MOBILITY OF TWO WINTER WHEAT HERBICIDES, CHLOROTOLURON AND FLUFENACET, IN UNAMENDED AND AMENDED SOIL AT FIELD SCALE

Jesús M. Marín-Benito[1*], María J. Carpio[1], José M. Ordax[1], M. Sonia Rodríguez-Cruz[1], Laure Mamy[2], María J. Sánchez-Martín[1]

[1] Institute of Natural Resources and Agrobiology of Salamanca (IRNASA-CSIC), 40-52 Cordel de Merinas, 37008 Salamanca, Spain
[2] UMR ECOSYS, INRA, AgroParisTech, Université Paris-Saclay 78850 Thiverval-Grignon, France
* Corresponding author: jesusm.marin@irnasa.csic.es

INTRODUCTION

The application to soil of organic residues rich in nutrients and organic matter (OM) is a conservative agricultural practice often used to improve the soil fertility as well as to preserve the soil from degradation. Numerous organic residues from agricultural and industrial activities can potentially be used as amendments, such as composted spent mushroom substrate (SMS) and green compost (GC). However, despite these residues can modify the dynamic and environmental fate of herbicides applied to the amended soils, only scarce field studies have been done to assess the effect of organic amendments on pesticides fate [1].

OBJECTIVE

The aim of this work was to assess the effect of the addition of two different organic amendments, SMS and GC, on the mobility of two winter wheat herbicides, flufenacet and chlorotoluron, in an agricultural soil under field conditions.

MATERIALS AND METHODS

ORGANIC AMENDMENTS

Organic amendments	pH	Moisture (%)	EC[c] (dS/m)	OM (%)	N (%)	C/N
SMS[a]	7.9	37.7	7.8	59.4	2.3	15.2
GC[b]	7.2	48.6	2.2	46.0	1.1	21.8

[a]Composted spent mushroom substrate from mushroom cultivation, [b]Green compost from pruning of plants from gardens and parks, [c]Electric Conductivity

❖ Amendment dose (dry weight basis):
- SMS: 140 t ha^{-1}
- GC: 85 t ha^{-1}

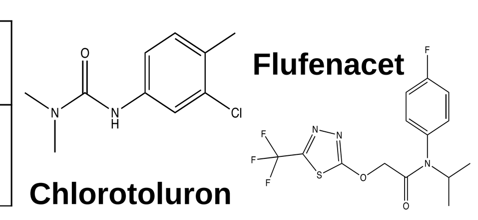

CHARACTERISTICS OF UNAMENDED AND SMS- AND GC-AMENDED SOILS (0-30 cm) AT TIME 0 DAY

Treatment	Depth (cm)	Bulk density (g cm^{-3})	pH	OC (%)	N (%)	C/N	θ_{FC}[a] (cm^3 cm^{-3})
S*	0-10	1.27	6.34	0.77	0.053	14.5	0.203
	10-30	1.40	6.62	0.91	0.073	12.5	0.195
S+SMS	0-10	1.02	7.11	2.53	0.237	10.7	0.290
	10-30	1.21	7.15	1.45	0.070	20.7	0.231
S+GC	0-10	1.10	6.99	1.63	0.136	12.0	0.249
	10-30	1.28	6.70	0.86	0.073	11.8	0.202

*Unamended soil: 14.9% clay, 4.7% silt and 80.4% sand (sandy loam soil)
[a]Soil water content at field capacity [2]

HERBICIDES AND TRACER ION

Herbicides	Water solubility (mg/L)	log Kow[a]	GUS Index
Chlorotoluron	74	2.5	3.02
Flufenacet	56	3.2	2.23



❖ Commercial formulations:
- Erturon (chlorotoluron 50% p/v)
- Herold (flufenacet 40% p/v)
- KBr

❖ Herbicides and tracer ion dose:
- Chlorotoluron: 15 kg a.i./ha
- Flufenacet: 5 kg a.i./ha
- Bromide ion: 53 kg a.i./ha


FIELD EXPERIMENT

❖ 3 treatments by quadruplicate
❖ 12 experimental plots (9×9 m^2) grown with winter wheat

