Leaching of pesticides in lysimeter and field trials with sandy loam soils

Tauchnitz, N.[1]; Rupp, H.[2], Kurzius, F.[3], Wolff, C.[1], Bergmann, E.[1], Haupt, R.[4], Hauser, B.[1], Schrödter, M.[1], Meissner, R.[2]

[1]State Institute for Agriculture and Horticulture Saxony-Anhalt,
[2]Helmholtz Centre for Environmental Research-UFZ,
[3]BGD Ecosax GmbH,
[4]Office of Agriculture, Land Consolidation and Forest Altmark

SACHSEN-ANHALT
Landesanstalt für Landwirtschaft und Gartenbau

HELMHOLTZ
ZENTRUM FÜR UMWELTFORSCHUNG UFZ

BGD ECOSAX GMBH

19th Lysimeter Conference, April 13-14, 2021, Online-Meeting

Background

- pesticide inputs from point or diffuse sources into surface waters may cause harmful effects on aquatic life communities
- surface water monitoring showed positive findings of pesticides that frequently exceeded environmental quality standards of European Water Framework Directive

➡ reduction measures of pesticide inputs

➡ more knowledge about pesticide input pathways

Objectives

- ✓ quantify **pesticide leaching** at conventional and reduced pesticides application in **lysimeter and field trials** to target mitigation measures of pesticide losses efficiently

- ✓ determine **degradation rates and sorption coefficients** of selected pesticides at the site specific properties in a laboratory study with **batch tests** for a better under-standing of the environmental fate

Study area

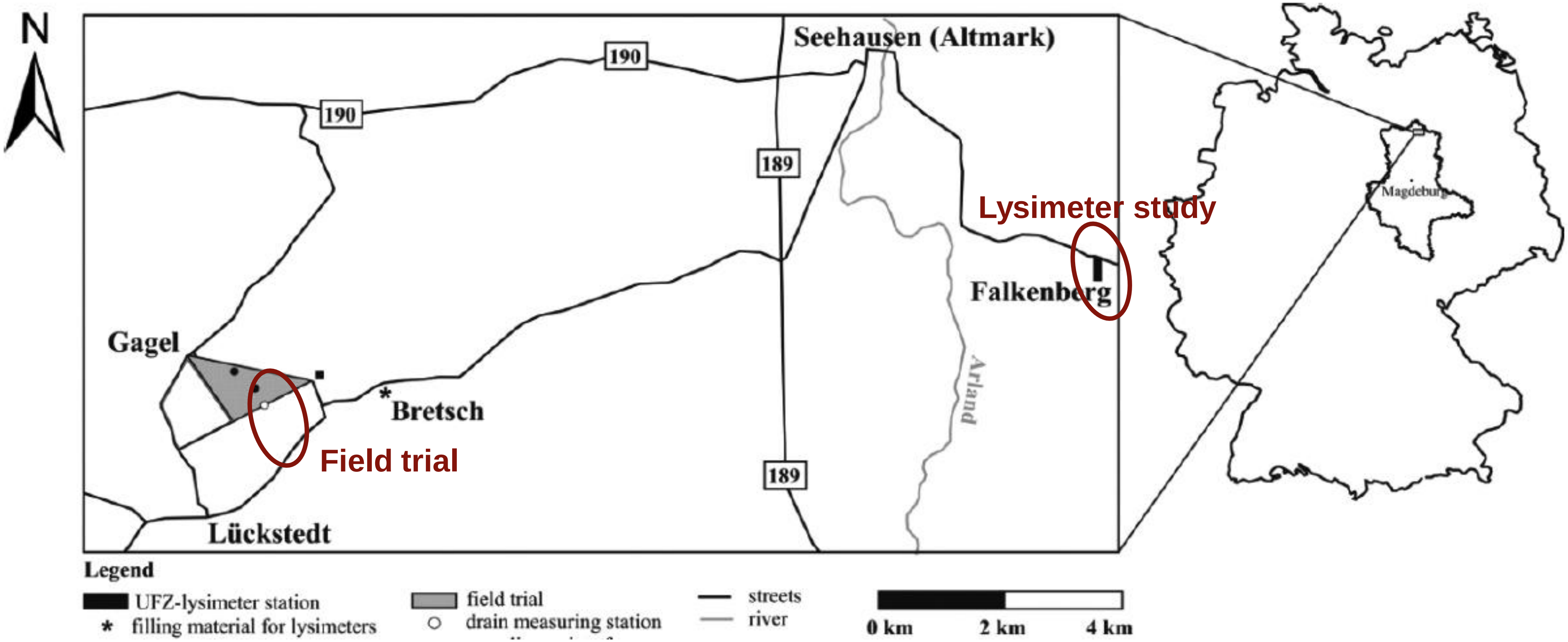


Figure 1: Localization of the testing sites in the northern Altmark-region (Bednorz et al., 2006)

Lysimeter trial

Helmholtz-centre for environmental research-UFZ

Location: **northern Altmark region**
Saxony-Anhalt (Germany)
Falkenberg (easting: 4487464, northing: 5858543)

Climatic conditions: **Long-term (1968-2007)**
precipitation: 524.5 mm yr^{-1};
annual mean temperature: 9.3 °C

