Contribution of plant to the DOC pool in a soil-plant-digestate system: a ^{13}C-labelling experiment

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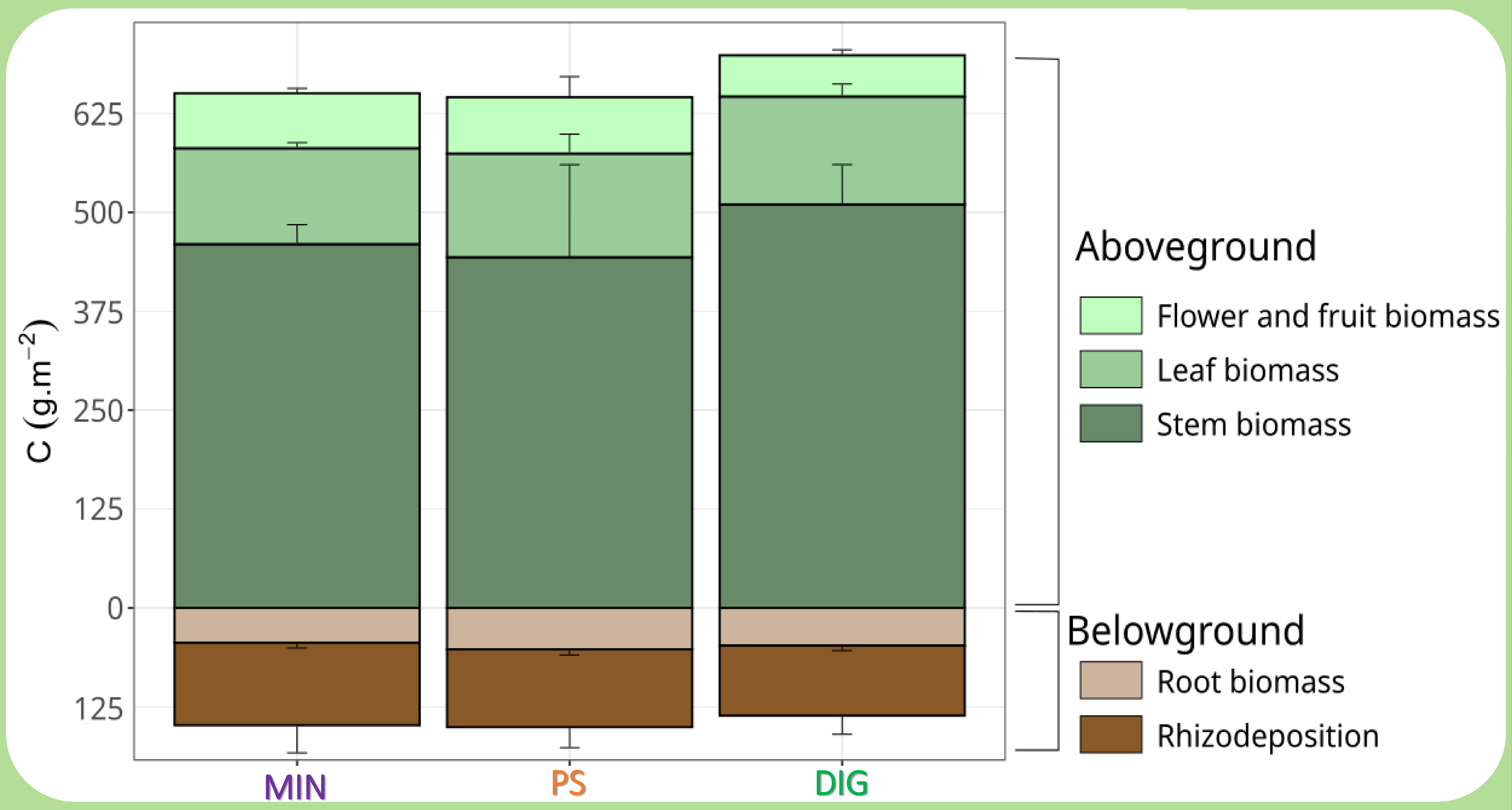
Introduction

- Carbon (C) cycle in agrosystems is not completely understood, in particular the **interactions** between **plant rhizodeposition** and **organic input** applied on soil
- Dissolved organic carbon (**DOC**): mobile and bioavailable fraction, important in the C cycle, heterogeneous composition supplied by various **sources** (plants, organic inputs)
- **Rhizodeposition**: release of organic C into the soil by roots
- **Biogas digestate**: chemically persistent composition after anaerobic digestion, biostimulant properties on crops [1]
- Previous lysimeter **field study**: **higher DOC concentrations** measured under a mustard winter crop for a pig slurry digestate treatment (compared to the original pig slurry and mineral fertilizer)
- **What is the contribution of the plant to the dissolved C pool ?**

Results

Average **δ^{13}C signals**: 1778‰ in leaves/stems/roots, 593‰ in flowers/fruits, 10.7‰ in the rhizosphere, -18.2‰ in the bulk labelled soil, 173‰ in the labelled water, -28.2‰ in the unlabelled soil and -26.5‰ in the unlabelled water

No significant differences between treatments regarding the **aboveground** and **belowground biomasses**. Very low **root:shoot ratio** (mean: 0.08 ± 0.01).