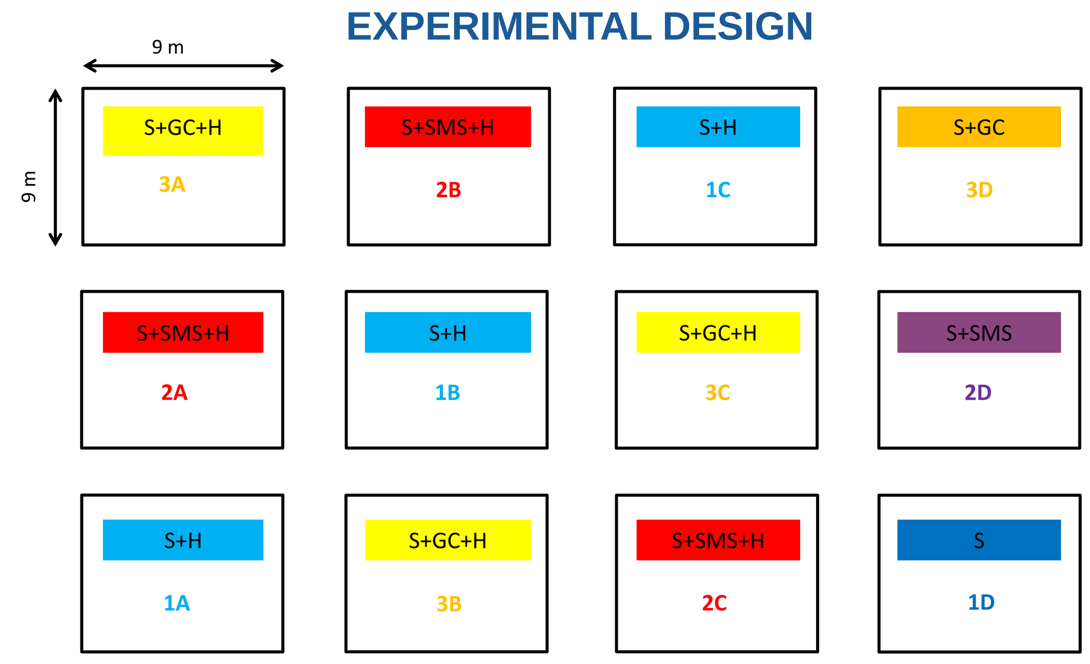
→ 3 control plots (without herbicide) | 9 plots treated with herbicide

→ Measurements in the soil

→ *Mobility* (0-100cm):
- Tracer ion
- Herbicides



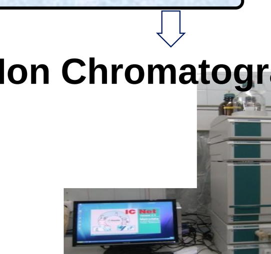
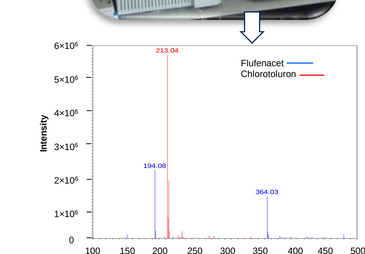
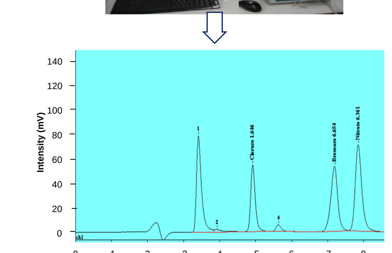
EXPERIMENTAL DESIGN



S = soil
H = herbicides
S+GC = soil + green compost
S+SMS = soil + spent mushroom substrate