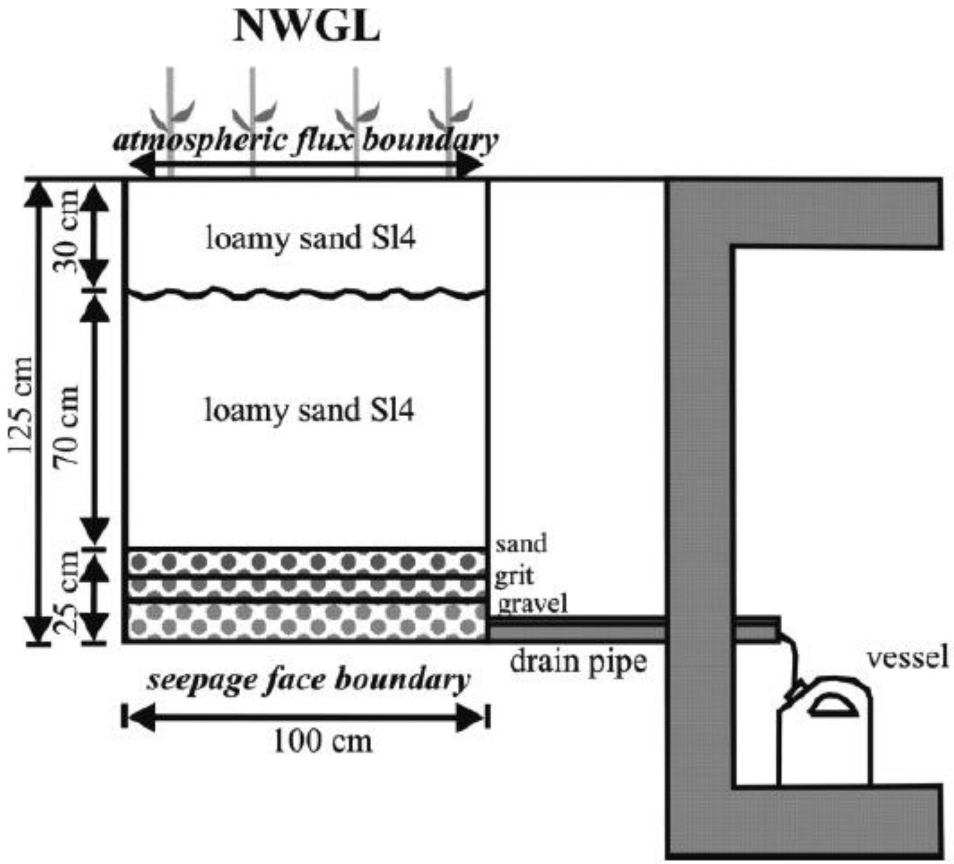
Soil properties: **Stagnic Gleysol-Luvisol**

Table: Selected soil physical and chemical parameters (Meissner et al., 2001; Godlinski et al., 2007)

Depth	Soil type	Clay	Silt	Sand	ρ_{dry}	u_{fc}	k_f	C_{org}	N_t	pH $CaCl_2$
cm		[%]			[g cm^{-3}]	[vol. %]	[cm d^{-1}]	[%]	[%]	
0-30	Sl4	12.1	14.3	73.6	1.48	15	21	1.0	0.13	5.8
30-100	Sl2	7.4	17.4	75.2	1.84	11	43	0.2	0.04	5.6

ρ_{dry}: dry density, u_{fc}: usable field capacity, k_f: saturated hydraulic conductivity

Lysimeter trial
Helmholtz-centre for environmental research-UFZ



- non weighable gravitation lysimeter
- horizon-wise filled in 1983 with soil substrate from region Bretsch (near field trial Lückstedt)

Figure 2: Schematic setup of lysimeters (Bednorz et al., 2006)

Lysimeter trial
Treatments

1. without pesticides -CONTR-

2. reduced pesticide application -RED-

3. conventional pesticide application -CONV-

- beginning september 2018 with sowing of winter wheat
- 3 replicates per treatment, no pesticide application before study (except seed treatments)
- analyses of all pesticide substances (applied in the study) and pre-screening of environmental relevant pesticides (55 substances) before study in seepage water
- composite watersamples at monthly frequencies (aliquots of seepage water), analyses of pesticide substances in plant biomass after harvest

