From petroleum contaminated soil to biofuels: case of *Miscanthus x giganteus*

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1. Miscanthus x giganteus

- *Poaceae* family
- Perennial grass
- C4 metabolism
- Low nutrition demand
- Second generation biofuel crop
- 15-25 t/ha (agricultural soil)
- Heat value 17 MJ/kg
- Non-invasive

Miscanthus x giganteus

Miscanthus x giganteus

fuel

animal bedding

mulch

construction materials

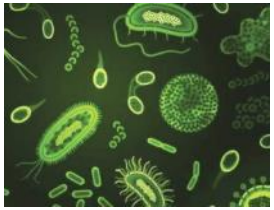
chemicals

packaging materials

phytoremediation

erosion prevention

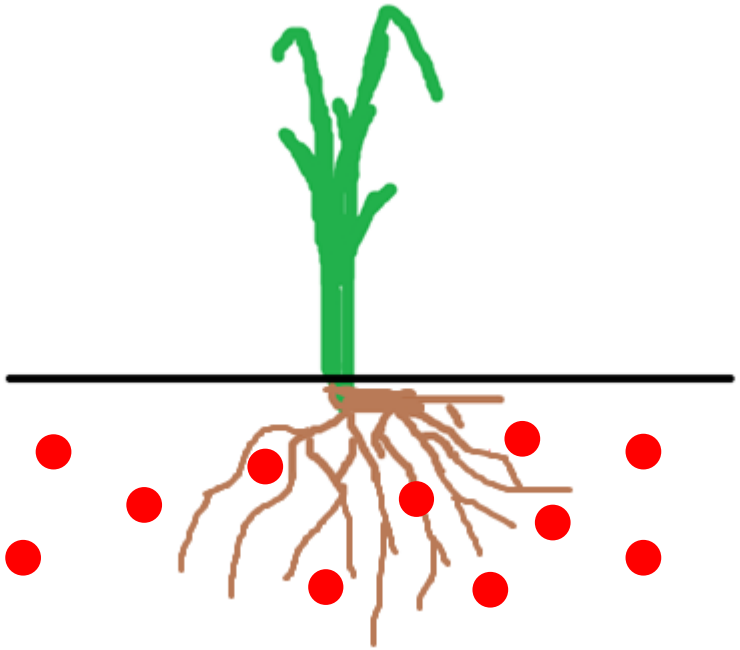
soil microorganisms development



organic matter

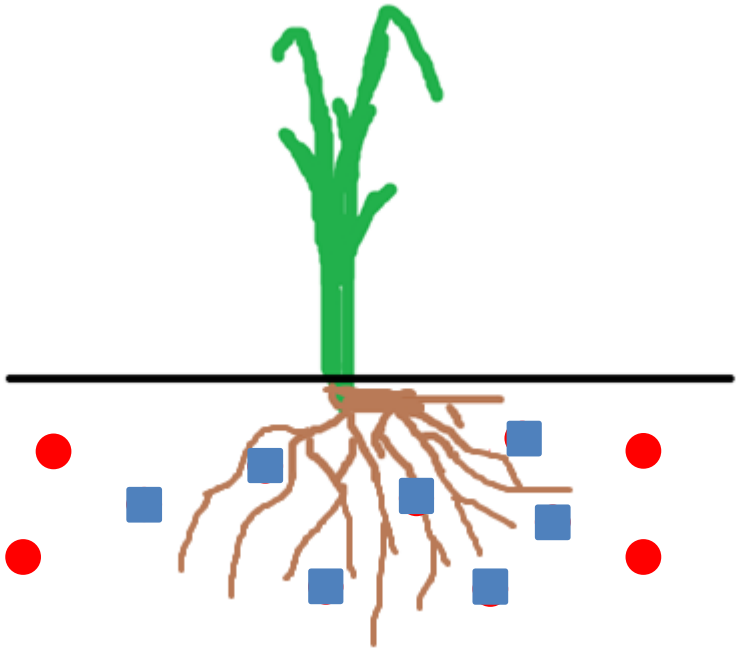
Phytoextraction

- =uptake of pollutants from soil to plants



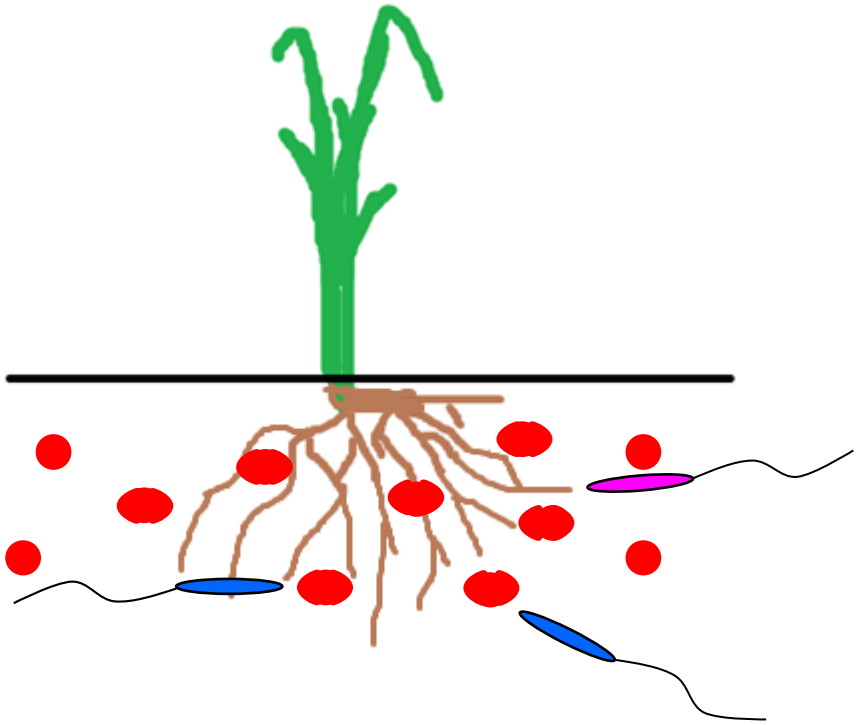
Phytostabilization

- =changing pollutants to less bioavailable / less toxic



Rhizodegradation

- =biodegradation of pollutants by microorganisms supported by plant roots



Second experiment – dilution of contaminated soil

JAN EVANGELISTA PURKYNĚ UNIVERSITY IN ÚSTÍ NAD LABEM
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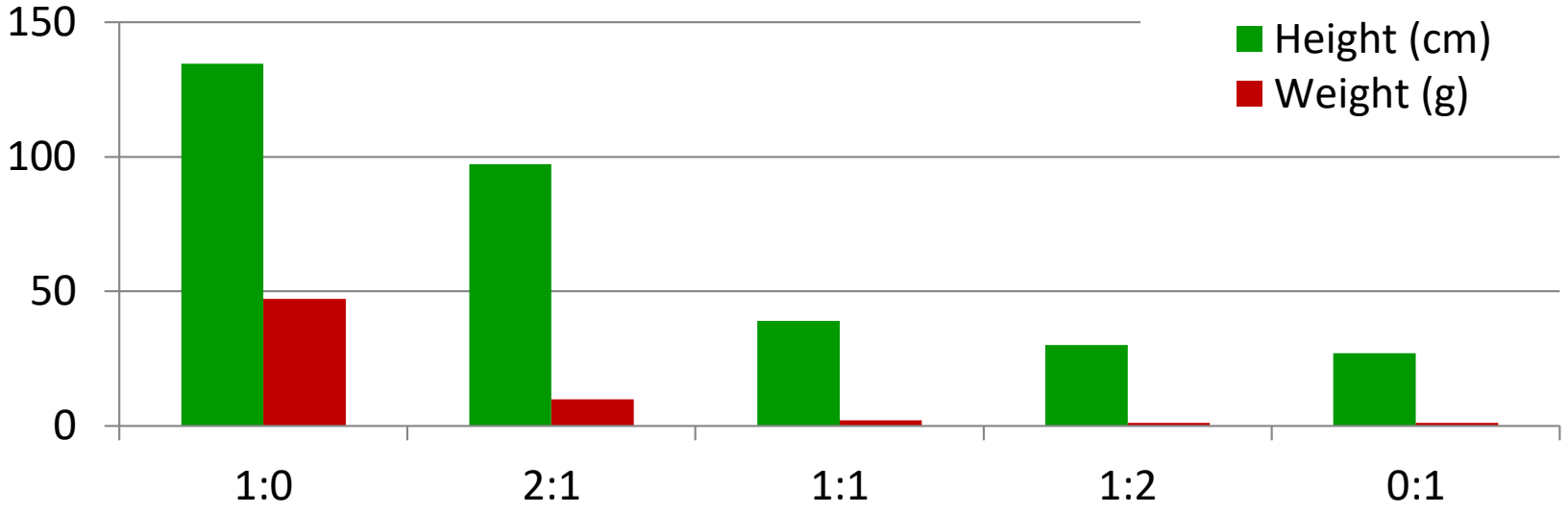
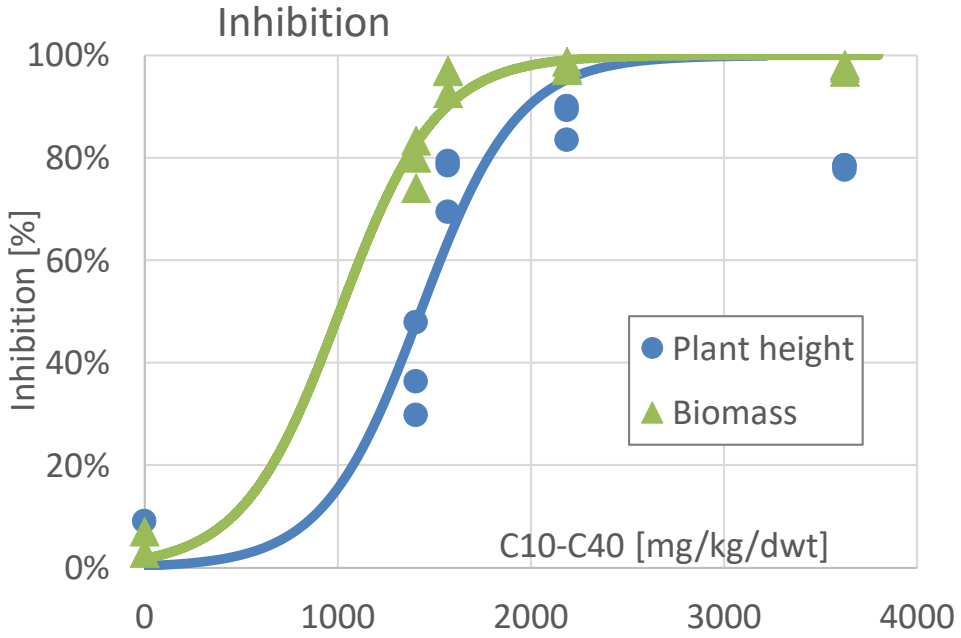
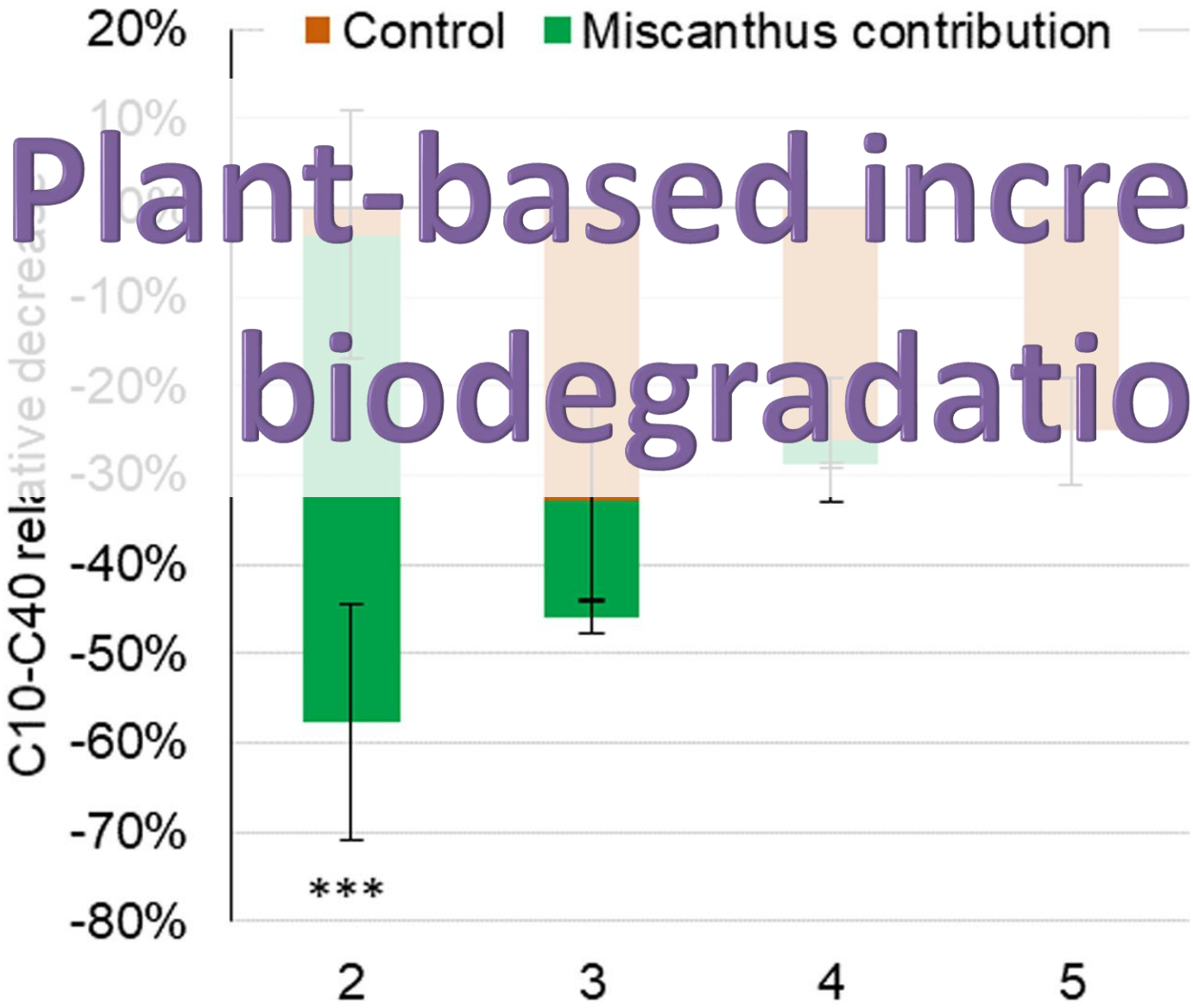




