 60 mL min^{-1}. At these conditions, the retention time for trifluralin was 7.92 minutes.

4 RESULTS AND DISCUSSION

Rain, irrigation and soil water tension data are showed in Figure 1. From 5 to 20 days after planting, the LVdf soil was the driest soil, followed by the PVA. The best moisture condition was found at the LVA. With sugarcane growth, the LVA lost the largest amount of water, becoming the driest soil. Higher amount of rainfall was at September 9th and 21st (36.3 and 60.2 mm, respectively), increasing soil moisture and causing leaching of trifluralin (Table 3). On October 8th, another rain event (23.3 mm) resulted in large percolation volumes, which was 27, 39 and 50% of the rainfall, respectively at LVdf, LVA and PVA soils.

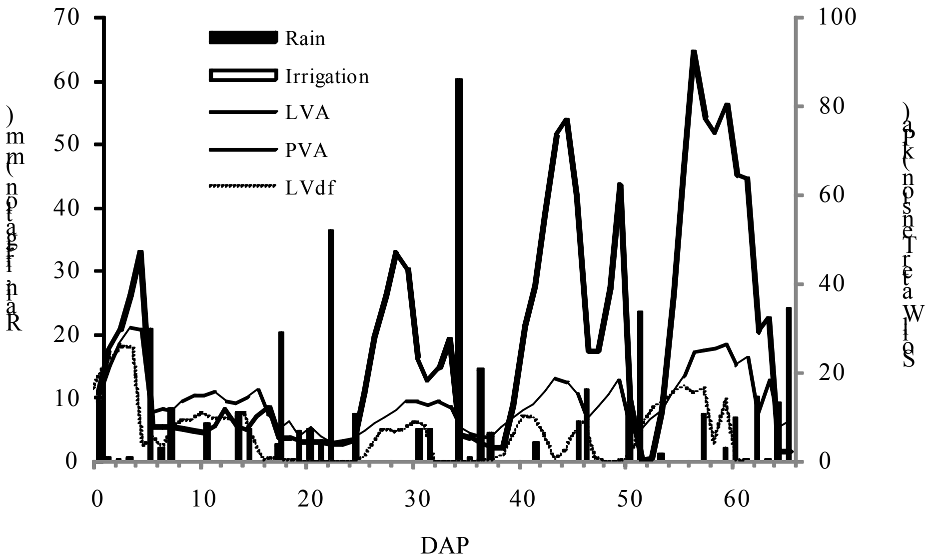

Figure 1. Precipitation (rainfall and irrigation) and soil water tension during the whole period of experiment.

Accordingly to the listed values, on Table 2, the flow rates at the drippers were uniform. The low coefficient of variation also means uniformity on irrigation among dates and soils. It shows that there was no clogging by root intrusion during the whole period of the experiment.

Table 2. Flow rate (L h^{-1}) and coefficient of variation (CV) at different dates

Soil	**Sept 7th**	**Sept 17th**	**Oct 4th**	**Oct 20th**
LVA	0.46a	0.44a	0.48a	0.51a
LVdf	0.44a	0.46a	0.50a	0.49a
PVA	0.50a	0.47a	0.53a	0.50a
CV (%)	10.58	4.67	14.96	9.93

Same characters reveal no difference according to Scott-Knott test, at 5% significant level.

Plant height values are shown at Figure 2. It can be verified that plant growth was also similar for all the soils, despite the little difference between the oxisols (LVdf and LVA), as compared to the argisoil (PVA). The lack of difference on plant growth is possibly an indicative of no water deficit due to possible root intrusion on drippers.

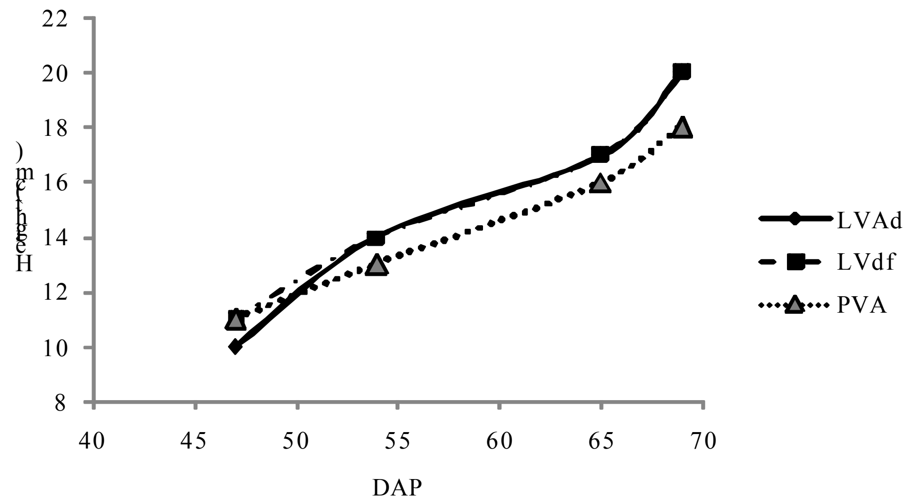

Figure 2. Plant height in different dates for three soil types.

Trifluralin concentration at the leachate is presented at Table 3, as well as the leachate volume and the quantity of trifluralin leached beyond 45 cm depth. It is important to notice that the application of Trifluralin was not done with soil in dry conditions, fact that might have given to the herbicide conditions for higher mobility due to possible convective flow.

