



# Atualidades sobre a nutrição com macro e micronutrientes em plantas cítricas

**Simpósio IPNI Brasil**  
8-9 de outubro de 2013

Dirceu de Mattos Jr.

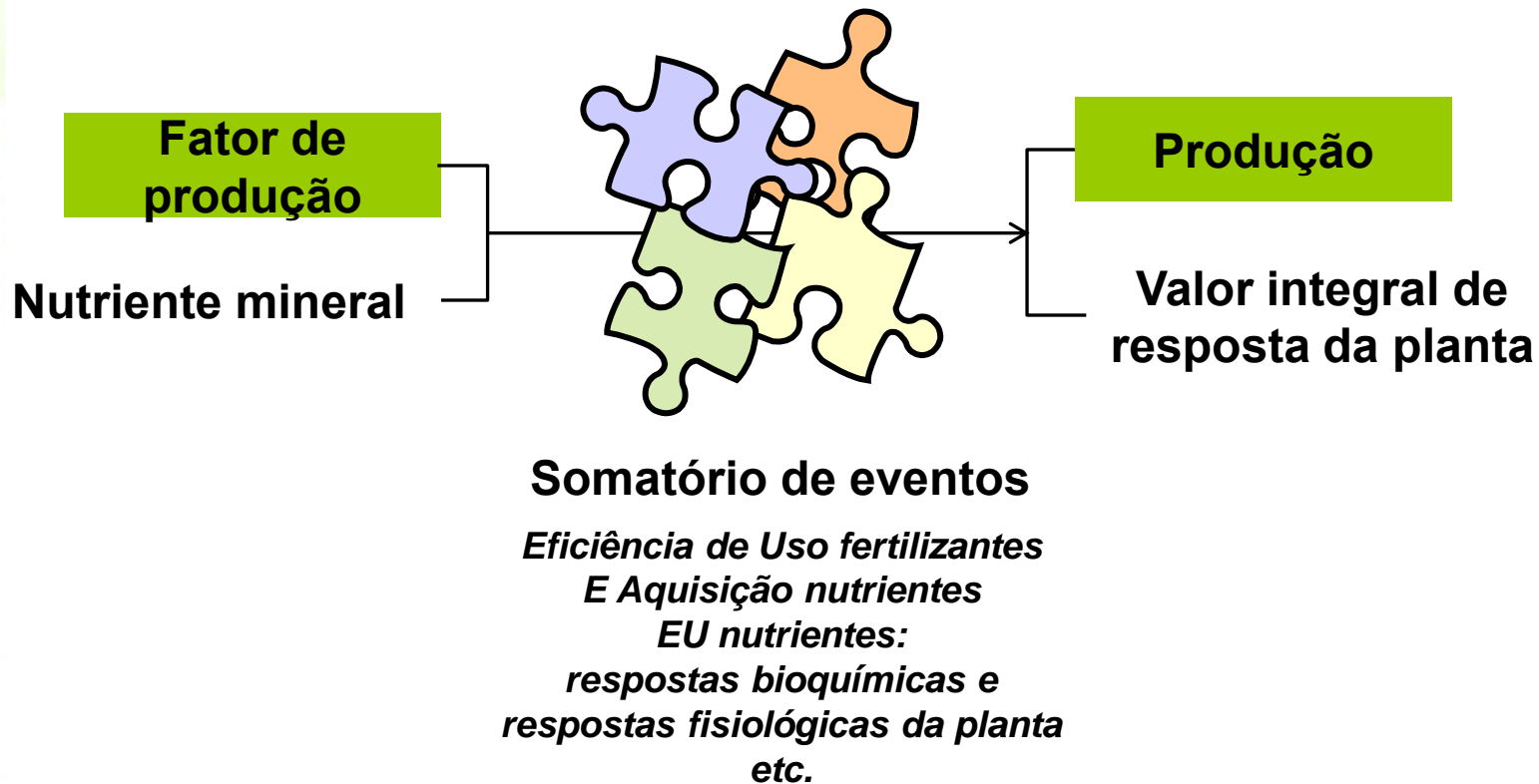


**Centro de Citricultura Sylvio Moreira**  
*Pesquisa para o agronegócio*

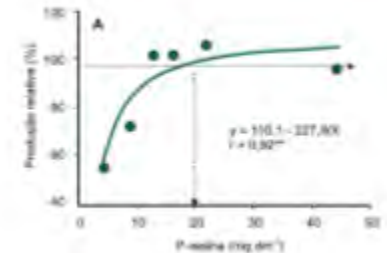


**1928 - 2013**

# Programa de pesquisa: *principais resultados e perspectivas*

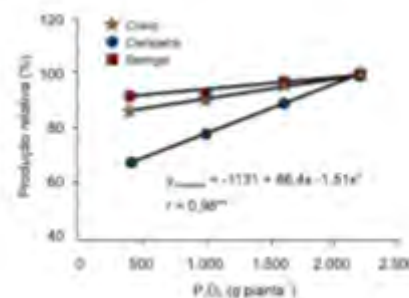
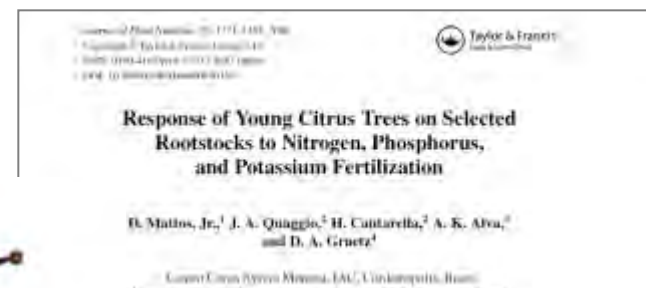


**Lula, Kirchner e Chávez vão discutir acordo**



4

Manejo adubação



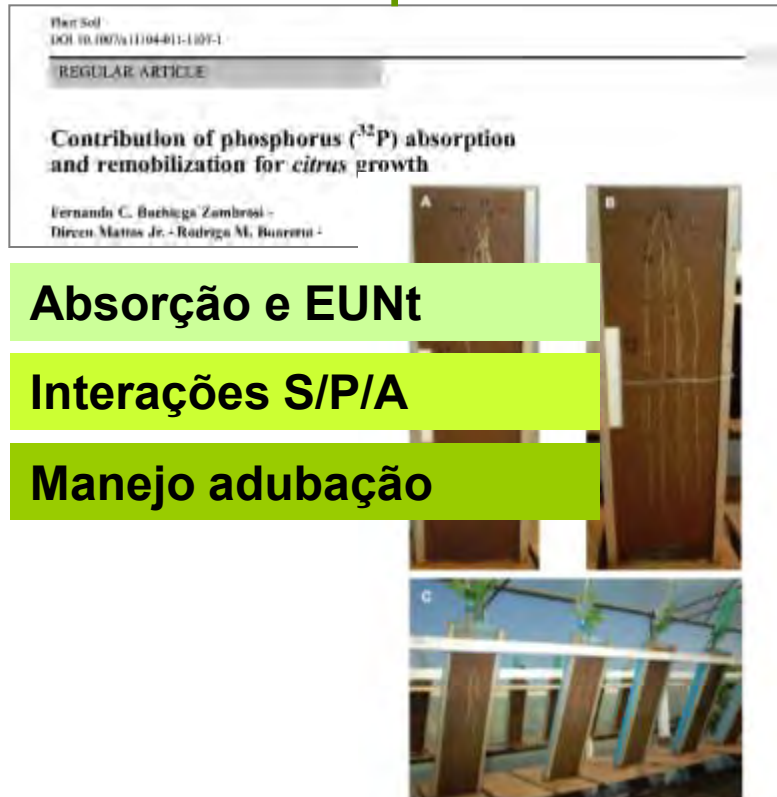
2

Aval. estado nutricional

4

Manejo adubação





1

Absorção e EUNt

3

Interações S/P/A

4

Manejo adubação

1

Absorção e EUNt

2

Aval. estado nutricional

J. Plant Nutr. Soil Sci. 2011, 174, 487–495

DOI: 10.1007/s11104-010-0320

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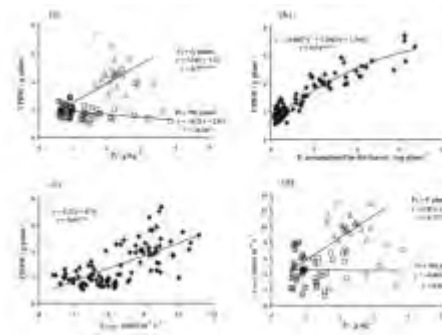
## Plant growth, leaf photosynthesis, and nutrient-use efficiency of citrus rootstocks decrease with phosphite supply

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- 1 Absorção e EUNt
- 2 Aval. estado nutricional
- 3 Interações S/P/A
- 4 Manejo adubação

... preceitos para o manejo eficiente de fertilizantes na citricultura, com base no método certo, fonte certa, dose certa e época certa (= 4 C's).





## INFORMAÇÕES AGRONÔMICAS

Nº 129 SETEMBRO/2012

# Nitrogênio, Potássio Micronutrientes

### 1. INTRODUÇÃO

A agricultura tem se colocado como importante atividade para o setor agrícola e a economia brasileira nas últimas décadas. Atualmente, em meio de

pressão (N) foram definidos em função da relação de extração desses nutrientes pelas frutas cítricas, ou seja, 1,5 a 2,0 kg  $\text{t}^{-1}$  de frutos frescos, na relação 1:1. Essa relação é considerada para boa aplicação, mas para cultivar em solos com teor muito elevado e baixa capacidade de retenção de K trocável.





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# Interpretação de resultados de análise de folhas de citros

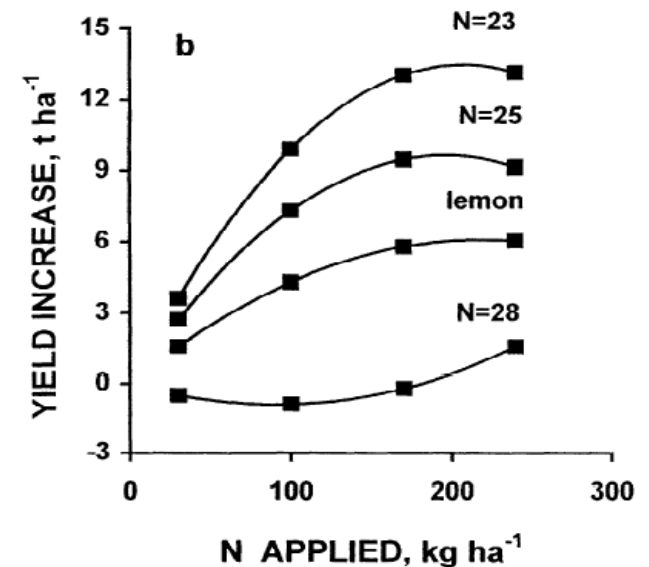
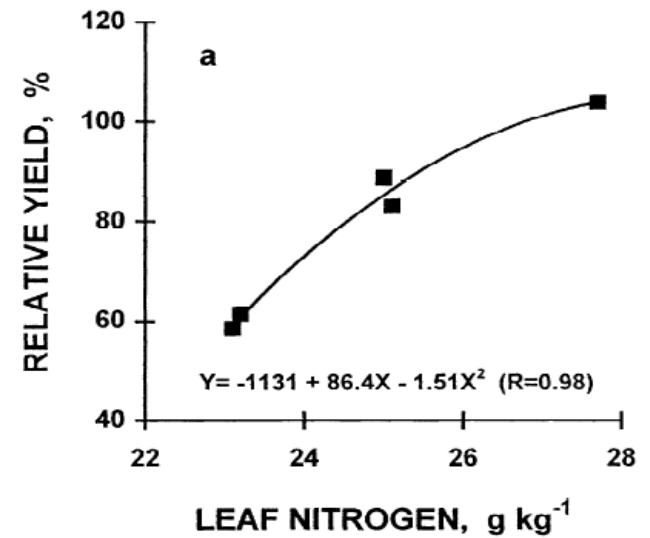


Figure 4. Correlation of leaf-N with relative yield (a) and citrus response to nitrogen according to the N concentration in leaves from 6-to-8-month-old fruiting terminals (b). **Quaggio et al. (1998)**



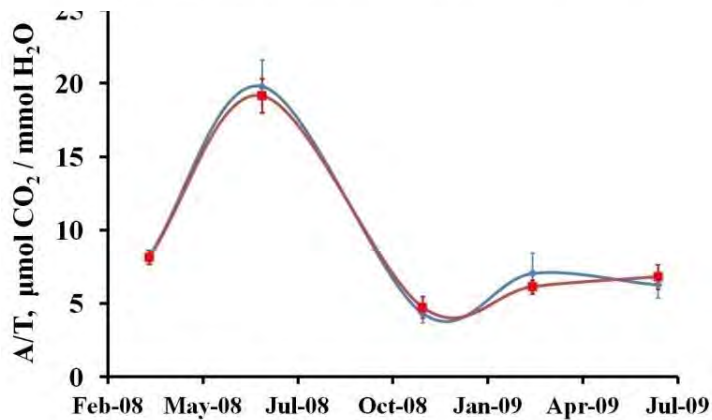
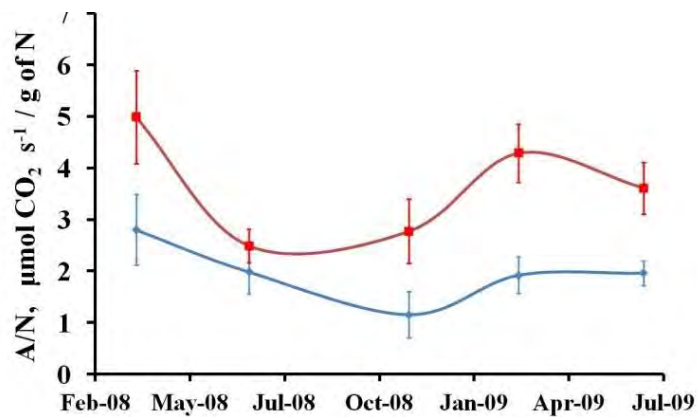
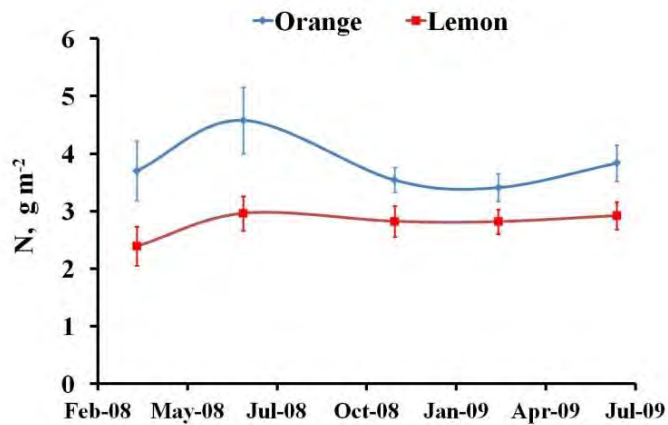


# Produção e eficiência de uso de N: laranja x limão

Boaretto et al. (dados não publicados)









