Activity of Exoenzymes in Treated Wastewater Irrigated Soils

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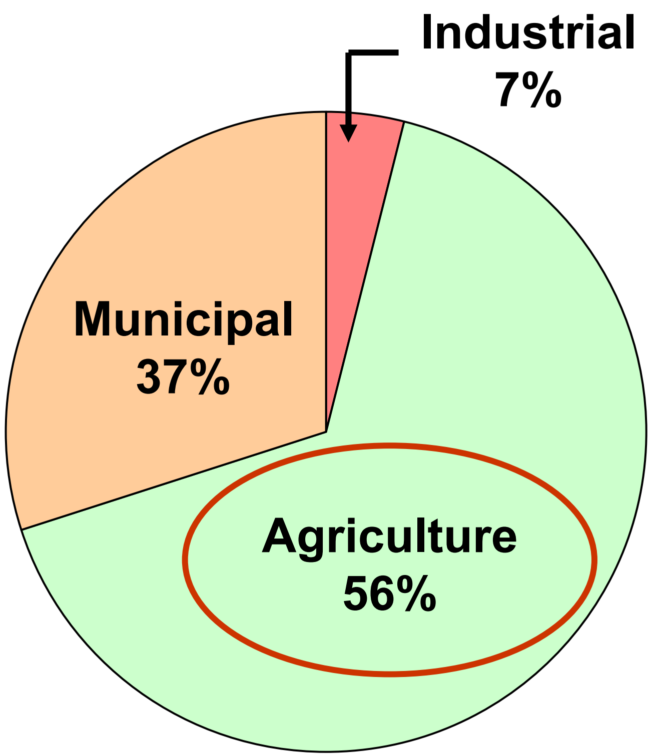
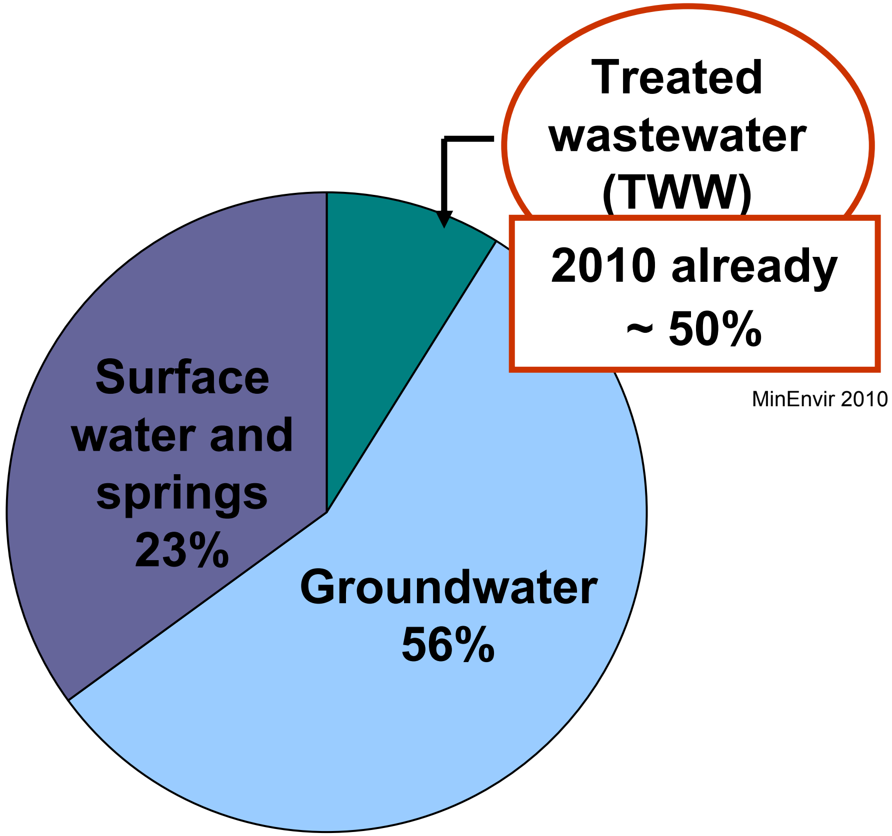
Water use in Israel

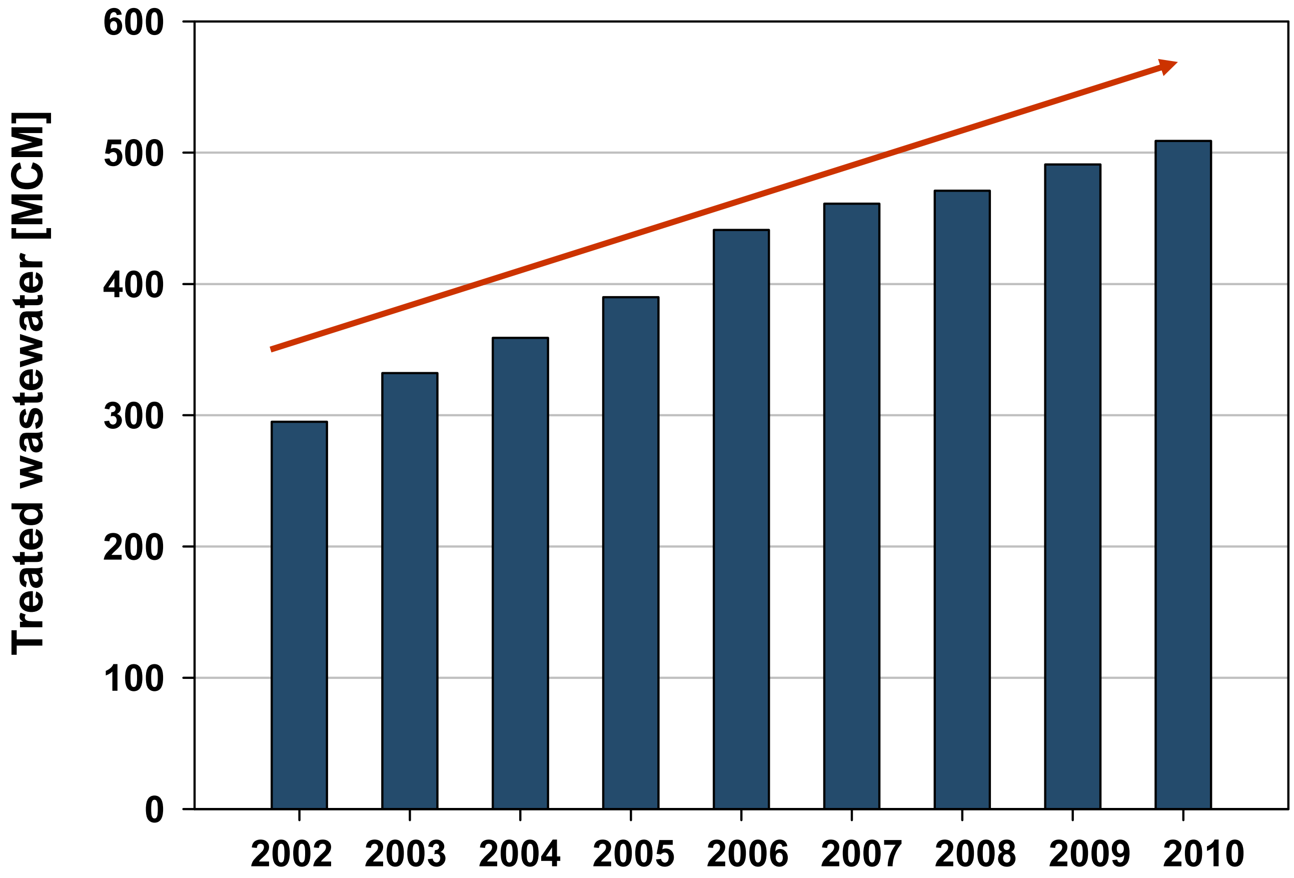


Israeli Ministry of Environmental Protection (2002)



Water Commision (2000)

Established and projected treated wastewater (effluent) use in Israel



MCM = million cubic meter

modified after Tal (2006)

Water quality

Parameter	Unit	TWW	FW
EC	dS/m	2.3	1.0
Cl	mg/L	364	201
Na	meq/L	21.4	4.3
Ca + Mg	meq/L	6.1	4.1
pH		8.3	7.4
DOC	mg/L	23.5	1.1
TOC	mg/L	47.6	< 10
BOD	mg/L	59.9 *	< 1
COD	mg/L	234.0 **	< 20

TWW – Treated WasteWater
FW - FreshWater

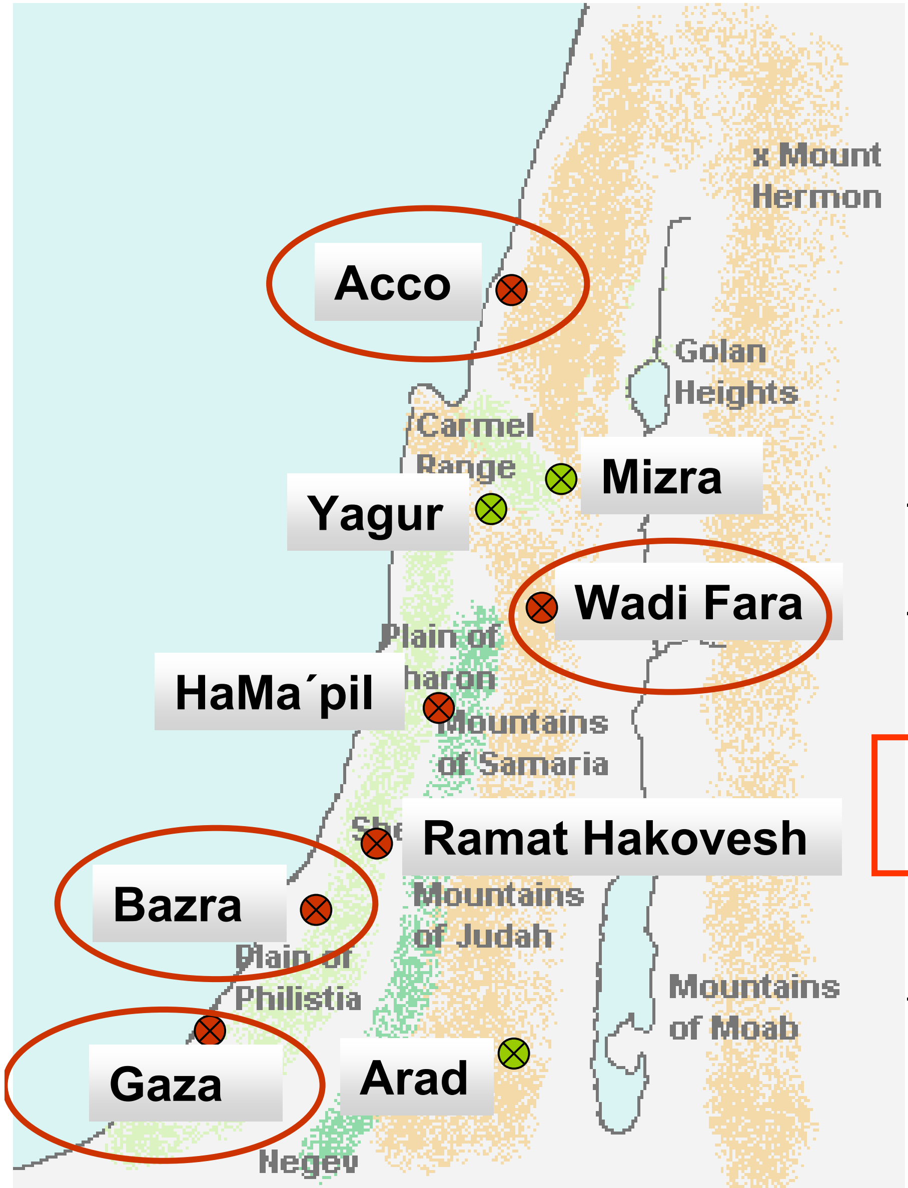
Upgraded Effluent Quality Standards (Jan 2010)

* BOD 10 mg/L
** COD 100 mg/L

(Israel Ministry of Environment 2010)

Treated wastewater is a source of organic carbon.

Materials and Methods



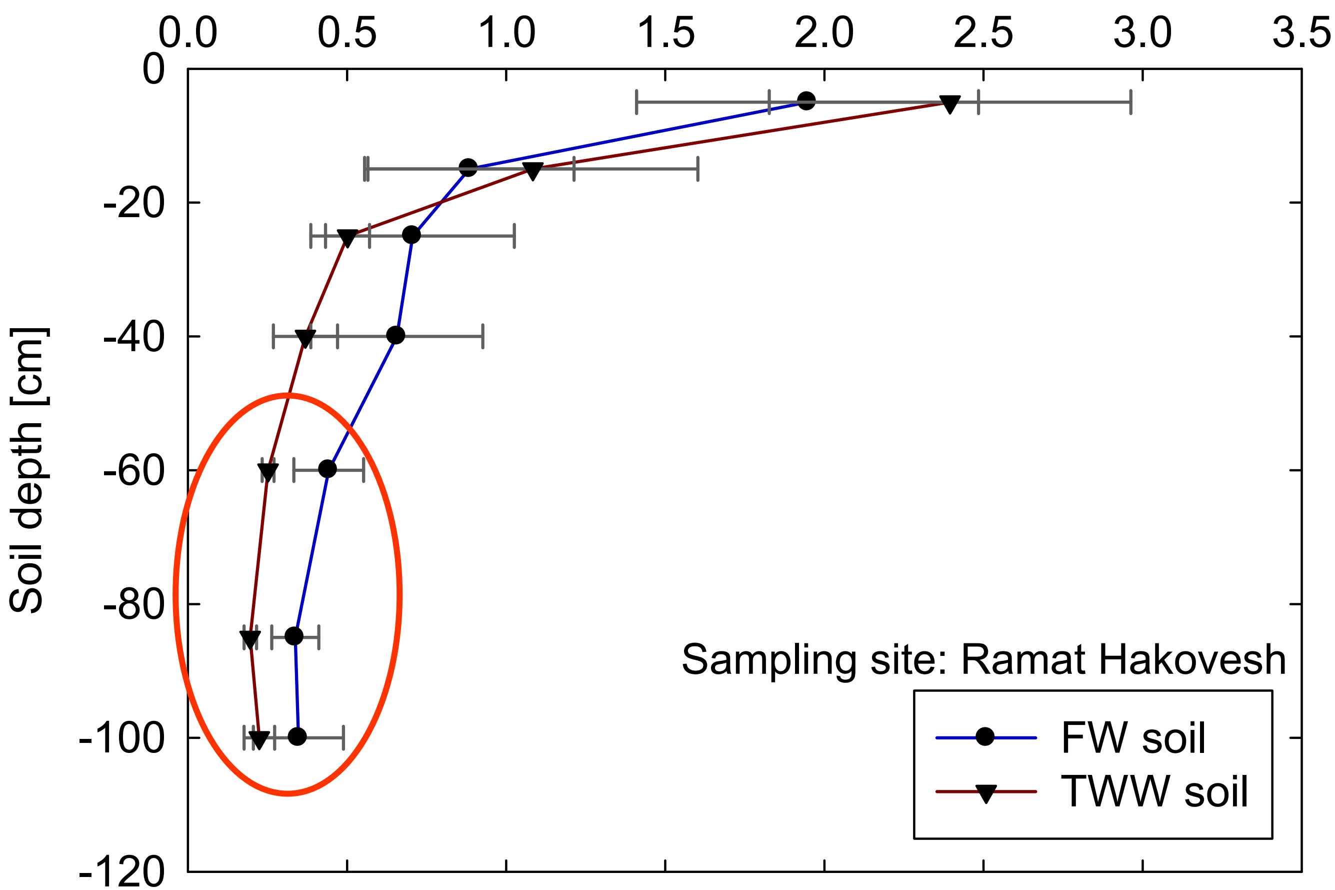
⊗ sampling sites

⊗ **S**oil **O**rganic **C**arbon - profiles

⭕ Enzyme activity studies

Sampling site ⊗	Land use	FAO classification	Sand (%)	Clay (%)	SOC (%)
Ramat Hakovesh	orchard	Chromic Luvisol	89	6	0.9
HaMa´pil	orchard	Chromic Luvisol	82	11	1.8
Bazra	grapefruit orchard	Chromic Luvisol	82	12	0.5
Acco	avocado orchard	Vertisol	22	52	1.0
Wadi Fara	field	Vertisol	11	66	2.3
Gaza	field	Chromic Luvisol	86	7	0.1