Between columns with or without plants, similar **DOC** concentrations (whatever the treatment) and higher **DIC** concentrations with plants. Plants contributed to 13.3 ± 6.2% of the **total dissolved C** (DOC + DIC).

Columns	Treatment	DOC	DIC	Total dissolved C from plants	% from plants in the total dissolved C
		mg.L^{-1}	mg.L^{-1}	mg.L^{-1}	%
With mustard (Labelled)	MIN	10.3 ± 1.8^a †	3.1 ± 0.6^a	1.6 ± 0.9^a	14.0 ± 8.0^a
	PS	13.4 ± 2.8^a	2.1 ± 1.1^a	2.1 ± 0.9^a	16.3 ± 8.3^a
	DIG	11.1 ± 1.7^a	2.8 ± 0.4^a	1.2 ± 0.1^a	9.6 ± 2.4^a
Without mustard (Unlabelled)	MIN	12.1 ± 1.0^a	0.4 ± 0.1^a		
	PS	13.4 ± 0.7^a	0.4 ± 0.1^a		
	DIG	13.2 ± 2.0^a	0.4 ± 0.1^a		

† Standard deviation

C from **rhizodeposition** measured in the **rhizosphere** (97 ± 26 g C.m^{-2}) and in **drained water** (44 ± 20 mg C.m^{-2}), higher compared to the C contained in roots (48 ± 5 g C.m^{-2}), resulting in a high **rhizodeposition:root ratio** (2.0 ± 0.5). Negative **priming effect** in **rhizosphere** (-1.2 ± 17% on average) and **drained water** (-161 ± 59% on average).

Treatment	C from rhizodeposition in rhizosphere soil	C from rhizodeposition in drained water	Rhizodeposition: root ratio	Priming effect in the rhizosphere	Priming effect in the drained water
	g C.m^{-2}	mg C.m^{-2}		%	%
MIN	104 ± 38^a	44 ± 25^a	2.4 ± 0.8^a	7 ± 24^a	-147 ± 64^a
PS	98 ± 16^a	58 ± 27^a	1.9 ± 0.3^a	-5 ± 11^a	-176 ± 59^a
DIG	89 ± 23^a	31 ± 2^a	1.8 ± 0.3^a	-6 ± 14^a	-160 ± 55^a

Material and methods

- Soil from the **field trial** (Luvisol-redoxisol, 1.2% C_{orga}, pH 6.3) that received pig slurry (PS), its digestate (DIG) or a mineral fertilizer (MIN)
- Greenhouse conditions
- **24 soil columns** (4 replicates/treatment):
  ↳ 12: containing 2 plants of **white mustard** (*Sinapis alba*), 12: soil only
- Columns with plants: airtight transparent chambers twice per week for 3h, injection of $^{13}CO_2$ (multi-pulse labelling by photosynthesis)

After 2.5 months of labelling:

- Induction of **drainage**
- Filtering, **DOC** and **DIC** (inorganic) concentrations measurement
- **δ^{13}C** measurement using cavity ring-down spectroscopy in: leaves, stems, flowers, fruits, roots and drained water samples
- **Rhizodeposition** and **rhizosphere priming effect** assessment

Discussion

- **^{13}C enrichment** in all parts of labelled plants, soil and drained water
- More **C** lost by **rhizodeposition** than C contained in **roots**, as observed by Hirte et al. (2018) [2]
- **Negative priming effect** (preferential use of fresh substrates by microorganisms)
- Additional **DIC** in columns with plants comes from plant-derived organic C that was **mineralized**, or **root respiration**
- **No higher DOC** concentrations observed for **DIG** compared to the other treatments (as observed in the field trial):
  ↳ In the greenhouse, **optimized conditions** (temperature, light)
  ↳ Enhanced **mineralization** of **organic matter**, **nutrients** more **available**
  ↳ Different plant **morphology** (aboveground biomass of 2 t DM.ha^{-1} in the field, 15 t DM.ha $^{-1}$ in the greenhouse)
  ↳ Plants **allocated** a majority of the fixed C to the **aboveground** parts
  ↳ **Rhizodeposition**, in particular **exudation**, can take part in nutrients recovery [3]: no need in this experiment
  ↳ No higher biomass for **DIG** treated plants, despite its **biostimulant properties** [1]: when the soil from the field trial was collected, presence of a cover crop sown a month earlier, **absorption** of the biostimulant molecules [4] that were no longer available for the labelling experiment ?

Conclusion

- **No significant differences** between MIN, PS and DIG regarding biomasses, rhizodeposition and rhizosphere priming effect
- **Higher DOC** concentrations **not observed** for **DIG** under greenhouse conditions

[1] Wu and Dong, 2020. Nutrients and Plant Hormones in Anaerobic Digestates, in: Biorefinery of Inorganics.
[2] Hirte et al., 2018. Below ground carbon inputs to soil via root biomass and rhizodeposition of field-grown maize and wheat at harvest are independent of net primary productivity. Agriculture, Ecosystems & Environment.
[3] Inderjit and Weston, 2003. Root Exudates: an Overview, in: Root Ecology, Ecological Studies.
[4] Wong et al., 2015. The importance of phytohormones and microbes in biostimulants: mass spectrometric evidence and their positive effects on plant growth. II World Congress on the Use of Biostimulants in Agriculture.

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