Influence of P fertilization on Fe chlorosis

Antonio Rafael
Sánchez Rodríguez
26/02/2016

Antonio R. Sánchez-Rodríguez
afs42@bangor.ac.uk

2003/2008: Agricultural Engineer

2009/2013: PhD: **Iron chlorosis**
(Dr MC del Campillo and Prof José Torrent)
FPU scholarship

2013/2014: Researcher at University of Córdoba
Entomopathogenic fungi – new roles
(Prof Enrique Quesada-Moraga)

2014/2016: Postdoc Bangor University (Wales, UK)
Extreme flood events (Prof Davey L Jones)
Postdoc Ramón Areces Foundation

Influence of P fertilization on Fe chlorosis

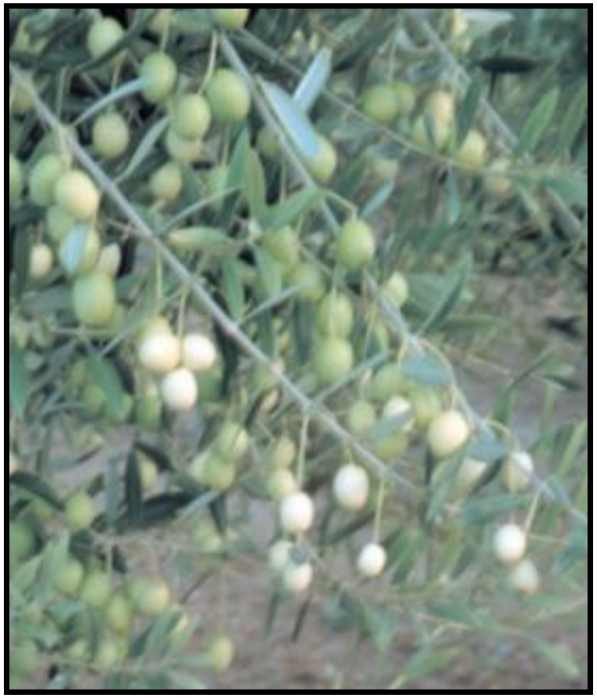
Antonio Rafael
Sánchez Rodríguez
26/02/2016

1. Iron chlorosis

IRON (Fe) CLOROSIS – Fe DEFICIENCY


Interveinal yellowing

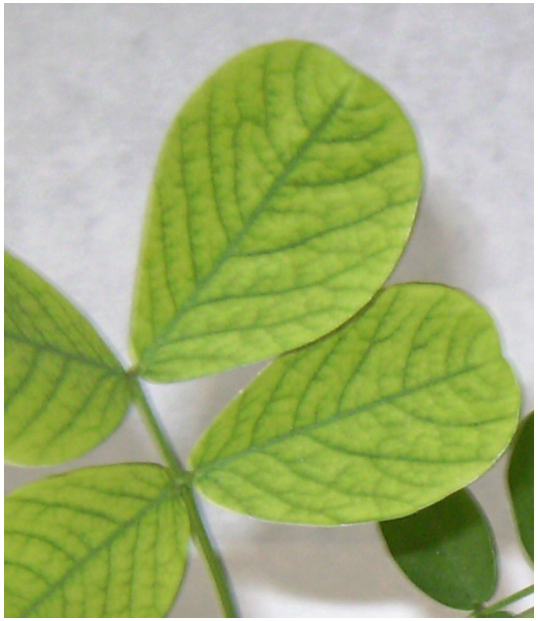

Necrosis


Reduction in yield and quality

Cereals, leguminous, fruit trees, grapevine, OLIVE trees

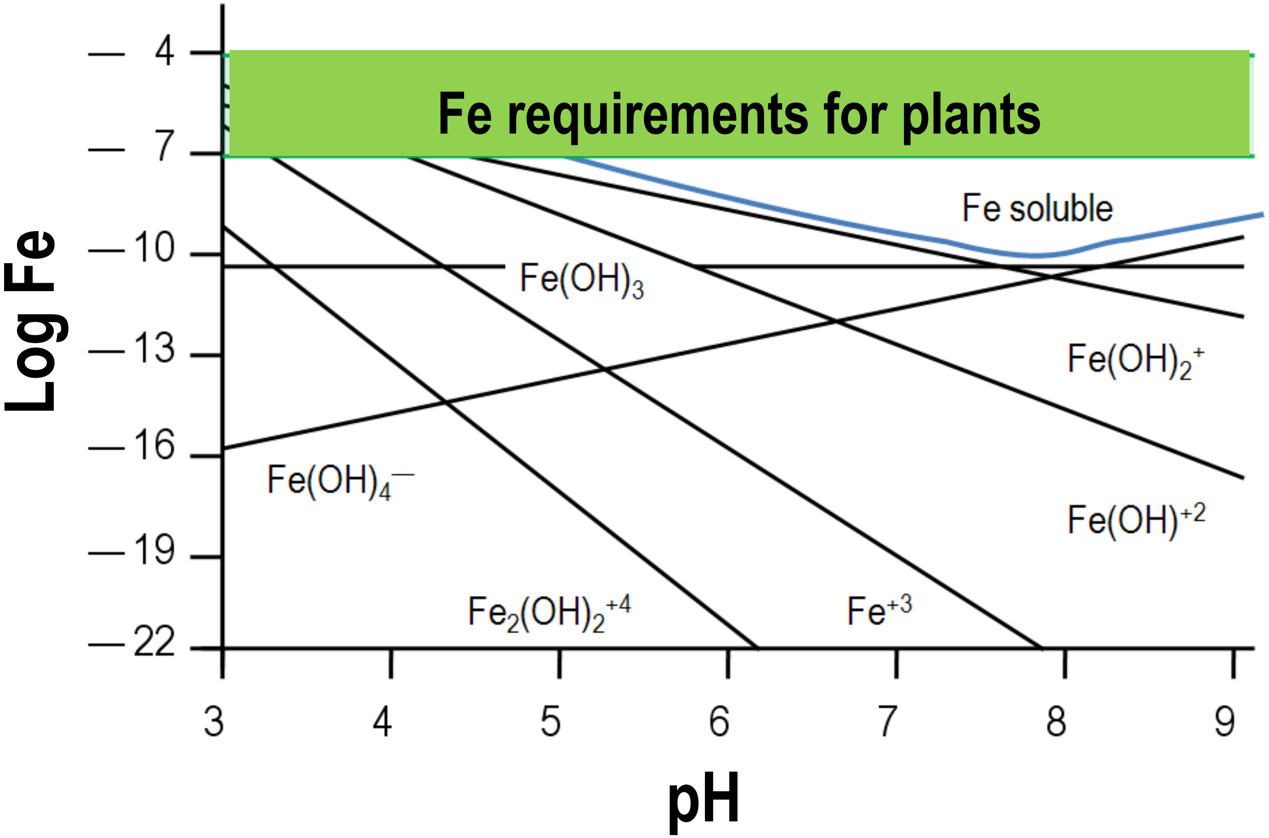
Calcareous soils: 30-35 % world soil surface and ≈70 % of soil surface in Spain

1. Iron chlorosis



Fe availability vs total Fe concentration (Marschner, 1995)