Lysimeter trial
Treatments

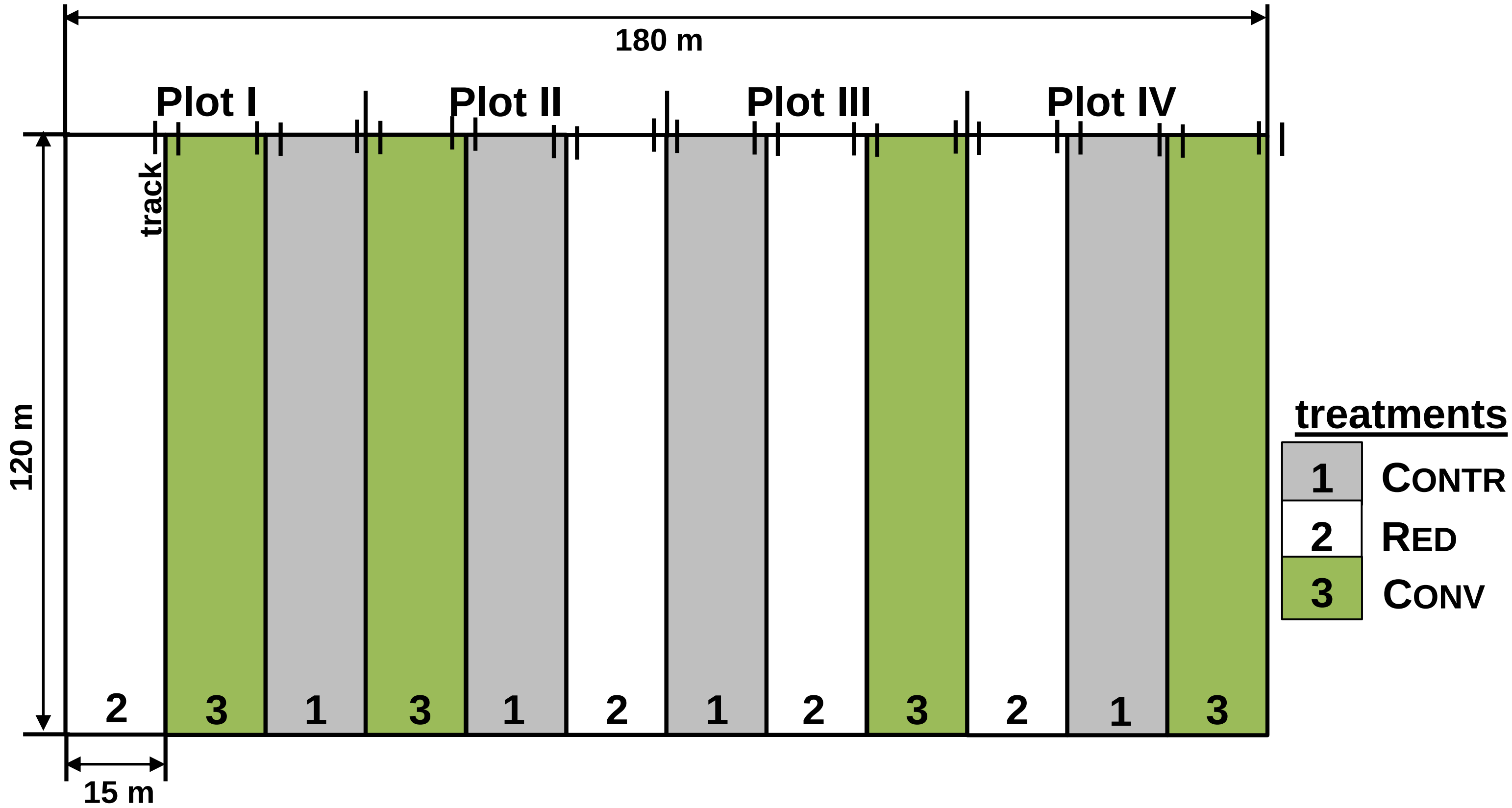
1. without pesticides -CONTR-

2. reduced pesticide application -RED-

3. conventional pesticide application -CONV-

Pesticide type	Treatments		
	1. CONTR	2. RED	3. CONV
Herbicides	- mechanical weed control	CONV **-25 %**	**100%**
Fungicides	-	CONV **-33 %**	**100%**
Insecticides	-	only when exceeding reference value - 100 %	**100%**
Growth regulators	-	CONV **-25 %**	**100%**

Field trial



- managed by the Agricultural Cooperative Lueckstedt
- randomized complete block design, four replicates per treatment
- <u>test parameters</u>: concentration of applied pesticides in soil and plant biomass, yields, weed density, diseases and pests

Applied pesticides in lysimeter and field trials

Year	Crop	Pesticide name	Pesticide type	Application Date	Pesticide substances
2019	**winter wheat**	Trinity	herbicide	18.10.2018	chlortoluron pendimethalin diflufenican
		Herold SC	herbicide	18.10.2018	diflufenican flufenacet
		Pointer SX	herbicide	18.10.2018	tribenuron-methyl
		Pronto Plus	fungicide	17.05.2019	tebuconazole spiroxamine
2020	**winter barley**	Trinity	herbicide	09.10.2019	chlortoluron pendimethalin diflufenican
		Shock down	insecticide	09.10.2019	lambda-cyhalothrin
		Malibu Pack	herbicide	09.10.2019	pendimethalin flufenacet
		Capalo	fungicide	28.04.2020	metrafenone epoxiconazole fenpropimorph
2021	**oilseed rape**	Gajus	herbicide	04.09.2020	picloram pethoxamid
		Targa Super 1	herbicide	04.09.2020	quizalafop-P
		Jaguar	insecticide	05.10.2020	lambda-cyhalothrin
		Tilmor	fungicide	05.10.2020	tebuconazole prothioconazole
		Runway	herbicide	05.10.2020	picloram clopyralid aminopyralid

17 different substances

Batch tests

- laboratory of BGD Ecosax GmbH
- soil samples (0-30 cm, 30-90 cm) from lysimeter fill soil
- determination of degradation rates (half-lives) and sorption coefficients (K_d, K_f) (sorption isotherms)
- <u>10 pesticide substances</u>: diflufenican, glyphosate, epoxiconazole, fenpropimorph, flufenacet, lambda-cyhalothrin, pendimethalin, spiroxamine, tebuconazole, tribenuron-methyl

Foto: BGD Ecosax GmbH

Pre-screening of pesticides

Concentrations in seepage water

	CONTR			RED			CONV		
	1	2	3	1	2	3	1	2	3
ACEMIPRI	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
ACLONIFEN	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
AMPA	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
AMSULFURO	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
AZOXYSTR	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
B-CYFLUTR	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
BENTAZON	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
BIFENOX	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
BOSCALID	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
CARBENAZI	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
CDFOPPPGY	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
CLMEQUATI	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
CLRIDAZON	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
CLTOLURON	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
DFLFNICAN	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
DICLPROP	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
DICOFOL	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
DIMETHACL	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
DIMETHOAT	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
DIURON	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
DOXSTRBIN	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
EPXCONAZO	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
ESFENVAL	0,079	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
FLUFEACET	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
FLUTAMON	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
FNPRMORPH	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
GLYPHOSAT	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
IMIDACLPR	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG

