Long-term effects of organic plant protection strategies in viticulture on soil quality and soil microbial communities

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Agricultural soils

Quality of agricultural soils is mainly measured by their productivity

- Productivity depends on their physical, chemical, and biological soil parameters

Grapevine microbiome consists of microbial communities in multiple habitats

- Its structure directly affects crop productivity and quality
- Different ways of managing crops can alter microbial community composition

Question: Does organic (ORG) and biodynamic (BD) management have a long-term impact on

1) Soil quality
2) enzymatic activity and microbial biomass in the soil
3) the soil + aboveground microbial community

INBIODYN-trial Geisenheim

Management systems

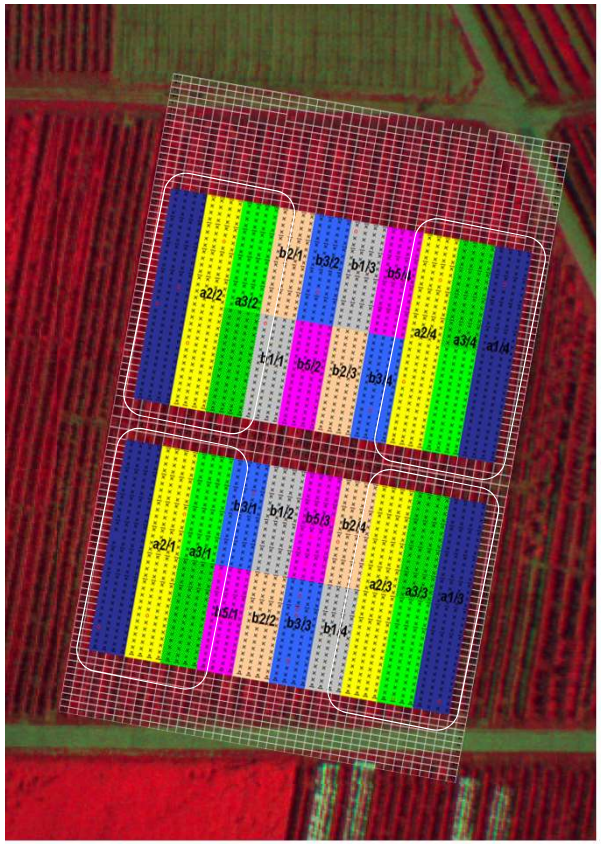
- Integrated (INT) according to good agricultural practice
- ORG according to Regulation (EU) No. 2018/848 and ECOVIN guidelines
- BD according to Regulation (EU) No. 2018/848 and demeter standards

	INT	ORG	BD
cover crop	winter cover crops + gras mixture (alternating)	winter cover crops + perennial mixture (Wolff-mixture or others)	
under-vine management	herbicides	mechanically	
fertilization	composted biological waste, mineral fertilization (N_{min})	composted farmyard manure	composted farmyard manure + biodynamic compost preparations (or cow pat pit preparation)
	ploughing of cover crops		
plant protection	synthetic fungicides, mating disruption	copper (max. 3 kg/ha and year), sulfur / bicarbonate + adhesives, mating disruption	
biodynamic preparations	-	-	horn manure + horn silica, compost preparations

INBIODYN-trial Geisenheim

Trial setup

- Trial site: Geisenheimer Mäuerchen (M4)
- Geisenheim/ Rheingau (49°59´; 7°56´)
- Planted in 1991; ~ 1 ha
- Spacing of 2 m between rows
- Spacing of 1.2 m within rows
- VSP system
- Riesling Gm 198-30
- rootstocks: Börner, SO4 (randomly distributed)
- Soil: sandy/clayey loam
- hortic anthrosol (due to long viticultural use)
- 4 field replicates



INT

ORG

BD

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Pictures: J. Döring

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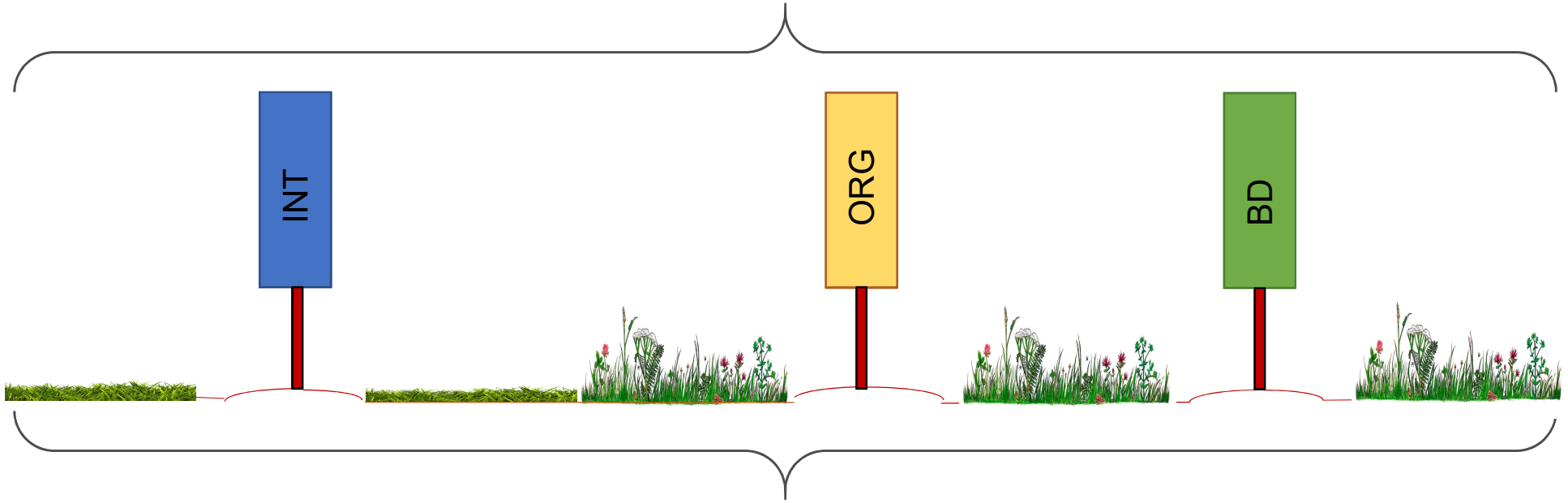
Assessment of soil quality and soil microbial biodiversity

