



PROAGRO
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Phosphorus use efficiency and legacy P in cropped systems

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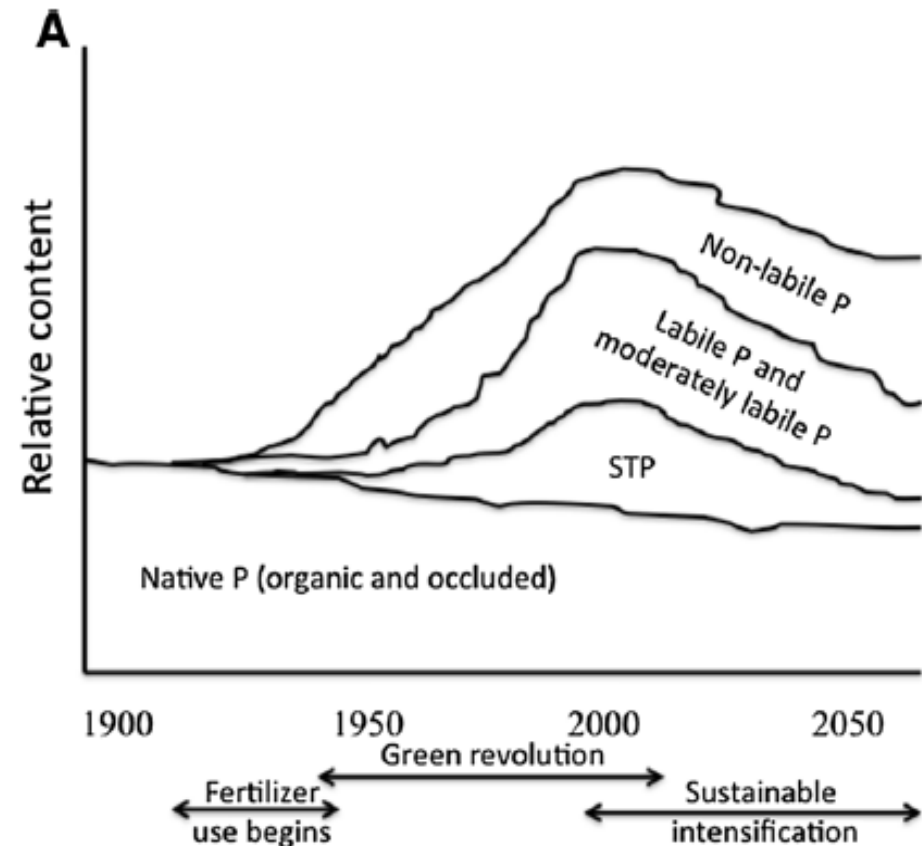
Definition of «legacy P»

Legacy: «Something received from the past or through past actions or carried over from an earlier time»

based on the definition of «surplus» as *an amount of something left over when requirements have been met, or an excess of supply over demand*

(Turner & Kim, 2024)

- **Should legacy P be only the above critical STP?**
- **Should really consider non-labile P as legacy P?**
- **How much of the legacy P is economically exploitable?**



Rowe et al. (2016)



How much legacy P we have in our soils?

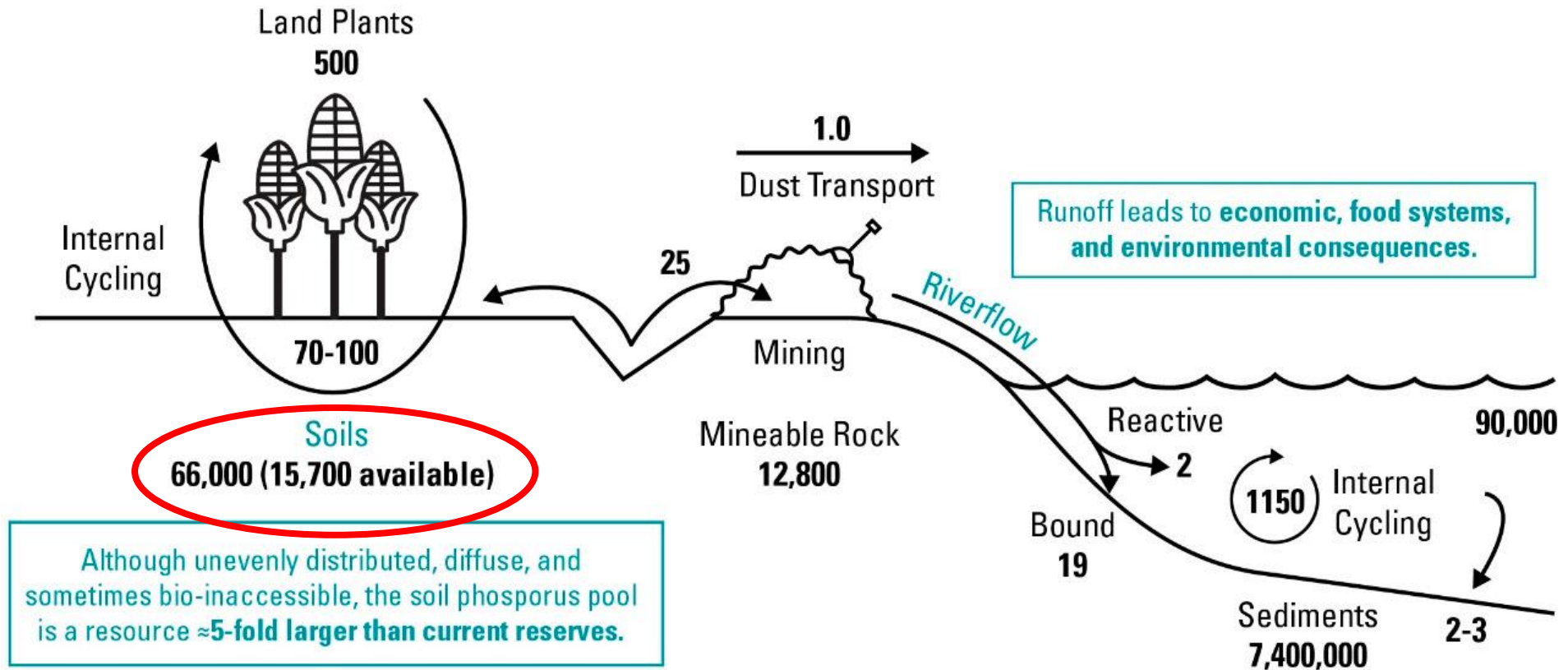


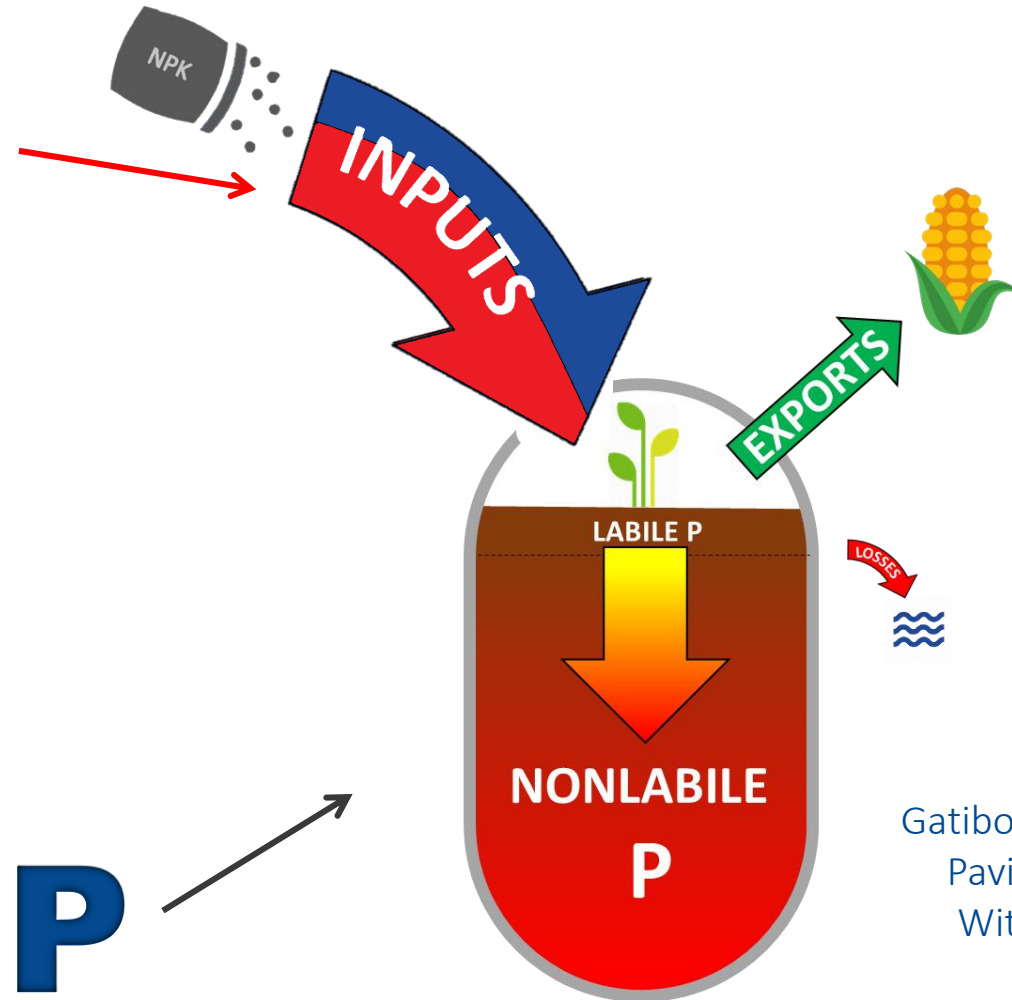
Figure 1. Global phosphorus flows with flux shown in units of 10^{12} g P/year. Recreated from Schlesinger and Bernhardt (2013) by Doydora et al. (2020)



P TAX

- EXTRA RATE → 35 kg/ha of P
- RATIO Input: Export → 2:1
- P Efficiency index → 0.50

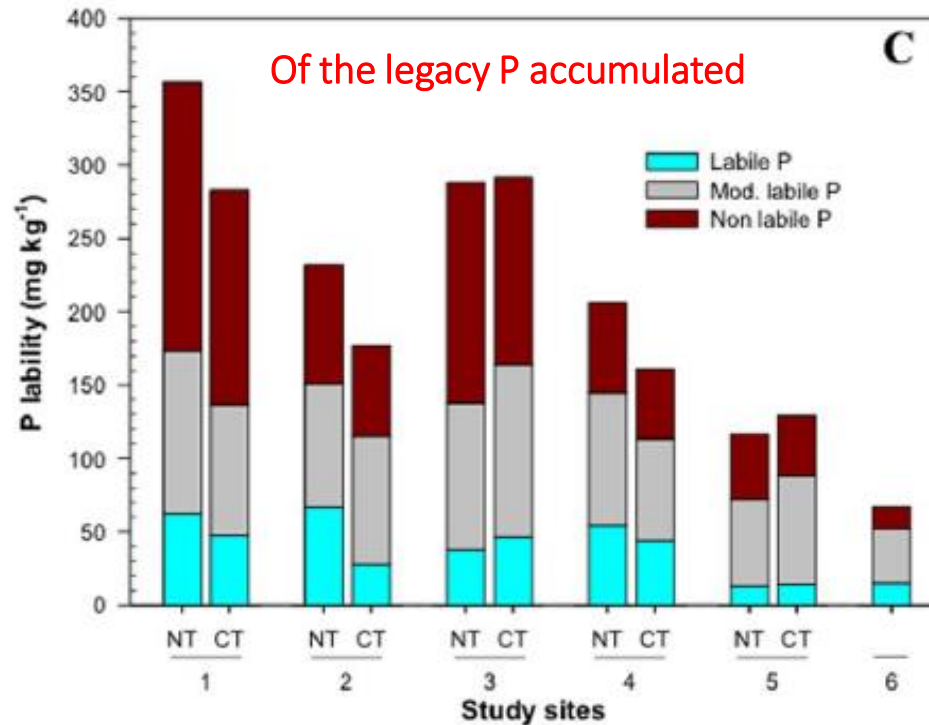
LEGACY P



Gatiboni (2018) – WCSS
Pavinato et al. (2020)
Withers et al. (2018)
Roy et al. (2016)



How much legacy P do we have in our soils?