	CONTR			RED			CONV		
	1	2	3	1	2	3	1	2	3
INDOXCARB	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
IRGAROL	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
ISOPROTUR	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
L_CYHLOTR	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
MCPA	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
MECOPROP	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
METALAXYL	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
METAMITRO	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
METAZACL	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
METOLACL	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
METRIBUZI	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
NICSULRON	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
PNDMTALIN	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
PRIMICARB	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
PROCLAZ	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
PRPCNAZOL	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
PRTIOCOZO	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
PYRCLOSTR	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
QUINMERAC	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
QUINOXFEN	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
SPIROXAMI	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
SULCOTION	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
TBCONAZOL	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	**0,079**
TERBUAZIN	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
THIACLPRI	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
TRFLOXSTR	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG
TRIBENURM	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG	<BG

BG: limit of detection

CONTR: without pesticides, RED: reduced pesticides application, CONV: conventional pesticide application

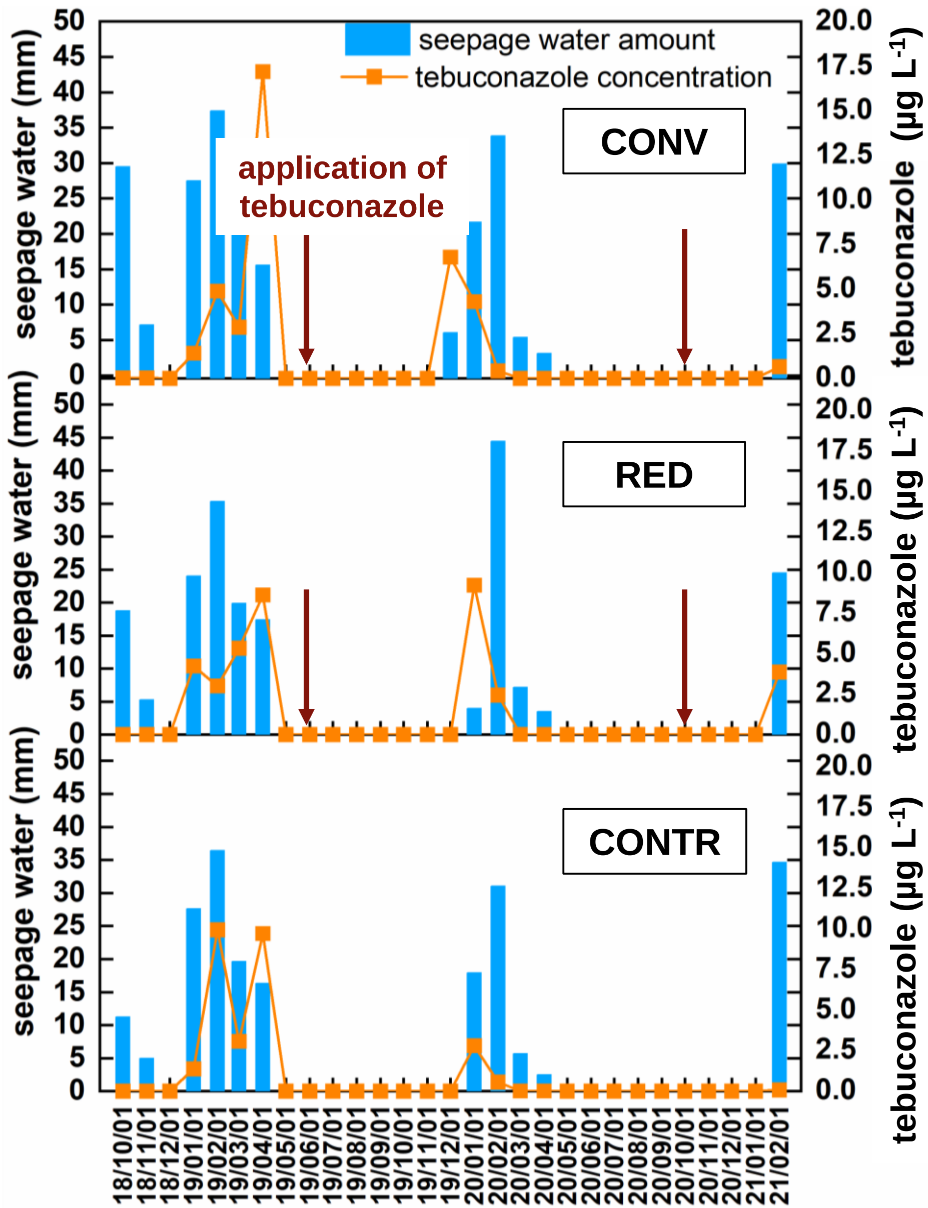
Seepage water amounts, N and C concentrations of seepage water in the study period (2018/10 – 2021/02)