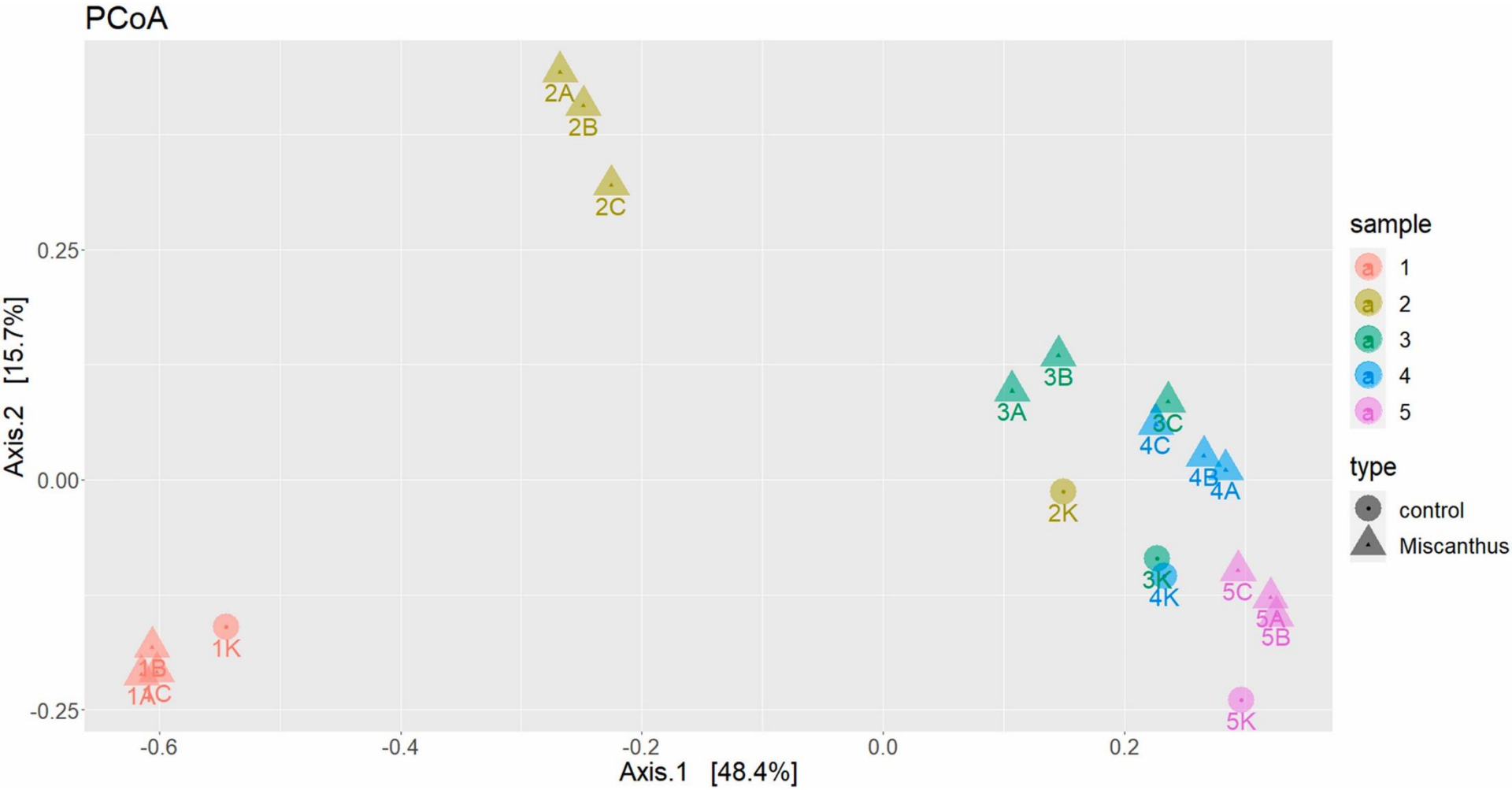
Aliphatics biodegradation



Plant-based increased biodegradation

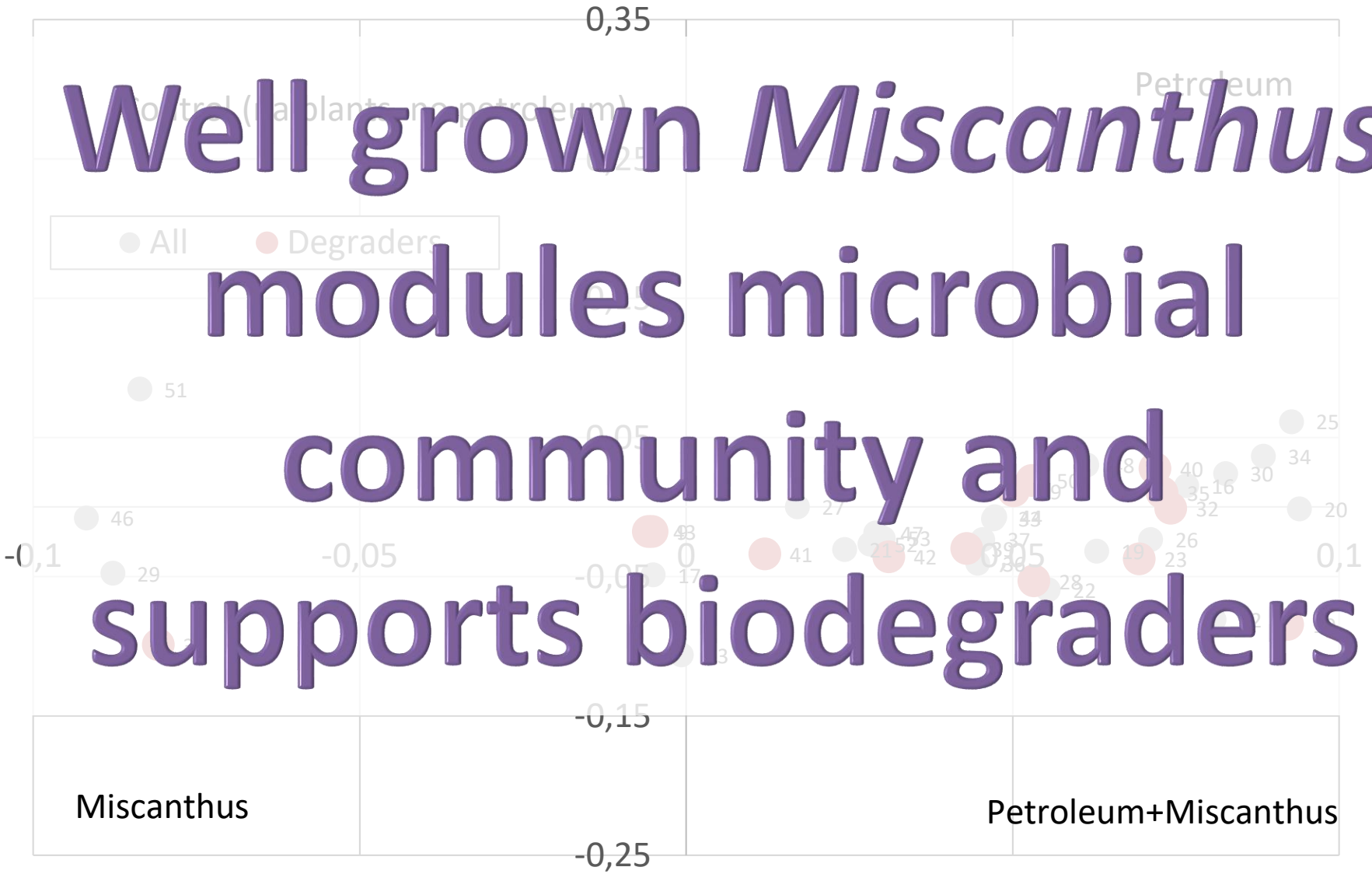
Nebeská et al., *Ecotox. Environ. Safety* 224 (2021) 112630