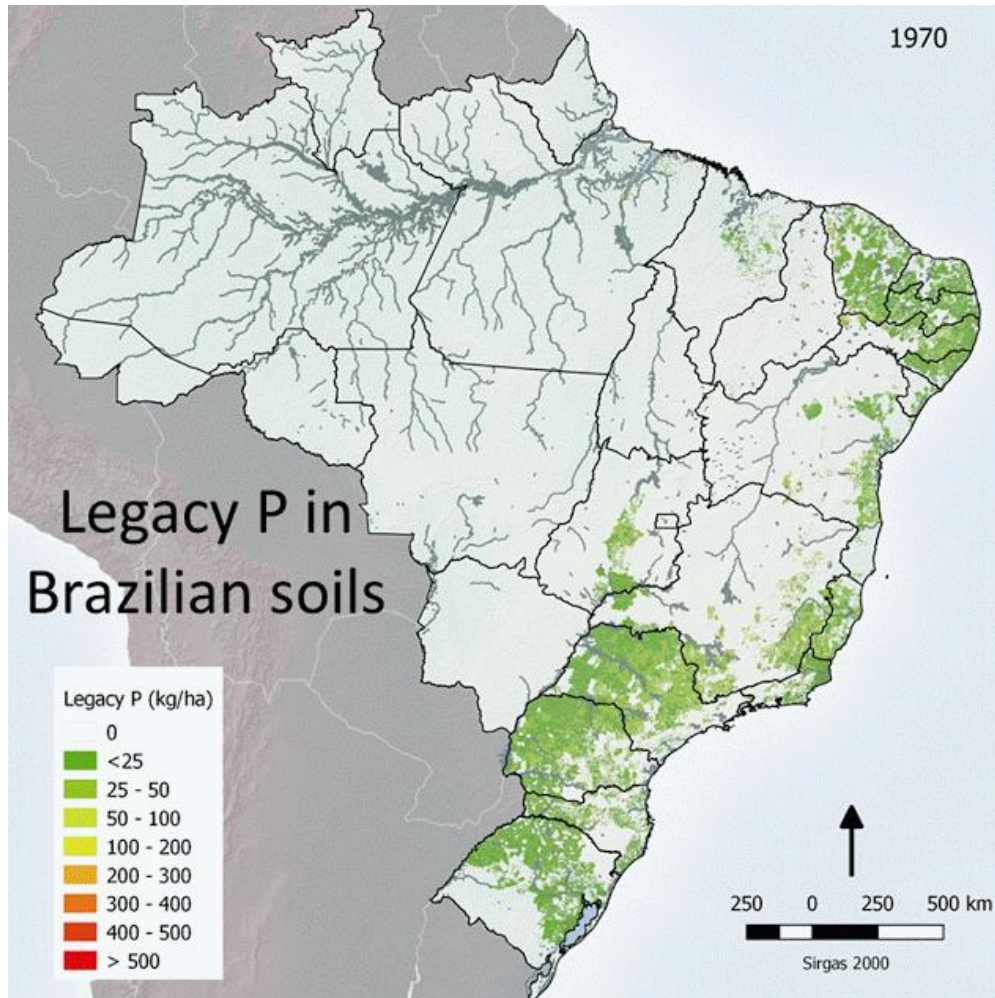


Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Location (City-State)	Costa Rica - Mato Grosso do Sul	Sapezal - Mato Grosso	Cristalina - Goiás	Tasso Fragoso - Maranhão	Planaltina - Distrito Federal	Botucatu - São Paulo
Biome	Cerrado	Cerrado	Cerrado	Cerrado	Cerrado	Atlantic Forest/ Cerrado
Rainfall ¹ (mm)	1937	2156	1606	1476	1570	1450
Altitude (m)	790	640	981	610	1014	840
Soil Order	Oxisol	Oxisol	Oxisol	Oxisol	Oxisol	Oxisol
Clay (%)	65.6	45.2	65.3	25.5	64.0	22.0
Date started (deforestation)	1974	1997	1977	1990	1976	2001
(trial began)	1994	2001	1992	2001	1994	(trial began)
Legacy period (years)	38	15	36	23	17	14

Withers et al (2018)

<https://www.nature.com/articles/s41598-018-20887-z>

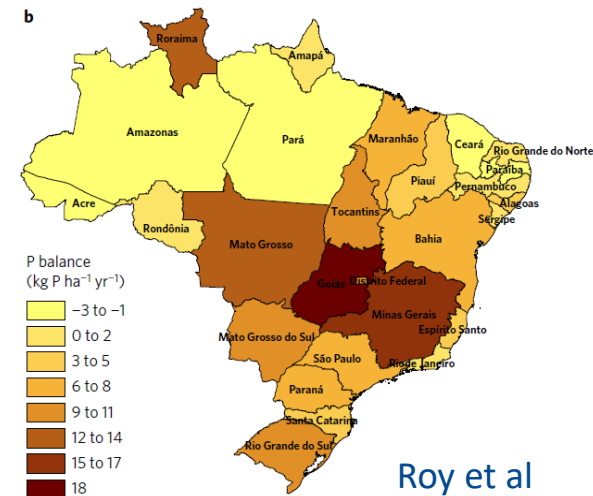
Legacy P in Brazil



LEGACY P in Brazil

33 Mi ton of P (2016)

May be 105 Mi ton (2050)

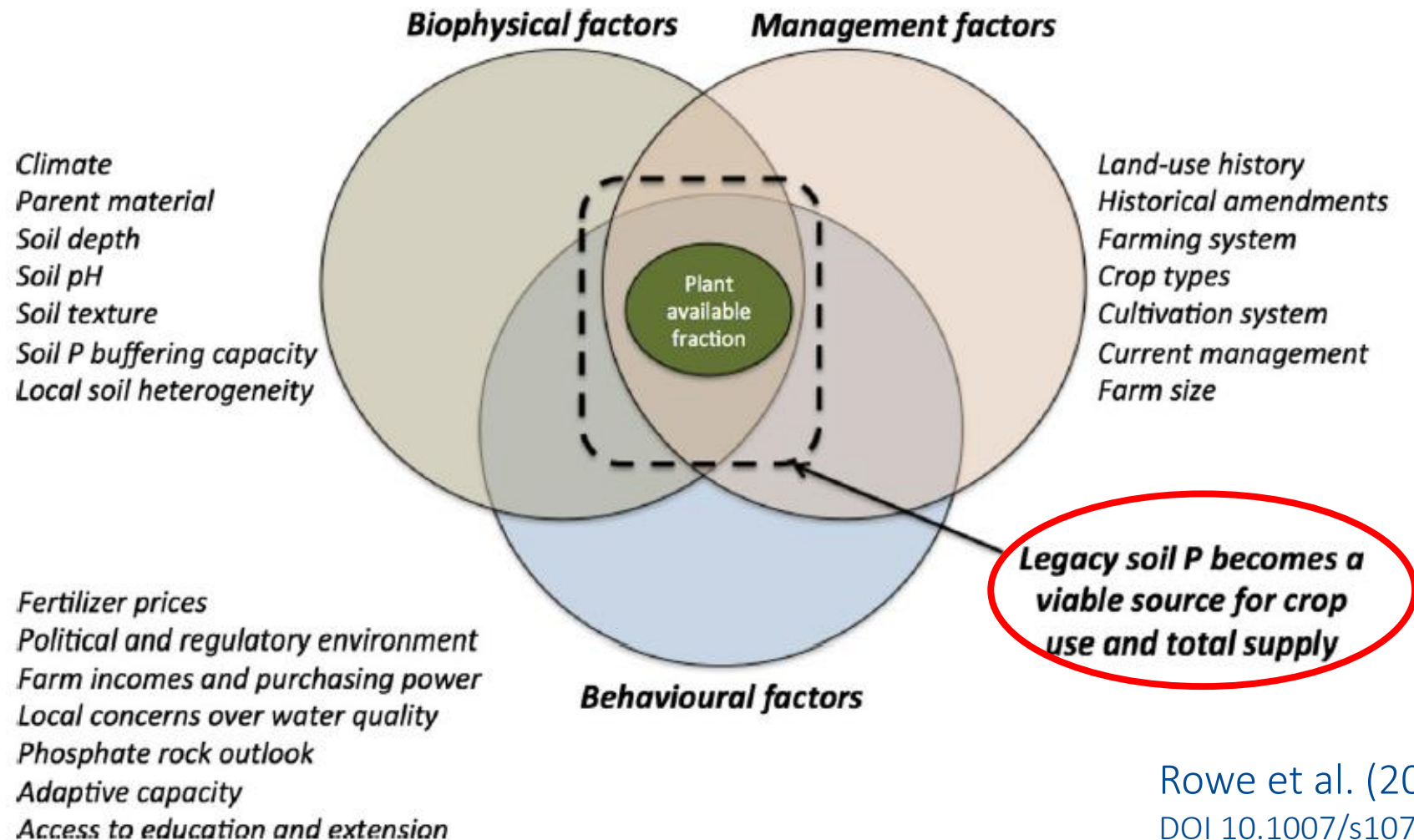


Roy et al
(2016)

Pavinato et al (2020)