# Aproveitamento N fertilizante e partição na planta

*aplicação N no solo (contêineres)*



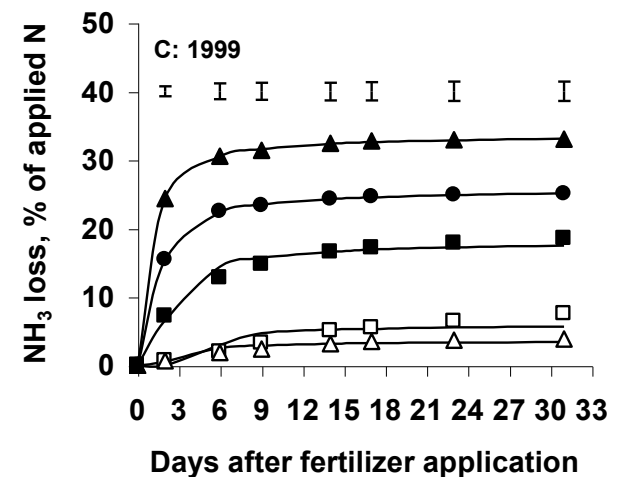
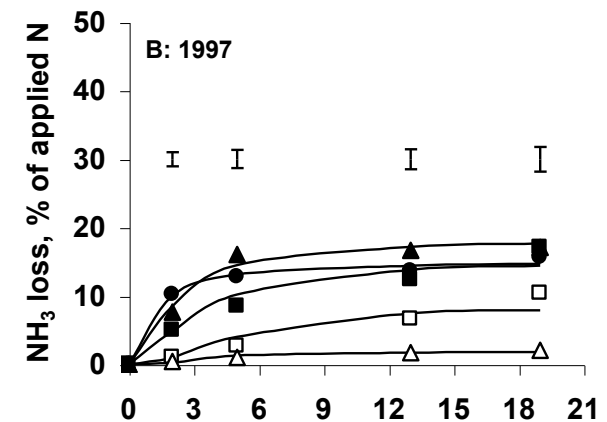
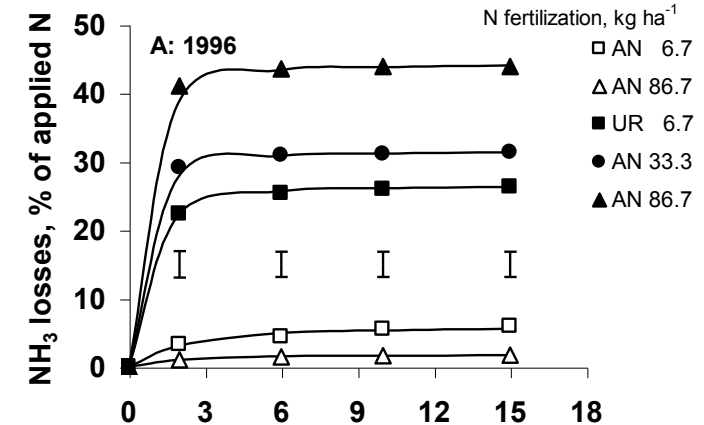
Parâmetros	Primavera		Verão	
	laranja	limão	laranja	limão
% absorvida do aplicado				
Aproveitamento	42,9	53,8	29,2	50,2
% entre partes				
parte nova	53	44	44	41
parte velha	9	13	8	11
raiz	39	43	48	49

Boaretto et al. (dados não publicados)



# Perda de N por volatilização de amônia

nitrato de amônio  
uréia



Cantarella et al. (2003)



# Absorção $\text{NH}_3$ volatilizada do $^{15}\text{N}$ -uréia

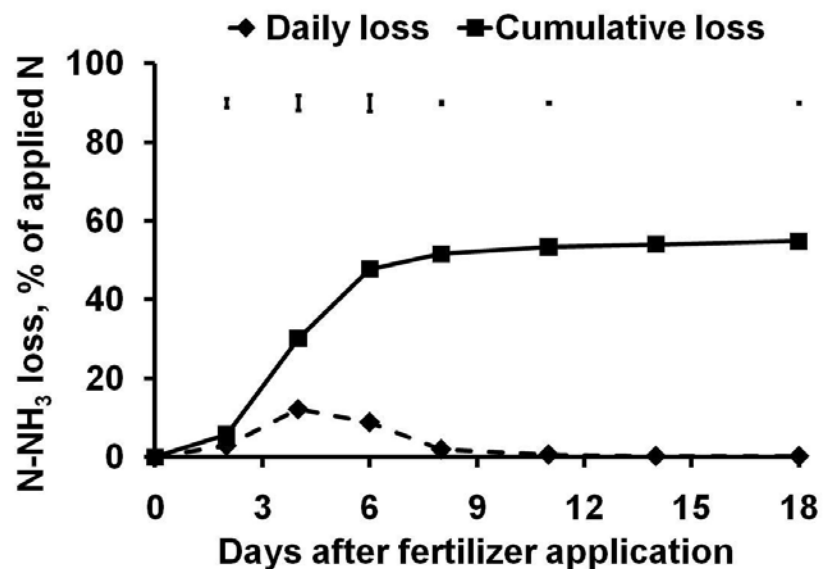
*folhas laranjeiras;  $\frac{1}{3}$  dose anual N*

- Guacho, pomar 4 anos  
7 x 3,5 m (408 pl/ha = padrão),  
100 g/planta de N
- Agrindus, pomar 8 anos  
6 x 2,7 m (617 pl/ha = adensado),  
133 g/planta de N

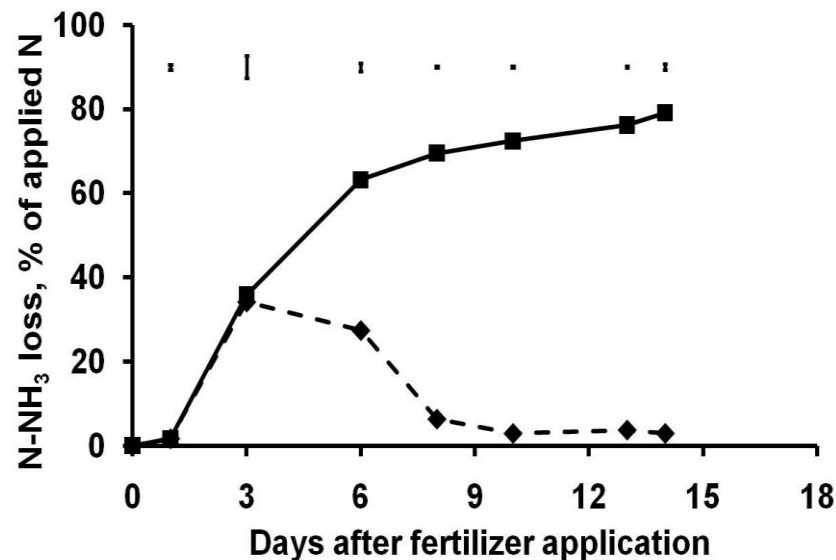


# Perdas de N

## volatilização de N-amônia



**Espaçamento padrão  
4 anos**



**Espaçamento adensado  
8 anos**



# Recuperação de N

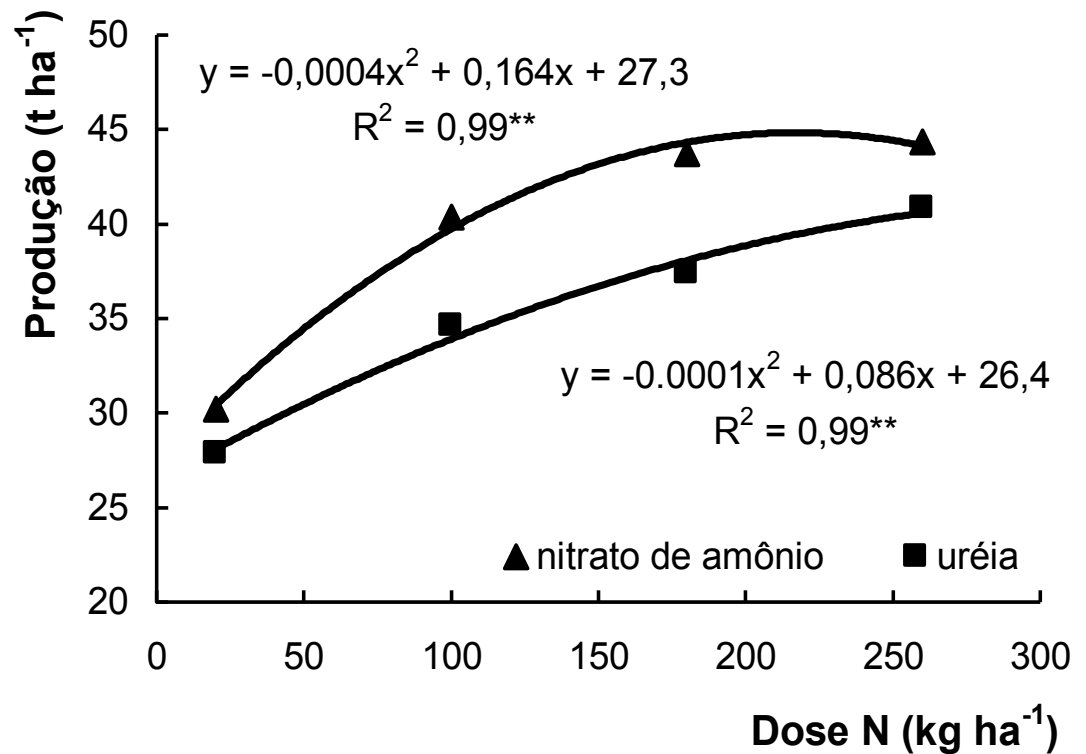
*absorção pelas folhas*

Estimativas	Espaçamento	
	padrão - 4 anos	adensado - 8 anos
N recuperado do volatilizado	3,2 %	7,3 %
N recuperado do aplicado	1,7 ± 0,1 %	6,1 ± 0,3 %
N recuperado (área)	0,7 ± 0,05 kg ha <sup>-1</sup>	4,9 ± 0,4 kg ha <sup>-1</sup>

Boaretto et al. (2012)



# Resposta dos citros à adubação N: sequeiro



Cantarella et al. (2003)





# Características dos principais fertilizantes nitrogenados

Fertilizante	Forma do N	Concentração	Outros nutrientes
		% N	%
Uréia	amídica	45	-
Nitrato de amônio	50% $\text{NH}_4^+$ , 50% $\text{NO}_3^-$	32	-
Sulfato de amônio	$\text{NH}_4^+$	20	21% S
URAN	50% amídica, 25% $\text{NH}_4^+$ , 25% $\text{NO}_3^-$	28	-
Nitrato de potássio	$\text{NO}_3^-$	13	44% $\text{K}_2\text{O}$
Nitrato de cálcio	$\text{NO}_3^-$	15	19% Ca
MAP	$\text{NH}_4^+$	9	48% $\text{P}_2\text{O}_5$

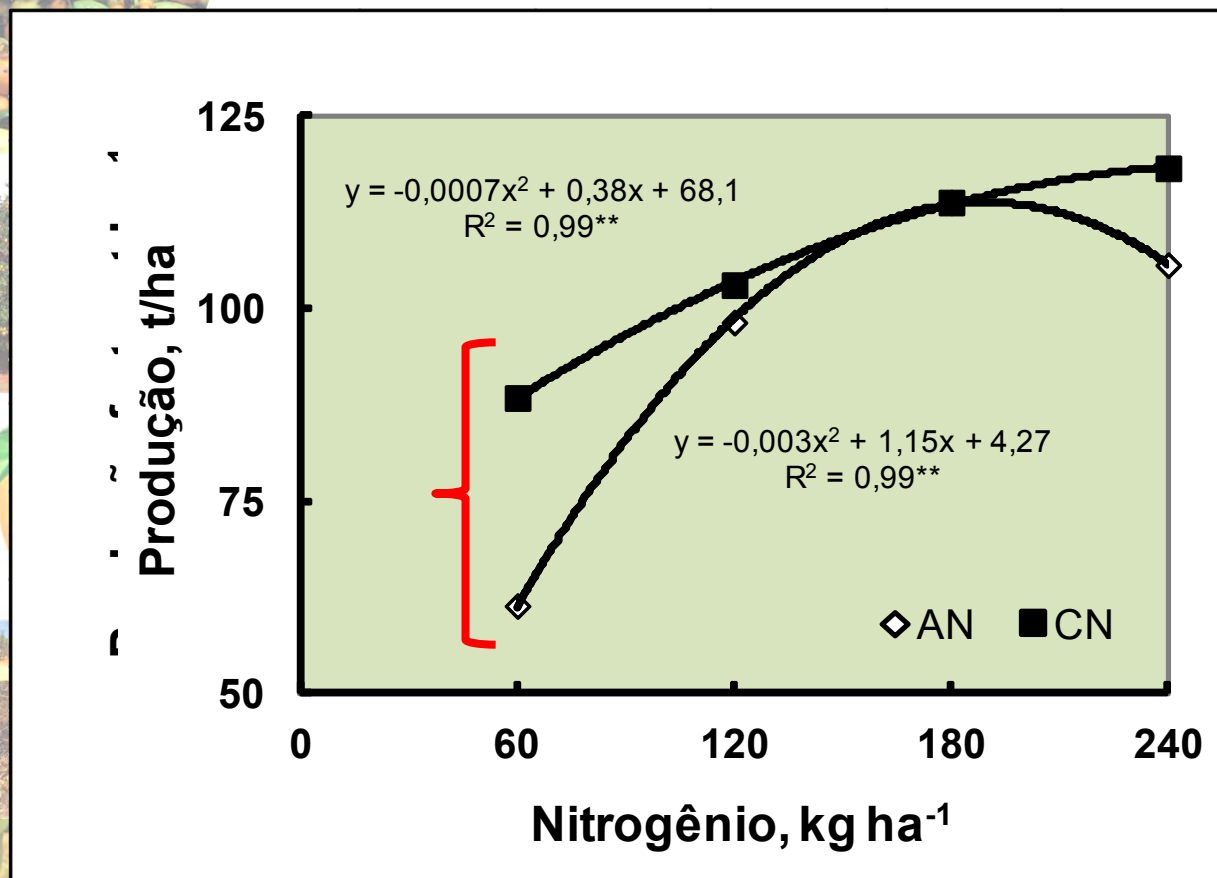


# Solubilidade e potencial de acidificação do solo

Fertilizante	Solubilidade em água	Índice de acidez (eq. $\text{CaCO}_3$ )	
		kg/kg N	kg/100 kg adubo
Uréia	Alta	-1,80	-148
Nitrato de amônio	Alta	-1,80	-79
Sulfato de amônio	Alta	-5,35	-107
MAP	Alta	-5,00	-45
Nitrato de potássio	Alta	+2,00	+26
Nitrato de cálcio	Alta	+1,35	+19

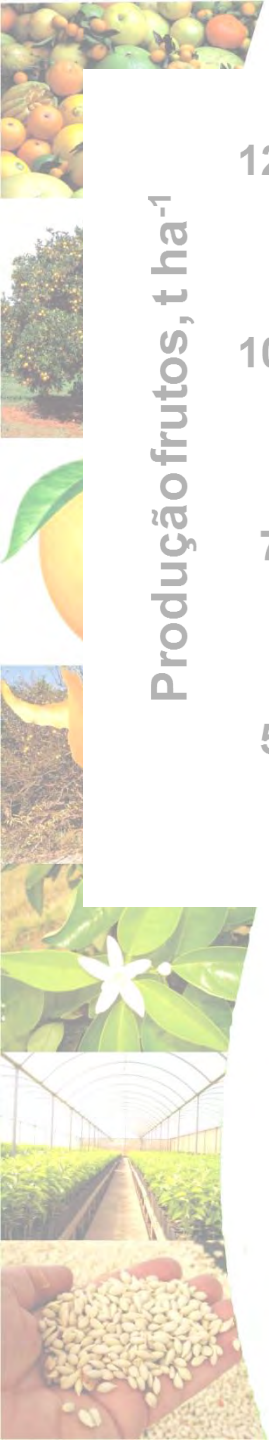
# **Resposta dos citros à adubação N: fertirrigação**



