Driving Soils to Change: Tyre Particles Modulate Microbial-Mediated Soil Functions & Nutrient Status in Vegetable Crops

Kundel D.[1*], Bigalke M.[2], Fliessbach A.[1], Stehle B.[1], Hammer M.[1], Nitzsche K. N.[2] & Bünemann E. K.[1]

01 Background

- Tyre particles (TP) from road traffic can infiltrate soil, potentially impacting microbial communities and crop yields.
- Global per capita TP emissions range from 0.23-4.5 kg/year [1], equivalent to 0.1-117 g TP/kg soil [2-6].
- A scarcity of data impedes comprehensive TP risk assessment in soils.

→ We grew leek and lettuce in the presence of five TP concentrations and measured the impact on the plant-soil system.

02 Material and Methods

- TP (<350 µm) were produced in liquid N from old tyres (Fig. 1).
- Leek and lettuce was grown in a slightly humic, loamy sand with 5 TP concentrations (0%, 0.1%, 0.5%, 1%, 3%) during 7 and 12 weeks (Fig. 2).
- We measured TP effects on
  - microbial catabolic profiles using the MicroResp™ test,
  - extracellular enzymatic activity upon addition of seven substrates with fluorometric enzyme assays,
  - plant biomass and trace metal concentrations

Fig. 1. TP production. a) generation of tyre curls, b) and c) freeze d) final TP.

Fig. 2. Plants were exposed to TP.