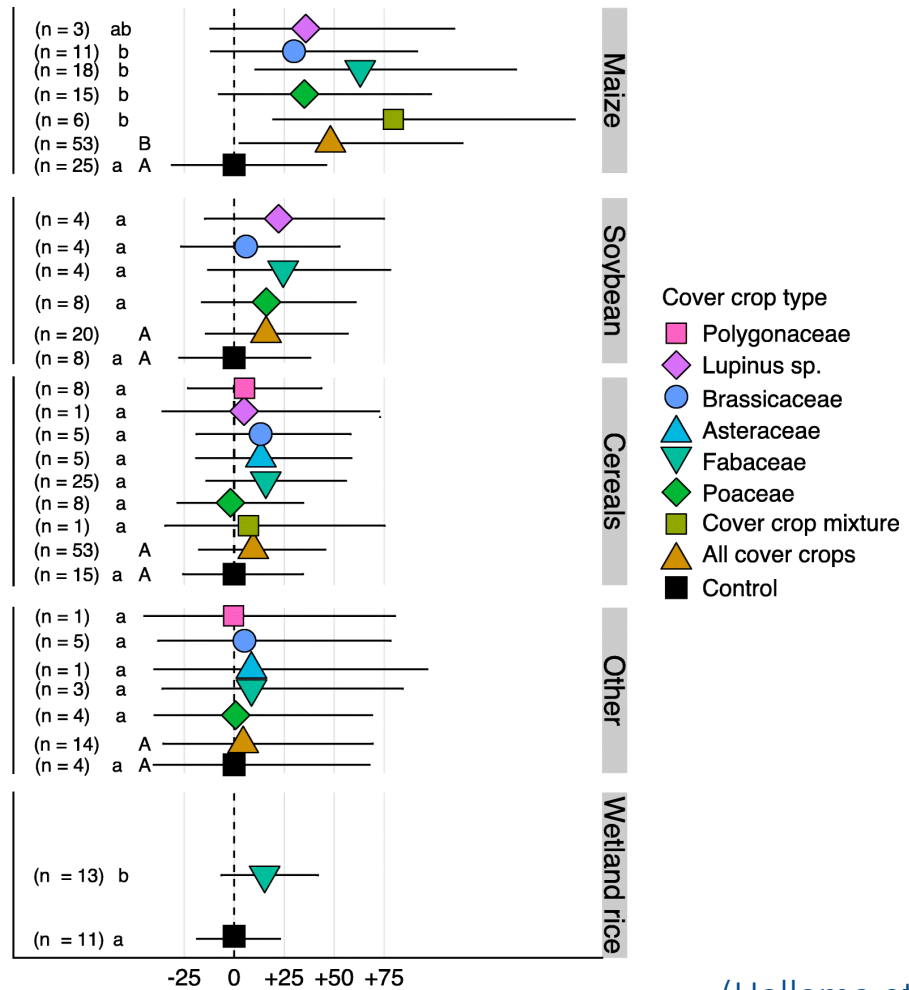
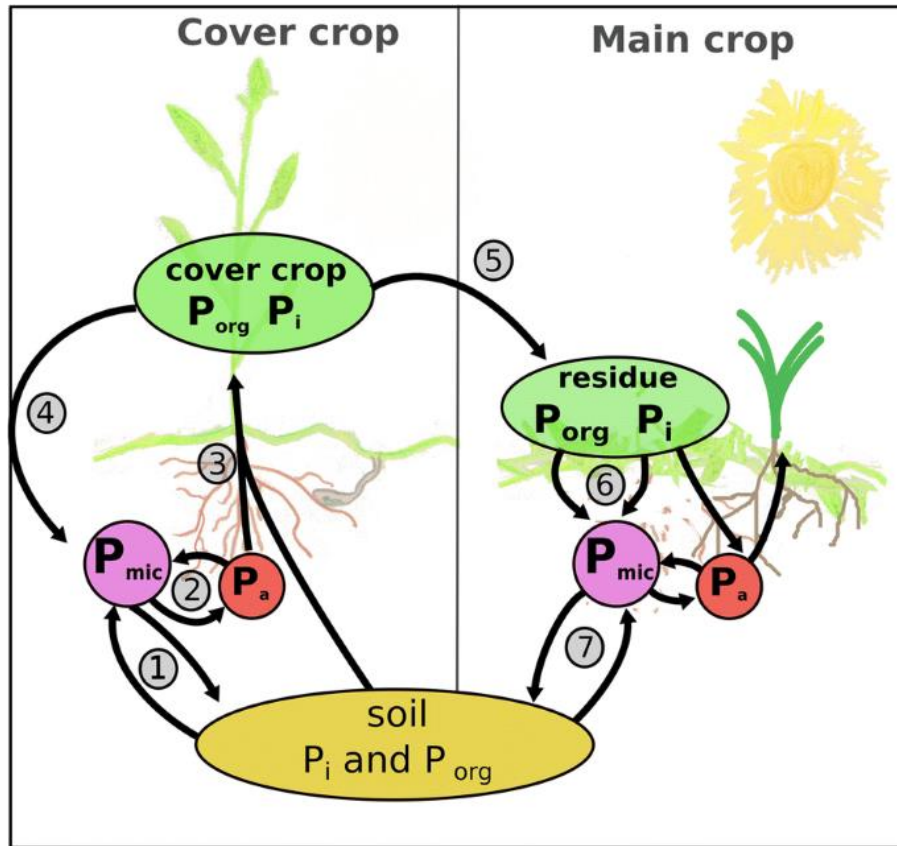


How much P plants can explore?



Rowe et al. (2016)

DOI 10.1007/s10705-015-9726-1

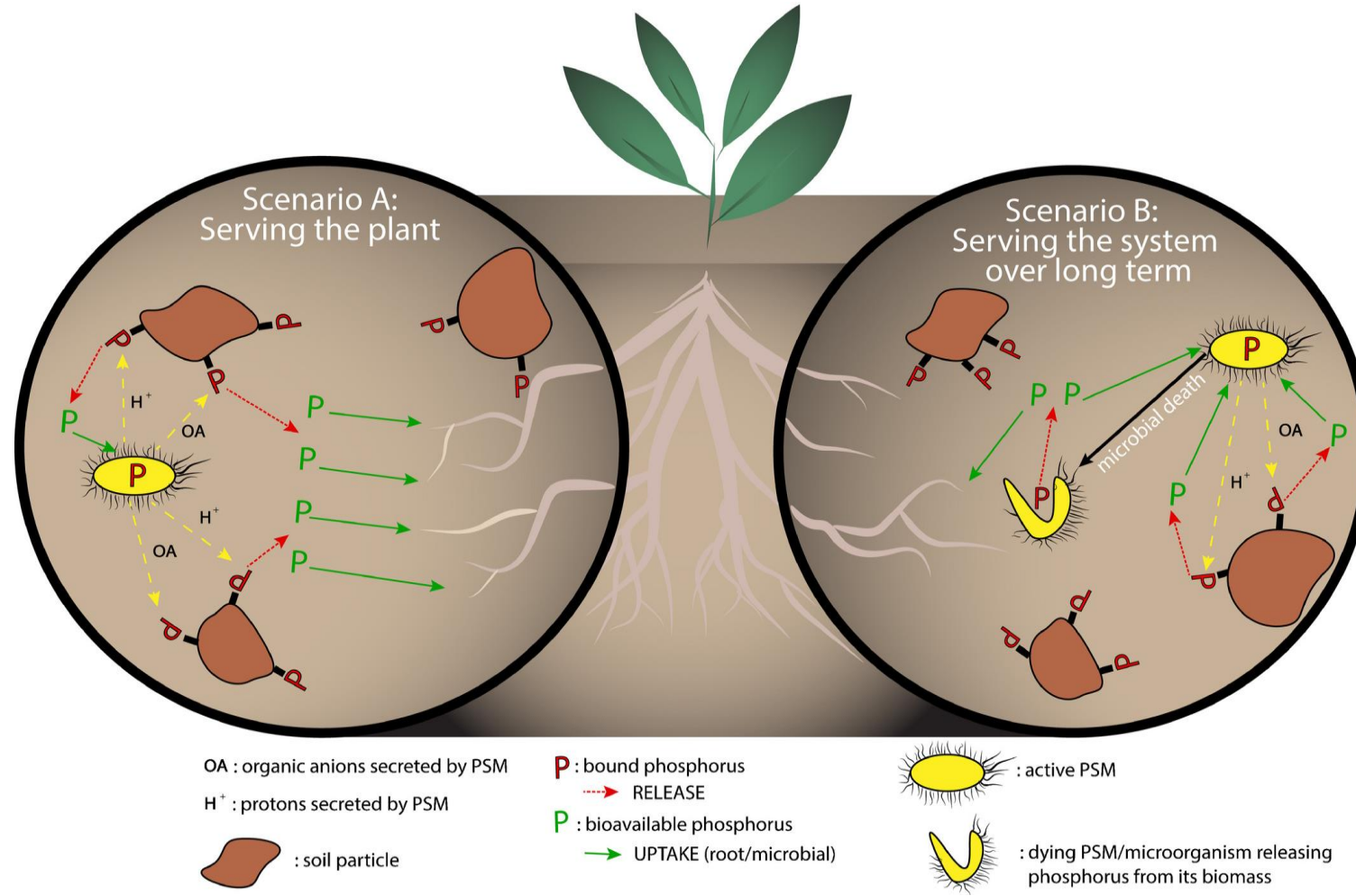


Change of main crop yield and shoot biomass with cover crops (%)

(Hallama et al., 2019)



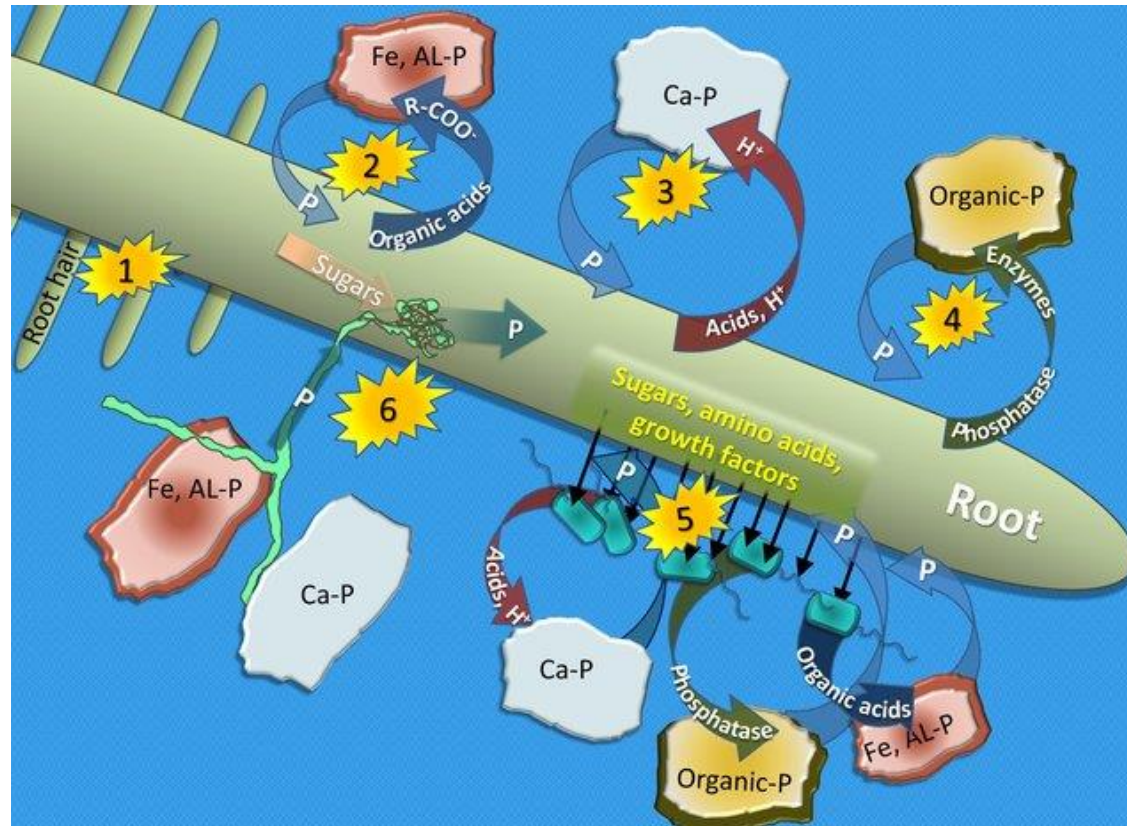
PSM solubilize P for their own demand or for plants?