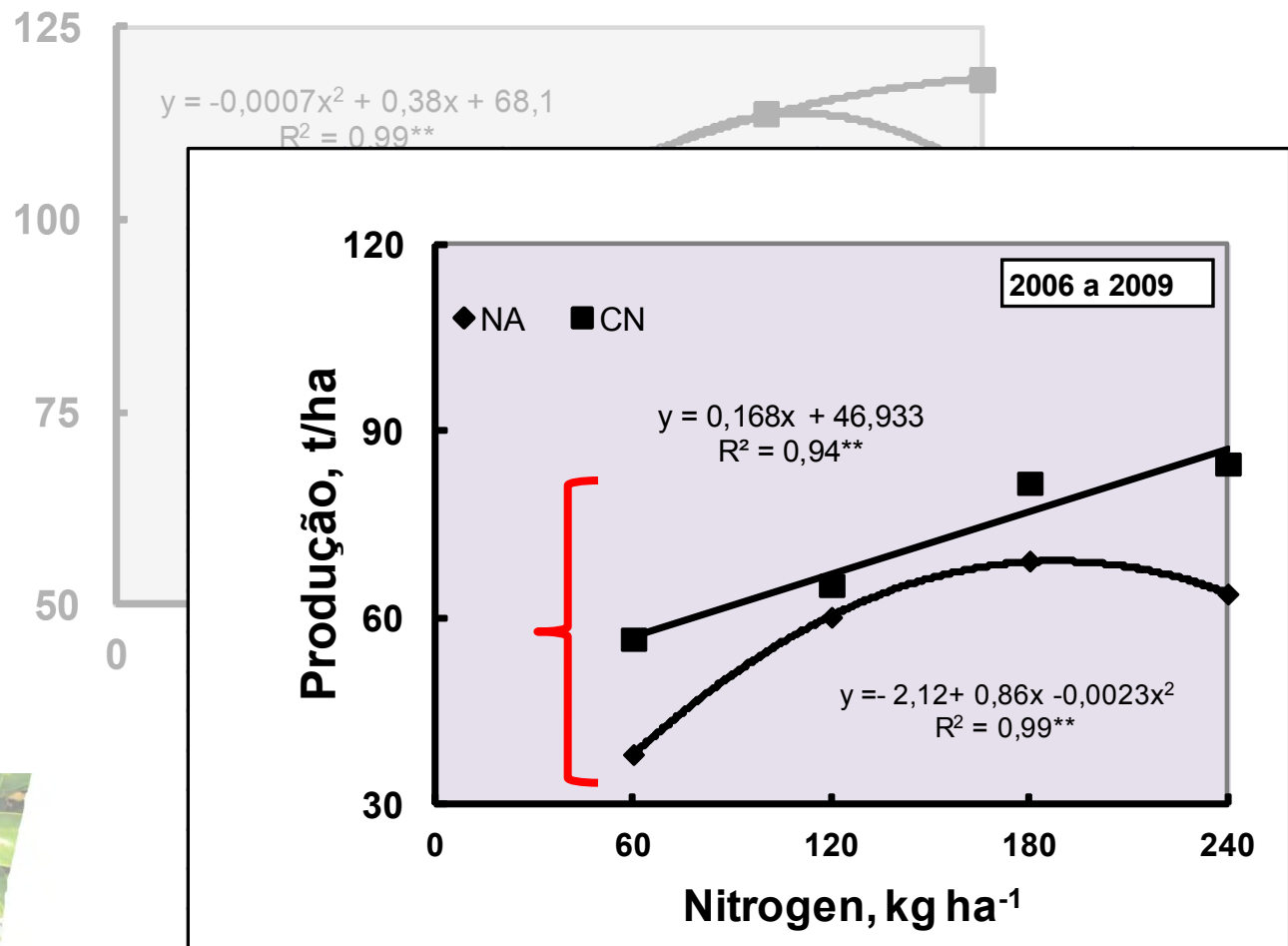


Dados 2006

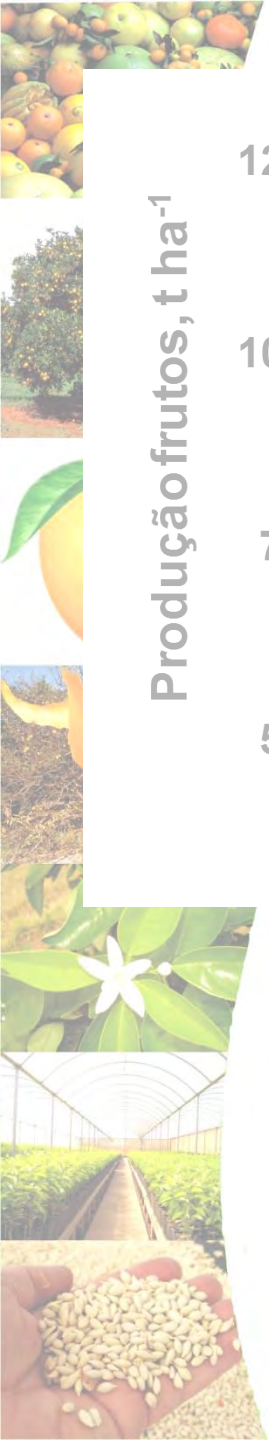




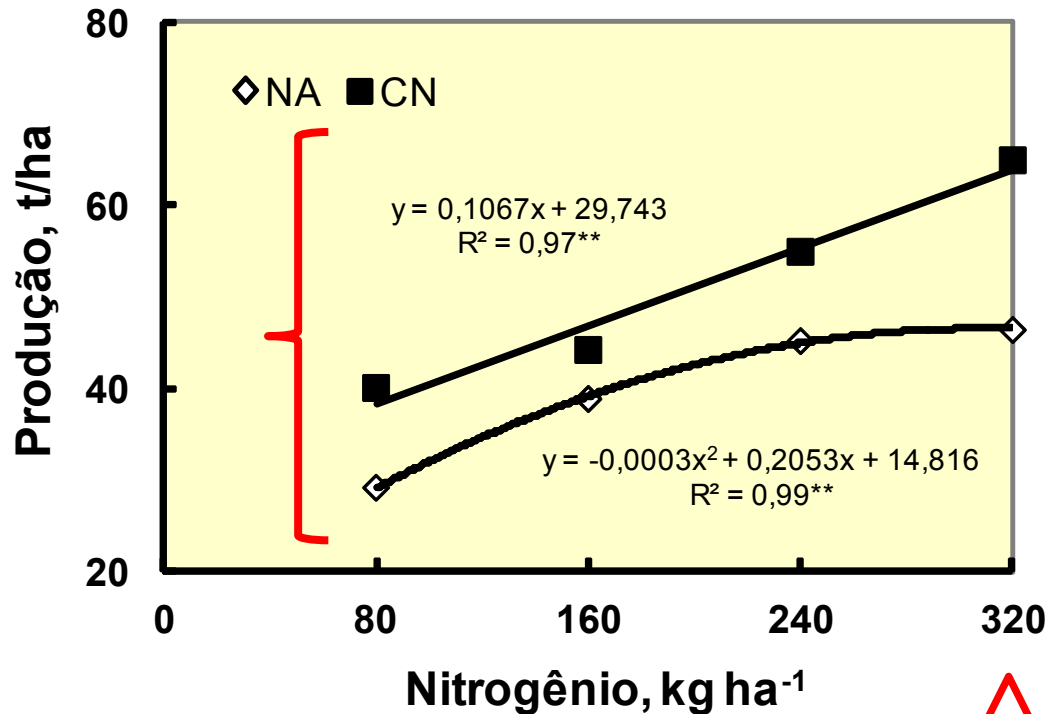
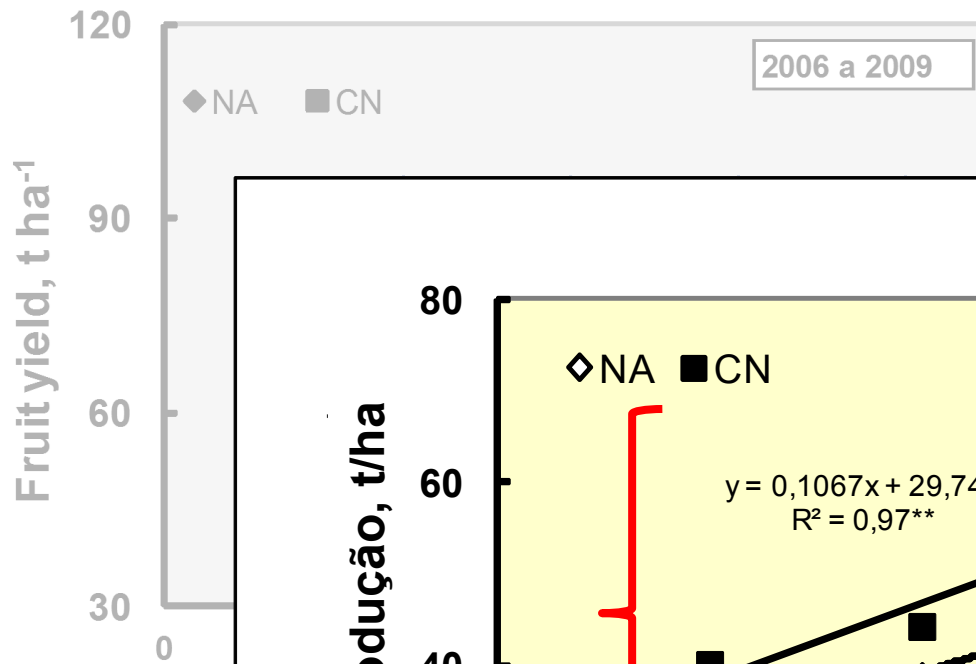
Produção frutos, t ha<sup>-1</sup>



Dados 2006 a 2008



Produção frutos, t ha<sup>-1</sup>

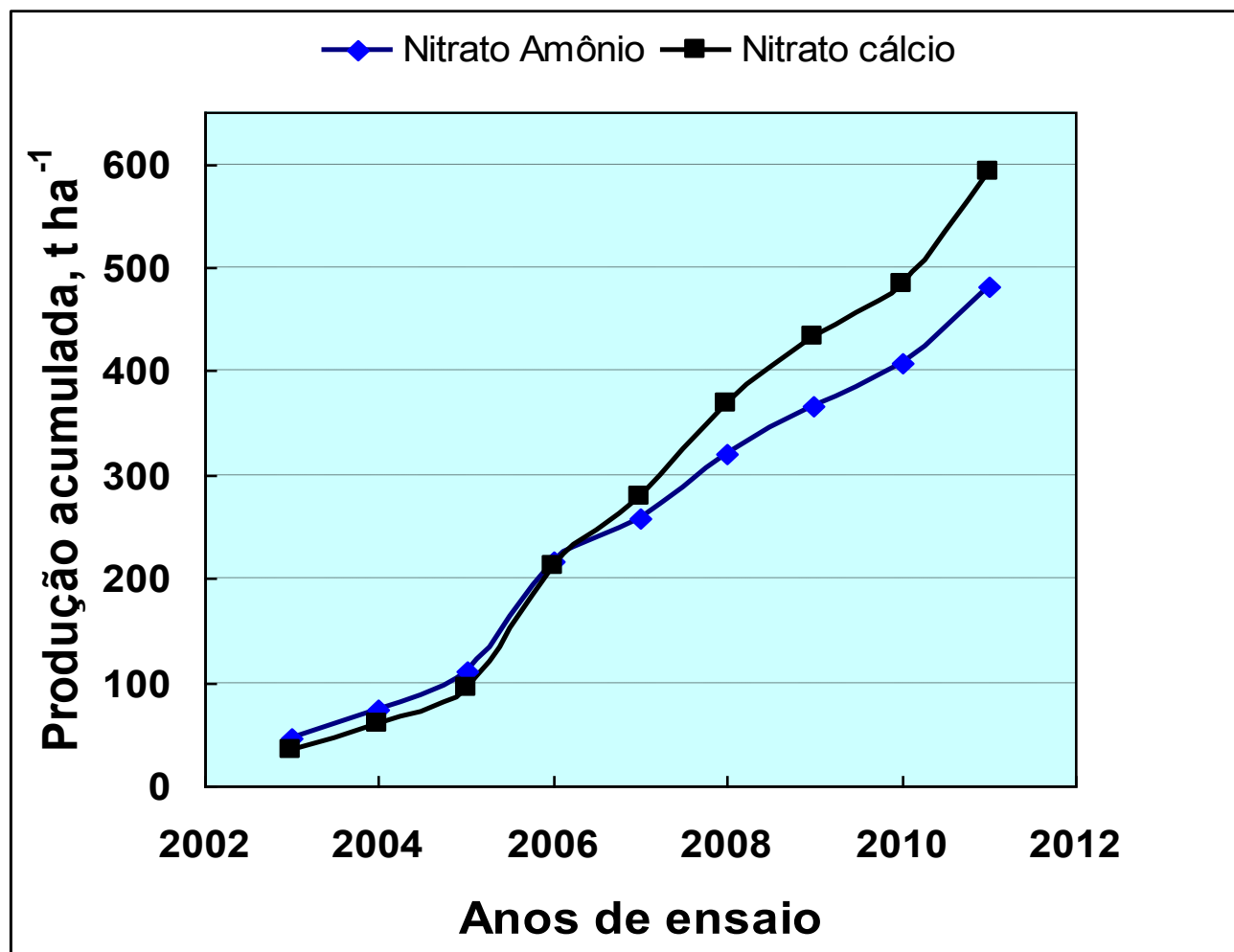


Dados 2011



# Produção acumulada de frutos:

2003-2011, N = 240 kg ha<sup>-1</sup>



# Equilíbrio iônico nos citros

Somatório de cátions = Somatório de ânions

( + )

=

( - )

$\text{Ca}^{2+}$

$\text{K}^{1+}$

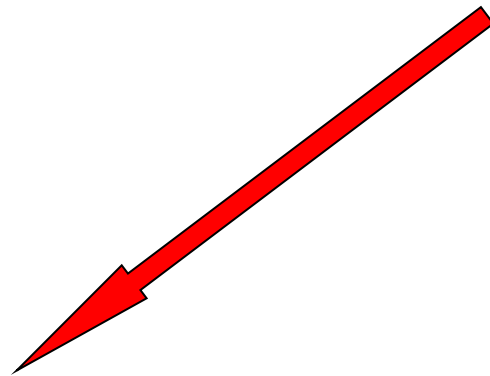
$\text{Mg}^{2+}$

$\text{NH}_4^+$

$\text{NO}_3^{1-}$

$\text{SO}_4^{2-}$

$\text{H}_2\text{PO}_4^{1-}$



# Nitrogênio:

## balanço de cargas

Table 1. Uptake of cations and anions by chickpea (*Cicer arietinum* L.) plants grown in culture solution for 24 days and supplied with either  $\text{NO}_3^-$  or  $\text{NH}_4^+$  (initial pH 6.0) All values are expressed as mmol of negative/positive charge per plant (adapted from Le Bot et al., 1990, with kind permission from Marcel Dekker Inc.)