		CONTR	RED	CONV
Precipitation (mm)	Σ 2018/10-2021/02	1179.2	1179.2	1179.2
Seepage water (mm)	**Mean** (± SD)	**213.3** (± 33)	**208.1** (± 11)	**243.8** (± 38)
NO_3^- (mg L^{-1})	**Mean** (± SD), Min - Max	**248.5** (± 31.5) 58.0 – 720.3	**346.7** (± 44.8) 132.4 – 918.1	**344.7** (± 8.8) 89.9 – 880.3
NO_2^- (mg L^{-1})	**Mean** (± SD), Min - Max	**0.03** (± 0.02) 0.0 – 0.3	**0.09** (± 0.02) 0.0 – 1.1	**0.24** (± 0.1) 0.0 – 3.9
NH_4^+ (mg L^{-1})	**Mean** (± SD), Min - Max	**0.01** (± 0.00) 0.0 – 0.07	**0.01** (± 0.00) 0.0 – 0.03	**0.02** (± 0.00) 0.0 – 0.2
Total N (mg L^{-1})	**Mean** (± SD), Min - Max	**59.1** (± 5.9) 15.3 – 127.1	**76.1** (± 12.0) 16.6 – 159.9	**64.8** (± 4.7) 5.0 – 148.9
Total C (mg L^{-1})	**Mean** (± SD), Min - Max	**58.5** (± 2.4) 39.5 – 71.3	**55.7** (± 3.2) 24.1 – 75.3	**50.9** (± 2.6) 28.8 – 75.6
DOC (mg L^{-1})	**Mean** (± SD), Min - Max	**15.4** (± 1.0) 7.2 – 26.8	**16.1** (± 1.2) 6.8 – 37.9	**15.5** (± 0.6) 10.0 – 22.4
pH	**Mean** (± SD), Min - Max	**8.0** (± 0.02) 7.7 – 8.3	**8.0** (± 0.13) 7.0 – 8.3	**8.0** (± 0.13) 7.6 – 8.3

DOC: dissolved organic carbon, SD: standard deviation

CONTR: without pesticides, RED: reduced pesticides application, CONV: conventional pesticide application

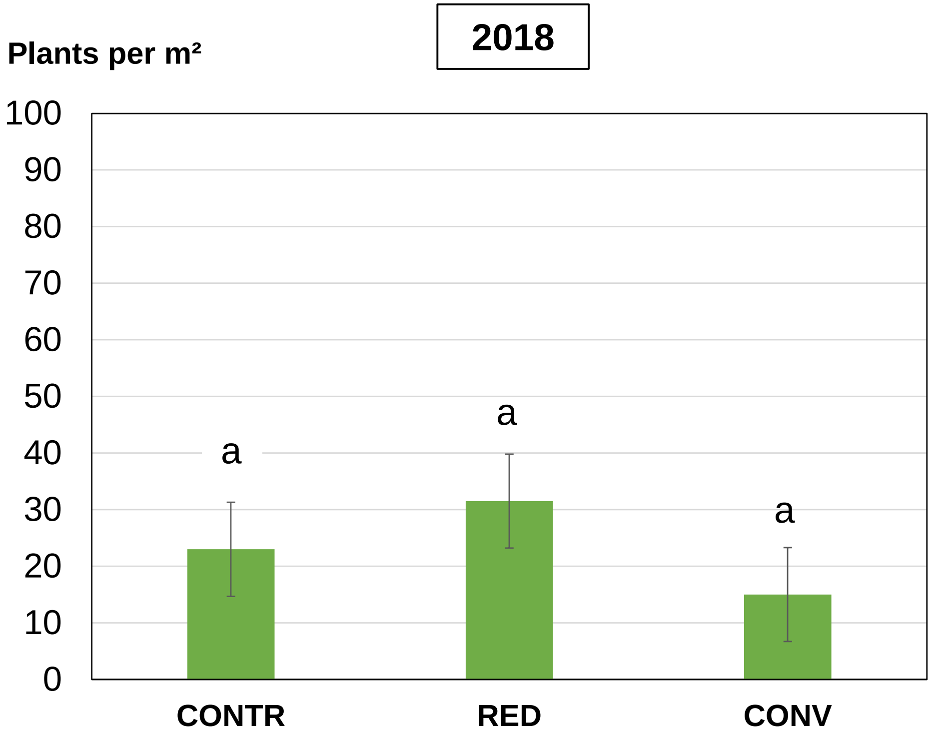
Detected pesticide substances in seepage water

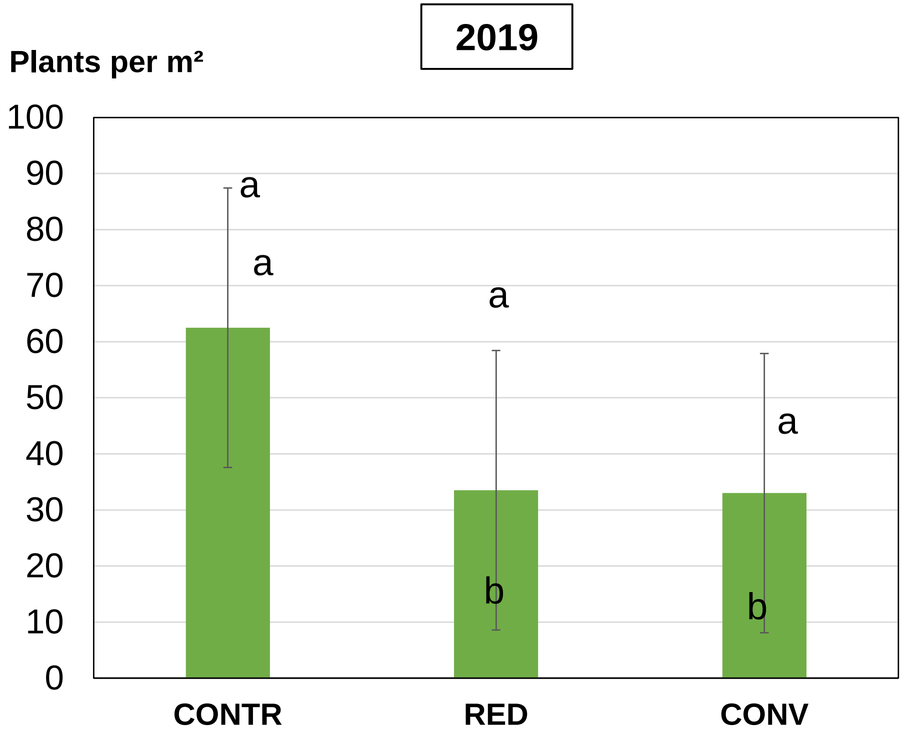


- positive findings of tebuconazole in seepage water with partly high concentrations
- tebuconazole was also detected in the CONTR-treatment and before it was applied in the trial – seed treatment in previous studies?
- other applied pesticide substances were not detected in seepage water

