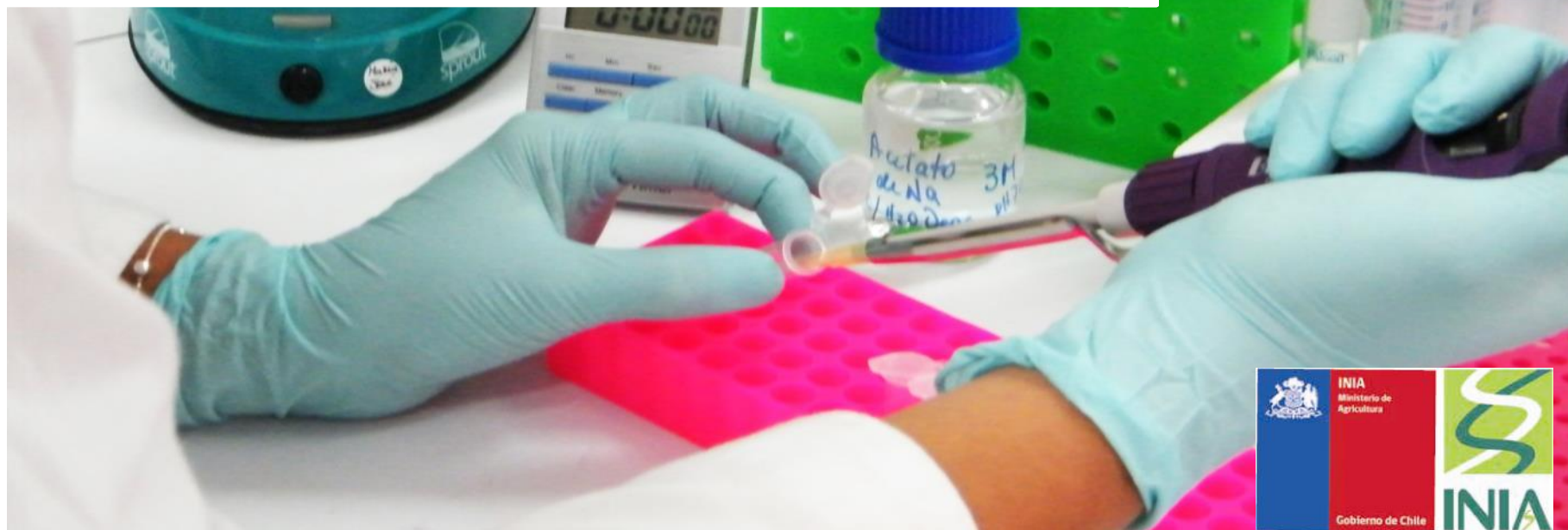


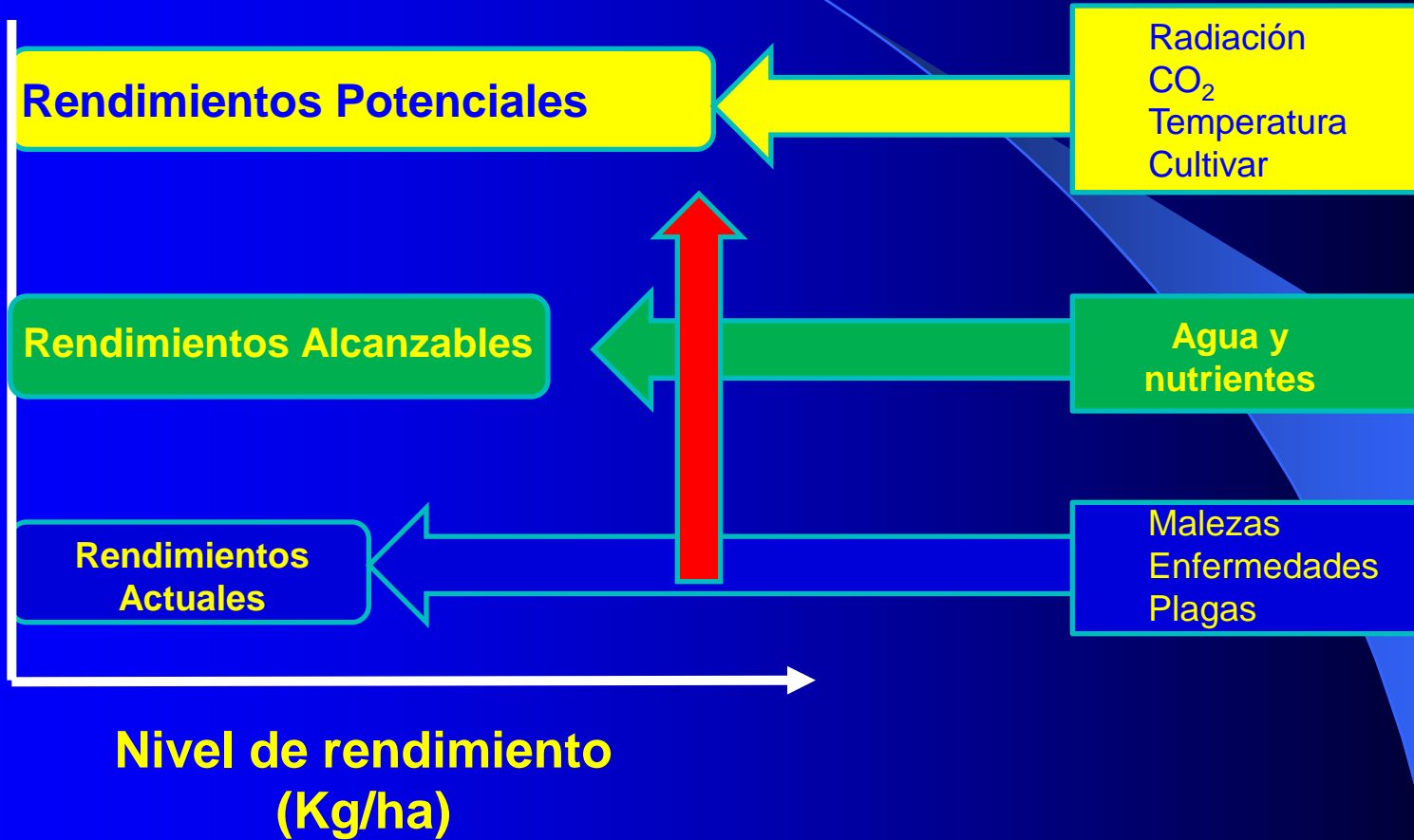
Estrategias de manejo en fertilización fosforada basada en estudios ecofisiológicos

Patricio Sandaña G.
Ing. Agr., M. Sc., Dr.

Instituto de
Investigaciones
Agropecuarias
INIA



Tipos de rendimiento



Cultivo de trigo y cebada en Chile

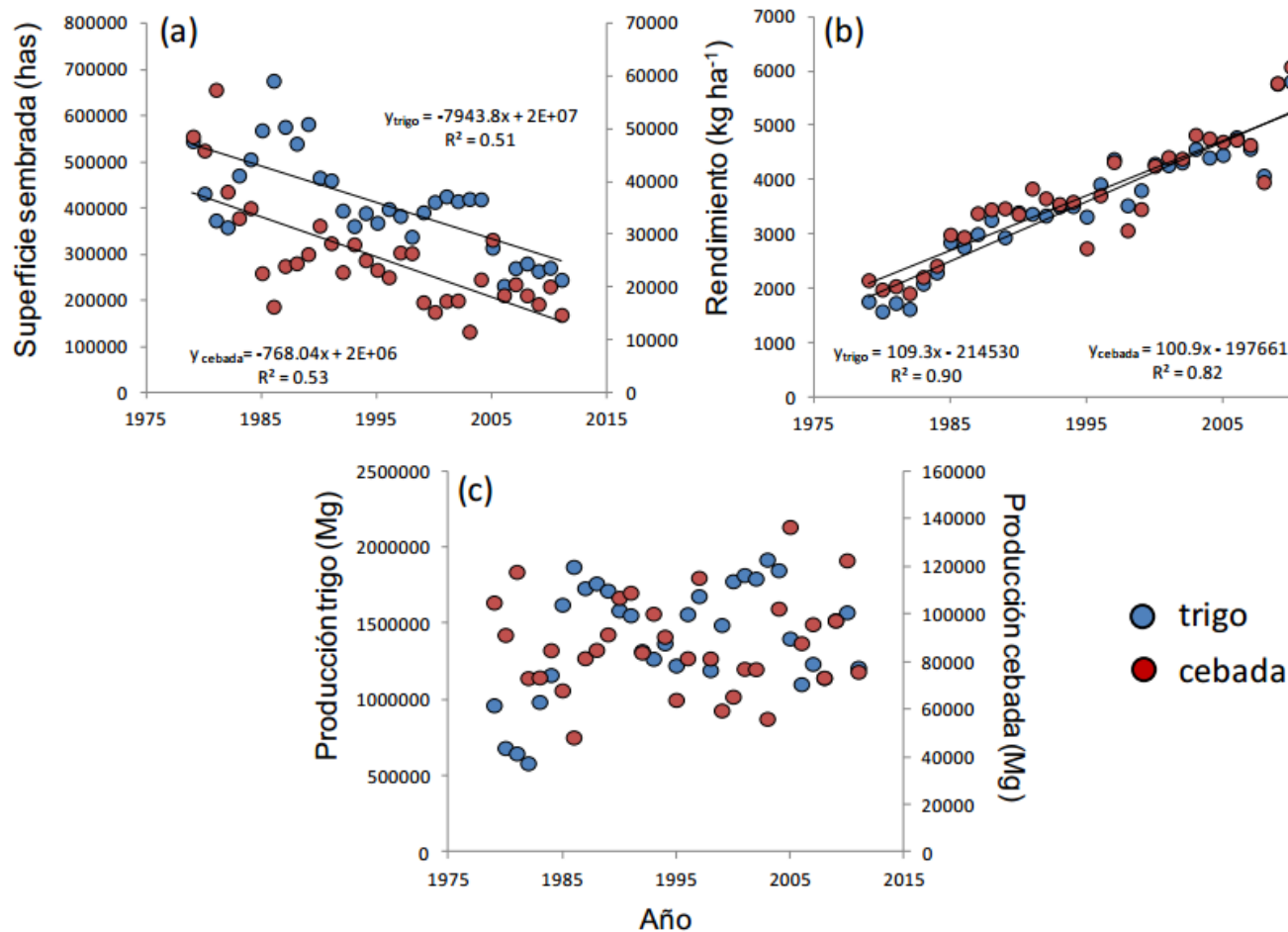
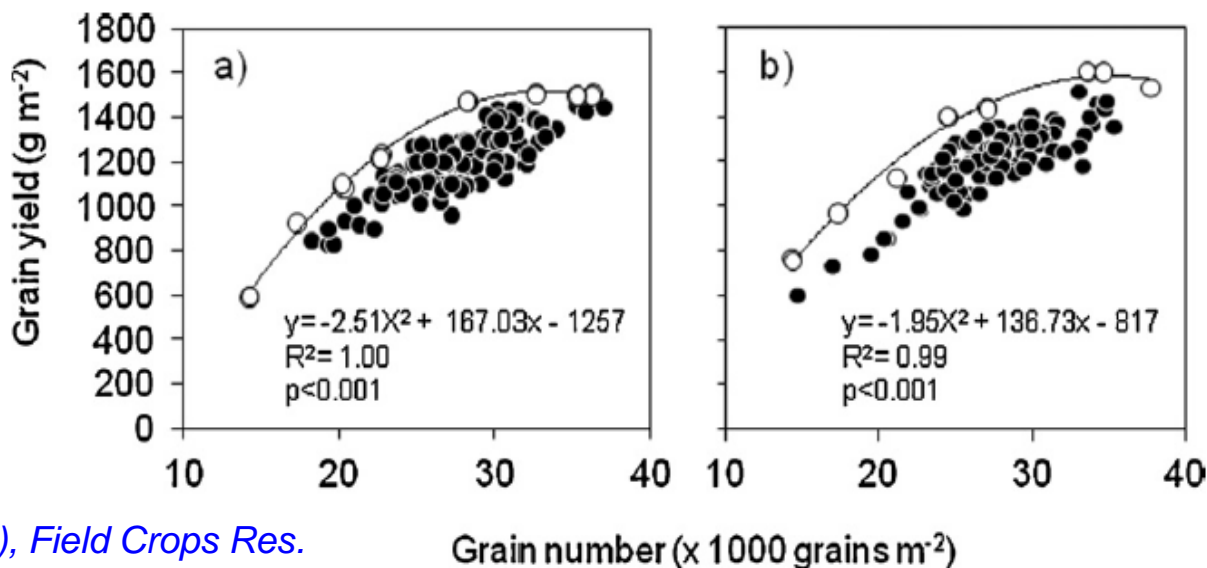


Figura 1. Superficie (a), rendimiento (b) y producción (c) de trigo y cebada en Chile desde el año 1979 al 2011.

Existe una importante brecha entre los rendimientos actuales y los potenciales en trigo

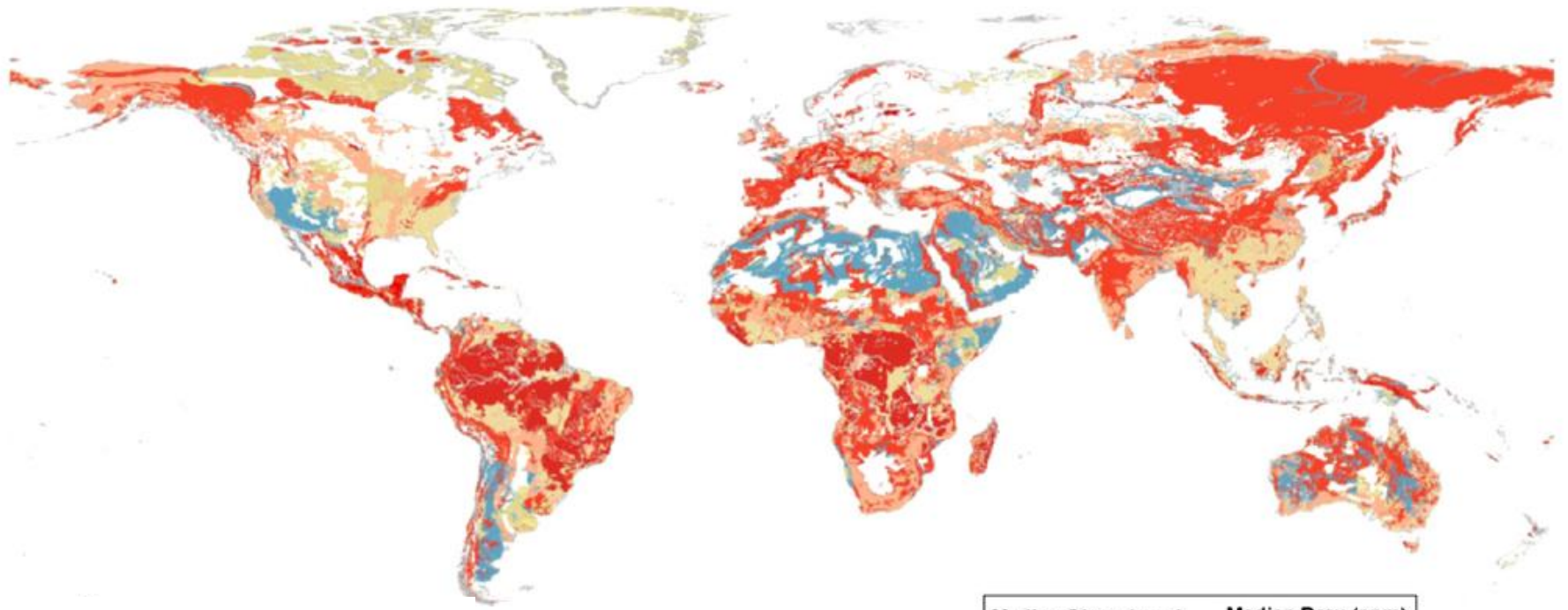


Bustos et al. (2013), Field Crops Res.

Grain number (x 1000 grains m⁻²)

Fig. 3. Relationship between grain yield and grain number of 105 DH lines in S₁ (a) and S₂ (b) of Exp. 1. The highest yields for different grain numbers (open circles) were fitted by a quadratic regression. The other lines are shown as closed circles.

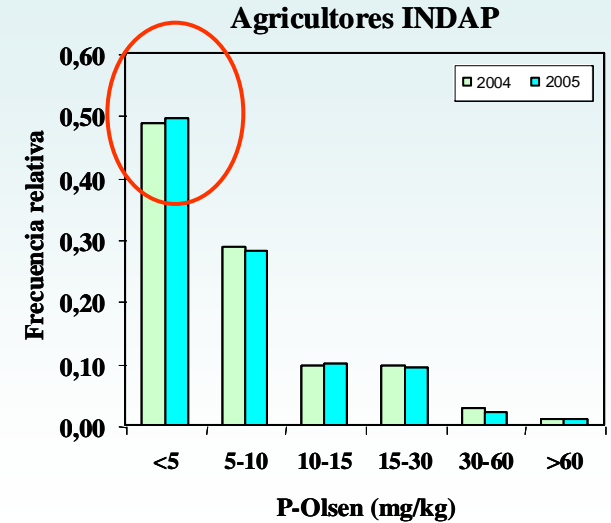
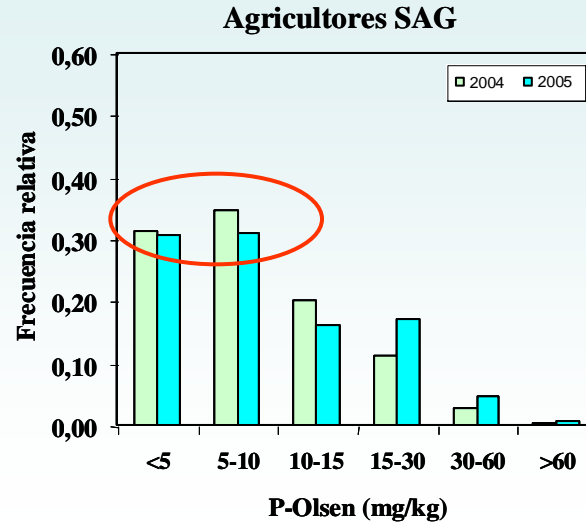
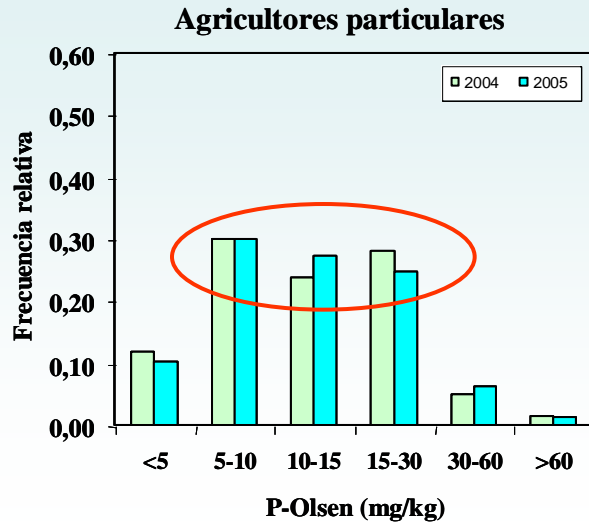
- **Cultivar**
- **Fecha de siembra**
- **Fertilización**
- **Riego**
- **Control de enfermedades y plagas**



Median Olsen (ppm)	Median Bray (ppm)
2 - 3	2.5 - 5
3.1 - 4	5.1 - 10
4.1 - 5	10.1 - 15
5.1 - 6	15.1 - 20
6.1 - 7	20.1 - 25
7.1 - 8	25.1 - 30
8.1 - 9	30.1 - 35
9.1 - 10	35.1 - 40
10.1 - 11	40.1 - 45

