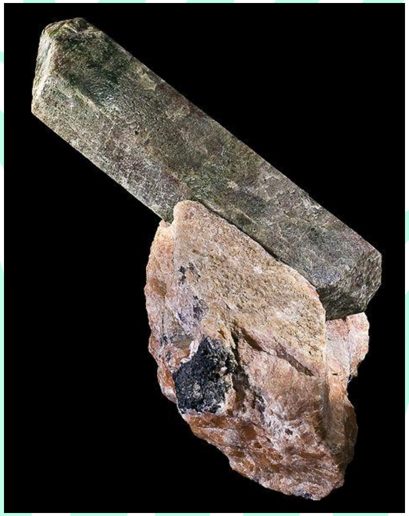
Seminar: Disponibilidade e Manejo de Fósforo no Solo / ESALQ-USP

Using phosphate resources as efficiently as possible with current production and agronomic use technologies

Dr. Luís Ignácio Prochnow
IPNI Brazil Program Director



APATITE

RESPONSE TO P

IPNI International Plant Nutrit

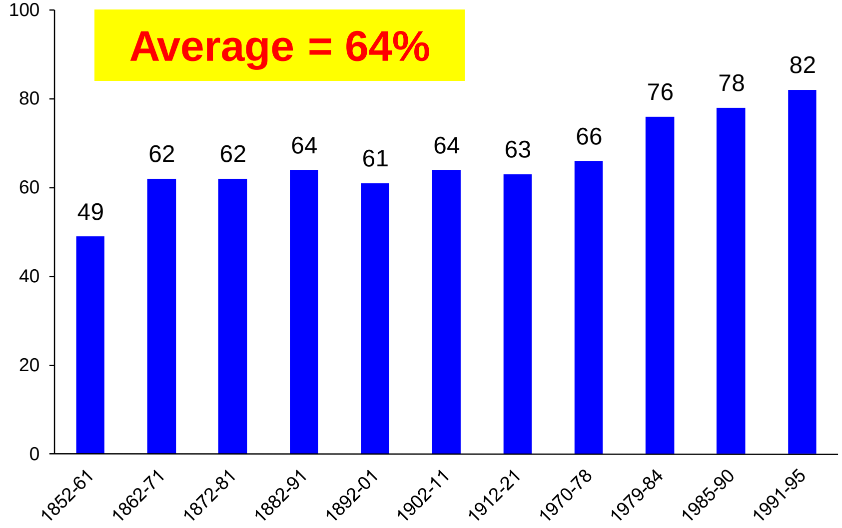
INTERNATIONAL PLANT NUTRITION INSTITUTE (IPNI)

✓ **Not-for-profit organization dedicated to research and education for the <u>responsable management of plant nutrients</u> for the benefit of the human family.**

“We train the trainers and influence the influencers”

Dr. Terry Roberts - President IPNI

Rothamsted, England
Wheat Experiment, 1852-1995



- ✓ **Oldest agronomic experiment int he world. Started in 1843.**
- ✓ **Effect of fertilizer on crop production.**

Source: Murrell, 2009

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AMONG OTHER SEVERAL ACTIVITIES
IPNI AWARDS

IPNI INTERNATIONAL:

- ✓ IPNI SCIENCE AWARDS
- ✓ IPNI SCHOLAR AWARDS
- ✓ IPNI PHOTO CONTEST

IPNI BRAZIL:

- ✓ IPNI BRAZIL PLANT NUTRITION AWARD – SENIOR
- ✓ IPNI BRAZIL PLANT NUTRITION AWARD – YOUNG RESEARCHER

SEMINAR: DISPONIBILIDADE E MANEJO DE FÓSFORO NO SOLO / ESALQ-USP

USING PHOSPHATE RESOURCES AS EFFICIENTLY AS POSSIBLE WITH CURRENT PRODUCTION AND AGRONOMIC USE TECHNOLOGIES

1. INTRODUCTION

Soybean P Response
Itiquira, MT

CONTROL

SSP

120 kg/ha of P_2O_5

ARAXA

GAFSA

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How to Optimize the use of P Resources?

GLOBAL TraPs

TRANSDISCIPLINARY PROCESSES FOR SUSTAINABLE PHOSPHORUS MANAGEMENT

GLOBAL TRAPs - LEADERS

Dr. Roland W. Scholz
ETH

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Dr. Amit H. Roy
IFDC

IFDC

GLOBAL TRAPs – GENERAL INFORMATION

- ✓ <u>Mission</u>: Lead to improved resource understanding and awareness, funneling into sustainable P management and stewardship.
- ✓ <u>Guiding question</u>: "*What new knowledge, technologies and policy options are needed to ensure that future phosphorus use is sustainable, improves food security and environmental quality and provides benefits for the poor?*
- ✓ *<u>Vision</u>: (1)* Leading global learning forum for sustainable P use in a transdisciplinary (joint, eye-level, transparent), complementary and non-politicized arena, (2) To define the current state of knowledge, (3) To define new technologies which are needed to better process, use and re-use phosphorus, (4) To define most valuable areas for policy intervention to ensure sustainable P use in the future.

GLOBAL TRAPs – WORKSHOP IV
El-Jadida, Marc 16–18 2012

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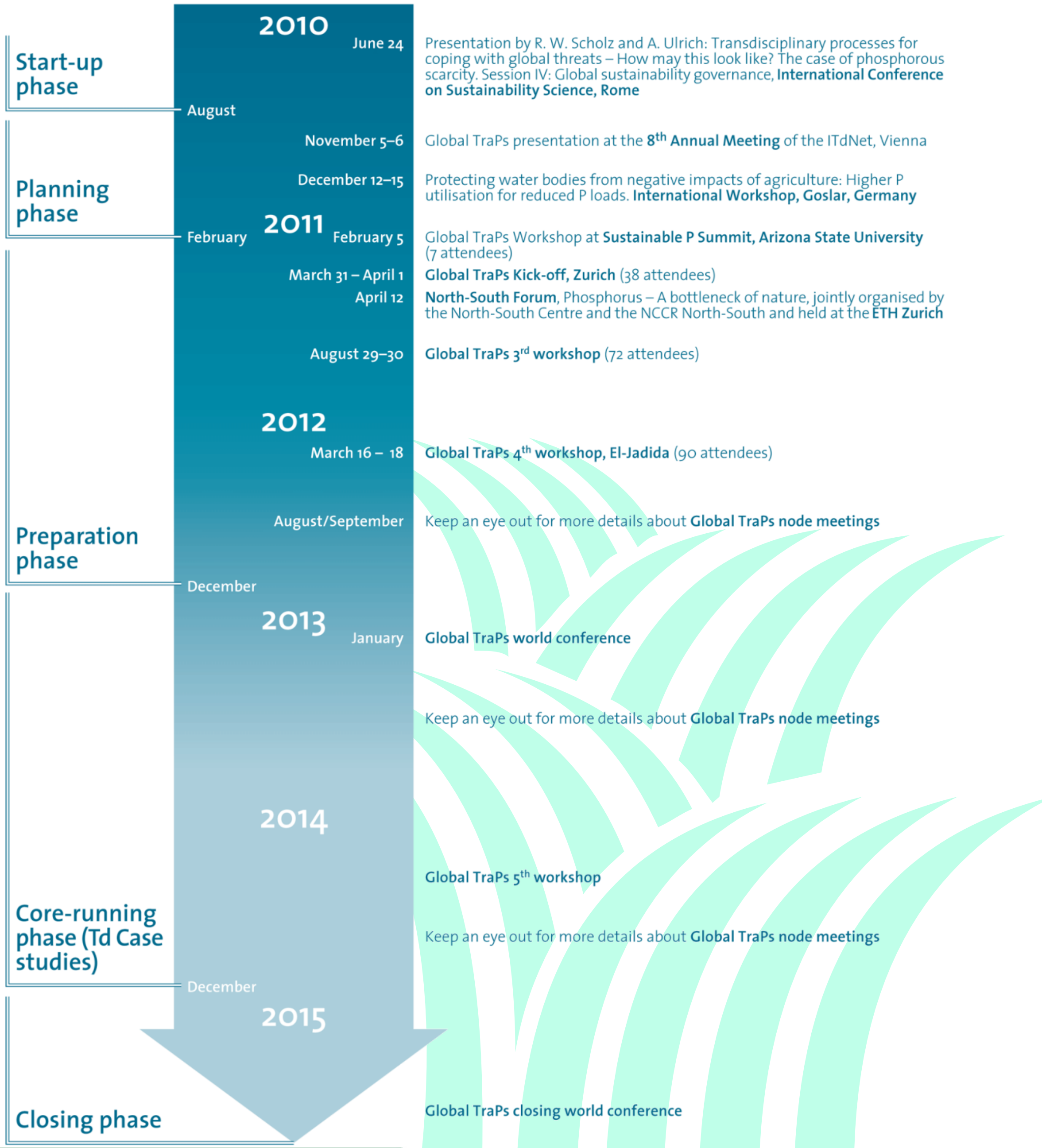
GLOBAL TRAPs: PROJECT TIMEFRAME