Problem: Fe bioavailability



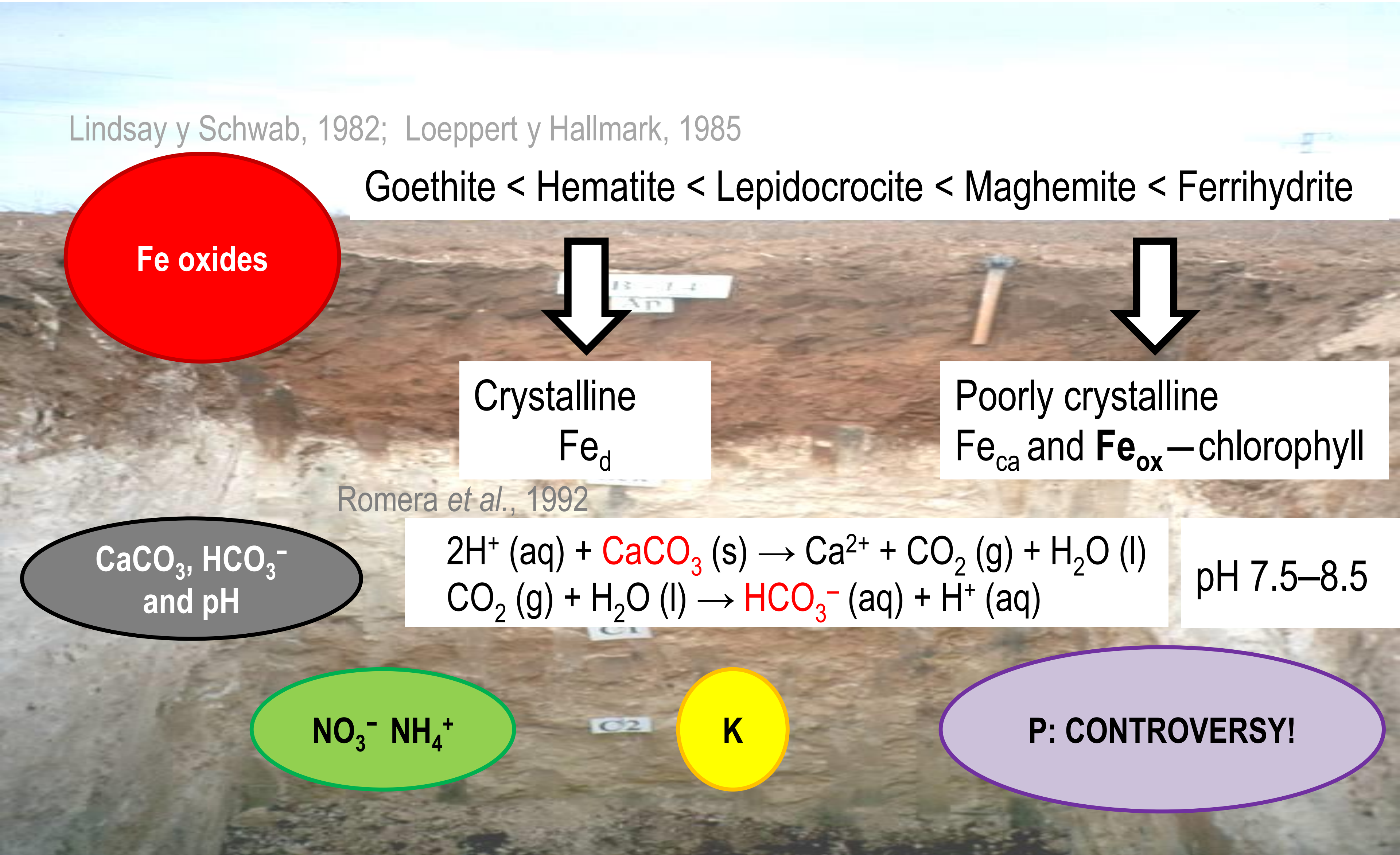
1. Iron chlorosis

Plant response to Fe deficiency (Marschner and Römheld, 1994)

Strategy I	Strategy II
Dicot + non graminaceous	Graminaceous
Fe^{+3} to Fe^{+2}	**No Fe reduction**
H^+ **Organic acids** Phenolic compounds	**Phytosiderophores** (C3 >>> C4)
Changes in root morphology (Landsberg, 1982; Romera and Alcántara, 2004)	
Ferric reductase activity inhibition at high pH and $CaCO_3$ content	Microbial degradation of phytosiderophores

1. Iron chlorosis

Soil properties related to Fe chlorosis



Lindsay y Schwab, 1982; Loeppert y Hallmark, 1985

Fe oxides

Goethite < Hematite < Lepidocrocite < Maghemite < Ferrihydrite

Crystalline
Fe_d

Poorly crystalline
Fe_{ca} and $\mathbf{Fe_{ox}}$ — chlorophyll

Romera *et al.*, 1992

$CaCO_3$, HCO_3^- and pH

$2H^+ (aq) + CaCO_3 (s) \rightarrow Ca^{2+} + CO_2 (g) + H_2O (l)$

$CO_2 (g) + H_2O (l) \rightarrow HCO_3^- (aq) + H^+ (aq)$

pH 7.5–8.5

NO_3^- NH_4^+

K

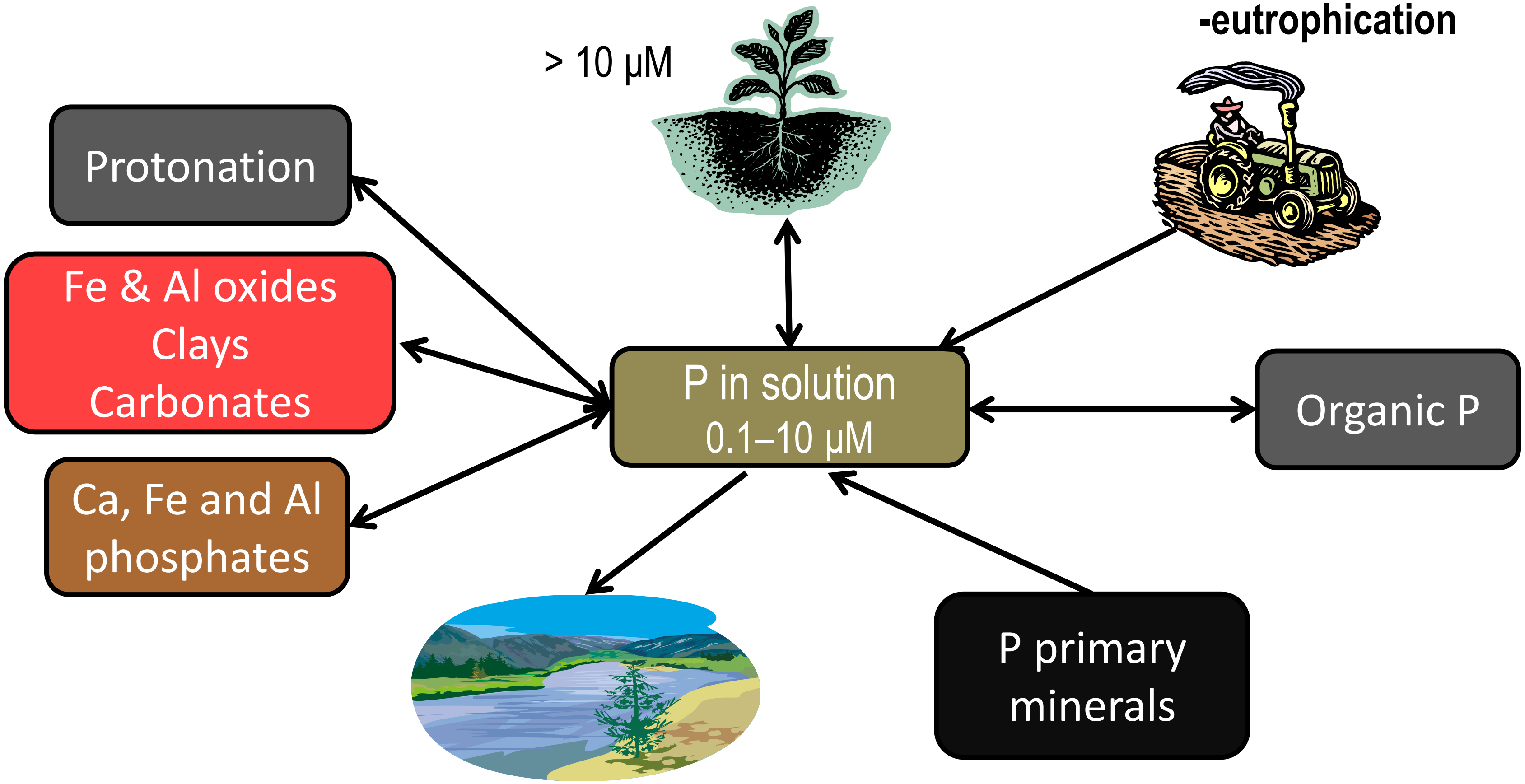
P: CONTROVERSY!