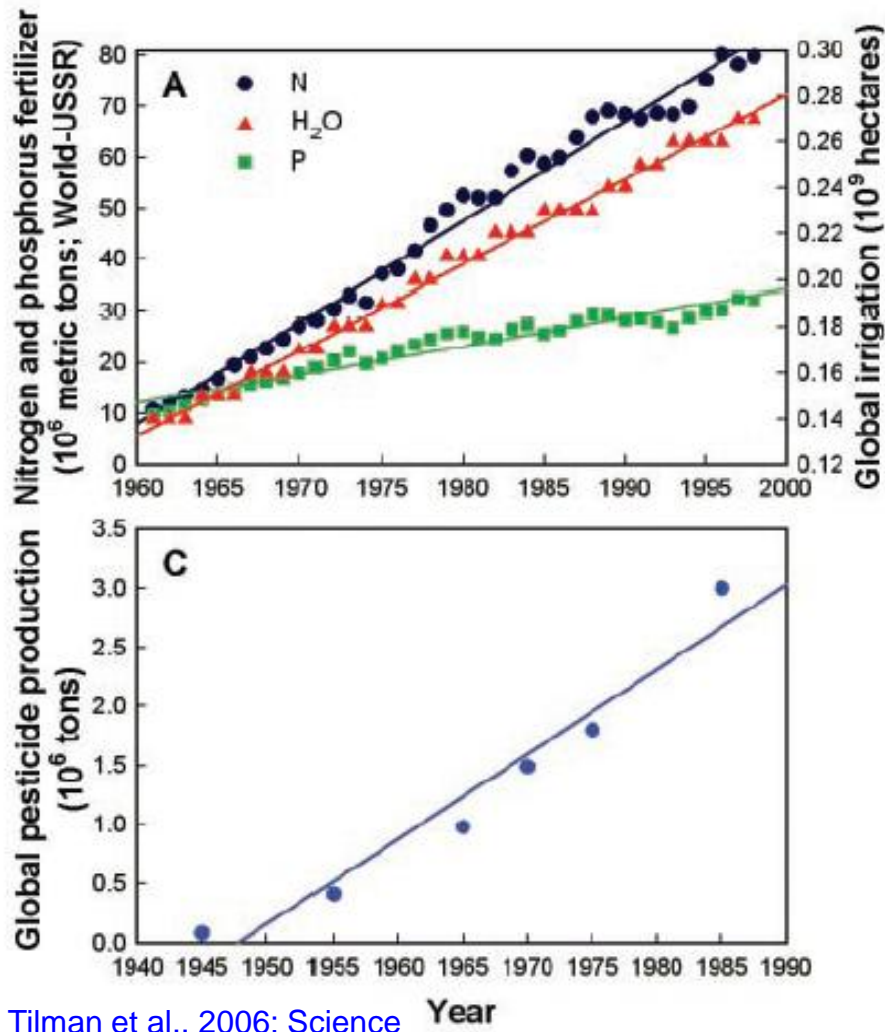
Lynch, 2011. Plant Physiology

Distribución de frecuencia de muestras P-Olsen, LAS UACH



Rango P-Olsen (mg/kg)	Frecuencia Relativa (%)		
	Agricultores	Agricultores Beneficiarios	
	Particulares	SAG	INDAP
< 5	11,0	30,9	49,1
5-10	30,0	32,9	28,4
10-15	25,5	18,0	9,7
15-30	26,4	14,0	9,4
30-60	5,7	3,7	2,5
> 60	1,4	0,5	0,9

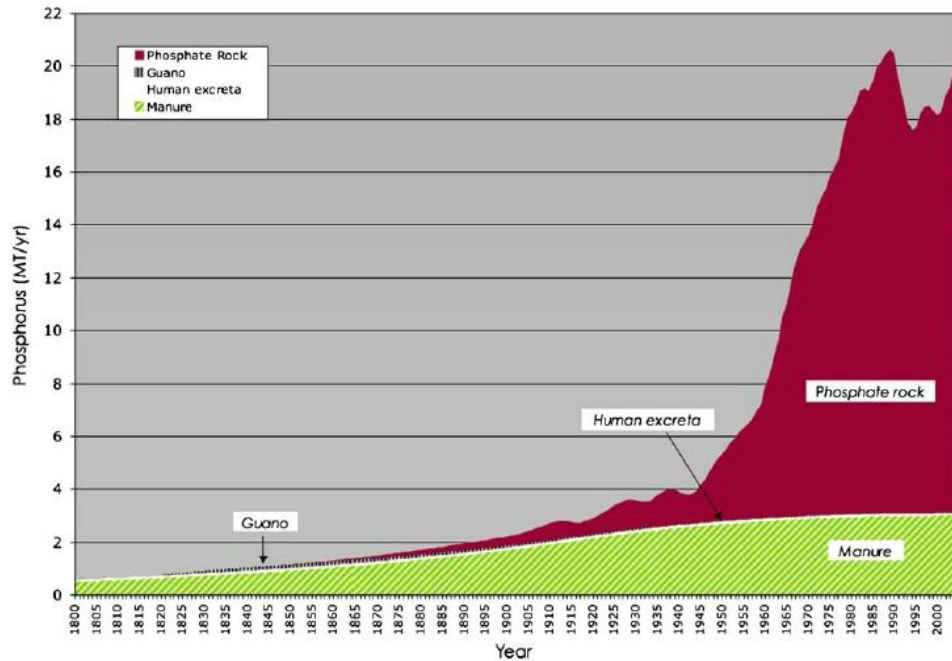
Evolución en el uso de insumos



Tilman et al., 2006; Science



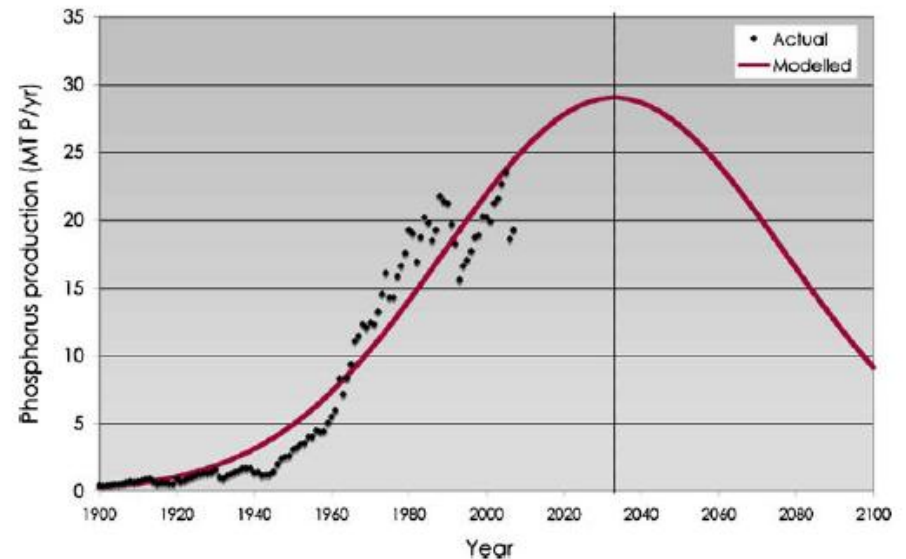
Historical global sources of phosphorus fertilizers (1800-2000)



Cordell et al., 2009; Glob. Envi. Chang.

hay necesidad de generar variedades más eficientes en el uso de fósforo y mejorar la eficiencia del uso de fertilizantes fosforados

Peak phosphorus curve



Eficiencia de uso externo de fósforo

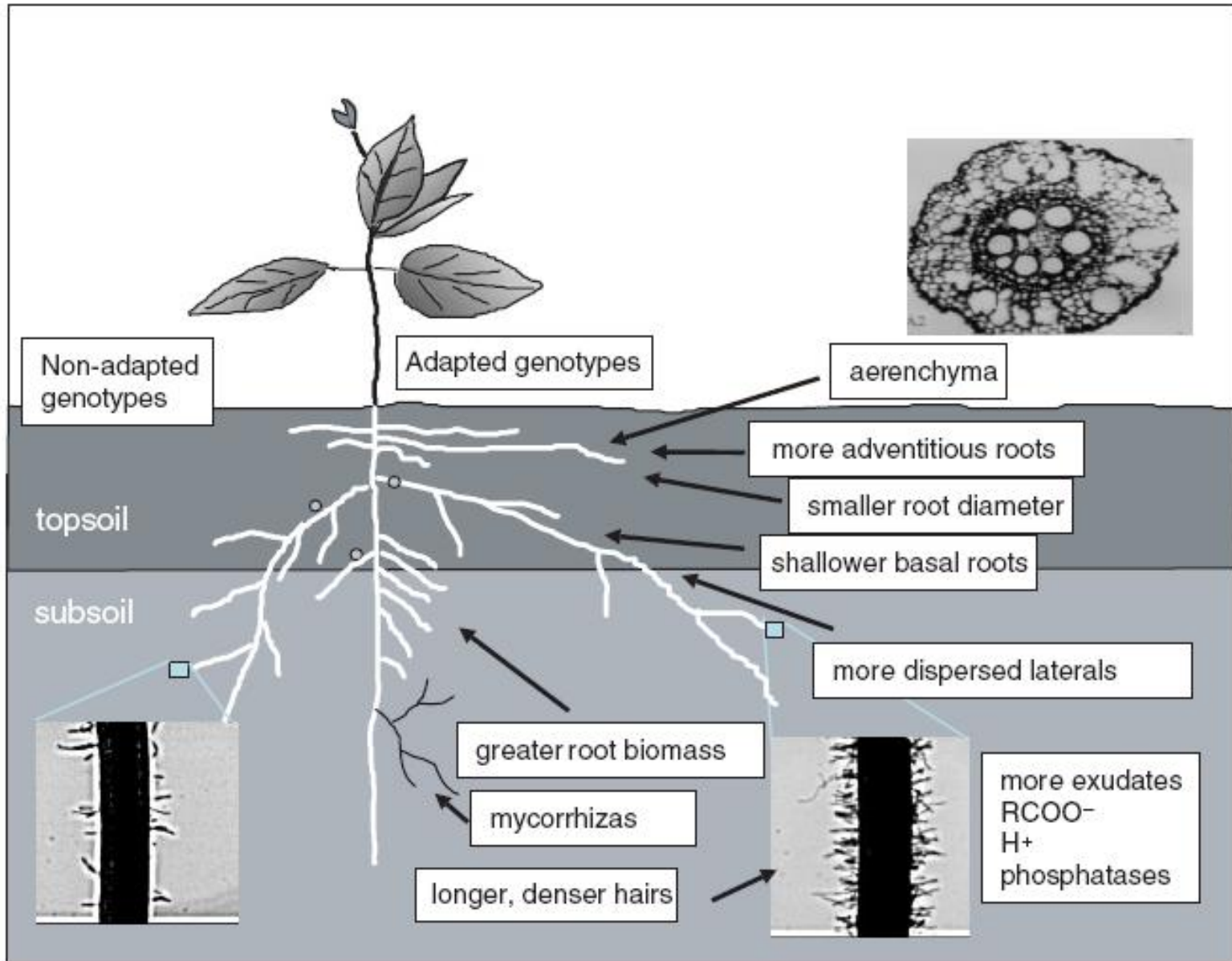


Fig. 4. Root adaptations to low phosphorus availability, as discussed in the text.

(Lynch. 2007; Australian Journal of Botany)

Hay variabilidad genotípica en la eficiencia de absorción

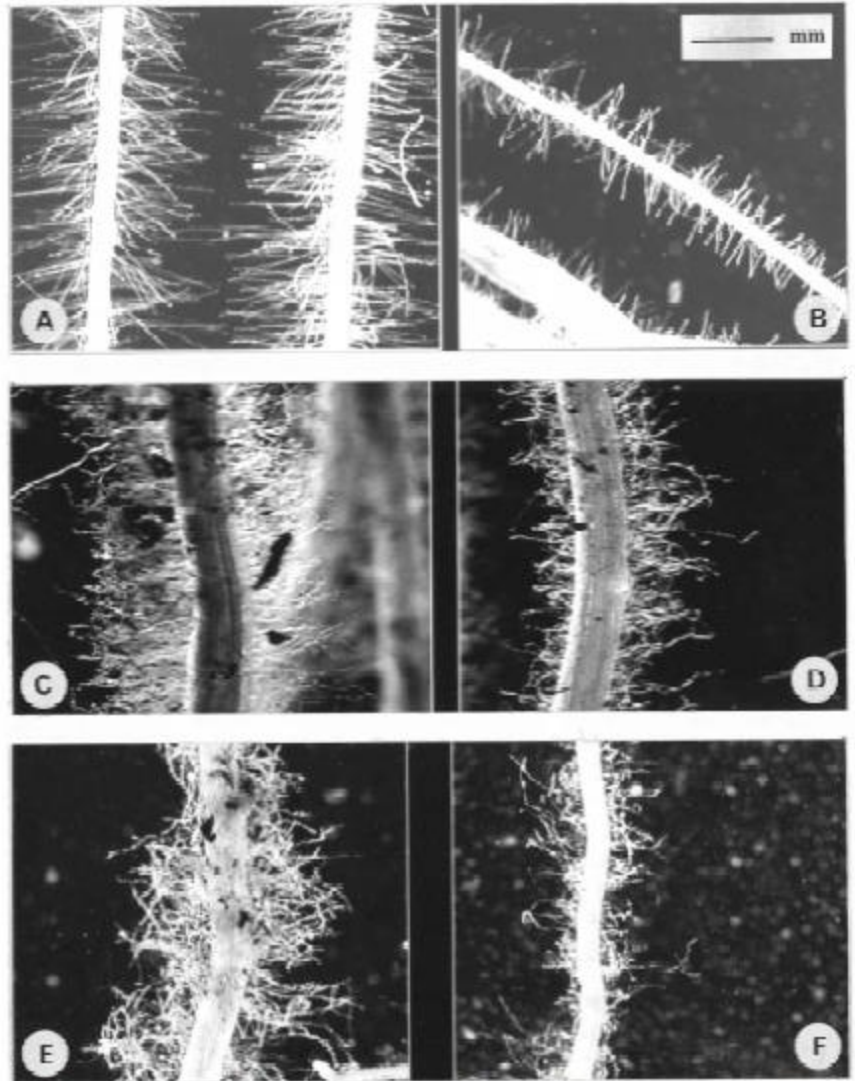
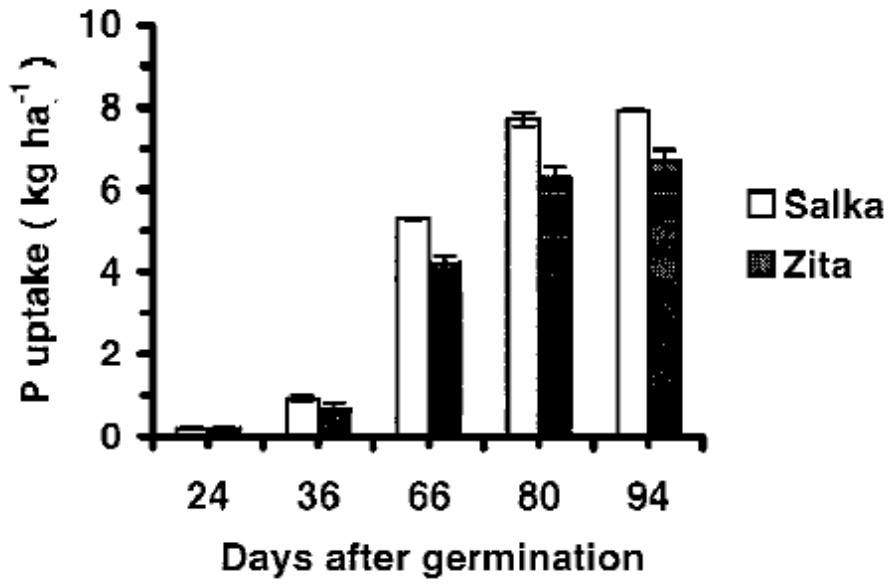
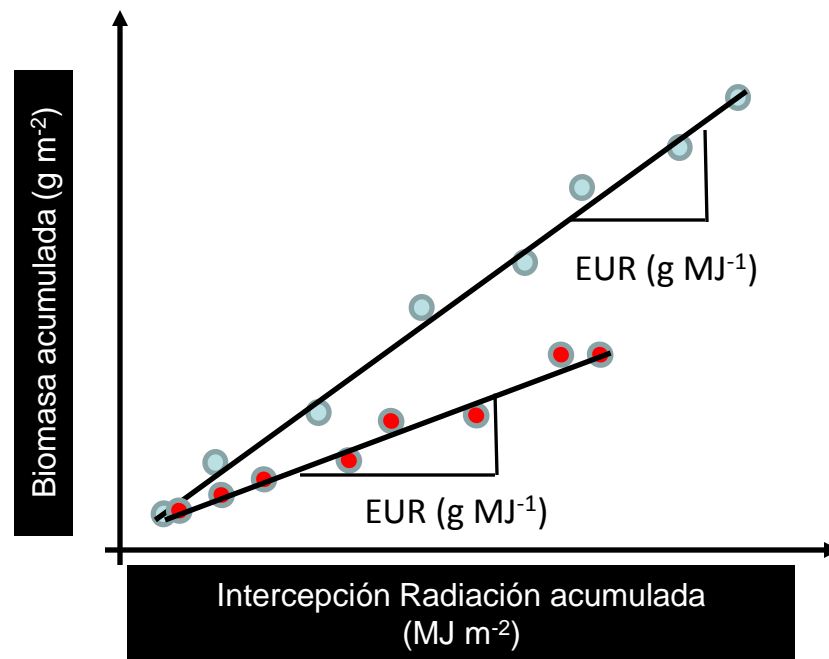
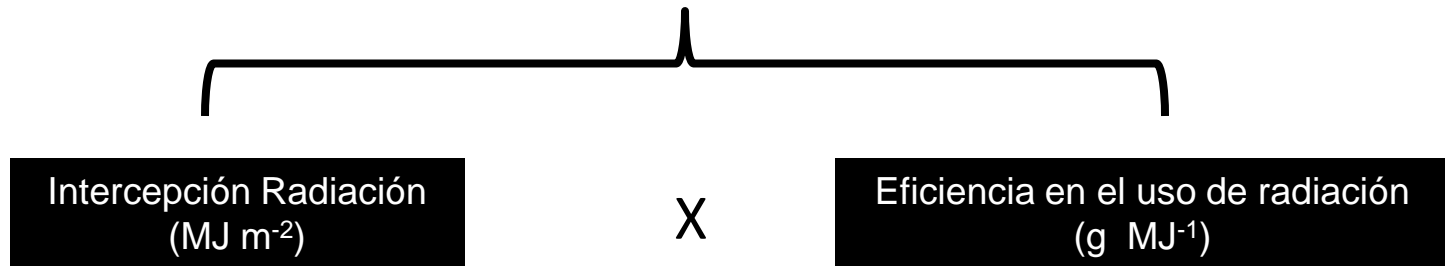


Figure 5. Root hairs of two spring barley cultivars (Salka and Zita) in different plant culture techniques. (A) Salka and (B) Zita in nutrient solution culture. (C) Salka and (D) Zita in soil culture. (E) Salka and (F) Zita in field experiment.