PCoA - microorganisms



Nebeská et al., *Ecotox. Environ. Safety* 224 (2021) 112630

Biodegrading organisms



Well grown *Miscanthus* modules microbial community and supports biodegraders

Nebeská et al., *Ecotox. Environ. Safety* 224 (2021) 112630

Third experiment – spiked soil

Third experiment – spiked soil

- Spiking of pure soil by pure diesel

Third experiment – spiked soil

Control

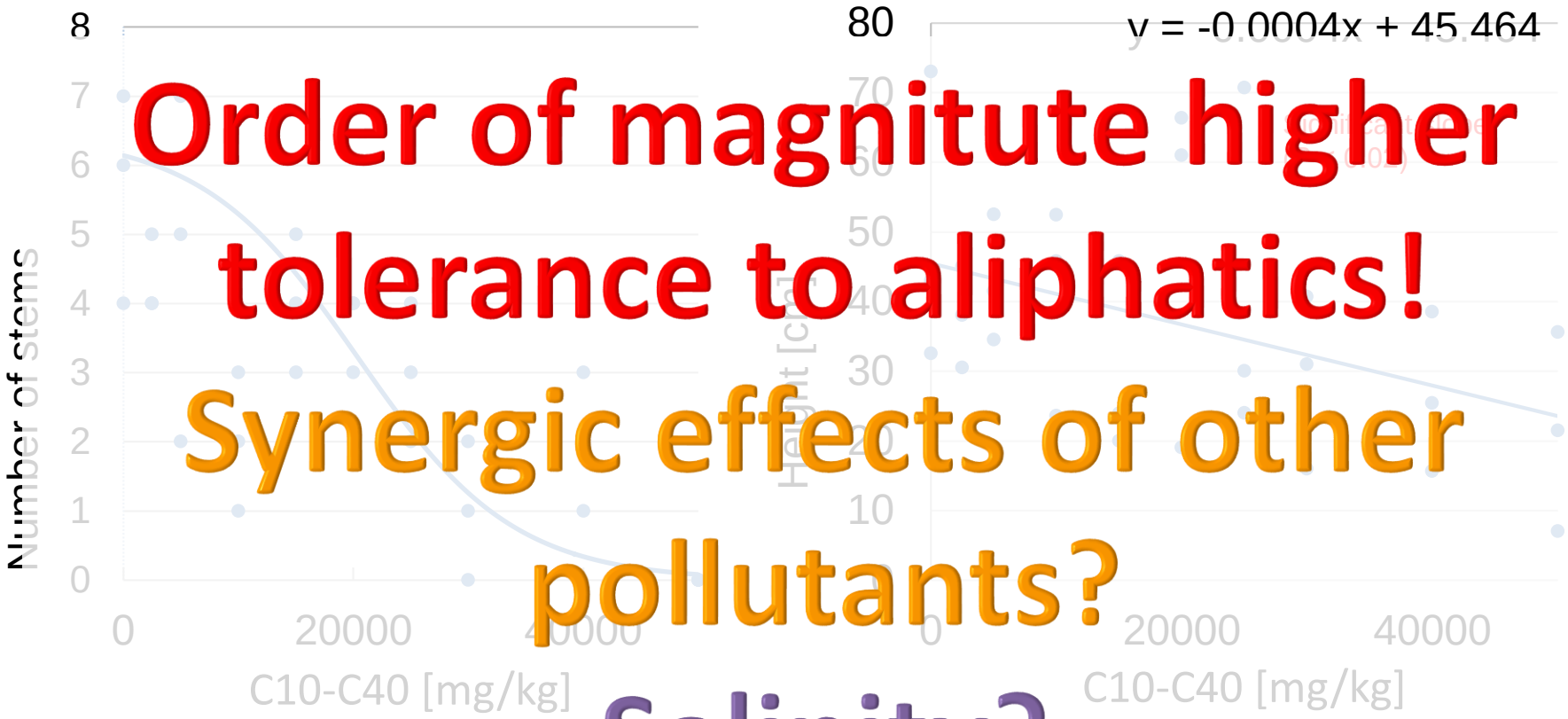
5000 mg/kg

25 000 mg/kg

50 000 mg/kg

Burdová et al. *J. Environ. Manag.* 344 (2023) 118475

Third experiment – spiked soil



Order of magnitute higher tolerance to aliphatics!

Synergic effects of other pollutants?

Salinity?

Nutrients?

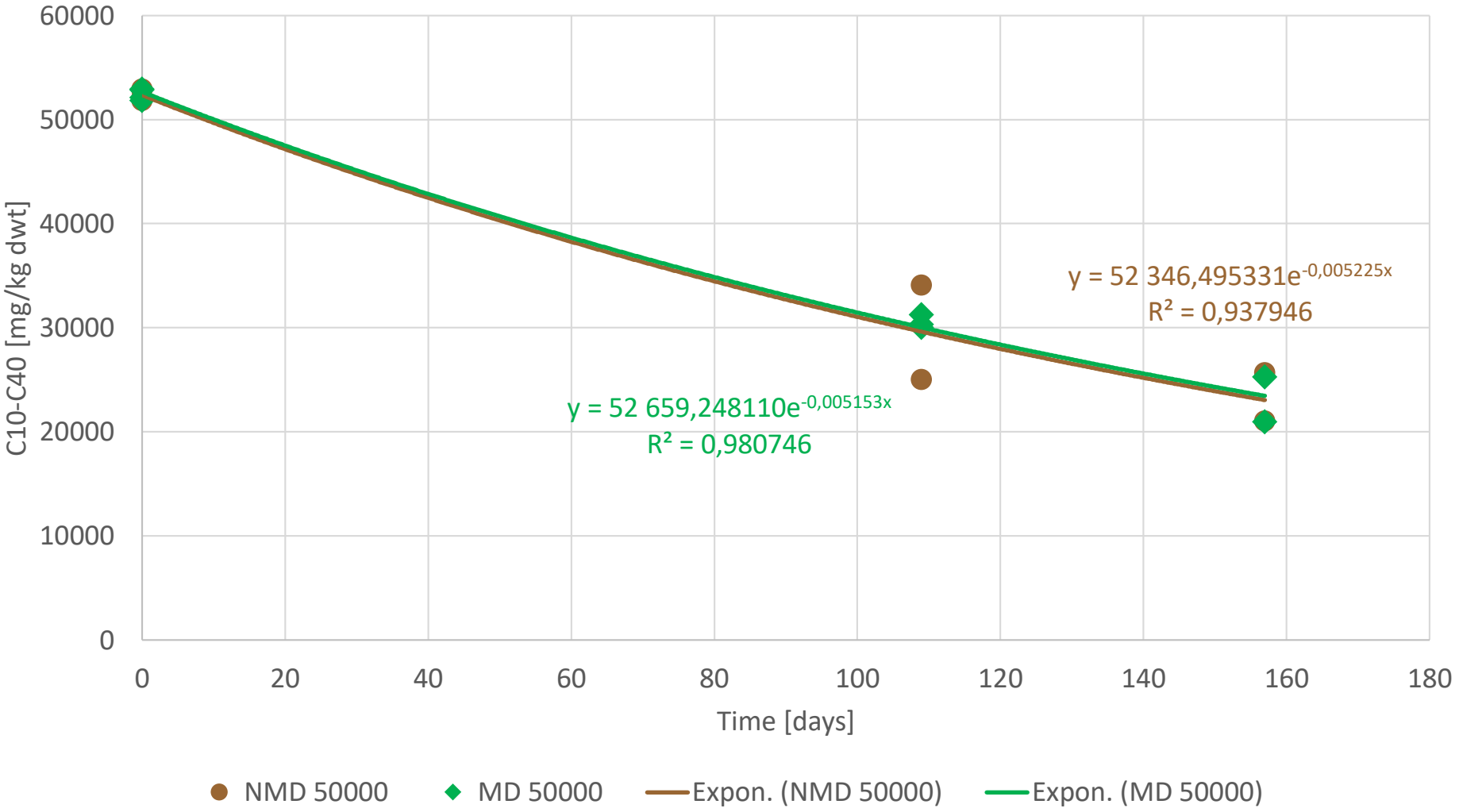
Burdová et al. *J. Environ. Manag.* 344 (2023) 118475

Kinetics – 2500 mg/kg

First order > zero order (AIC)

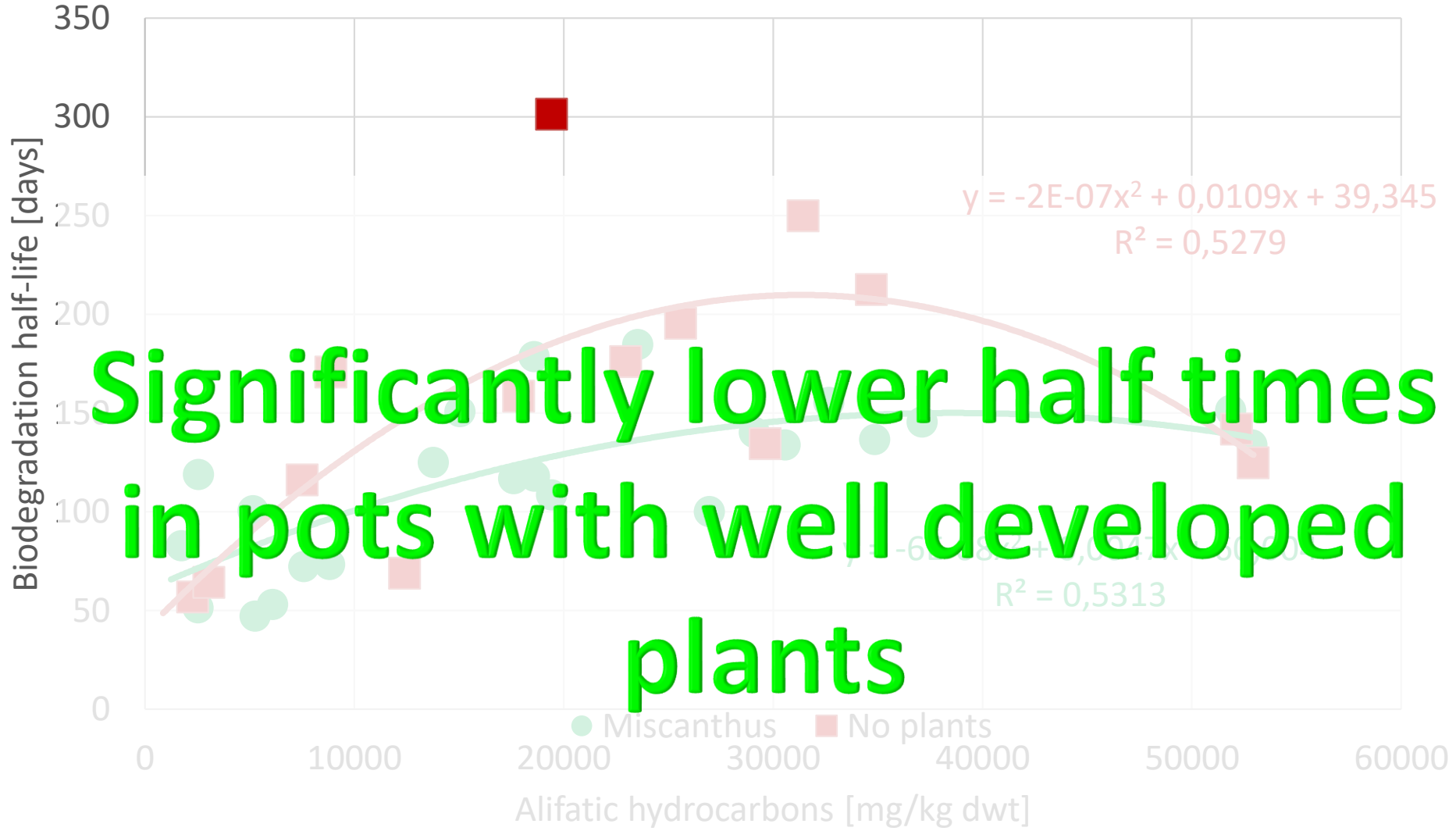
Burdová et al. *J. Environ. Manag.* 344 (2023) 118475