CONTR: without pesticides, RED: reduced pesticides application, CONV: conventional pesticide application

Weed abundance in the field trial

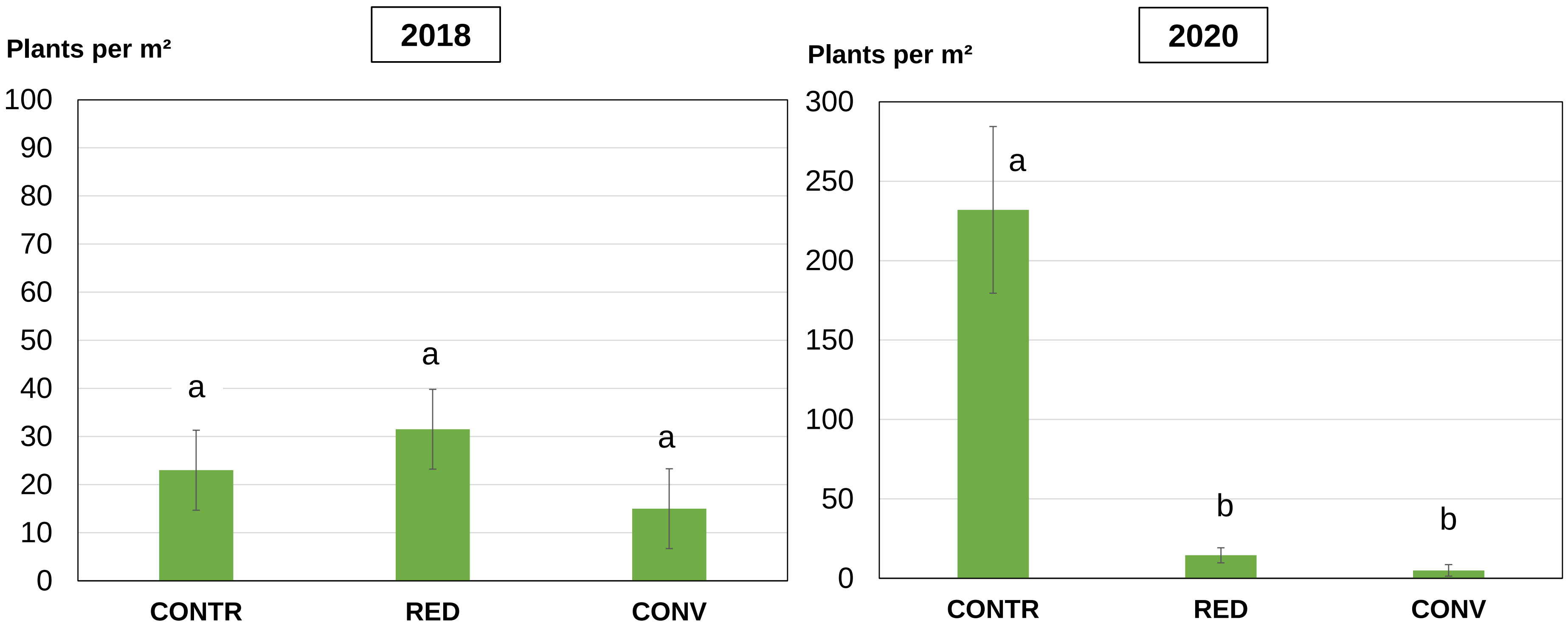




Different letters indicate significant differences between treatments ($p < 0.05$, $n=4$, Tukey-HSD)

CONTR: without pesticides, RED: reduced pesticides application, CONV: conventional pesticide application

Weed abundance in the field trial

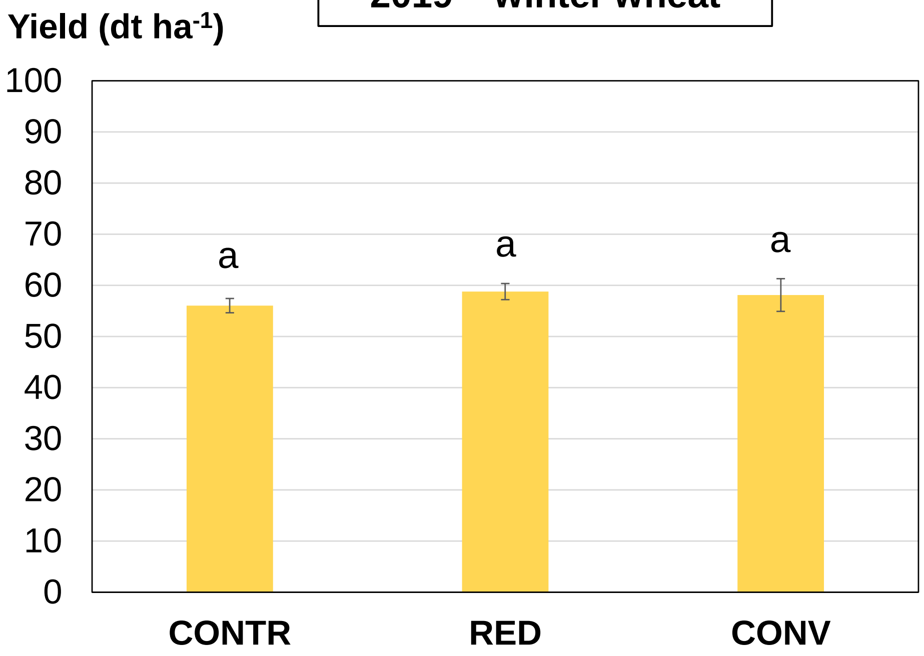


Different letters indicate significant differences between treatments ($p < 0.05$, $n=4$, Tukey-HSD)