Aboveground fungal/bacterial community
(Steng 2022)



Soil quality
(Hendgen et al. 2020)

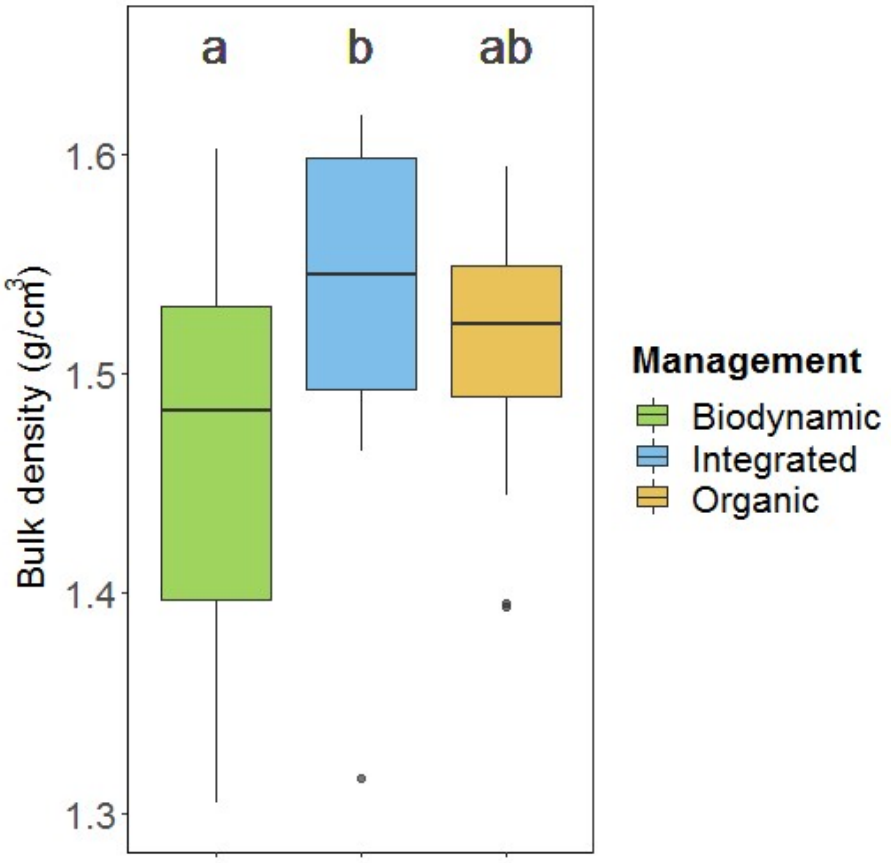
Microbial biomass and enzymatic activity
(Di Giacinto et al. 2020)

Soil fungal/ bacterial community
(Hendgen et al. 2018, Steng 2022)

Soil quality - physical and chemical traits

- Bulk density in INT viticulture significantly enhanced
- BD treatment shows lowest bulk density

- Systems did not differ in soil pH, C/N, %N, available water capacity (AWC)

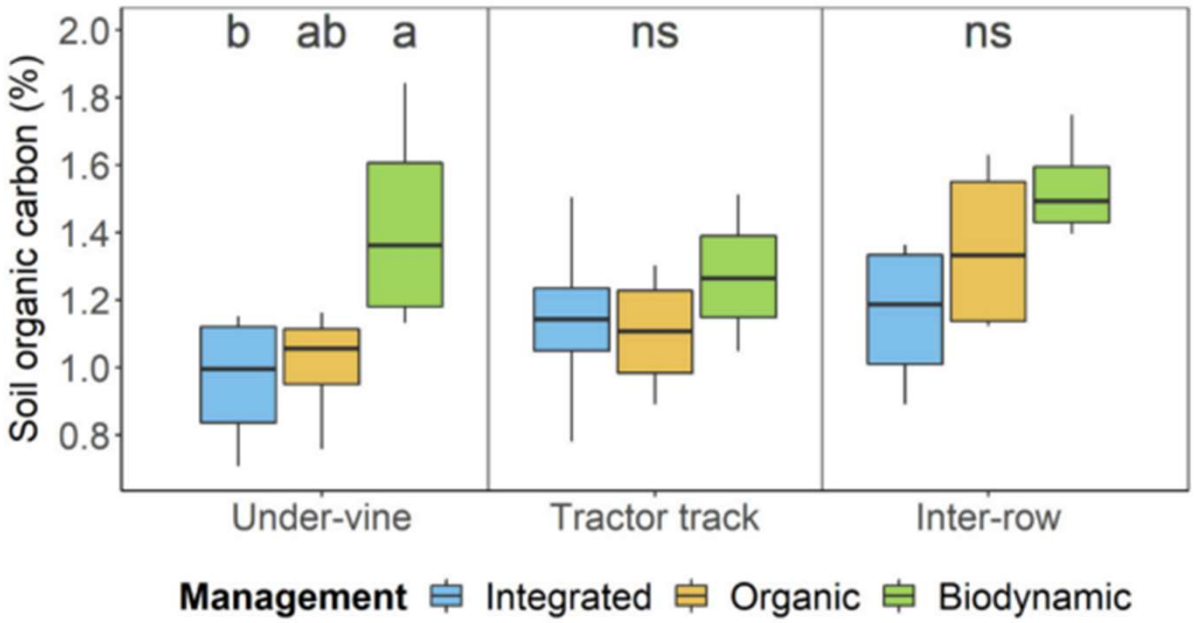


Hendgen et al. 2020

Soil quality - physical and chemical traits

- Bulk density in INT viticulture significantly enhanced
- BD treatment shows lowest bulk density