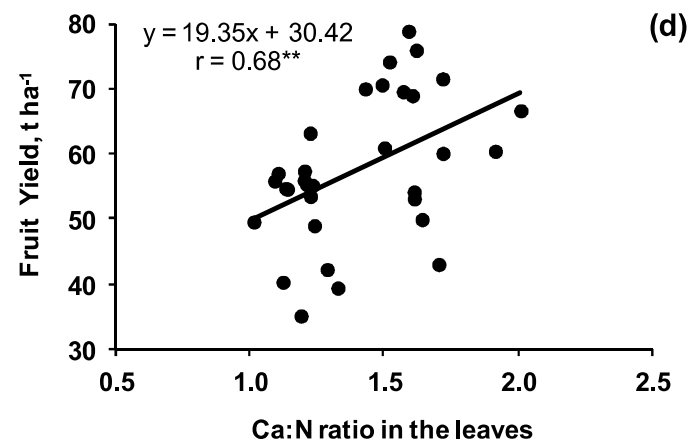
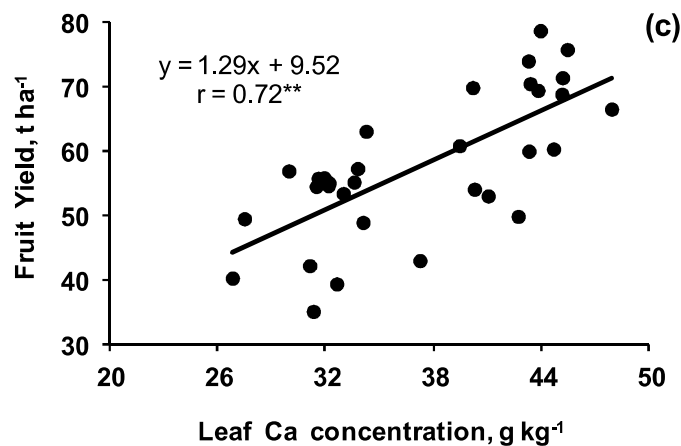
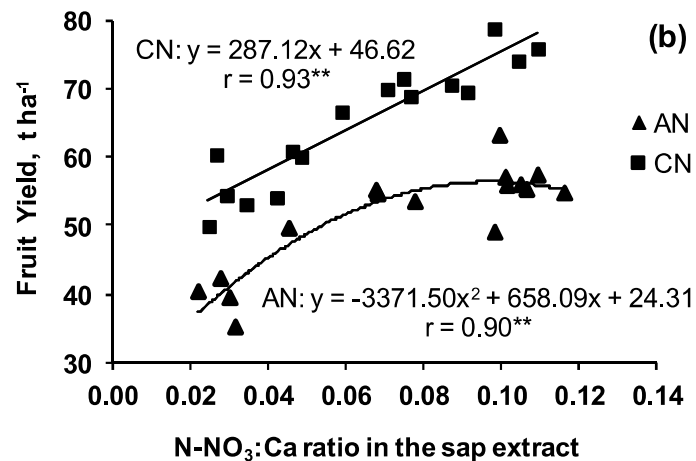
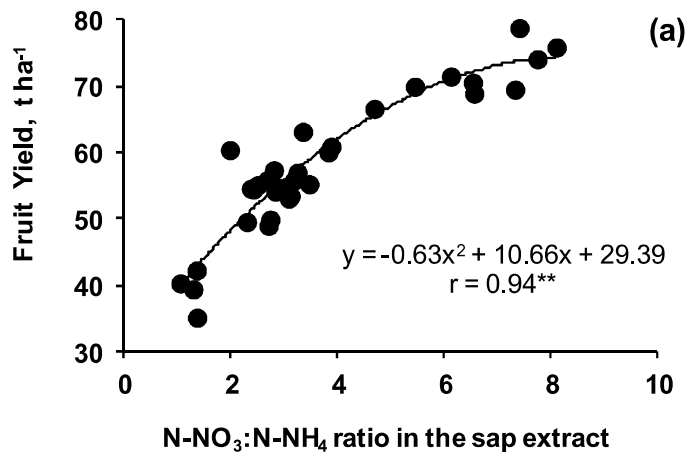
Nutrientes na planta	$\text{NO}_3^-$	$\text{NH}_4^+$
$\text{NH}_4^+$	–	7.82
$\text{K}^+$	3.10	1.38
$\text{Na}^+$	0.02	0.02
$\text{Ca}^{2+}$	2.00	0.63
$\text{Mg}^{2+}$	0.92	0.66
$\Sigma C$ (Sum of cations)	6.04	10.51
$\text{NO}_3^-$	7.39	–
$\text{H}_2\text{PO}_4^{2-}$	0.71	0.63
$\text{SO}_4^{2-}$	0.79	0.82
$\text{Cl}^-$	0.05	0.12
$\Sigma A$ (Sum of anions)	8.94	1.57
$\Sigma C - \Sigma A$	–2.90	8.94
$\text{H}^+/\text{OH}^-$ release*	–3.03	6.84

\*As measured by titrating the nutrient solution back to its initial pH (negative and positive values stand for net  $\text{H}^+$  and  $\text{OH}^-$  release, respectively).

Hinsinger et al. (2003)



# Nitrogênio e cálcio



# Estudos com raízes após 10 anos

Dose de N= 160 kg/ha



**Nitrato de amônio**



**Nitrato de cálcio**



# Estudos com raízes após 10 anos

Dose de N= 320 kg/ha



**Nitrato de amônio**

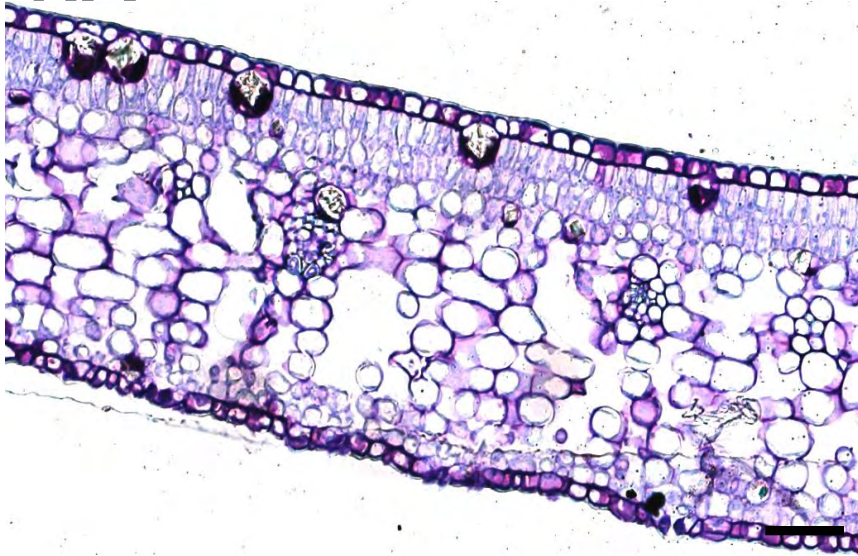


**Nitrato de cálcio**



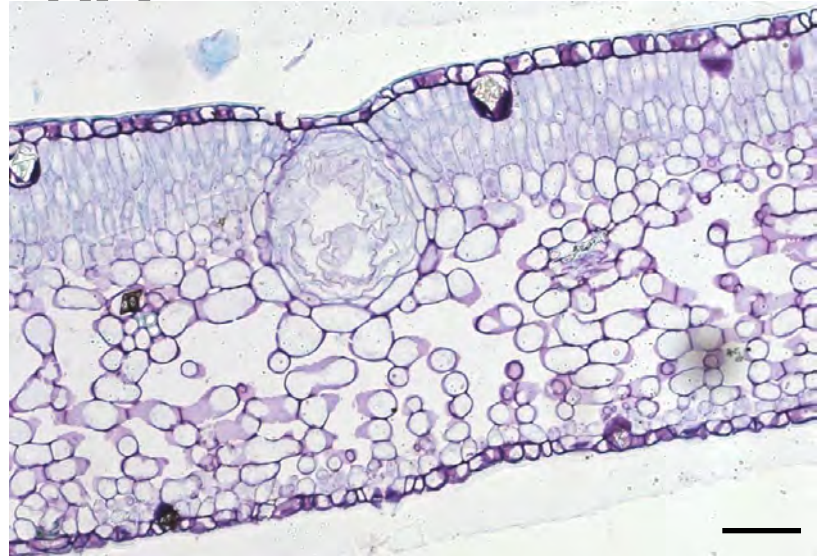
**80 kg/ha de N**

**NA**



**320 kg/ha de N**

**NA**



**NCa**



**NCa**





# Análise das safras: 2009, 2010 e 2011

Doses N kg ha <sup>-1</sup>	Produção t ha <sup>-1</sup>	Massa de frutos, g	Sólidos por caixa, kg	Sólidos por ha, kg
<b>Nitrato amônio</b>				
80	39,3	230	3,23	2889
160	53,2	216	3,25	3940
240	57,9	199	3,55	4641
320	54,3	195	3,43	4290
<b>Média</b>	<b>51,2 b</b>	<b>210 b</b>	<b>3,36 a</b>	<b>3940 b</b>
<b>Nitrato cálcio</b>				
80	51,7	229	3,08	3637
160	60,5	226	3,11	4257
240	70,1	226	2,99	4792
320	74,9	225	3,10	4293
<b>Média</b>	<b>64,3 a</b>	<b>227 a</b>	<b>3,07 b</b>	<b>4495 a</b>
CV, %	26,7	13,7	23,4	14,4

# Análise de extrato de seiva: **médias 2010 a 2011**

Doses de N kg ha <sup>-1</sup>	pH	NH <sub>4</sub>	NO <sub>3</sub>	N-total	Ca	Mg	P	K
	----- mg L <sup>-1</sup> -----							
<b>Nitrato amônio</b>								
80	5,5	24	31	1959	1584	1080	509	4397
160	5,5	29	78	2515	1700	1260	446	4286
240	5,5	38	122	2453	1777	1575	365	3976
320	5,5	48	127	2513	1778	1805	362	4120
<b>Média</b>	<b>5,5a</b>	<b>35a</b>	<b>89b</b>	<b>2360a</b>	<b>1710b</b>	<b>1430a</b>	<b>421b</b>	<b>3995b</b>
<b>Nitrato cálcio</b>								
80	5,5	16	42	2293	2066	1047	624	4323
160	5,5	19	71	2224	2105	879	516	3947
240	5,5	22	140	2691	2557	777	456	3905
320	5,5	23	171	2642	2507	720	415	3807
<b>Média</b>	<b>5,5a</b>	<b>20b</b>	<b>106a</b>	<b>2463a</b>	<b>2309a</b>	<b>856b</b>	<b>503a</b>	<b>4195a</b>

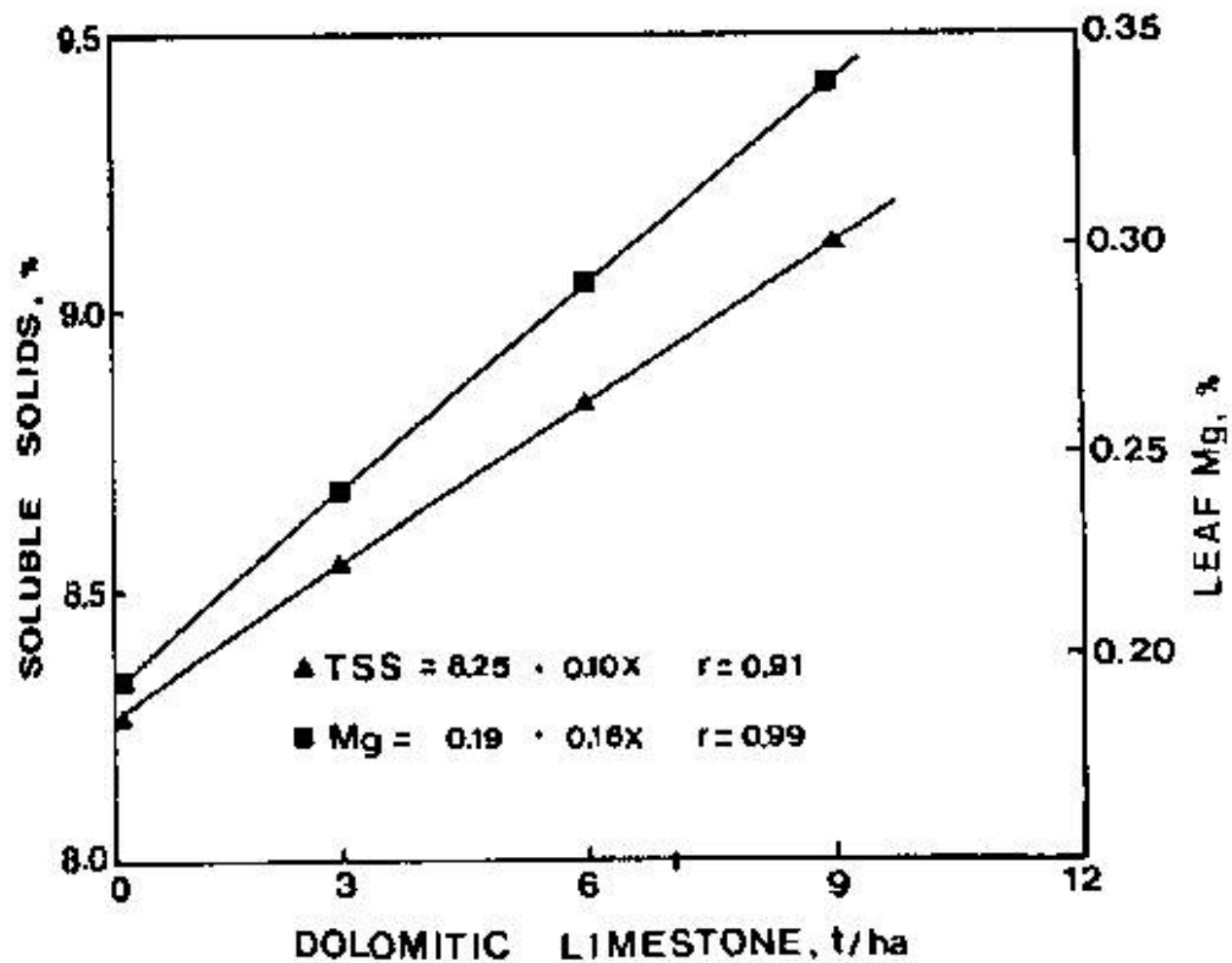
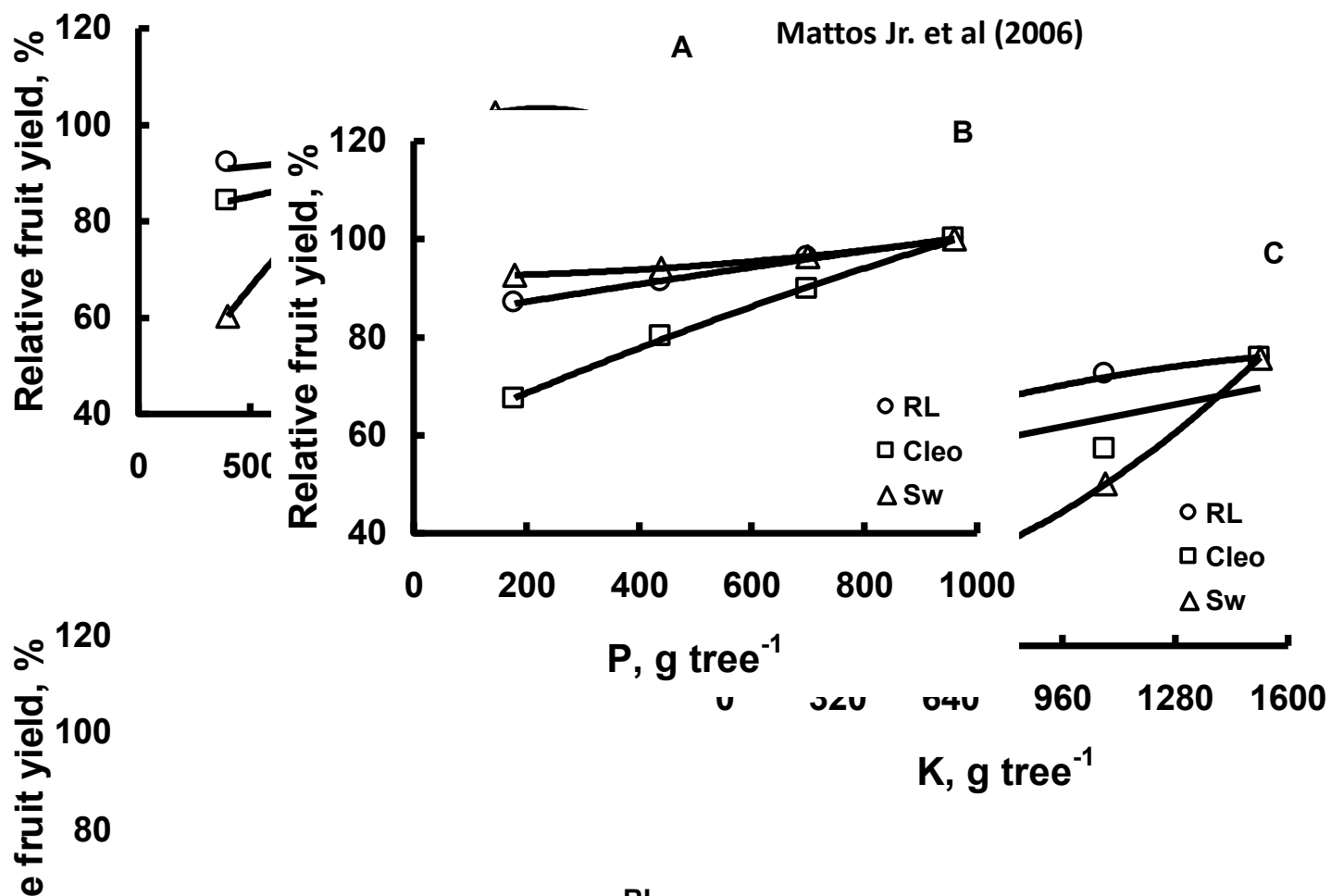


Figure 7. Effects of rates of dolomitic limestone on leaf Mg and total soluble solids in fruits in 1989.