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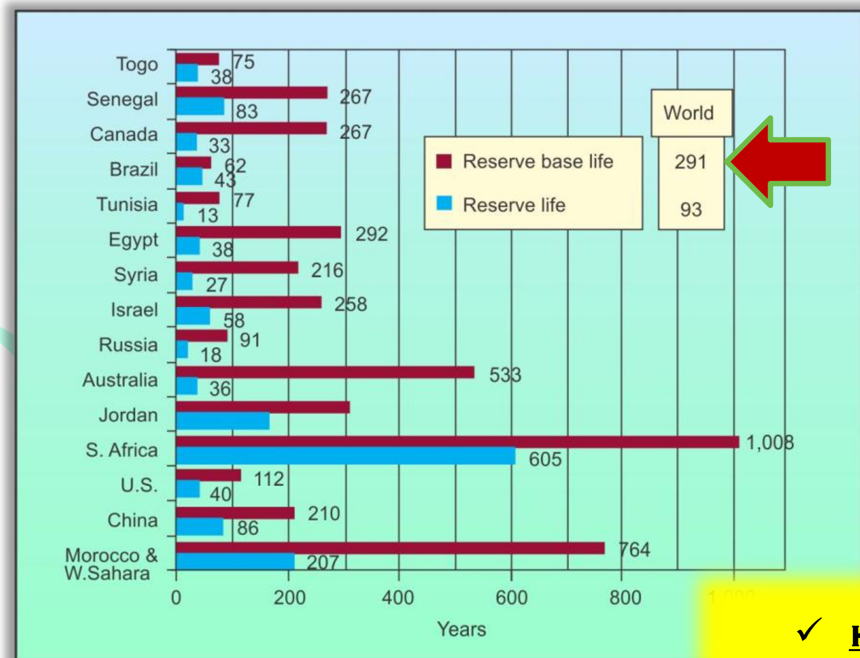
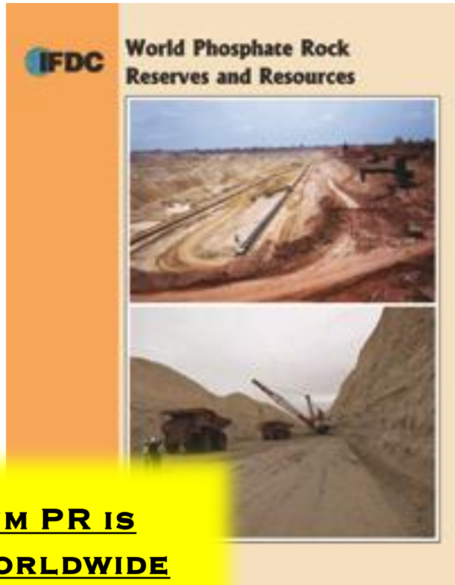
Phosphate mine reserve life and reserve base life



Source: USGS, 2009; Adapted from Fixen, 2009.

New IFDC Report Indicates World Reserves of Rock Phosphate Are Adequate to Meet Demand



✓ **High Premium PR is decreasing worldwide**

How to Optimize the use of P Resources in Agriculture?

Emphasis in Two important Aspects:

- ✓ How we Produce?
- ✓ How we utilize (Agronomics)?

2. HOW WE UTILIZE? AGRONOMICS

FACTORS INFLUENCING THE AGRONOMIC EFFECTIVENESS OF P SOURCES

- ✓ **Fertilizer Properties.**
- ✓ Crop.
- ✓ Soil Properties.
- ✓ Fertilizer and Soil Management.

✓ **Physical Properties:**

- State (fluid or soilid)
- Particle size.
- Consistency/Hardness.
- Fluidity.
- Density.
- Mixtures with other Nutrient Sources.

✓ **Chemical Properties:**

- Chemical composition (compounds present).
- Concentration.
- Other compounds Present (desirable or not)/Other nutrients.
- Reaction in soil(s): acidity or basicity level.

✓ **Physical-Chemical Properties:**

- Solubility.
- Hygroscopicity.
- "Metalling"/Caking.
- Salinity.

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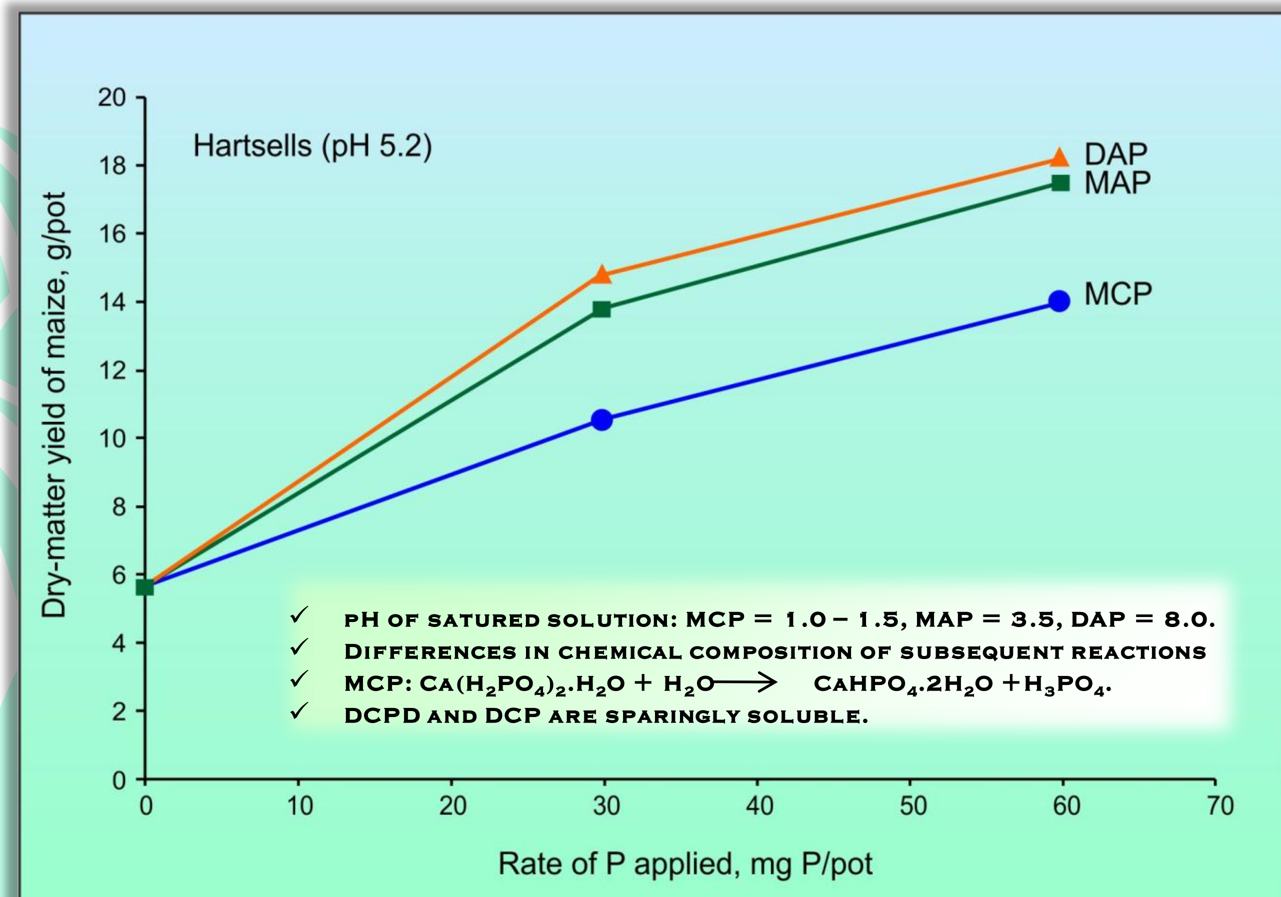
Dry-matter yield of maize (6 weeks) obtained with different P sources on an acid Hartsells soil (pH 5.2)



- ✓ pH of satured solution: MCP = 1.0 – 1.5, MAP = 3.5, DAP = 8.0.
- ✓ Differences in chemical composition of subsequent reactions
- ✓ MCP: $Ca(H_2PO_4)_2.H_2O + H_2O \longrightarrow CaHPO_4.2H_2O + H_3PO_4$.
- ✓ DCPD and DCP are sparingly soluble.

Source: Bouldin and Sample (1959).

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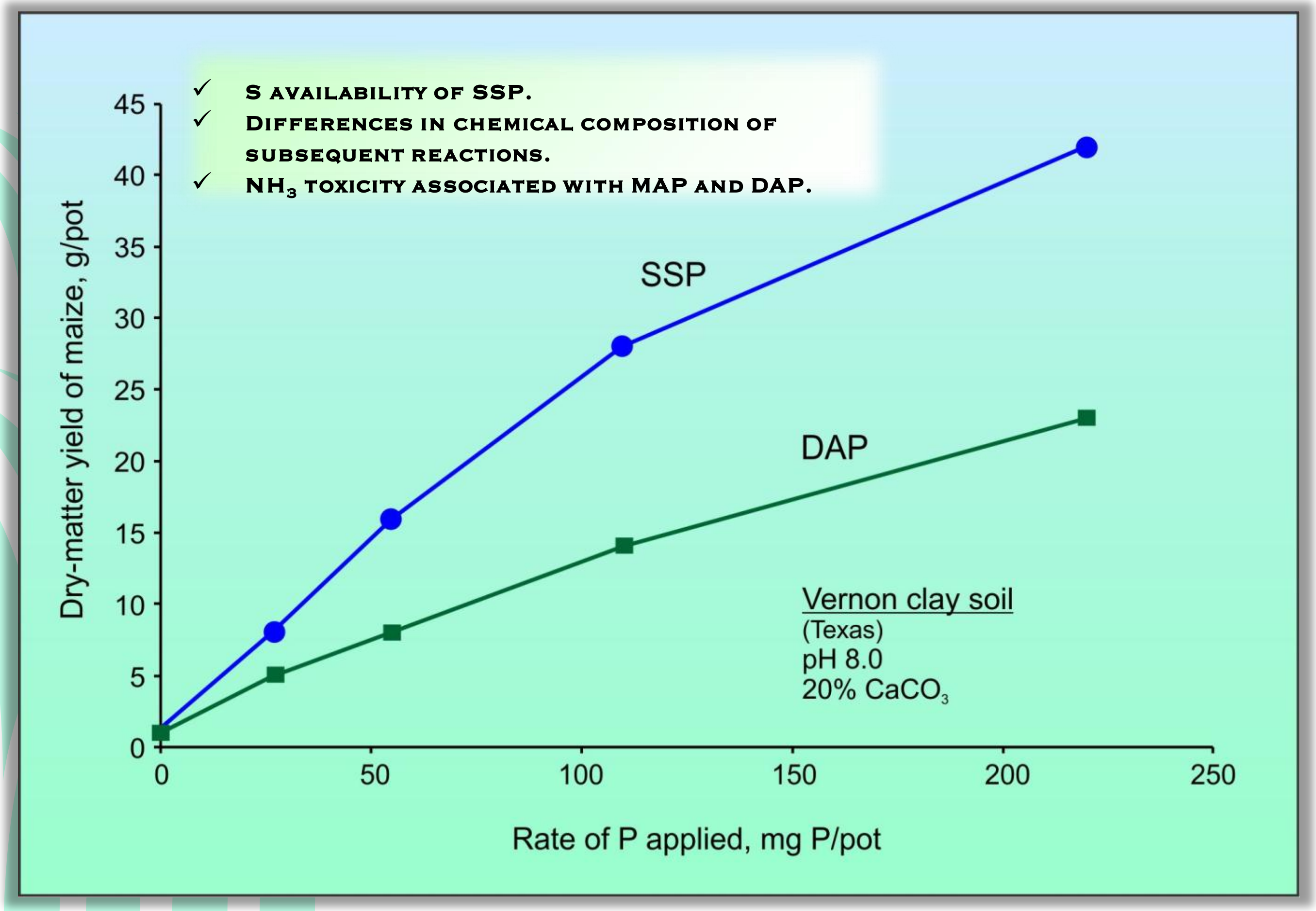
Dry-matter yield obtained with SSP and DAP when P was broadcast to a calcareous soil