1. Iron chlorosis

Soil P reactions

P macronutrient

(High)P-fertilization
-expensive
-eutrophication



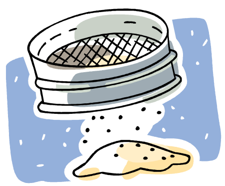
AIM: to clarify the role of P on Fe bioavailability in calcareous soils

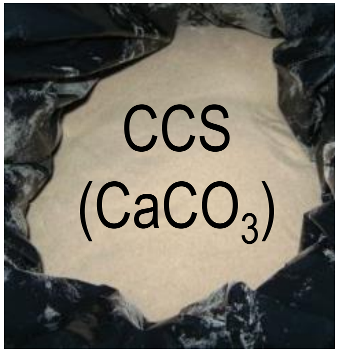
Hypothesis: P covers Fe oxide surfaces (high-affinity) and reduces Fe availability for plants

2. Artificial substrates – Growth chamber

Sánchez-Rodríguez AR, del Campillo MC, Torrent J (2013) **Phosphate aggravates iron chlorosis in sensitive plants grown on model calcium carbonate-iron oxide systems**. Plant and Soil 373:31–42 DOI: 10.1007/s11104-013-1785-y

Substrate preparation





Mixtures for preliminary and factorial experiments

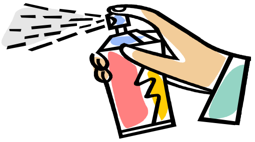
2. Artificial substrates

PRELIMINARY EXPERIMENT

Substrate	Fe(%)	$CaCO_3$ (%)
Poor in Fe	4	40
Rich in Fe	10	10

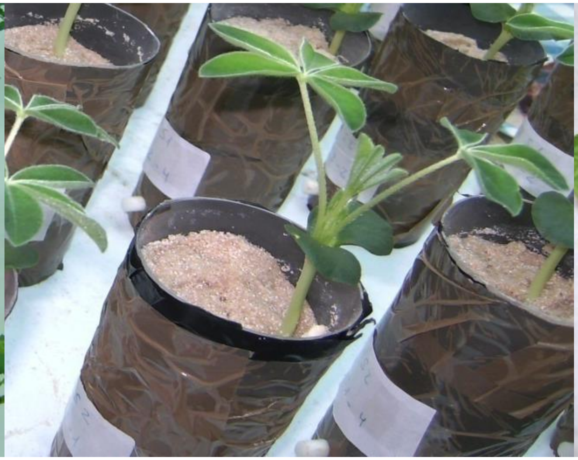
P treatments

LOW P
2
µg P pot $^{-1}$

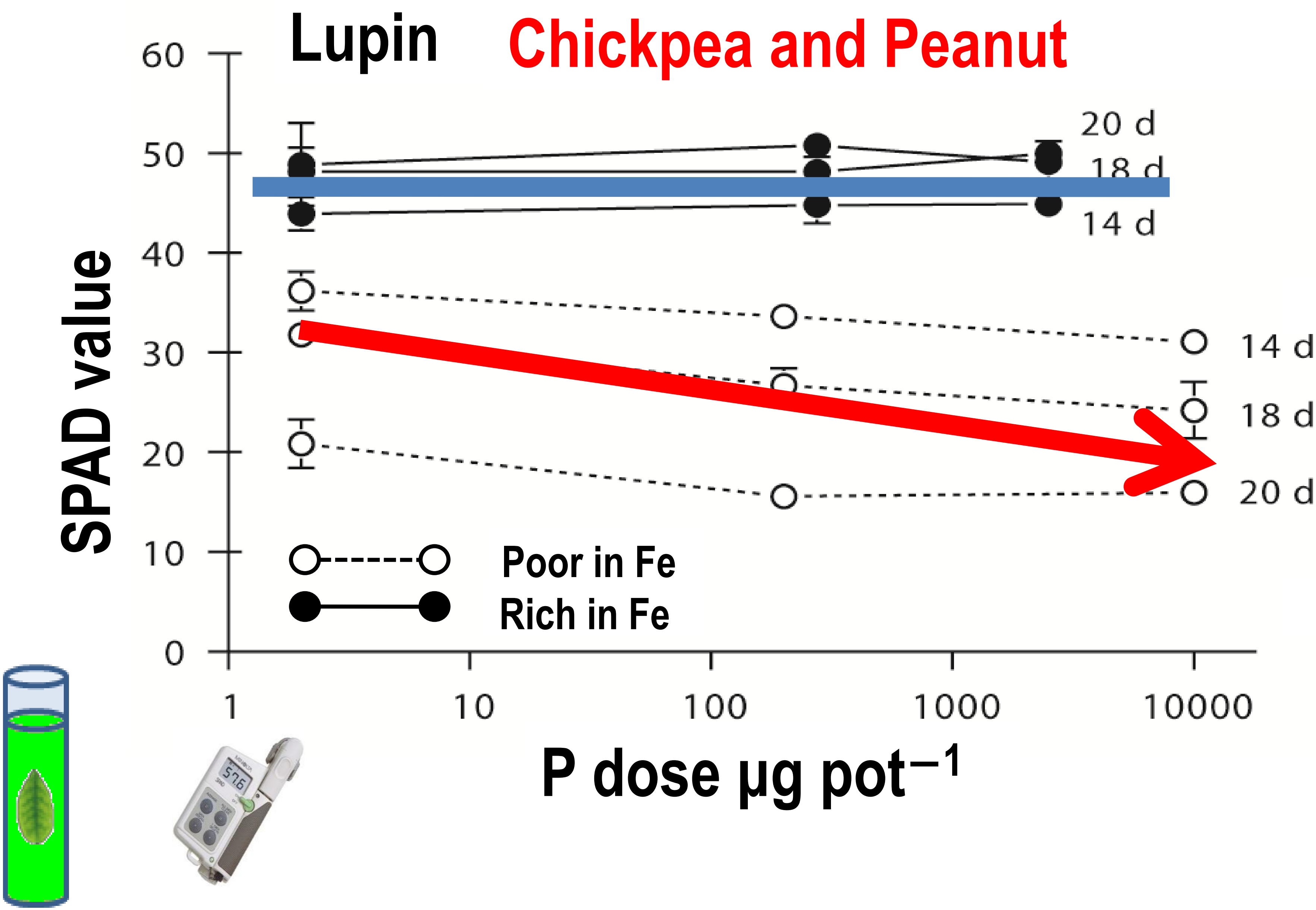


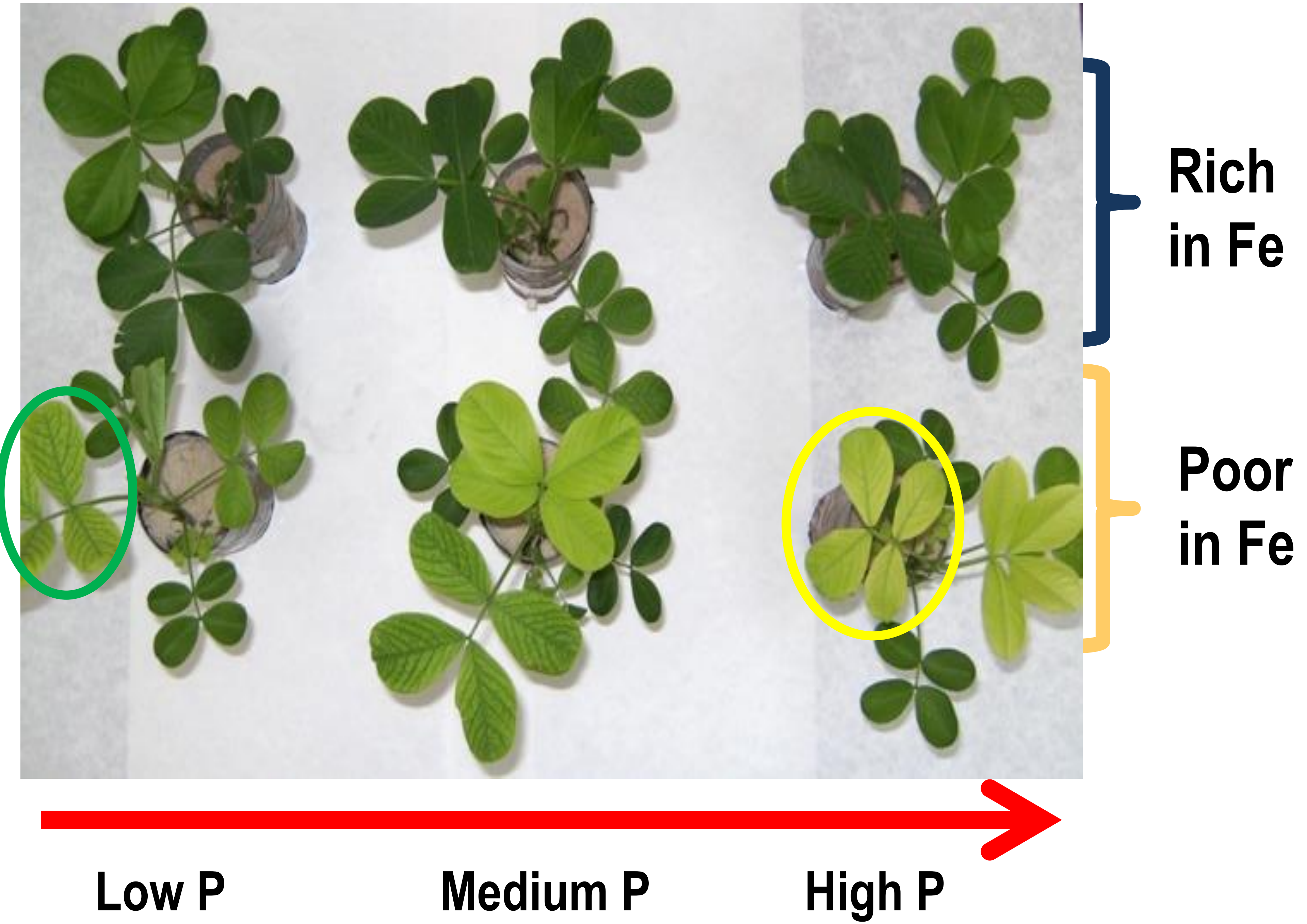
MEDIUM P
200–275
µg P pot $^{-1}$

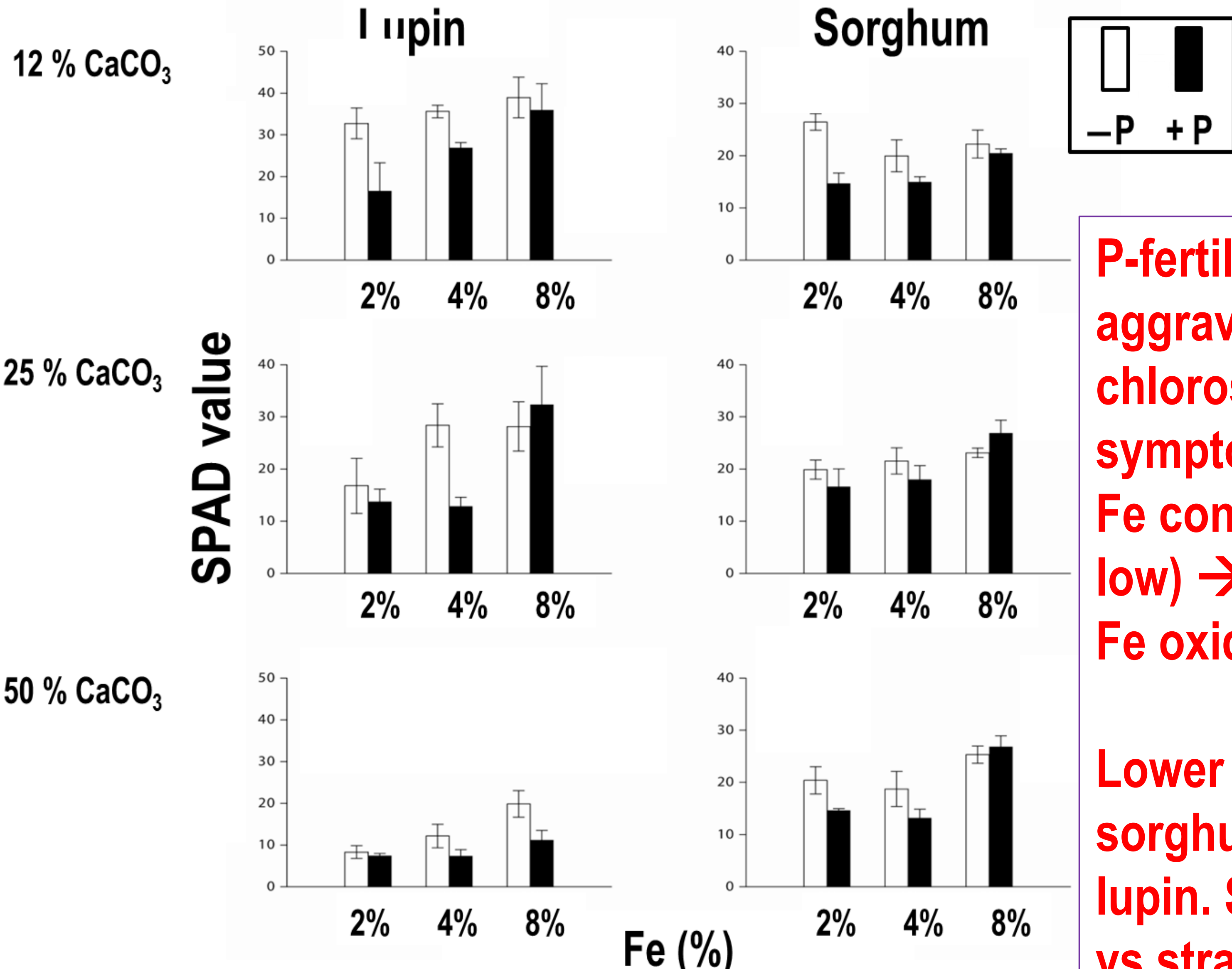
HIGH P
2,500–10,000
µg P pot $^{-1}$



2. Artificial substrates




Rich
in Fe
Poor
in Fe
Low P
Medium P
High P



P-fertilization aggravates Fe chlorosis symptoms (when Fe content is low) → P covers Fe oxide surfaces