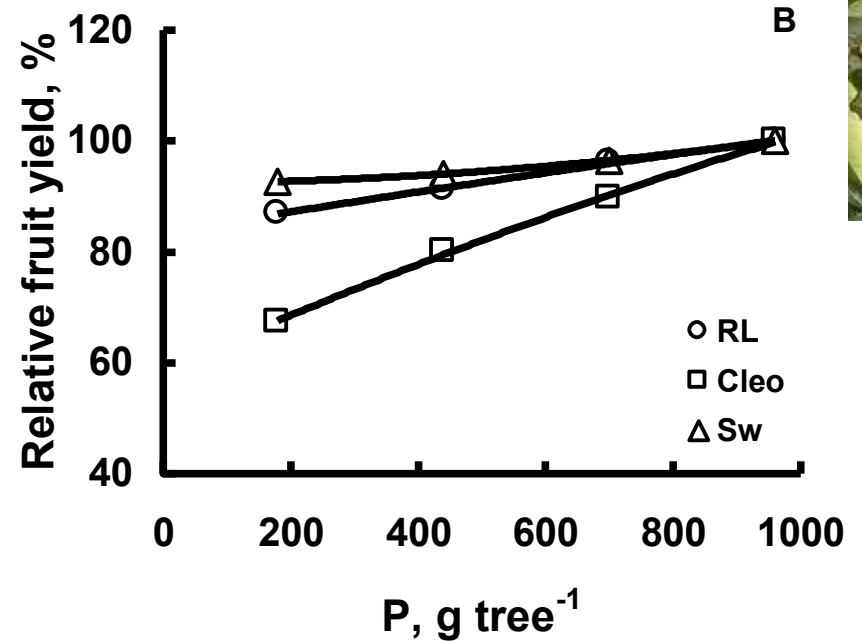
Quaggio et al. (1992)

# Demanda de nutrientes: porta-enxertos





# Deficiência de P nas folhas laranjeira Pêra NO CAMPO

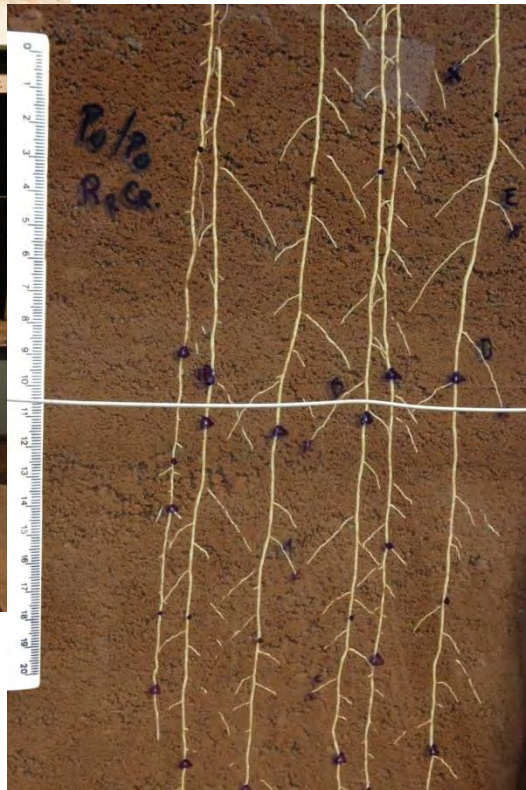
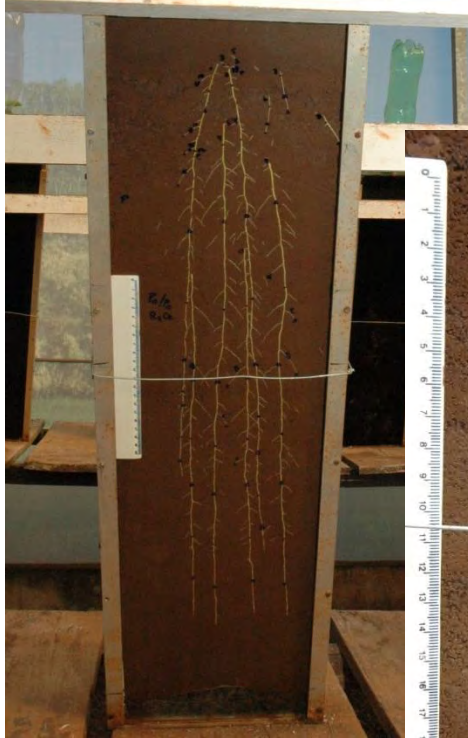


Mattos Jr. et al (2006)





**Pêra/Cravo**  
 **$P_0P_0$**



**$P_0 = 4 \text{ mg dm}^{-3}$**

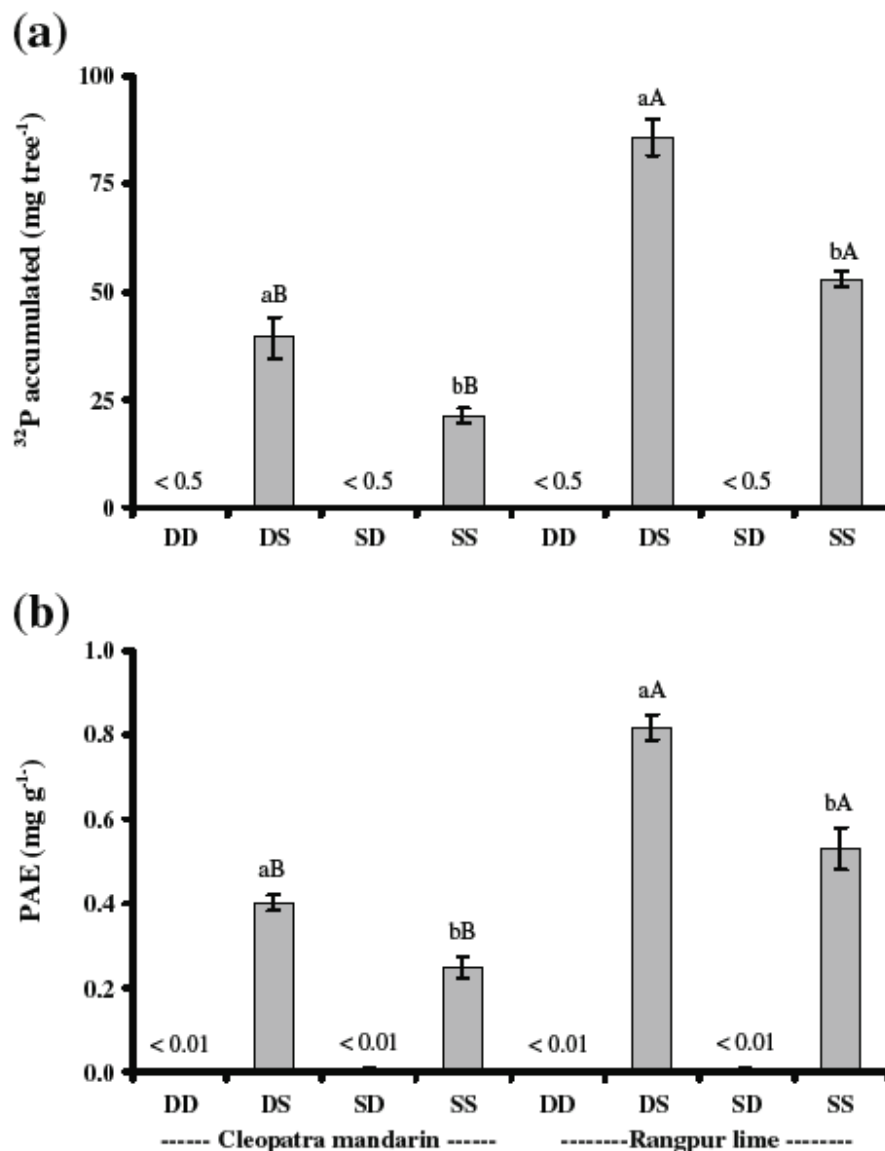


**Pêra/Cléo**  
 **$P_0P_0$**



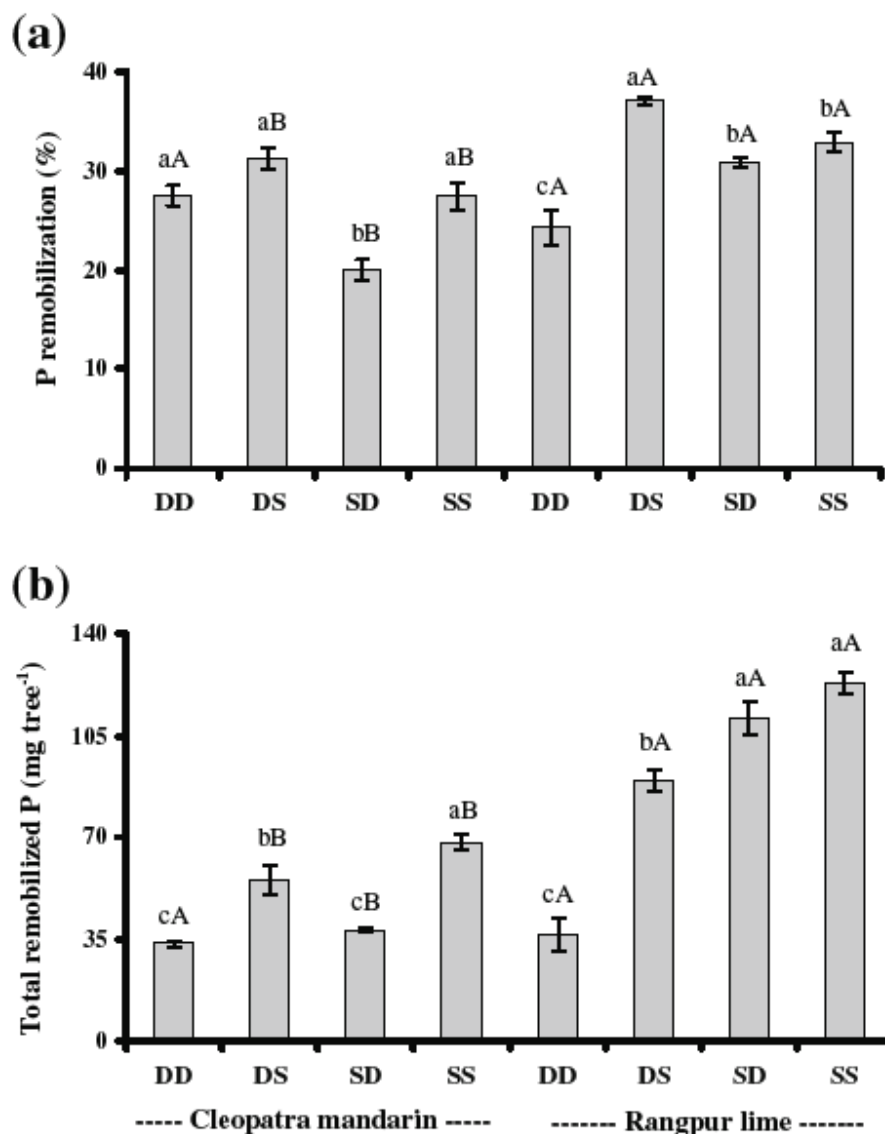
**Fig. 1**  $^{32}\text{P}$  Phosphorus ( $^{32}\text{P}$ ) accumulated **a** and efficiency of P absorption and transport to the shoot (PAE) **b** of sweet orange trees on Cleopatra mandarin or Rangpur lime rootstocks subjected to varying P availability in the nutrient solution (NS). D and S are P deficient and sufficient NS, respectively. DD, DS, SD and SS are management of P supply, in which the first and second letter refers to P availability in the NS before and after labeling with  $^{32}\text{P}$ , respectively. Significant interaction ( $p < 0.05$ ) between P treatments and rootstocks occurred for both  $^{32}\text{P}$  accumulated and PAE. P treatments comparison: columns followed by different lowercase letters within the same rootstock are significantly different by the Duncan's multiple range test ( $p < 0.05$ ). Rootstocks comparison: columns followed by different uppercase letters for the same P treatment are significantly different by the F test ( $p < 0.05$ ). The bars indicate the standard-error ( $n = 3$ )

Zambrosi et al. (2012)

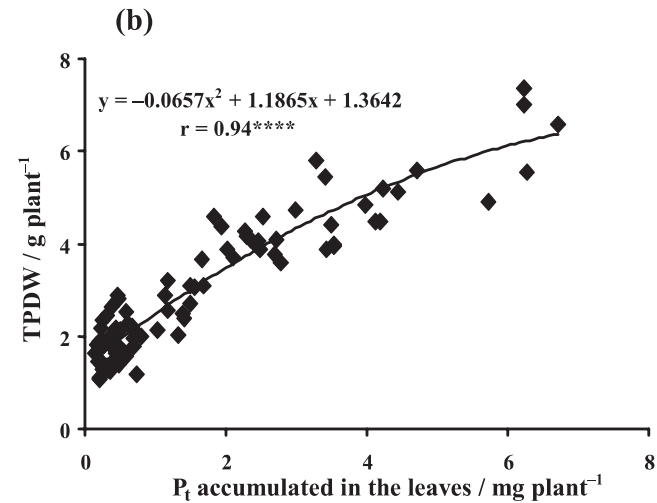


**Fig. 2** Phosphorus (P) remobilization **a** and total remobilized P **b** of sweet orange trees on Cleopatra mandarin or Rangpur lime rootstocks subjected to varying P availability in the nutrient solution (NS). D and S are P deficient and sufficient NS, respectively. DD, DS, SD and SS are management of P supply, in which the first and second letter refers to P availability in the NS before and after labeling with  $^{32}\text{P}$ , respectively. Significant interaction ( $p < 0.05$ ) between P treatments and rootstocks occurred for P remobilization and total remobilized P. P treatments comparison: columns followed by different lowercase letters within the same rootstock are significantly different by the Duncan's multiple range test ( $p < 0.05$ ). Rootstocks comparison: columns followed by different uppercase letters for the same P treatment are significantly different by the F test ( $p < 0.05$ ). The bars indicate the standard-error ( $n=3$ )

Zambrosi et al. (2012)







**Figure 1:** a) Relationships between total-plant dry weight (TPDW) and total leaf P ( $P_t$ ) from either  $P_0 + P_i$  (triangles,  $n = 48$ ) or  $P_0 + \text{Phi}$  plants (squares,  $n = 48$ ) in Carrizo citrange (CC) and Smooth Flat Seville (SFS) citrus rootstock seedlings combined; b) TPDW vs.  $P_t$  accumulated in the leaves across all treatments ( $n = 96$ ); c) TPDW vs. net assimilation of  $\text{CO}_2$  ( $A_{\text{CO}_2}$ ) across all treatments ( $n = 96$ ), and d) net assimilation of  $\text{CO}_2$  ( $A_{\text{CO}_2}$ ) and total leaf P ( $P_t$ ) from either  $P_0 + P_i$  (triangles,  $n = 48$ ) or  $P_0 + \text{Phi}$  plants (squares,  $n = 48$ ) in CC and SFS citrus rootstock seedlings combined. ns: nonsignificant ( $p > 5\%$ ); \*\* $p < 1\%$ ; \*\*\* $p < 0.1\%$ ; \*\*\*\* $p < 0.01\%$ .