Source: Lu et al., (1987).

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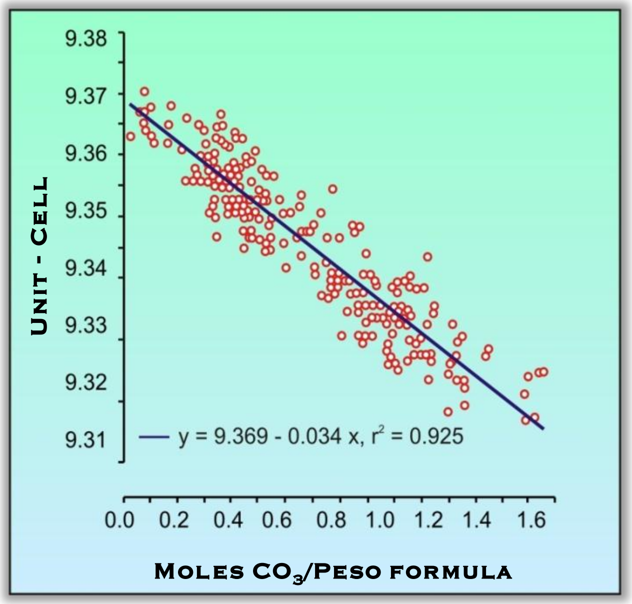
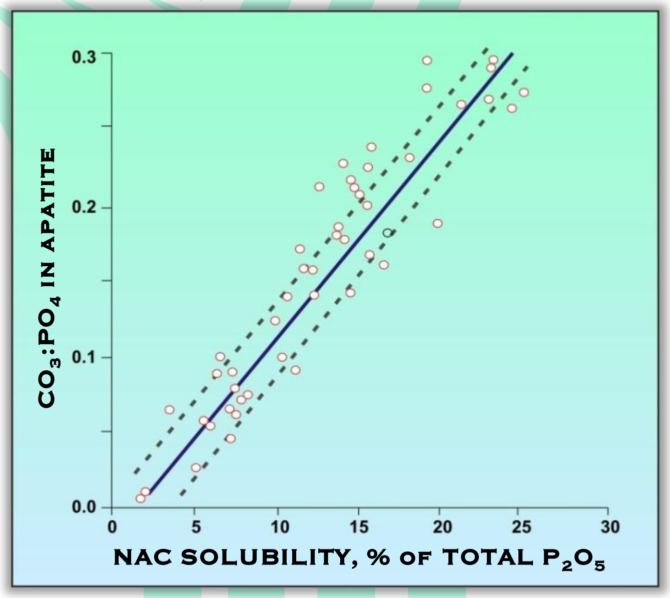
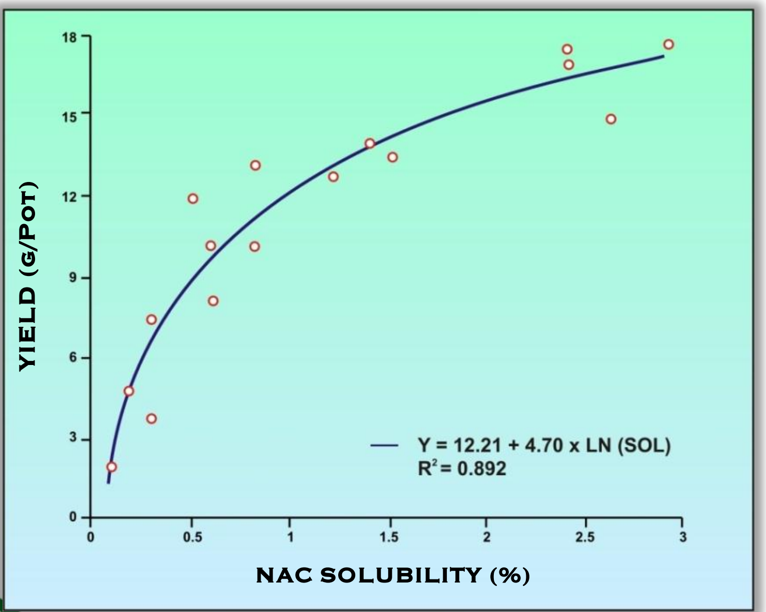
FROM THE PR TO ITS AGRONOMIC EFFECTIVENESS

PR	Comprimento do eixo a (Å)	Formula da Apatite [a]
Kaiyang, China	9.372	$Ca_{9.98}Na_{0.01}Mg_{0.01}(PO_4)_{5.94}(CO_3)_{0.06}F_{2.02}$
Hahotoe, Togo	9.351	$Ca_{9.79}Na_{0.15}Mg_{0.06}(PO_4)_{5.39}(CO_3)_{0.61}F_{2.24}$
Pesca, Colombia	9.346	$Ca_{9.76}Na_{0.18}Mg_{0.07}(PO_4)_{5.28}(CO_3)_{0.72}F_{2.29}$
El-Hassa, Jordan	9.339	$Ca_{9.68}Na_{0.23}Mg_{0.09}(PO_4)_{5.12}(CO_3)_{0.88}F_{2.35}$
Gafsa, Tunisia	9.328	$Ca_{9.59}Na_{0.30}Mg_{0.12}(PO_4)_{4.90}(CO_3)_{1.10}F_{2.44}$
North Carolina, USA	9.322	$Ca_{9.53}Na_{0.34}Mg_{0.13}(PO_4)_{4.77}(CO_3)_{1.23}F_{2.49}$







Source: Hammond et al., (1986).

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FACTORS INFLUENCING THE AGRONOMIC EFFECTIVENESS OF P SOURCES

- ✓ Fertilizer Properties.
- ✓ Crop.
- ✓ Soil Properties.
- ✓ Fertilizer and Soil Management.

- ✓ Crop.
- ✓ Cropping System/Rotation.

CROP – GRASS
SYSTEMS OF CULTIVATION

SANTA FÉ: MAIZE WITH BRACHIARIA

P RECOVERY
Oxisol, 22 Years

SSP	P Recovery	
	Annual Crops[1]	Annual + Grass[2]
kg/ha de P_2O_5	---------------- % ---------------	
100	44	85
200	40	82
400	35	70
800	40	62

[1] A área foi cultivada por dez anos com soja, seguida de um plantio com milho e quatro ciclos da seqüência milho-soja, dois cultivos de milho e um de soja.

[2] A área foi cultivada por dois anos com soja, seguida de nove anos com braquiária mais dois anos com soja e dois ciclos da seqüência milho-soja, e cinco anos com braquiária.

Source: Sousa et al., 2007.