Gahoonia et al., (1999) Plant and Soil

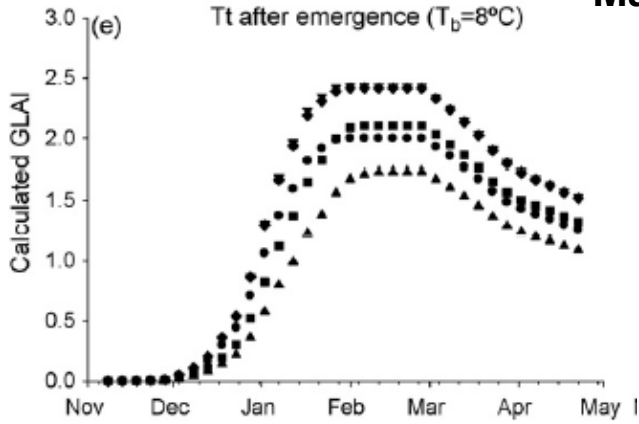
¿La deficiencia de P como afecta al cultivo?

$$\text{Rendimiento (g m}^{-2}\text{)} = \text{Biomasa del cultivo (g m}^{-2}\text{)} \times \text{Índice de cosecha}$$

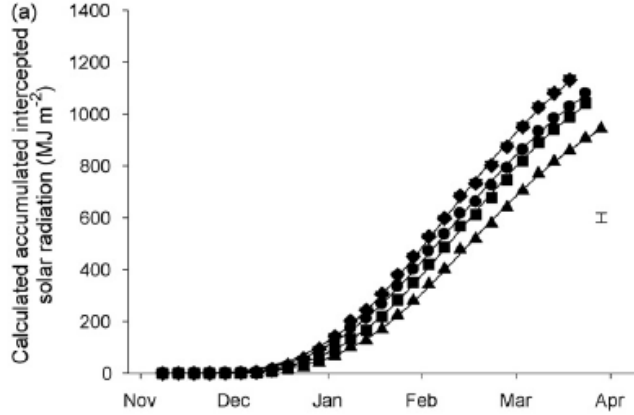


Variaciones en la disponibilidad de P podrían afectar los componentes ecofisiológicos de captura y el uso de la radiación

Maíz



Fletcher et al. 2008; Field Crops Research

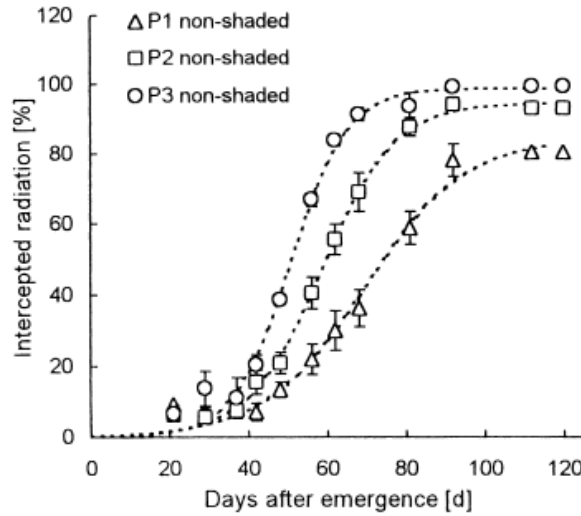
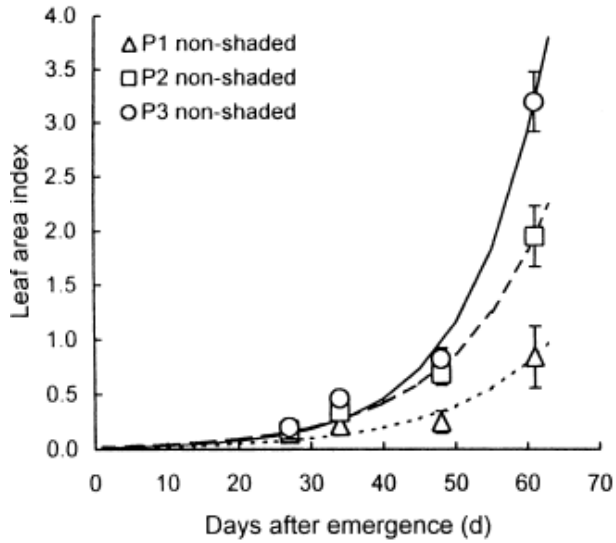


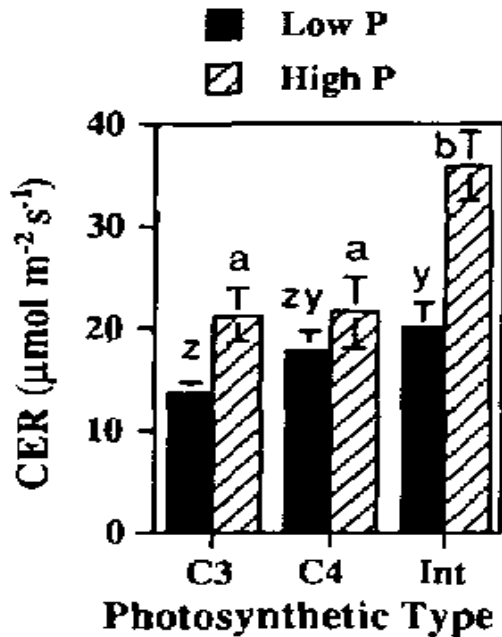
< IAF y < RI

Trigo

Rodríguez et al. 2000 Field Crops Research

¿Fotosíntesis?





Halsted & Lynch. 1996; *J. Exp. Bot.*

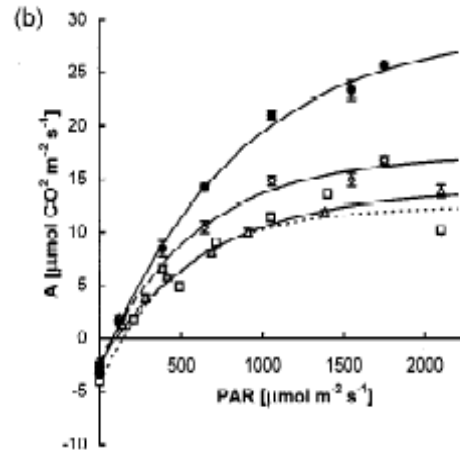


Figure 3. Light response curves of photosynthesis (A) for leaf 4 (a) and leaf 5 (b), at the different levels of P supply. Every dot is the average of three replications and bars represent the standard errors. Lines were fitted by Equation (2).

Rodríguez et al.. 1998; *Plant and Soil*

Trigo

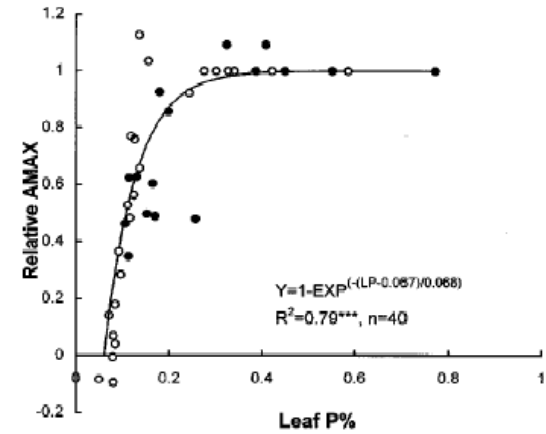
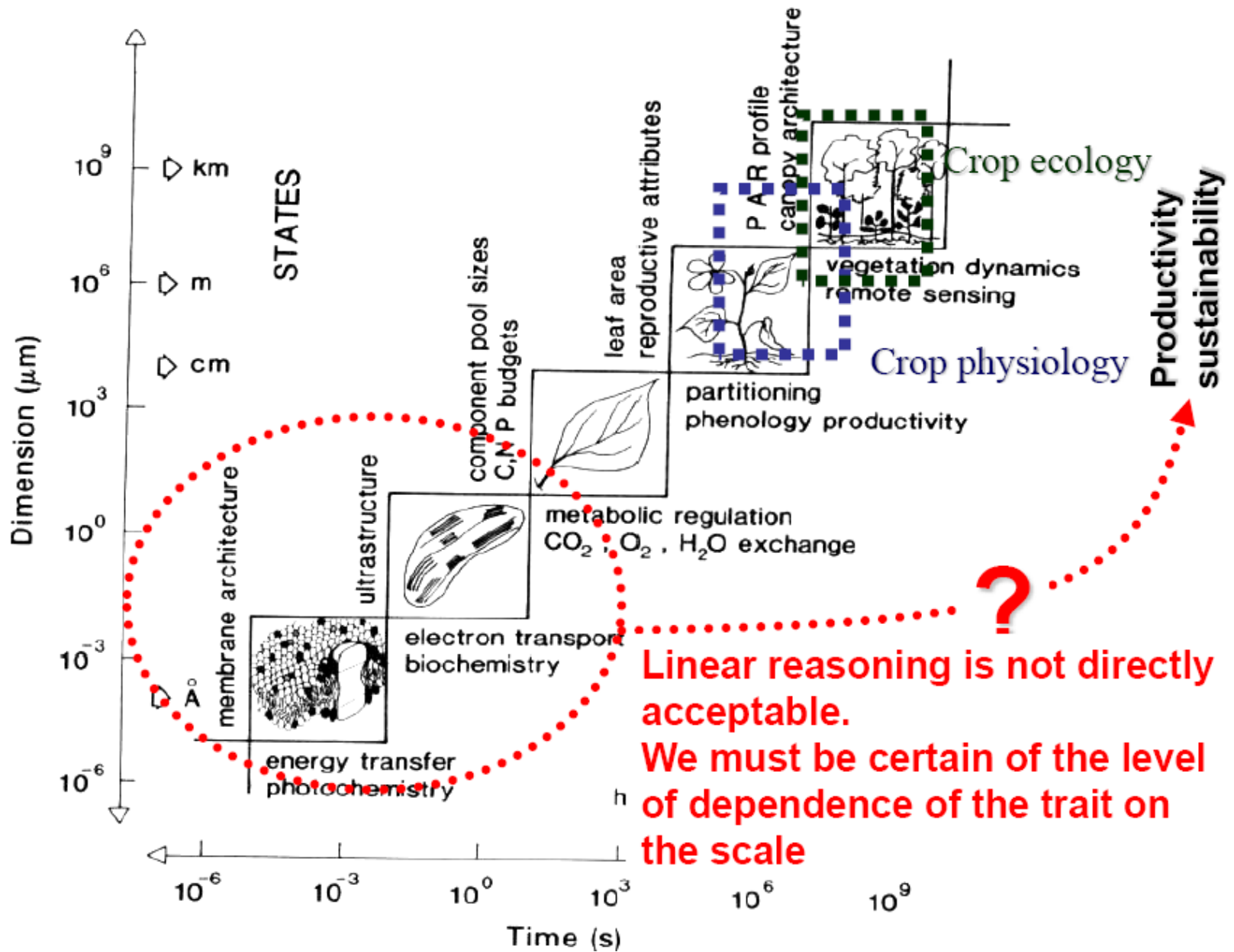


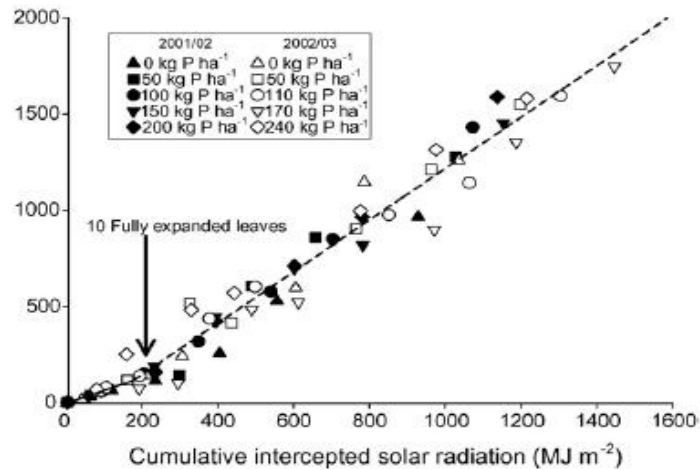
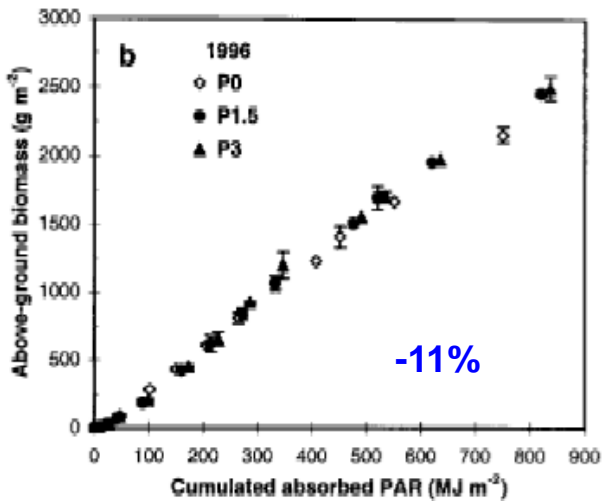
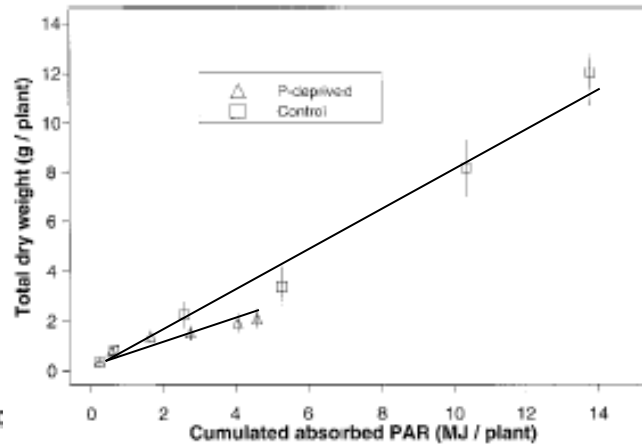
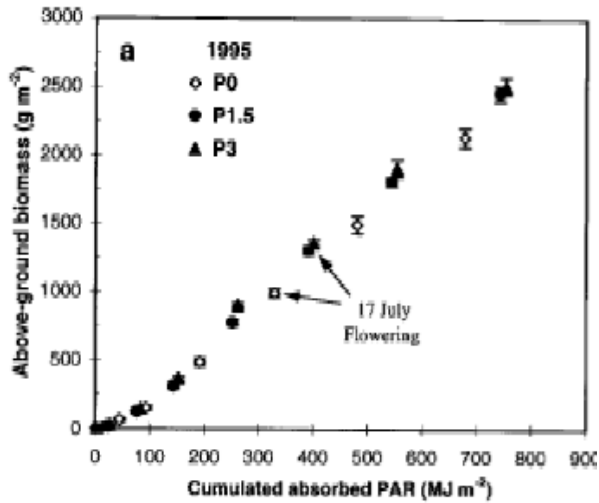
Figure 4. Relative photosynthesis at high radiation calculated with respect to the value of AMAX of P4 plants for each harvest. Closed symbols are from recently expanded leaves and open symbols from older leaves.

Sin embargo, a nivel de cultivo no hay respuestas claras en la EUR



Maíz *Mollier & Pellerin 1999; J. Exp. Bot.*

Plenet et al. 2000; Plant and Soil



Fletcher et al. 2008; Field Crops Research

Treatment		IPAR (MJ/m ² /d)	RUE (g/MJ)
Light	P level		
<i>Expt 1</i>			
1.00	High	11.5	2.0
1.00	Low	9.0	2.0
0.56	High	5.3	2.1
0.56	Low	4.2	2.2
S.E.D. (6 D.F.) [‡]		0.11	ns
S.E.D. (6 D.F.) [§]		0.20	ns
<i>Expt 2</i>			
1.00	High	8.4	2.5
1.00	Low	4.4	1.8
0.56	High	4.5	2.5
0.56	Low	2.2	1.6
S.E.D. (6 D.F.) [‡]		0.34	0.30
S.E.D. (6 D.F.) [§]		0.27	0.33

Lázaro et al. (2009); J. Agric. Sci.

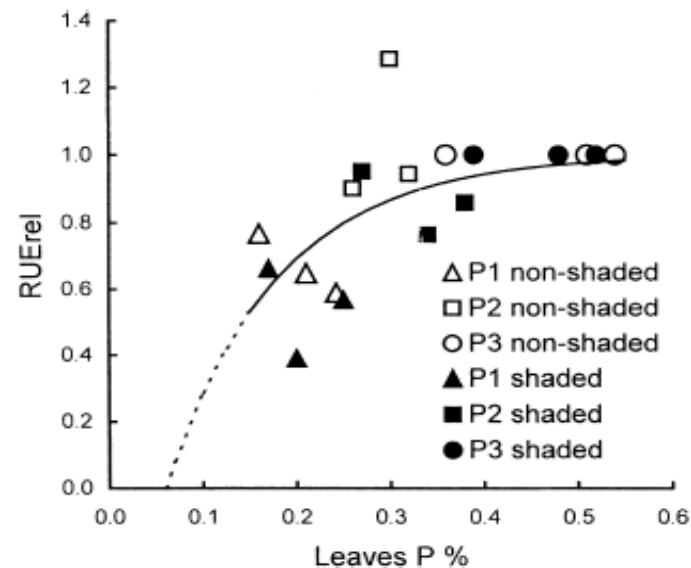
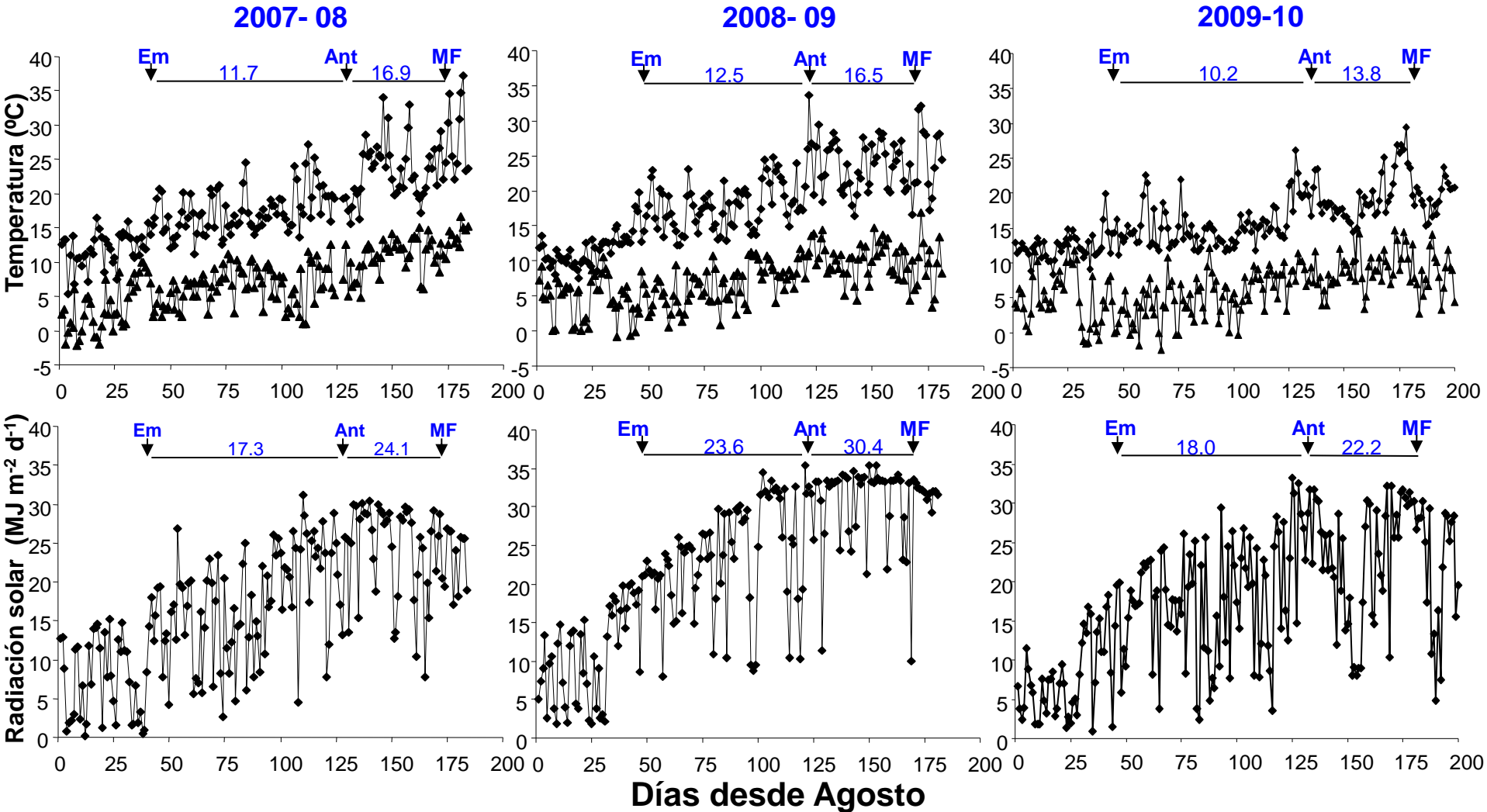


Fig. 9. Relative values of RUE with respect to the control non-shaded and shaded treatments, as a function of the concentration of P in the leaves. Lines are fitted by Eq. (4).