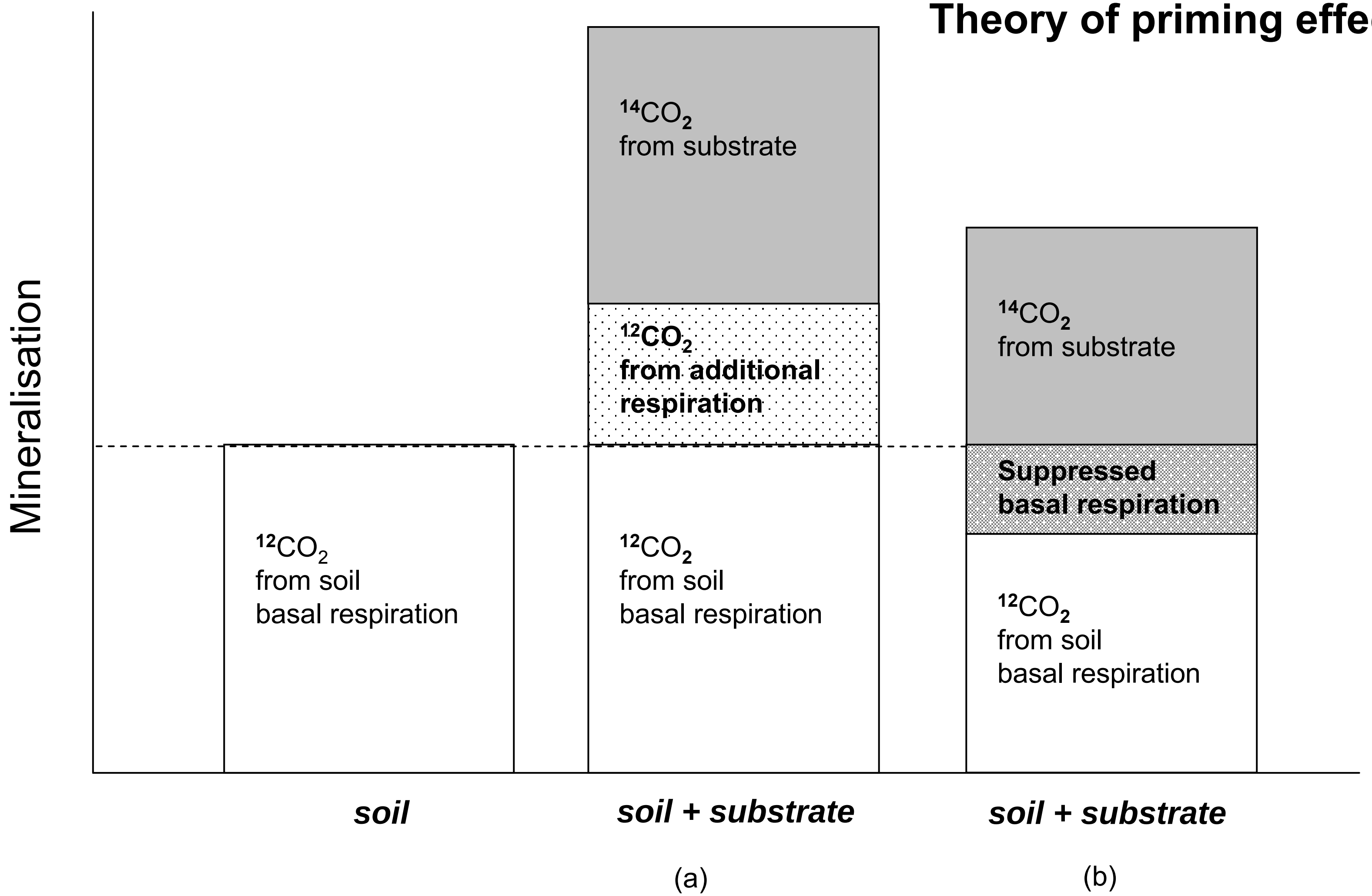
Soil organic carbon content (SOC)



- first ~50 cm similar SOC-content
- less SOC in the subsoil (deeper ~50 cm)

Materials and Methods

Theory of priming effects



(a) acceleration of SOM decomposition – positive priming effect

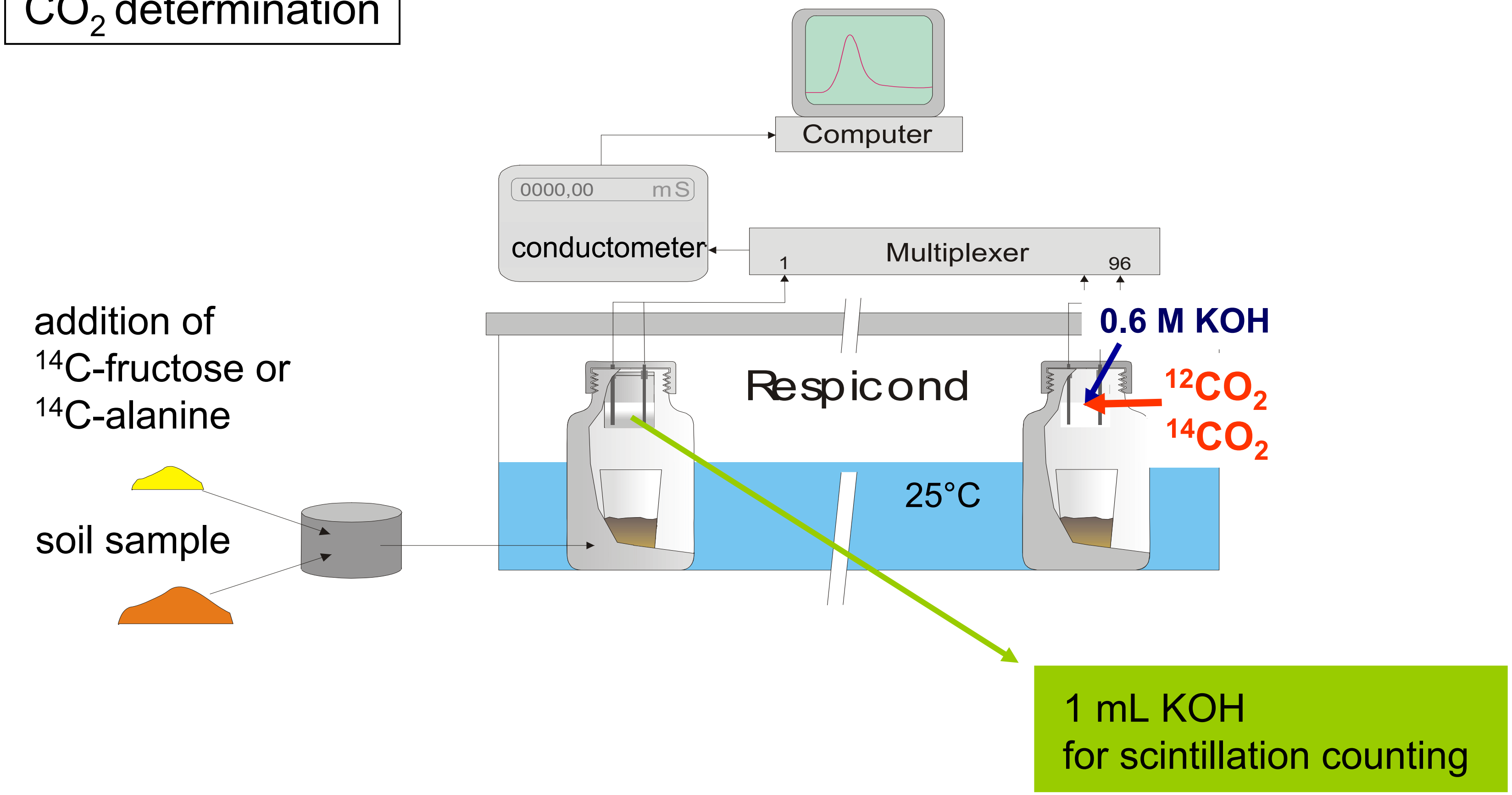
(b) retardation of SOM decomposition – negative priming effect

modified after Kuzyakov et al. (2000)

Jüschke & Marschner

Incubation of soil samples with additions of easily available organic substrates

CO_2 determination



Gosda, W. modified after Nordgren (1988)

Jüschke & Marschner

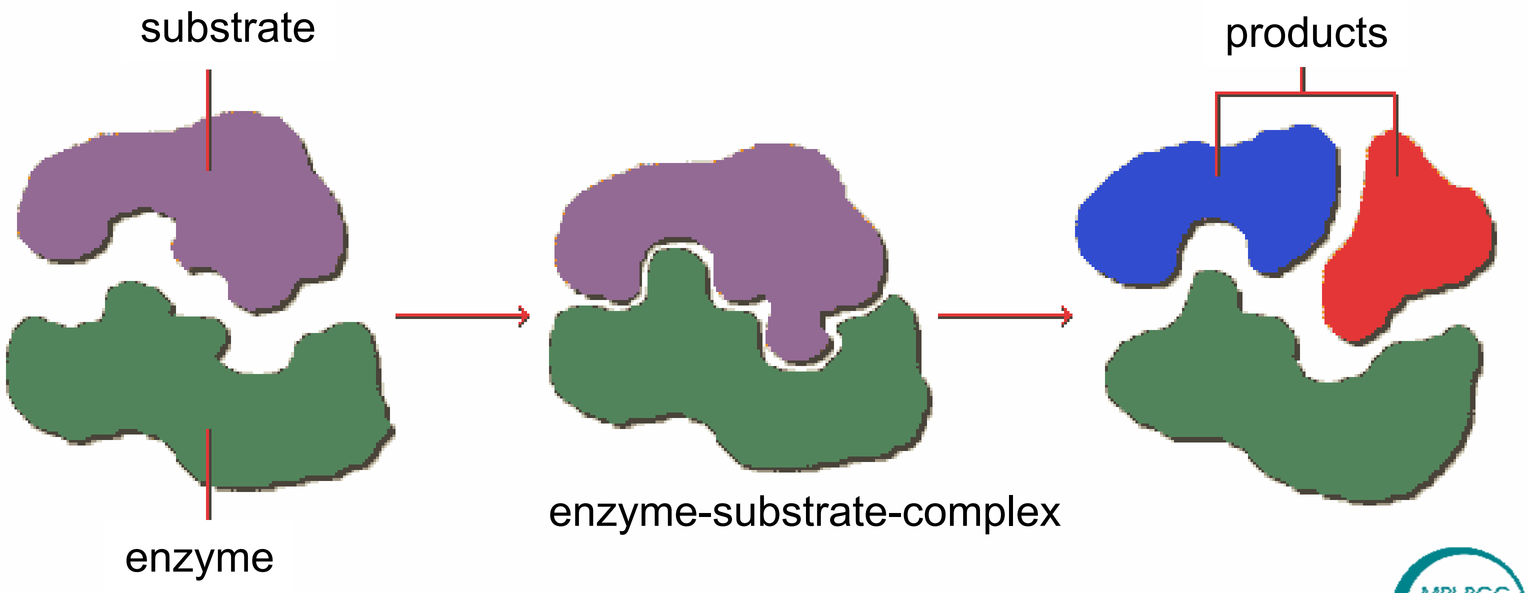
Treated wastewater is a source of organic carbon.

organic carbon = substrate for soil microorganisms

↳ **Effect on soil microbial communities and activities**

↳ **Hypothesis**: increased release of exoenzymes into the soil and alteration in mobilisation of nutrients

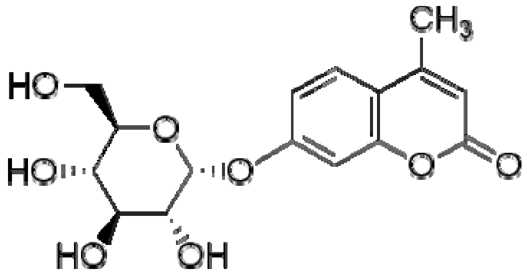
↳ ? Effects along soil profiles



Materials and Methods

A range of hydrolytic enzymes, involved in C, N and P cycles, were investigated using a fluorimetric microplate assay (after Marx et al. 2001).

Measurements with the help of fluorescence substrates (4-MUF = 4-Methylumbelliferon and AMC = 7-amino-4-methylcoumarin)



4-MUF-α-D-Glycoside

α-D-Glycosidase ⟶ degradation of soluble sugars and starch

α –Glucosidase

ß- Glucuronidase

ß –Cellobiohydrolase

ß- Xylosidase

ß- Glucosidase

N-acetyl-ß-glucosaminidase

Acid phosphatase

Leucin aminopeptidase

Tyrosin aminopeptidase

Arginin aminopeptidase

Jüschke & Marschner

Results

Soil microbiological parameter along 3 irrigated soil profiles
- Bazra, Acco and Wadi Fara -

Soil depth [cm]	C_{mic}	C_{mic}/C_{org}	$q\,CO_2$	acc. CO_2	SOC_{min}	SOC_{min} alanine	SOC_{min} fructose	PE alanine	PE fructose
0-10	+	+ -		++	++ -	++ -	++ -	+ -	-
10-20	++	+ -		+++	+++	+	++ -	- -	- - -
20-30		+	+	+	+ -	++	+ -		-
30-50	+ -	-		+++	+	- - -	- -	(2)	- (2)
50-70	+ -	-			+ -	+ -	+		+
70-100	++ -	- -	+ - -	+ -	-	-	- -	(2)	- (2)

Bazra, Acco and Wadi Fara

	no difference between TWW and FW
- - -	TWW < FW (three sampling sites)
- -	TWW < FW (two sampling sites)
-	TWW < FW (one sampling site)
+ - -	TWW < FW (two sampling sites) and TWW > FW (one sampling site
+ -	TWW < FW (one sampling site) and TWW > FW (one sampling site)
++ -	TWW < FW (one sampling site) and TWW > FW (two sampling sites)
+	TWW > FW (one sampling site)
++	TWW > FW (two sampling sites)
+++	TWW > FW (three sampling sites)

Student t-Test p<0.05

(2) - only two of three sampling sites showed significant differences between control and treated sample, therefore only these values were calculated

Jüschke & Marschner

Soil microbiological parameter along 3 irrigated soil profiles
- Bazra, Acco and Wadi Fara -

Soil depth [cm]	α-glu	ß-Xyl	N-acet	ß-glucoro	ß-cello	ß-glu	pho	Leu	Tyr	Arg
0-10		+	++	+	++	++	+ -	++	+++	++
10-20	+	+		+	+	+	+	++	+	+
20-30		+		+	++	++	++	++	+	++
30-50	+ -	+ -	+ -		+	+	++	+	+ -	++
50-70		+ -	+ -	-		+ -	+	++ -	-	+ -
70-100	-	-	-		-	-	-	-	-	+ -

Bazra, Acco and Wadi Fara

	no difference between TWW and FW
- - -	TWW < FW (three sampling sites)
- -	TWW < FW (two sampling sites)
-	TWW < FW (one sampling site)
+ - -	TWW < FW (two sampling sites) and TWW > FW (one sampling site
+ -	TWW < FW (one sampling site) and TWW > FW (one sampling site)
++ -	TWW < FW (one sampling site) and TWW > FW (two sampling sites)
+	TWW > FW (one sampling site)
++	TWW > FW (two sampling sites)
+++	TWW > FW (three sampling sites)

Student t-Test p<0.05

(2) - only two of three sampling sites showed significant differences between control and treated sample, therefore only these values were calculated

α-glu = α-glucosidase; β-Xyl = β-Xylosidase; N-acet = N-acety-β-glucosamidase, pho = acid phosphatase; β-glucoro = β-glucorosidase; β-cello = β-cellobiohydrolase; β-glu = β-glucosidase; Leu = Leucin aminopepdidase; Tyr = Tyrosin aminopepdidase; Arg = Arigin aminopepdidase