Kinetics – 50 000 mg/kg



Burdová et al. *J. Environ. Manag.* 344 (2023) 118475

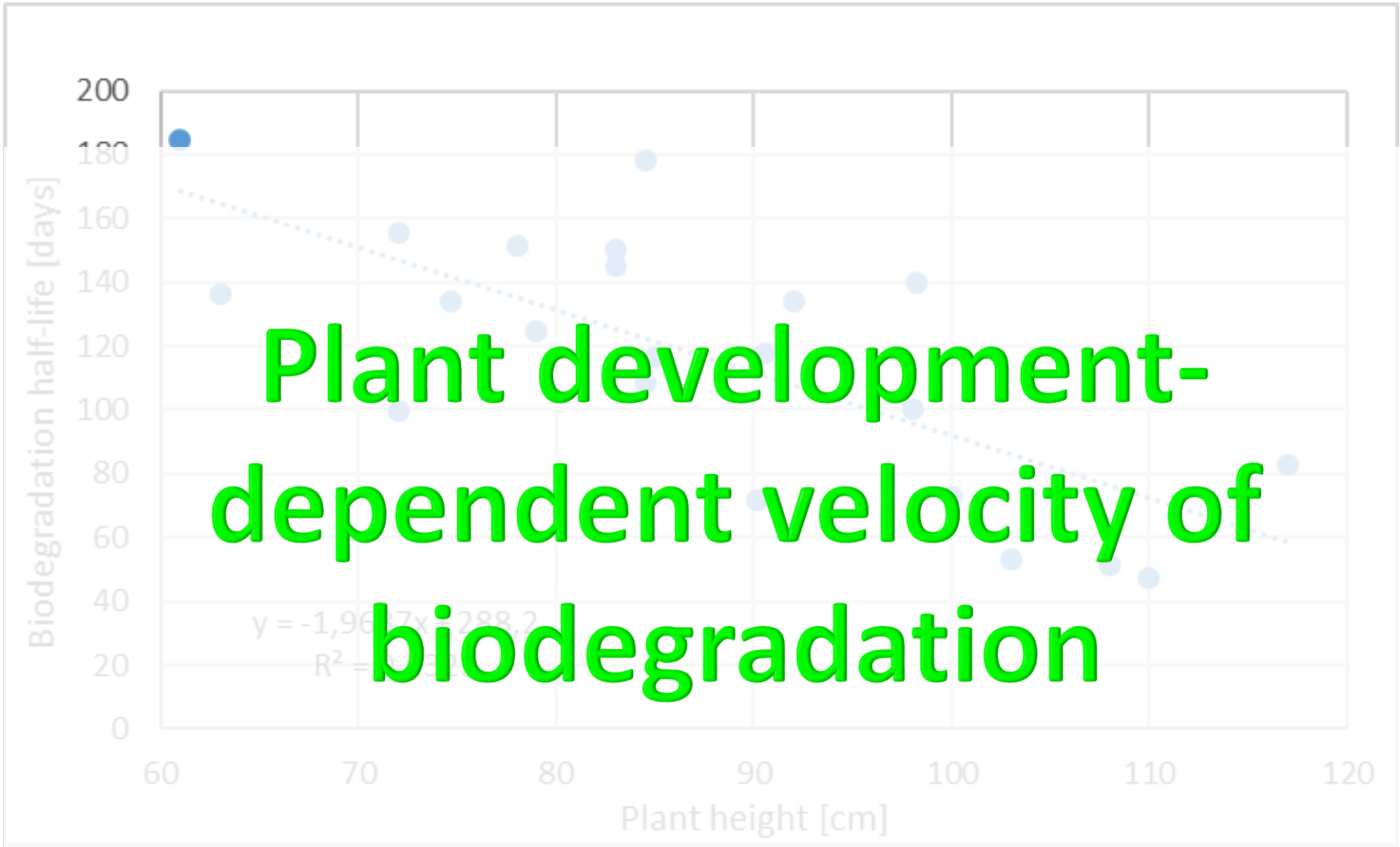
Half times of degradation



Significantly lower half times in pots with well developed plants

Burdová et al. *J. Environ. Manag.* 344 (2023) 118475

Half times of degradation

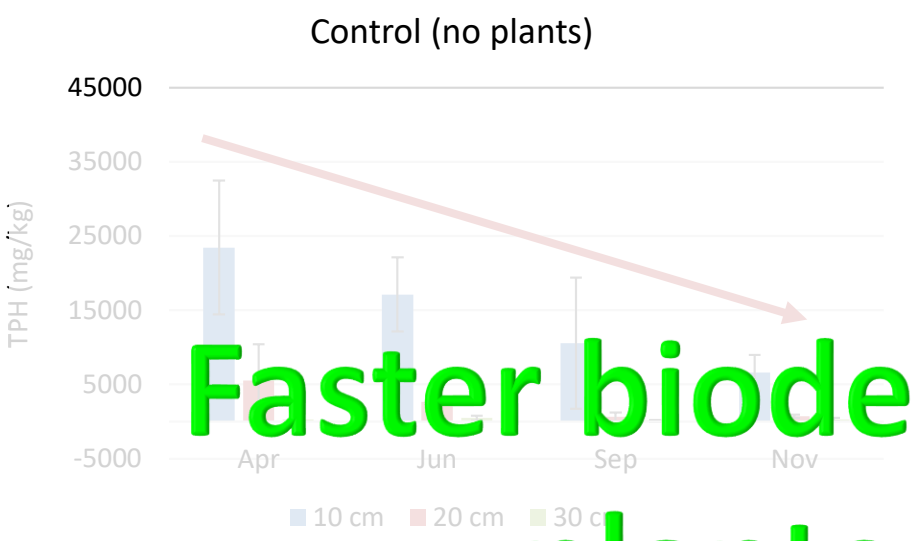


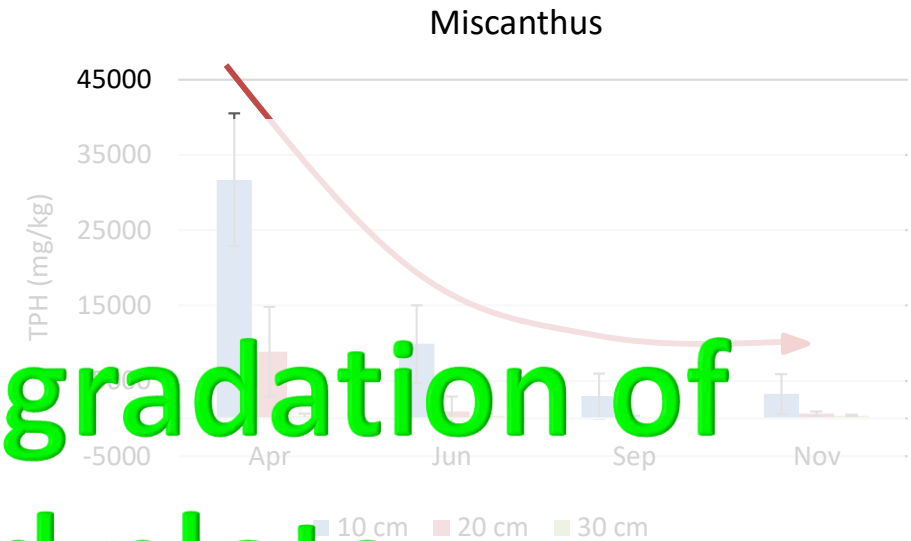
Burdová et al. *J. Environ. Manag.* 344 (2023) 118475

Field experiment

- Area of biogas plant, Ahníkov
- Artificial contamination with diesel

Diesel degradation – 1st year





Faster biodegradation of planted plots

1st-order kinetics

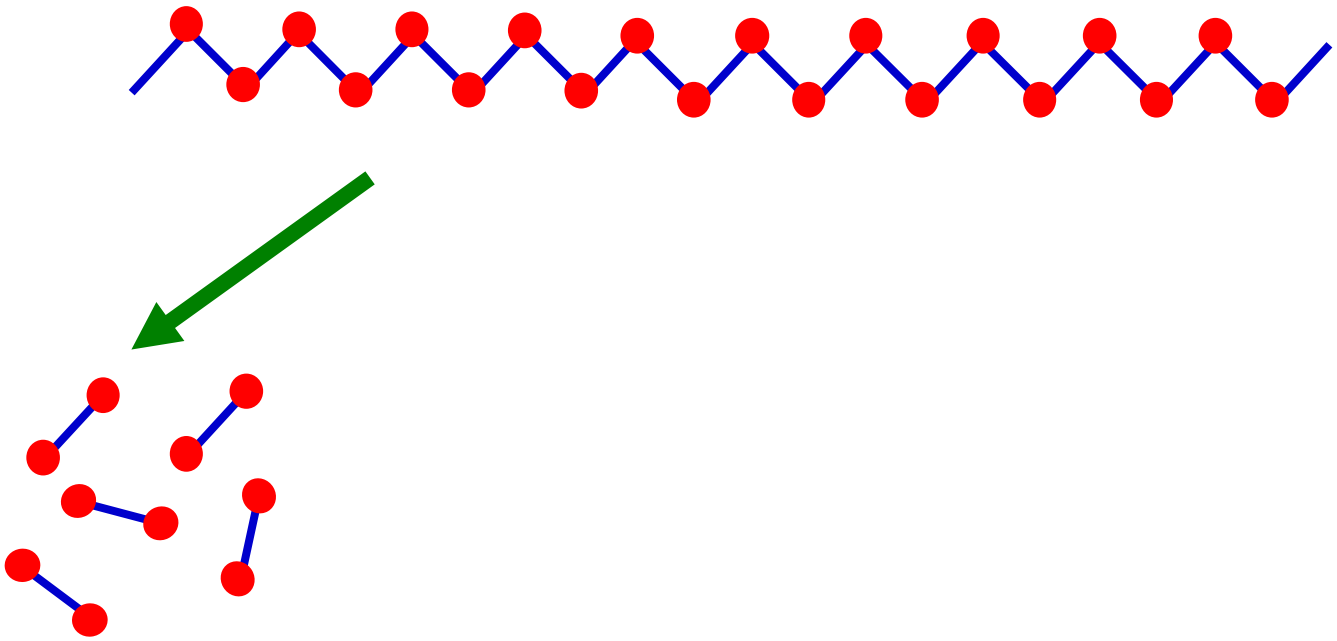
Degradation efficiency

	Apr			
C-10cm	0%	27%	55%	72%
C-20cm	0%	52%	88%	87%
M-10cm	0%	69%	91%	90%
M-20cm	0%	89%	98%	92%

4. Energetic use of biomass

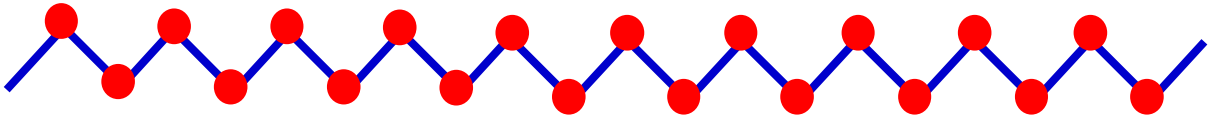
- Direct burning
- + high heating value
- - burns quickly