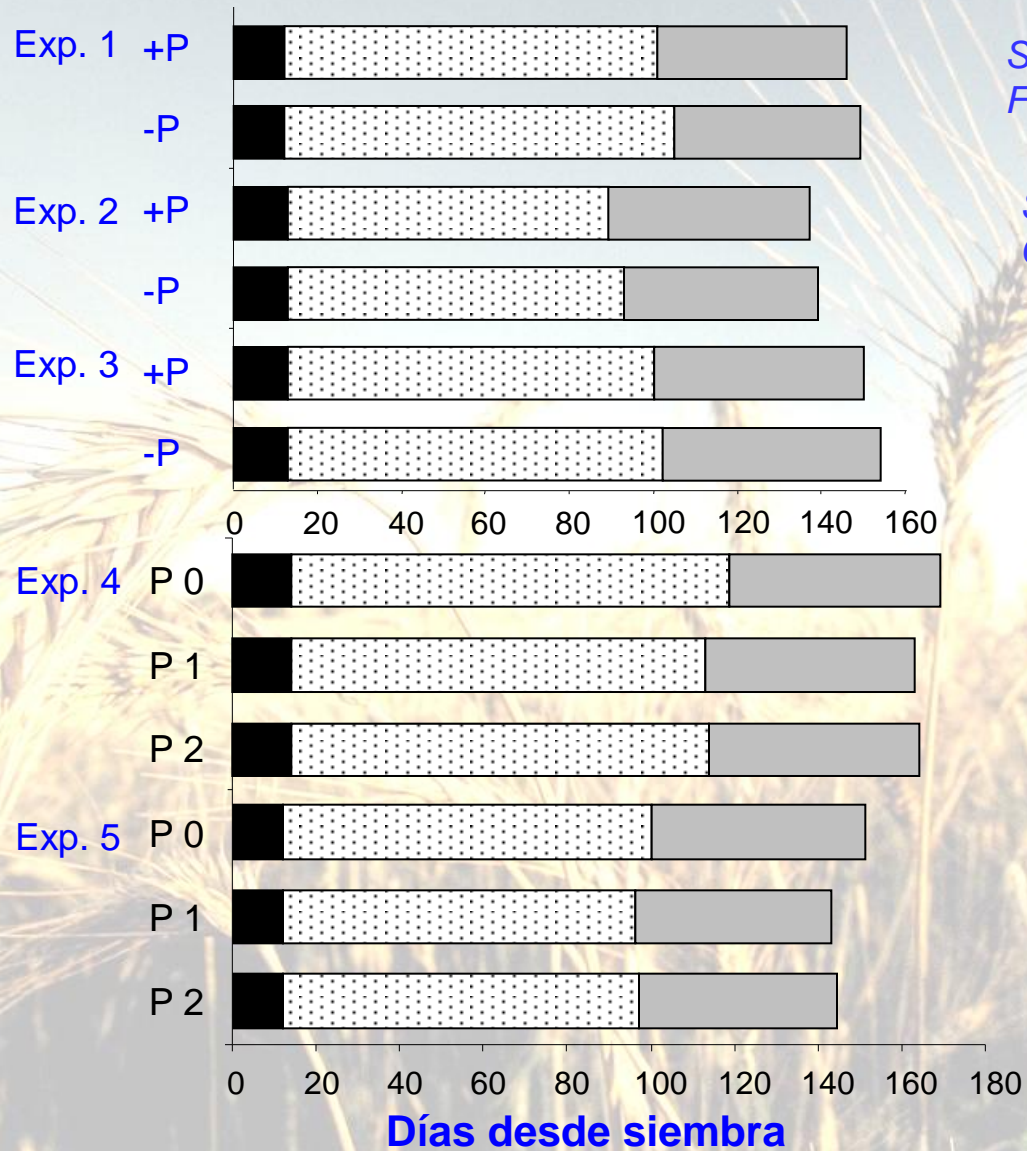
Rodríguez et al., 2000; Field Crops Res.

Algunos resultados en el sur de Chile

CONDICIONES CLIMATICAS EN EXPERIMENTOS



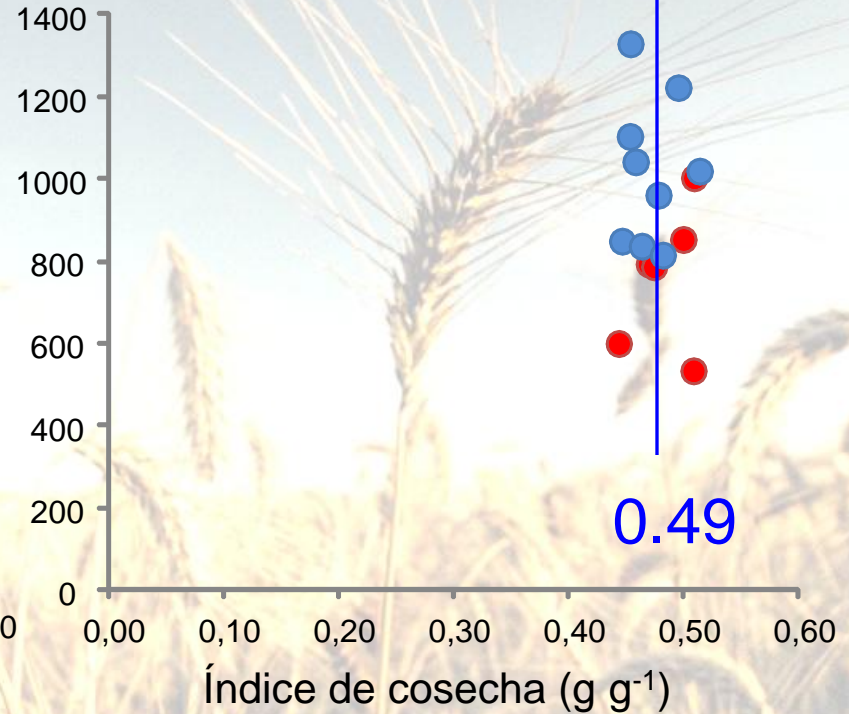
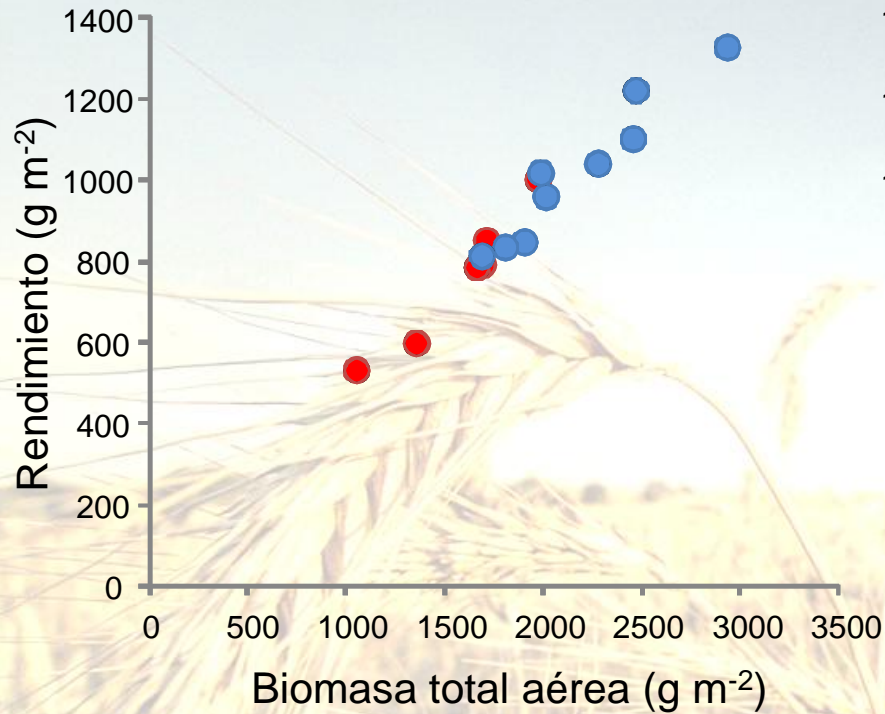
EFECTO DEL FOSFORO EN FENOLOGIA



*Sandaña and Pinochet, 2011.
Field Crops Res.*

*Sandaña et al., 2012 Field
Crops Res.*

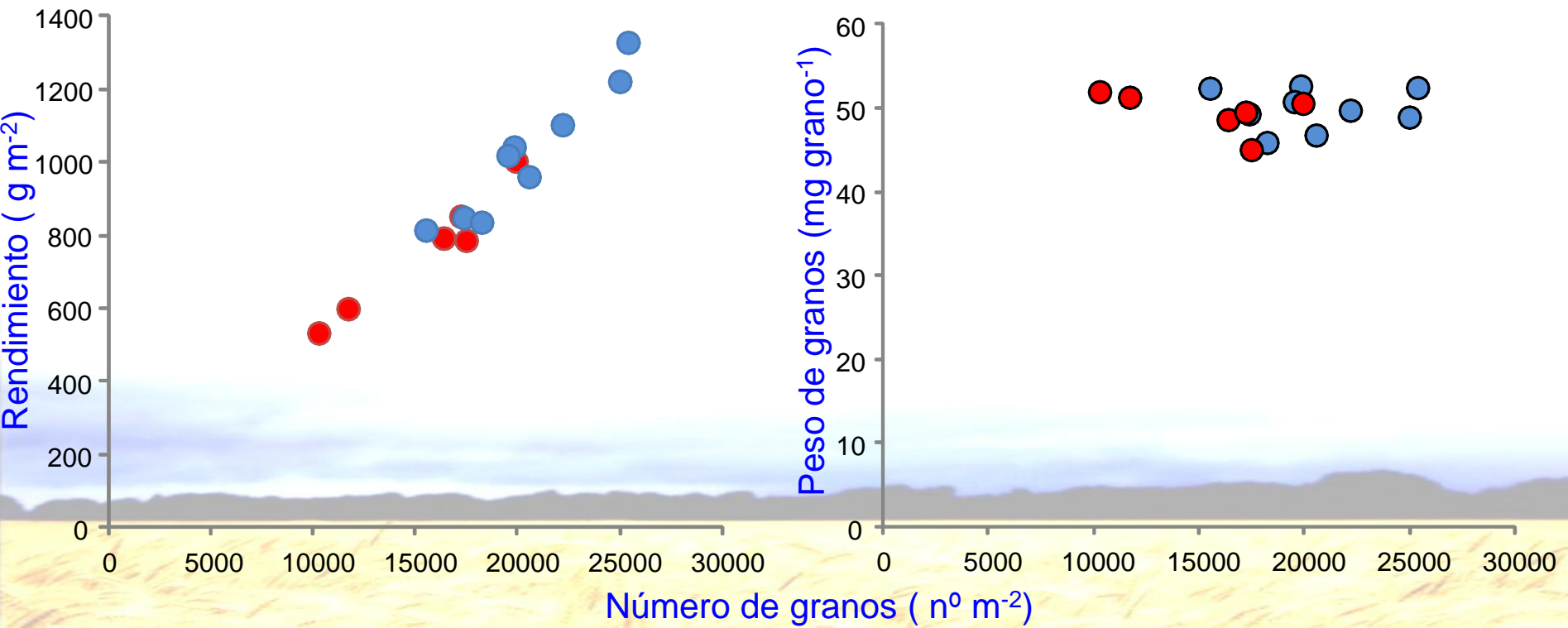
BIOMASA, PARTICION Y SU IMPACTO EN RENDIMIENTO



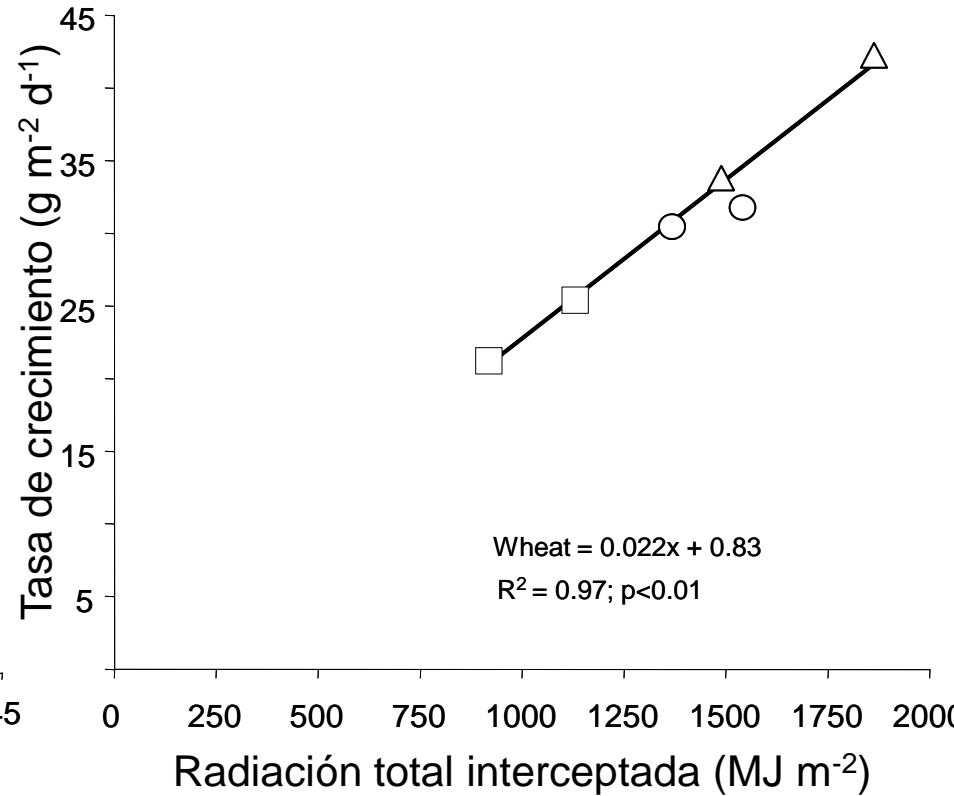
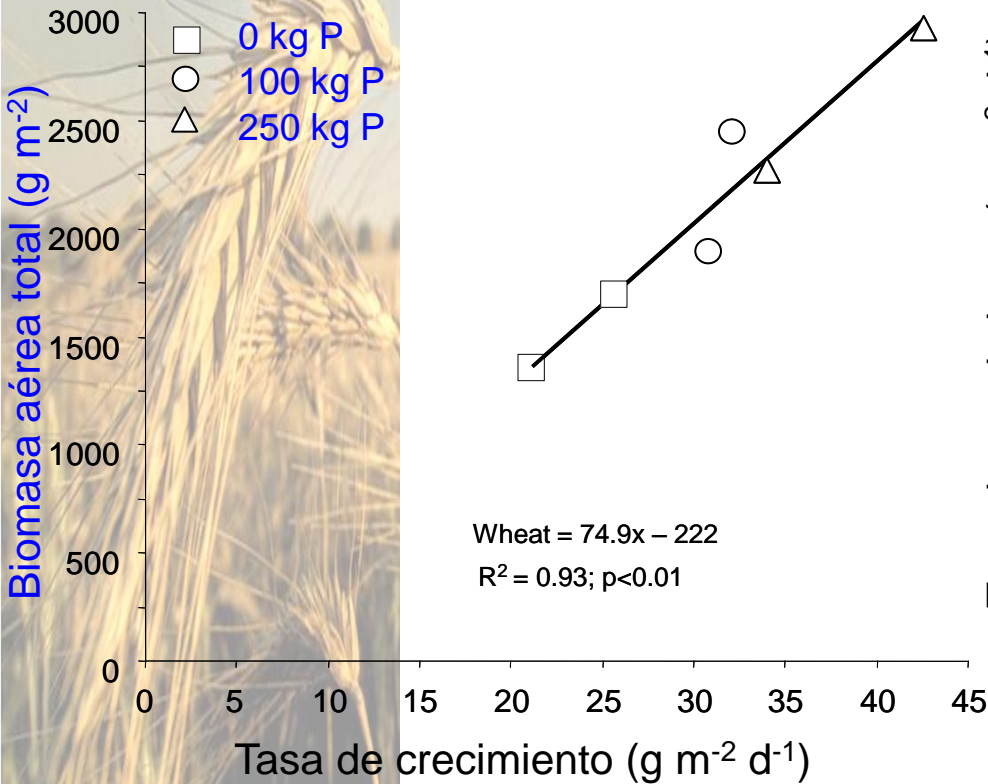
*Sandaña and Pinochet, 2011.
Field Crops Res.*

*Sandaña et al., Field Crops
Res. (2012)*

NUMERO Y PESO DE GRANOS



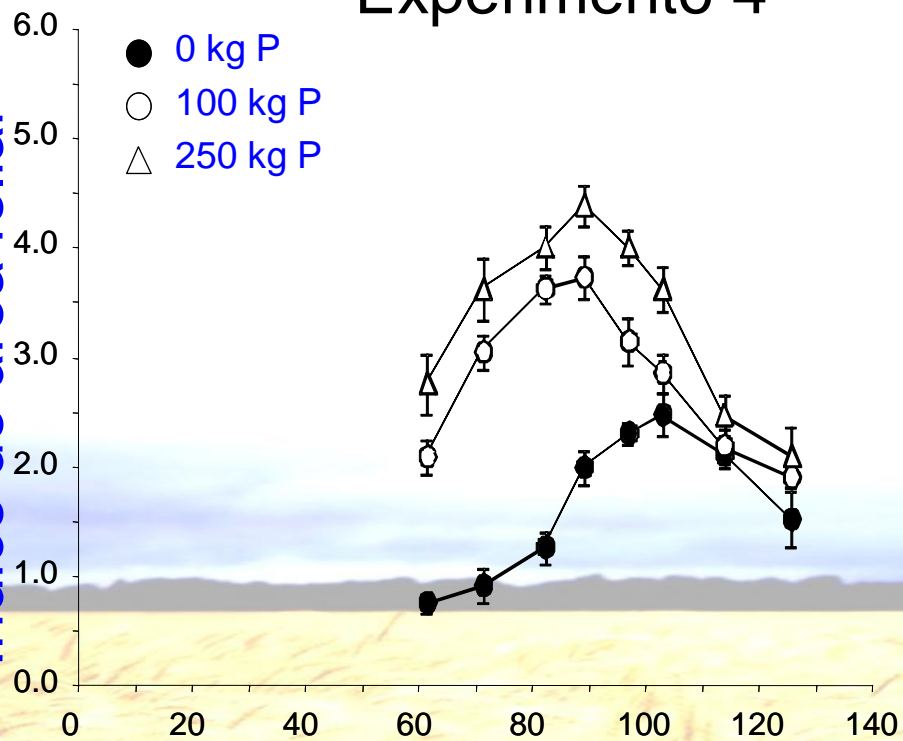
CAPTURA Y USO DE RADIACIÓN



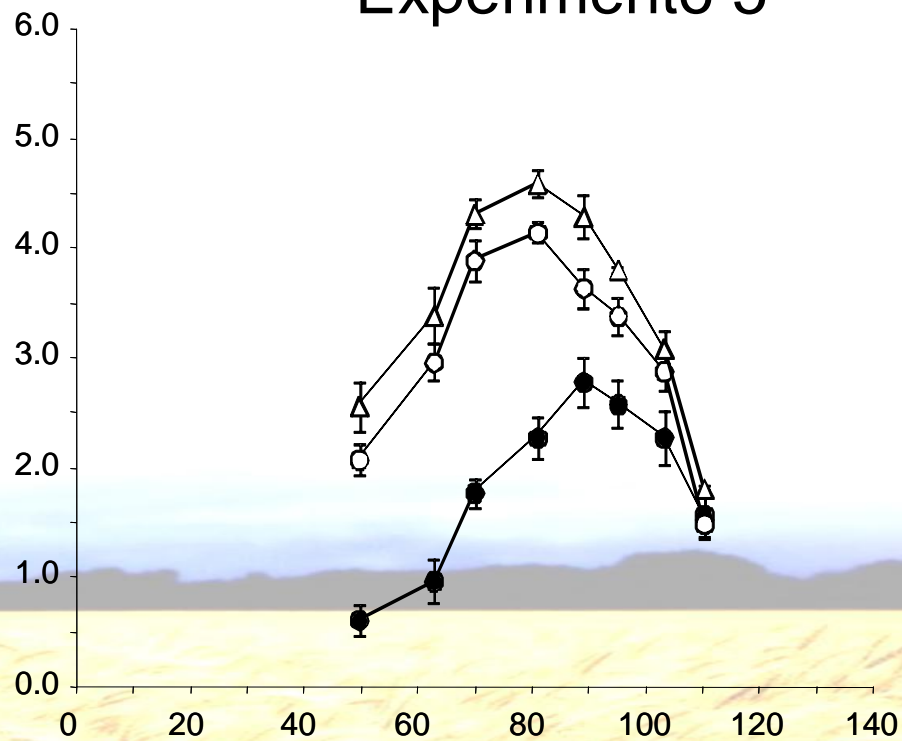
Sandaña et al., Field Crops Res. (2012)