03 Results: Tyre particle addition affects…

extracellular enzymatic activity

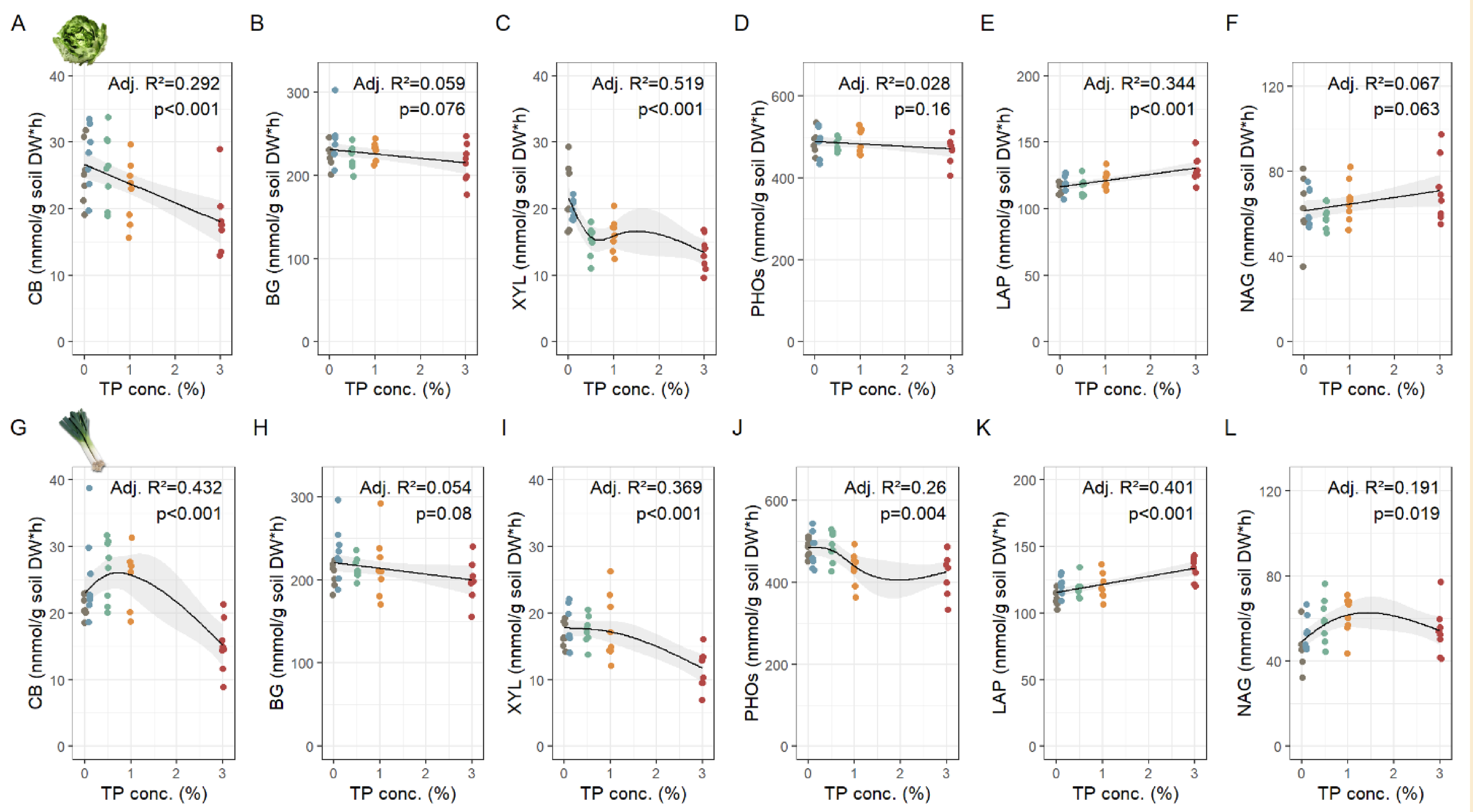

Fig. 3: Effect of TP addition on extracellular enzyme activity involved in C-cycling (CB, BG, XYL), P-cycling (PHOs) and N-cycling (LAP, NAG) measured for lettuce and leek.

Raw data points with smoothed splines and 95% CIs.
Adj. R^2= Adjusted R^2 value, p: p-value of smoothing term.
CB: 4-Methylumbelliferyl-ß-D-glucopyranoside;
BG: 4-Methylumbelliferyl-ß-D-glucopyranoside;
XYL: 4-Methylumbelliferyl-ß-D-xylopyranoside;
PHOs: 4-Methylumbelliferyl phosphate;
LAP: 7-Leucin-7-amido-4-methylcoumarin-hydrochloride,
NAG: 4-Methylumbelliferyl N-acetyl-ß-D-glucosaminide.

plant biomass

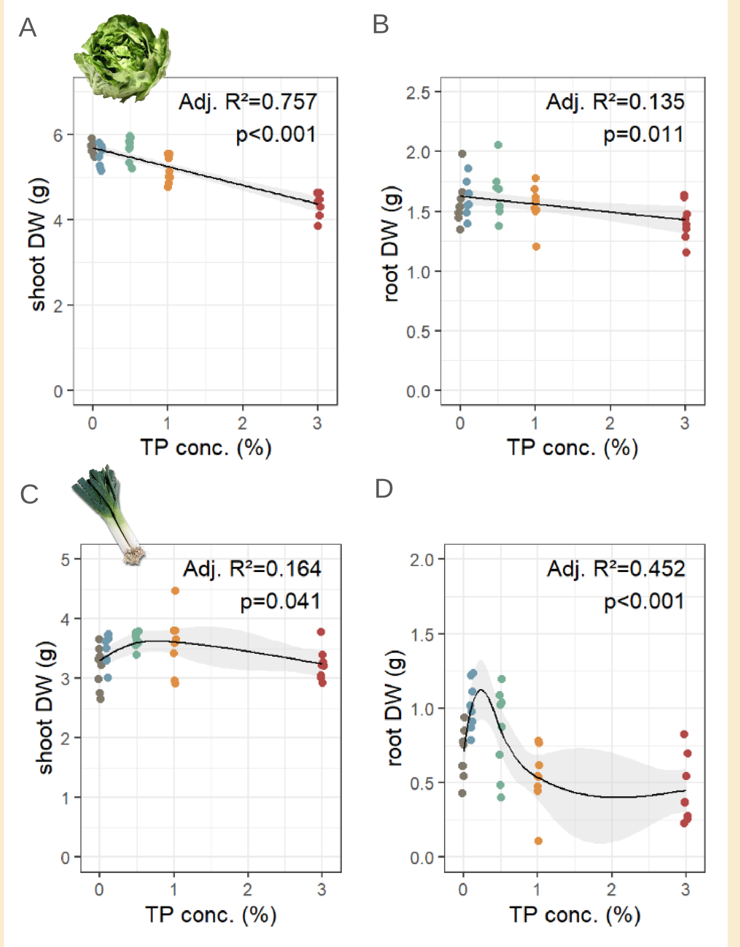

Fig. 5: Effects of TP addition on lettuce (A, B) and leek (C, D) shoot and root dry weight (DW)

Raw data points with smoothed splines and 95% confidence intervals. Adj. R^2= Adjusted R^2 value, p: p-value of smoothing term

