Effect of compost amendment and compaction on the fate and ecotoxicological impact of isoproturon in soil

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Abstract The objective of this work was to study the effect of compost amendment and soil compaction on the fate and ecotoxicological impact (measured through two soil enzyme activities) of isoproturon. Compost addition and compaction did not significantly affect the fate of isoproturon. The lack of effect of compost can be due to the date of soil sampling and the delay after the amendment. The compost was added to the soil one year before. However, the effect of compost on properties such as pesticide degrading activities strongly varies with time after the amendment. Compaction had no effect probably because the porosity reduction does not affect the habitable pore space accessible to degrading microorganisms. Compost addition and/or soil compaction did not modify the impact of isoproturon on urease maybe because the incubation conditions were not limiting for the biological activity or because of repeated application of compost to the soil. However, the β-glucosidase was significantly affected by both isoproturon and compaction, except for the amended soil. The compost might act as a buffer with regard to compaction.

Introduction

Organic matter decline and compaction are two major processes of soil degradation. Compaction changes the physical properties of soils (porosity, air content…) with consequences on their biological functioning. Compost amendment is a current practice to compensate for the loss of organic matter, which could contribute to increase soil aggregate stability and limit compaction. Furthermore, composts also modify the chemical and biological properties of soils (e.g. stimulation of indigenous microflora, introduction of exogenous microorganisms). Although poorly documented, both compost addition and compaction could affect the fate and impact of pesticides in soils.
Thus, the objective of this work was to study the effect of compost amendment and soil compaction on the fate and ecotoxicological impact of isoproturon (one of the most used cereals herbicides in Europe).

Material and Methods

Soil and composts

Undisturbed soil cores (5 cm diameter, 2 cm height) were sampled in the interfurrows of two plots located in a long-term French experimental site (Feucherolles, Yvelines): one control plot (no compost) and one plot receiving a co-compost of sewage sludge and green waste (Table 1). The last compost addition and isoproturon application were carried out 12 months and 20 months before sampling, respectively.

Table 1. Main soil characteristics of the control and compost amended plots

Soil	pH (water)	Clay (%)	Loam (%)	Sand (%)	Organic carbon (%)
Control	6.75	17	76	7	1.19
Compost	6.76	17	76	7	1.41

Half of the soil samples were compacted leading to an increase in soil density of 0.3 g cm^{-3} as observed following wheeling: from 1.30 g cm^{-3} before compaction to 1.60 g cm^{-3} after compaction for the control soil, and from 1.15 to 1.45 g cm^{-3} for the amended soil.

Fate of isoproturon in soils

Soil samples (compacted and not compacted) were placed in 500 mL jars then treated with ^{14}C-isoproturon at agronomic doses (0.29 mg g^{-1} dry soil, equivalent to 1 kg ha^{-1}).

Soil water content was adjusted to reach 80% of pF 2.5.

Each jar contained vials with NaOH to trap the $^{14}CO_2$, and with water to maintain a constant relative humidity. The jars were incubated at 28°C in darkness for 49 days. The NaOH traps were periodically sampled and replaced to determine the mineralization kinetics of isoproturon.

At 0, 7 and 49 days, four sequential extractions of soil samples were done: one with $CaCl_2$ 0.01 M for 24 hours and three with CH_3OH, each for 18 hours. Samples were mechanically shaken at 20°C in the dark and then centrifuged for 15 min at 9000 g. Non-extractable residues corresponded to the radioactivity remaining in the soil pellet after the four extractions.

The $^{14}CO_2$ and the extractable ^{14}C were measured by liquid scintillation counting. The amounts of non-extractable residues were determined by liquid scintillation counting of the $^{14}CO_2$ evolved after soil combustion.

Ecotoxicological impact of isoproturon in soils

The incubation conditions were similar as those of the fate study (0.29 mg isoproturon g^{-1} dry soil, 28°C, darkness), except that soil samples were treated with non-labelled isoproturon.