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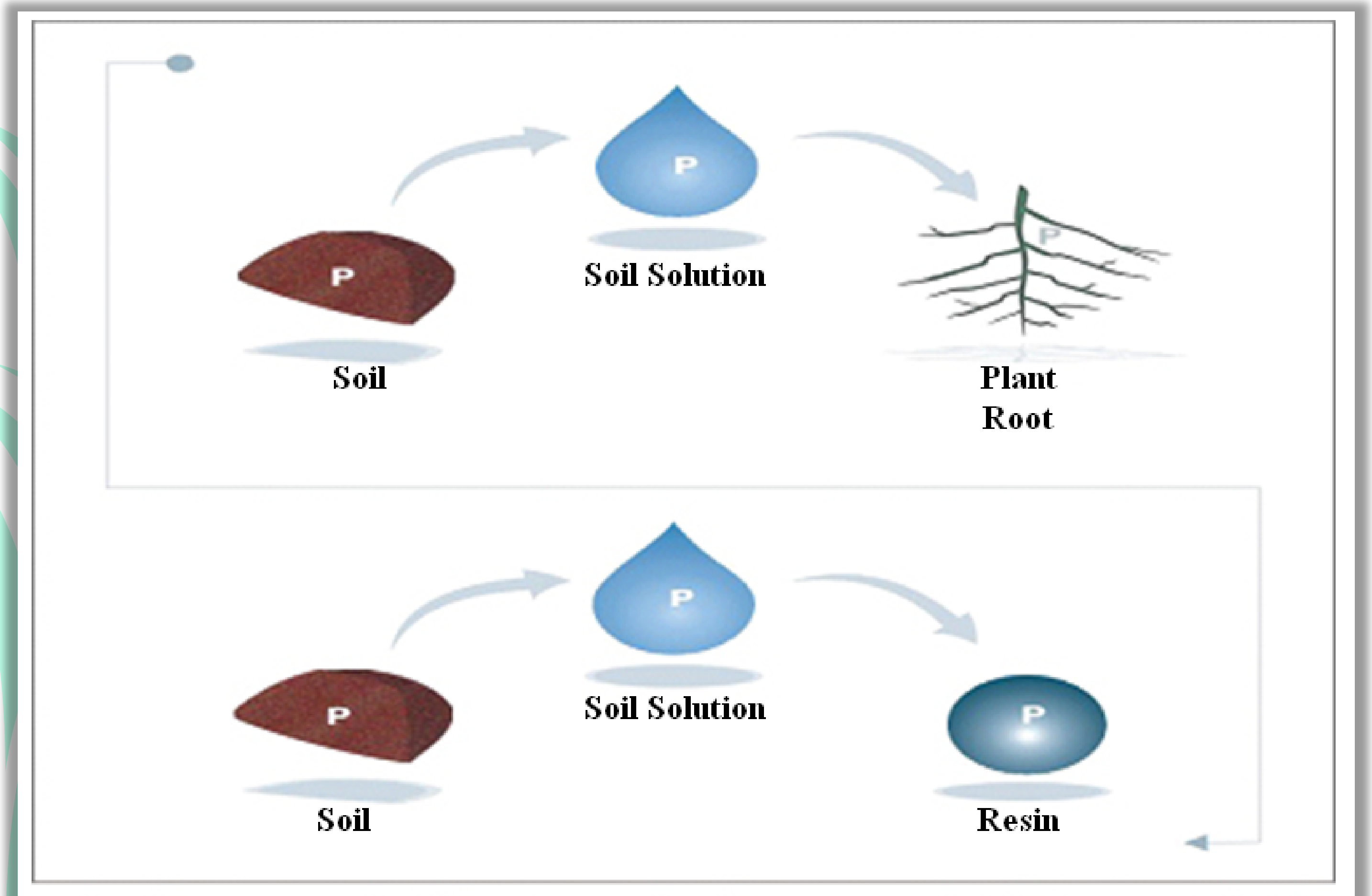
FACTORS INFLUENCING THE AGRONOMIC EFFECTIVENESS OF P SOURCES

- ✓ Fertilizer Properties.
- ✓ Crop.
- ✓ **Soil Properties.**
- ✓ Fertilizer and Soil Management.

- ✓ Soil P Availability.
- ✓ Soil pH.
- ✓ Soil P Fixation (Precipitation and Specific Adsorption).
- ✓ Soil Mineralogy.
- ✓ Soil Granulometry.
- ✓ Soil OM.
- ✓ Mycorrhizaes.

Schematic demonstration of P extracted from soils by ion exchange resin



Source: Better Crops/Vol. 93 (2009, N° 1).

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EFFECT OF SOIL pH IN THE AMOUNT OF P IN PLANT LEAF AND SOIL P BY DIFFERENT METHODOLOGIES

Crop and Location	pH CaCl$_2$	Leaf P (g Kg^{-1})	Soil P (mg dm^{-3})			
			Mehlich 1	Bray 1	Olsen	Resina
Beans Pariqüera-Açu	3.8 d *	2.44 b	17 a	20 a	41 a	33 b
	4.2 c	3.21 a	18 a	21 a	33 b	36 ab
	4.7 b	3.25 a	18 a	20 a	26 c	38 ab
	5.1 a	3.26 a	19 a	18 a	19 d	43 a
	5.2 a	3.25 a	20 a	19 a	21 d	43 a
Sunflower Mococa	4.3 c	2.79 c	12 b	24 a	17 a	22 b
	4.6 c	3.27 b	12 b	22 a	17 a	26 ab
	5.3 b	3.81 a	16 a	25 a	16 a	33 ab
	5.5 ab	3.87 a	15 a	20 a	12 a	35 a
	5.7 a	3.80 a	16 a	20 a	12 a	37 a
Soybean Mococa	4.3 a	1.85 c	6 a	15 a	10 a	13 c
	4.8 d	2.06 bc	7 a	16 a	11 a	16 c
	5.5 c	2.44 ab	5 a	13 a	7 a	17 bc
	6.1 b	2.26 a	7 a	17 a	8 a	22 ab
	6.4 a	2.55 a	7 a	15 a	8 a	27 a
Soybean Ribeirão Preto	4.5 d	2.35 b	9 a	20 a	18 a	16 c
	4.9 c	2.69 ab	8 a	22 a	15 ab	19 bc
	6.1 b	2.88 a	8 a	20 a	13 ab	23 b
	6.6 a	2.85 a	10 a	24 a	12 b	34 a

Source: RAIJ and QUAGGIO (1990).

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Factors Influencing The Agronomic Effectiveness Of P Sources

- ✓ Fertilizer Properties.
- ✓ Crop.
- ✓ Soil Properties.
- ✓ Fertilizer and Soil Management.

- ✓ Placement.
- ✓ Management of other nutrients.
- ✓ Water Management.
- ✓ Management of other limiting factors.

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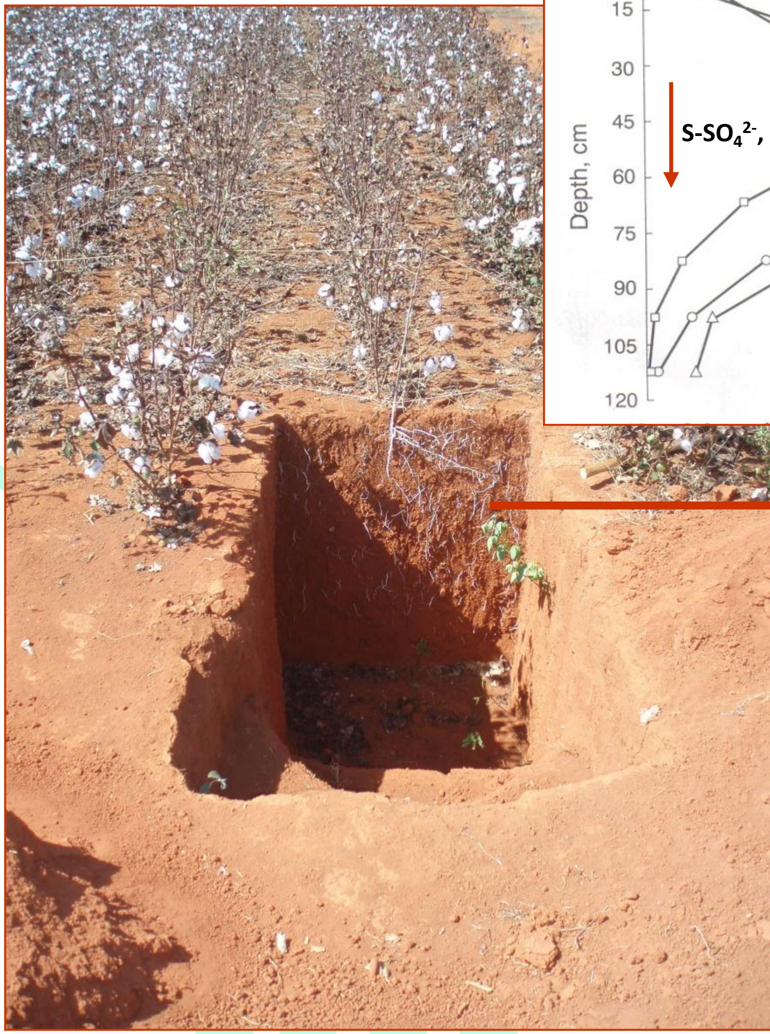
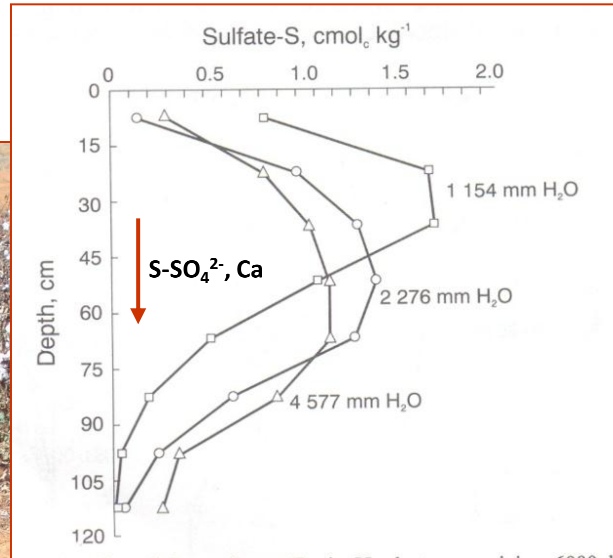
PHOSPHOGYPSUM





Experiment: EMBRAPA Cerrado.
Photo: IPNI.