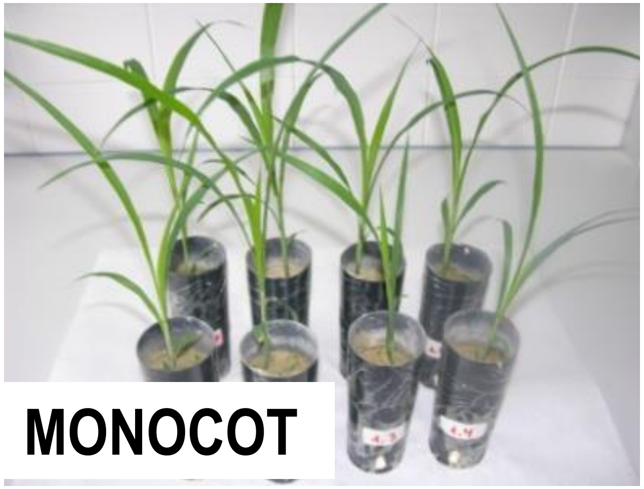
Lower effect on sorghum than on lupin. Strategy II vs strategy I

3. Calcareous soils

Sánchez-Rodríguez AR, del Campillo MC, Torrent J (2014) **The severity of iron chlorosis in sensitive plants is related to soil phosphorus level**. Journal of the Science of Food and Agriculture DOI: 10.1002/jsfa.6662

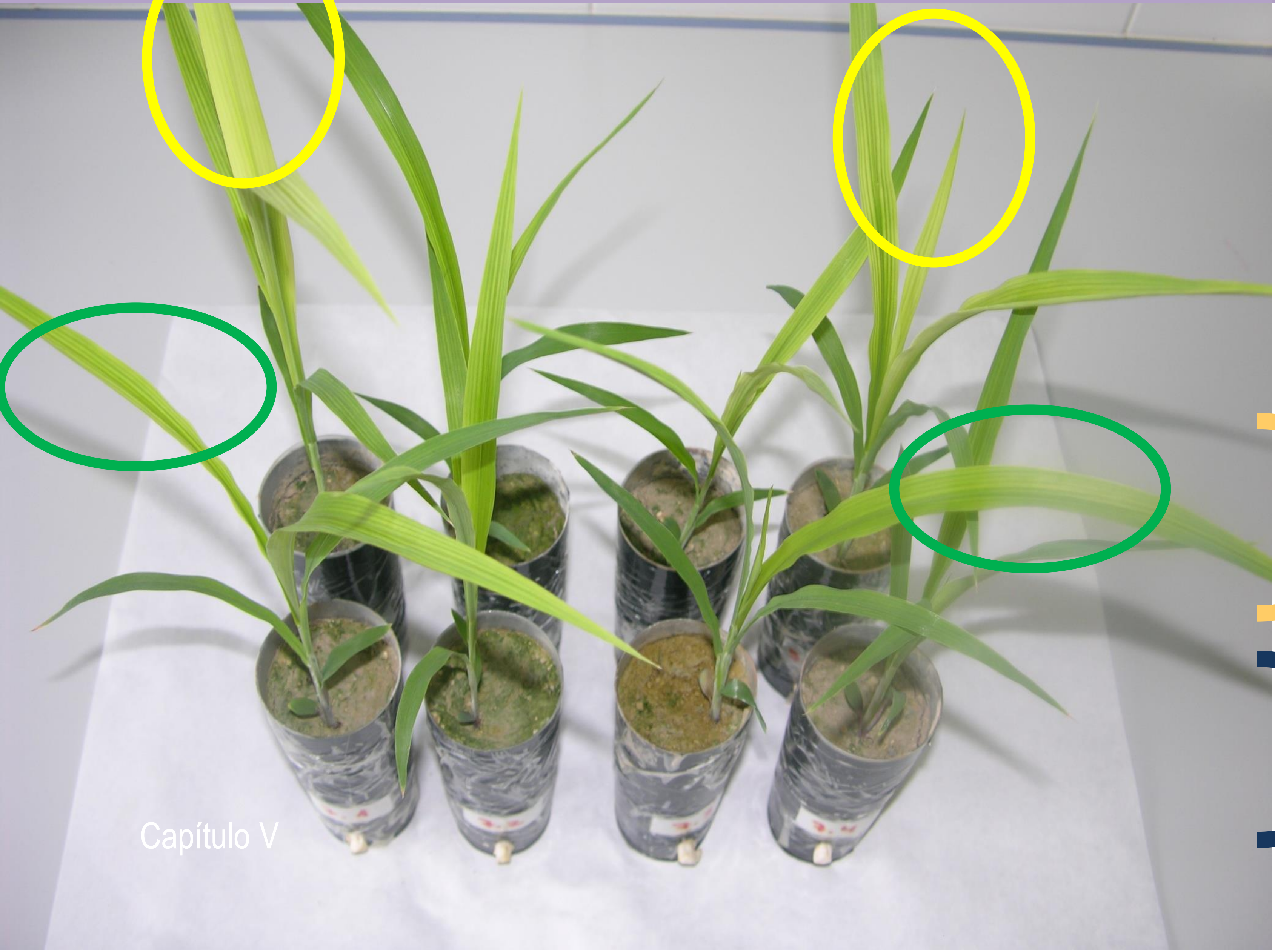
Growth chamber

Property	Unit	Experiment 1 24 soils	
		Max	Min
Clay	g kg^{-1}	415	125
$CaCO_3$		925	300
Active lime		330	61
pH		8.6	8.1
Olsen P	mg kg^{-1}	75	2
Fe_d	g kg^{-1}	4.4	0.7
Fe_{ca}		1.49	0.37
Fe_{ox}		0.71	0.17



24 calcareous soils
2 P treats. (low and high)