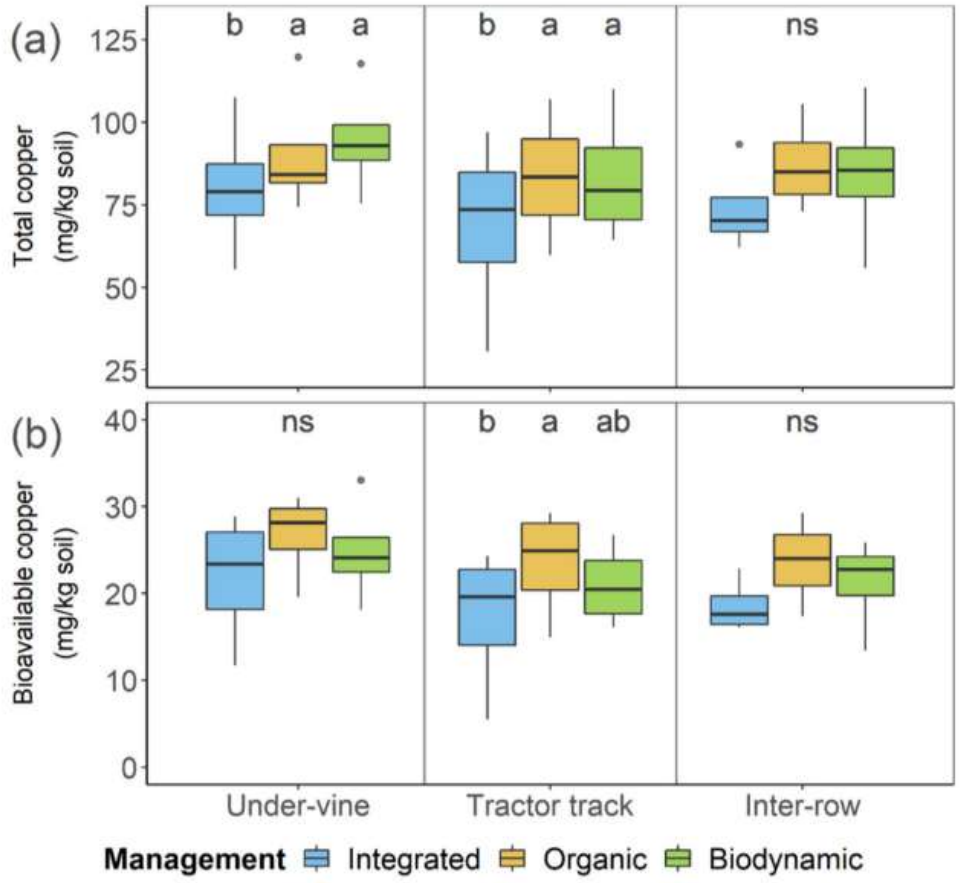
- Soil organic carbon (SOC) content significantly higher in BD viticulture → higher SOC in all three positions



Hendgen et al. 2020

Soil quality - physical and chemical traits

- Copper content (total + bioavailable) significantly enhanced in ORG and BD treatments
- Total copper:
  - int 74 mg/kg soil
  - org and bd 87 mg/kg soil
- Bioavailable copper:
  - int 19 mg/kg soil
  - org 24 mg/kg soil
  - bd 22 mg/kg soil



Hendgen et al. 2020

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  - int 74 mg/kg soil
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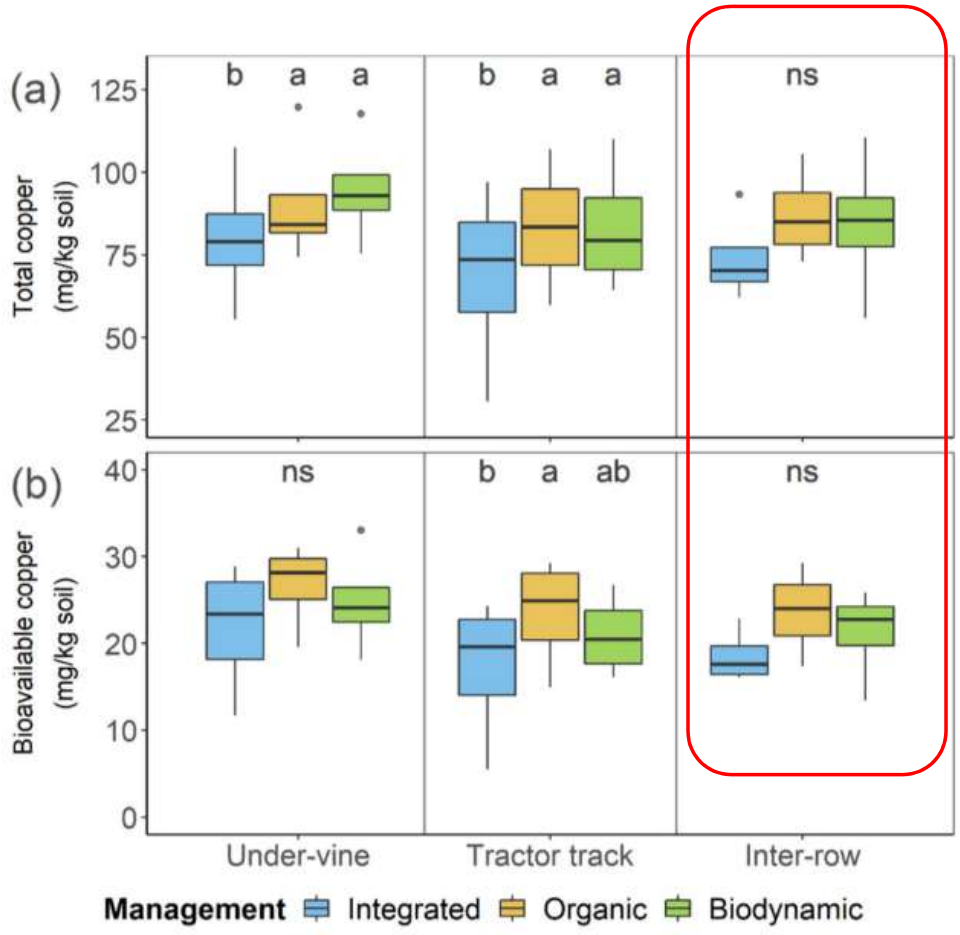
- Bioavailable copper:
  - int 19 mg/kg soil
  - org 24 mg/kg soil
  - bd 22 mg/kg soil
- No significant effects of total + bioavailable copper content in inter-row