VARIACION DEL INDICE DE AREA FOLIAR

Experimento 4



Experimento 5

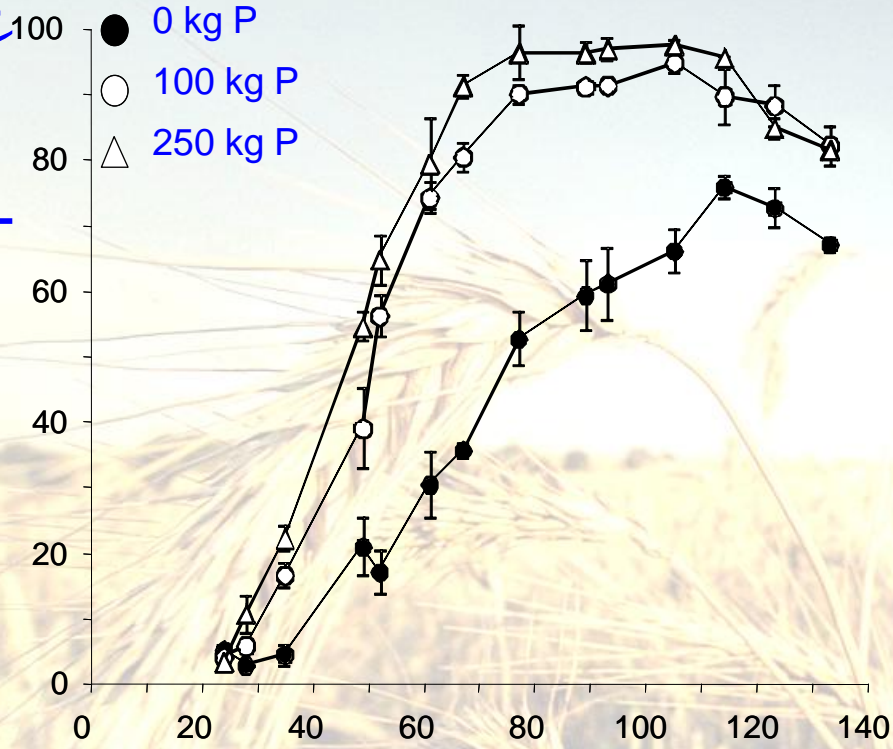


Días desde emergencia

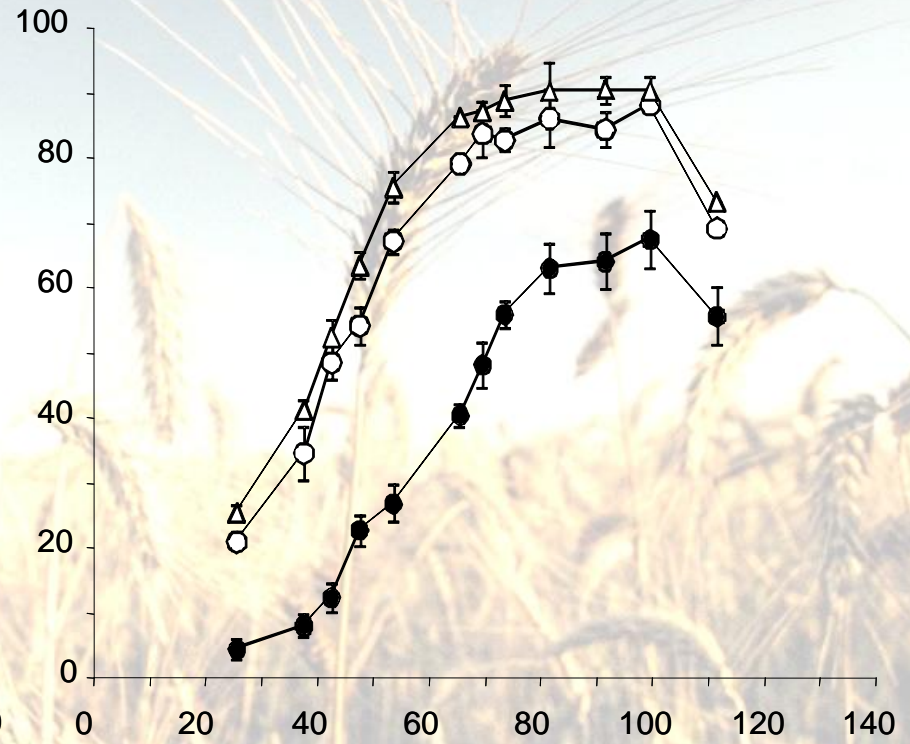
RADIACION INTERCEPTADA

Radiación interceptada (%)

Experimento 4



Experimento 5



Días desde emergencia

EFICIENCIA DE USO DE LA RADIACION

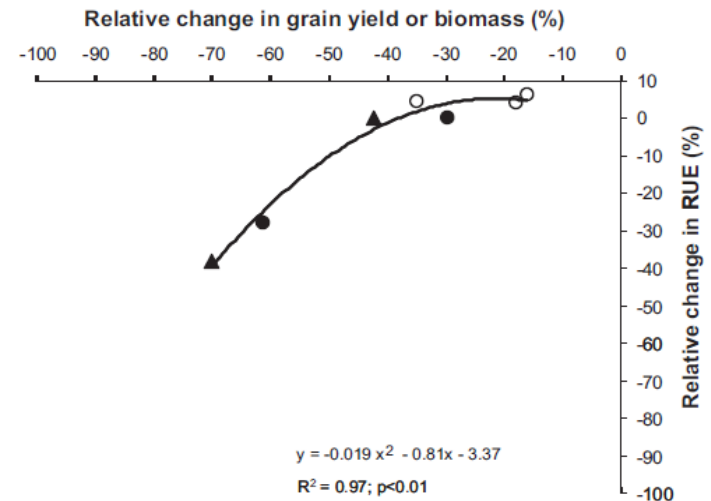
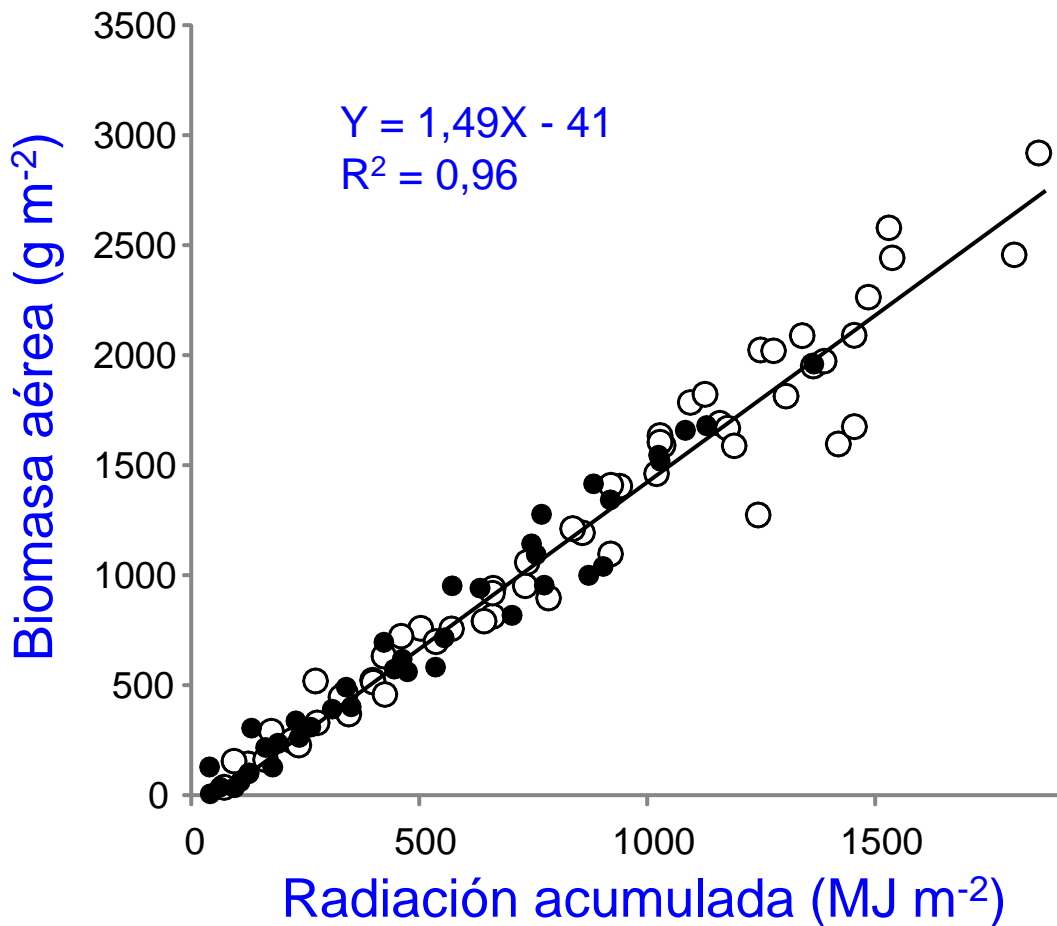
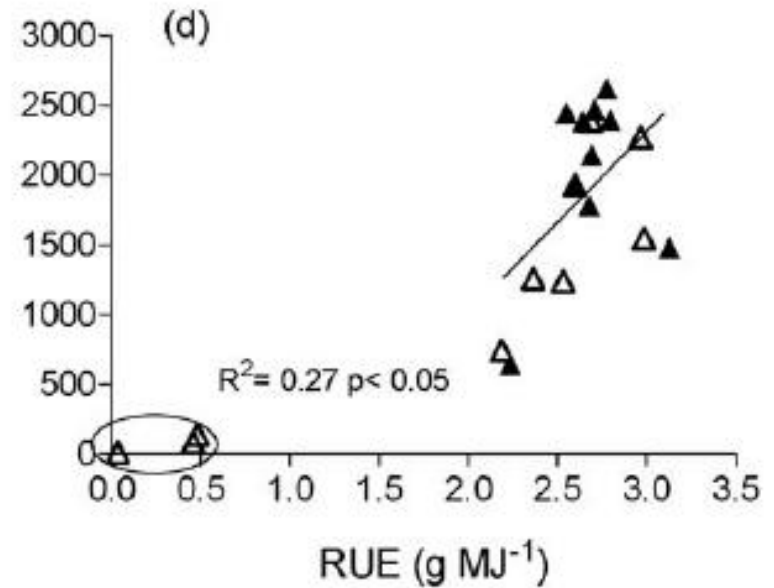
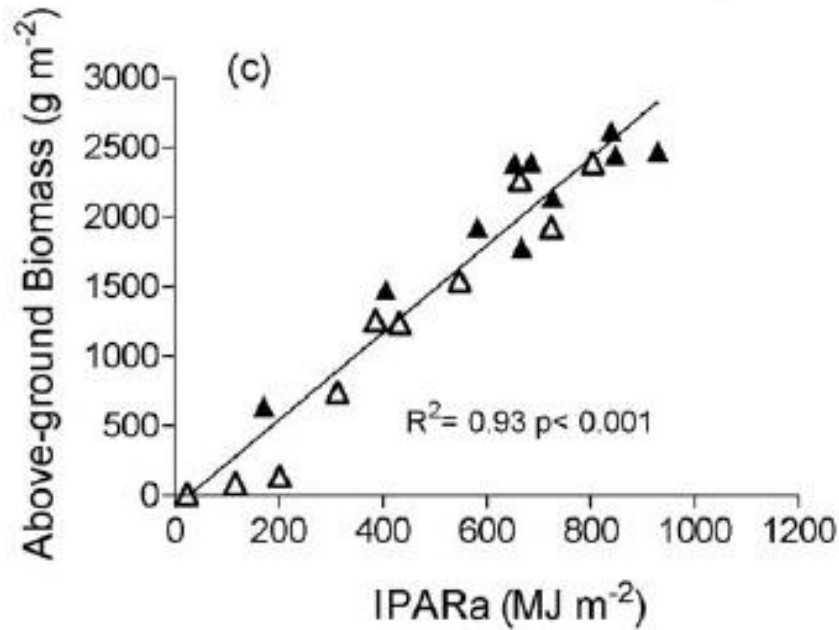


Fig. 7. Relationship between relative change in radiation use efficiency (RUE) and relative change in grain yield (circles) or biomass (triangles) under P deficiency recorded in the present study (open circles) and previous studies in non-shaded treatments of Lázaro et al. (2009) (closed circles) and Rodríguez et al. (2000) (closed triangles) under P deficiency.

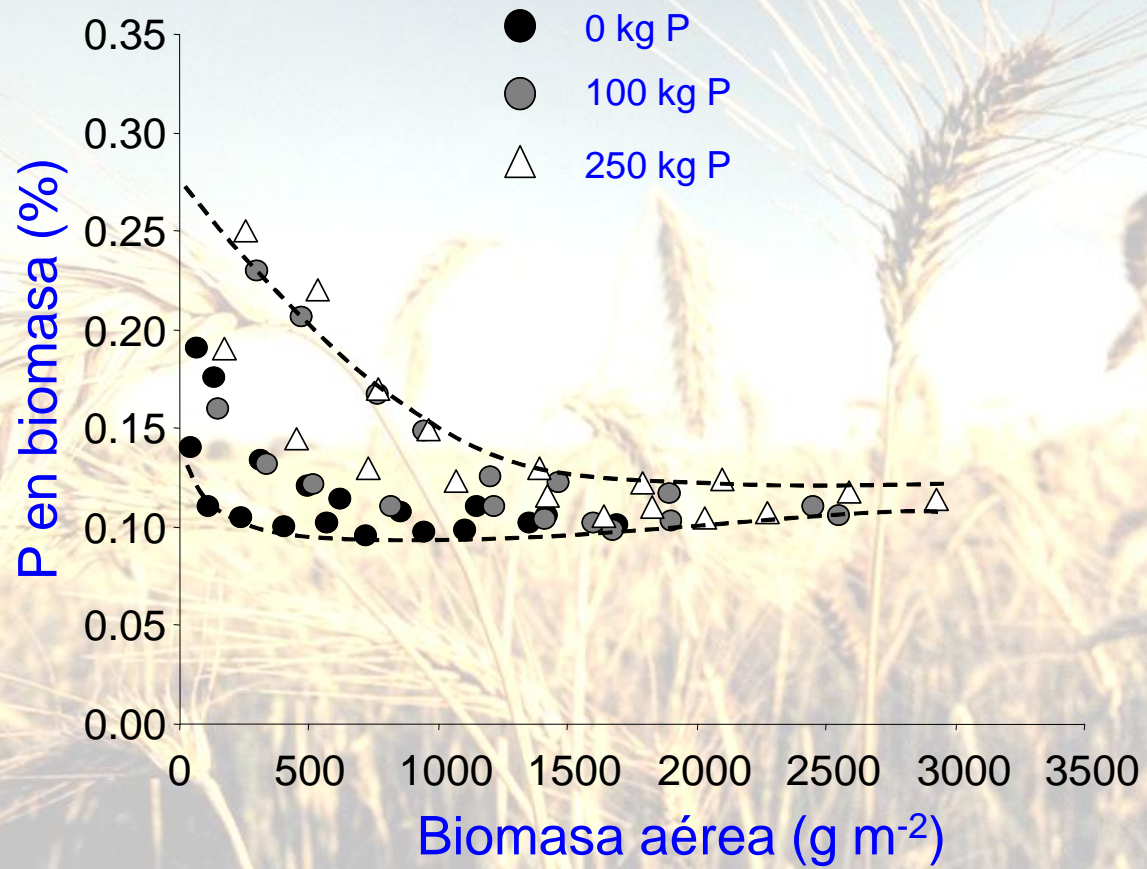
*Sandaña and Pinochet, 2011.
Field Crops Res.*

Similares respuestas con Aluminio

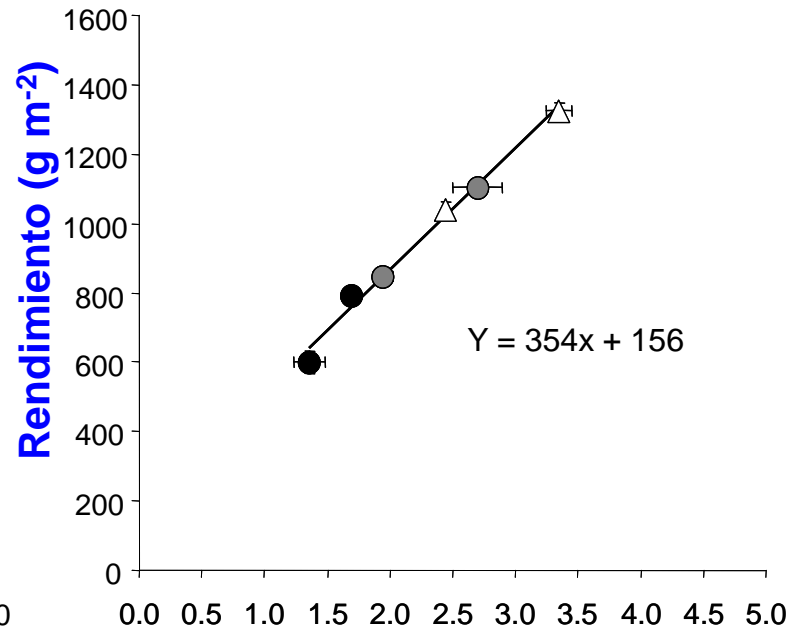
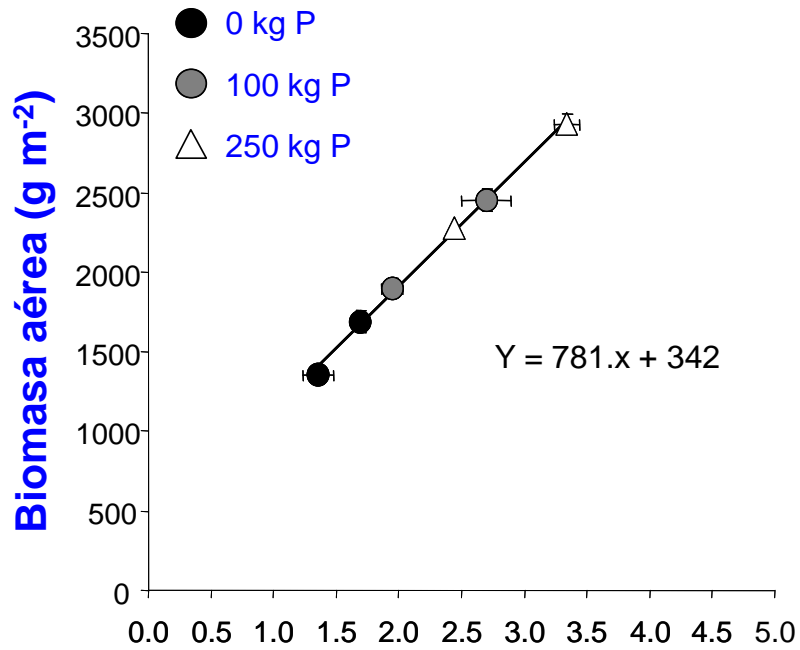


Valle et al., (2009), Field Crops Res.