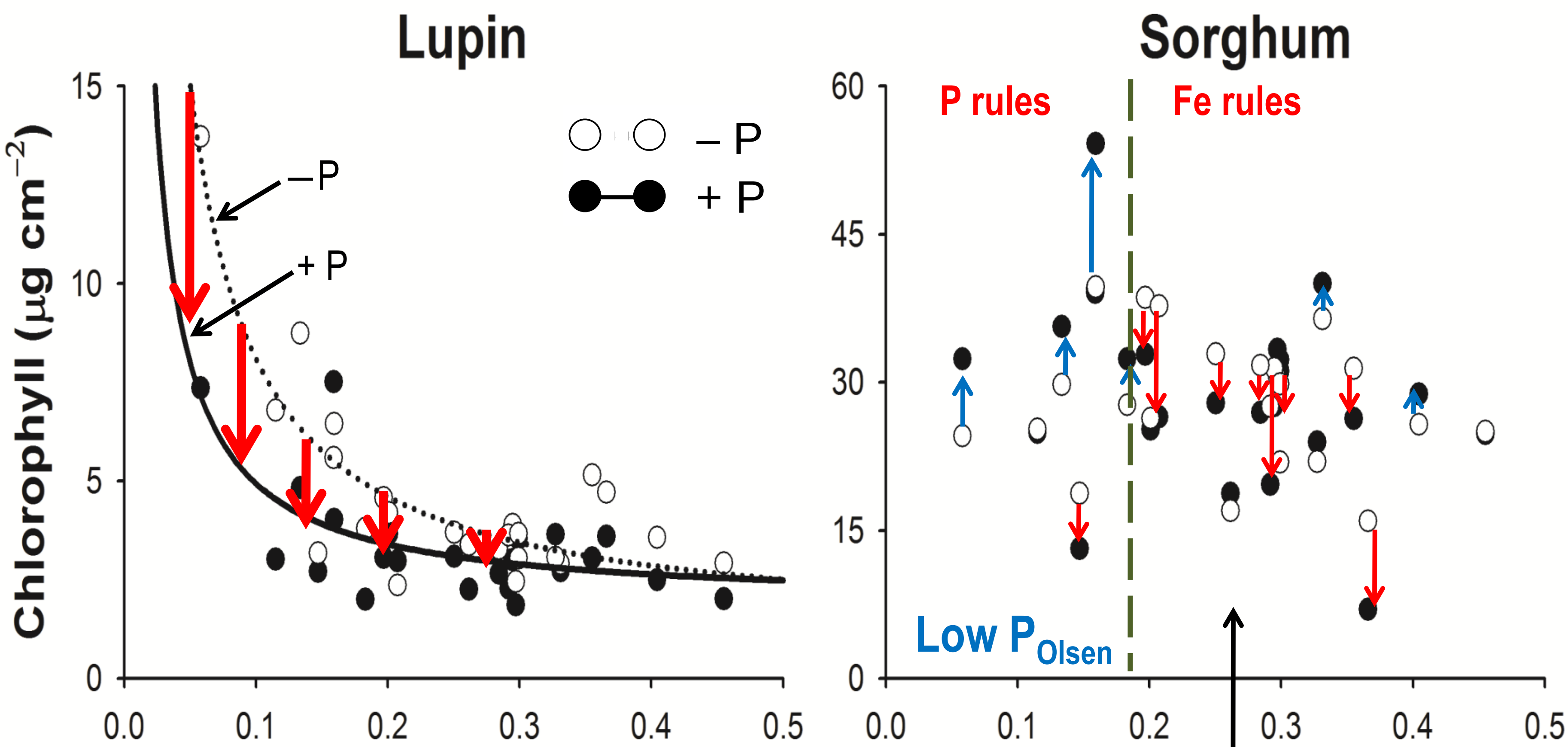
3. Calcareous soils



+ P

–P

3. Calcareous soils



$$\sqrt{P_{Olsen} / Fe_{ox}}$$

P covered Fe oxide surface

4. Experimental fields

Sánchez-Rodríguez AR, Cañasveras JC, del Campillo MC, Barrón V, Torrent J. 2013. **Iron chlorosis in field grown olive as affected by phosphorus fertilization**. European Journal of Agronomy 51:101–107 DOI: ttp://dx.*doi*.org/10.1016/j.eja.2013.07.004

4. Experimental fields

‘Arbequina’ 4 years old

‘Ocal’ 15 years old

‘Manzanilla’ 3 years old

‘Picudo’ 4 years old

4. Experimental fields

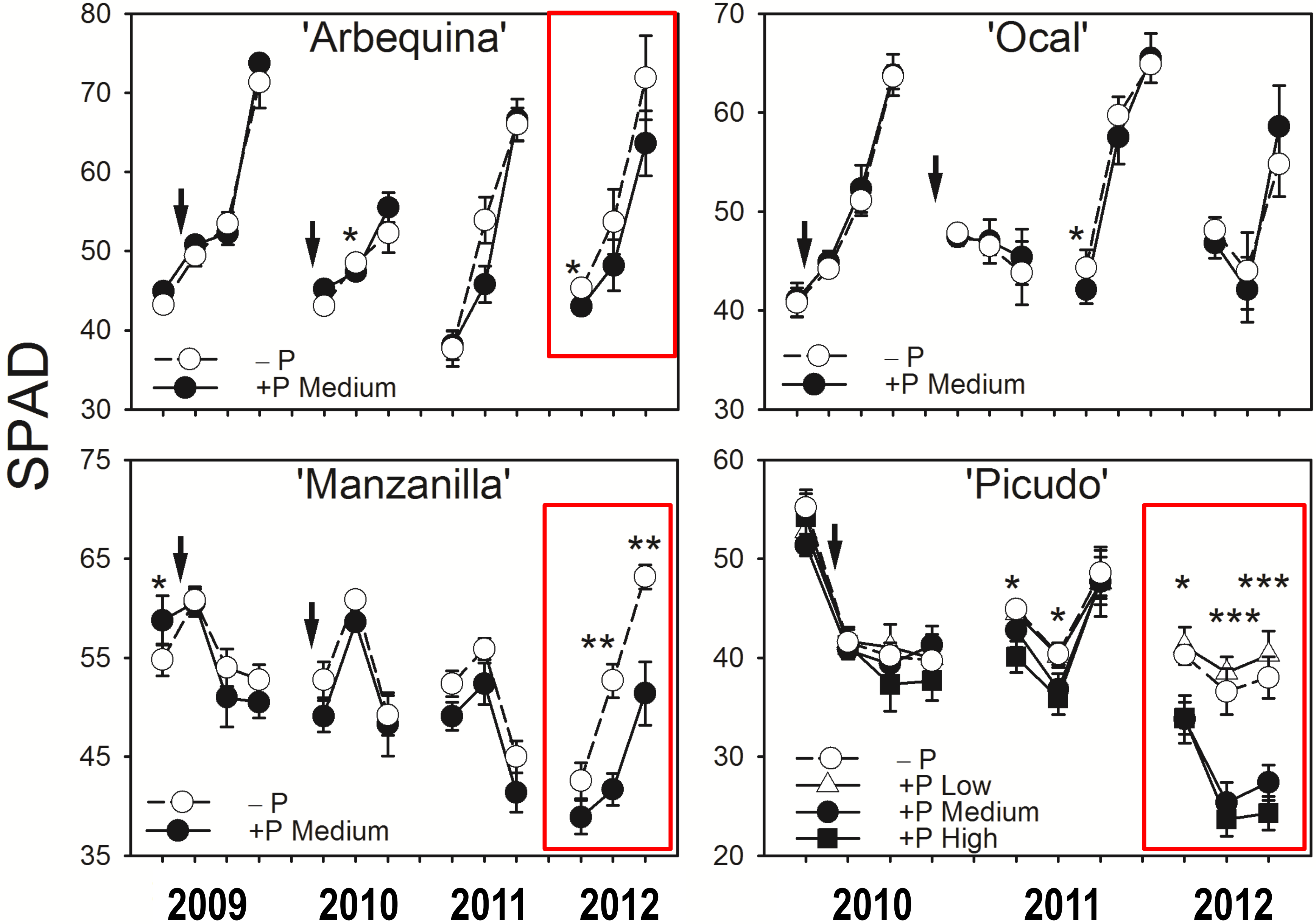
Soil properties

Cultivar	Clay ($g\ kg^{-1}$)	CCE ($g\ kg^{-1}$)	pH	Olsen P ($mg\ kg^{-1}$)	Fe forms ($g\ kg^{-1}$)		Olsen P / Fe_{ox}
					Fe_{ox}	Fe_d	
‘Arbequina’	300	470	8.1	29	0.42	4.9	0.07
‘Ocal’	320	480	8.5	19	0.39	4.5	0.05
‘Manzanilla’	250	640	7.8	21	0.21	2.9	0.10
‘Picudo’	230	755	8.4	13	0.20	2.2	0.07

Critical $Fe_{ox} \approx 0.35\ g\ kg^{-1}$ (Benítez *et al.*, 2002)