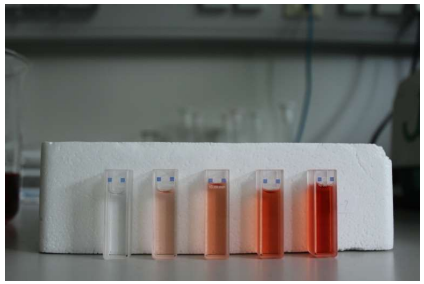


Hendgen et al. 2020

Soil microbial biomass and enzymatic activity

Enzymatic activities May-August 2016

- 5 enzymatic activities:
  - β-glucosidase GLU
  - dehydrogenase DHA
  - urease UR
  - catalase CAT
  - phosphatase PHO



- substrate is added to the soil and is incubated; amount of fission products are measured photometrically (400nm)
- Sample preparation according to Alef et al. (1991)

Di Giacinto et al. 2020

Microbial community analysis (PLFAs and NLFAs) May-August 2016

- Phospholipid-derived fatty acids and neutral lipid fatty acids: chemotaxonomic markers in microbial ecology
- PLFAs are structural parts of cellular membranes → estimation of total biomass: `population indicators`
- different markes for bacteria, fungi, protozoa (PLFAs) and arbuscular mycorrhizal fungi AMF (NLFAs)
- sample prepration according to Frostegård et al. (1993), measurements by GC-FID

Soil microbial biomass and enzymatic activity

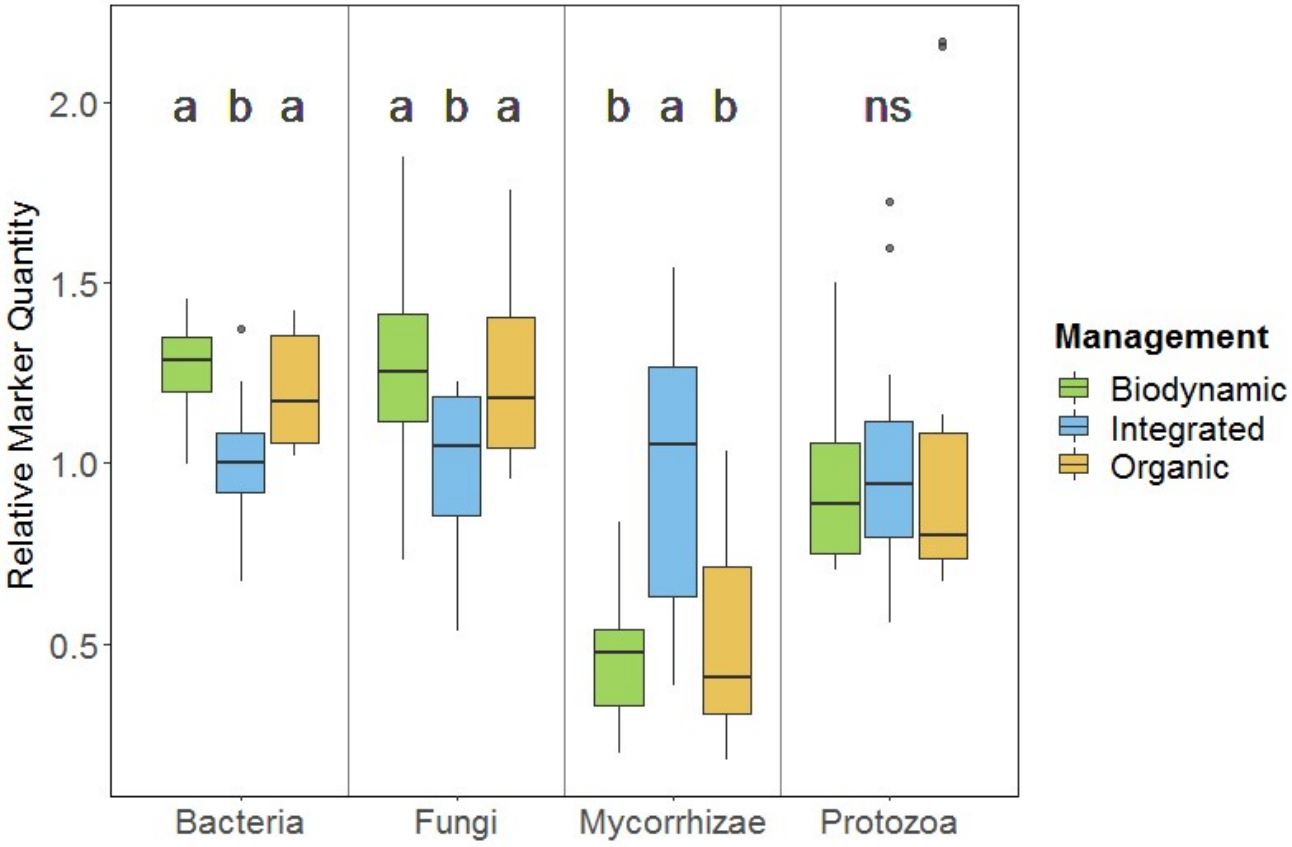
Enzymatic activities and PLFAs/NLFAs from May-August 2016

Parameter	INT (mean ± sd)		ORG (mean ± sd)		BD (mean ± sd)		treat
Soil Analysis							
N min [NO_3-N kg ha^{-1}]	4.42 ± 2.43	b	12.27 ± 11.78	a	11.79 ± 6.81	a	**
RWC [%]	47.74 ± 11.15	-	47.01 ± 13.20	-	48.52 ± 12.73	-	ns
Enzymatic activity							
GLU [µg ρNP g^{-1} h^{-1}]	564.52 ± 163.10	b	730.96 ± 176.79	a	753.96 ± 192.63	a	***
CAT [% of O_2 released]	8.76 ± 3.35	b	13.38 ± 6.78	a	12.61 ± 6.98	ab	*
UR [µg NH_4-N g^{-1} h^{-1}]	24.07 ± 5.44	b	27.31 ± 5.35	ab	29.44 ± 4.92	a	*
DHA [µg TPF g^{-1} h^{-1}]	0.656 ± 0.137	b	0.714 ± 0.152	ab	0.756 ± 0.132	a	*
PHO [µg ρNP g^{-1} h^{-1}]	217.81 ± 82.03	-	222.09 ± 73.95	-	227.8 ± 82.7	-	ns