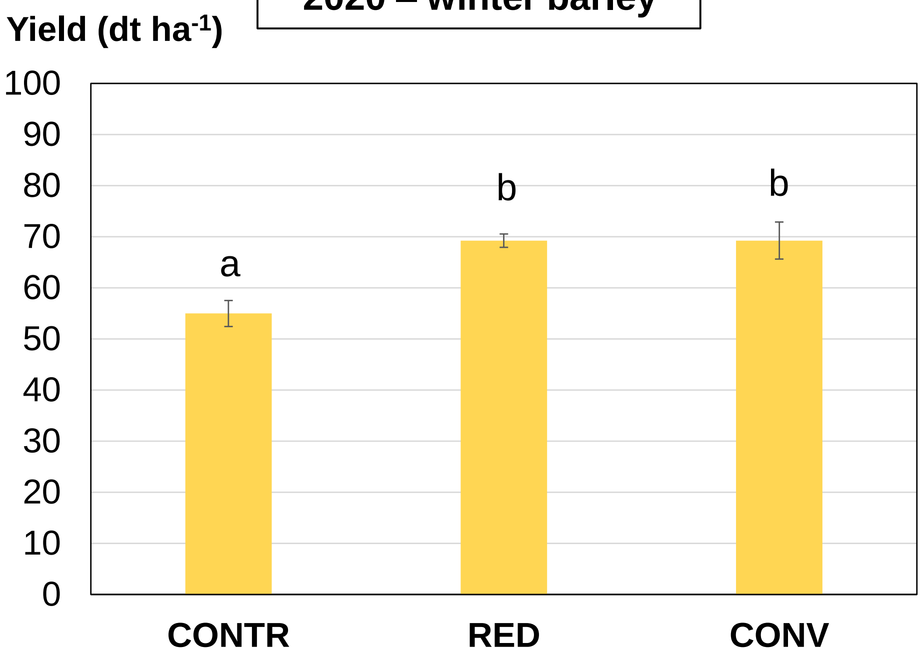
CONTR: without pesticides, RED: reduced pesticides application, CONV: conventional pesticide application