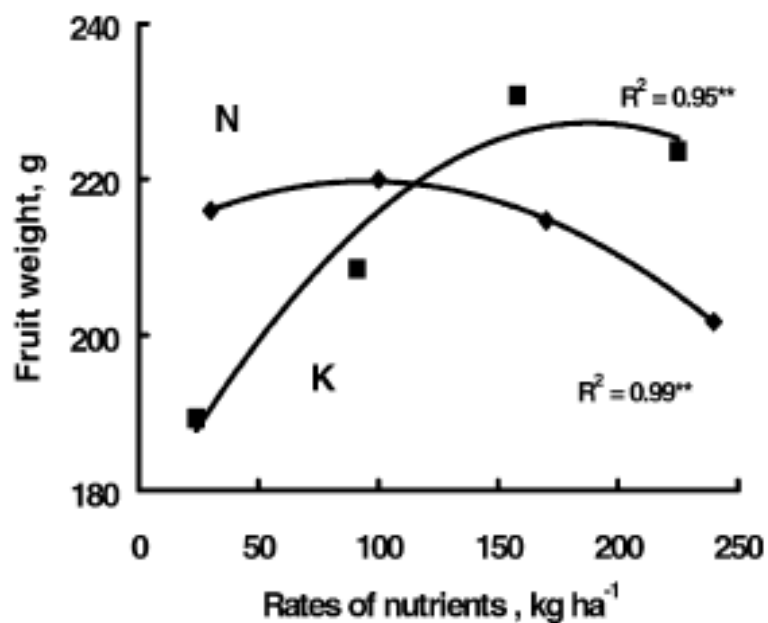
# Produção e qualidade da fruta

Rendimento em SS

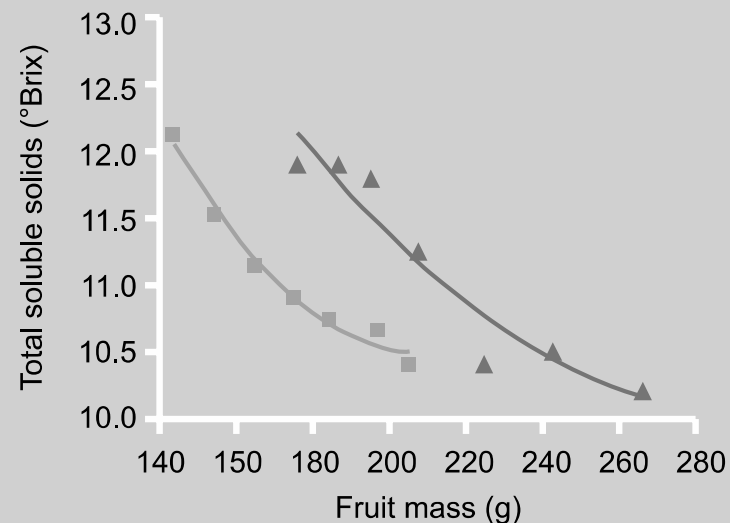
Qualidade externa



# Qualidade da fruta: respostas N e K



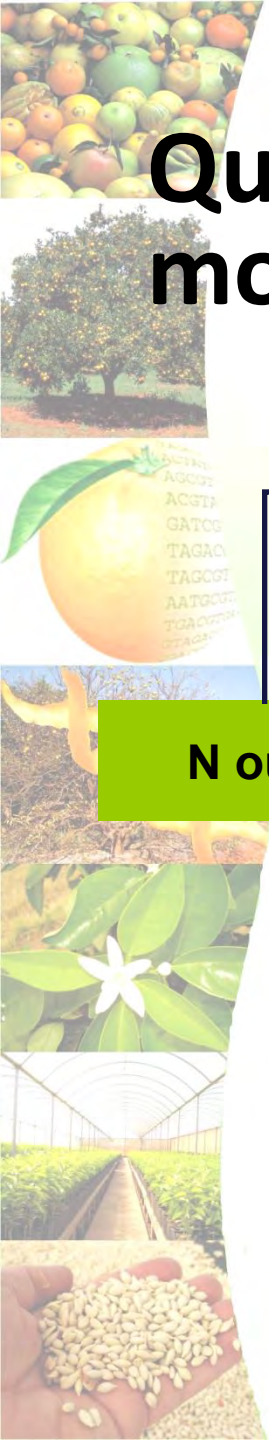
Quaggio et al. (2002)



▲ Valencia  
 $y = 1E10^{-4} x^2 - 0.07 x + 22.81$   
 $R^2 = 0.92^{**}$

■ Pêra  
 $y = 4E10^{-4} x^2 - 0.16 x + 26.89$   
 $R^2 = 0.98^{**}$

Quaggio et al. (2006)





# Potássio

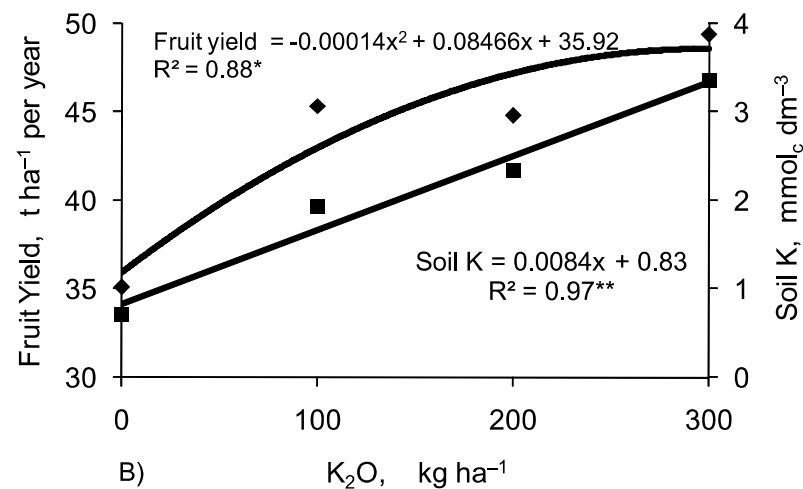
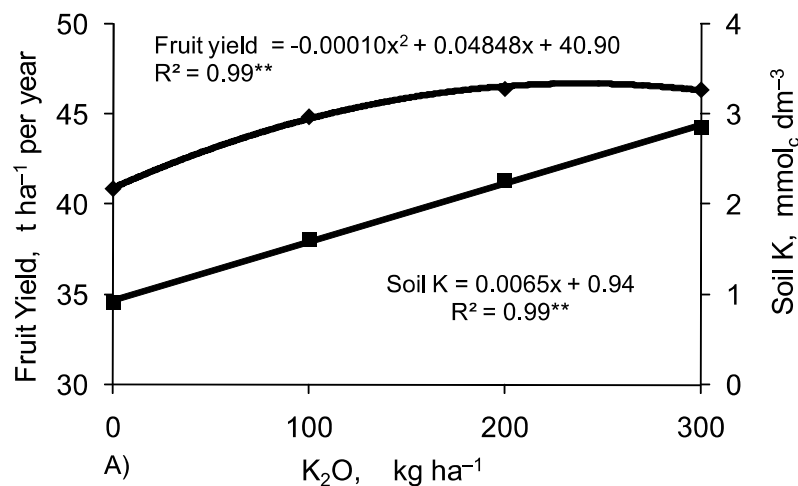


Figure 1 – Effects of potassium fertilization on fruit yield of (A) ‘Pêra’ (Santa Cruz do Rio Pardo) and (B) ‘Valencia’ (Matão) sweet oranges in two locations in the State of São Paulo, Brazil. Data represent mean values for the 2001-2004 period. \*Significant at  $p < 0.05$ . \*\*Significant at  $p < 0.01$ .

# Potássio

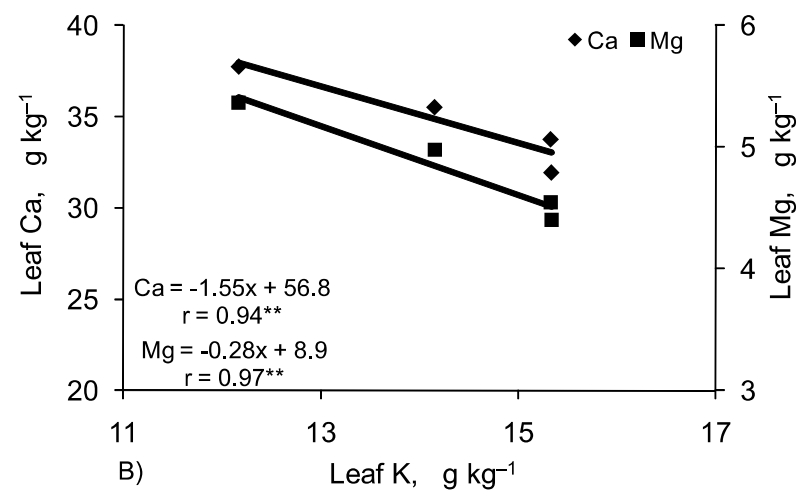
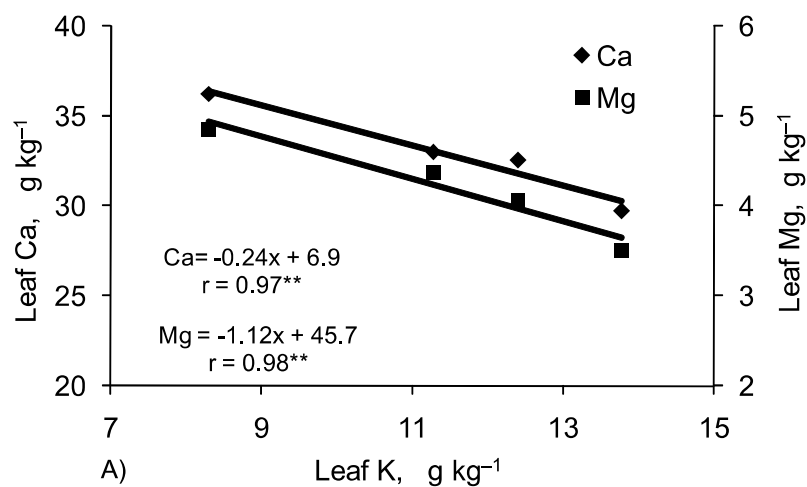
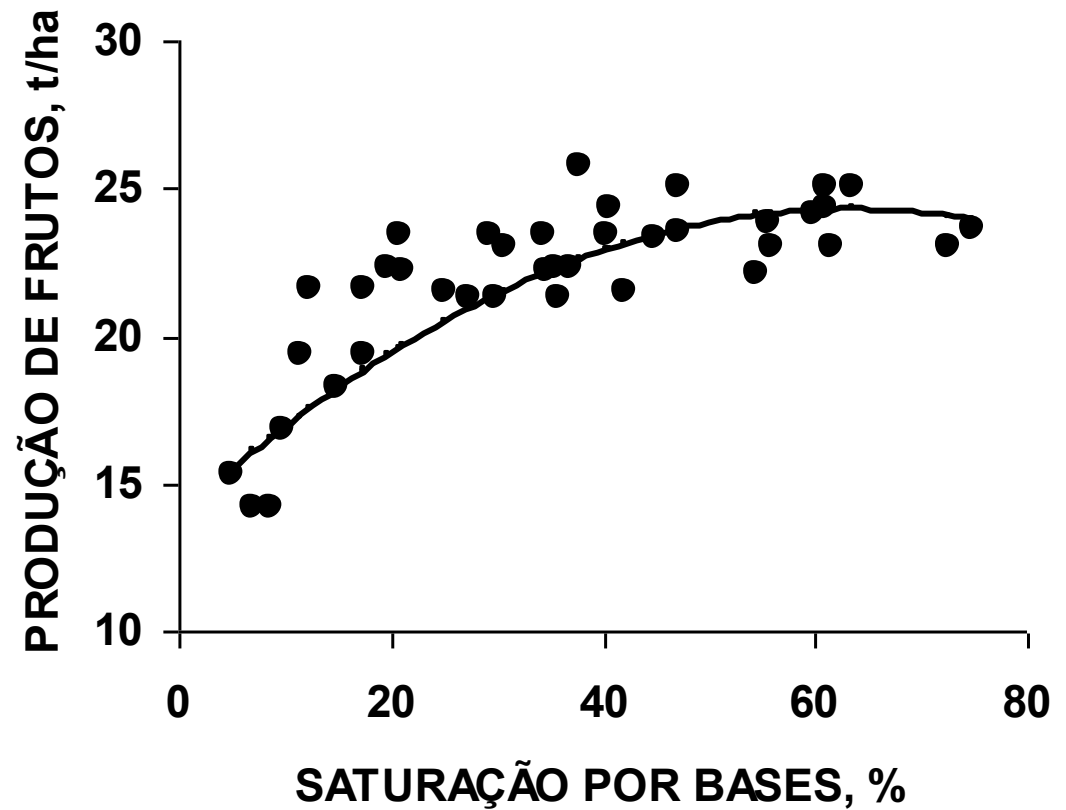


Figure 4 – Effect of potassium on calcium and magnesium concentration in leaves of (A) 'Pêra' (Santa Cruz do Rio Pardo) and (B) 'Valencia' (Matão) sweet oranges in two locations in the State of São Paulo, Brazil. Data represent mean values for the 2001-2004 period.  
\*\*Significant at  $p < 0.01$ .