Di Giacinto et al. 2020

Soil microbial biomass and enzymatic activity

Enzymatic activities and PLFAs/NLFAs from May-August 2016



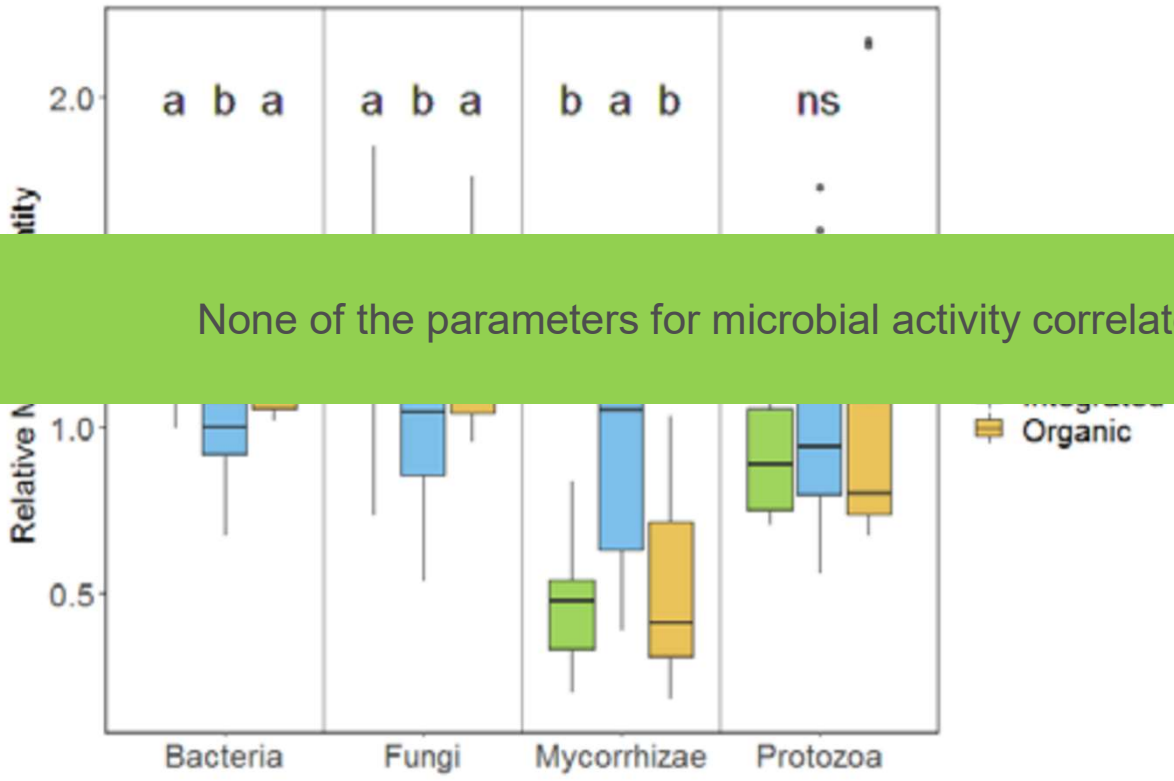
Relative quantities of bacteria (PLFA 16:1ω7), fungi (PLFA 18:2ω6), arbuscular mycorrhizae (NLFA 16:1ω5) and protozoa (PLFA 20:4ω6) markers in the cover-cropped rows of the different management systems across four sampling dates in 2016

- Fungal and bacterial biomass significantly enhanced in ORG and BD viticulture
- AMF biomass significantly increased in INT viticulture

Di Giacinto et al. 2020

Soil microbial biomass and enzymatic activity

Enzymatic activities and PLFAs/NLFAs from May-August 2016



Relative quantities of bacteria (PLFA 16:1ω7), fungi (PLFA 18:2ω6), arbuscular mycorrhizae (NLFA 16:1ω5) and protozoa (PLFA 20:4ω6) markers in the cover-cropped rows of the

None of the parameters for microbial activity correlated with copper contents in the soil

- Fungal and bacterial biomass significantly enhanced in ORG and BD viticulture
- AMF biomass significantly increased in INT viticulture (lower N_{min})

Di Giacinto et al. 2020

Soil microbial community

Species richness and community composition of fungi and bacteria in soil in August 2015

- Soil sampling: management system, position, depth
- DNA extraction

  PowerSoil DNA Isolation Kit, MoBio Laboratories Inc., Carlsbad, CA, USA)
- DNA amplification: ITS2, 16s-rRNA

  fungi: primer mix according to Ihrmark et al. 2012

  bacteria: primer mix as modified by to Caporaso et al. 2012
- sequencing: Illumina Miseq
- bioinformatic data management
- comparison with database