Curva de dilución de P en biomasa

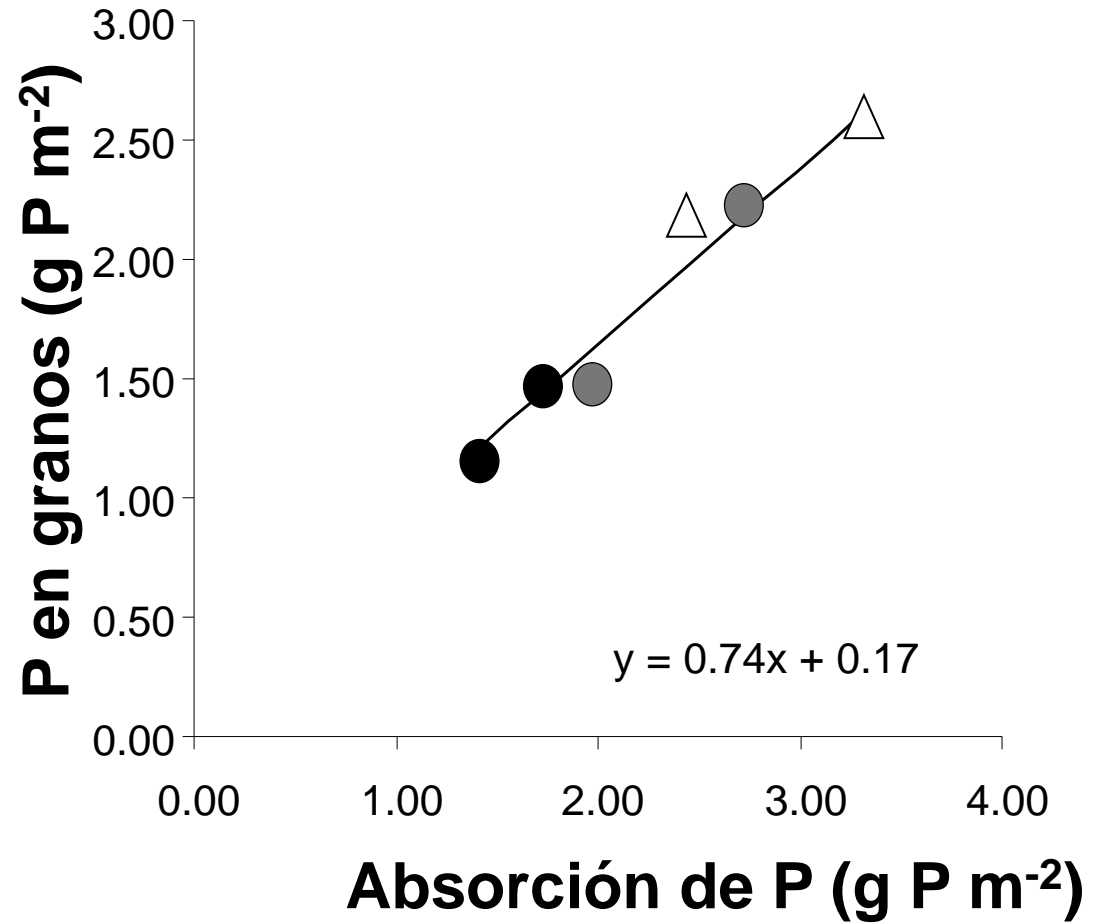


EFICIENCIA DE UTILIZACION DE P



Absorción de P (g m⁻²)

INDICE COSECHA DE P



Algunas aplicaciones prácticas de la información generada

DETERMINACIÓN DE LA DOSIS DE FERTILIZACION

$$\text{Dosis} = \frac{\text{Demanda} - \text{Suministro}}{\text{Eficiencia de fertilización}}$$

Rendimiento

Índice
Cosecha

Biomasa total
(kg ha⁻¹)

X

% mínimo
óptimo nutriente

Kg de nutriente ha⁻¹

DEMANDA NUTRIENTE

Ambiente
Cultivar
Manejo

Nutriente
Cultivar

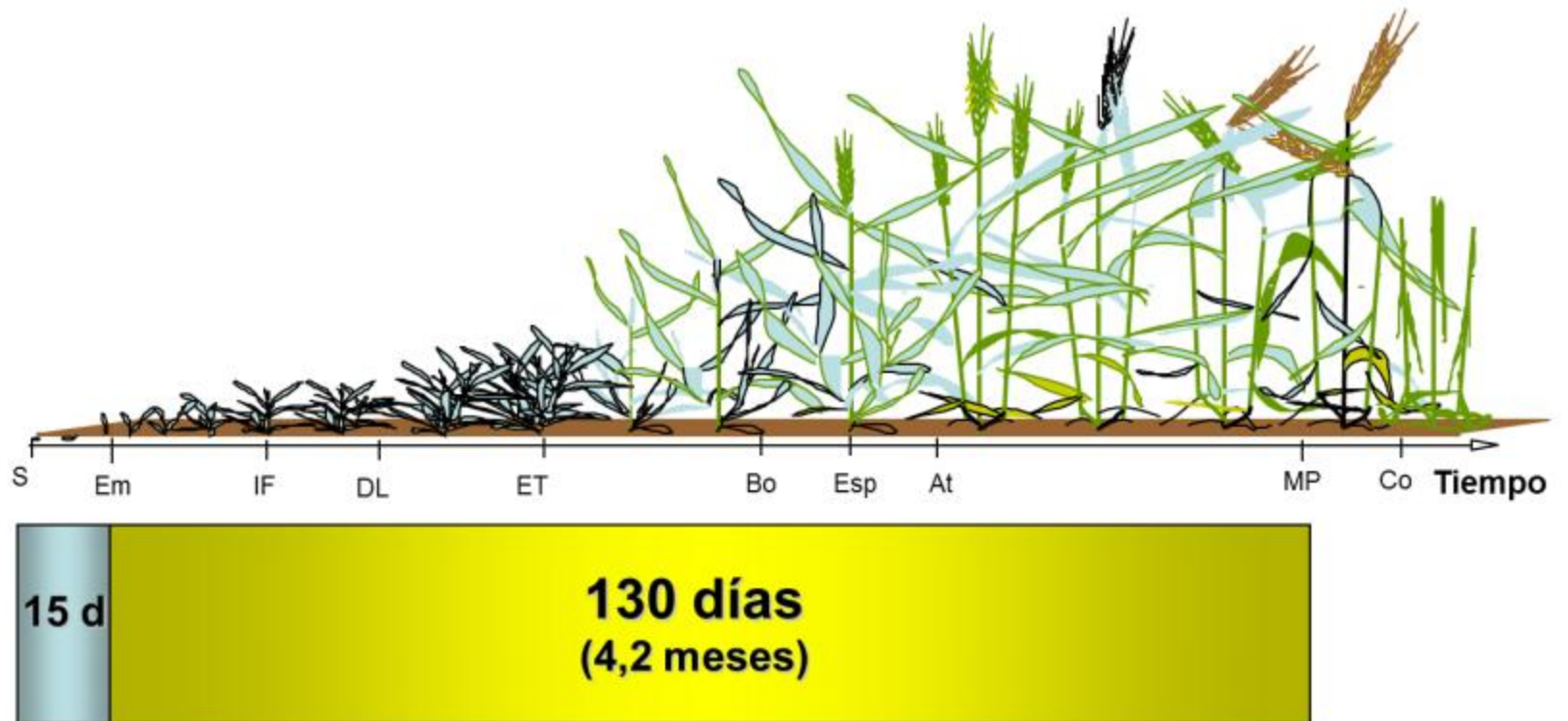
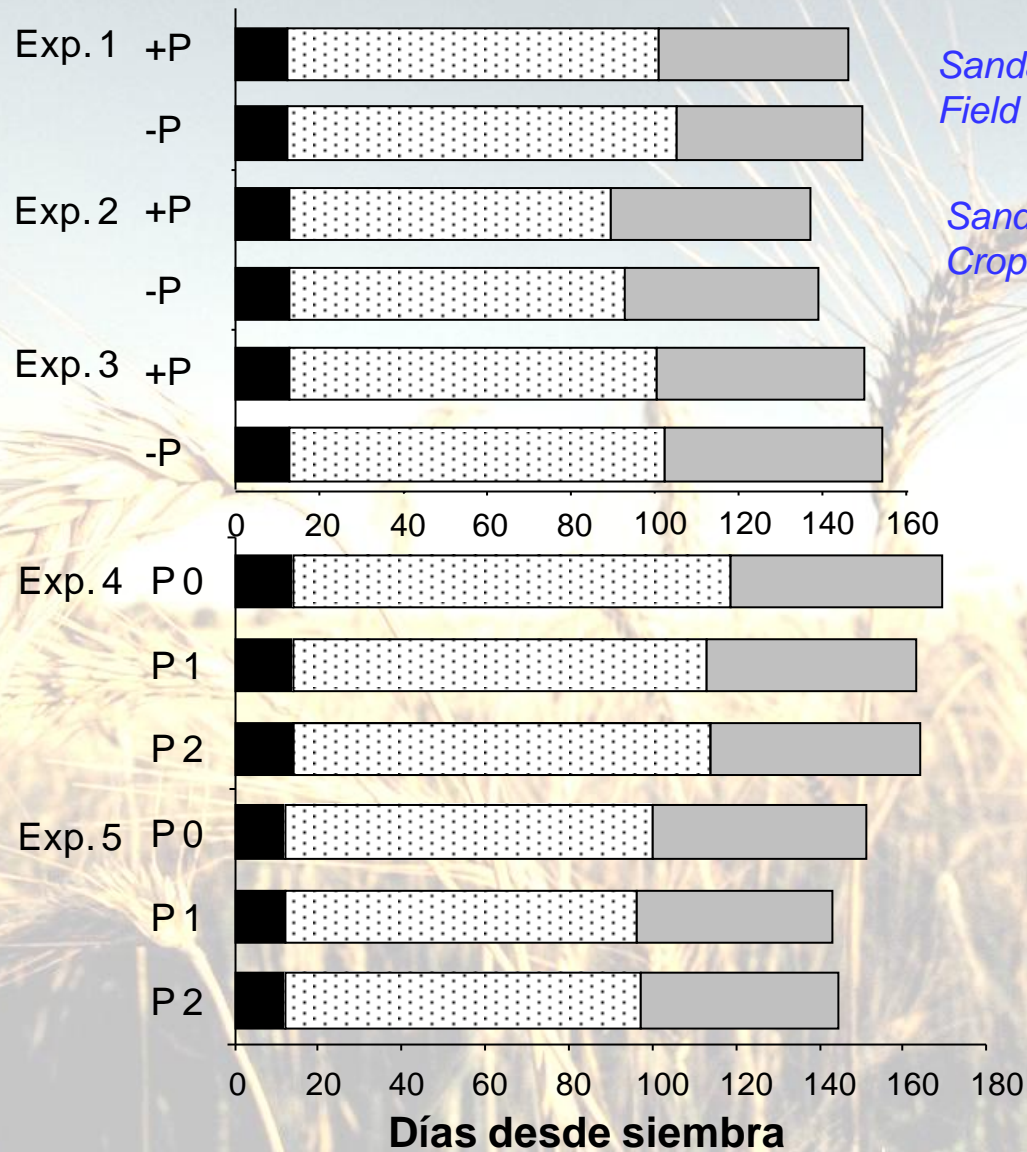


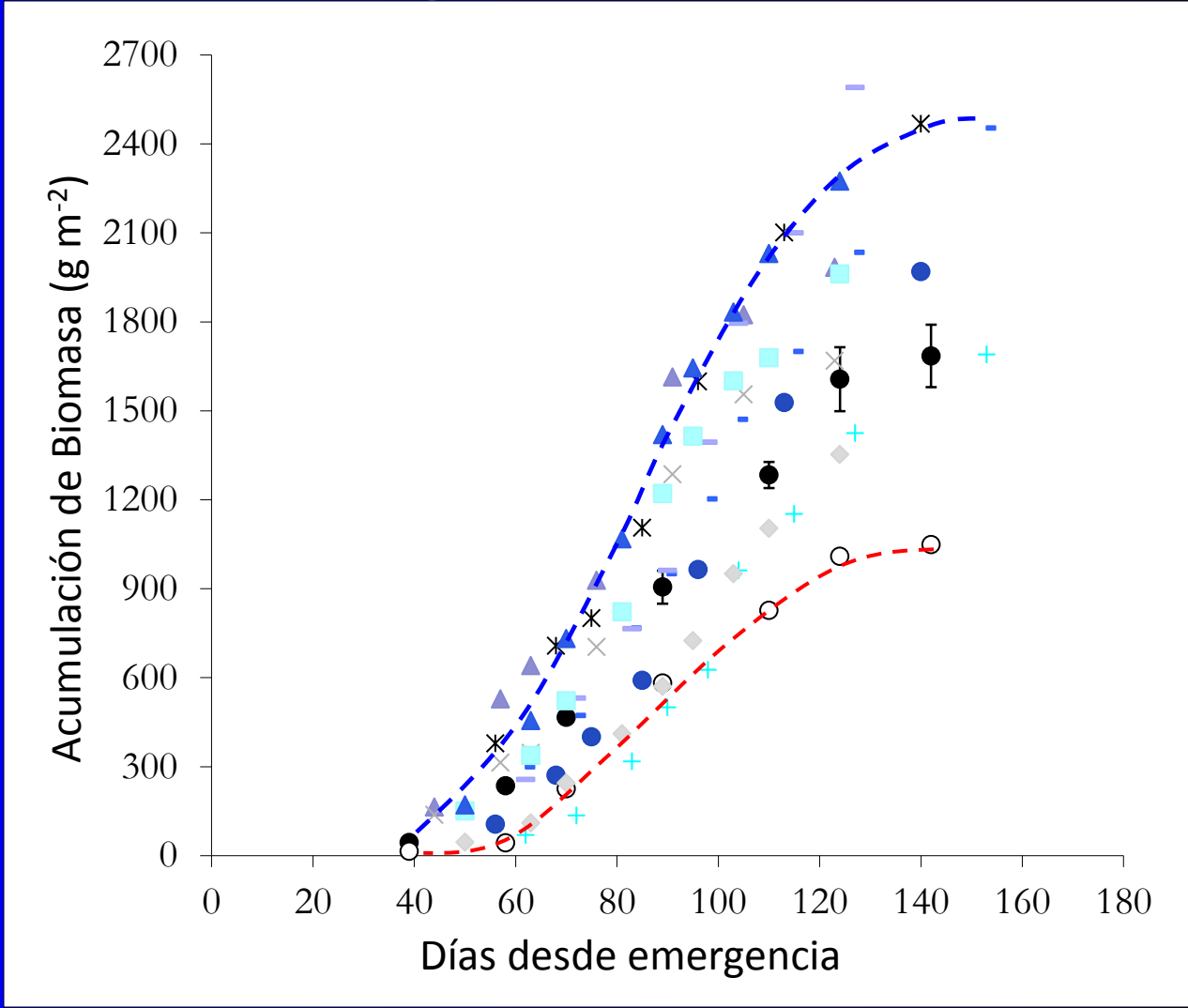
Figura 5. Ciclo un cultivo primaveral sembrado en Septiembre en la zona sur de Chile (Adaptado de Slafer y Rawson, 1995).