Method: Marx et al. 2001

Jüschke & Marschner

Soil microbiological parameter along 3 irrigated soil profiles - Bazra, Acco and Wadi Fara -

Soil depth [cm]	α-glu	ß-Xyl	N-acet	ß-glucoro	ß-cello	ß-glu	pho	Leu	Tyr	Arg
0-10		+	++	+	++	++	+ -	++	+++	++
10-20	+	+		+	+	+	+	++	+	+
20-30		+		+	++	++	++	++	+	++
30-50	+ -	+ -	+ -		+	+	++	+	+ -	++
50-70		+ -	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
70-100	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Changes in SOC- quality due to continuously priming in the field by addition of TWW – long-term effect

Bazra, Acco and Wadi F

	no differen
- - -	TWW < FW (three sampling sites)
- -	TWW < FW (two sampling sites)
-	TWW < FW (one sampling site)
+ - -	TWW < FW (two sampling sites) and TWW > FW (one sampling site
+ -	TWW < FW (one sampling site) and TWW > FW (one sampling site)
++ -	TWW < FW (one sampling site) and TWW > FW (two sampling sites)
+	TWW > FW (one sampling site)
++	TWW > FW (two sampling sites)
+++	TWW > FW (three sampling sites)

Student t-Test $p<0.05$

f three sampling sites showed significant differences between control and treated sample, therefore only these values were calculated

α-glu = α-glucosidase; β-Xyl = β-Xylosidase; N-acet = N-acety-β-glucosamidase, pho = acid phosphatase; β-glucoro = β-glucorosidase; β-cello = β-cellobiohydrolase; β-glu = β-glucosidase; Leu = Leucin aminopepdidase; Tyr = Tyrosin aminopepdidase; Arg = Arigin aminopepdidase

Method: Marx et al. 2001

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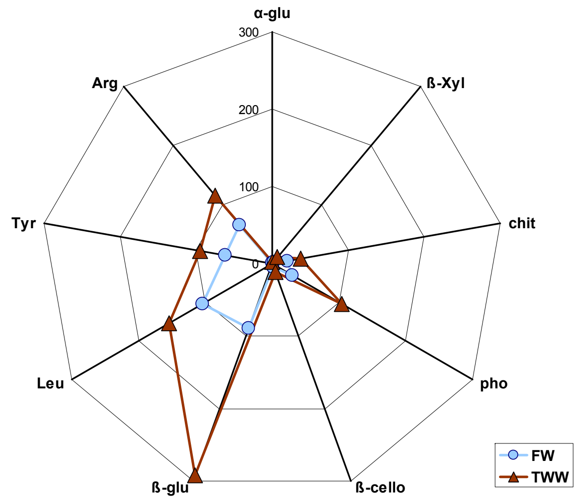
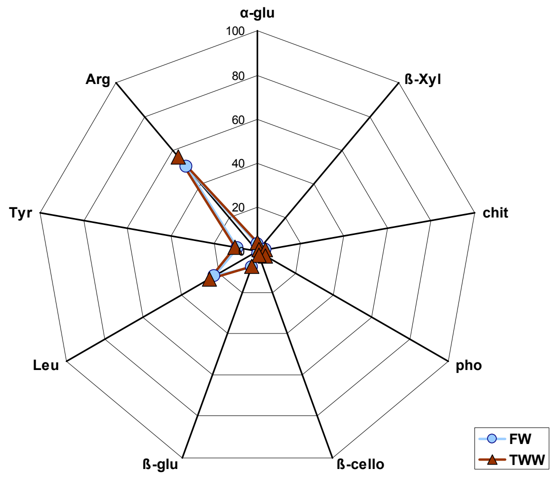
BAZRA – enzyme activities