Hendgen et al. 2018

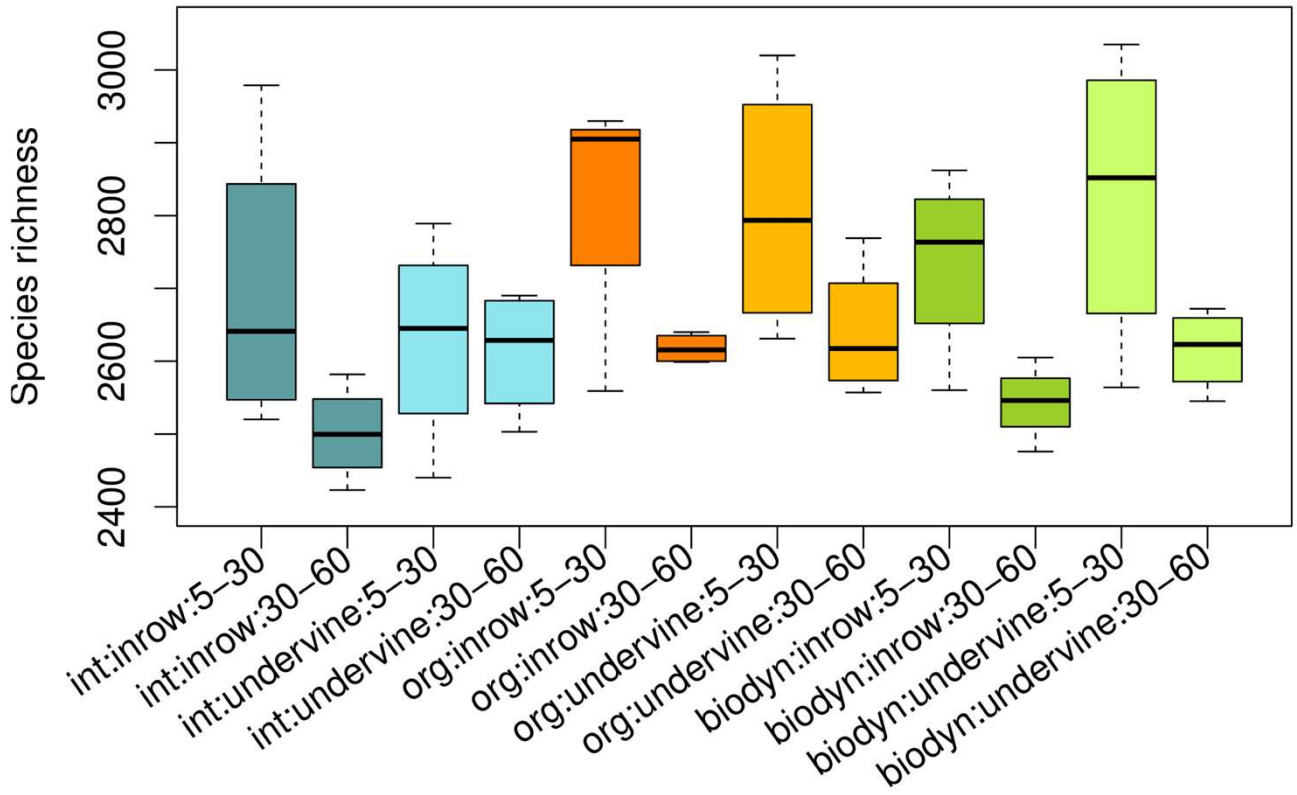
https://www.scinexx.de/wp-content/uploads/0/1/01-35285-barcode_1.jpg

https://www.hellblaurosa.de/media/image/f0/7d/ba/selecta-memo-pepito-und-seine-freunde-memoryspiel-38380-40239.jpg

https://jeltsch.org/sites/jeltsch.org/files/styles/large/public/field/image/PCR_tube_0.png?itok=V0DRJe9M

Soil microbial community: bacteria

Species richness of bacteria in soil in August 2015



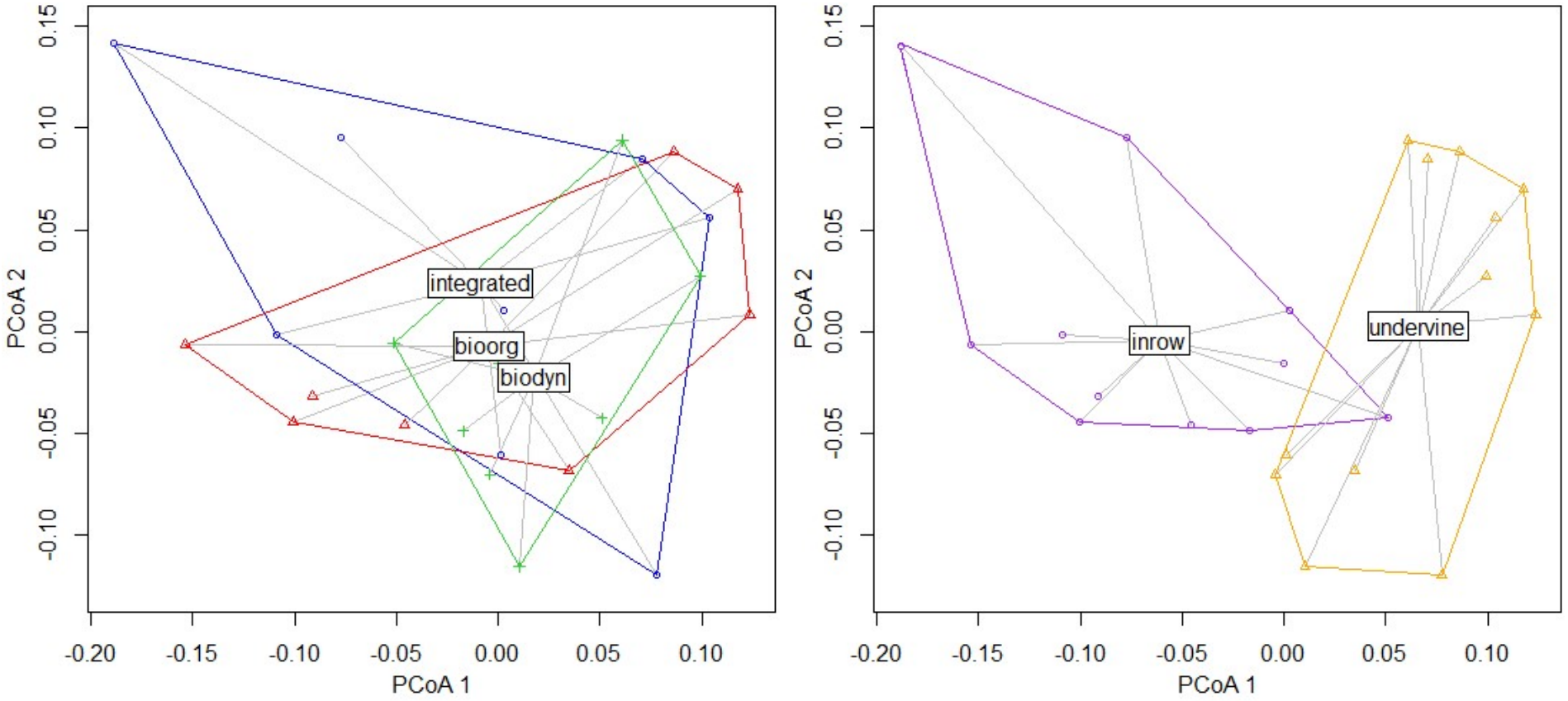
- **management system**: org more species compared to int
- **position**: no difference
- **depth**: topsoil more species compared tosubsoil