(Raymond et al., 2021)

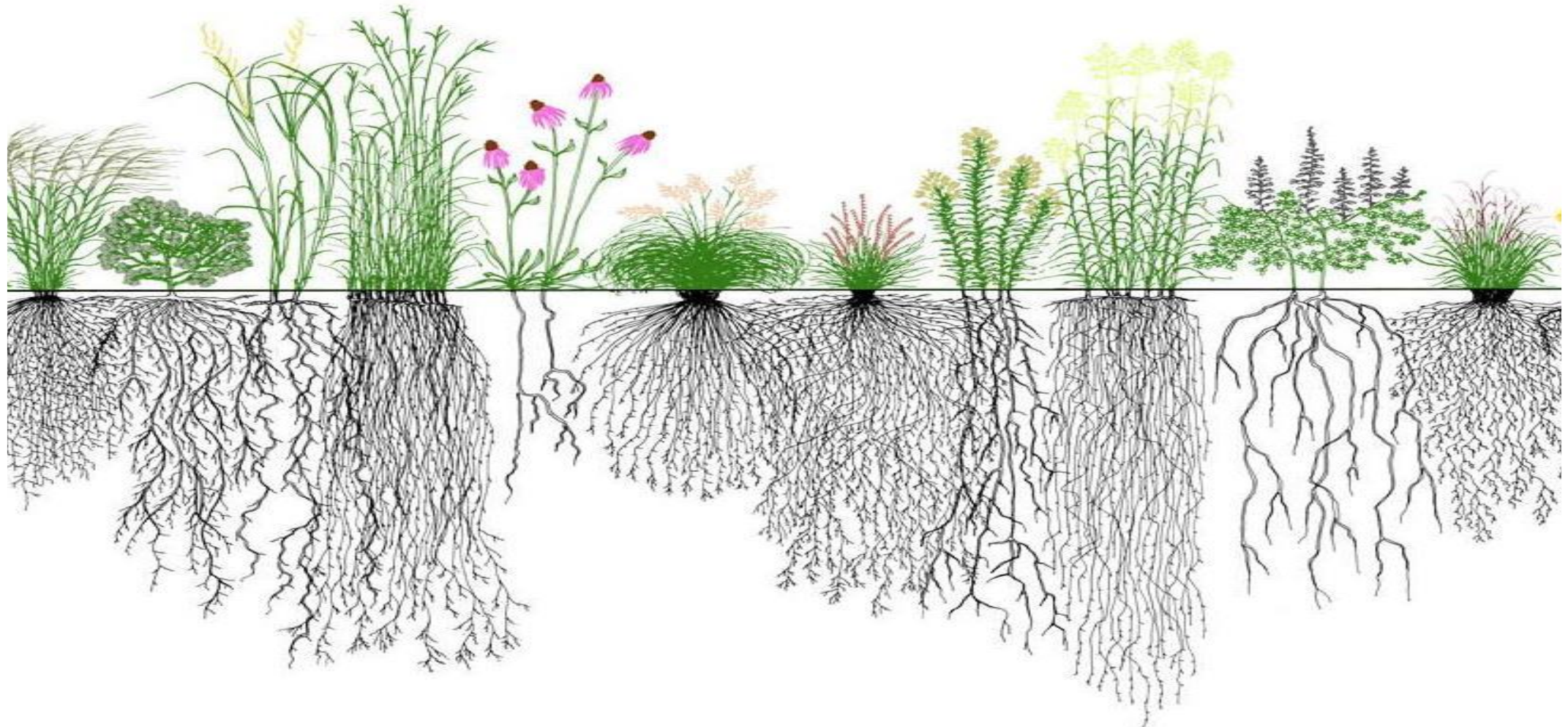


Strategies of microorganisms and plants for soil P exploitation

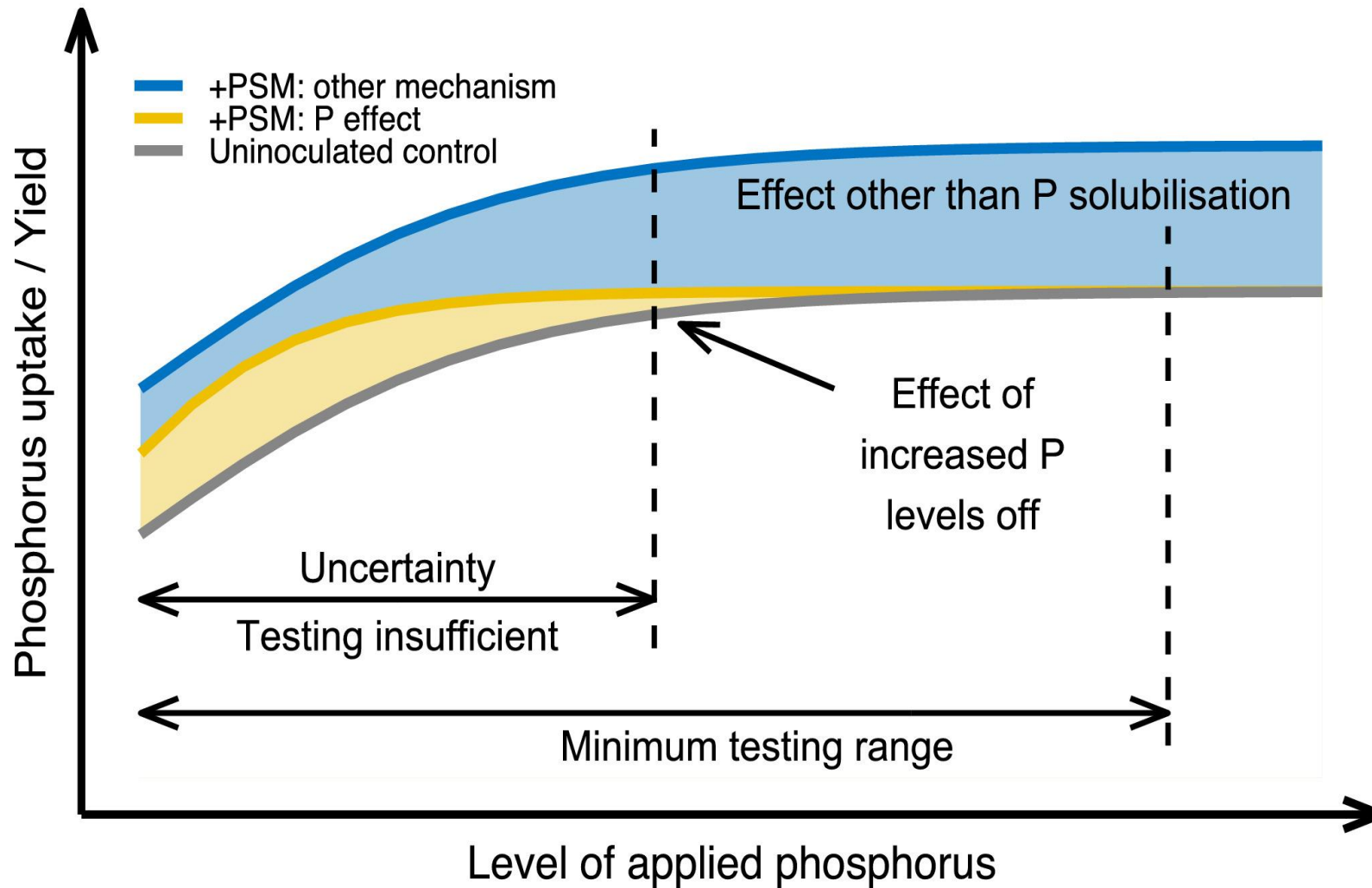


- (1) Increased root absorptive surface area. (2) Chelate iron or aluminum to release P. (3) Dissolve Ca–P compounds with acid exudates (4) Exude phosphatase enzymes to release P from organic compounds. (5) Exude substances to stimulate P-solubilizing rhizobacteria. (6) Encourage colonization by mycorrhizal fungi that help plants take up P.
(Diagram courtesy of Ray R. Weil)

Root diversity in the system



Microorganisms for solubilizing P



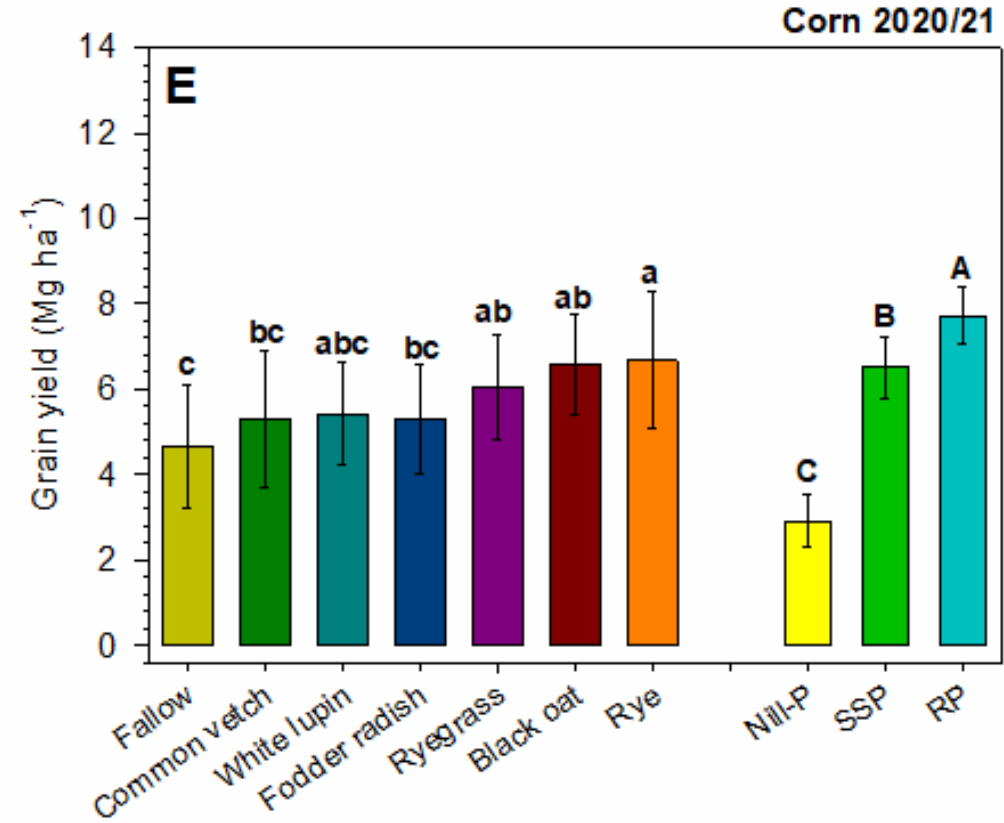
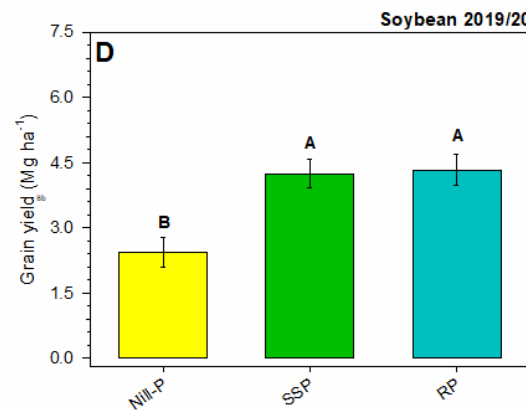
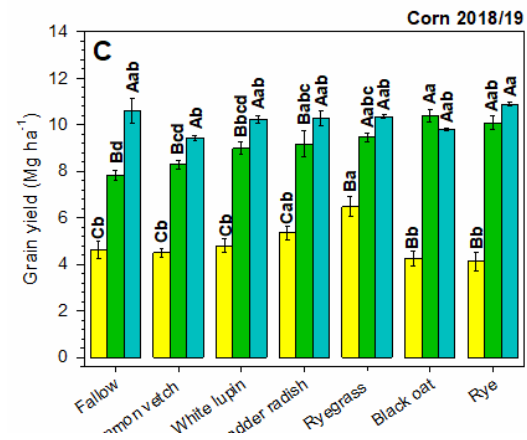
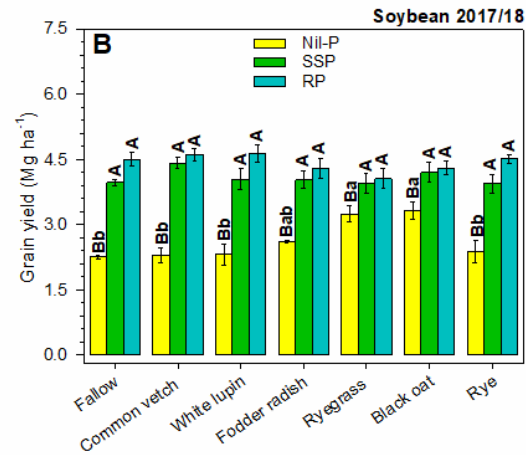
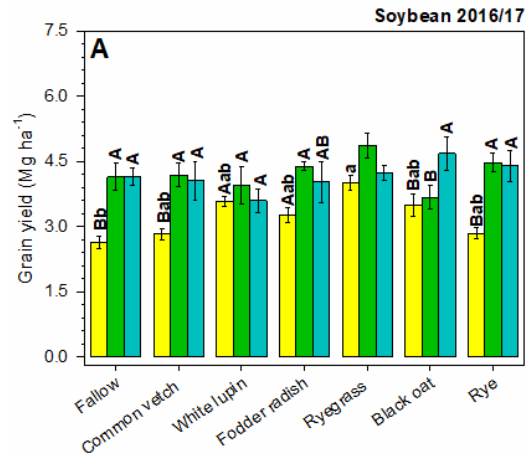
(Raymond et al., 2020)