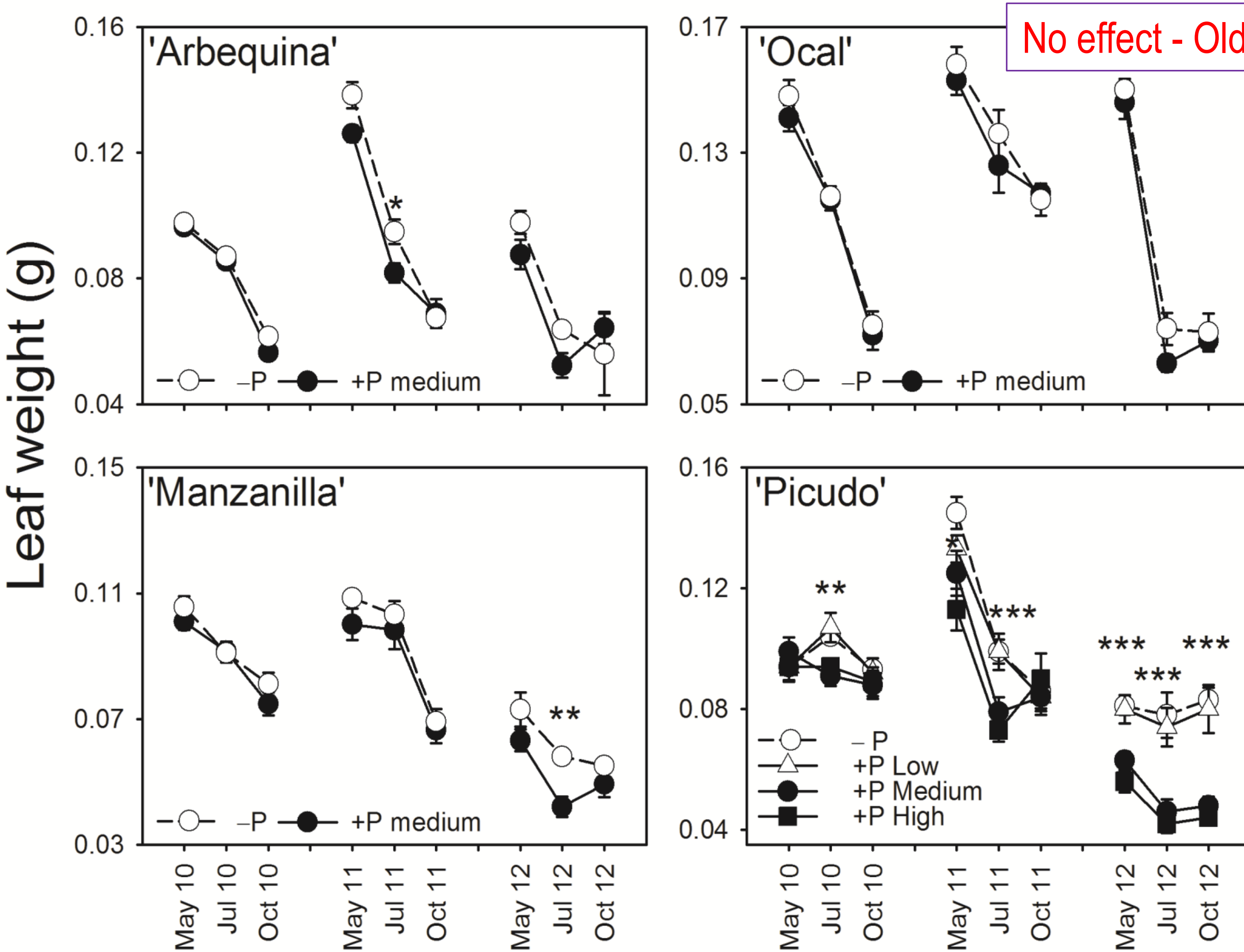
4. Experimental fields

Cultivar	P (g $tree^{-1}$)			
	Control	Low P	Medium P	High P
‘Arbequina’	0		31	
‘Ocal’	0		90	
‘Manzanilla’	0		31	
‘Picudo’	0	50	100	150



SPAD
'Arbequina'
'Ocal'
'Manzanilla'
'Picudo'
– P
+P Medium
+P Low
+P High
2009
2010
2011
2012

No effect - Older olive trees



Lower Fe_{ox} → stronger P effect. Application of P aggravates Fe chlorosis in olive trees grown on low Fe_{ox} content soils (< 0.35 mg kg^{-1})

5. Organic acids

Sánchez-Rodríguez AR, del Campillo MC, Torrent J, Jones DL (2014) **Organic acids alleviate iron chlorosis in chickpea grown on two calcareous soils fertilized with phosphorus**. Journal of Soil Science and Plant Nutrition

PRIFYSGOL BANGOR UNIVERSITY

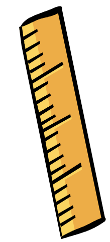
2 soils (low and high in available Fe)