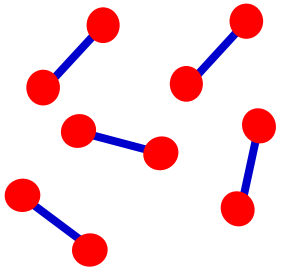
Pyrolysis



gas

Pyrolysis

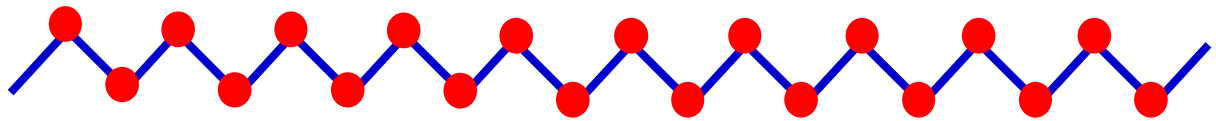


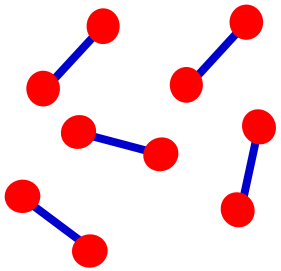


gas

oil

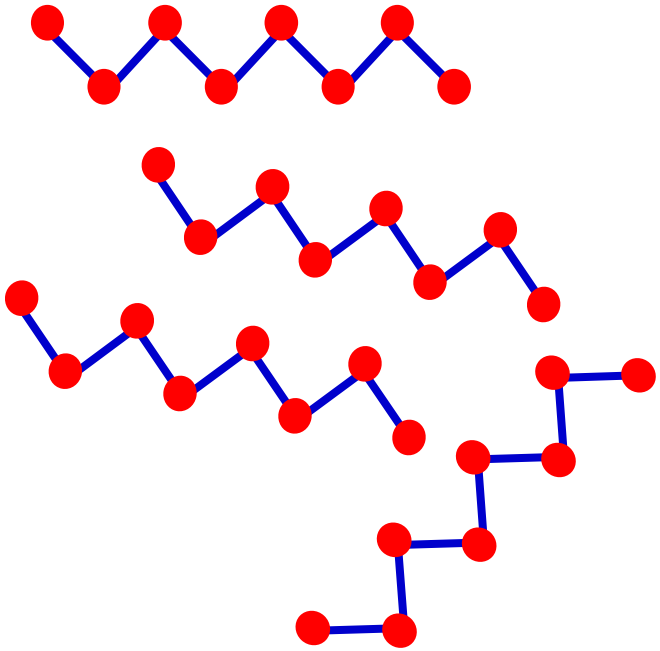
Pyrolysis





gas

biochar



oil

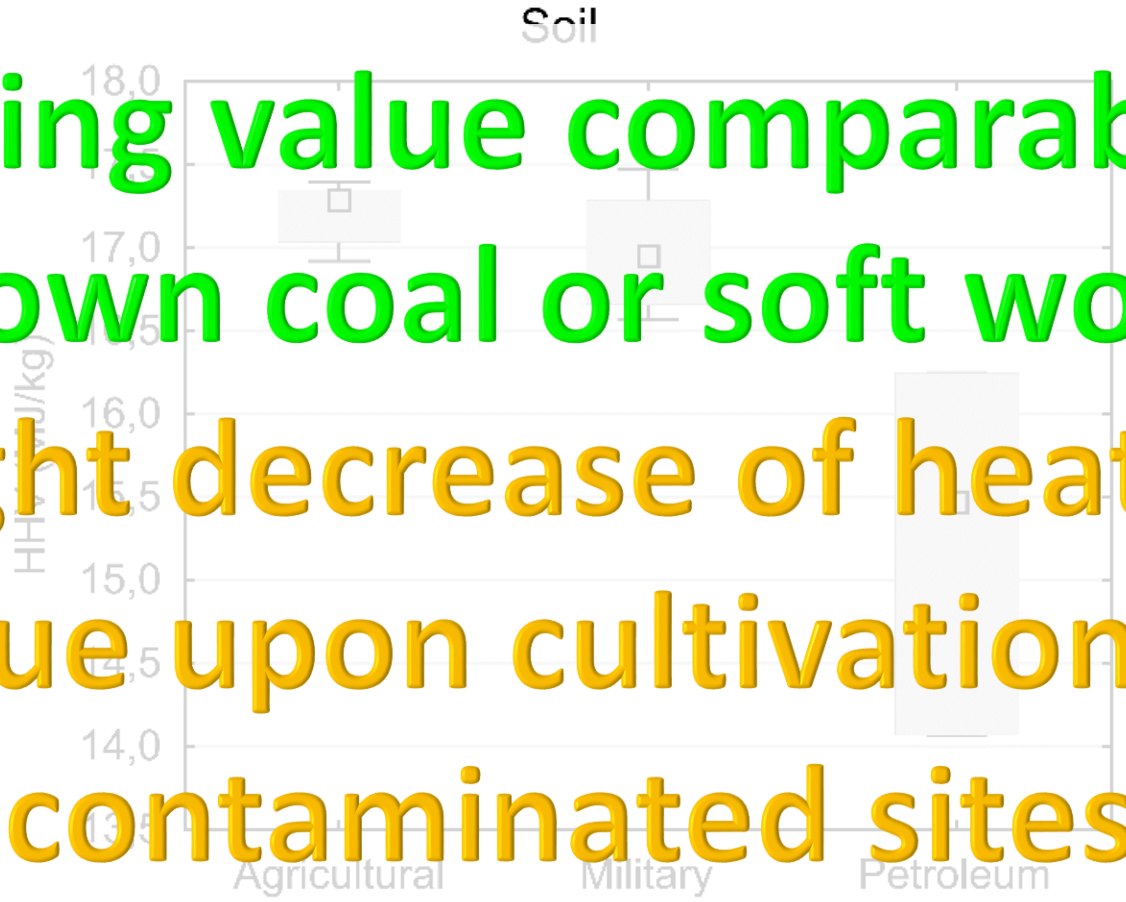
4. Energetic use of biomass

- Biomass is dominantly lignocellulose
- Hydrolysis
- → sugars → fermentations
  - → bioethanol → bioethane → biopolyethylene
  - → lactic acid → PLA
  - → …
  - → …
  - → … other green chemicals

4. Energetic properties of biomass

No petroleum hydrocarbons detected in biomass even from highly contaminated soils

Energetic properties of biomass



Heating value comparable to brown coal or soft wood

Slight decrease of heating value upon cultivation on contaminated sites

Nebeská et. al. *Studia Oecologica* 1 (2019) 61-67.

Energetic properties of biomass

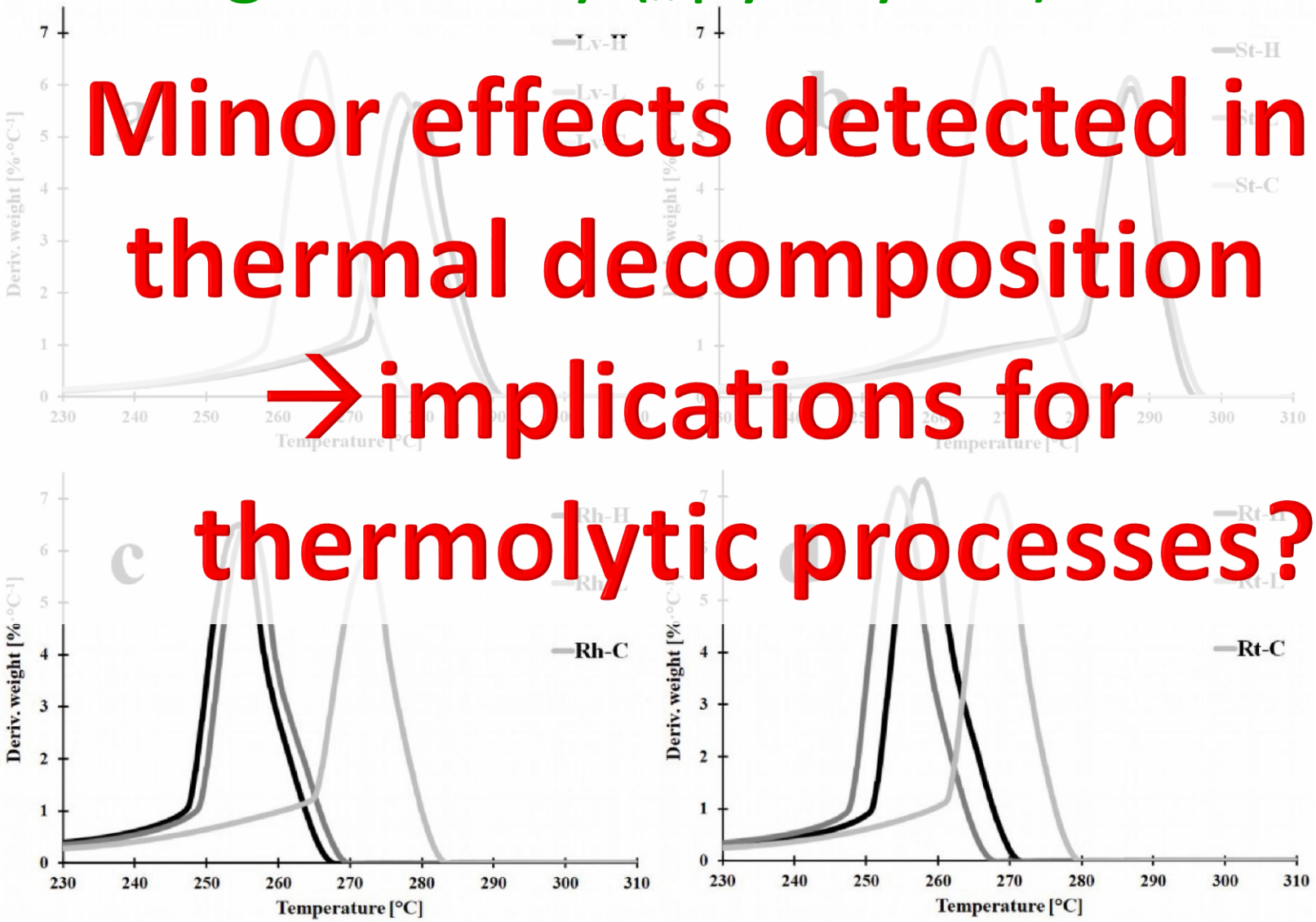
Empty Cell	C	H	N	S
	wt. %	wt. %	wt. %	wt. %
Rt-C	43.9 ± 8.8	5.80 ± 1.16	0.31 ± 0.06	<0.05
Rt-L	43.7 ± 8.7	5.89 ± 1.18	0.36 ± 0.07	<0.05
Rt-H	43.3 ± 8.7	5.89 ± 1.18	0.42 ± 0.08	<0.05
Lv-C	39.8 ± 8.0	5.58 ± 1.12	0.42 ± 0.08	<0.05
Lv-L	39.3 ± 7.9	5.51 ± 1.10	0.41 ± 0.08	<0.05
Lv-H	38.9 ± 7.8	5.45 ± 1.09	0.34 ± 0.07	<0.05
Rh–C	43.2 ± 8.6	5.96 ± 1.19	0.22 ± 0.05	<0.05
Rh-L	42.9 ± 8.6	5.89 ± 1.18	0.34 ± 0.07	<0.05
Rh–H	42.8 ± 8.6	5.99 ± 1.20	0.39 ± 0.08	<0.05
St-C	43.5 ± 8.7	5.55 ± 1.11	0.22 ± 0.02	<0.05
St-L	43.4 ± 8.7	5.99 ± 1.20	0.23 ± 0.05	<0.05
St-H	42.1 ± 8.4	5.91 ± 1.18	0.33 ± 0.07	<0.05

Insignificant differences in elemental composition

Burdová et al., *J. Clean. Product.* 406 (2023) 136984

Thermogravimetry („pyrolysis“)

Minor effects detected in thermal decomposition →implications for thermolytic processes?