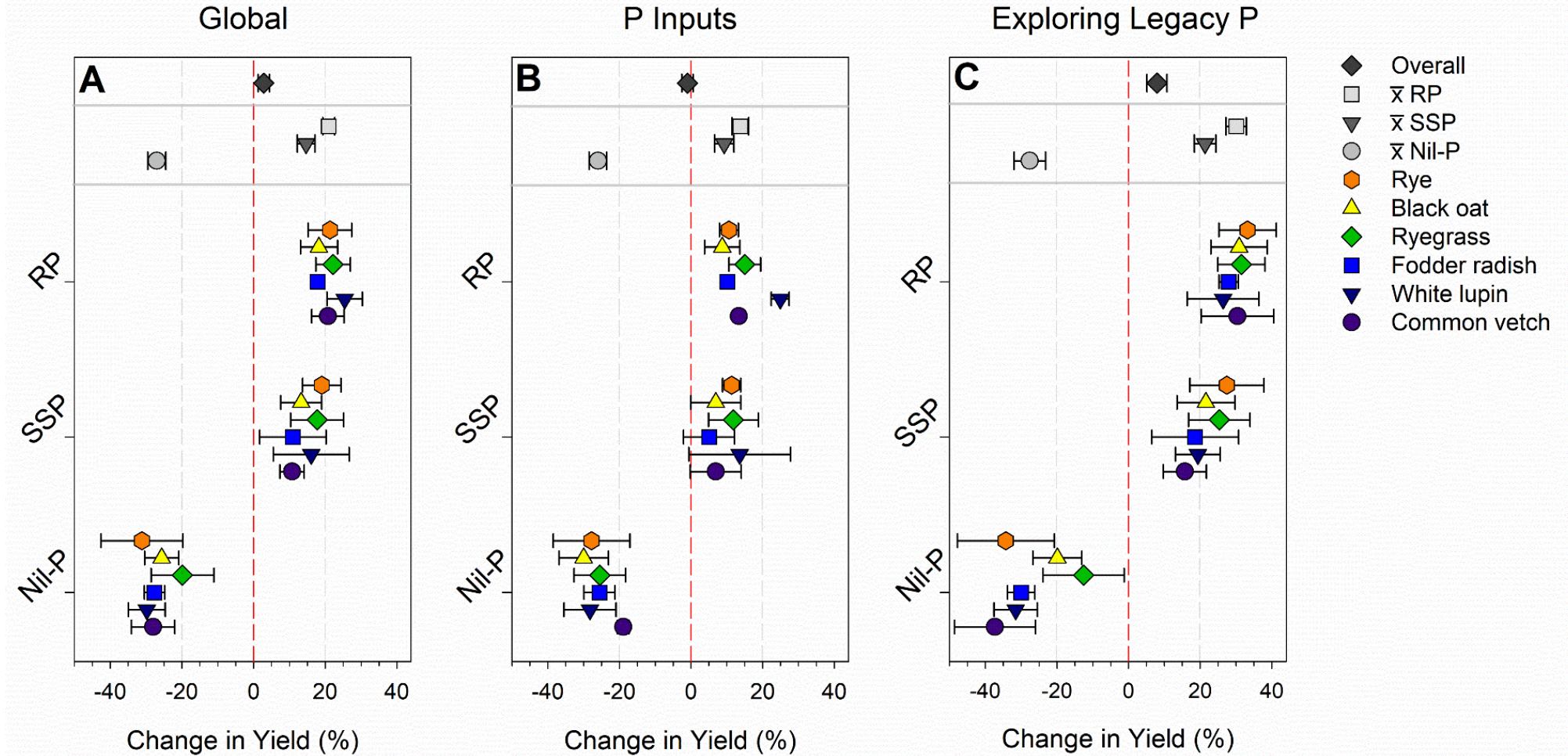
Results cover crops

CASE STUDY 1

Cash crop yield – Dois Vizinhos - PR



CASE STUDY 1. Meta-analysis of 12 crop cycles



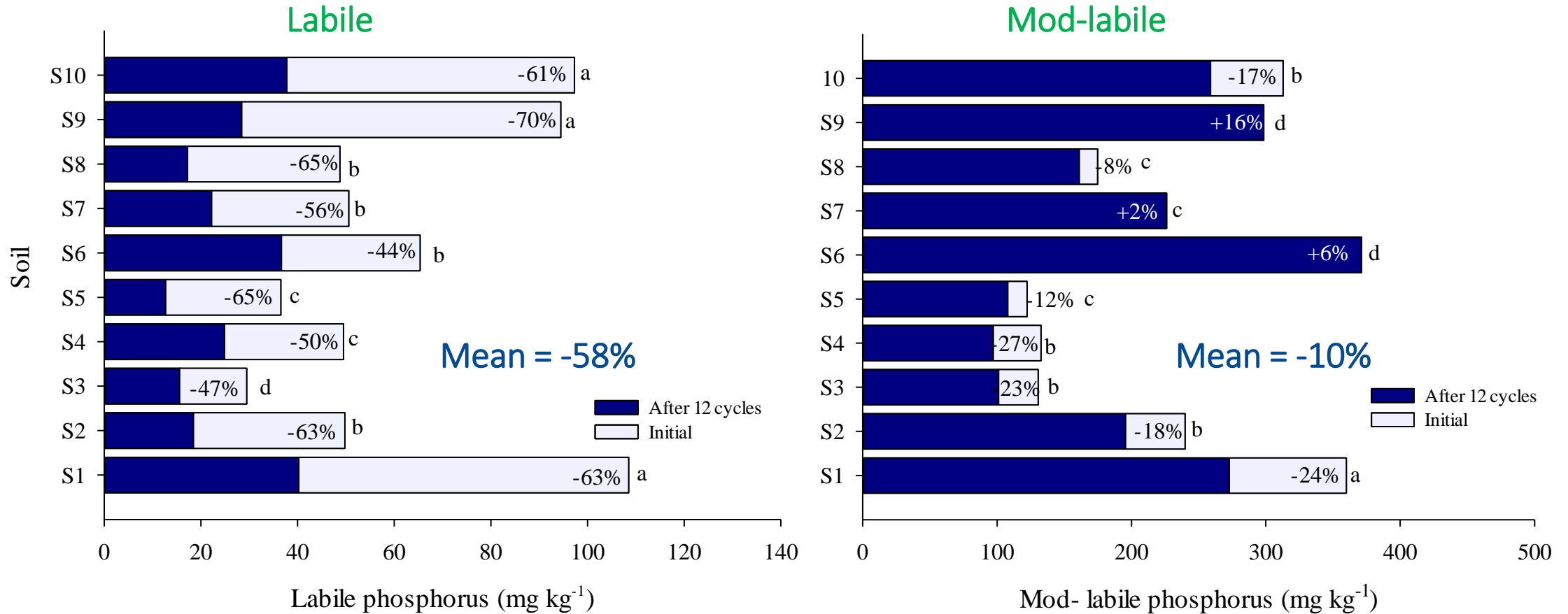
CASE STUDY 2. 10 SOILS – BRAZIL. 6 SOILS – UK