Hendgen et al. 2018

Soil microbial community: bacteria

community composition of bacteria in soil in August 2015

topsoil



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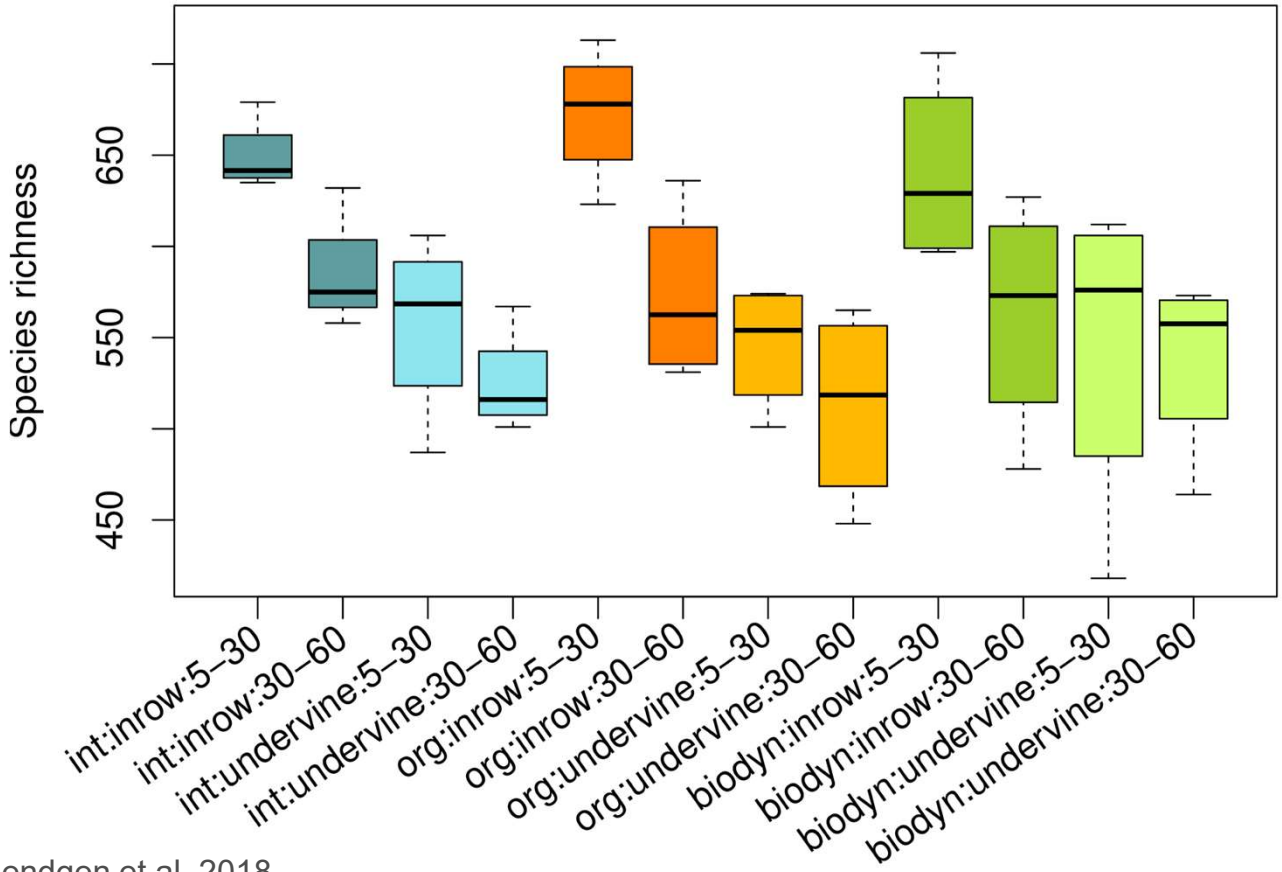
Soil microbial community: fungi