0-10 cm



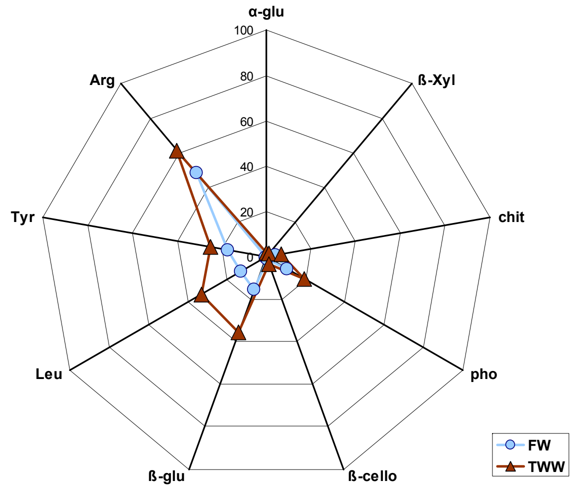
max: 291.6 nmol g^{-1} h^{-1}

10-20 cm



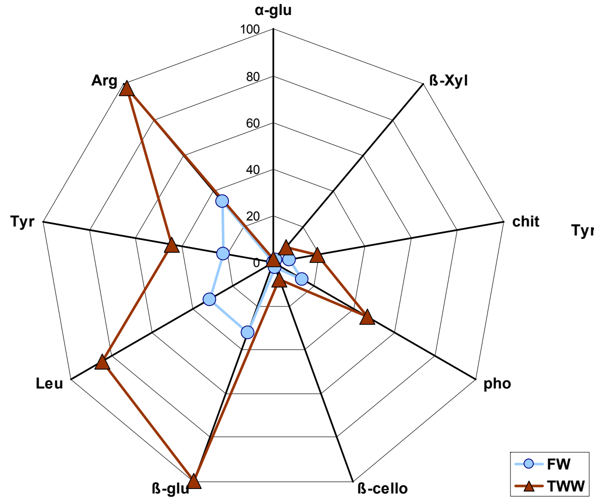
max: 55.7 nmol g^{-1} h^{-1}

20-30 cm



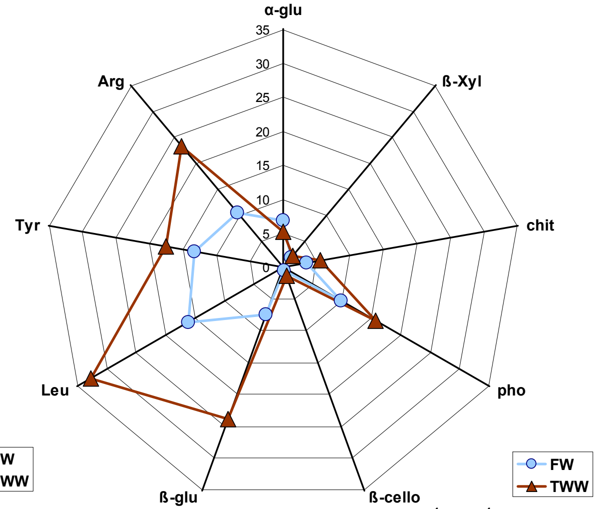
max: 61.2 nmol g^{-1} h^{-1}

30-50 cm



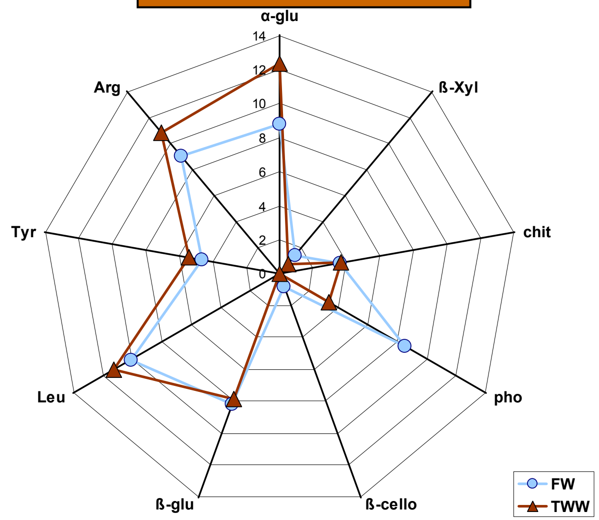
max: 99.6 nmol g^{-1} h^{-1}

50-70 cm



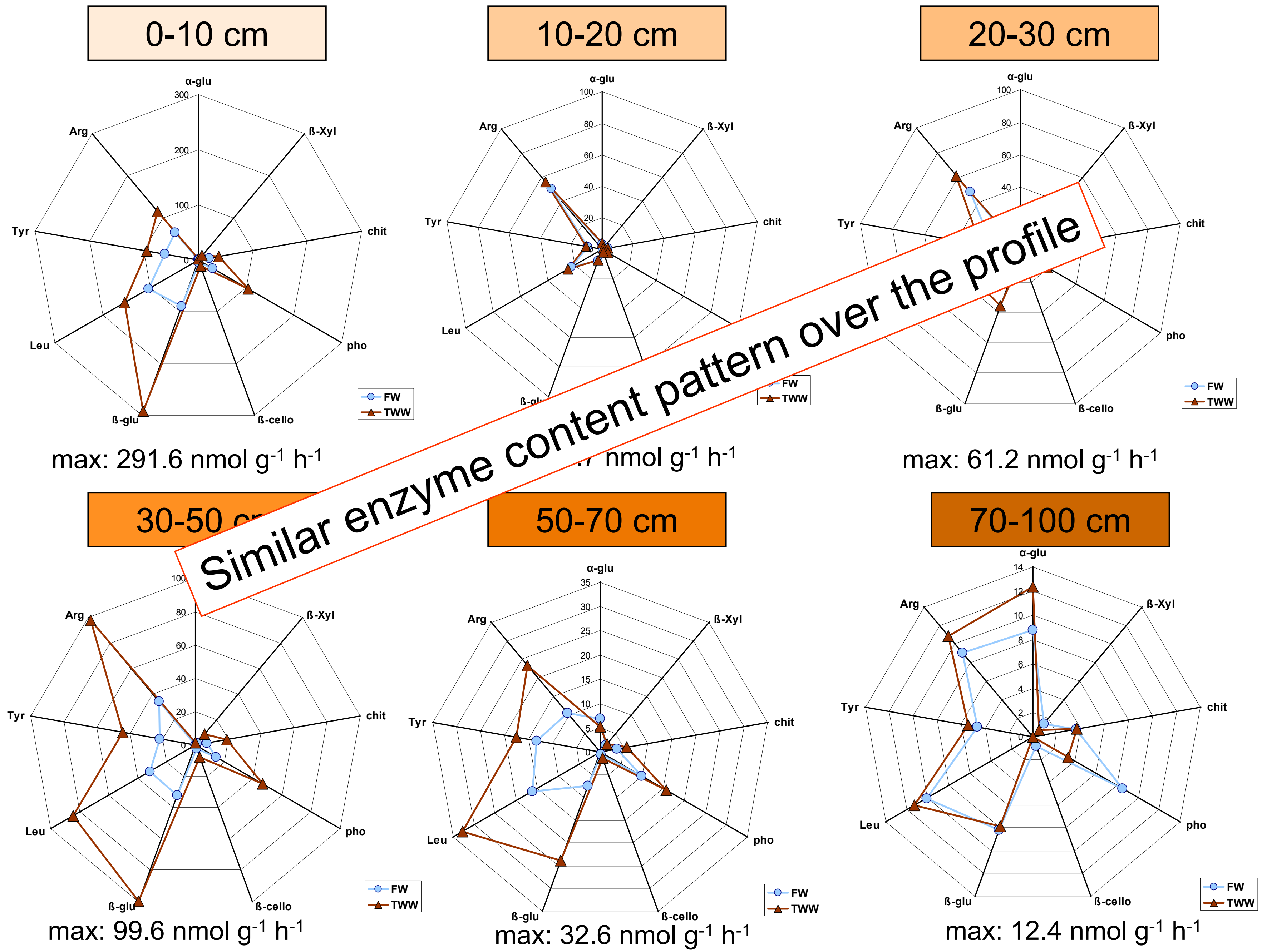
max: 32.6 nmol g^{-1} h^{-1}

70-100 cm



max: 12.4 nmol g^{-1} h^{-1}

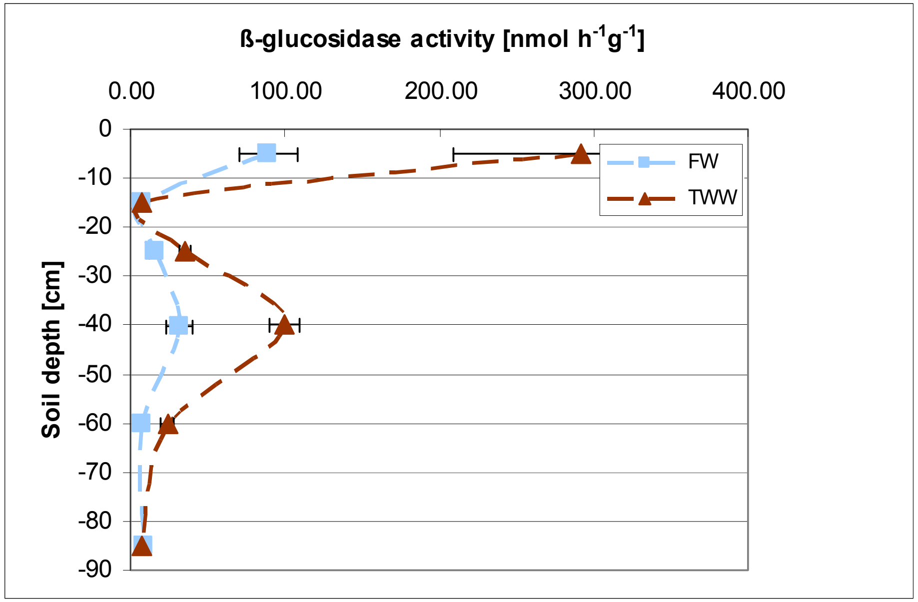
BAZRA – enzyme activities



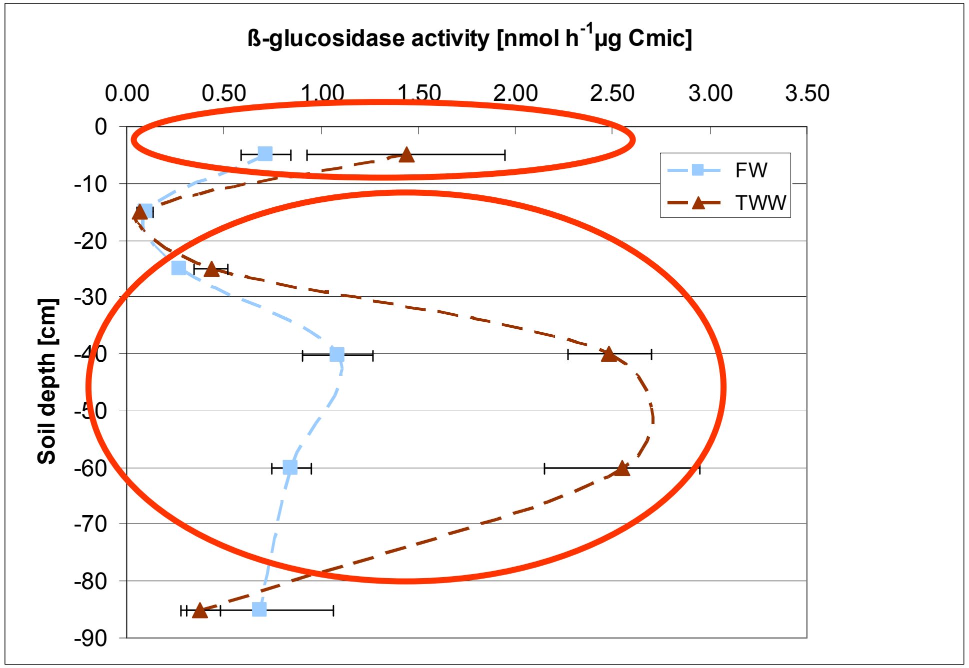
Bazra – soil enzyme profiles

β-glucosidase

nmol h^{-1} g^{-1} dry soil



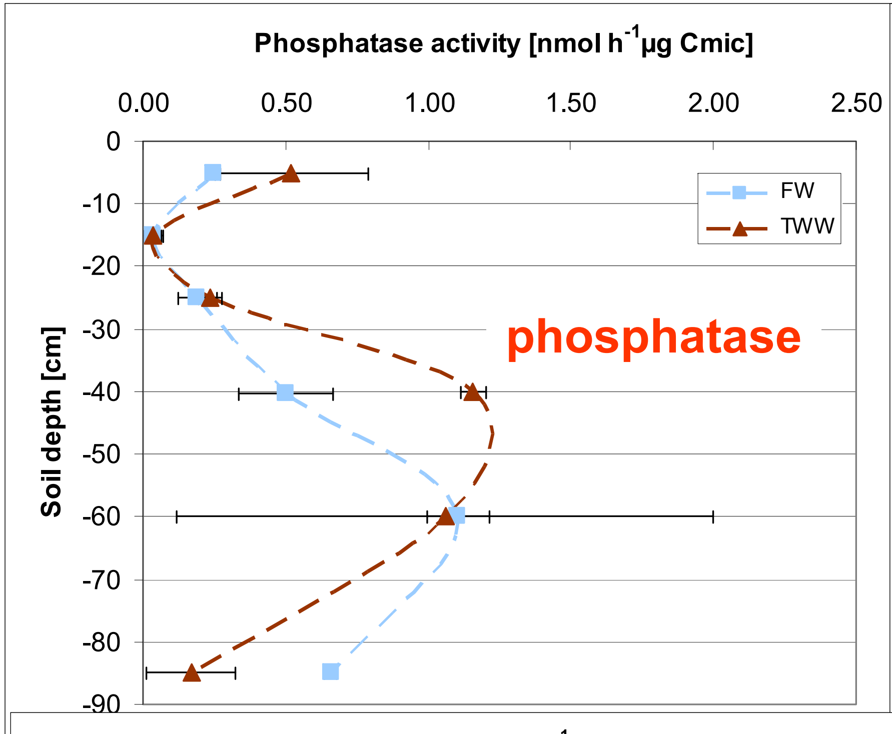
nmol h^{-1} μg^{-1} C_{mic}

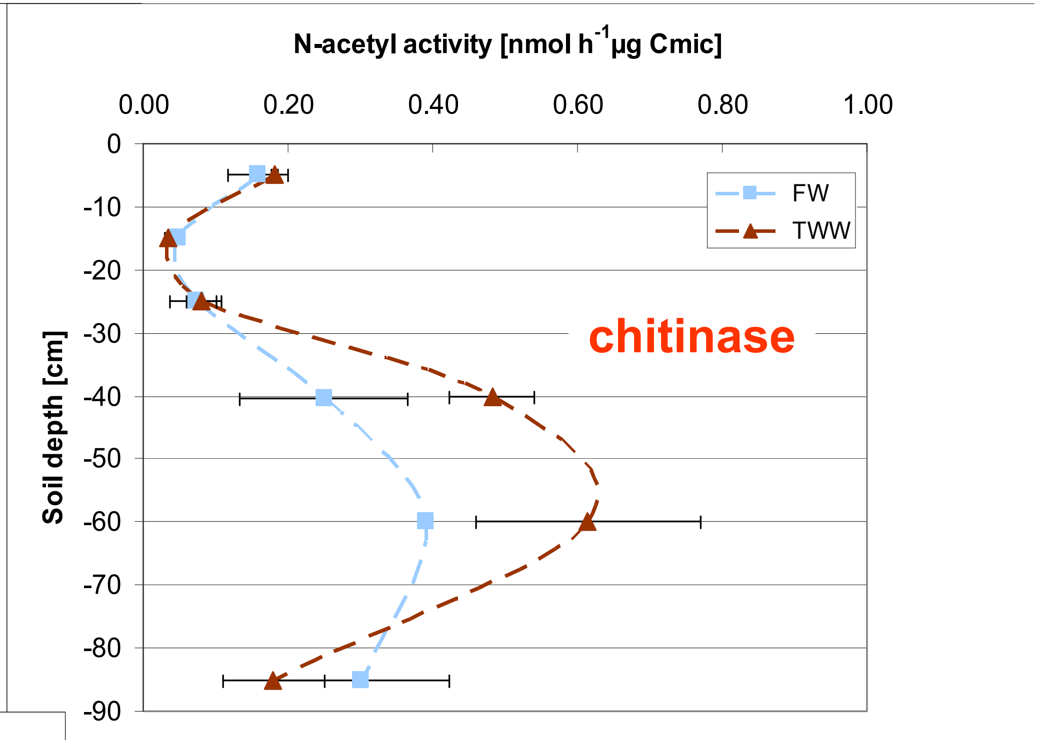


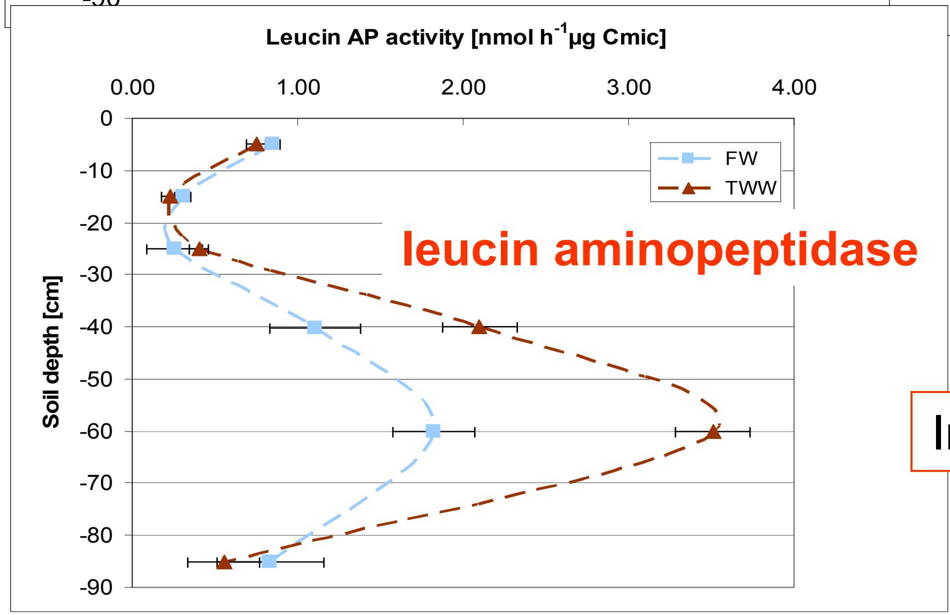
- clear differences between FW and TWW
- activity increase with soil depth
- high correlation with microbial biomass carbon