CASE STUDY 2. MEAN: 10 SOILS – BRAZIL



BRACHIARIA

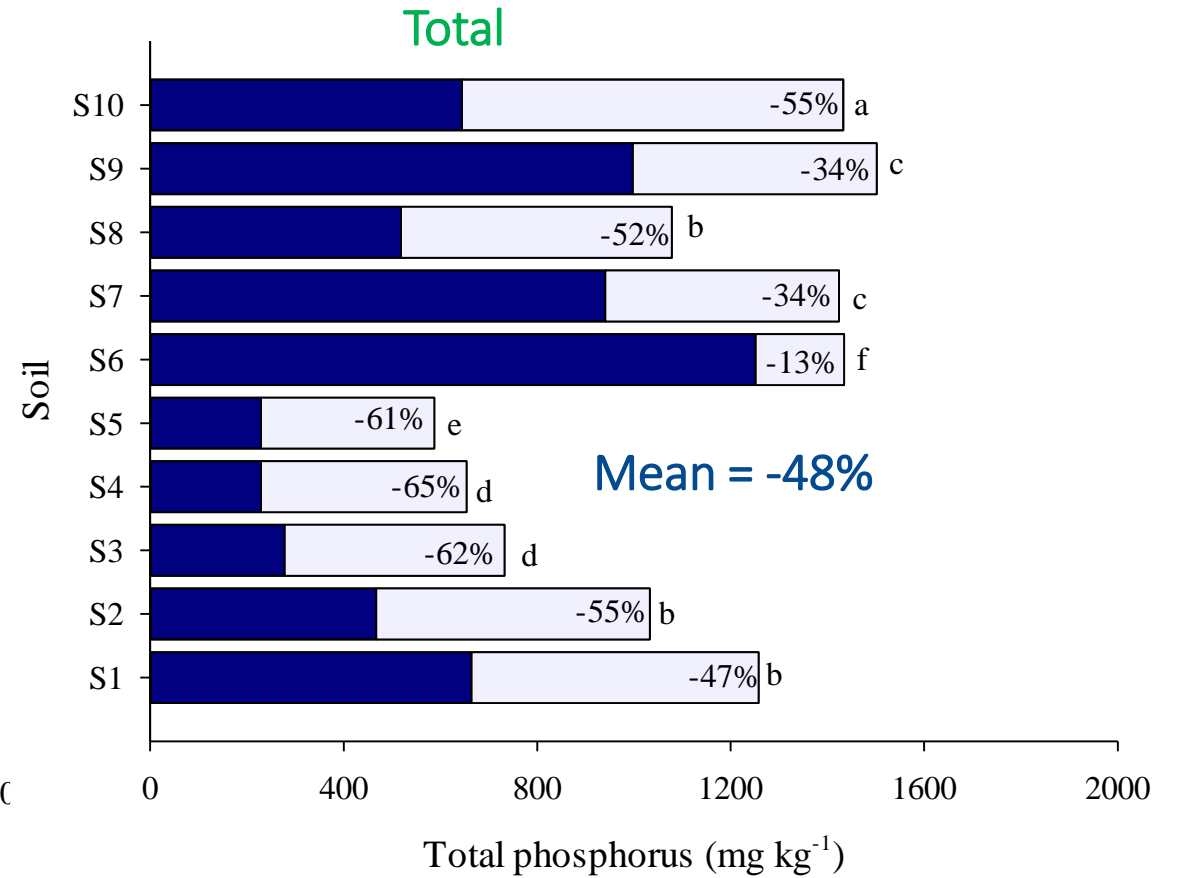
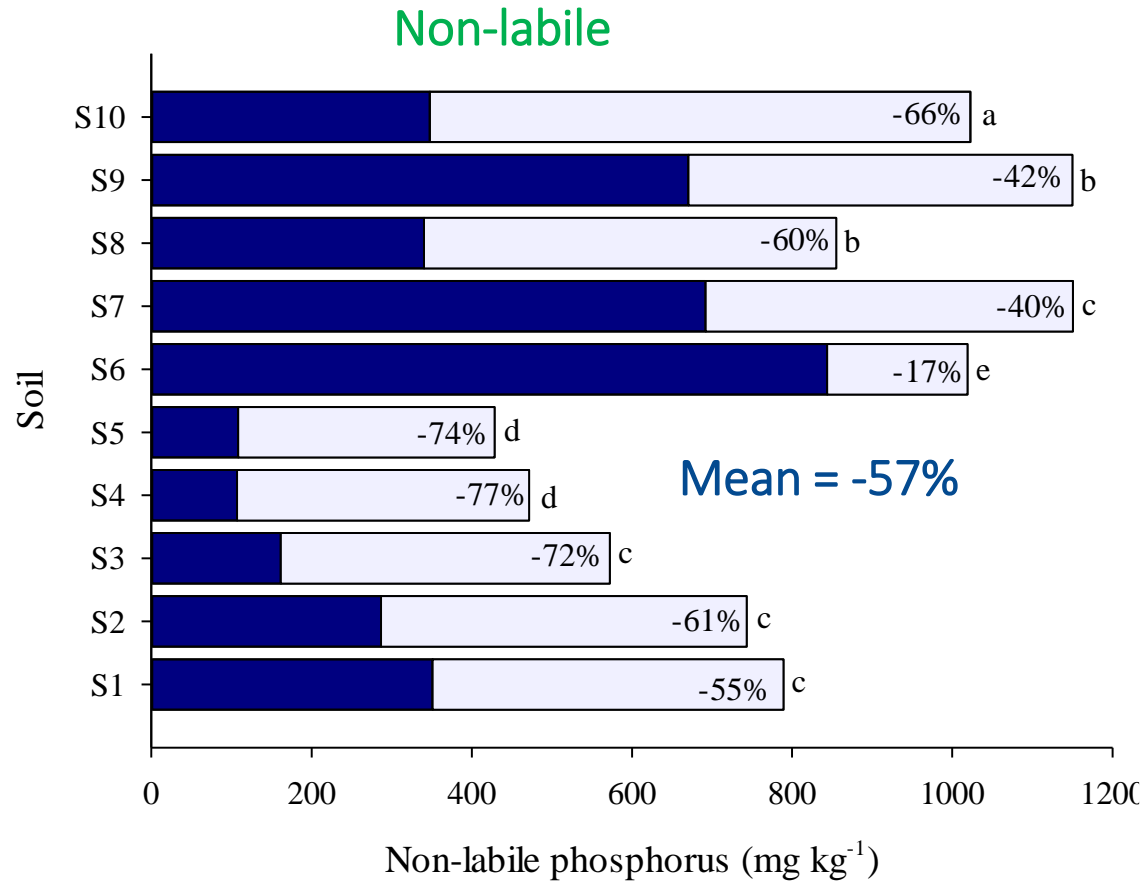


Pavinato et al. (in preparation)

CASE STUDY 2. MEAN: 10 SOILS – BRAZIL



BRACHIARIA



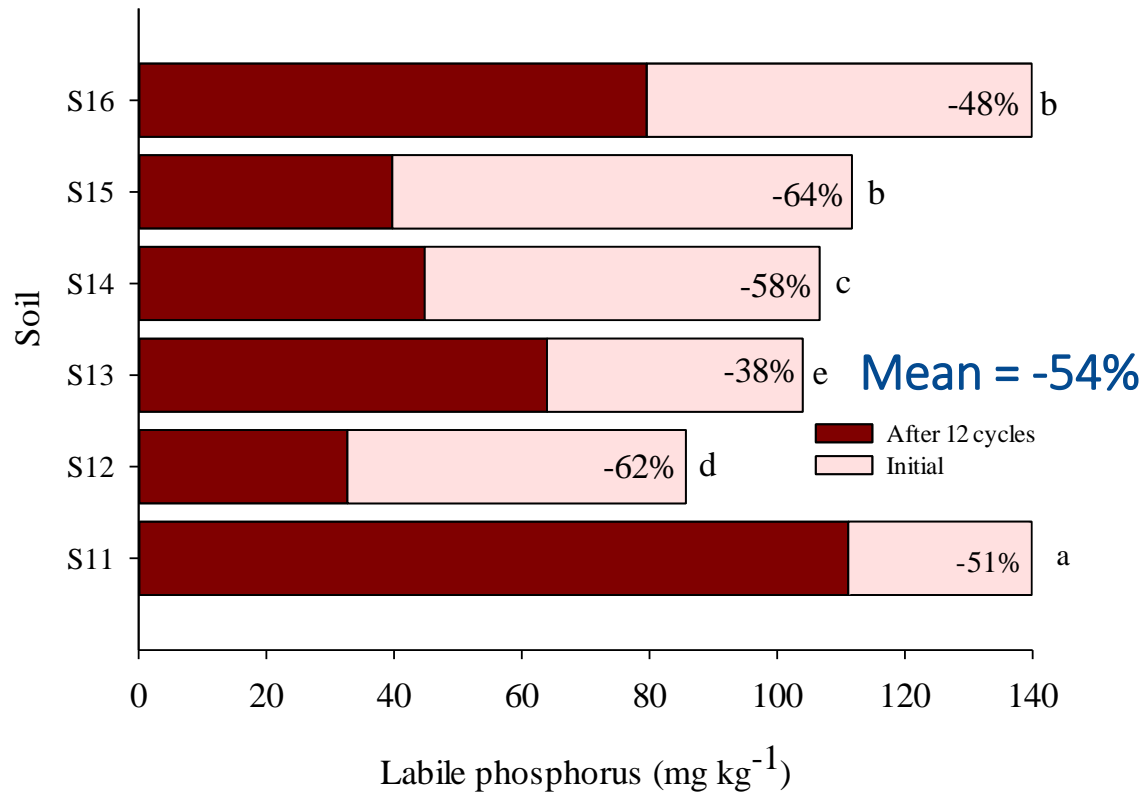
Pavinato et al. (in preparation)