The ecotoxicological impact of isoproturon was then studied at 0, 7 and 60 days through the measure of two enzyme activities involved in C (β-glucosidase) and N (urease) cycles. The activity of the β-glucosidase was determined after incubation of 1 g of the soil sample with p-nitrophenyl-β-D-glucopyranoside 0.05 M, and that of urease after incubation of 1 g of soil with urea 0.4 M. Three measures of enzyme activity were done for each soil sample. The absorbance of the reaction products were determined by UV spectrophotometer at 410 nm for β-glucosidase and at 610 nm for urease.

Some samples (amended or not, compacted or not) were also incubated without isoproturon treatment as control.

Five replicates were done for each soil, compaction, treatment, and sampling date.

Statistical analyses

Statistical analyses were done with XLSTAT (AddinSoft, Brooklyn, NY, USA).

The effect of compost, compaction and isoproturon on enzyme activities was tested by the Mann-Whitney test.

The effect of compost and compaction on extractable and non-extractable ^{14}C residues with time was tested with a three-ways ANOVA (compost, compaction and time as factors). The mineralization at the end of the incubation was compared for the different treatments by means of ANOVA.

The effects were considered significant when $p < 0.05$.

Results

Fate of isoproturon in soils

Both compost amendment and compaction did not affect the fate of isoproturon in soil (Figures 1, 2).

At the end of the incubation, the mineralization of isoproturon reached a maximum of 20%. A difference between amended and not amended soils, compacted or not compacted soils did not occur (Figure 1). From 0 to 49 days, a decrease in the ^{14}C extractable amounts was observed with an increase in the mineralization and in the amounts of non-extractable residues (Figure 2).

The amounts of total extractable ^{14}C were not different in the four incubation conditions, and they were very high at days zero and seven (more than 80% and 50% of initial ^{14}C, respectively). The $CaCl_2$-extractable ^{14}C provides an estimate of the risk of groundwater contamination by the herbicides and/or its metabolites, therefore these risks were very high at the beginning of incubation. Nevertheless, the proportions of $CaCl_2$-extractable ^{14}C were lower in the amended soils (45-50% of initial ^{14}C) than in the not amended soils (60% of initial ^{14}C) at day zero. Indeed, organic matter is known to increase the sorption of isoproturon in soils and therefore to decrease its mobility [3]. After 49 days, almost 20% of the initial ^{14}C were still extractable, but there was no difference between amended and not amended soils (Figure 2).

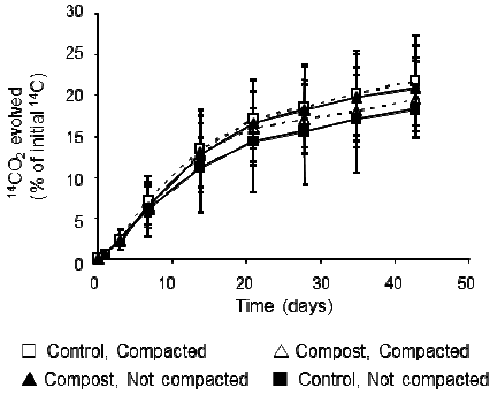

Figure 1. Mineralization kinetics of isoproturon in amended or not amended soil, compacted or not compacted

In all cases, the main dissipation pathway was the formation of non-extractable residues: at the end of incubation, they reached more than 70% of the initial ^{14}C (Figure 2). The amounts of non-extractable residues were similar in the amended and not amended soils, though they generally increase with the soil organic carbon content [4]. This result was also observed for pesticides such as 2,4-D and carbetamide which are, similar to isoproturon, low sorbed pesticides [5].