Jüschke & Marschner

Bazra – soil enzyme profiles







nmol h^{-1} μg^{-1} C_{mic}

→ similar pattern like β-glucosidase

→ activity increase with soil depth

maybe due to tree roots or shift in texture

Increased amounts of tree roots under TWW

Jüschke & Marschner

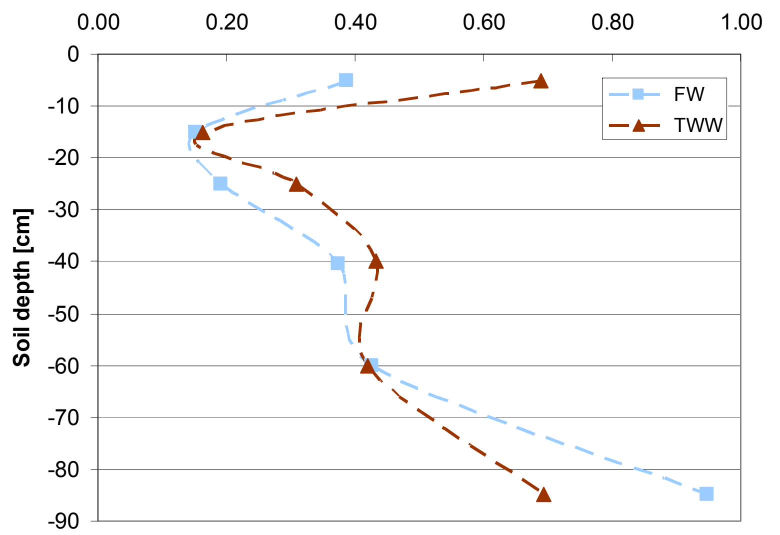
MPI-BGC Jena

RUB

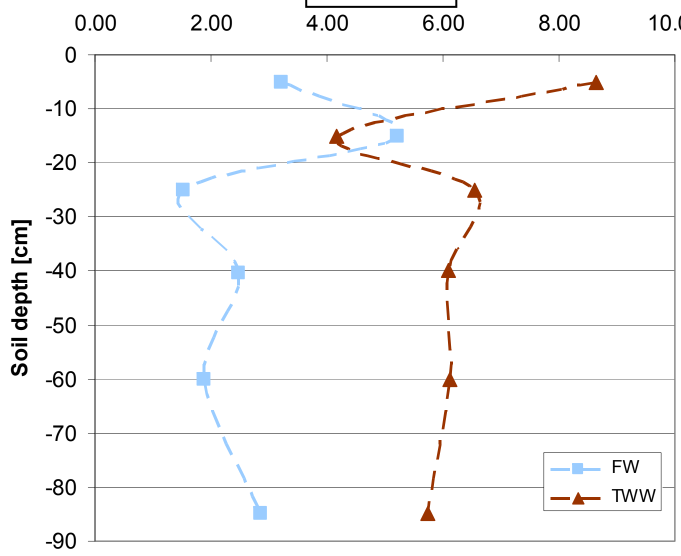
Results

Bazra – soil enzyme profiles

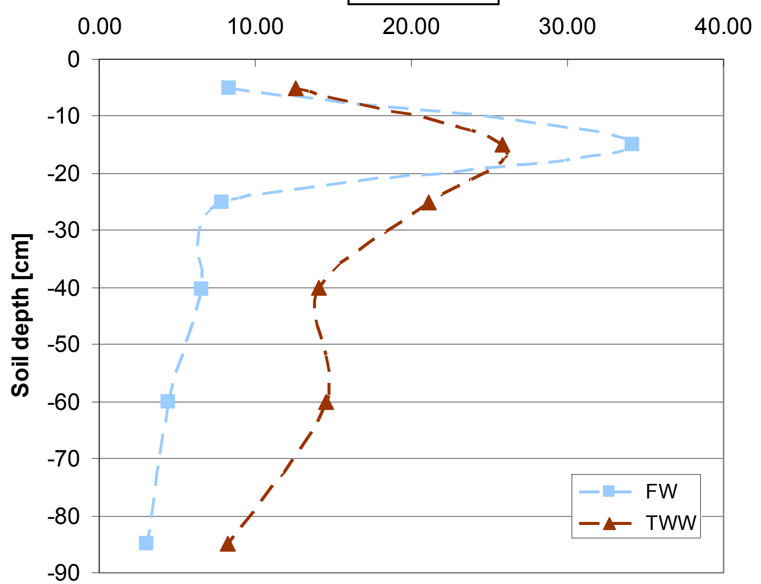
C : N



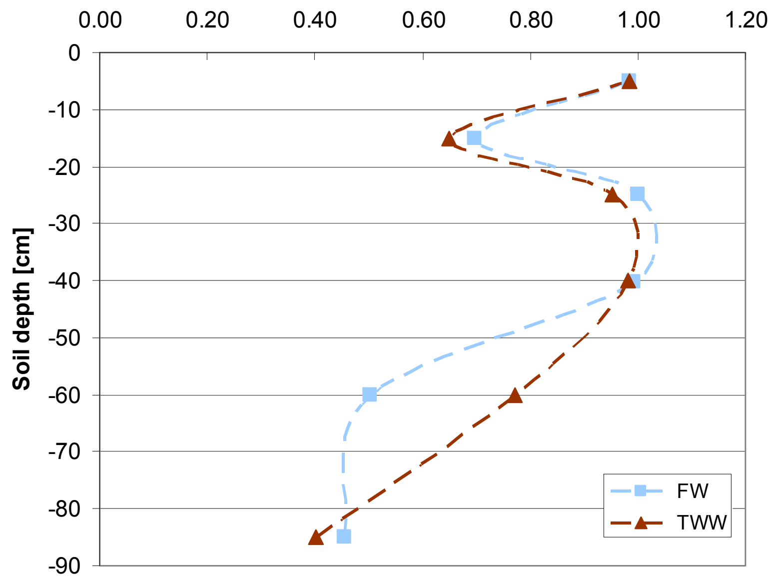
C : P



N : P

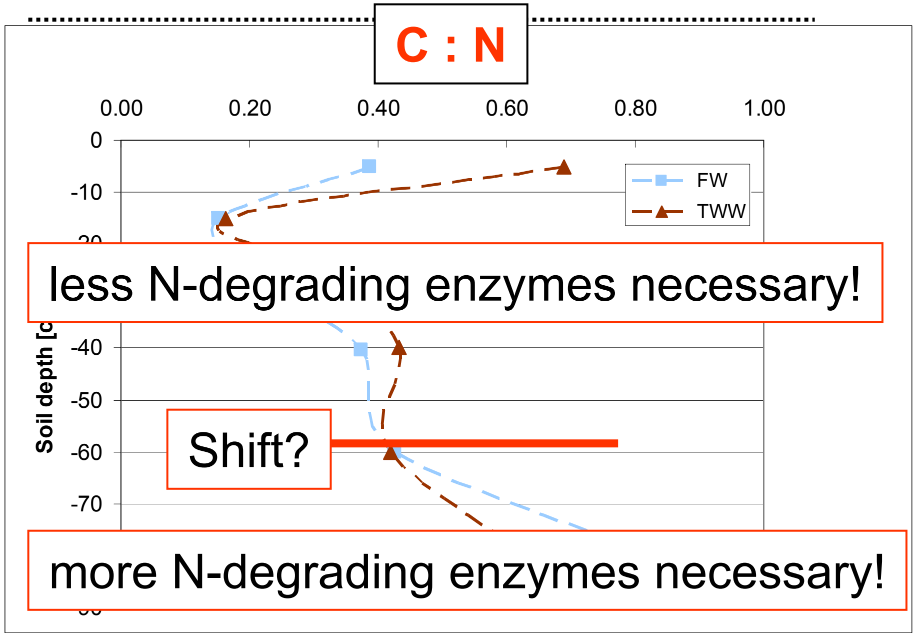


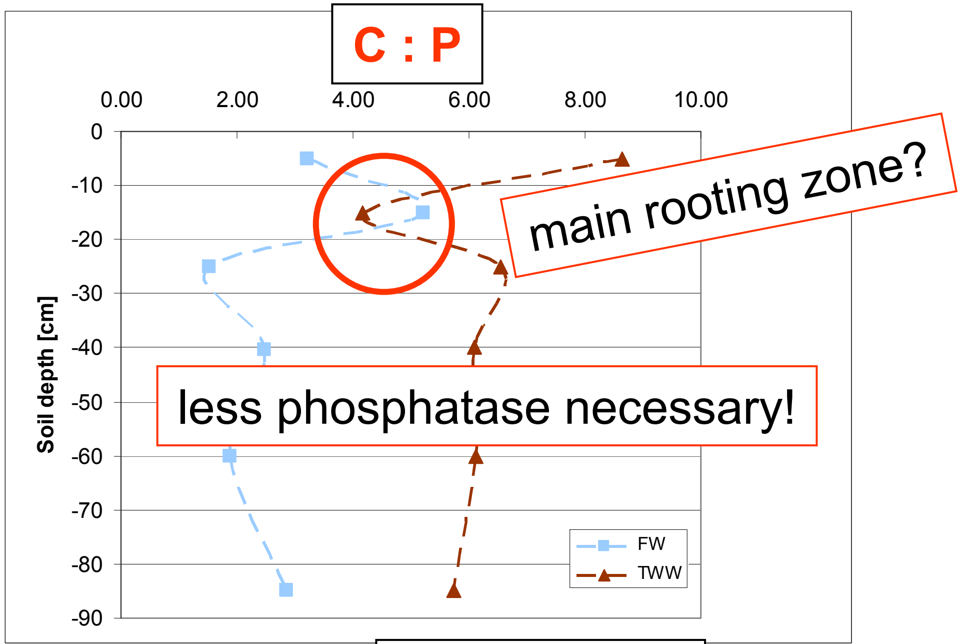
Cell : C

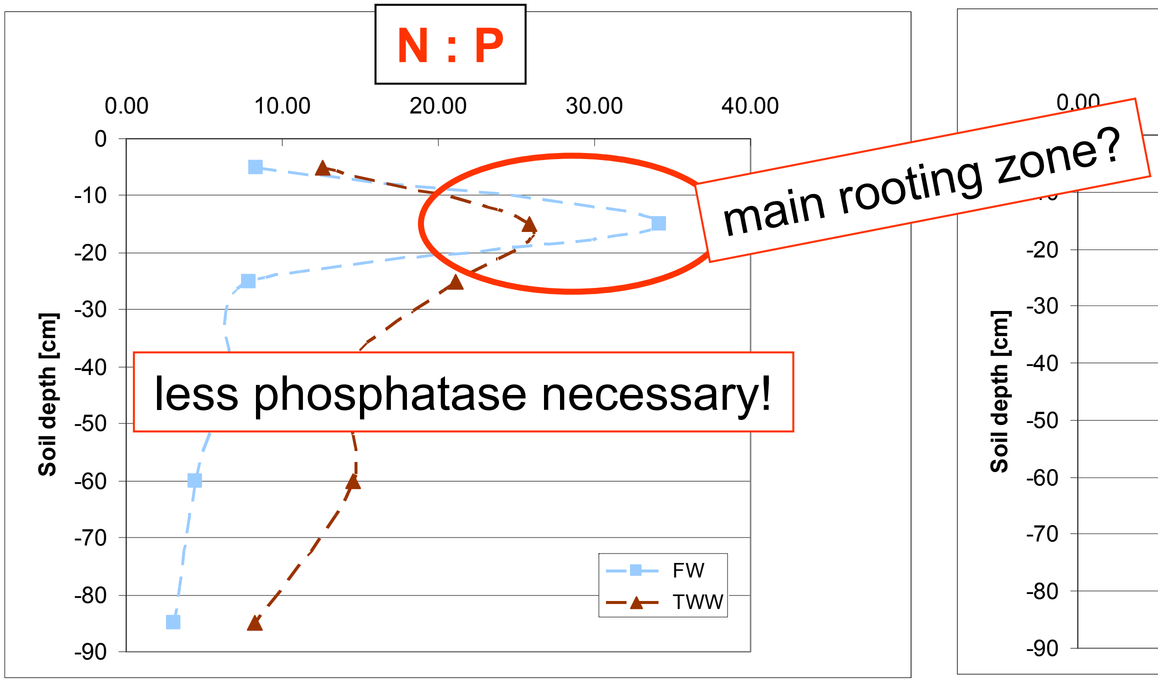


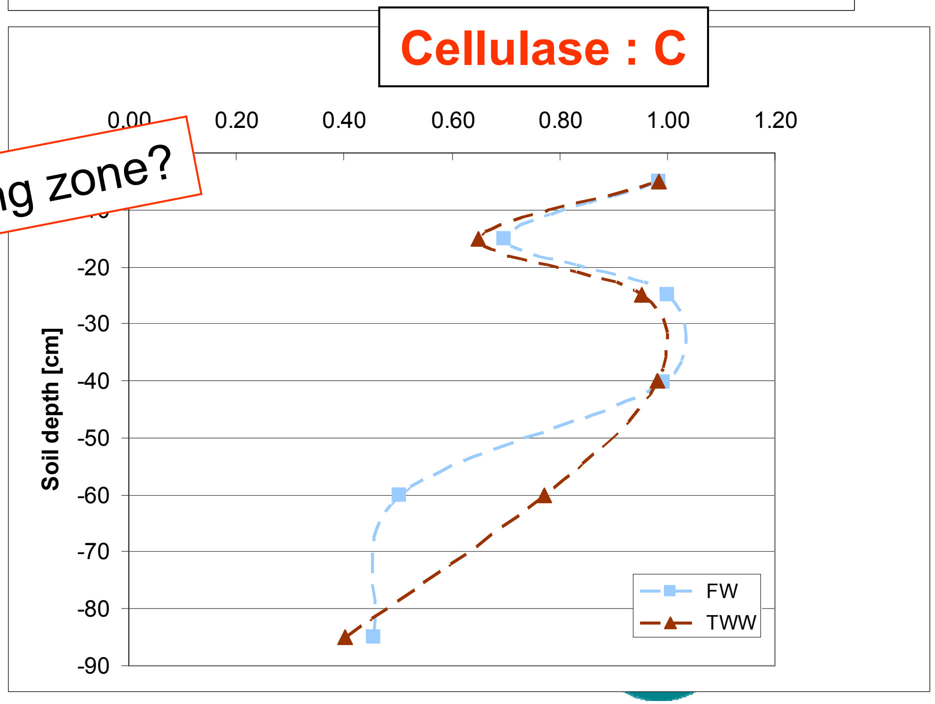
Results

Bazra – soil enzyme profiles



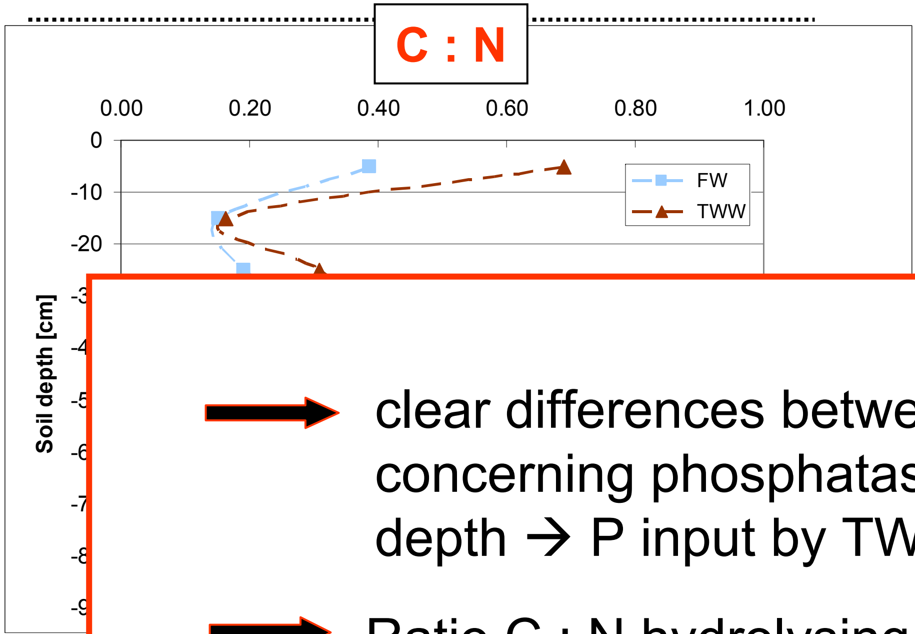


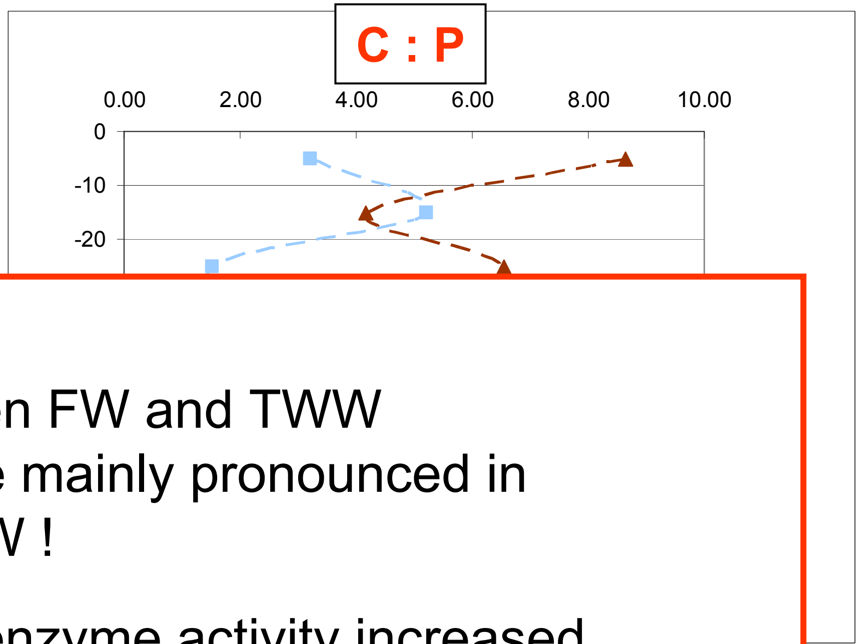




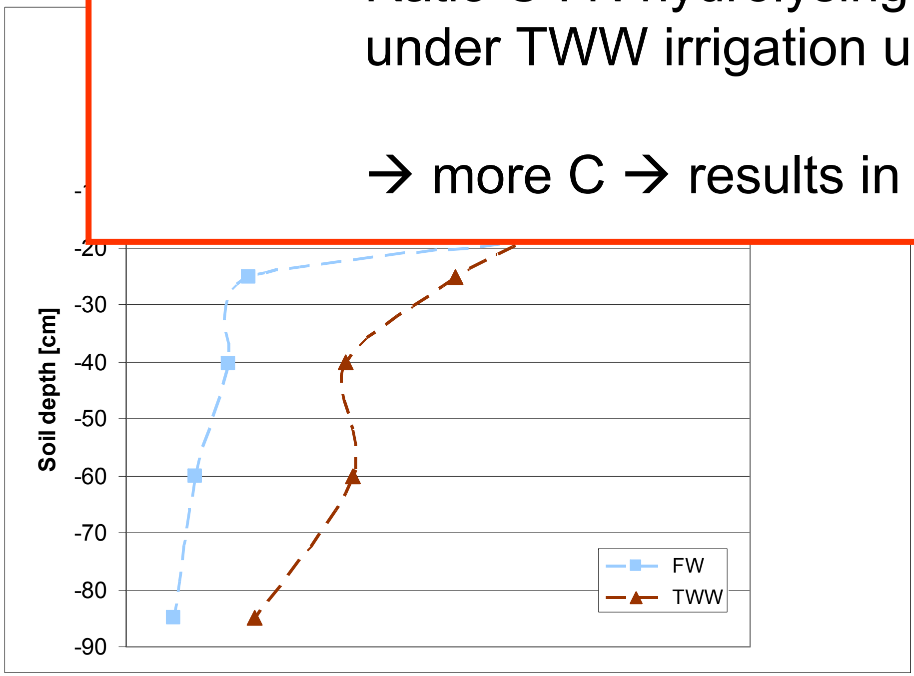
Results

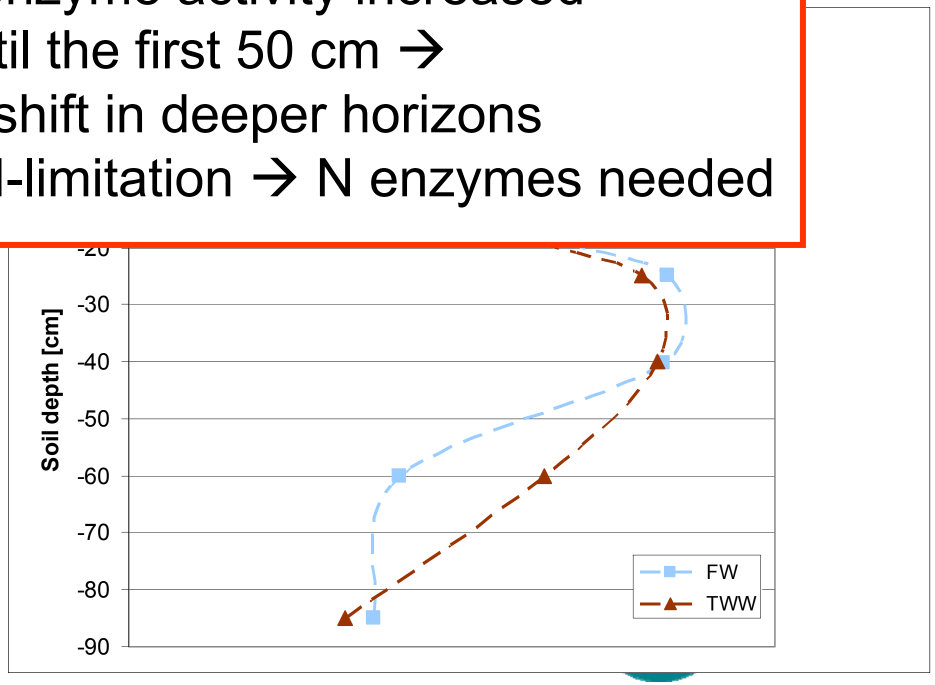
Bazra – soil enzyme profiles



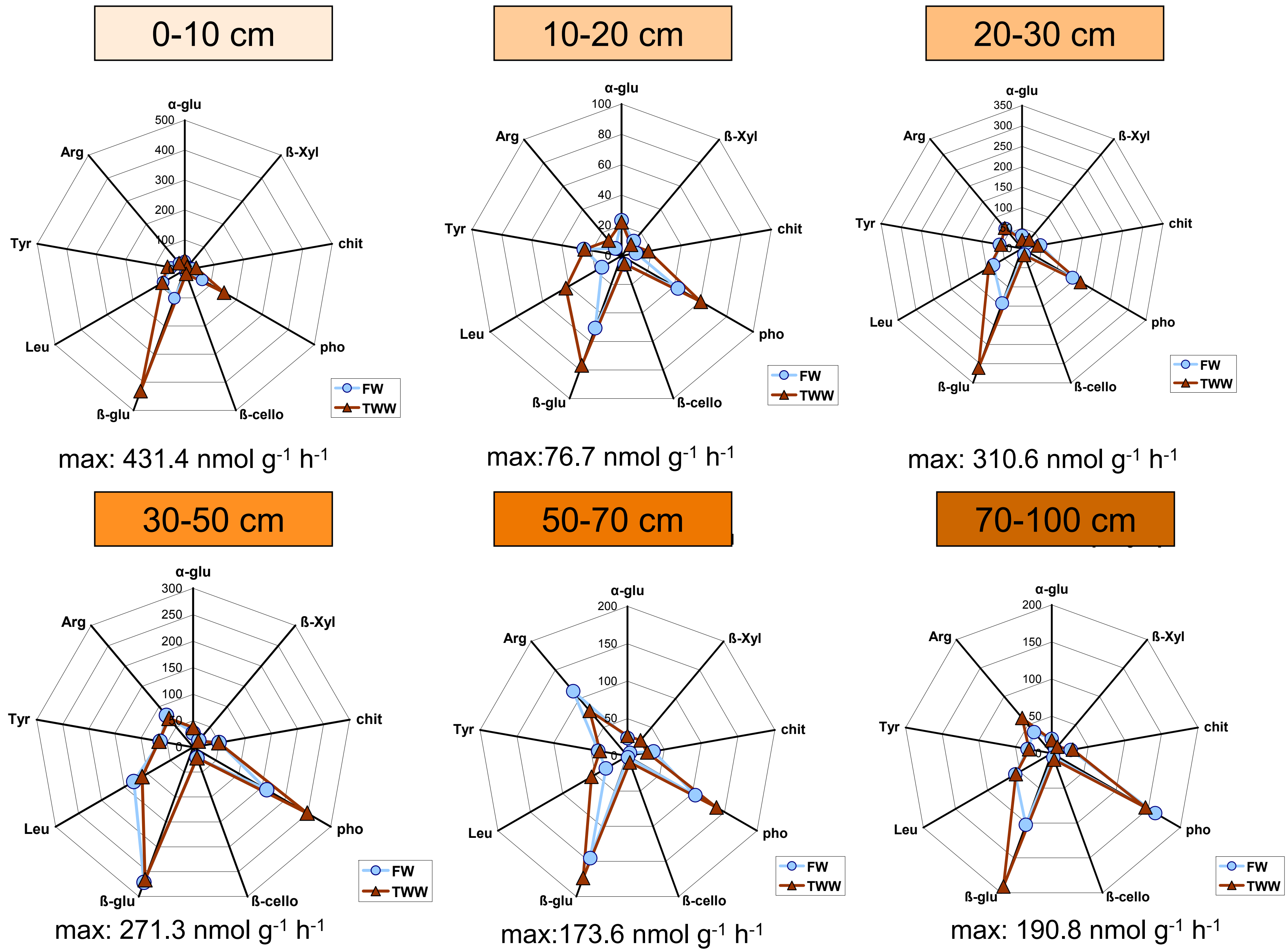


- clear differences between FW and TWW concerning phosphatase mainly pronounced in depth → P input by TWW !
- Ratio C : N hydrolysing enzyme activity increased under TWW irrigation until the first 50 cm → shift in deeper horizons → more C → results in N-limitation → N enzymes needed