CASE STUDY 2. MEAN: 6 SOILS – UK

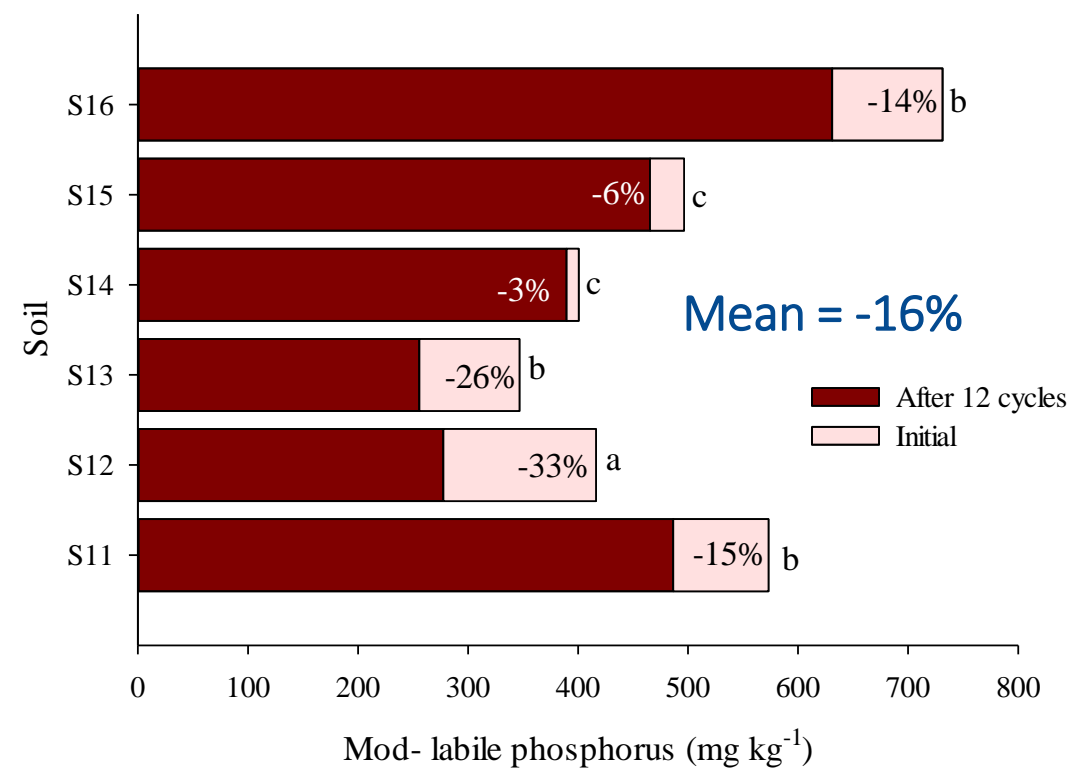


BRACHIARIA

Labile



Mod-labile



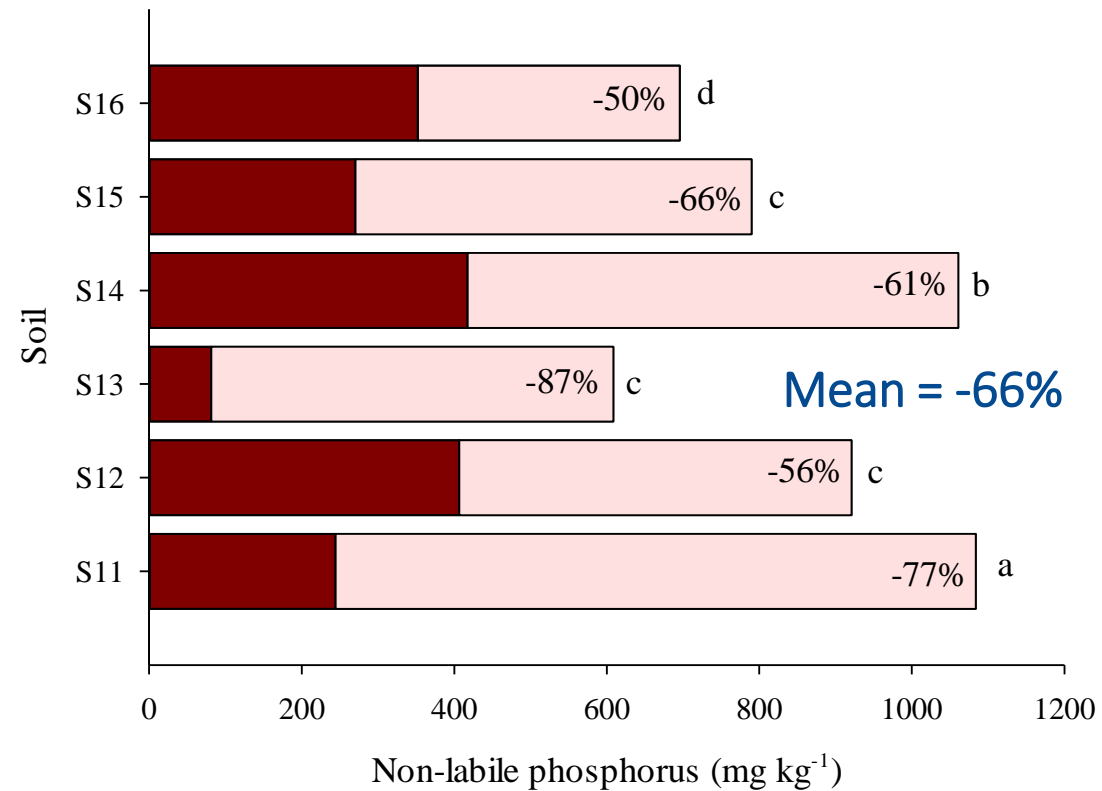
Pavinato et al. (in preparation)

CASE STUDY 2. MEAN: 6 SOILS – UK



BRACHIARIA

Non-labile



Pavinato et al. (in preparation)



Long-term results of fertilizer P management – Embrapa BRASIL

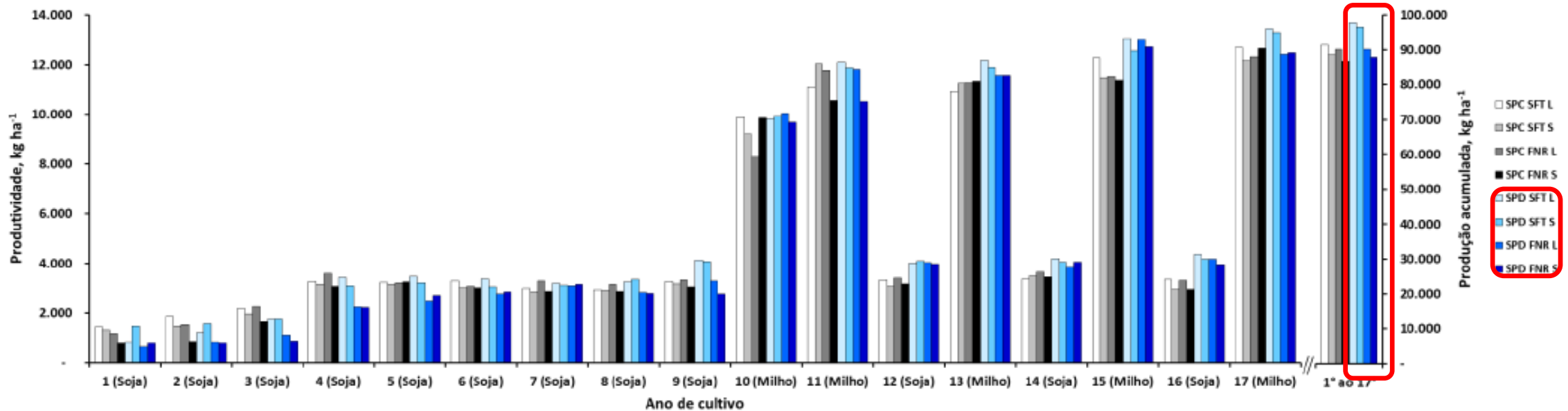


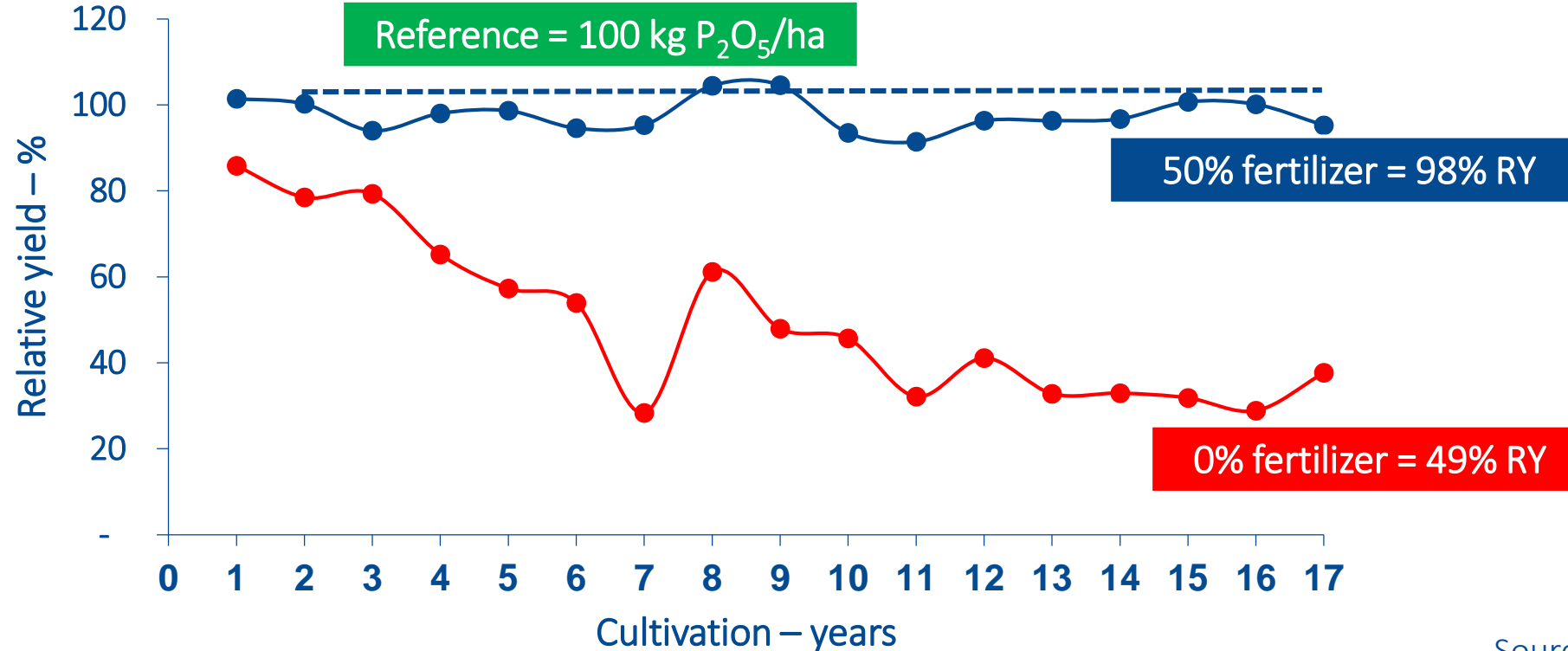
Figure. Annual and accumulated productivity of soybeans and corn in a very clayey Red Oxisol cultivated for 17 years in SPC (conventional) or SPD (no-till), receiving 80 kg ha⁻¹ year⁻¹ of P₂O₅ as TSP or FNR, applied by broadcast (L) or in the sowing furrow (S). The annual and accumulated grain yield obtained in the treatment without phosphate fertilizer in SPC was 199 kg ha⁻¹ and 3,385 kg ha⁻¹, respectively.

Source: Nunes (2014) – Embrapa Cerrados



Management of fertilizers – improving PUE

Clay Oxisol-NT – soybean/maize + millet as cover crop
10 mg dm⁻³ (Mehlich) – **adequate** (81–90% RY)



Source: Nunes (2018)



Management of fertilizers – improving PUE

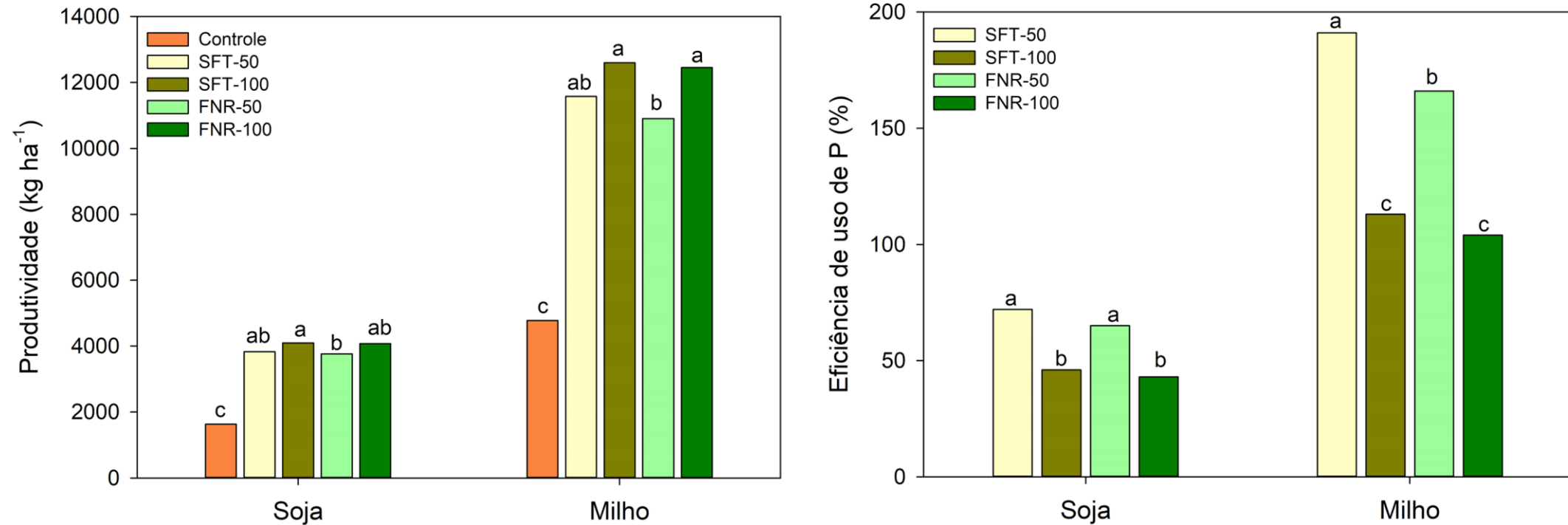


Figure. Average productivity and P use efficiency, average of 11 soybean harvests and 11 maize harvests.
Doses: 50 e 100 kg ha⁻¹ ano⁻¹ de P₂O₅

Lenir Gotz (thesis)