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Nutrient Absorption By Barley As A Function Of Liming And Phosphogypsum Application

Tratamento	N	P	K	Ca	Mg	S
	g.kg^{-1}					
Lime						
No lime	107,4	6,9	185,4 b	23,2	15,6	12,9
Lime on Soil Surface	128,8	8,2	207,7 ab	32,7	13,3	15,6
Lime Mixed to the Soil	138,9	7,2	237,6 a	32,3	16,1	17,2
F Value	6,03ns	4,23ns	7,59*	3,82ns	4,48ns	1,87ns
CV (%)	18,1	18,2	14,5	35,0	16,0	36,1
Phosphogypsum, t.ha^{-1}						
0	109,3	5.4	192,3	26,6	14,4	5,7
3	115,5	7.8	178,1	25,0	15,2	11,7
6	141,6	7.9	227,9	30,6	15,6	20,6
9	133,8	8.6	242,7	35,3	14,9	22,8
Effect	L**	L**	L**	L**	ns	L**
CV (%)	18,9	29,2	17,1	24,2	23,9	27,6

Médias seguidas por letras iguais nas colunas não diferem significativamente pelo teste de Tukey ao nível de 5%. L: efeito linear por regressão. ns: Não significativo a 5%, **:Significativo a 1%.

Extracted from E.F. Caires et al.

Source: Bragantia, Campinas, 60(3), 213-223, 2001.

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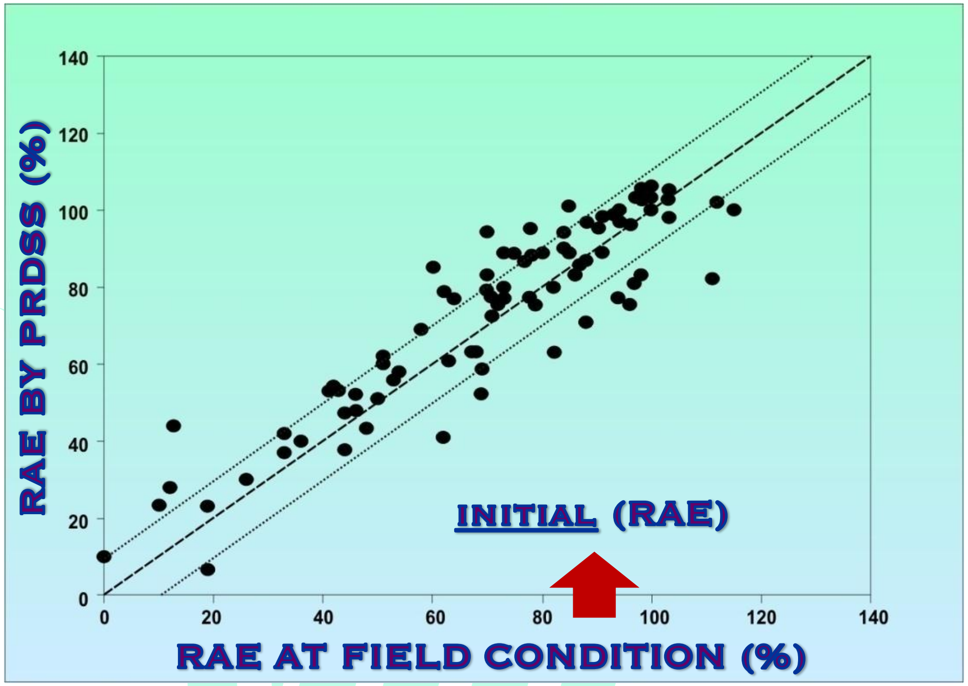
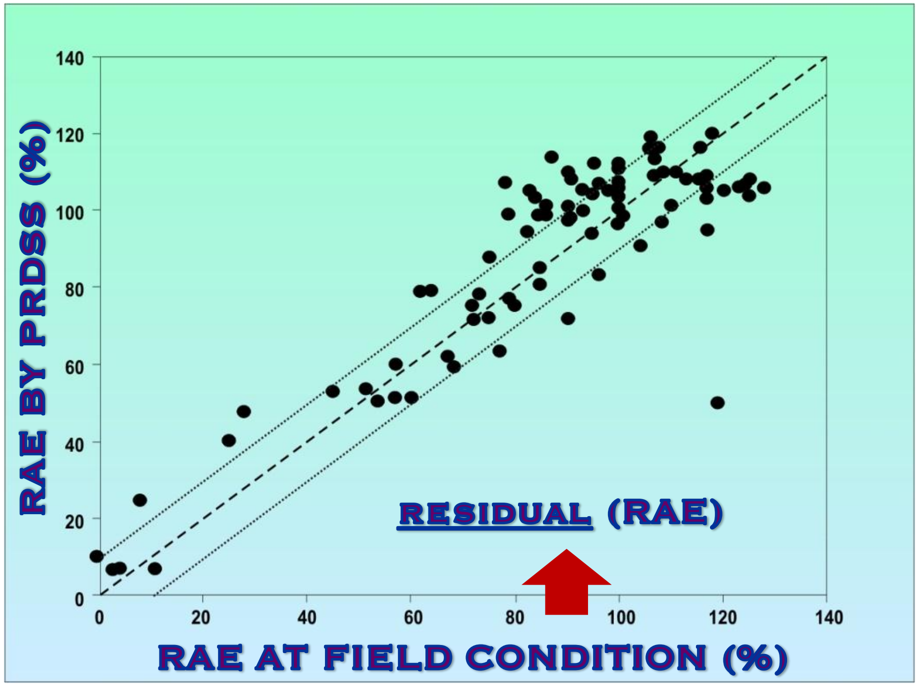
Phosphate Rock Decission Support System (PRDSS)





HTTP://WWW-ISWAM.IAEA.ORG/DAPR/SRV/EN/HOME

Source: U. Singh e S. H. Chien (2008), unpublished data.

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3. POTENTIAL NEW P SOURCES

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CHAPTER EIGHT

Recent Developments of Fertilizer Production and Use to Improve Nutrient Efficiency and Minimize Environmental Impacts

S. H. Chien,*[1] L. I. Prochnow,† *and* H. Cantarella‡

Contents

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† International Plant Nutrition Institute (IPNI), Piracicaba, SP, Brazil
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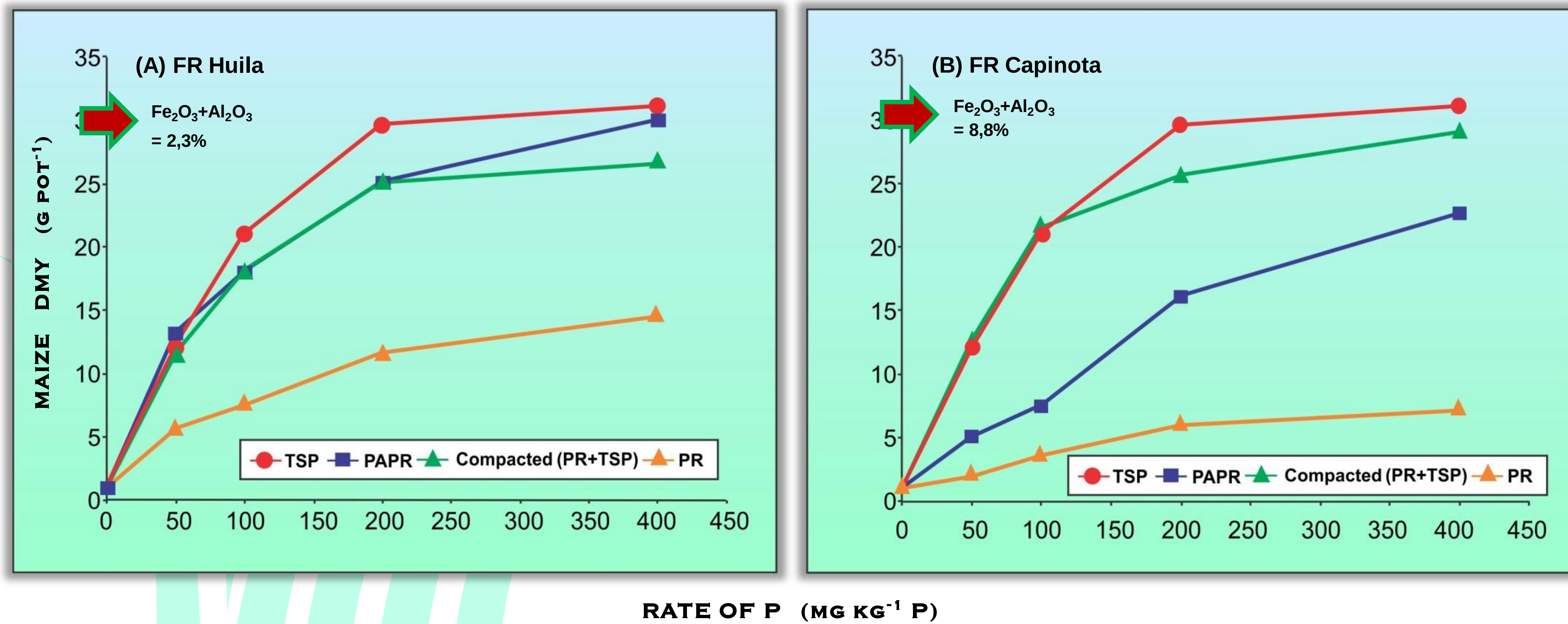
RAE OF ALTERNATIVE SOURCES OF P AS RELATED TO REGULAR HIGH WSP SSP

P SOURCE	RAE			
	WHEAT		RYEGRASS	
	DMY	P UPTAKE	DMY	P UPTAKE
SSP (STANDARD)	100	100	100	100
PM PR	1	1	30	15
LG PM SSP	91	87	99 ←	95
PM PR + SSP (C)	99 ←	88	95 ←	77
PM PR + SSP (M)	69 ←	57	86 ←	72

→ 6,0% $CaAlH(HPO_4)_2F_2$

SOURCE: PROCHNOW ET AL. (2004).