Burdová et al., *J. Clean. Product.* 406 (2023) 136984

Risk elements

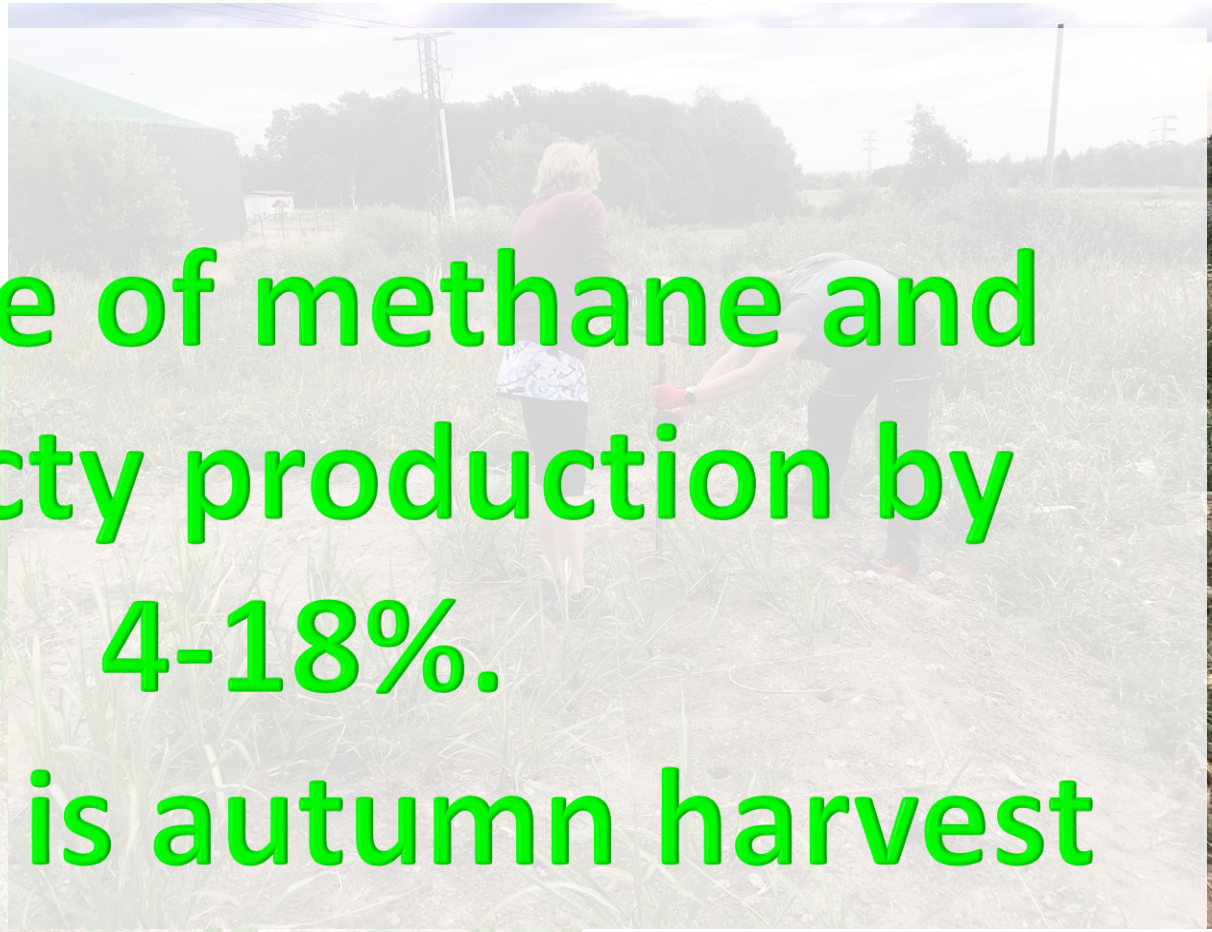
Risk element	Miscanthus (mg/kg dwt)	Brown coal (mg/kg)
As	6 ± 6	15 (0.1-1290)
Cu	58 ± 24	34 (5-298)
Ni	N.D.	41 (1-280)
Pb	60 ± 60	24 (0-75)
Hg	N.D.	0.26 (0.03-1.84)
Cr	N.D.	55 (9-135)
Co	N.D.	15 (2-109)
Zn	63 ± 19	60 (1-239)
V	N.D.	102 (15-435)

Significantly lower concentration of risk elements in the biomass even from polluted soil

Pidlisnyuk et al. *Env. Pollut.* 249 (2019) 330-337

http://www.chemicke-listy.cz/docs/full/2006_06_462-466.pdf

Biogas from *Miscanthus*



Increase of methane and electricty production by 4-18%.

Optimal is autumn harvest and pelleting.

Ignored topics

- Use of biochar and ash
- Plant stress
- Plant priming
- Materials from *Miscanthus*
- Green chemicals from *Miscanthus*
- Increased carbon sequestration
- Improvement of soil properties

Takeaway conclusions

- *Miscanthus x giganteus* can be cultivated on the petroleum contaminated soil
- But it is not simple
- Bioremediation can be achieved
- High production can be achieved
- Biomass is clean and useable for energetic purposes
- Further field large-scale experiments required

Funding

- NATO MYP-M4M SPS G6094 Mitigation of Climate Change through Advanced Phytotechnology for Military Lands
- CZ.01.1.02/0.0/0.0/20_321/0025228 New preparates for optimization of biomass of the second generation energetic plants
- UJEP-IGA-2024-44-007-2 Plants and brownfields - ecology, reclamation, phytoremediation

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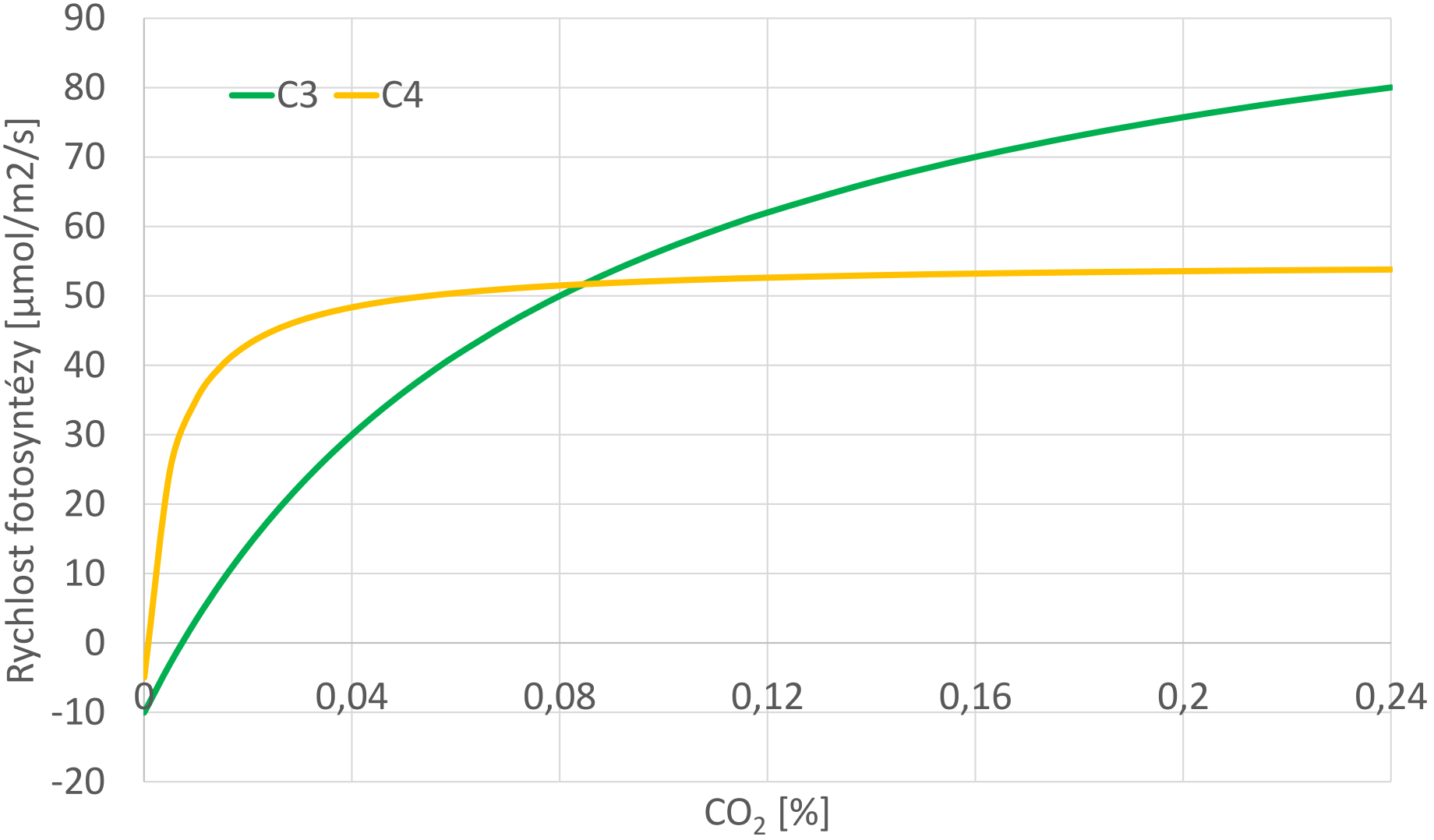
This workshop is supported by:

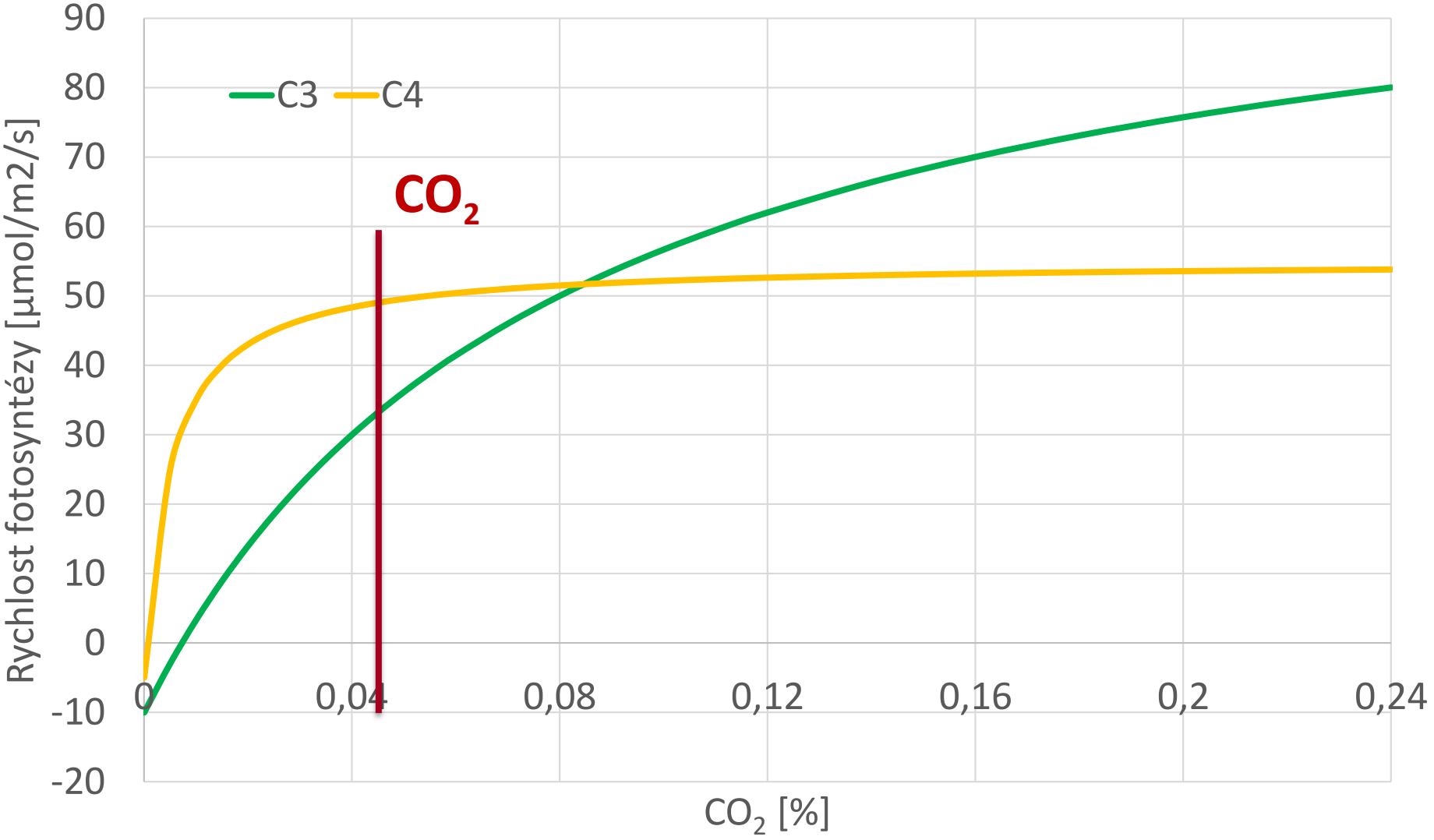
The NATO Science for Peace and Security Programme