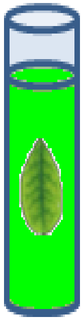
<u>Three treatments:</u>

–P

+P: 25,000 µg P per pot

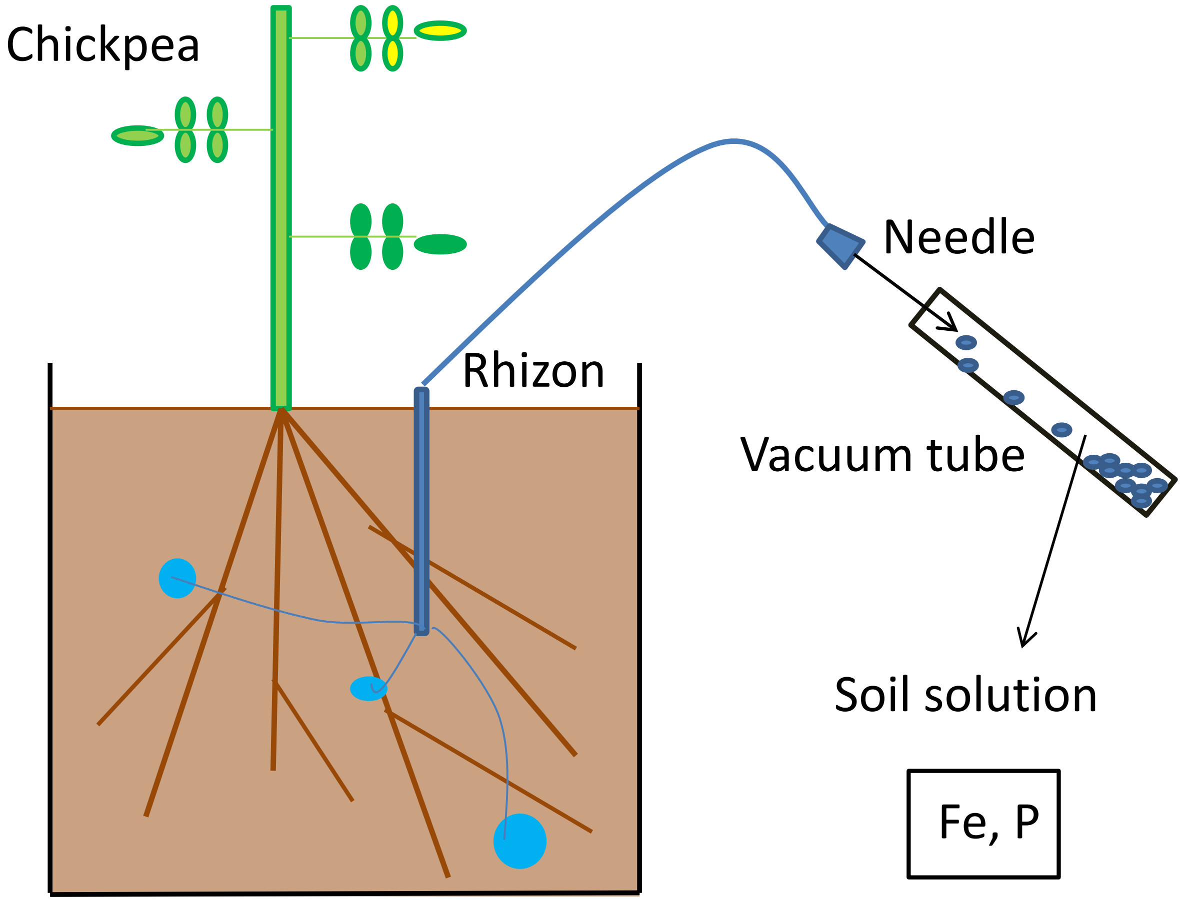
+P+OA: 25,000 µg P per pot





Mineral nutrient concentration

5. Organic acids



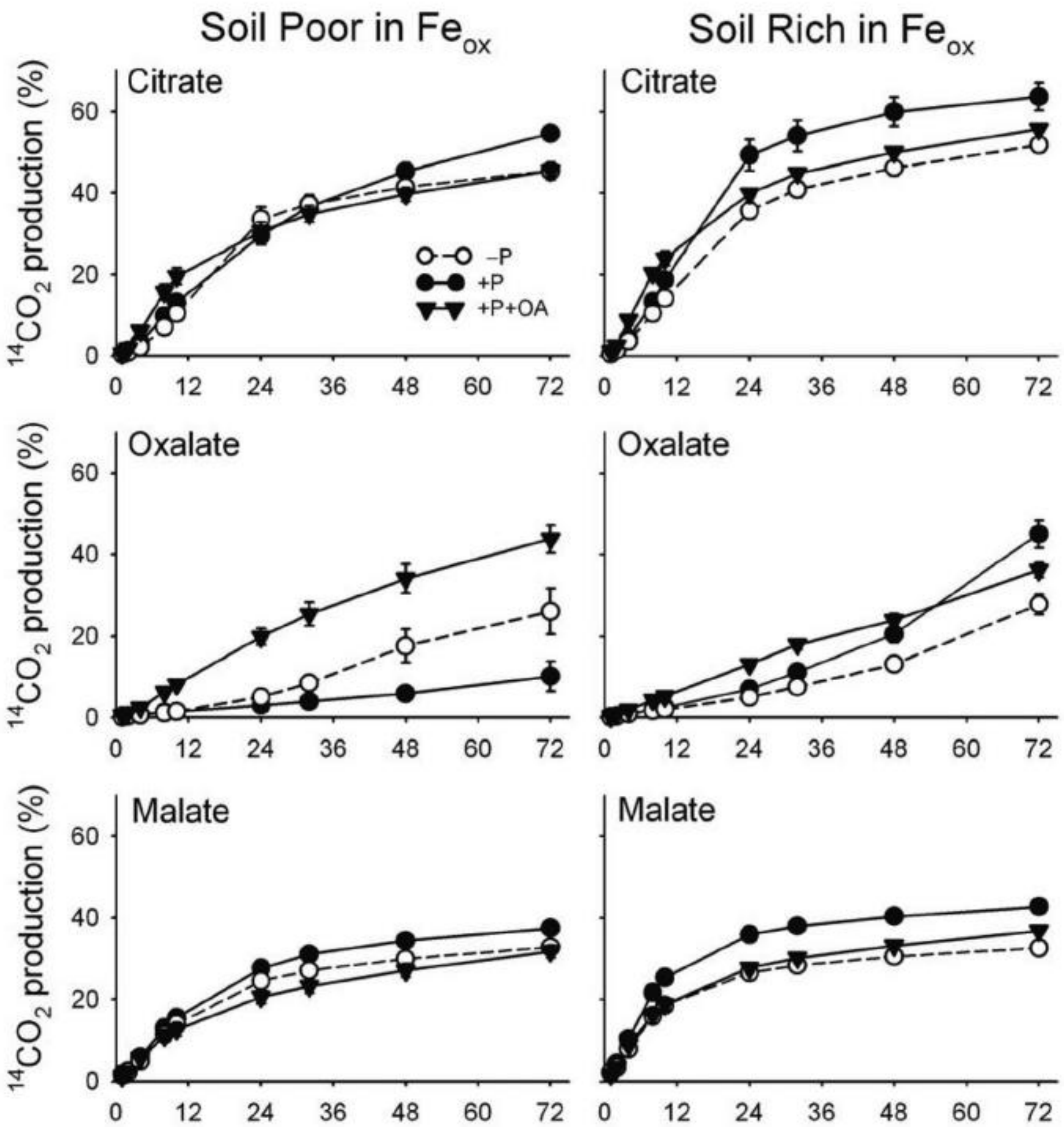
5. Organic acids

Treatment	Chlorophyll (mg g^{-1})	Ferric reductase activity (nmol g^{-1} h^{-1})
Poor in Fe_{ox}		
−P	4.5 a	263 b
+P	3.4 b	430 a
+P +OA	4.1 a	378 ab
P-value	0.007	0.035
Rich in Fe_{ox}		
−P	7.1	301 b
+P	6.4	1023 a
+P +OA	5.8	784 a
P-value	0.324	0.019

Key role of non-crystalline Fe oxides in the availability of Fe for plants (chlorophyll content in plants grown on soil rich in Fe > soil poor in Fe)

Organic acids partially alleviate the effect of P fertilization, specially for plants grown on the poor in Fe_{ox} soil

5. Organic acids



5. Organic acids

Root architecture using WinRhizo ® software – root scanning

Treatment	Diameter (cm)	Total Length (m $plant^{-1}$)	Surface area (cm^2 $plant^{-1}$)	Root volume (cm^3 $plant^{-1}$)
Poor in Fe_{ox}				
−P	0.83	3.48 a	0.91 a	1.91 a
+P	0.85	2.72 b	0.72 b	1.53 b
+P+OA	0.91	1.84 c	0.53 c	1.20 b
P-value	0.146	<0.001	<0.001	0.005
Rich in Fe_{ox}				
−P	0.80 b	2.47 a	0.68	1.36
+P	0.84 ab	2.37 ab	0.62	1.31
+P+OA	0.89 a	1.91 b	0.53	1.19
P-value	0.040	0.015	0.051	0.344

+P → increased P in soil solution

+P+OA → increased P and Fe in soil solution → inhibits the root response mechanisms

6. Conclusions

1. Fe strategy and plant sensitivity to Fe chlorosis are related to the magnitude of the negative effect of P fertilization

2. The **relation P Olsen / Fe_{ox}** —indicating degree of coverage of the poorly crystalline Fe oxides by P— is **useful to understand the effect of P fertilization on Fe chlorosis**

3. High values of P Olsen should be avoided in calcareous soils in order not to aggravate Fe chlorosis in olive trees, minimizing fertilizer cost and water eutrophication, especially in soils with less than 0.35 g kg^{-1} Fe_{ox} content

4. **High P fertilization can aggravate Fe chlorosis symptoms of sensitive plants grown on calcareous soils. This effect depends on Fe uptake strategy, species, age, soil available P and non crystalline Fe oxide content**.

Thank you for your attention

FUNDACION RAMON ARECES

Postdoctoral fellowship