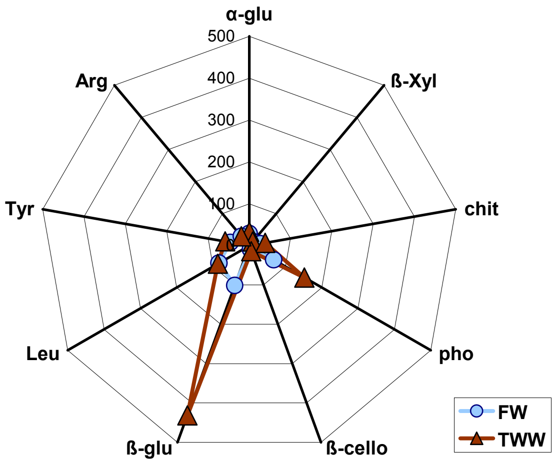


Acco – enzyme activities



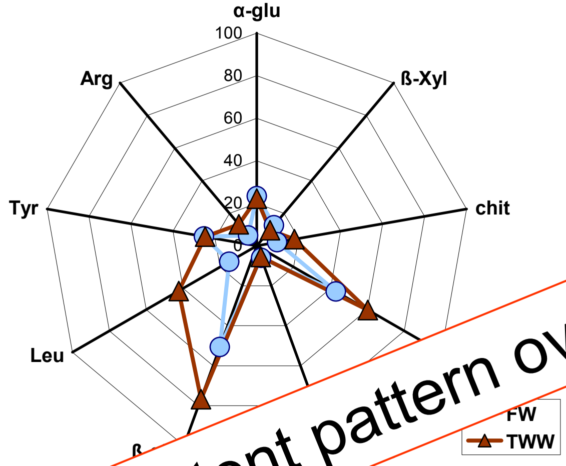
Acco – enzyme activities

0-10 cm

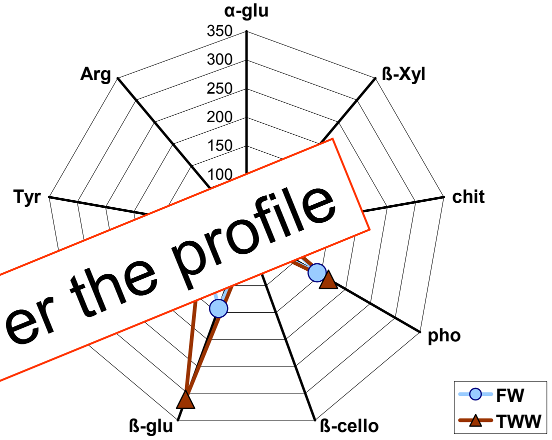


max: 431.4 nmol g^{-1} h^{-1}

10-20 cm



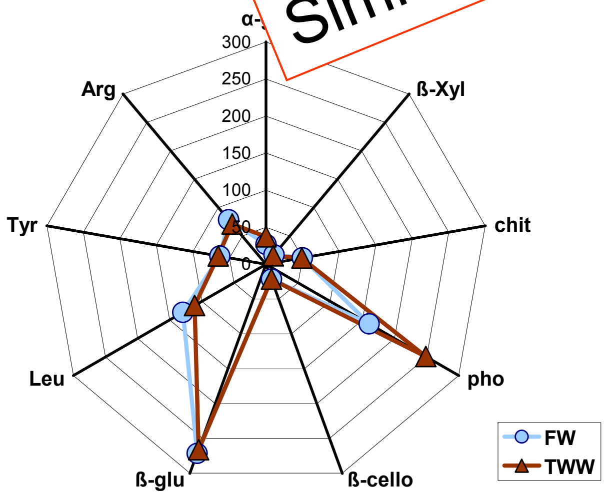
20-30 cm



max: 310.6 nmol g^{-1} h^{-1}

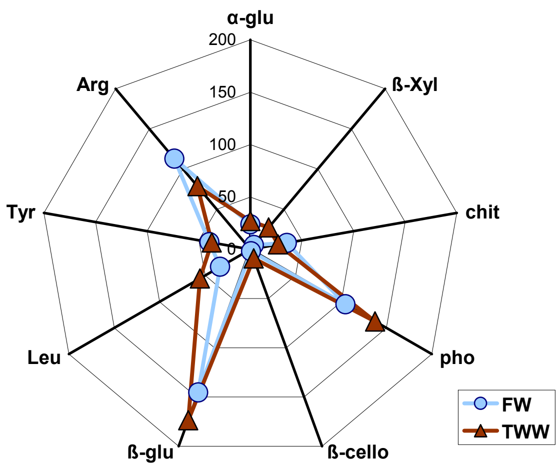
Similar enzyme content pattern over the profile

30-50 cm



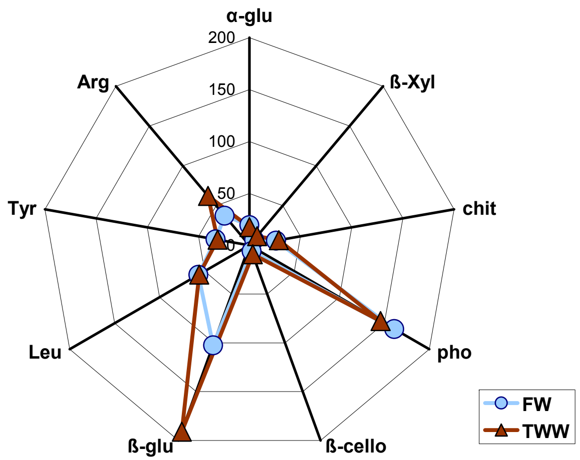
max: 271.3 nmol g^{-1} h^{-1}

50-70 cm



max:173.6 nmol g^{-1} h^{-1}

70-100 cm

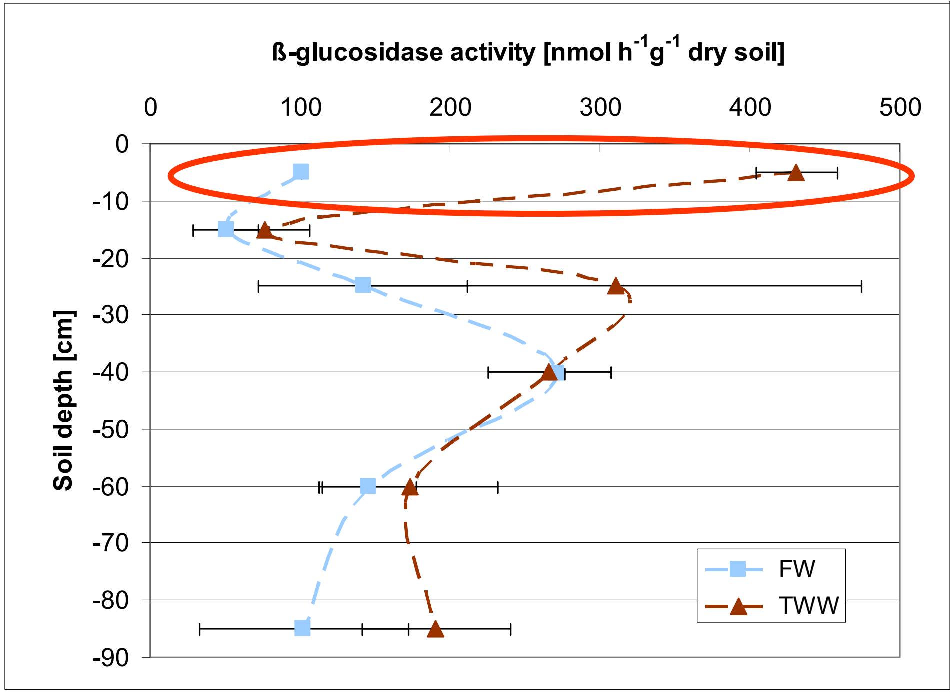


max: 190.8 nmol g^{-1} h^{-1}

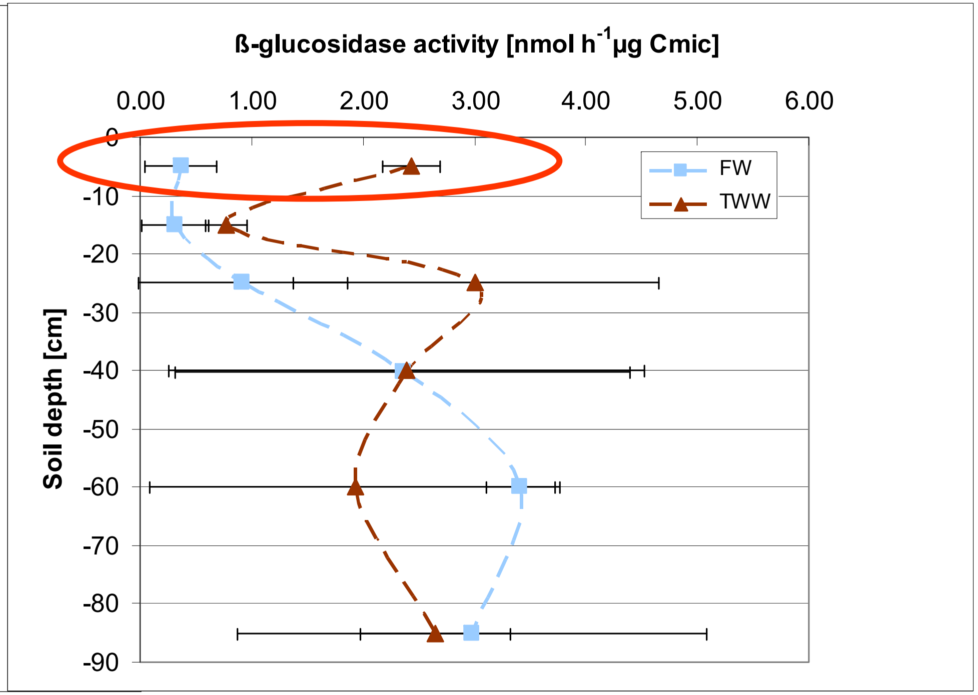
Acco – soil enzyme profiles

β-glucosidase

nmol h^{-1} g^{-1} dry soil



nmol h^{-1} μg^{-1} C_{mic}

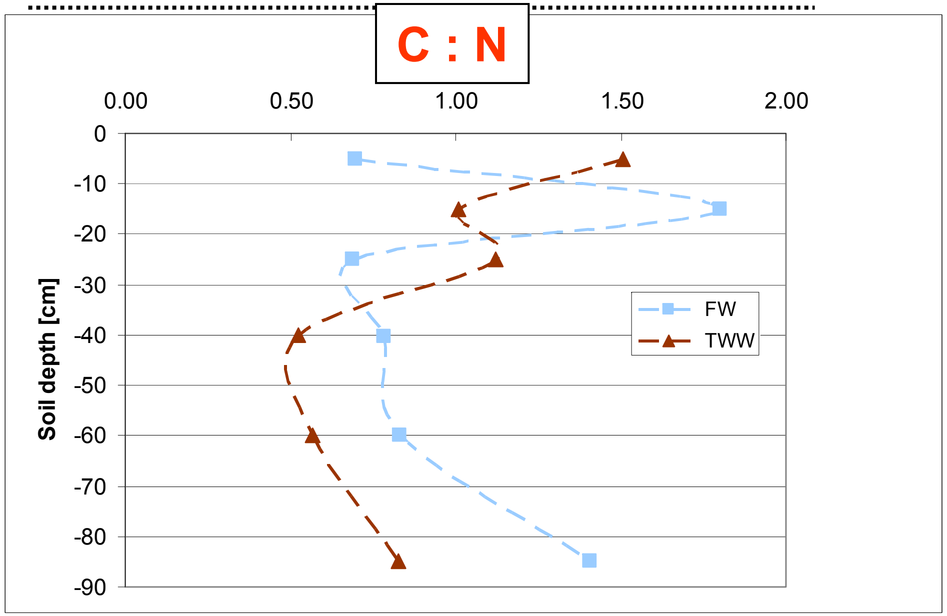


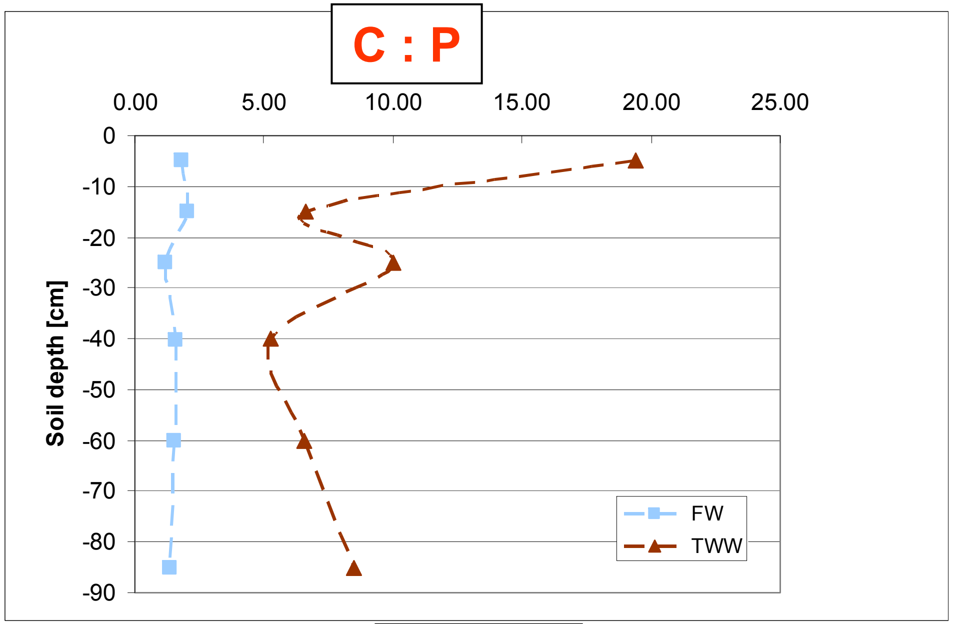
- clear differences between FW and TWW only in topsoil
- activity increase with soil depth only under FW irrigation
- Distribution along the profile reflects the transportation of carbon