MAIZE DMY WITH ALTERNATIVE SOURCES OF P
(A) FR HUILA AND (B) FR CAPINOTA



$$Ca_{10}(PO_4)_{6-X}(CO_3)_XF_{0.4X+2} + 12H^+ \rightleftharpoons 10Ca^{2+} + (6-X)H_2PO_4^- + XCO_2 + (2+0.4X)F + XH_2O$$

Source: Menon and Chien (1990).

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4. PRODUCTION OF REGULAR FULLY ACIDULLATED P SOURCES

NOT PAPR

BACKGROUND INFORMATION

- ✓ In some countries, including Brazil, acidulated P fertilizers have to have high water-soluble P (WSP; 90%) in the Neutral Ammonium Citrate (NAC) + H_2O soluble P fraction (legislation).
- ✓ Premium Grade PR is decreasing worldwide.
- ✓ High amounts of energy and money are spent in order to always produce P fertilizers with high contents of WSP.
- ✓ Part of the apatite concentrates are discarded.
- ✓ Is it really necessary for totally acidulated P sources to always have high water solubility?

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Lehr (1980)

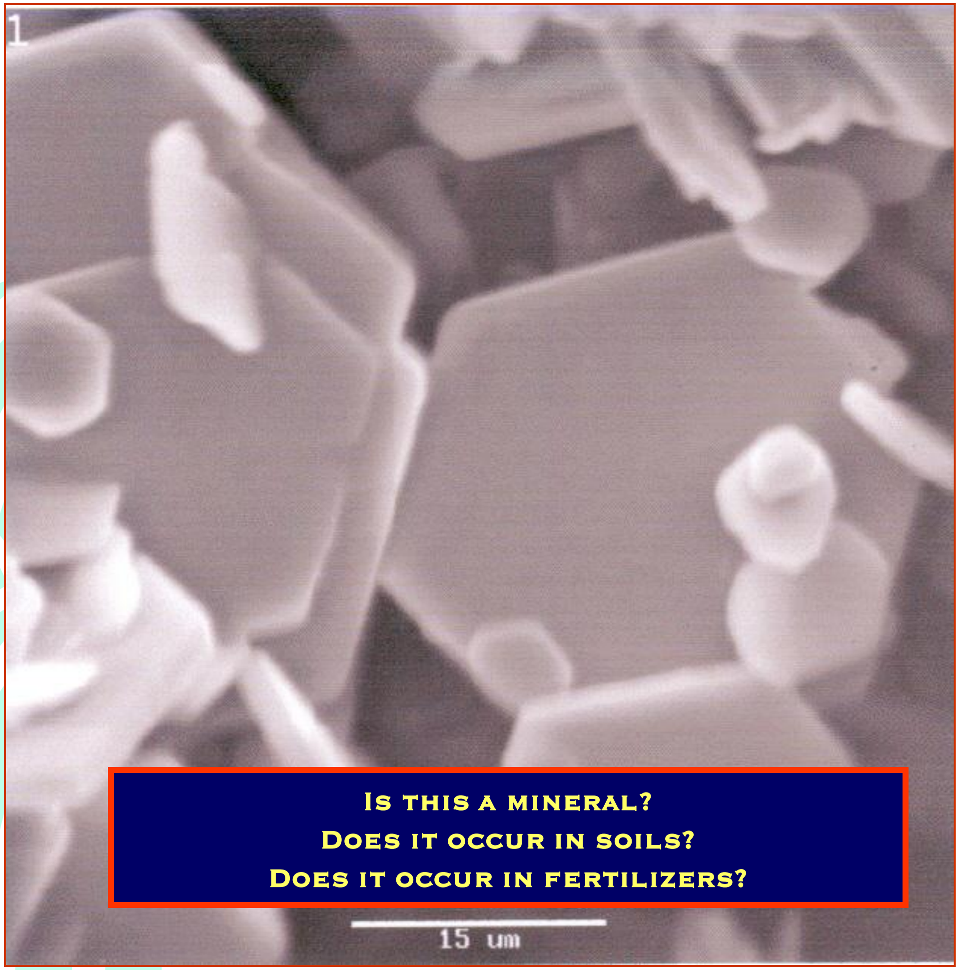
Are water-insoluble phosphates to be avoided at all cost?

The need for a more realistic set of product specifications is one of the most important problems confronting phosphate producers to seek relief from unnecessary and costly purification steps. Only agronomic research can provide the necessary guidance.

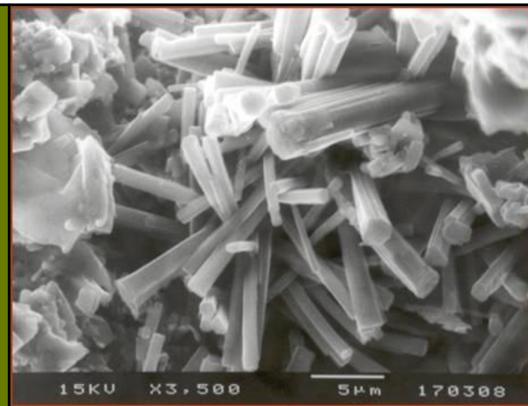
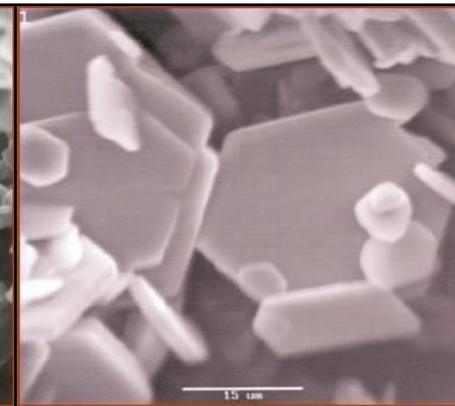
WHAT IS THIS?


Is this a mineral?
Does it occur in soils?
Does it occur in fertilizers?
15KV X3,500 5µm 170308

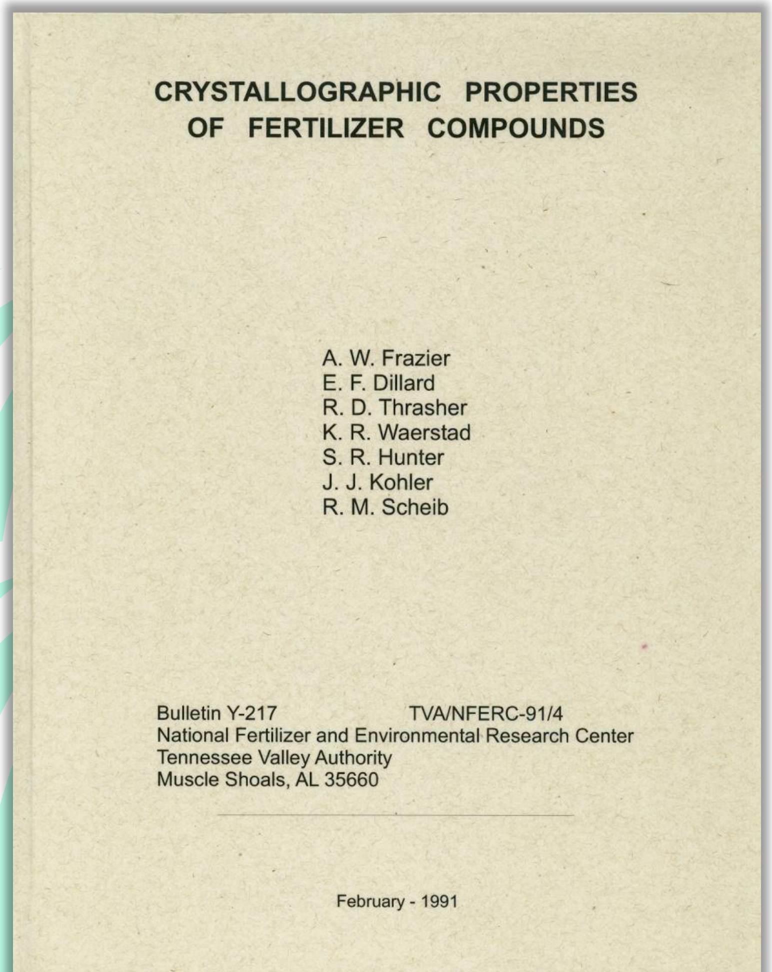
WHAT IS THIS?



Is this a mineral?
Does it occur in soils?
Does it occur in fertilizers?

QUESTION/ COMPOUND CHARAC.		
Chemical Formula	$Fe_3KH_8(PO_4)_6.6H_2O$	$Fe_3KH_{14}(PO_4)_8.4H_2O$
Is it a mineral?	NO	NO
Where does it precipitate?	P Fertilizer, Generally in SSP	P Fertilizer, Generally in TSP
Total P (TP)	20.4	23.8
NAC Soluble P (CSP)	19.3	22.8
Water Soluble P (WSP)	0.03	0.2
(WSP/CSP) * 100	0.2	0.9
RAE(MCP; Upland Rice)	33	73
RAE (MCP; Flooded Rice)	75	104

BOOK ON FERTILIZER COMPOUNDS



CRYSTALLOGRAPHIC PROPERTIES OF FERTILIZER COMPOUNDS

A. W. Frazier
E. F. Dillard
R. D. Thrasher
K. R. Waerstad
S. R. Hunter
J. J. Kohler
R. M. Scheib

Bulletin Y-217 TVA/NFERC-91/4
National Fertilizer and Environmental Research Center
Tennessee Valley Authority
Muscle Shoals, AL 35660

February - 1991

Calcium Dihydrogen Phosphate, $Ca(H_2PO_4)_2.H_2O$

CALCIUM DIHYDROGEN PHOSPHATE HYDRATE

Common Synonyms: Monocalcium phosphate, superphosphate
Structural Formula: $Ca(H_2PO_4)_2 \cdot H_2O$
CAS Number: 7758-23-8

Environmental Data

DOT Number: EPA Number: RQ Number:
Hazard Classification:
Comments:

Occurrence

Important constituent of superphosphate made by acidulation of phosphate rock with H_2SO_4, H_3PO_4, or HNO_3. Hydrolysis product of vitreous calcium polyphosphate.