Management of fertilizers – improving PUE

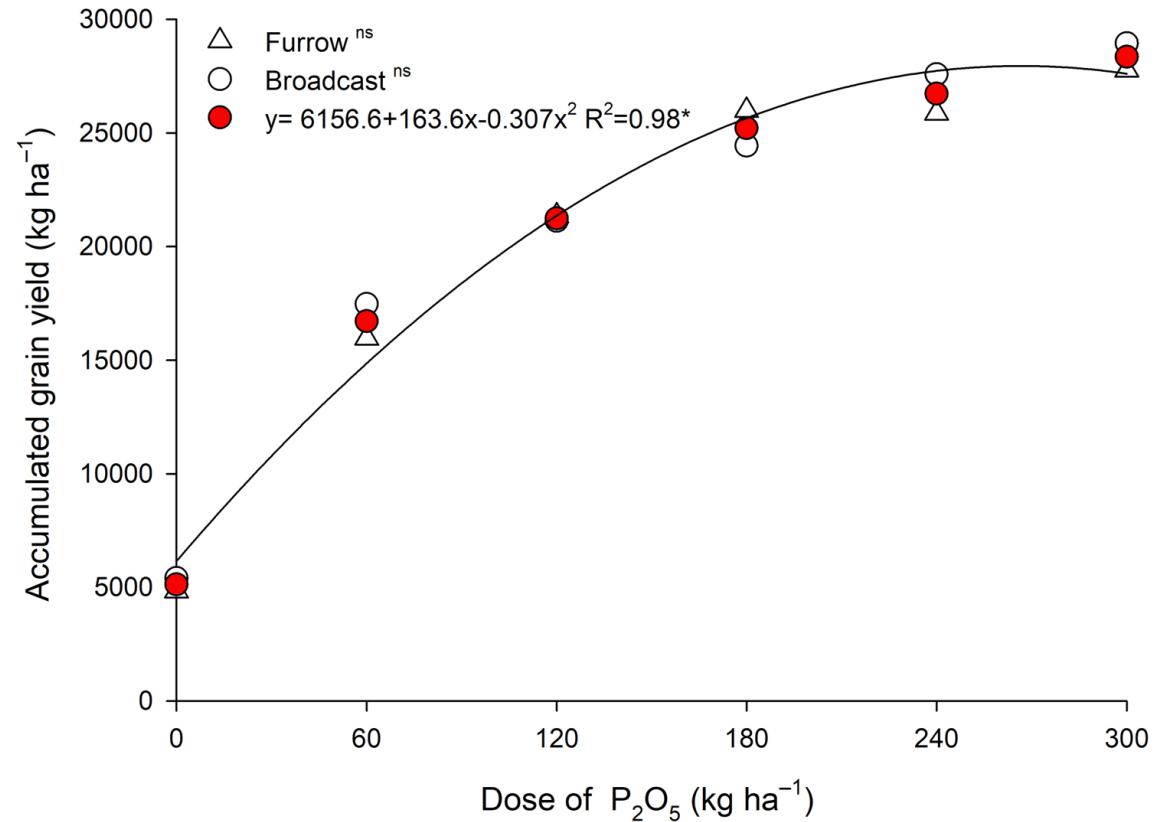


Figure. Accumulated productivity of 6 soybean crops + 1 off-season corn crop as a function of P₂O₅ doses applied in the furrow or broadcast. Sapezal – MT

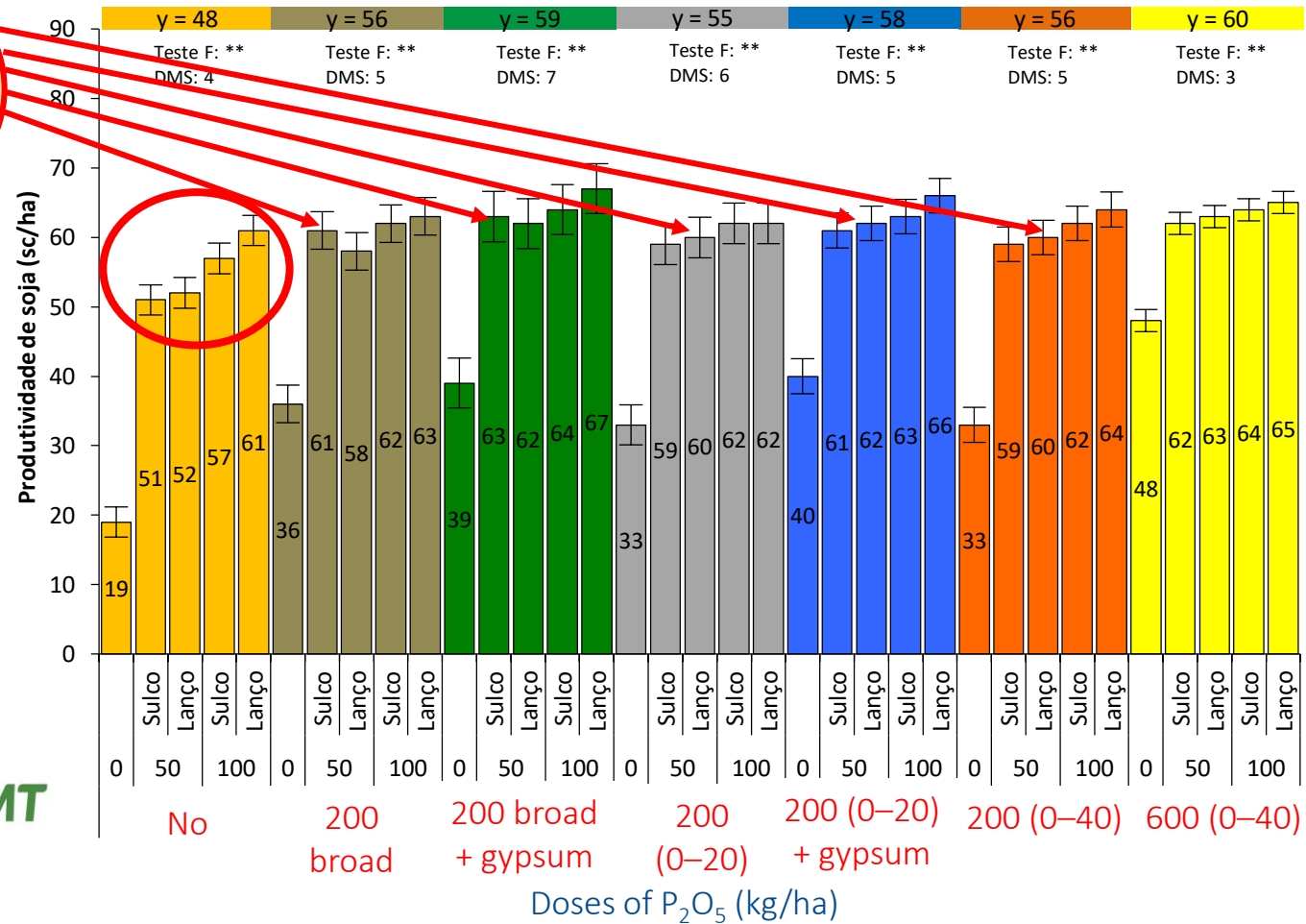
Gotz et al. (2023)

Soybean



Média de 9 safras (2010/11 a 2018/19)

± 90–100% PUE
(50 kg/ha P₂O₅)



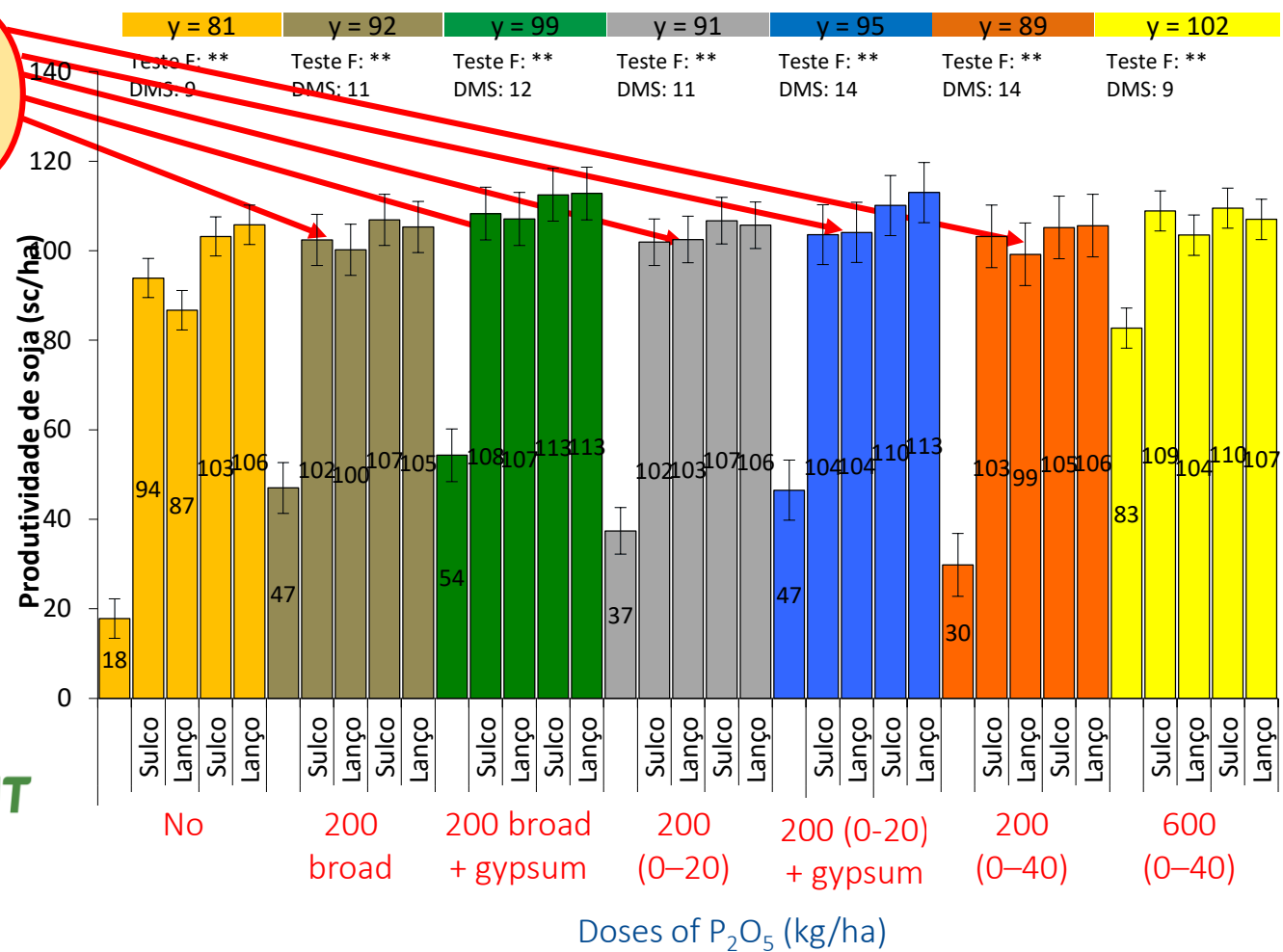
Bertol (2024) –
Informações
pessoais

Maize



Média de 5 Safras (2013/14 a 2017/18)

± 90–100% PUE
(50 kg/ha P₂O₅)



Bertol (2024) –
Informações
pessoais



Final remarks

- Soil/fertilizer/plant management is a major factor for (re)cycling more legacy P in the production system
- Crops with root capacity to explore BETTER the whole soil are more P efficient and may be able to explore economically PART OF the legacy P

Plant breeding for more efficient varieties should be focused nowadays

Microorganisms (PGPM) play important roles in the mobilization of soil P for a sustainable agriculture





Phosphorus use efficiency and legacy P in cropped systems



@gefaesalq