Thank you for your attention

C_4 plants


C3
C4
Rychlost fotosyntézy [µmol/m2/s]
90
80
70
60
50
40
30
20
10
0
-10
-20
0
0,04
0,08
0,12
0,16
0,2
0,24
CO2 [%]

C_4 plants


90
80
70
60
50
40
30
20
10
0
-10
-20
C3
C4
CO2
Rychlost fotosyntézy [µmol/m2/s]
0
0,04
0,08
0,12
0,16
0,2
0,24
CO2 [%]

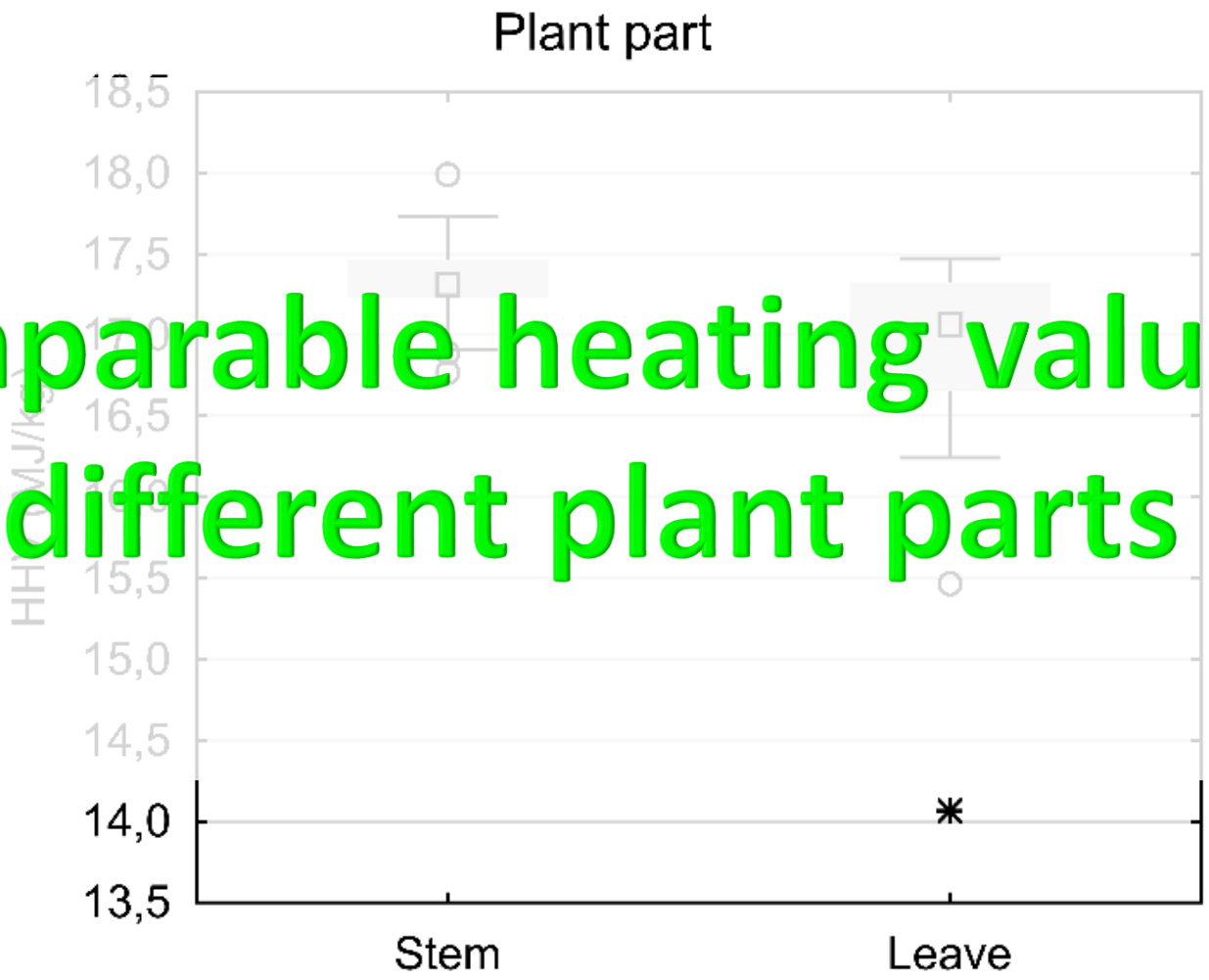
Energetic properties of biomass

Plant	Heating value (MJ/kg)
Miscanthus x giganteus	16.02 – 20.13
Coal (black coal)	32.86 – 33.00
Lignite (brown coal)	15.63 – 25.10
Wood chips	19.91
Softwood	20.00
Pine wood	16.64
Wheat straw	17.00 – 18.91

Heating value comparable to brown coal

Nebeská et. al. *Studia Oecologica* 1 (2019) 61-67.

Energetic properties of biomass



Comparable heating value of different plant parts

Nebeská et. al. *Studia Oecologica* 1 (2019) 61-67.

History - motivation

- NATO SPS G4687 2016-2021 - using *Miscanthus*
- Previous research on HC biodegradation
- majority of *Miscanthus* phytoremediation on trace elemens

⇒ gap in productive phytoremediation of organic polutants by *Miscanthus*

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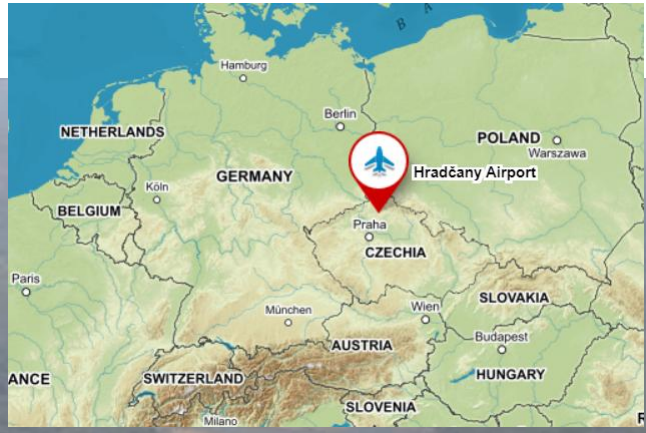
This project is supported by: The NATO Science for Peace and Security Programme

Mimoň airport

- Constructed for Czechoslovak army in 30's
- But used only by…
  - German army during WWII
  - And Soviet army after 1968