Preparation

Add $Ca(OH)_2$ or CaO to concentrated H_3PO_4; recrystallize product from hot 50% H_3PO_4 solution with slow cooling and constant stirring. Wash crystals with dry acetone and dry in vacuum.

Properties

Stable in air. Dissolves incongruently in H_2O to leave residue of $CaHPO_4 \cdot 2H_2O$ or $CaHPO_4$. Dehydrates above 108° C. to $Ca(H_2PO_4)_2$ or to calcium acid pyrophosphate. NH_4, K, Cl, and Br readily substitute in lattice, with slight changes in properties.

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CALCIUM DIHYDROGEN PHOSPHATE HYDRATE

Optical Data

Crystal System, Class, and Habit:
Triclinic, I. Crystallizes as colorless (010) plates elongated on c. Modifying forms include {100}, {001}, {110}, {011}, {111}, and the pair (101) and (101). Polysynthetic twinning (albite law) with (010) as the composition plane. Carlsbad twinning

Refractive Indices:
α: 1.496 β, ω, or mean: 1.515 γ: 1.529 d: 0.000

Optical Properties:
Biaxial (-), 2V=(81.5°). Z is ppd. to (010) and is inclined to the a-axis by 2°40' in acute β; the X-Y plane is ppd. to (010), with X and OAP inclined to (010) by 37° in obtuse α. r >v, very weak. β=118.5°, d=2.22(2.23)

Unit Cell Data

Unit Cell Contents: $2[Ca(H_2PO_4)_2 \cdot H_2O]$
Crystal System: Triclinic Calculated Density: 2.190
Lattice Constants:
α: 99°50' β: 118°31' γ: 83°9'
a: 5.670 b: 11.920 c: 6.510
Probable Space Group: P1̄

X-ray Data (D-Spacings and Intensities)

11.740	75	5.850	9	5.660	15	5.340	1	4.940	9	4.900	20
4.650	3	4.420	15	4.320	9	4.160	13	3.880	100	3.690	90
3.580	13	3.400	5	3.350	15	3.190	15	3.180	13	3.150	9
3.080	7	2.996	25	2.952	30	2.935	9	2.833	11	2.788	9
2.728	9	2.688	13	2.677	5	2.669	25	2.652	3	2.640	1
2.585	11	2.560	20	2.537	1	2.473	7	2.452	15	2.422	7
2.406	9	2.392	9	2.347	3	2.323	3	2.296	3	2.266	1
2.240	3	2.211	3	2.158	7	2.147	7	2.124	5	2.097	3
2.081	9	2.046	3	2.021	9	1.996	20	1.958	7	1.942	11
1.934	9	1.925	7	1.881	1	1.872	3	1.863	1	1.854	1
1.845	3	1.831	5	1.792	11	1.780	3	1.762	7	1.745	7
1.722	3	1.703	9								

Infrared Absorption Bands (cm^{-1})
(VS=Very Strong, S=Strong, M=Medium, W=Weak, B=Broad, H=Shoulder)

3450	S	3100	S,B	2400	W,B	2280	W,B	1653	M	1234	S	1145	S
1100	SH	1080	VS	952	VS	910	SH	880	M	852	M	670	M
571	M	547	M	503	VS	395	M						

$Fe_3KH_{14}(PO_4)_8 \cdot 4H_2O$

POTASSIUM TRIALUMINUM 14-HYDROGEN PHOSPHATE TETRAHYDRATE

Common Synonyms:
Structural Formula: $KAl_3H_{14}(PO_4)_8 \cdot 4H_2O$
CAS Number: 66451-30-7

Environmental Data

DOT Number: EPA Number: RQ Number:
Hazard Classification:
Comments:

Occurrence

A major sludge phase in merchant-grade wet-process H_3PO_4. Considerable Fe substitution for Al is usual. Forms in wet-process H_3PO_4 (28 to 32% P_2O_5) prepared from ores containing acid-soluble K minerals when concentrated beyond 35% P_2O_5.

Preparation

Add soluble K salt to wet-process H_3PO_4 (54% P_2O_5) containing Al at temps. from 25 to 100° C.

Properties

Insoluble in H_2O; dissolves incongruently in dilute H_3PO_4, but is relatively insoluble in H_3PO_4 over concentration range 35 to 60% P_2O_5; solubility increases with temperature. The Na analog is known. Substitution of Na for K increases its solubility and makes it hygroscopic. Forms an ispmorphous series in which Fe replaces Al and NH_4 or Na replaces K. Citrate soluble; equivalent to concentrated superphosphate (49% P_2O_5) as P source for growing plants; can be dehydrated at 100° C. without affecting agronomic value.

References

Blanch, J. E., Ger. Patent 1,161,246, Jan. 16, 1964

Lehr, J. R., Frazier, A. W., and Smith, J. P., J. Agr. Food Chem. 14, 27-33 (1966)

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Schwarzenbach, D., Naturwissenschaften 52 (12), 343-4 (1965)

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Waerstad, K. R. and Frazier, A. W., Powder Diffraction 2(3), 187-90 (September 1987)

Frazier, A. W. and Kim, Y. K., "Redistribution of Impurities in Wet-Process Phosphoric Acid", TVA Bulletin Y-202, April 1988

Frazier, A. W. and Kim, Y. K., Fert. Res. 21, 45-60 (1989)

Frazier, A. W., Fe-NH4-PO4-H_2O at 75° C. publication in progress

POTASSIUM TRIALUMINUM 14-HYDROGEN PHOSPHATE TETRAHYDRATE

Optical Data

Crystal System, Class, and Habit:
Monoclinic, 2/m. Pseudohexagonal plates, tabular on (001), sometimes elongated along b and modified by (100) and {110} .

Refractive Indices:
α: 1.500 β, ω or mean: 1.528 γ: 1.531 ϵ: 0.000

Optical Properties:
Biaxial (-), 2V=36°, Xwc, Ywa and Z=b. d=2.35 g/cc.

Unit Cell Data

X-ray Data (D-Spacings and Intensities)

9.710	2	8.770	100	4.350	7	3.760	4	3.730	8	3.710	11
3.260	6	3.200	4	3.040	6	2.990	11	2.930	14	2.820	2
2.710	1	2.390	2	2.380	2	2.150	1	1.944	2	1.916	1
1.795	2	1.759	1								

Infrared Absorption Bands (cm^{-1})
(VS=Very Strong, S=Strong, M=Medium, W=Weak, B=Broad, H=Shoulder)

3564	M	3445	M	3100	S,B	2400	W,B	1600	W	1196	S	1215	S
1144	VS	1088	VS	1070	SH	1045	SH	960	S	930	S	730	W,B
591	S	538	S	510	S	446	W						

GENERAL CONCLUSIONS FOR ENTIRE RESEARCH PROJECT

- ✓ When working with alternative totally acidulated P fertilizers it is fundamental to access its chemical composition (<u>compounds present in the WIPF</u>).
- ✓ Fe-P compounds can be agronomically more effective as a source of P under flooded soil systems than for upland crop systems.
- ✓ Research has showed <u>not to be necessary</u> to always have high water-solubility in fully acidulated phosphate fertilizers. Data obtained suggest that the <u>WSP requirement</u> should be related to <u>the soil system, the crop and the chemical composition of the fertilizer</u>.

STUDY 1

Characterization and agronomic evaluation of single superphosphates varying in iron phosphate impurities

P Source	P				Fe	FI
	Total	Available	Water	2% C.A.		
	%					
MCP	55.8	55.3	54.6	54.3	1.3	99
SSP1	20.8	19.6	16.8	17.6	2.2	86
SSP2	17.2	16.1	12.8	14.1	4.3	80
SSP3	17.7	16.4	7.5	10.2	5.8	46

N.	Compound	SSP1	SSP2	SSP3
1	Fe3KH8(PO4)6	0.4	0.4	0.6
2	Fe3NaH8(PO4)6	5.02	3.35	6.36
3	Fe3H9(PO4)6	0.4	6.19	12.34
4	Na2SiF6	0.25	0.41	0.33
5	Ca10(PO4)6OH0.97F1.03	2.82	2.6	3.09
6	Ca4SiAlSO4F13	2.18	0.4	2.1
7	SiO2	0	0	0.73
8	CaF2	0.25	1.44	0
9	MgSO4	0.35	0.4	0.45
10	SrSO4	1.53	1.32	1.17
11	ZnSO4	0.07	0.1	0.15
12	Ti2(SO4)3	0.92	1.4	1.88
13	BaSO4	1.92	1.14	1.28
14	Al2(SO4)3	0.25	1.27	1.08
15	Ba(H2PO4)2	0.19	0.41	0.28
16	CaSO4	49.15	49.7	46.87
17	Ca(H2PO4)2	34.19	19.08	12.81
	TOTAL	99.89	89.61	91.52

P Source	Dry-matter yield	P uptake
	Upland Rice	
MCP	100	100
SSP1	98	88
SSP2	96	93
SSP3	88	76
	Flooded Rice	
MCP	100	100
SSP1	97	91
SSP2	111	110
SSP3	102	85
MCP: Standard source of P		
RAE = $(\beta_i/\beta_{MCP})*100$, i = other SSP		

Source: PROCHNOW, L.I.; CHIEN, S.H.; TAYLOR, R.W.; CARMONA, G.; HENAO, J. & DILLARD, E.F. Agronomy Journal. 95:293-302, 2003.