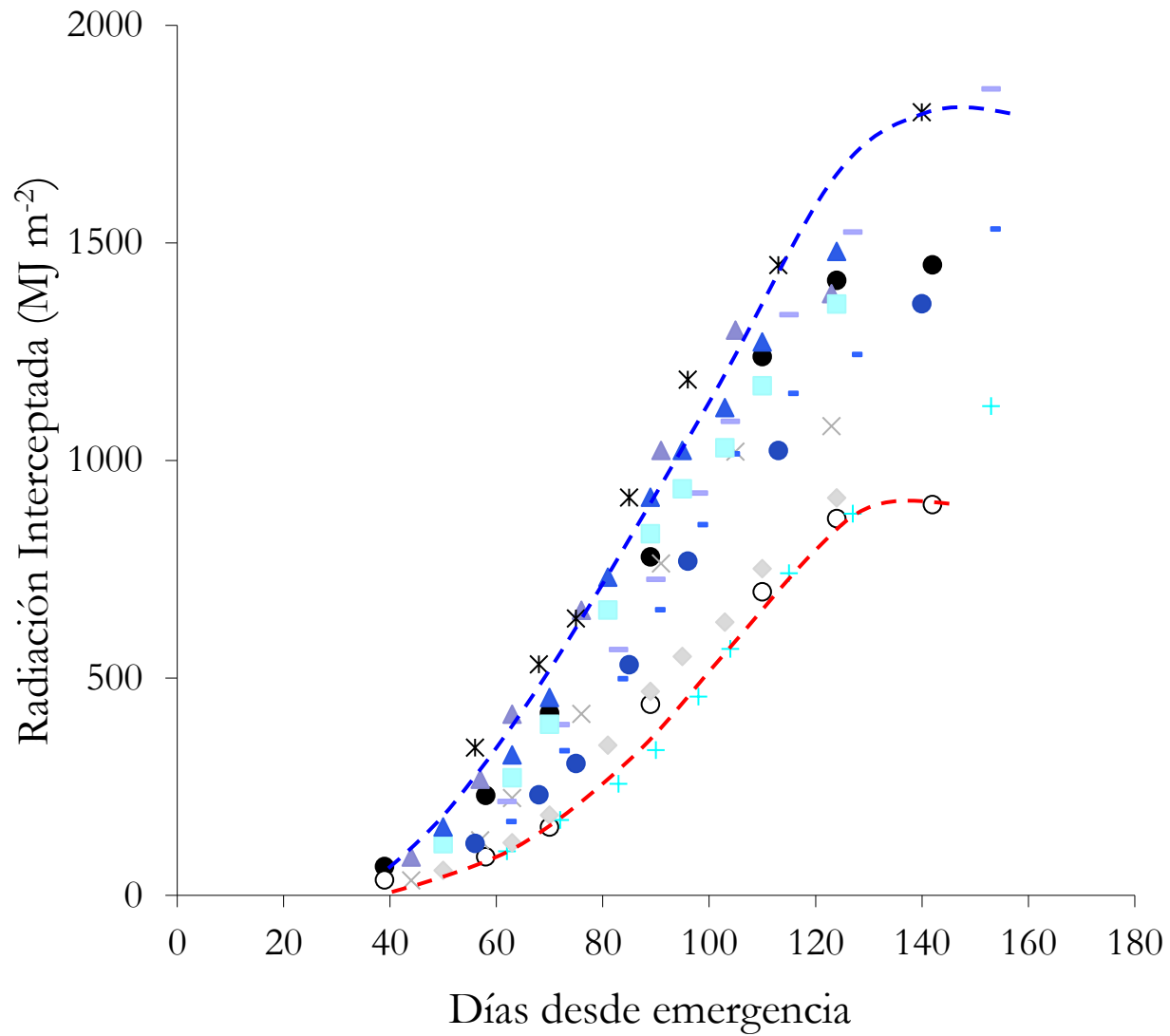
EFECTO DEL FOSFORO EN FENOLOGIA

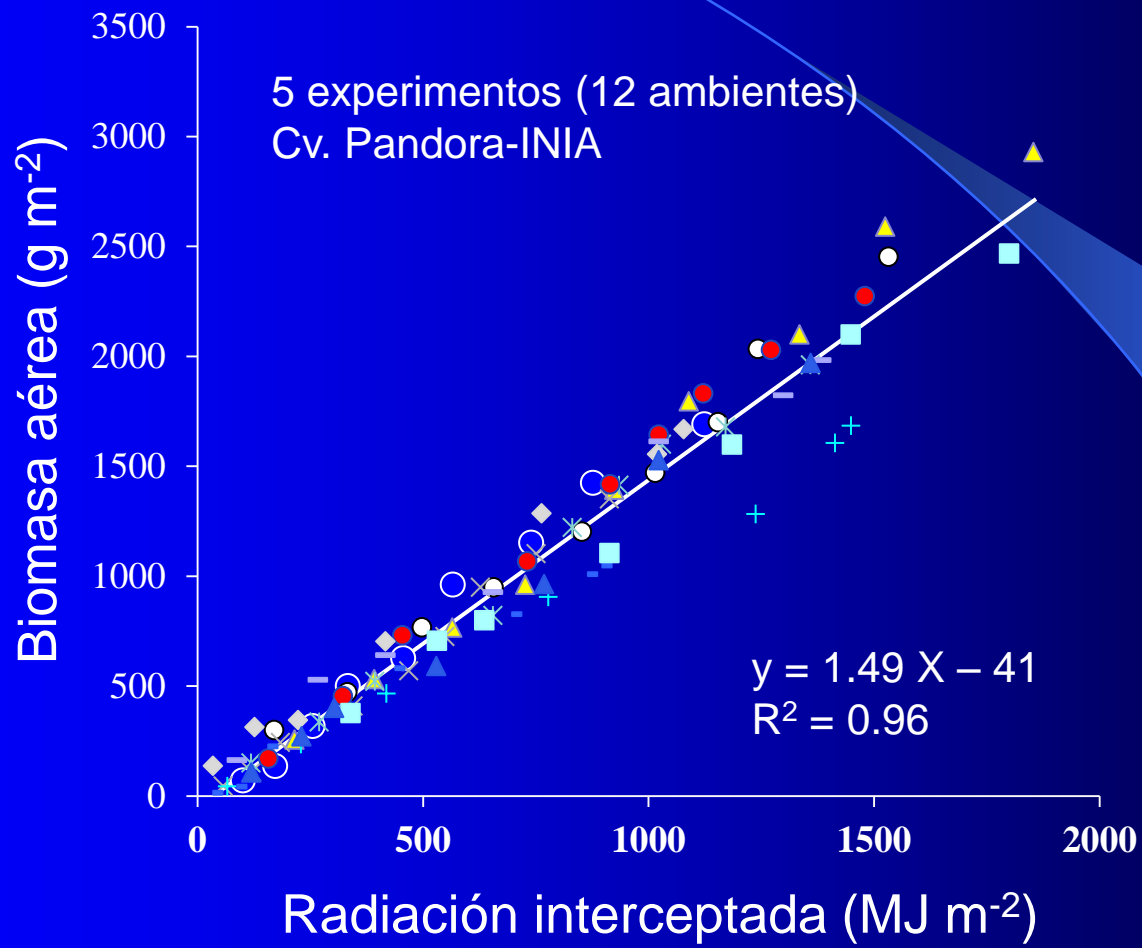


*Sandaña and Pinochet, 2011.
Field Crops Res.*

*Sandaña et al., 2012. Field
Crops Res.*





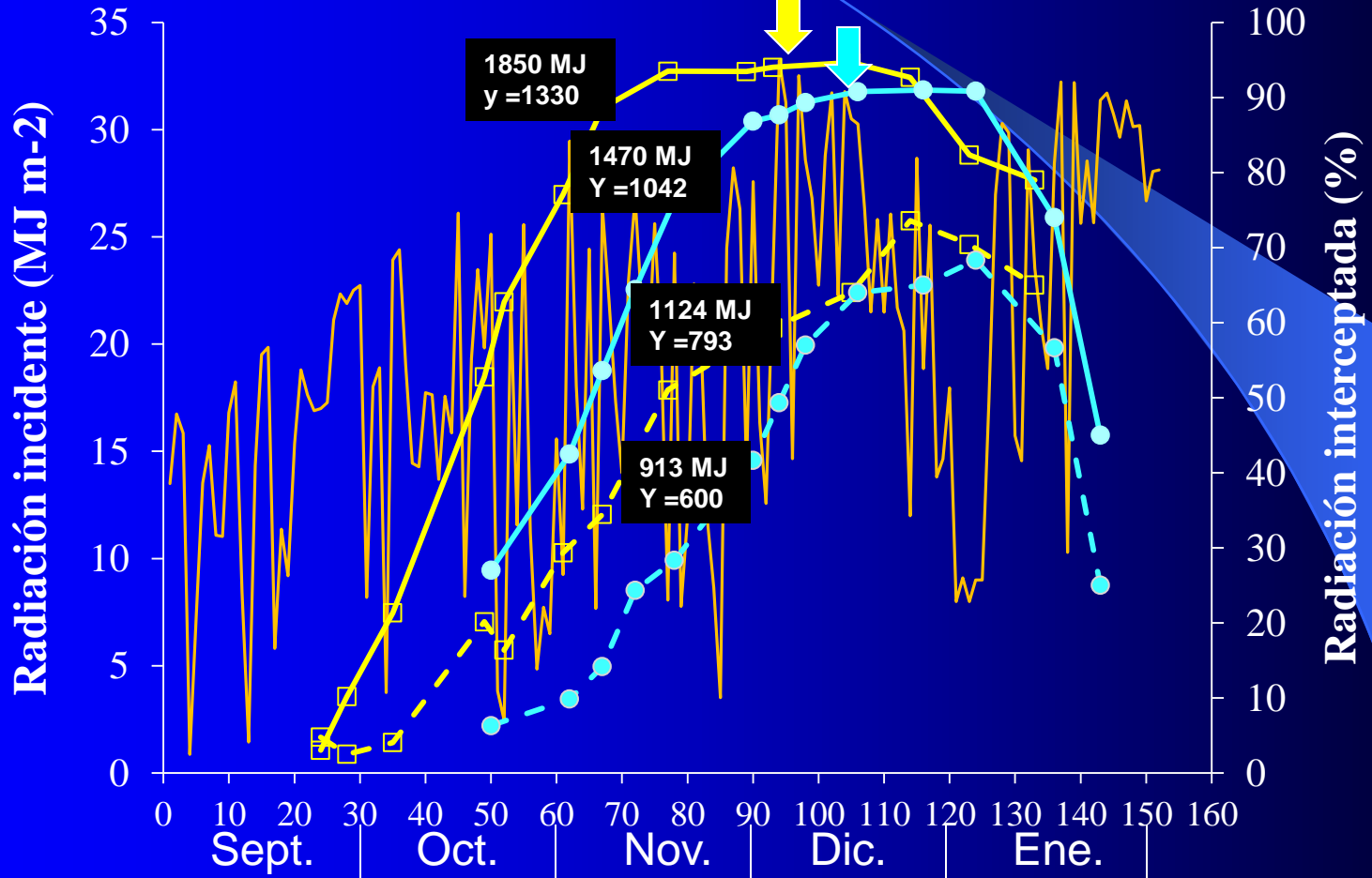


Emergencia

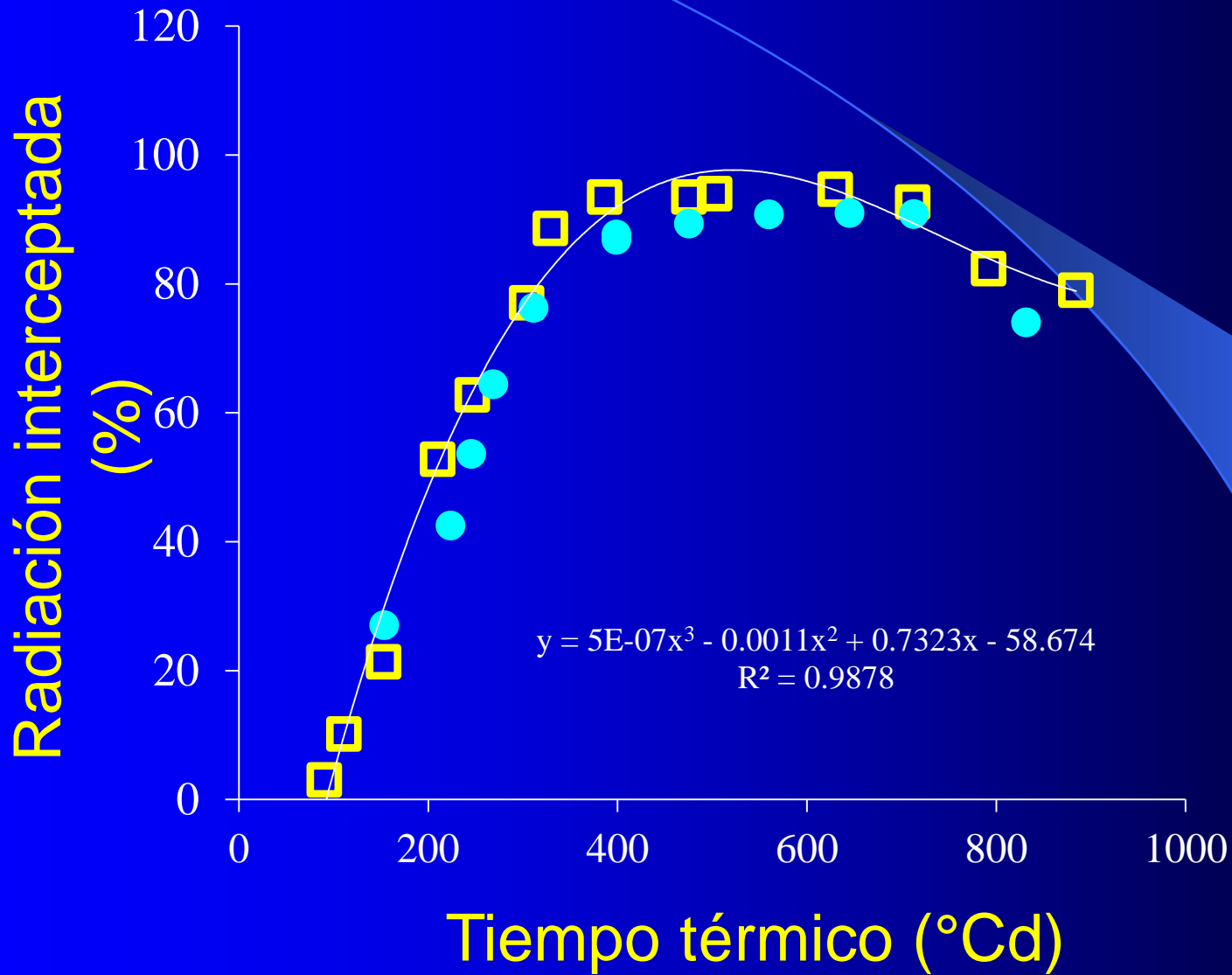
2 Septiembre

23 Septiembre

Antesis

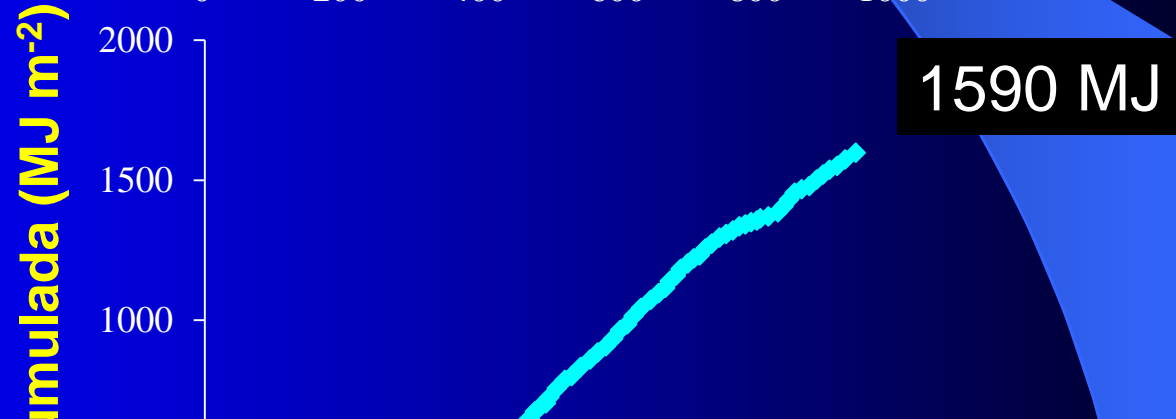
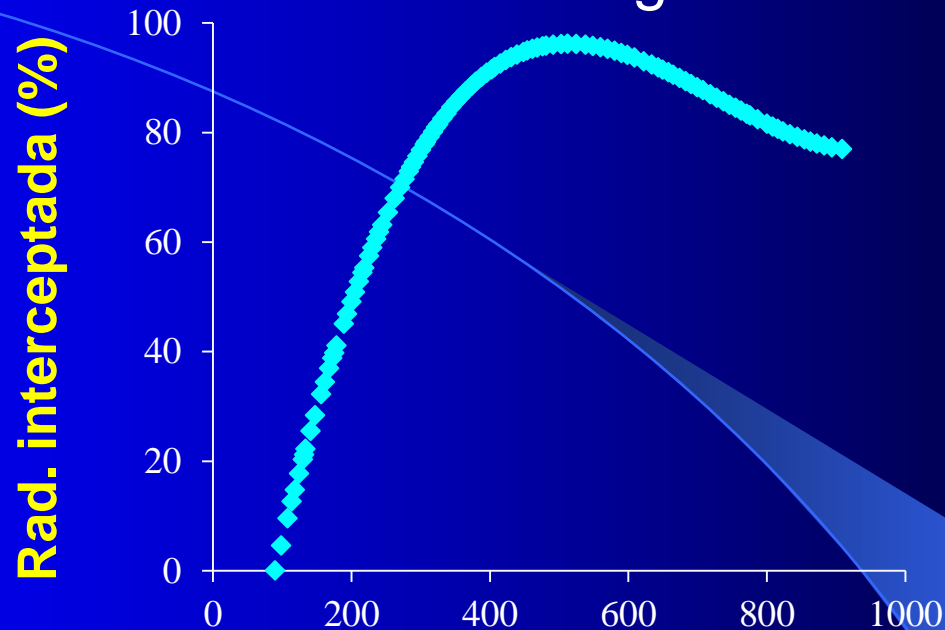


Respuestas en RI según tiempo térmico

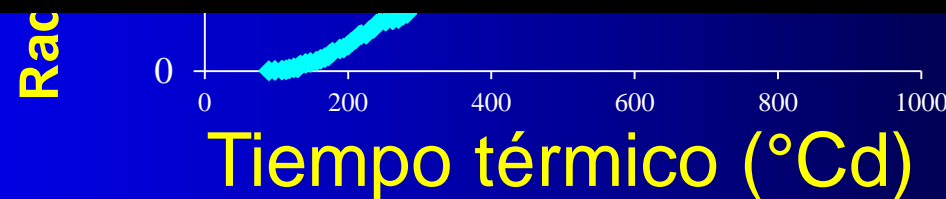


Emergencia 12 Septiembre

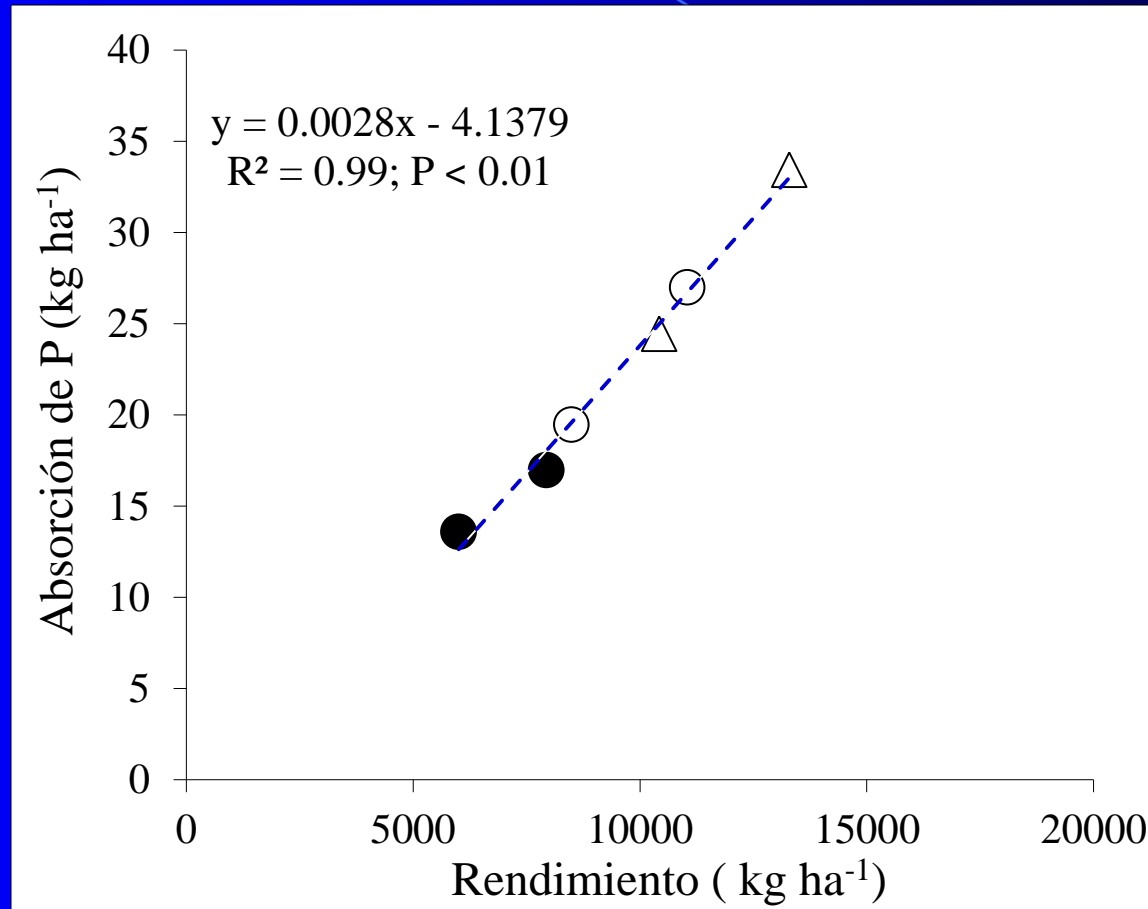
Modelo de crecimiento Simple



$$\text{Rend} = 1.49 \text{ g/MJ} \times 1590 \text{ MJ} \times 0.49 = 1160 \text{ g m}^{-2}$$