# Calagem para citros

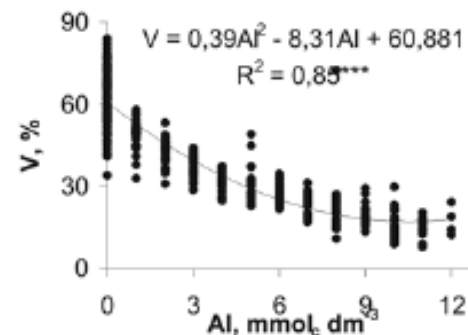
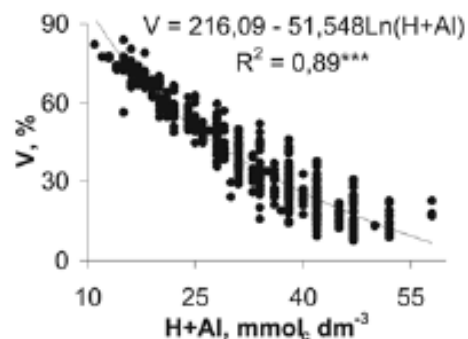
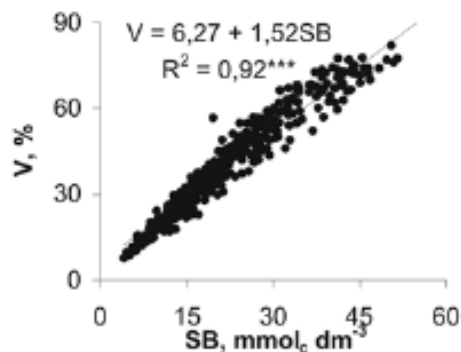
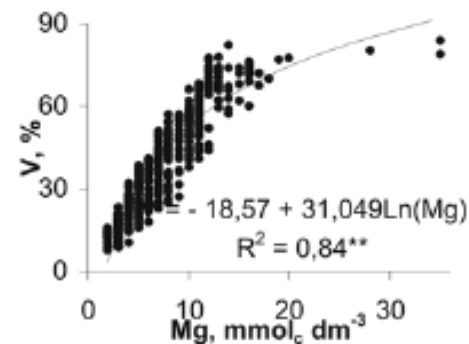
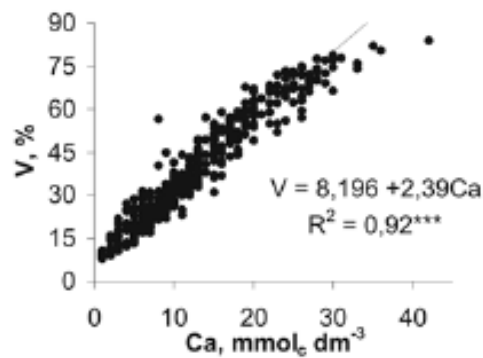
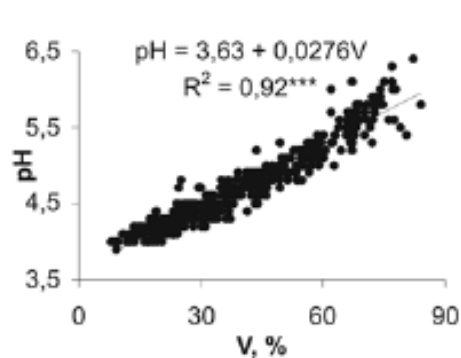
Quaggio et al. (1992a)





# Calagem para citros

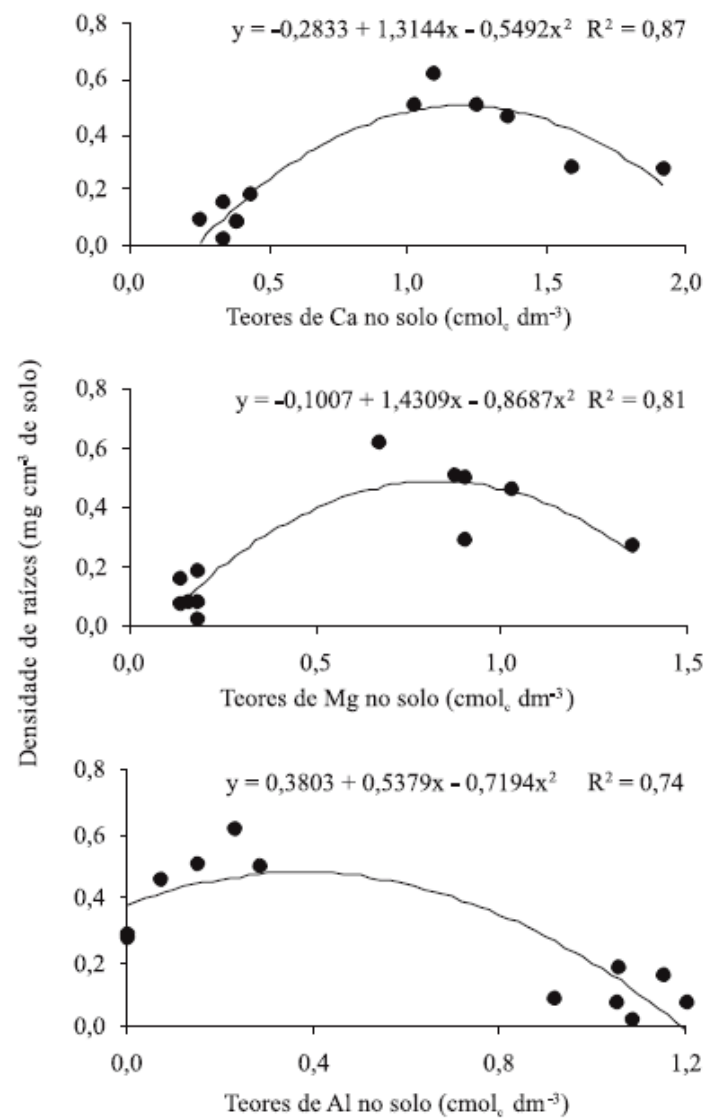
Camacho et al. (2007)





# Calagem para citros

Auler et al. (2011)

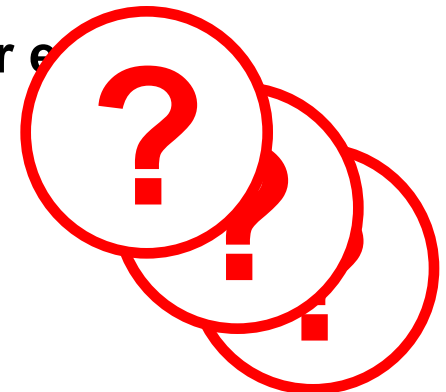


**Figura 2.** Densidade de raízes de laranjeira 'Valência' enxertada no porta-enxerto *P. trifoliata*, em função dos teores de Ca, Mg e Al trocável no solo, nas camadas de 10–20 e 20–40 cm de profundidade.

# Mironutrientes



- Fotossíntese e evolução de  $O_2$
- Transporte de  $e^-$  (reações redox, armazenamento energia)
- Síntese de aa, proteínas e AIA
- Síntese DNA e RNA
- Estresse oxidativo
- Metabolismo de CH, lipídeos e N
- Lignificação
- Metabolismo de fenóis
- Integridade de parede celular e membranas
- Mal funcionamento vasos e transporte de CH
- Outros processos...



# Distúrbios fisiológicos da falta de boro





# Boro

Deficiente

Adequado

Excesso

Valência/  
Sunki



Valência/  
Swingle



Mesquita (em andamento)



# Boro

Deficiente

Adequado

Excesso

Valência/  
Sunki



Valência/  
Swingle



Mesquita (em andamento)

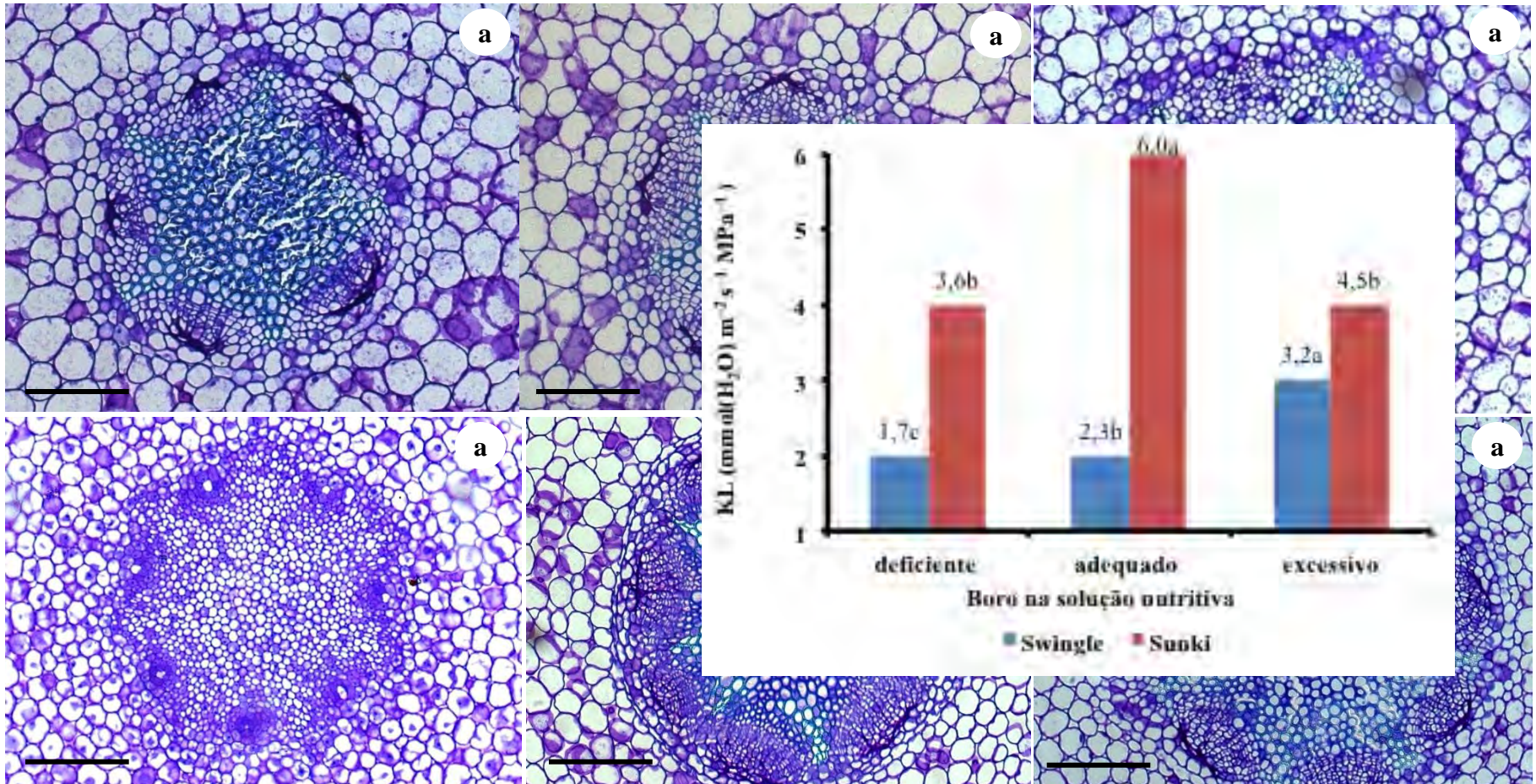


# Boro

Deficiente

Adequado

Excesso



# Novos resultados e perspectivas: **Zn**

## Teor de Zn no tecido vegetal e no solo

### Teor de Zn

#### Franco arenoso

#### Muito argiloso

### Folhas

#### velhas

#### novas

#### velhas

#### novas

### Tratamentos

Fonte e dose (g de Zn planta<sup>-1</sup>)

**Controle**

**ZnSO<sub>4</sub> 1,0**

**ZnSO<sub>4</sub> 5,0**

**ZnO 1,0**

**ZnO 5,0**

8,7 ± 0,4

18,7 ± 5,2

79,9 ± 16,3

9,4 ± 1,5

20,7 ± 5,3

9,9 ± 1,6

31,8 ± 4,8

143,7 ± 16,5

11,8 ± 0,7

41,7 ± 6,7

10,9 ± 0,2

14,4 ± 1,5

49,6 ± 15,3

13,2 ± 0,8

15,4 ± 0,8

11,0 ± 1,7

15,9 ± 2,3

114,7 ± 55,5

16,4 ± 3,0

18,3 ± 2,1

### Teor de Zn no solo

#### Franco arenoso

#### Muito argiloso

mg dm<sup>-3</sup>

1,0 ± 0,28

31,6 ± 9,2

121,3 ± 19,0

6,9 ± 2,0

84,0 ± 25,5

1,8 ± 0,2

29,4 ± 6,2

73,8 ± 49,5

8,7 ± 5,82

44,9 ± 10,37

**Hippler (2012)**

# Novos resultados e perspectivas: **Mn**

## ○ Teor de Mn no tecido vegetal e no solo

Tratamentos	Teor de Mn				Teor de Mn no solo	
	Franco arenoso		Muito argiloso		Franco arenoso	Muito argiloso
	Folhas					
	velhas	novas	velhas	novas		
Fonte e dose (g de Mn planta <sup>-1</sup> )	----- mg kg <sup>-1</sup> -----				----- mg dm <sup>-3</sup> -----	
Controle	40,0 ± 7,7	55,5 ± 17,5	45,3 ± 8,3	23,3 ± 5,0	9,3 ± 4,3	5,9 ± 0,6
MnSO <sub>4</sub> 0,7	104,0 ± 30,3	145,5 ± 33,1	54,0 ± 8,8	23,5 ± 4,4	31,7 ± 20,7	12,1 ± 9,9
MnSO <sub>4</sub> 3,5	550,8 ± 129,0	951,3 ± 478,4	141,5 ± 54,5	84,3 ± 44,2	52,6 ± 10,8	30,1 ± 14,2
MnCO <sub>3</sub> 0,7	46,8 ± 5,1	80,8 ± 16,6	43,0 ± 1,4	22,5 ± 2,1	39,9 ± 14,1	13,9 ± 8,9
MnCO <sub>3</sub> 3,5	62,0 ± 18,5	136,5 ± 61,4	45,3 ± 8,32	27,5 ± 4,0	63,6 ± 24,2	26,8 ± 17,6

Hippler (2012)





# HLB na Flórida

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**McKinnon Co.  
Flórida, fev. 2013**

Sadio



Test.