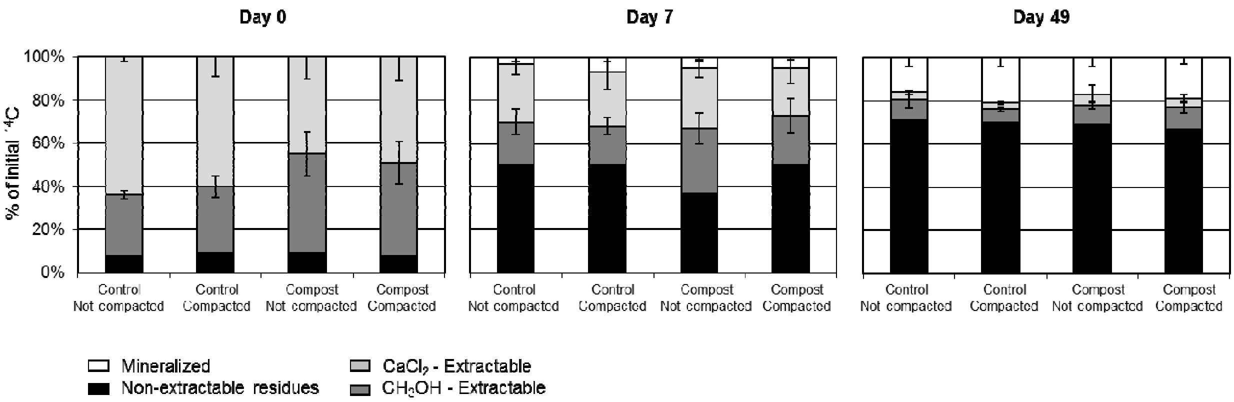

Figure 2. Overall balance of the fate of isoproturon after 0, 7 and 49 days in compacted and not compacted soil, amended or not with compost

Compaction had no effect on the fate of isoproturon probably because the reduction in porosity did not affect the habitable pore space accessible to degrading microbial communities [1].
The unexpected lack of effect of compost can be due to the chemical characteristics of this compost [2], to the lack of significant change in the soil properties after compost addition, or because the effect of compost on pesticide degrading activities strongly vary according with the time of sampling and the delay with the last amendments.

Ecotoxicological impact of isoproturon

No significant impact of isoproturon on the β-glucosidase and urease activities was observed when comparing the isoproturon treated and untreated soil samples (Table 2). This can be explained by the adaptation of microorganisms following the previous applications of the herbicide in the field [6].
The effect of isoproturon on the urease activity was not impacted by compaction or compost addition (Table 2). That lack of effect may be due to non-limiting incubation conditions for the biological activity or repeated application of compost in the soil for ten years.
However, the β-glucosidase was significantly affected by compaction except in the soil which was amended with compost. It seems that the compost acts as a buffer with regards to compaction.

Table 2. Effect of compost amendment and compaction on the ecotoxicological impact of isoproturon measured through the β-glucosidase and urease enzyme activities

Conditions of soil incubation		β-glucosidase	Urease
Effect of isoproturon (treated / untreated)	No compost (compacted / not compacted)	ns	ns
	Compost (compacted / not compacted)	ns	ns
Effect of compost addition on the impact of isoproturon	Not compacted (compost / no compost)	s	ns
	Compacted (compost / no compost)	s	ns
Effect of compaction on the impact of isoproturon	No compost (compacted / not compacted)	s	ns
	Compost (compacted / not compacted)	ns	ns

s: significant (Mann-Whitney test, $p < 0.05$), ns: not significant ($p > 0.05$)

Conclusion and perspectives

The study of the coupled effect of compost addition and compaction on the fate and impact of isoproturon showed that there were very few modifications compared to the not amended and not compacted soils. The overall fate of isoproturon was similar as the amounts of mineralized, extractable and non-extractable residues were generally not significantly different. Nevertheless, considering the impact of isoproturon on enzyme activities, it seems that compost can act as a buffer with regards to the effects of compaction.

However further research should be performed with other composts, pesticides, and biological indicators (e.g. microbial biomass, fatty acids).

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