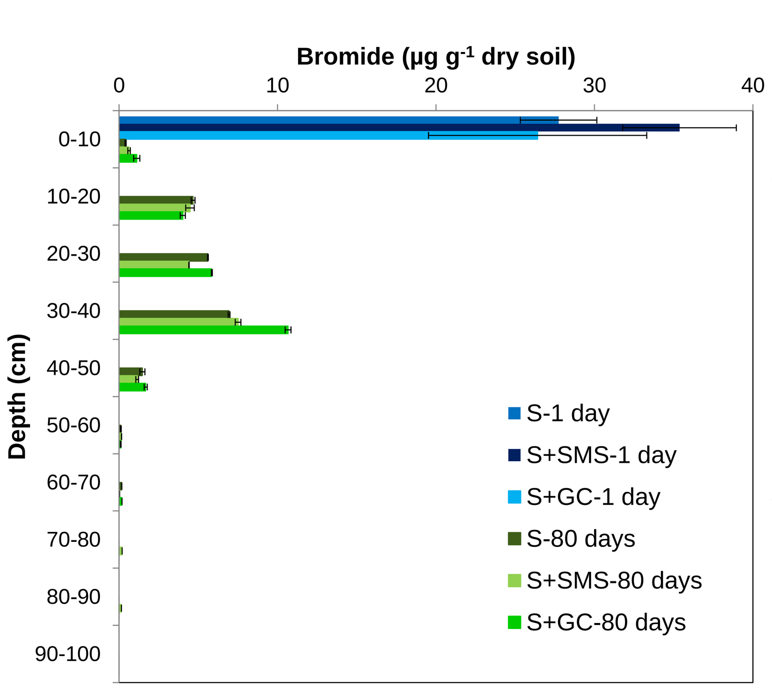
EXTRACTION AND ANALYSIS OF HERBICIDES AND TRACER ION

1. Sampling soil profiles (5 replicates/plot, 0-100 cm) Dates: 1, 17, 33, 60 and 80 days after application
2. Sub-sampling: 10 segments of 10 cm
3. Sieving (<2 mm) Determination of soil moisture content
4. 6 g soil + 12 mL acetonitrile (herbicides) | 6 g soil + 12 mL deionized water (bromide ion)
5. Ultrasonic bath (1 h) Rotatory shaker (24 h)
6. Centrifugation and filtration
7. Evaporation of 8 mL of herbicide extracts (herbicides)
8. Re-dissolution of the residue in 0.75 mL of acetonitrile
9. Quantification
10. HPLC-DAD-MS | Ion Chromatography