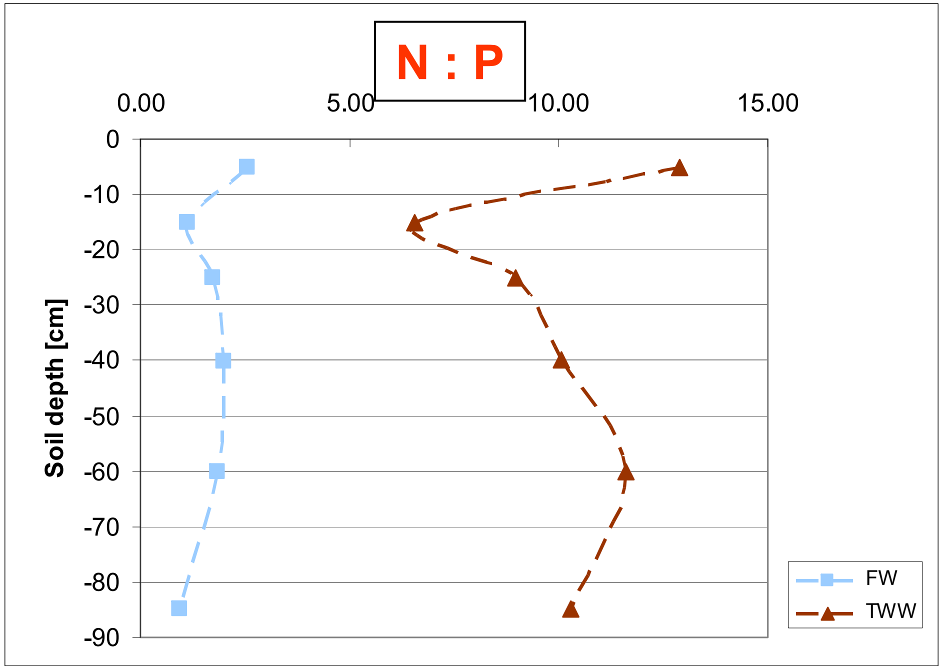
Jüschke & Marschner

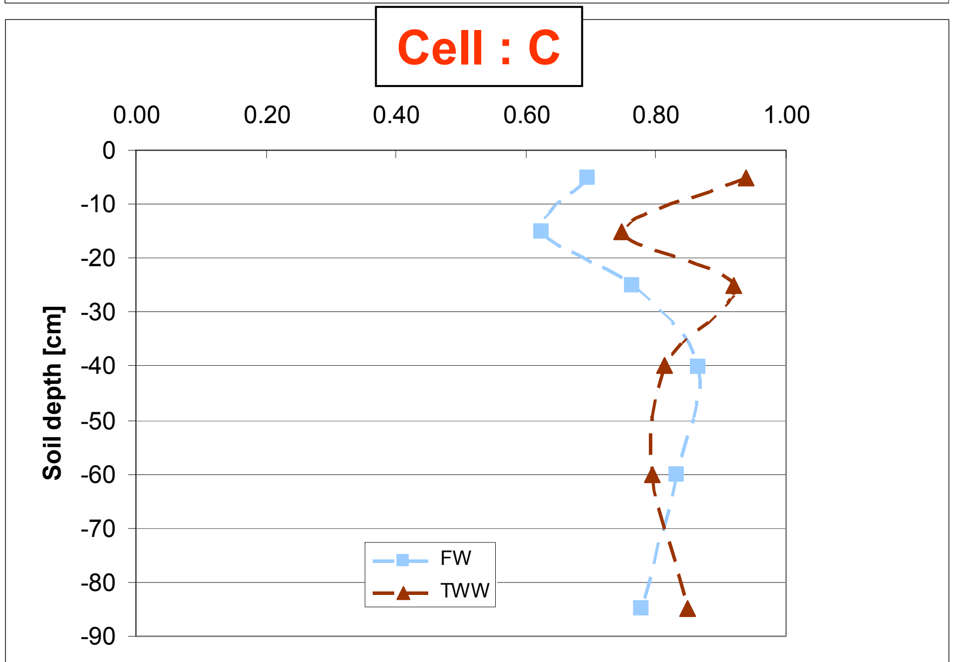
Results & Discussion

Acco – soil enzyme profiles





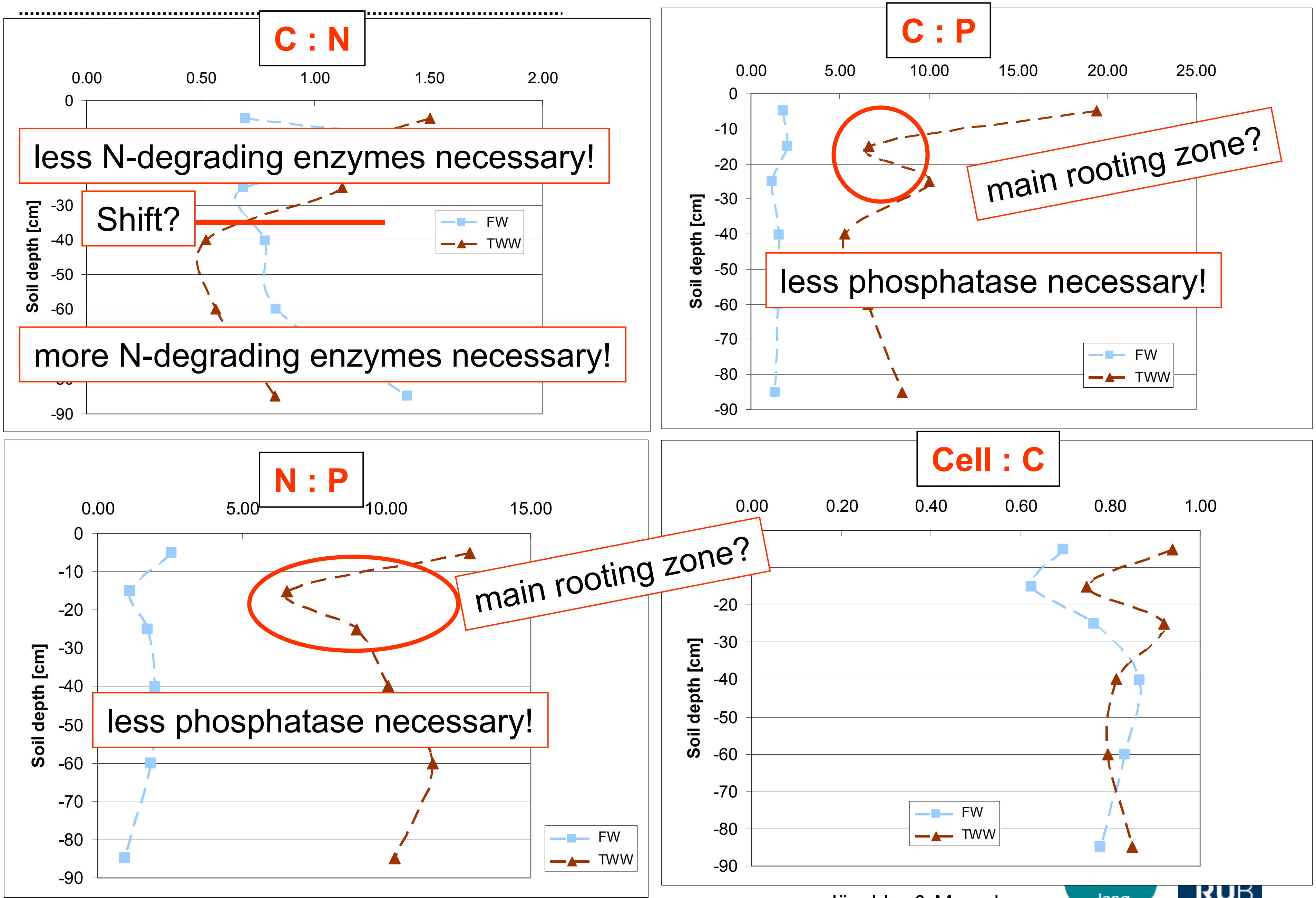




Jüschke & Marschner

Results & Discussion

Acco – soil enzyme profiles



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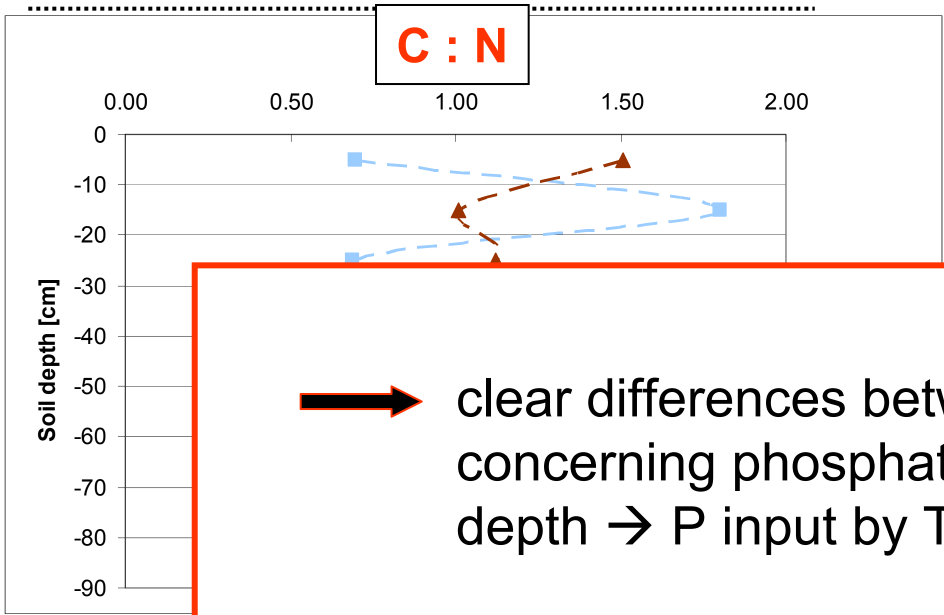
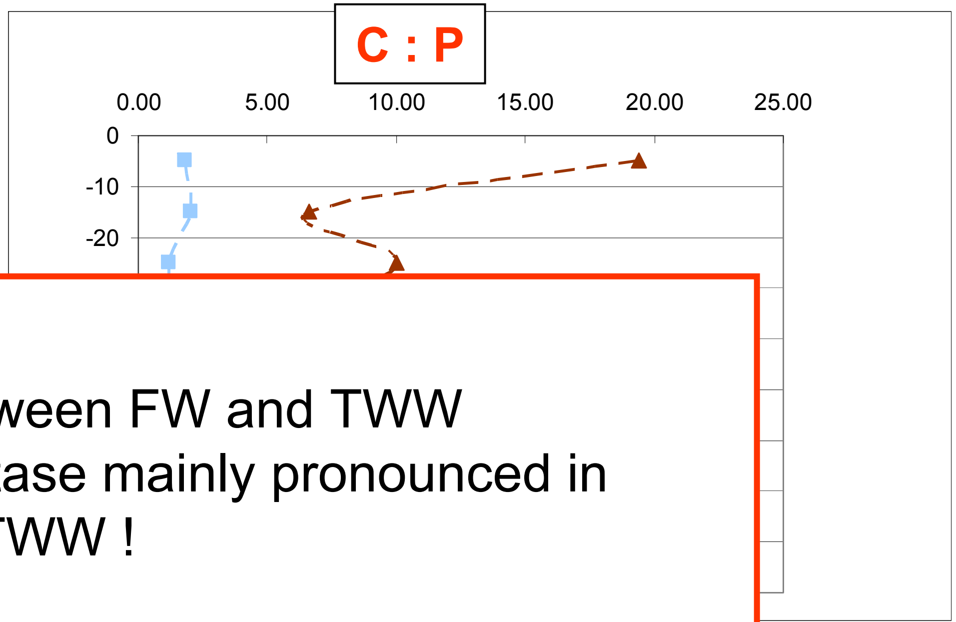
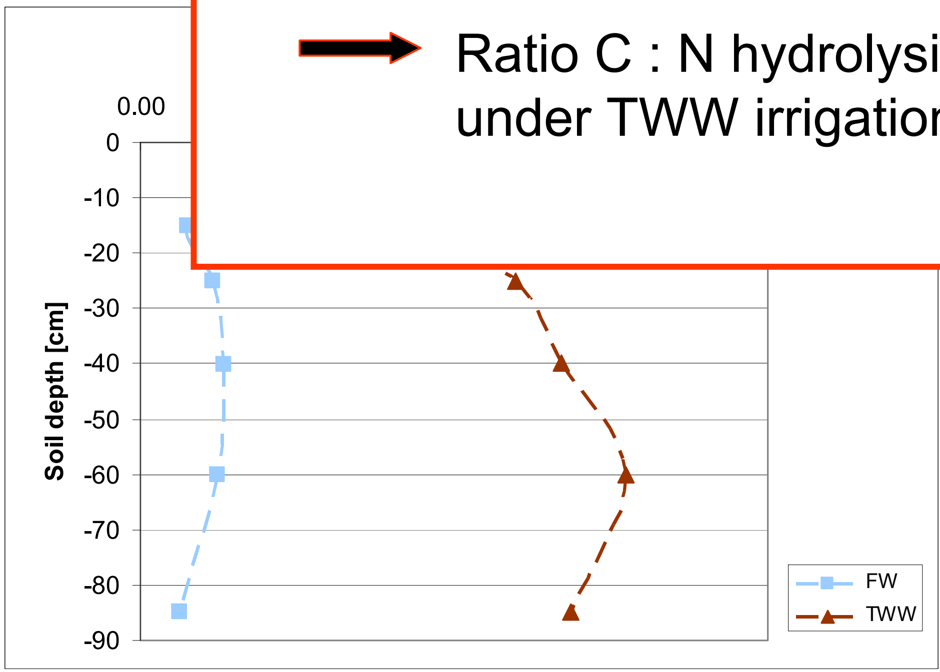
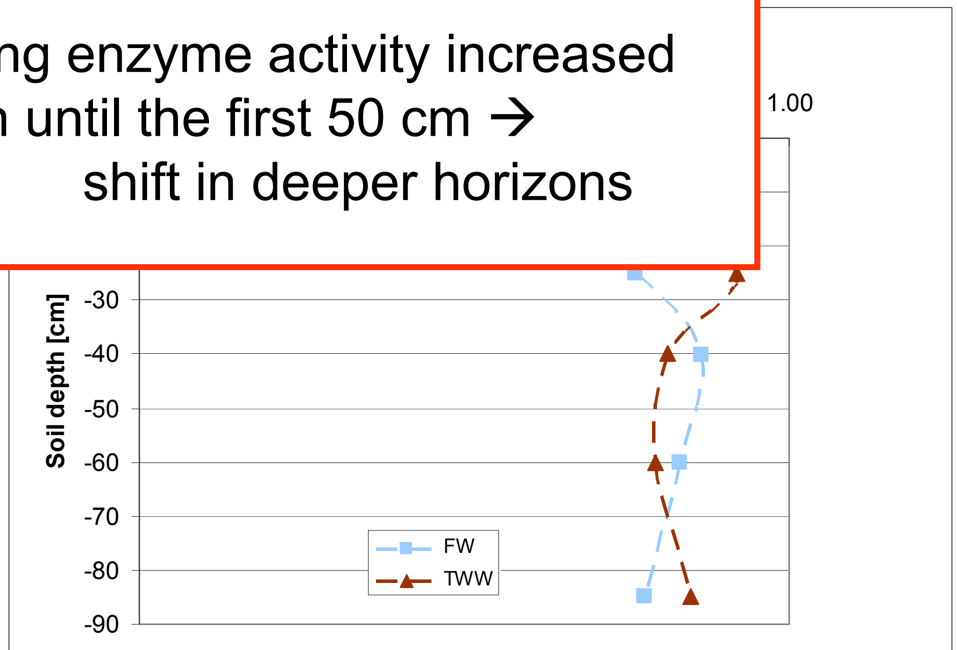
Acco – soil enzyme profiles







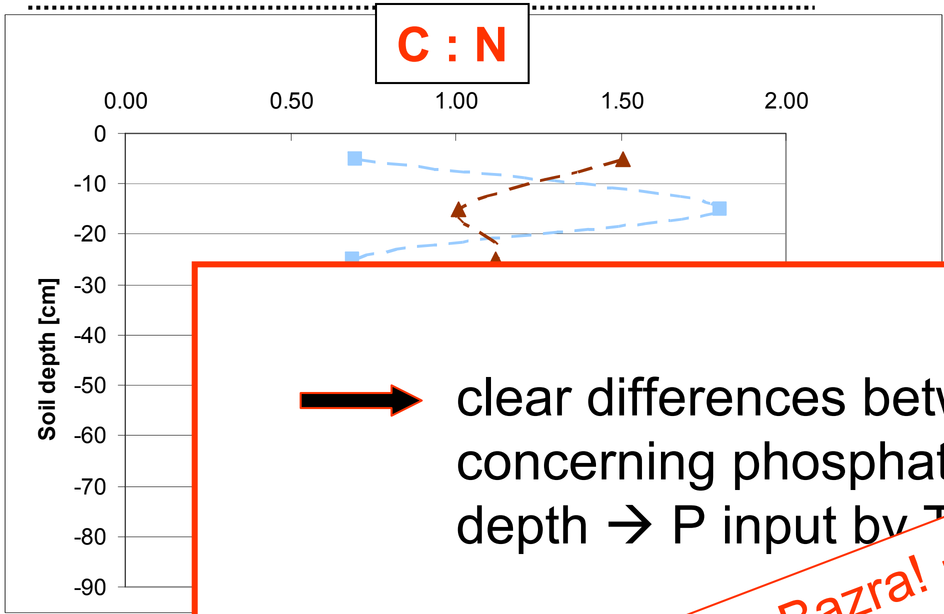


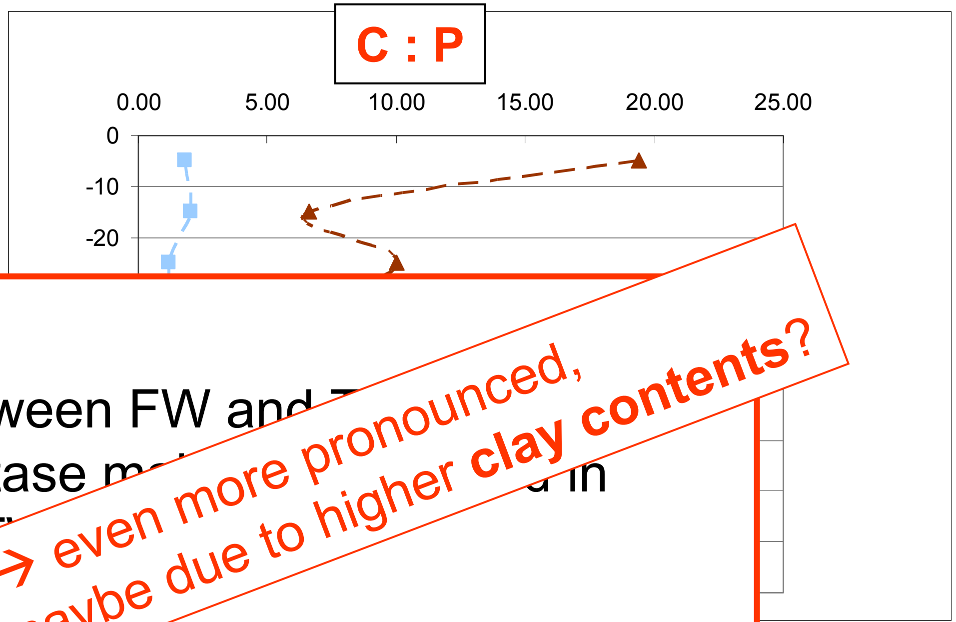
- clear differences between FW and TWW concerning phosphatase mainly pronounced in depth → P input by TWW !