+Micros

+Phi

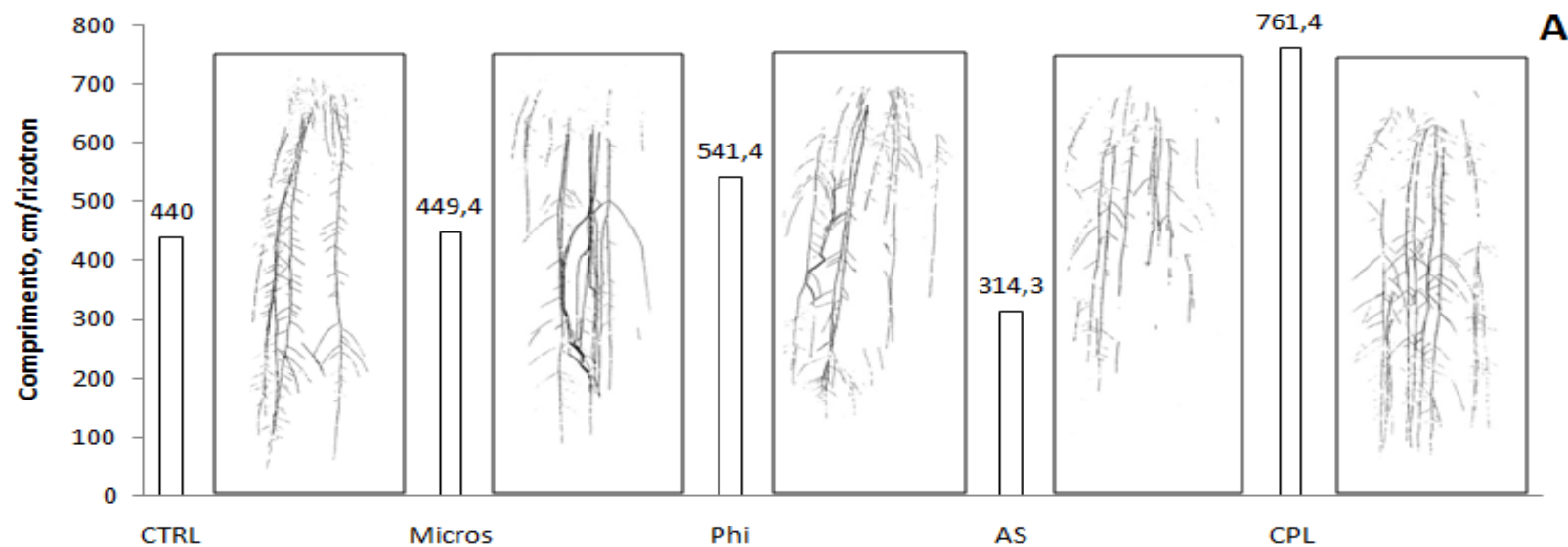
+SA

Completo

HLB+

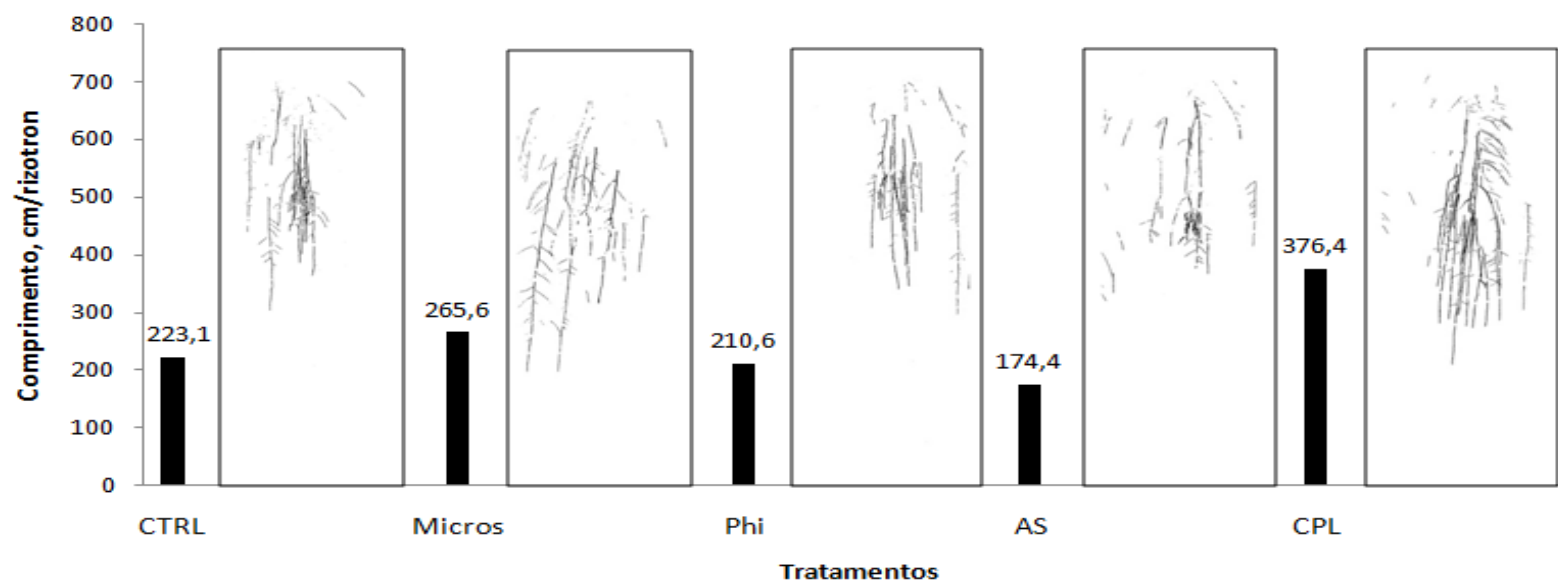


**Sadio**



**A**

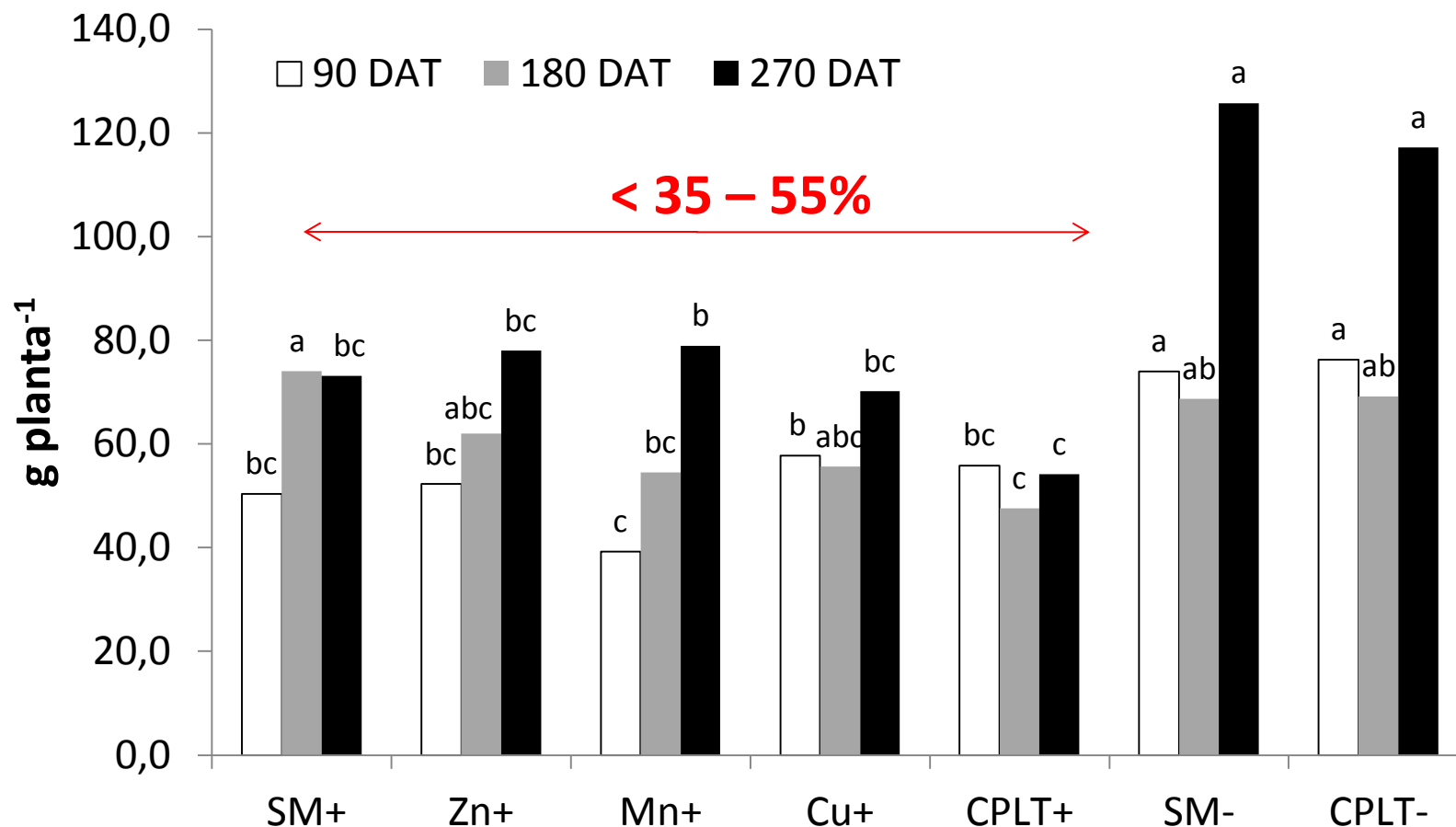
**HLB+**



**B**

## 2 Experimento micronutrientes

### Massa seca de raízes





# 3 Experimento de campo

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**Planta assintomática**



**Planta sintomática (HLB)**

**Teste F**

**Sanidade**

**Trat (T)**

**S\*T**

**HLB-Sintomático**

**HLB-Assintomático**

[illegible]

# PCR e características folhas

50 folhas/amostra

TRATAMENTOS		PCR	AF abr/12	MS	PCR	AF nov/12	MS
		CT	cm <sup>2</sup>	g	CT	cm <sup>2</sup>	g
HLB-Sintomático	Test	22,3	912	12,4	21,9	1116	13,5
	Micros 1	25,1	783	10,4	26,9	1057	13,0
	KNO <sub>3</sub>	22,4	883	11,0	31,0	1022	10,8
	Micros 2	23,9	821	11,8	23,5	1057	11,9
	Phi	22,8	960	12,4	21,6	1039	12,6
	AS	20,1	877	11,1	26,1	1008	12,0
	CPLT	23,3					
	Comercial	22,4					
	<b>Média</b>	<b>22,8</b>					
Assintomático	Test	37,1					
	Micros 1	35,7					
	KNO <sub>3</sub>	27,2					
	Micros 2	36,7	1284	12,8	ND	1140	13,2
	Phi	36,4	1033	10,4	ND	1269	14,6
	AS	33,5	1173	11,4	ND	1114	13,0
	CPLT	32,0	1366	13,0	ND	1240	12,7
	Comercial	33,6	865	9,9	ND	1040	11,5
	<b>Média</b>	<b>34,0</b>	<b>1163</b>	<b>11,7</b>	-	<b>1157</b>	<b>13,1</b>
<b>Teste F</b>							
Sanidade (S)		-	**	NS	-	NS	NS
Trat (T)		-	NS	NS	-	NS	NS
S*T		-	*	NS	-	NS	NS

**Ct>36 – negativo HLB**  
**Ct<36 – positivo HLB**

**maior valor Ct, menor concentração da bactéria na amostra**

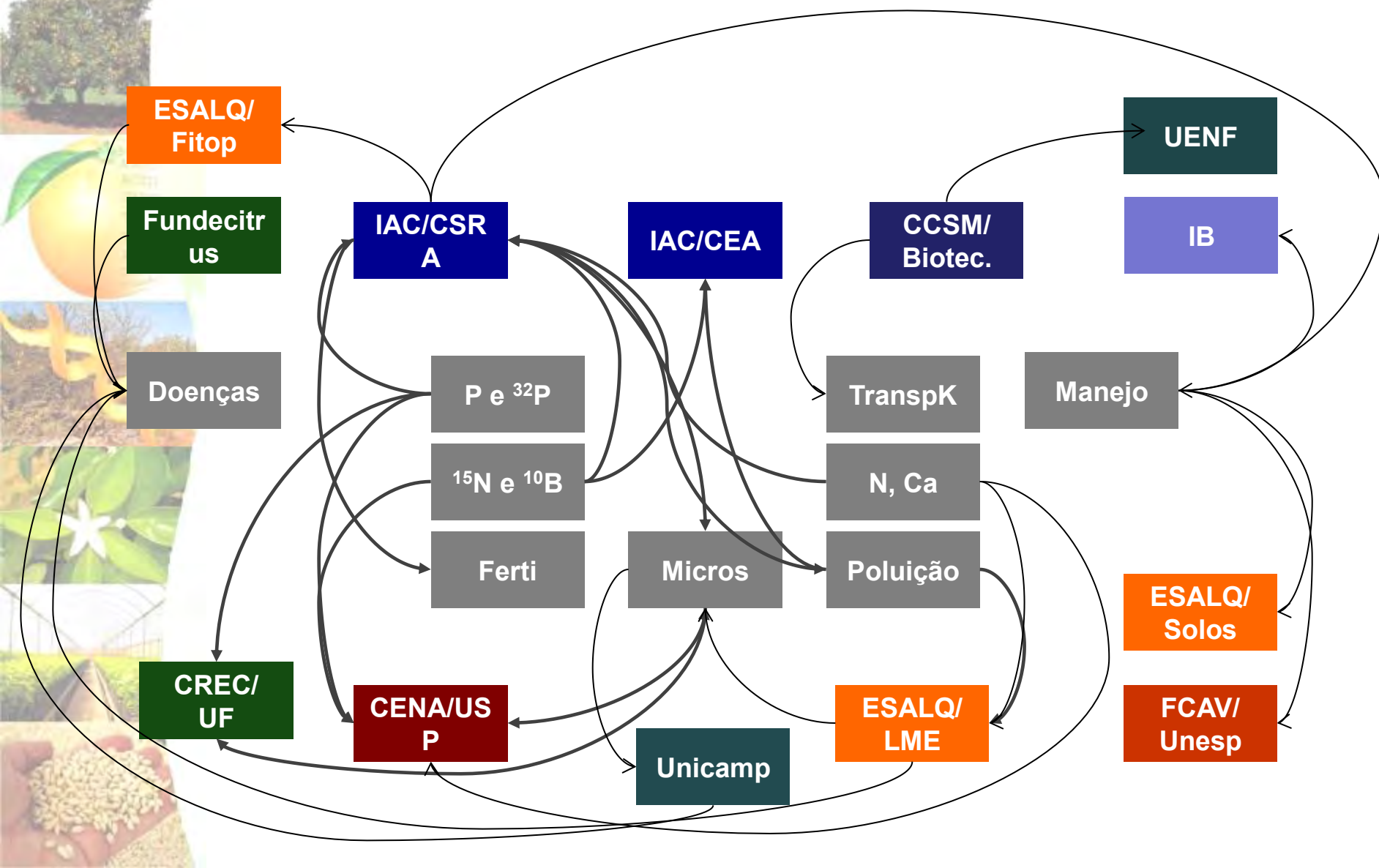
# PCR e características folhas

50 folhas/amostra

TRATAMENTOS		PCR →	AF abr/12	MS	PCR →	AF nov/12	MS
		CT	cm <sup>2</sup>	g	CT	cm <sup>2</sup>	g
HLB-Sintomático	Test	22,3	912	12,4	21,9	1116	13,5
	Micros 1	25,1	783	10,4	26,9	1057	13,0
	KNO <sub>3</sub>	22,4	883	11,0	31,0	1022	10,8
	Micros 2	23,9	821	11,8	23,5	1057	11,9
	Phi	22,8	960	12,4	21,6	1039	12,6
	AS	20,1	872	11,4	26,1	1098	12,9
	CPLT	23,3	867	11,3	25,4	1071	12,7
	Comercial	22,4	831	11,4	22,1	1106	13,4
	<b>Média</b>	<b>22,8</b>	<b>866</b>	<b>11,5</b>	<b>24,8</b>	<b>1071</b>	<b>12,6</b>
Assintomático	Test	37,1	1169	11,8	ND	1251	13,3
	Micros 1	35,7	1123	11,6	ND	1170	13,5
	KNO <sub>3</sub>	27,2	1292	12,5	ND	1032	12,8
	Micros 2	36,7	1284	12,8	ND	1140	13,2
	Phi	36,4	1033	10,4	ND	1269	14,6
	AS	33,5	1173	11,4	ND	1114	13,0
	CPLT	32,0	1366	13,0	ND	1240	12,7
	Comercial	33,6	865	9,9	ND	1040	11,5
	<b>Média</b>	<b>34,0</b>	<b>1163</b>	<b>11,7</b>	-	<b>1157</b>	<b>13,1</b>
<b>Teste F</b>							
Sanidade (S)		-	**	NS	-	NS	NS
Trat (T)		-	NS	NS	-	NS	NS
S*T		-	*	NS	-	NS	NS



# Equipe de pesquisa IAC/CCSM





**Grato pela atenção!**