Species richness of fungi in soil in August 2015



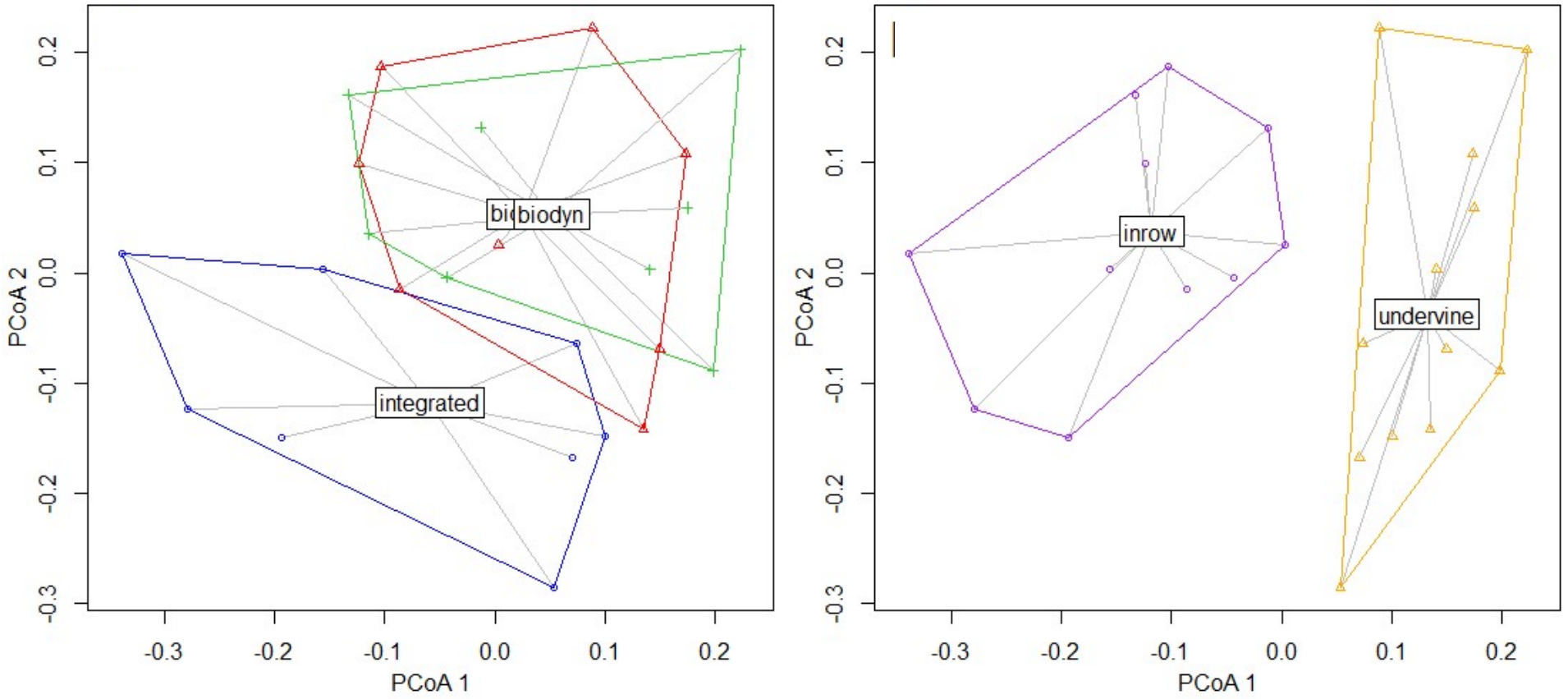
Hendgen et al. 2018

- **management system**: no difference
- **position**: inrow richer than undervine
- **depth**: topsoil richer than subsoil

Soil microbial community: fungi

community composition of fungi in soil in August 2015

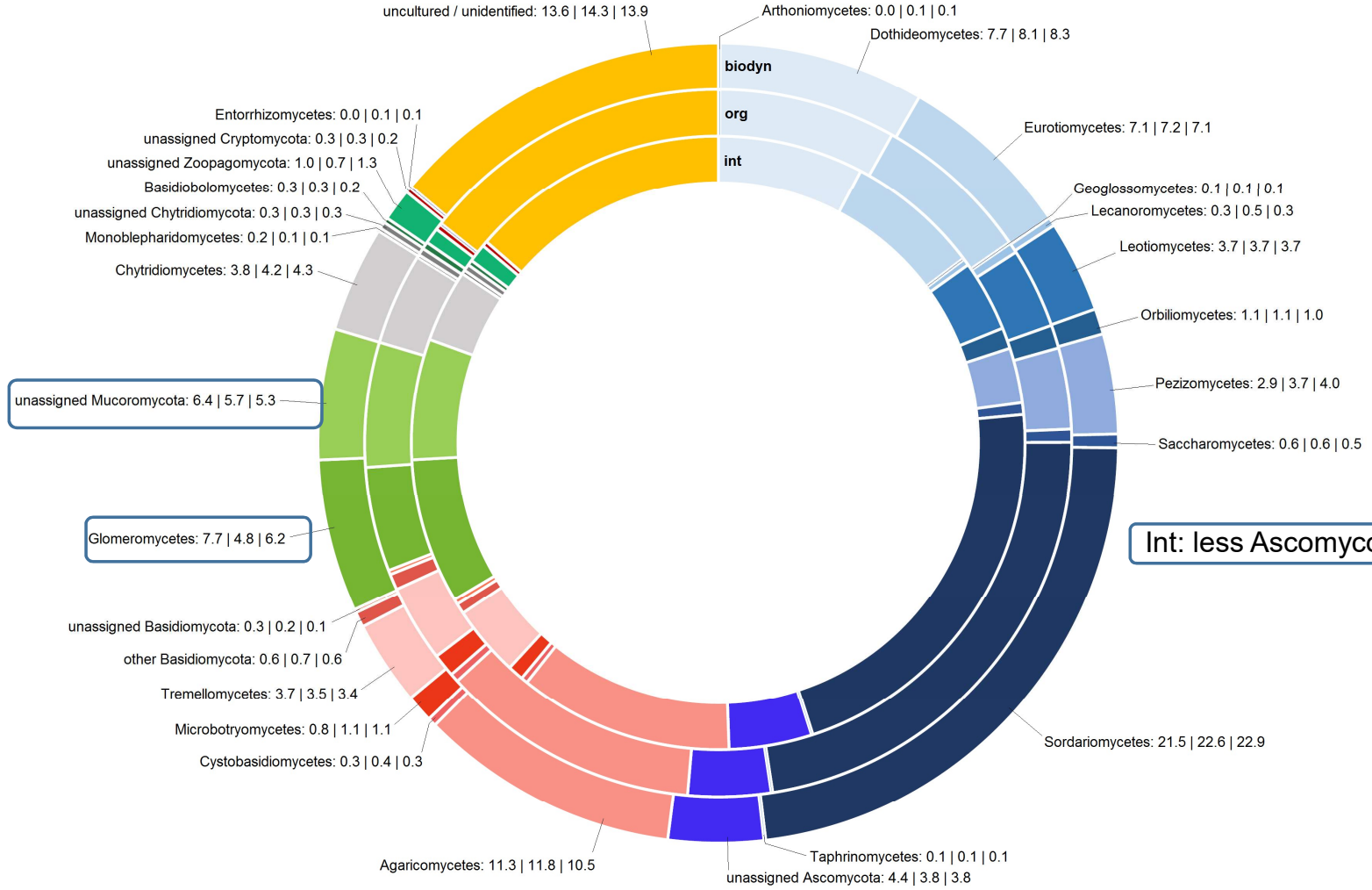
topsoil



Hendgen et al. 2018

Soil microbial community: fungi

Taxonomc classification



Int: more Mucoromycota and Glomeromycetes

Int: less Ascomycota

Hendgen et al. 2018

Conclusion

- Management system highly affects soil quality as well as soil microbial biomass, enzymatic activities in the soil and fungal community composition below- and aboveground
- ORG and BD management are caracterized by
  - ➢ higher SOC, lower bulk density, higher Cu contents and higher N_{min} in soil
  - ➢ Higher enzymatic activities, higher microbial biomass of bacteria and fungi and lower biomass of AMF
  - ➢ Higher species richness of bacteria in soils (ORG)
  - ➢ Completely different community composition of fungi in soil, on leaves and on grapes (BD)
- Main reasons for changes: spraying regime and cover crop mixtures → effects on crop productivity?

Thanks

- Thank you for your attention
- More questions? Please don`t hesitate to contact me: johanna.doering@hs-gm.de
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Literature cited

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