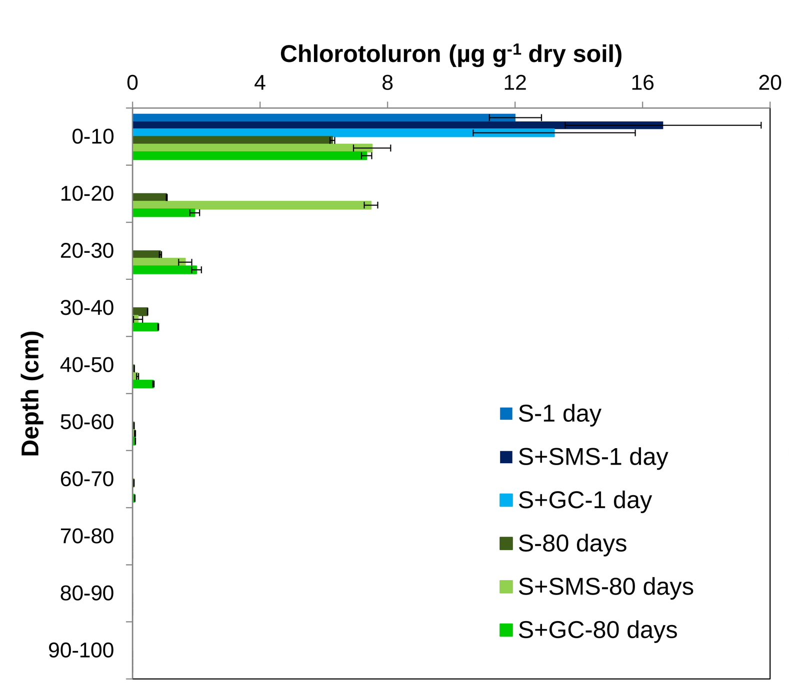





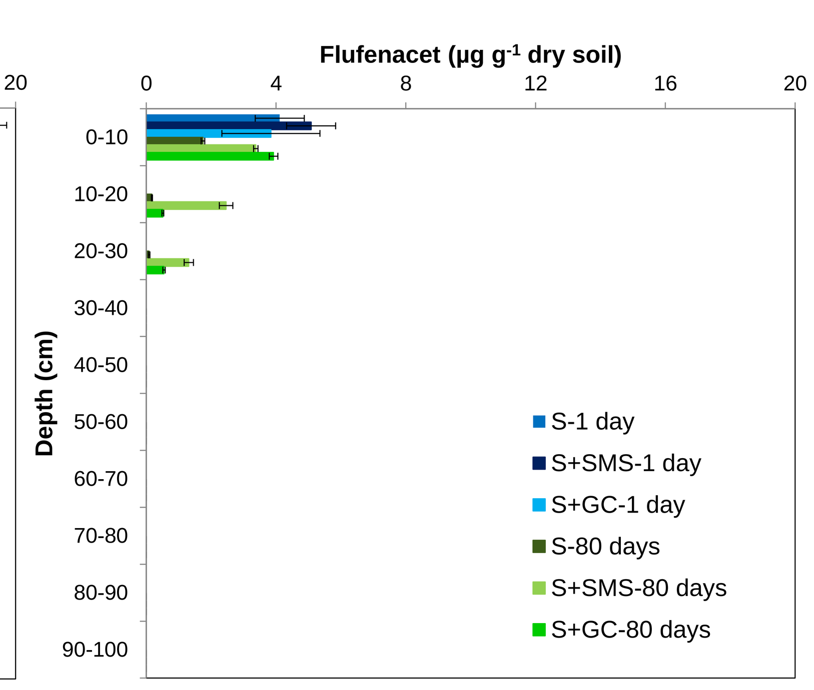
RESULTS AND DISCUSSION

DISTRIBUTION PROFILES OF BROMIDE, CHLOROTOLURON AND FLUFENACET IN UNAMENDED, SMS- AND GC-AMENDED PLOTS



- Amounts of bromide lower than 0.7% of the applied dose were detected at 60-70 cm-depth in S and S+GC plots, and at 80-90 cm-depth in S+SMS plots.
- The highest amounts of bromide were measured at 30-40 cm-depth.





- Chlorotoluron, the less hydrophobic herbicide, reached 50-60 cm-depth in S+SMS, and 60-70 cm-depth in S and S+GC (<0.6% of the applied dose).
- Flufenacet was limited to 20-30 cm-depth in all treatments.
- The highest amounts of herbicides were found at 0-10 cm-depth and the percentage of herbicides recovered at this depth was higher for amended soils than for unamended soils.
- Eighty days after application, the recovered amounts of herbicides in the topsoil were (% of the applied doses): 52% (S), 45% (S+SMS) and 55% (S+GC) for chlorotoluron; and 42% (S), 53% (S+SMS) and 73% (S+GC) for flufenacet.

❑ Eighty days after application, and following 69.8 mm of cumulative rainfall, concentration profiles showed that mobility increased in the order flufenacet < chlorotoluron < bromide.
❑ SMS and GC addition to soil were found to decrease both flufenacet and chlorotoluron mobility.
❑ These results agree with the higher OC content of amended soils, which could enhance the herbicides adsorption by soil and consequently decrease their mobility [1, 3].

CONCLUSION AND PERSPECTIVES

❑ The results obtained show that the application to soil of spent mushroom substrates (SMS) and green compost (GC) organic amendments could help to reduce groundwater contamination by herbicides in winter wheat cropping systems.

❑ Adsorption, dissipation, and microbiological studies are in progress in order to interrelate these processes with the environmental fate of the herbicides.

ACKNOWLEDGEMENTS: This work was funded by MINECO/FEDER UE (Project AGL2015-69485-R). María José Carpio thanks the University of Salamanca for her predoctoral USAL-Santander fellowship. Jesús M. Marín-Benito thanks MINECO for his Juan de la Cierva-Incorporación contract (Ref.: IJCI-2014-19538).

REFERENCES:
[1] Herrero-Hernández, E., Andrades, M. S., Marín-Benito, J. M., Sánchez-Martín, M. J., and Rodríguez-Cruz, M. S. (2011). "Field-scale dissipation of tebuconazole in a vineyard soil amended with spent mushroom substrate and its potential environmental impact." Ecotoxicology and Environmental Safety 74, 1480–1488.
[2] Rawls, W. J., Brakensiek, D. L., and Saxton, K. E. (1982). "Estimation of soil water properties." Transactions of the American Society of Agricultural Engineers, 1316–1320. Paper No. 81-2510.
[3] Herrero-Hernández, E., Marín-Benito, J. M., Andrades, M. S., Sánchez-Martín, M. J., and Rodríguez-Cruz, M. S. (2015). Field versus laboratory experiments to evaluate the fate of azoxystrobin in an amended vineyard soil. Journal of Environmental Management 163, 78–86.