microbial respiration profiles

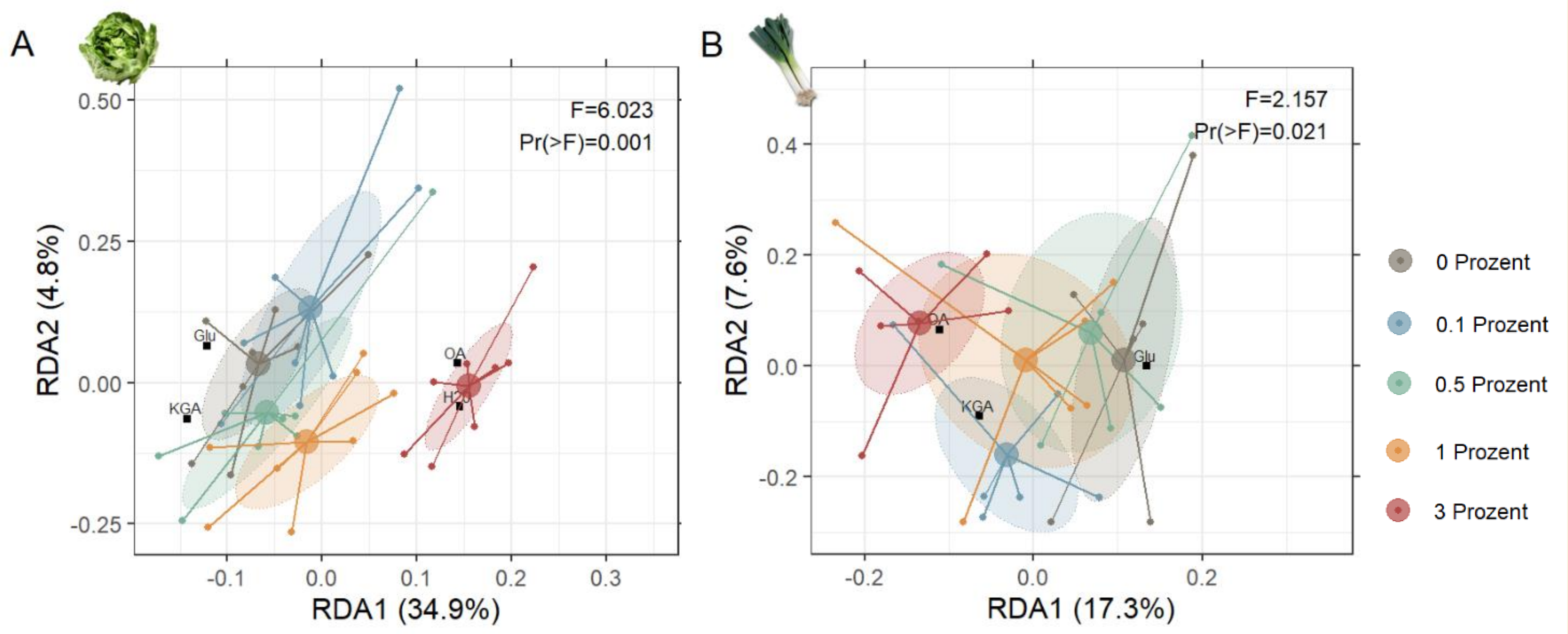

Fig. 4: Redundancy analysis (RDA) on catabolic expression profiles upon addition of 8 substrates[1] and different TP concentrations for lettuce (A) and leek (B).

[1]water (H20); D-glucose (GLU); L-alanine (ALA); gamma-aminobutyric acid (ABA); n-acetyl-glucosamine (NAG); oxalic acid (OA); alpha-ketoglutaric acid (KGA); xylan (XYL)

plant nutrition

Element	Lettuce	Leek
N (%)	-	-
P (µg/g)	+	0
S (%)	+	0
Ca (µg/g)	+	0
K (µg/g)	0	-
Na (µg/g)	-	+
Zn (µg/g)	+	+
Cu (µg/g)	0	+

Table 1: Effects of TP addition on plant nutritional status.

Pairwise comparisons between the 0% and 3% TP groups, with increases compared to the control group marked as "+", decreases as "-", and no discernible effect marked as "0".

04 Discussion

- TP exposure induced distinct microbial catabolic profiles and significant shifts in extracellular enzymatic activity, TP exposure led to adverse impacts on plant biomass.
- TP led to higher Zn uptake of ~30-55 % relative to the controls → but Zn below toxic threshold (~ 100 µg g^{-1}).

The intricate mechanisms behind our observations require further investigation, but our study highlights the urgency of minimizing TP entries into soils to preserve soil quality in the long term and advocates for proactive measures to safeguard our vital soil ecosystems.

Author affiliation
[1]Soil Sciences Department, Research Institute of Organic Agriculture (FiBL), Frick, Switzerland
[2] Institute of Applied Geosciences, Technical University of Darmstadt, Darmstadt, Germany
* Presenting author

Bibliography
[1] Kole et al. (2017). Int. J. Environ. Res. Public Health 14.
[2] Wik & Dave, (2009). Environ. Pollut. 157, 1–11.
[3] Wagner et al. (2018). Water Res. 139, 83–100.
[4] Baensch-Baltruschat et al. (2018). Sci. Total Environ. 733, 137823.
[5] Sieber et al. (2020). Environ. Pollut. 258, 113573.
[6] Müller et al. (2022). Chemosphere 294, 133653.