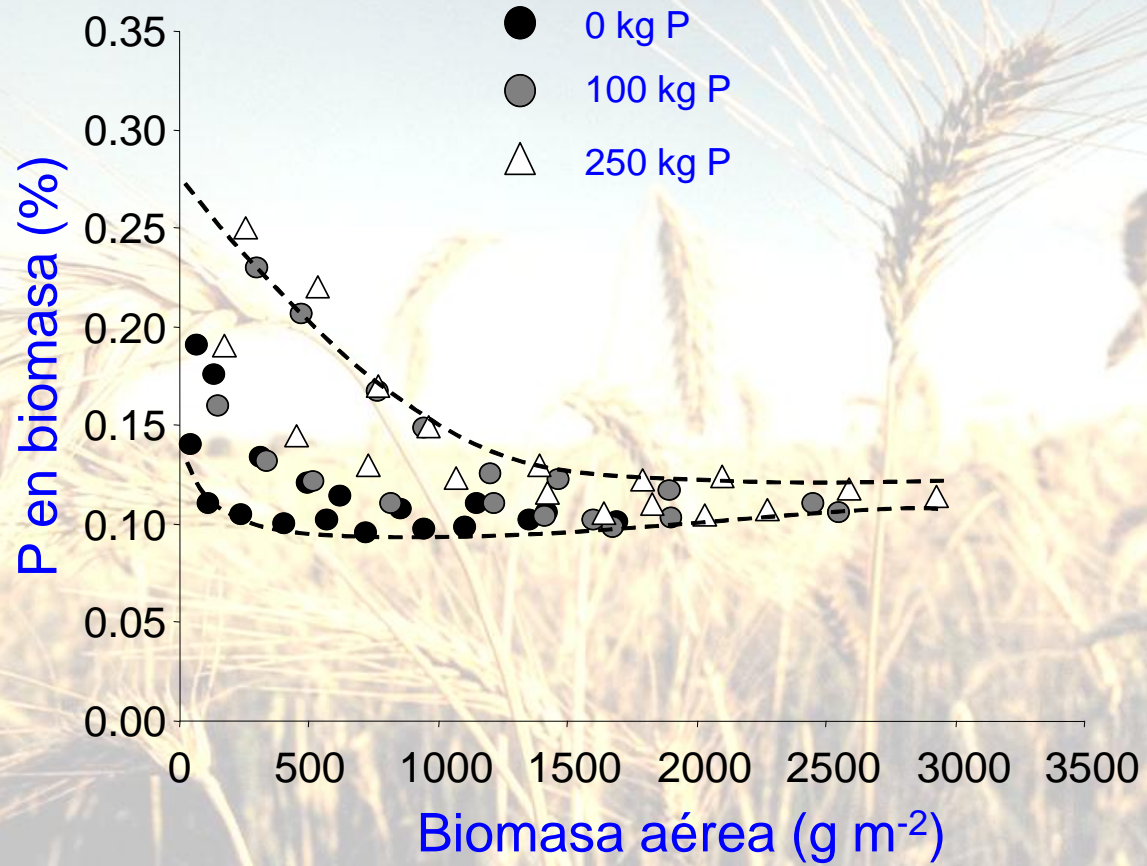


Determinación de factor de demanda de P

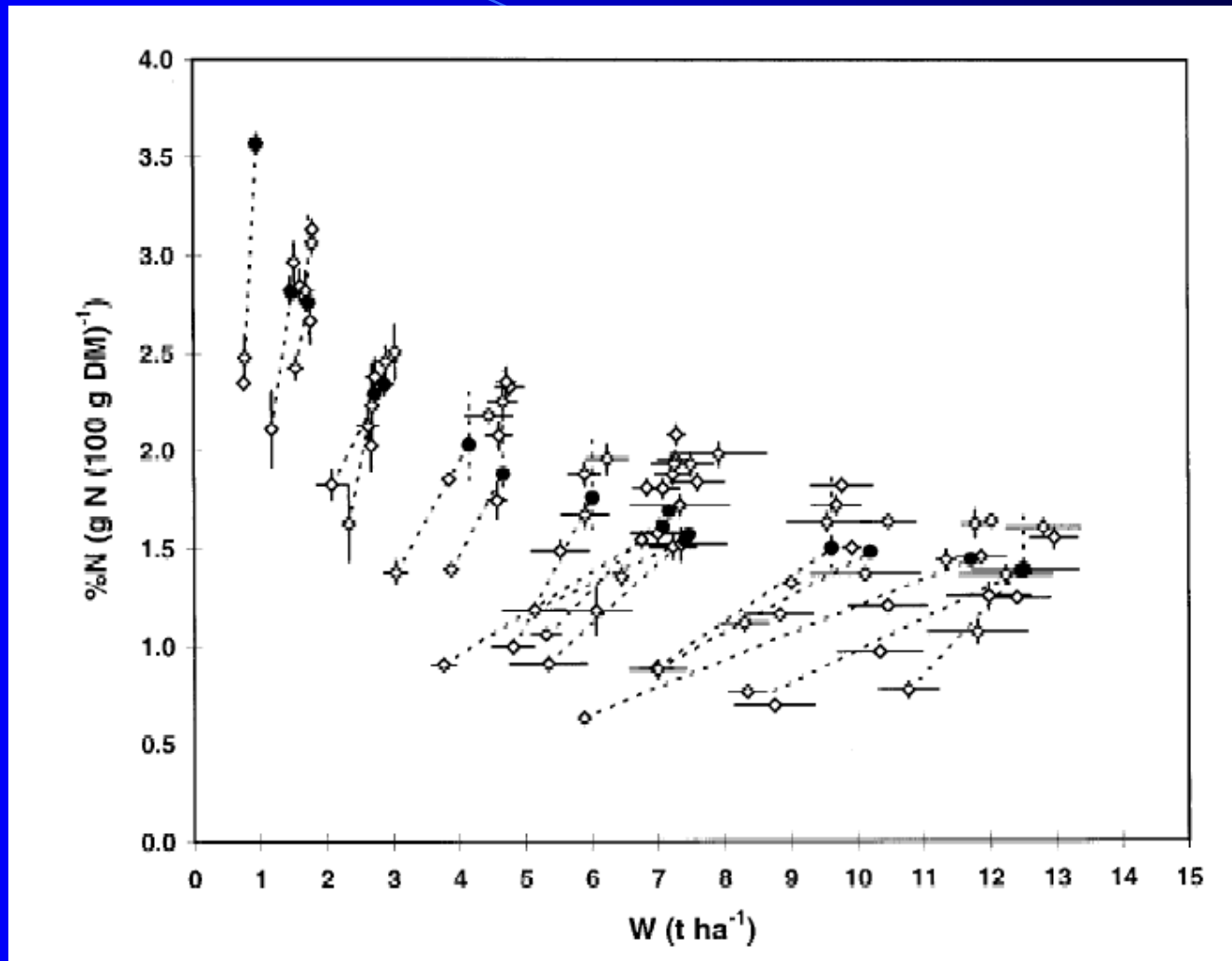


Rend.7000 kg = Demanda de P = $0.0028 \times 7000 = 19.6$ kg P/ha

Curva de dilución de P en biomasa

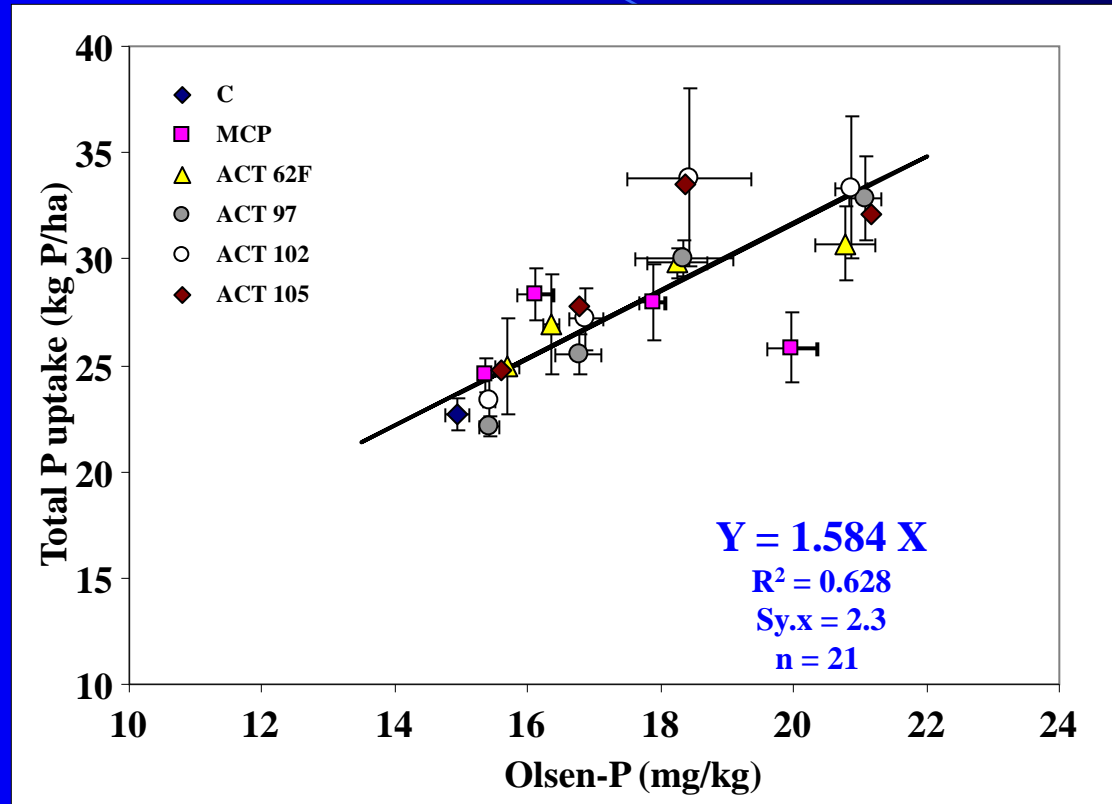


Concentración crítica de N en maíz



Plenet and Lemaire (2000)

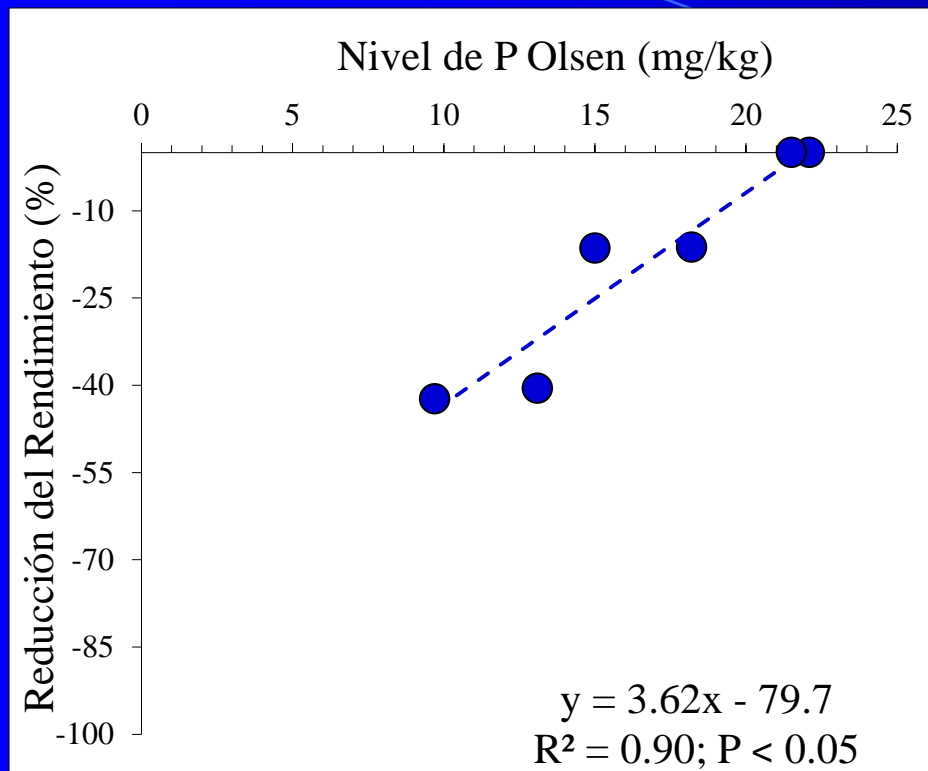
Factor de Eficiencia de Absorción P en Trigo



Fuente: Dante Pinochet

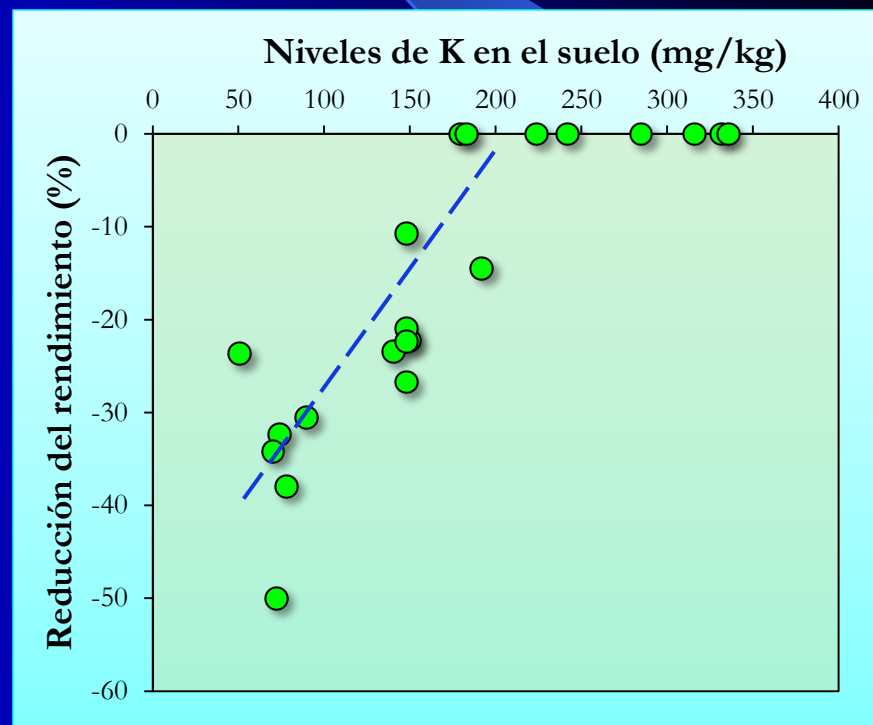
Este factor es útil para estimar el suministro en base al análisis de suelo

Umbral de P Olsen en trigo

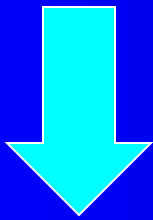


Permite decidir cuando fertilizar el cultivo

Ej: Umbral de K en papa



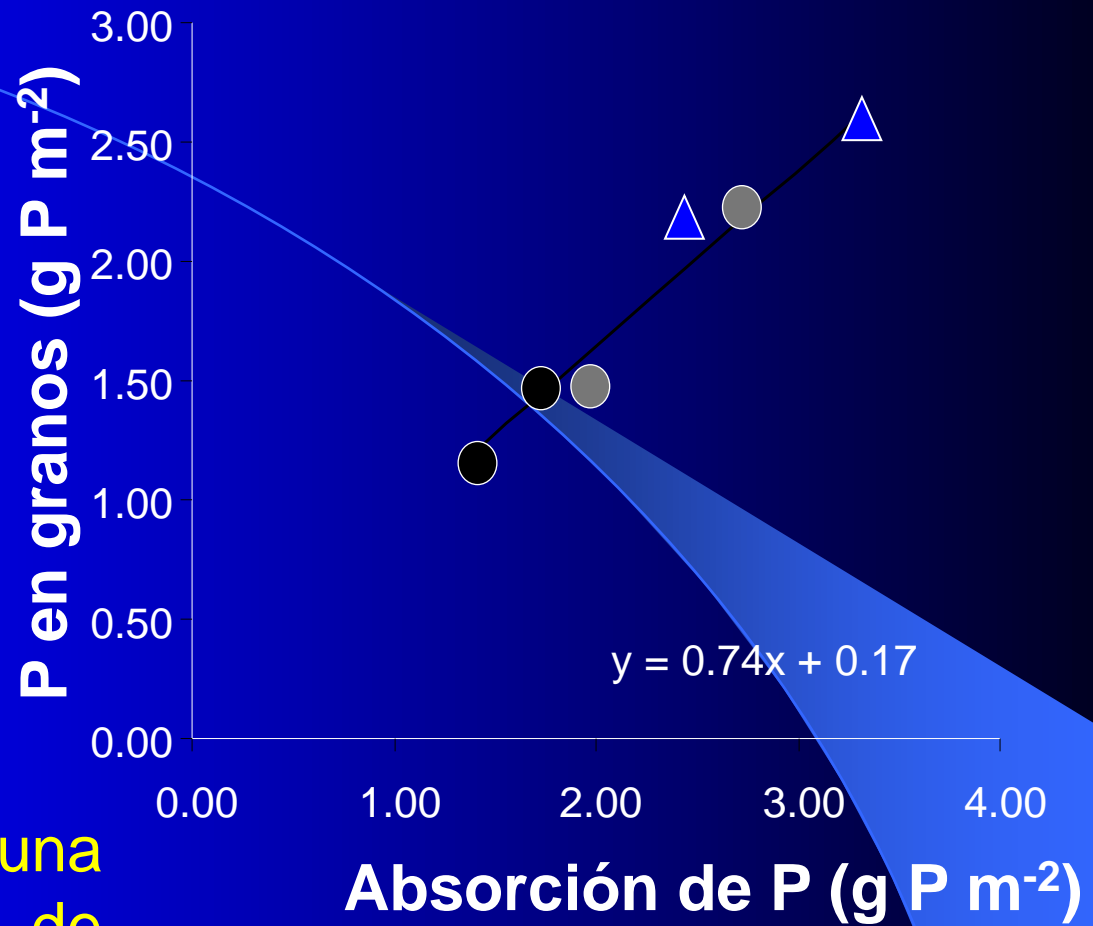
INDICE COSECHA
DE P



Permite hacer una estimación de una dosis de mantención de P

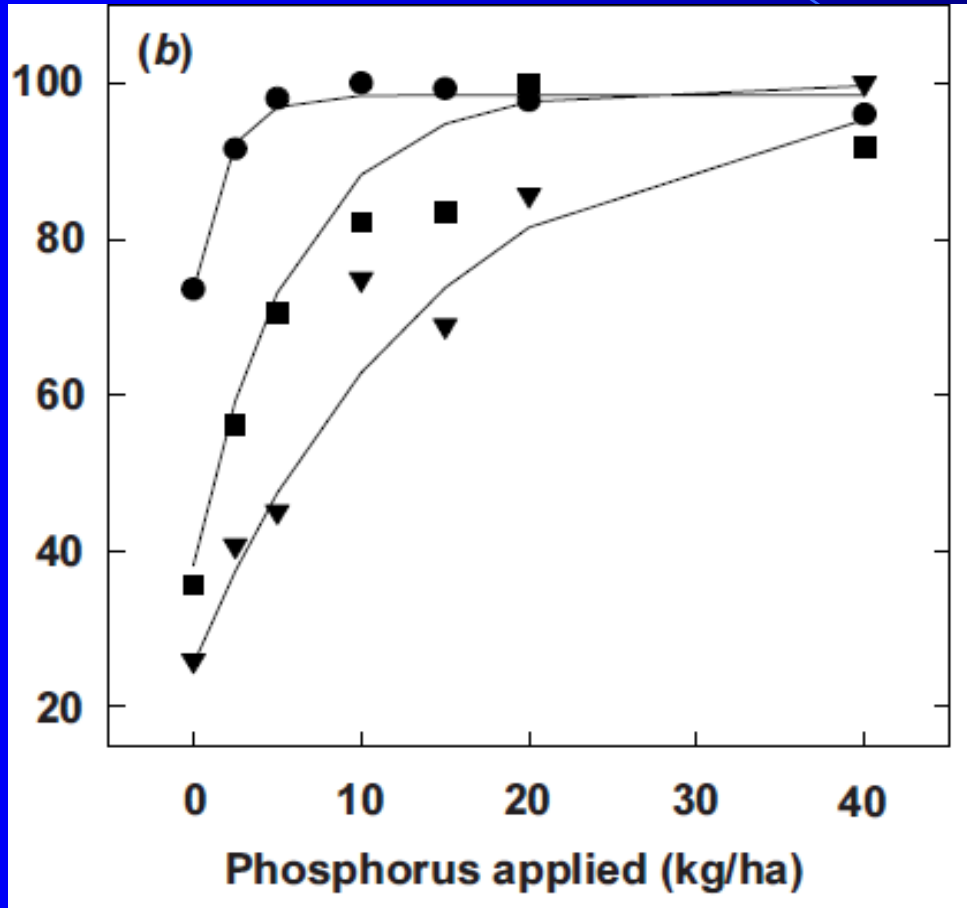
Demanda estimada= 25 kg P/ha

Dosis de mantención= 25 kg P/ha x 0.74= 18.5 kg P/ha



IMPORTANCIA DE LA FECHA DE SIEMBRA SOBRE LA RESPUESTA A LA FERTILIZACION FOSFORADA

Rendimiento relativo (%)

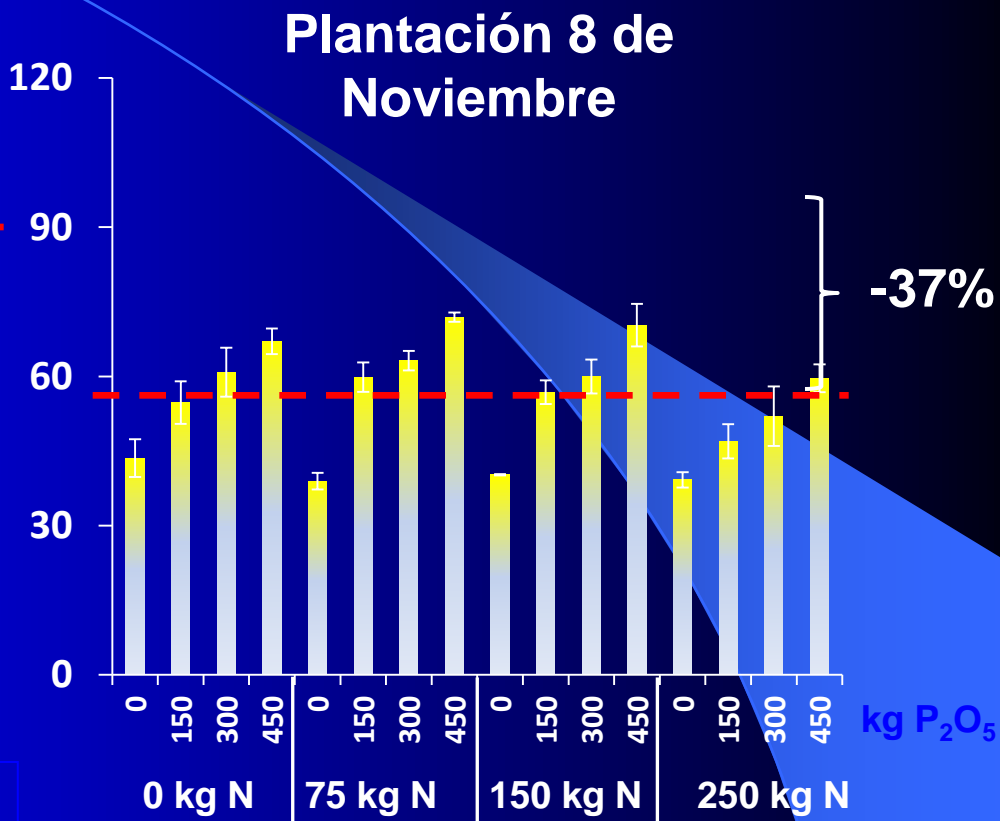
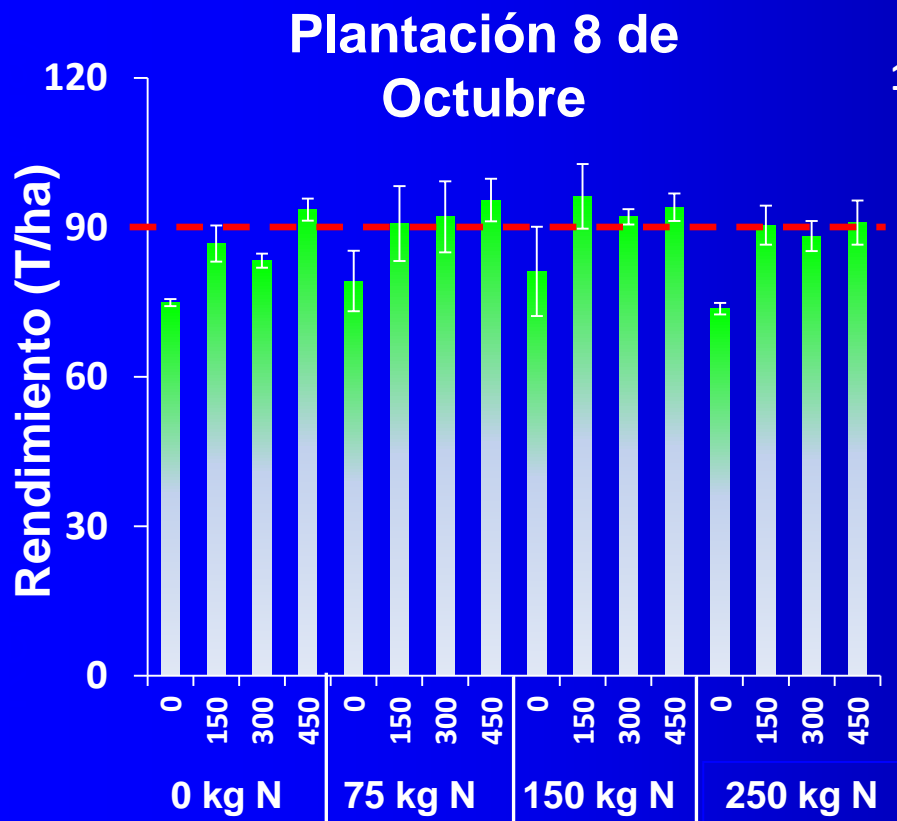


A mayor atraso en la siembra más sensible es el cultivo frente a la deficiencia de P

Baten et. al. (1999) Aust. J. Exp. Agric.

PUYEHUE-INIA EN DISTINTAS DOSIS DE N Y P

INIA-Remehue (2012-13) en dos fechas de plantación bajo riego



kg P₂O₅

CONCLUSION

El estudio presentado es un pequeño ejemplo de que la ecofisiología de cultivos permite incrementar el entendimiento de las respuestas de los cultivos frente al manejo o ambiente y que, la información generada, sirve como base para mejorar racionalmente el manejo y la eficiencia del cultivo.

MUCHAS GRACIAS