Table 3. Average concentration (µg L^{-1}) of Trifluralin at different dates

	Avg concentration (µg L^{-1})			**Leached volume (liters)**			**Quantity (µg)**		
Soil	2/out	10/out	22/out	2/out	10/out	22/out	2/out	10/out	22/out
LVdf	0.00b	0.65a	0.40a	0.0b	5.0a	3.0a	0.0	3.3	1.2
LVA	3.75a	0.75[a]	0.33a	3.0a	7.3a	5.3a	11.3	5.5	1.7
PVA	0.94b	0.31[a]	0.53a	4.0a	9.3a	8.0a	3.8	2.9	4.2

Four days after planting (Oct 2^{nd}), trifluralin was detected only at the leachate of LVA soil. The value found was under the allowed limit for the drinking water (20.0 µg L^{-1}) by the Brazilian regulation (CONAMA, 2008), and also under the allowed limit (2 µg L^{-1}) by

EPA/USA (1988). Among the tested soils, higher leaching of trifluralin was found at LVA soil, even though the LVdf soil tends to present higher permeability, which points out for a preferential flow at the LVA soil which might have also contributed for the lower water content (less water remain at soil since it moves in preferential paths) and consequently higher soil water potential at this soil as can be observed in Figure 1.

Tavares et al. (1996) evaluated the adsorption and desorption of Trifluralin in soils and concluded that when the Trifluralin is adsorbed to the organic fraction, desorption to soil solution is very low. Comparing the leaching of Trifluralin (Table 3) with organic matter content of the soils (Table 1), it can be noticed that where organic matter was higher (LVdf), Trifluralin leaching was lower. At LVA, with lower organic matter content, the Trifluralin leaching was higher, confirming the important role of organic matter on preventing Trifluralin leaching in soils. It is important to notice that clay fraction also contributes to reduce herbicide mobility due to its adsorption characteristics.

Although the Trifluralin content in the soil leachate were lower than allowed limit by EPA, repeated applications of this product on soils, combined with strong rainfall events, might result in contamination of groundwater, especially if preferential flow is possible.

5 CONCLUSIONS

Since drip flow rate along the time was uniform, Trifluralin prevented drip clogging by root system or its growth was not sufficiently intense to cause root intrusion and drip clogging.

Since Trifluralin leached beyond 45cm depth in LVA, despite its lower permeability, preferential flow might be an important parameter that can account for deep soil contamination in this type of soil.

Amount of Trifluralin at the leachate was under the allowed limit by Brazilian regulation, but above the value accepted by American legislation (EPA).

6 REFERENCES

ANDRADE, C. L. T.; JÚNIOR, J. C. F. B. In: ALBUQUERQUE, P. E. P.; DURÃES, F. O. M. **Uso e Manejo de Irrigação.** Brasília, DF: Embrapa Informação Tecnológica, 2008. p. 317-400.

BERNARDO, S.; SOARES, A. A.; MANTOVANI, E. C. **Manual de Irrigação**. 7. ed. Viçosa: Ed. UFV, 2005. 611 p.

CASAGRANDE, A. A. **Tópicos de morfologia e fisiologia da cana-de-açúcar.** Jaboticabal: FUNEP, 1991. 157p.

CASTRO, N. R. A.; RIGITANO, R. L. O.; LIMA, J. M.; GUERREIRO, M. C. Lixiviação do inseticida thiamethoxam em macrolisímetros de duas classes de solo. **Ciência e Agrotecnologia**, Lavras, v. 32, n. 6, p 1818-1823, nov./dez., 2008.

CHRISTOFFOLETI, P. J.; OVEJERO, R. F. L. **Comportamento dos herbicidas aplicados ao solo na cultura da cana-de-açúcar**. Piracicaba: CP 2, 2009. 72 p.

CFSEMG (Comissão de Fertilidade do Solo do Estado de Minas Gerais). **Recomendações para o uso de corretivos e fertilizantes em Minas Gerais**. 5. ed. Lavras, 1999. 359 p.

CONAB (Companhia Nacional do Desenvolvimento). **Acompanhamento da safra brasileira: cana-de-açúcar, primeiro levantamento, abril/2009**; p. 1-15; Brasília, 2009.

CONAMA (Conselho Nacional de Meio Ambiente). **Resolução nº 396/2008**. p. 1-11; Brasília, 2008.

DALRI, A. B. Irrigação em cana-de-açúcar. In: SEGATO, S. V.; PINTO, A. S.; JENDIROBA, E.; NÓBREGA, J. C. M. **Atualização em Produção de Cana-de-açúcar.** ESALQ/USP, 2006. p 157-170.

EMBRAPA. Centro Nacional de Pesquisa de Solos (Rio de Janeiro, RJ). **Manual de métodos de análise de solos**. 2. ed. Rio de Janeiro, 1997. 212p.

ESTADOS UNIDOS. **Environmental Protection Agency. Health Advisory Summary. Atrazine.** Washington, DC: Environmental Protection Agency, Office of Drinking Water, 1988. 820p.

PIZARRO CABELLO, F. **Riegos localizados de alta freqüência (RLAF): goteo, microaspersión, exudación**. 3. ed. Madrid: Mundi-Prensa, 1996. 513p.

TAVARES, M. C. H.; LANDGRAF, M. D.; VIEIRA, E. M.; REZENDE, M. O. O. Estudo da adsorção-dessorção da trifluralina em solo e em ácido húmico. **Química Nova**, v. 19, p.605-608, 1996.

Van GENUCHTEN, M. T. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. **Soil Science Society of America Journal,** v. 44, p.892-898, 1980.