Yields in the field trial

2019 – winter wheat



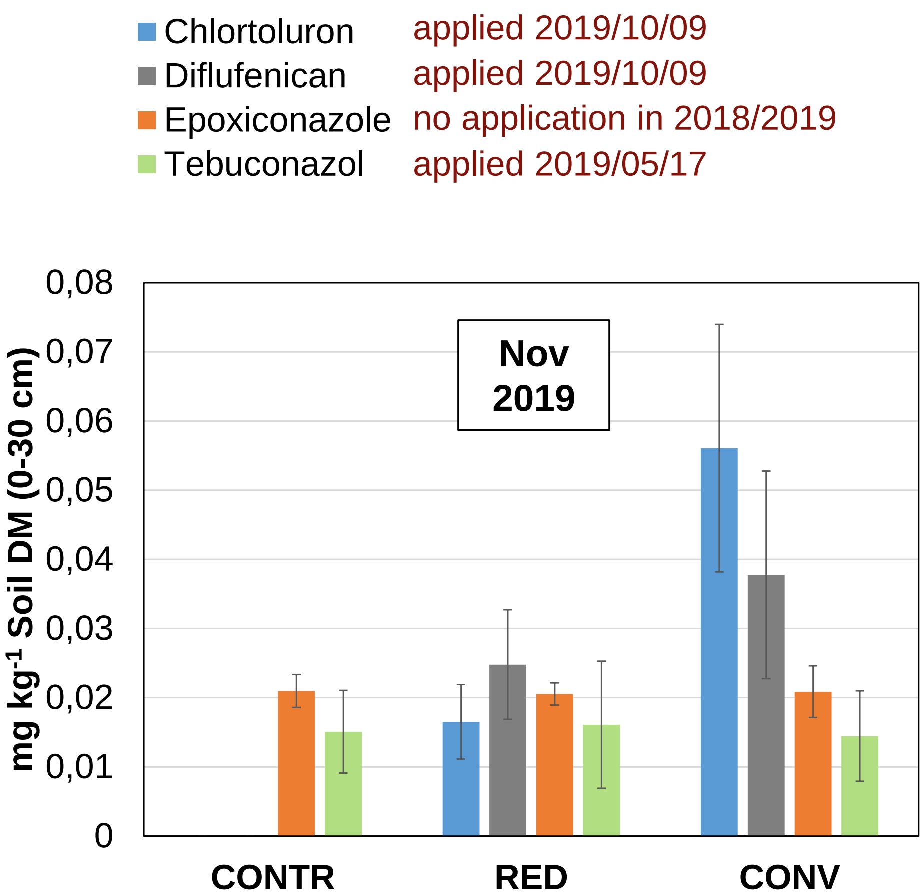
2020 – winter barley

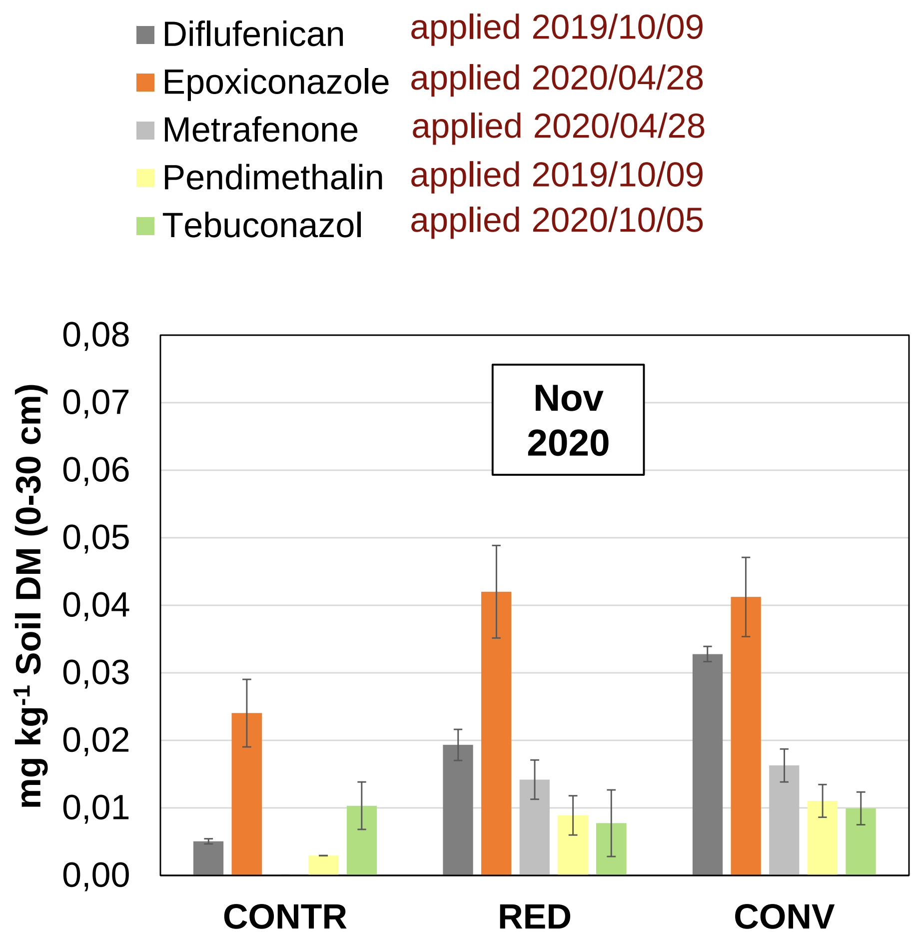


Different letters indicate significant differences between treatments ($p < 0.05$, n=4, Tukey-HSD)

CONTR: without pesticides, RED: reduced pesticides application, CONV: conventional pesticide application

Pesticide residues in the top soil (0-30 cm)





CONTR: without pesticides, RED: reduced pesticides application, CONV: conventional pesticide application

Sorption of pesticide substances (batch tests)

	K_d (L kg^{-1}) 0-30 cm	K_d (L kg^{-1}) 30-90 cm	K_d (L kg^{-1}) PPDB	Evaluation (PPDB)
diflufenican	306.8	288.4	134 (51-211)	non-mobile
glyphosate	303.5	174.6	209 (5-510)	slightly mobile
epoxiconazole	87.8	22.4	12 (8-18) -K_f	slightly mobile
fenpropimorph	204.4	342.9	44 (22-75) -K_f	non-mobile
flufenacet	6.4	2.4	4.4 (1.5-8.9)	moderately mobile
lambda-cyhalothrin	76.7	119.5	3709 (1245-6890)	non-mobile
pendimethalin	519.3	1013.0	228 (120-677)	non-mobile
spiroxamine	213.5	320.3	142 (5-893) -K_f	non-mobile
tebuconazole	28.5	8.9	12.7 (7.7-15.9) -K_f	slightly mobile
tribenuron-methyl	n.d.	n.d.	1.1 (0.1-2.1)	mobile

n.d.: not determinable

PPDB (Pesticide Properties DataBase), University of Hertfordshire, 2021: http://sitem.herts.ac.uk/aeru/ppdb/en/index.htm

Degradation of pesticide substances (batch tests)

	DT_{50} (days) 0-30 cm	DT_{50} (days) 30-90 cm	DT_{50} lab (days), PPDB	Evaluation (PPDB)
diflufenican	26	28	94.5 (41.4-318)	moderately persistent
glyphosate	69	104	15 (1-67.7)	non-persistent
epoxiconazole	49	76	353.5 (127-1000)	persistent
fenpropimorph	43	126	19.6 (9.5-124)	non-persistent
flufenacet	38	67	19.7 (7-37.4)	non-persistent
lambda-cyhalothrin	40	53	175 (43-1000)	persistent
pendimethalin	62	44	182.3 (97-270)	persistent
spiroxamine	36	42	22.1 (19.8-145.3)	non-persistent
tebuconazole	80	234	365 (>365)	very persistent
tribenuron-methyl	n.d.	n.d.	9.1 (2.9-23.1)	non-persistent

n.d.: not determinable

PPDB (Pesticide Properties DataBase), University of Hertfordshire, 2021: http://sitem.herts.ac.uk/aeru/ppdb/en/index.htm

Summary

- leaching of tebuconazole in seepage water also before application in the trial and in the CONTR treatment → presumably caused by seed treatment in the past
- no detection of other applied pesticide substances in seepage water (previously application of 17 different substances)
- no significant differences in weed abundance and yields between RED and CONV treatments
- positive findings of pesticide residues in the top soil (substances applied in the trial and others)
- determined sorption coefficients and degradation rates of batch tests confirm results of the lysimeter and field trials

Thanks for your attention !