- Ratio C : N hydrolysing enzyme activity increased under TWW irrigation until the first 50 cm → shift in deeper horizons

Results & Discussion

Acco – soil enzyme profiles

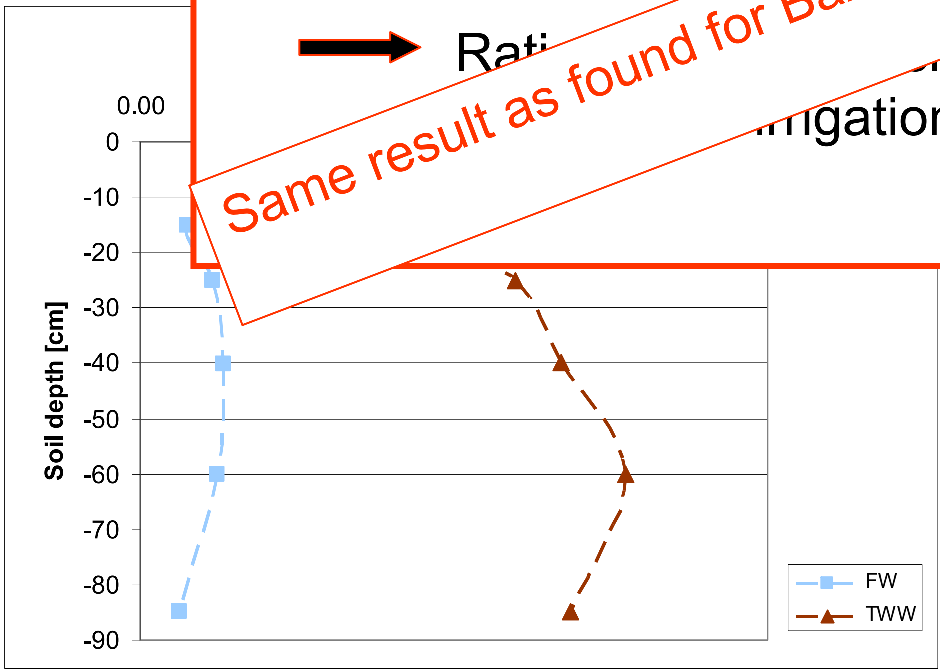


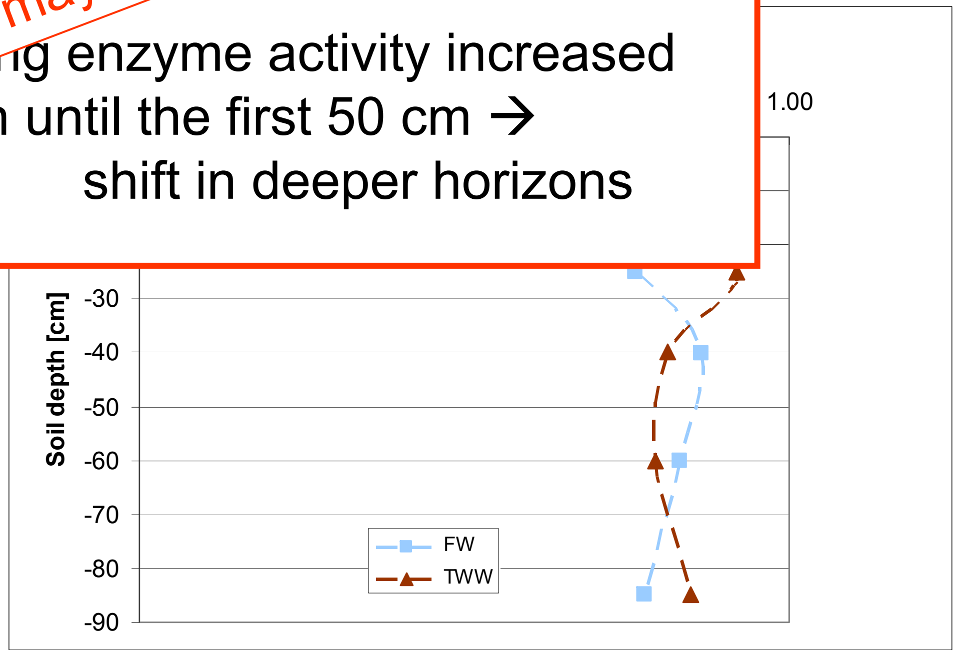


- clear differences between FW and T... concerning phosphatase m... ...d in depth → P input by T...

- Rati... ...ing enzyme activity increased ... irrigation until the first 50 cm → shift in deeper horizons

Same result as found for Bazra! → even more pronounced, maybe due to higher **clay contents**?





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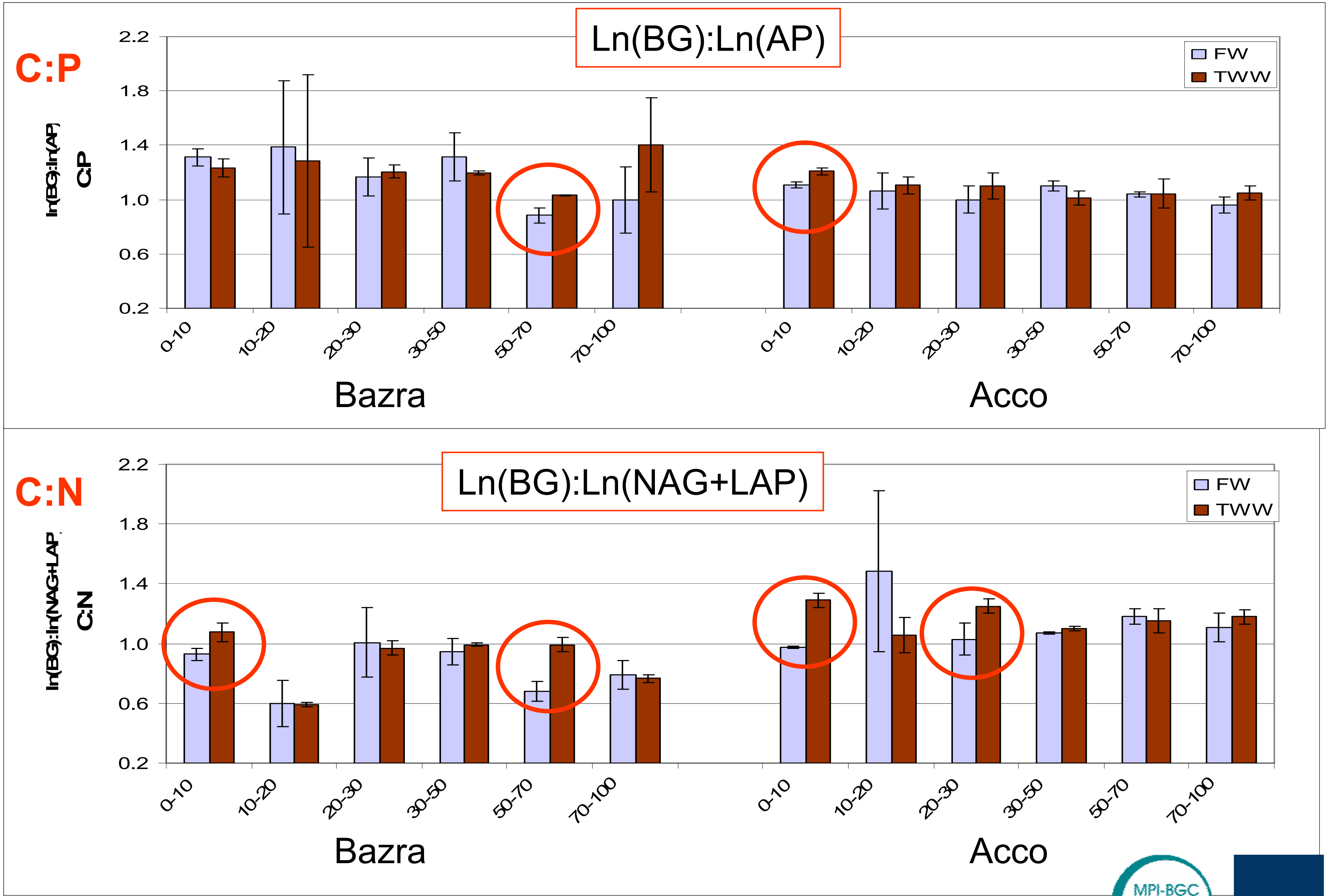
Results

Nutrient aquisation activity (Sinsabaugh et al. 2008)



(calculated on the basis of g dry soil)

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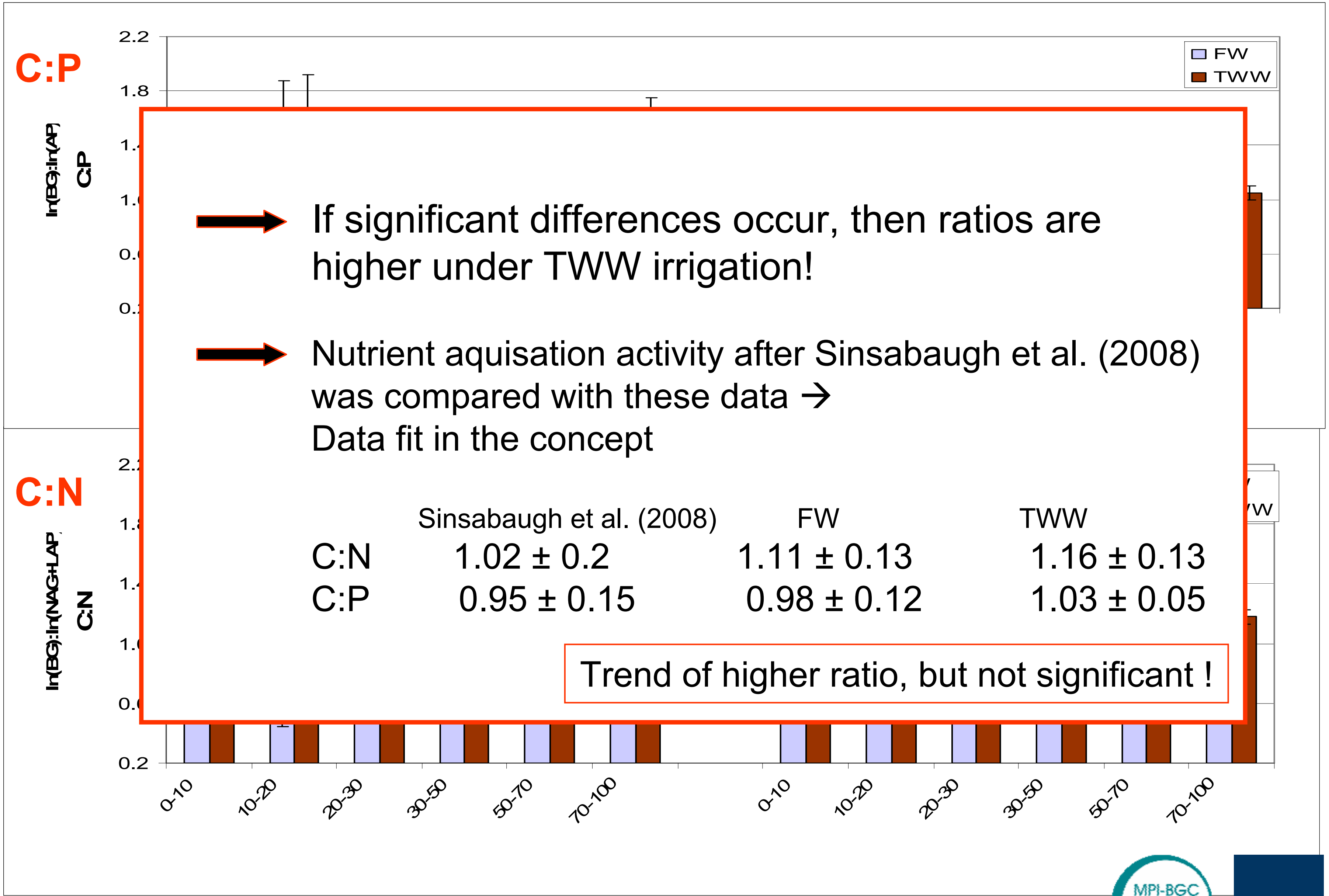
Results & Discussion

Nutrient aquisation activity (Sinsabaugh et al. 2008)



→ If significant differences occur, then ratios are higher under TWW irrigation!

→ Nutrient aquisation activity after Sinsabaugh et al. (2008) was compared with these data →
Data fit in the concept

	Sinsabaugh et al. (2008)	FW	TWW
C:N	1.02 ± 0.2	1.11 ± 0.13	1.16 ± 0.13
C:P	0.95 ± 0.15	0.98 ± 0.12	1.03 ± 0.05

Trend of higher ratio, but not significant !

(calculated on the basis of g dry soil)

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Transport of carbon down the soil profiles, which is then used as source for microorganisms

- Higher total enzyme activity = higher degradation of SOC
- Continously triggered priming effects resulted in stronger decrease of SOC → not masked by C input in the subsoil

Decreased phosphatase activity in the subsoil horizons

- P supply by the TWW is enough, less phosphatase necessary

Clay minerals as possible drivers for enzyme activity (clay bind proteins)

- Clay-humus-complexes
  3-dimensional network
  → active enzymes incorporated (Paul and Mc Laren, 1975)

…before it´s open for discussion …

Thank you for attention

Acknowledgements

- Our cooperation partners: Yona Chen, Yitzhak Hadar (Israel)
  Jamal Safi (Gaza Strip)

- My recent workplace, the MPI for Biogeochemistry in Jena, Germany

MPI-BGC Jena

Bundesministerium für Bildung und Forschung

DFG Deutsche Forschungsgemeinschaft

Picture: drip irrigation system - Elisabeth Jüschke 2004