• Petroleum contamination
• Remediation since 1989
removed ~50%

First pot experiment

- Military locality + petrolum rafinery sludge





Control


Military soil

Cd Pb
Zn Cu


MIX 3:1

Cd Pb
Zn Cu


MIX 1:1

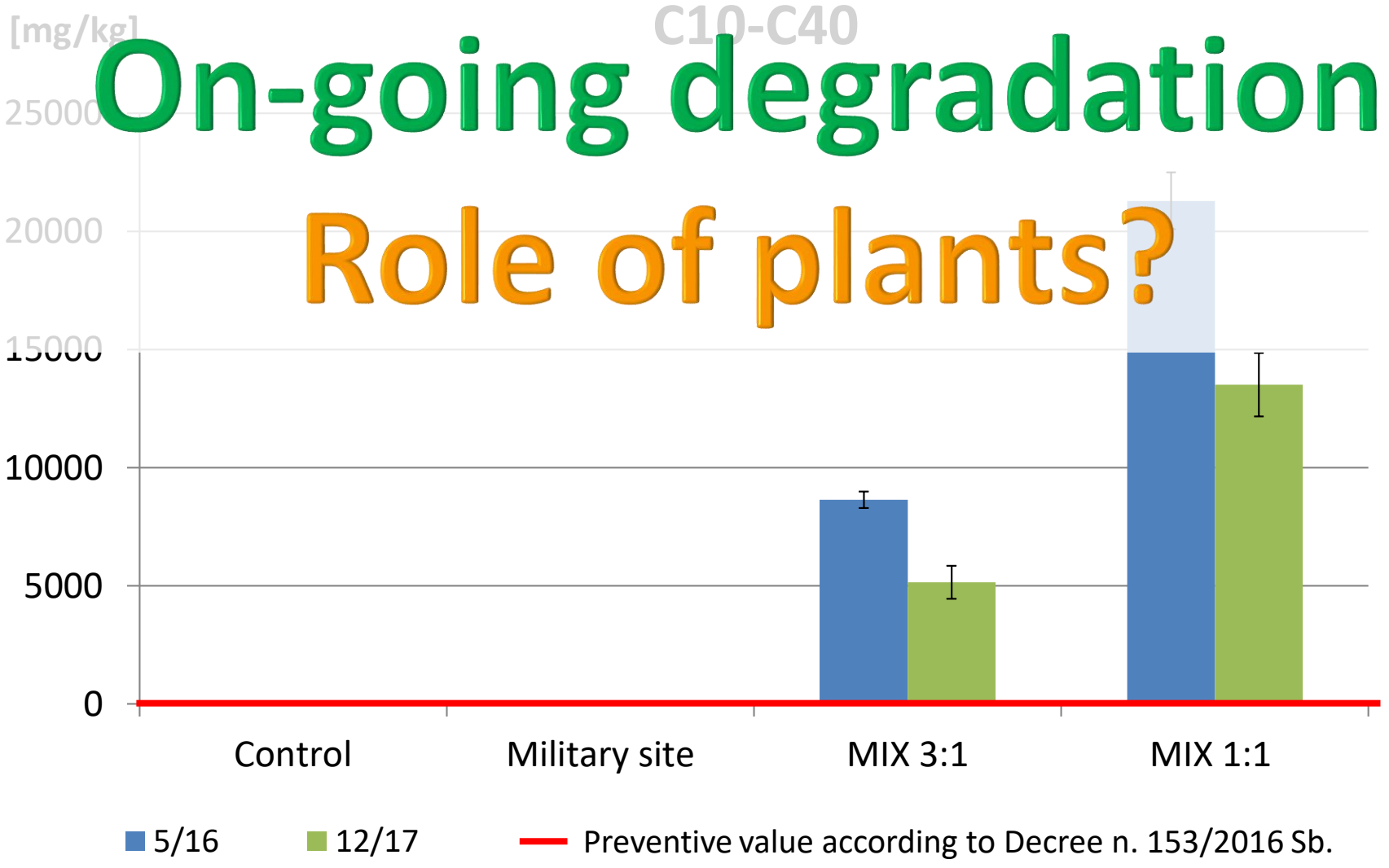
Cd Pb
Zn Cu

First pot experiment

Biomass

Significant inhibition of plant growth in petroleum-contaminated soil

Petroleum hydrocarbons

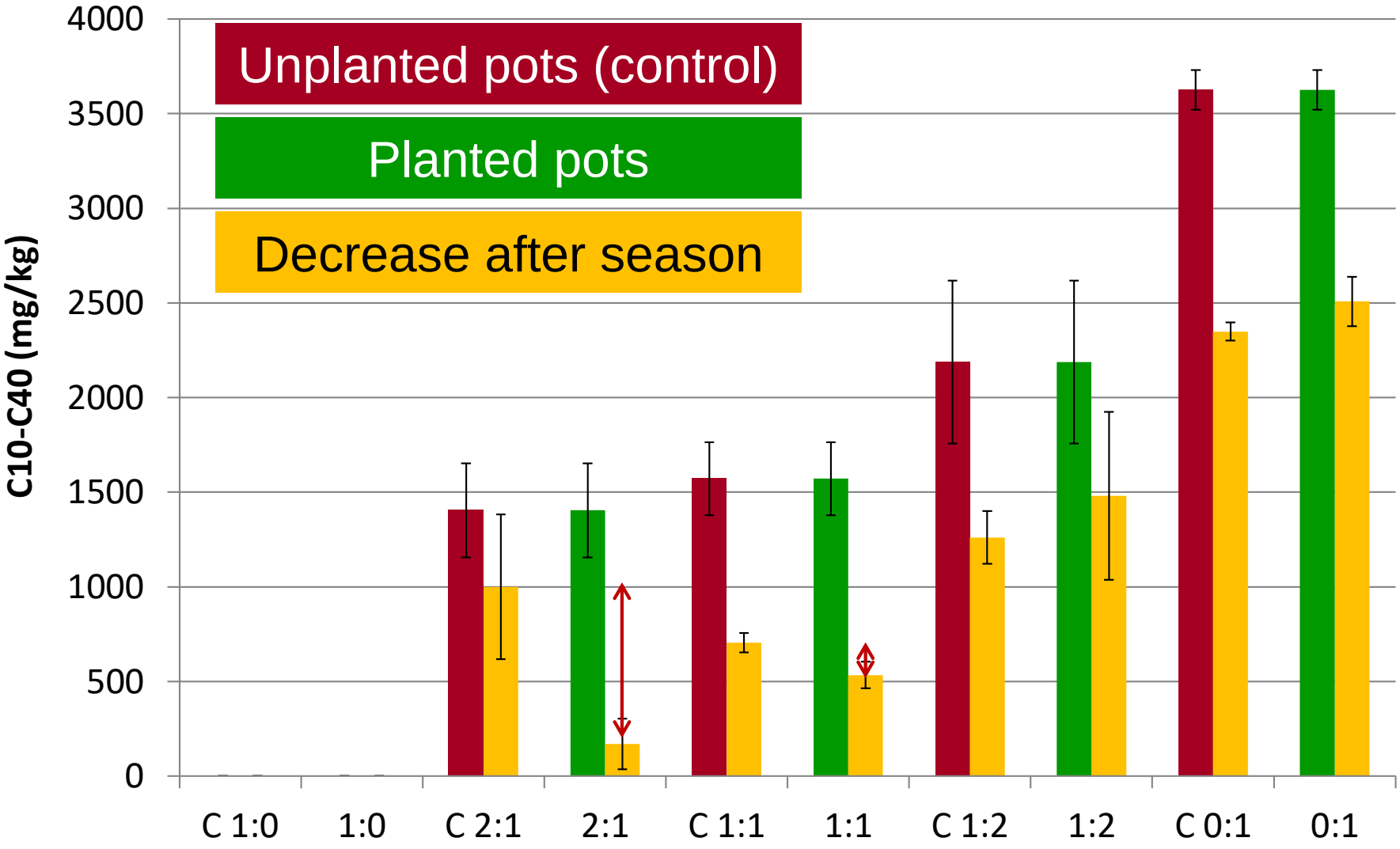


On-going degradation

Role of plants?

Nebeská et al., *Appl. Sci.* 11 (2021) 1866

Aliphatics degradation

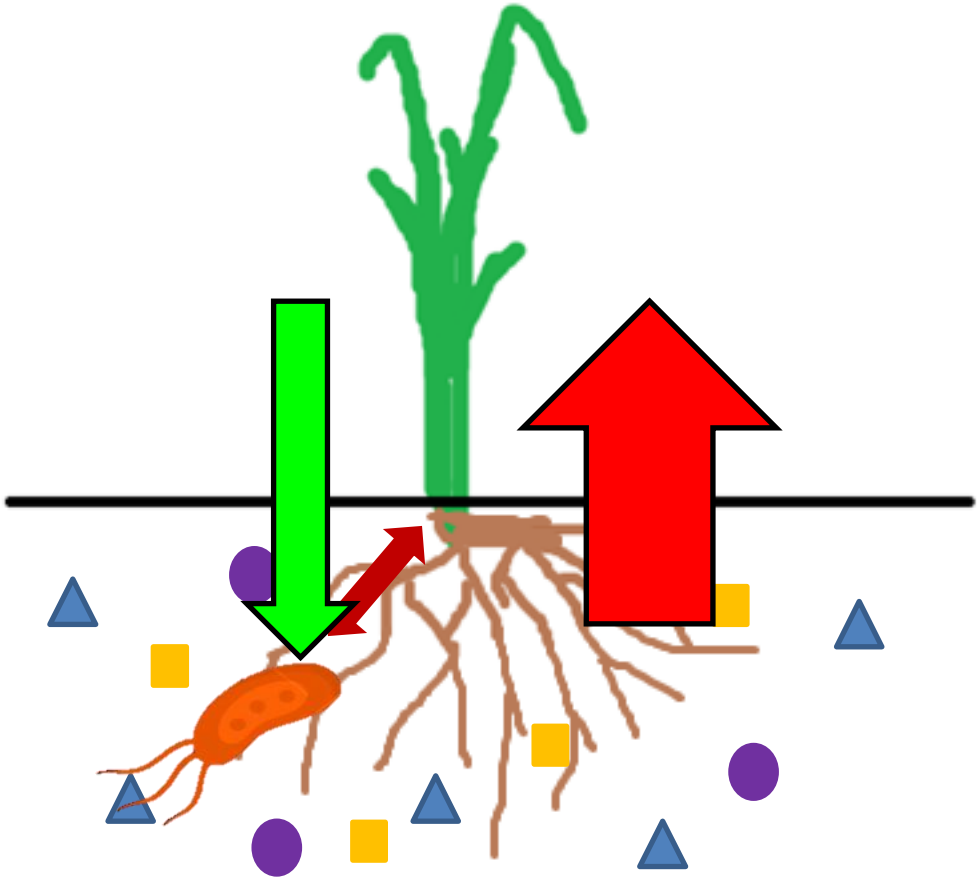


Nebeská et al., *Ecotox. Environ. Safety* 224 (2021) 112630

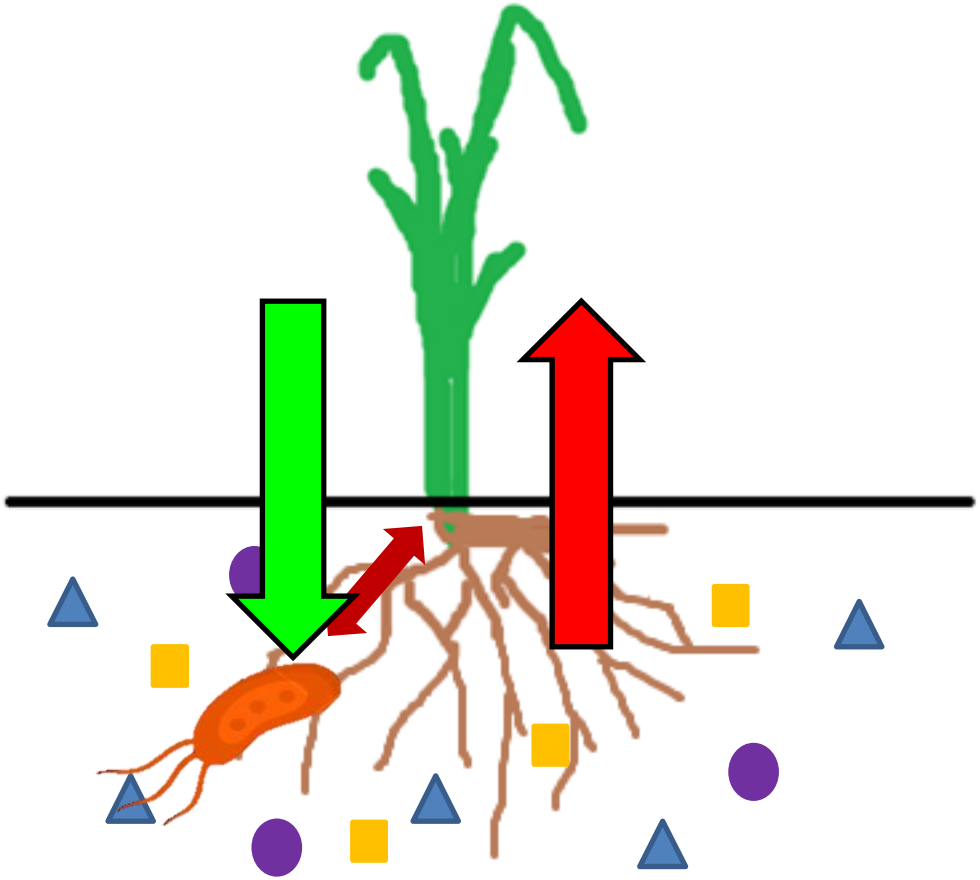
Second experiment – more diluted

Rostliny a půda

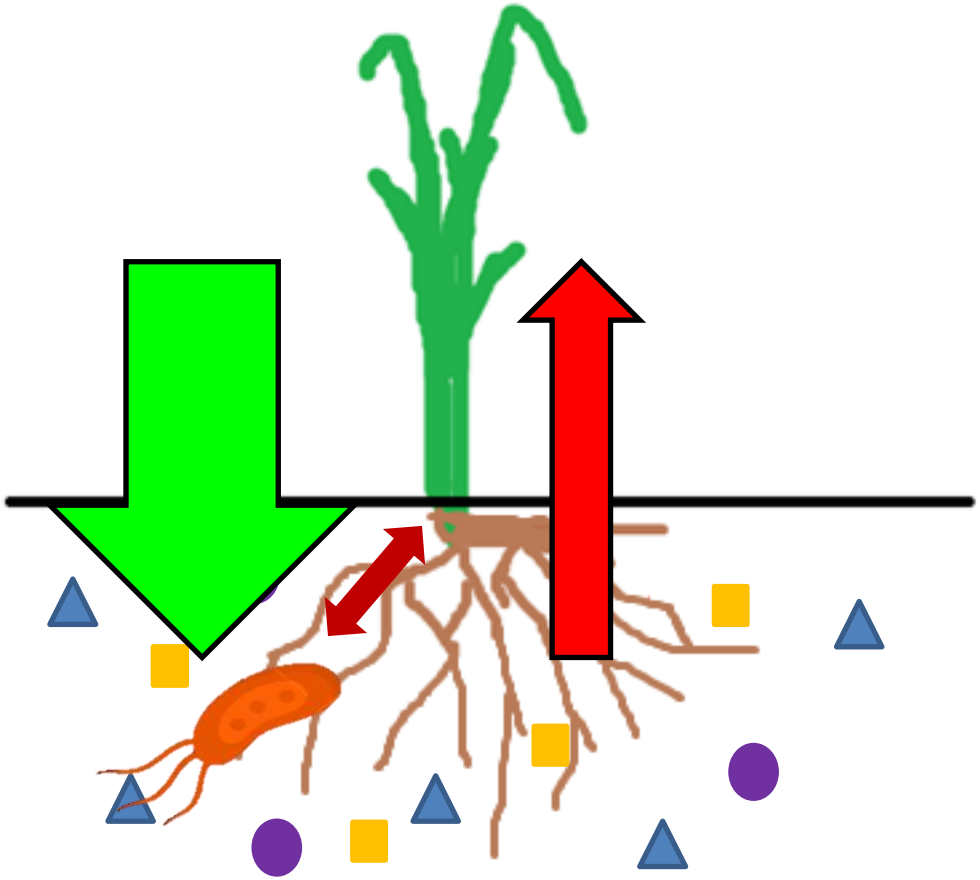
- Jednoleté



Rostliny a půda



Rostliny a půda



Field experiment 2022
- diesel spill

Analyses not yet completed ☹

Inhibition of weed

Stimulation of *Miscanthus*

IPC 2024 ☺