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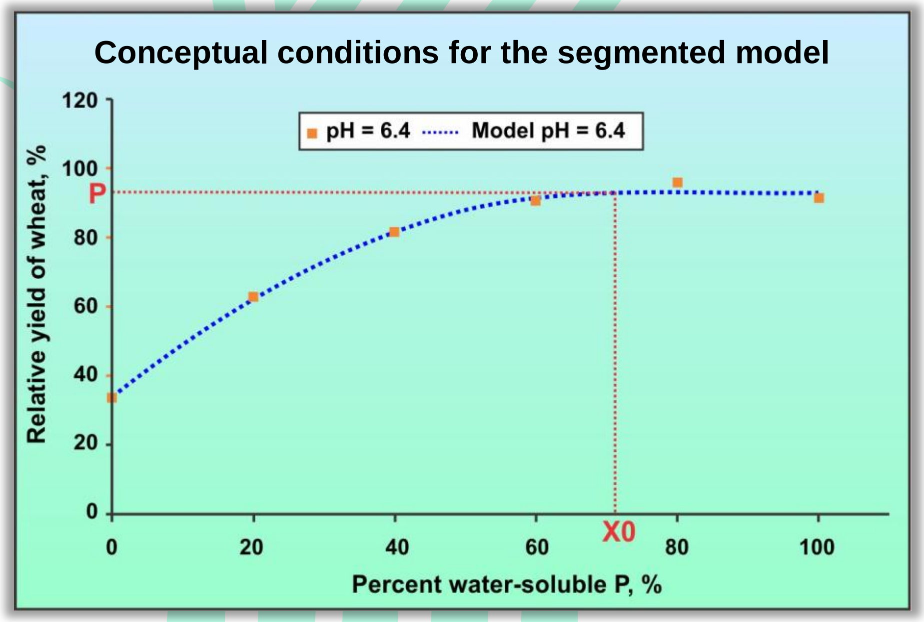
STUDY 2

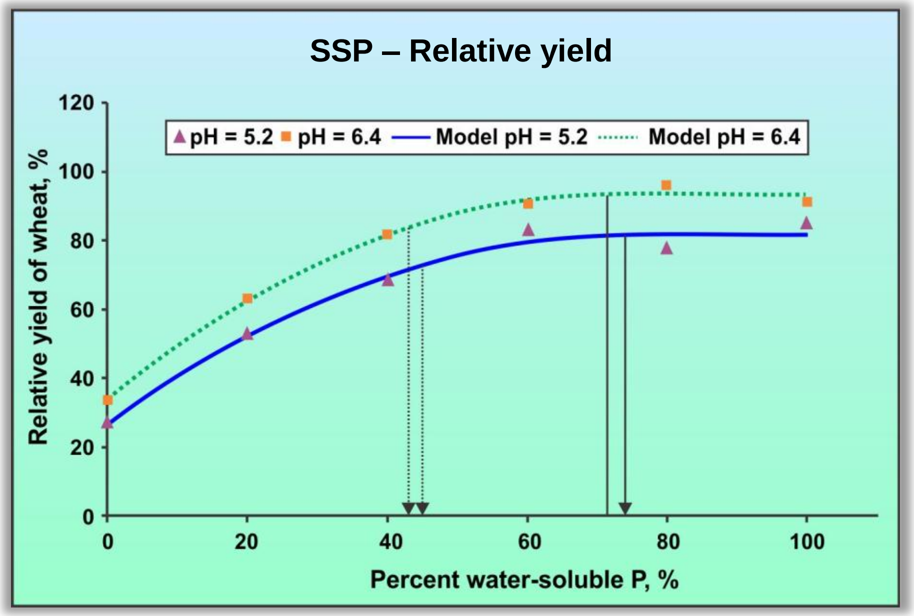
Plant Availability of Phosphorus in Four Superphosphate Fertilizers Varying in Water-Insoluble Phosphate Compounds

✓ Model:
Segmented (quadratic and linear)

✓ RY = (DMY Si/DMY Sj)*100
Si: highest DMY

✓ Plateau:
- y=a+bx+cx2 if x<x0 and y=P if x>x0
- Two sections must meet at x0
- The curve must be smooth (first derivative with respect to x are the same at x0
- These conditions imply that:
- x0 = -b/2c and P=a-b2/4c.





Source: Prochnow, L.I.; Chien, S.H.; Carmona, G.; Henao, J.; Dillard, E.F.; Austin, E.R. Soil Science Society of America Journal, 72:462-470, 2008.

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STUDY 2

Plant Availability of Phosphorus in Four Superphosphate Fertilizers Varying in Water-Insoluble Phosphate Compounds

Compound	P Source			
	TSP 1	TSP 2	SSP 1	SSP 2
	%			
$Fe_3(K, Na, H)H_8(PO_4)_6$	4.7		19.3	4.3
$Fe_3KH_{14}(PO_4)_8$		1.6		
$CaAlH(HPO_4)_2F_2$				6.0
$Ca_{10}(PO_4)_6(OH, F)$	5.0	3.4	3.1	6.4
SiO_2	0.7		0.7	18.7
$CaSO_4$	3.1		46.9	40.3
$Ca(H_2PO_4)$	81.8	87.9	12.8	16.7
Total	95.3	92.9	82.8	92.4

Fonte de P[a]	pH	Modelo de regressão segmentada			Dose (mg kg^{-1} P) requirida para alcançar [b]		WSP (%) requerido para alcançar [c]	
		Equação quadrática (R^2)	SE[d]	Plateau	Plateau	90% do plateau	Plateau	90% do plateau
					----- mg P kg^{-1} ------		------------- % -----------	
MCP-DMY	5,2	$y = 0,94 + 0,957x - 8,8 \times 10^{-3}x^2$ (0,98)	1,25	26,9	54,3	36,8		
MCP-RY	5,2	$y = 3,27 + 3,337x - 30,0 \times 10^{-3}x^2$ (0,97)	4,37	93,9	54,3	36,8		
MCP-DMY	6,4	$y = 0,70 + 1,447x - 19,3 \times 10^{-3}x^2$ (0,97)	1,45	27,8	37,4	25,4		
MCP-RY	6,4	$y = 2,44 + 5,047x - 67,4 \times 10^{-3}x^2$ (0,95)	5,05	96,9	37,4	25,4		
TSP 1-RY	5,2	$y = 35,44 + 1,249x - 7,9 \times 10^{-3}x^2$ (0,97)	1,57	84,9			79	46
TSP 1-RY	6,4	$y = 34,13 + 1,830x - 15,3 \times 10^{-3}x^2$ (0,96)	2,66	88,8			60	36
TSP 2-RY	5,2	$y = 47,98 + 0,745x - 3,9 \times 10^{-3}x^2$ (0,97)	2,14	83,5			95	49
TSP 2-RY	6,4	$y = 42,97 + 1,161x - 6,8 \times 10^{-3}x^2$ (0,96)	5,04	92,9			86	48
SSP 1-RY	5,2	$y = 17,93 + 1,705x - 11,4 \times 10^{-3}x^2$ (0,97)	3,62	81,6			75	48
SSP 1-RY	6,4	$y = 24,42 + 1,897x - 13,1 \times 10^{-3}x^2$ (0,97)	2,21	93,2			72	46
SSP 2-RY	5,2	$y = 58,76 + 0,683x - 4,7 \times 10^{-3}x^2$ (0,96)	4,02	83,7			73	31
SSP 2-RY	6,4	$y = 60,97 + 0,926x - 6,9 \times 10^{-3}x^2$ (0,95)	5,24	92,1			67	31

Source: PROCHNOW, L.I.; CHIEN, S.H.; CARMONA, G.; HENAO, J.; DILLARD, E.F.; AUSTIN, E.R. Soil Science Society of America Journal, 72:462-470, 2008.

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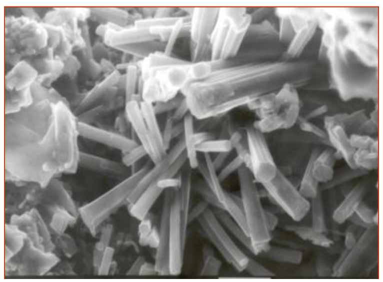
STUDY 3

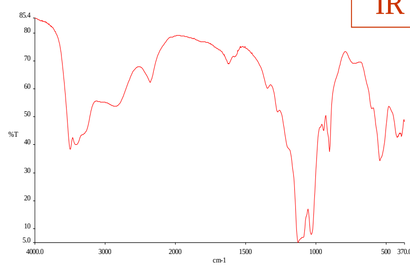
Synthesis, characterization and agronomic evaluation of iron phosphate impurities in superphosphates

$Fe_3KH_8(PO_4)_6.6H_2O$

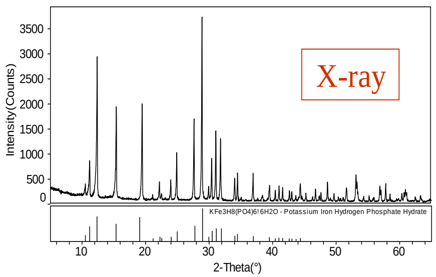
SEM



IR



X-ray



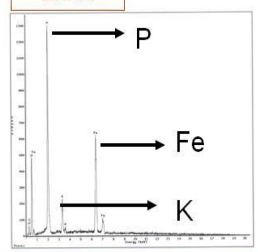
Chemical Analysis for total P, Fe, K, S and water of hydration ➔

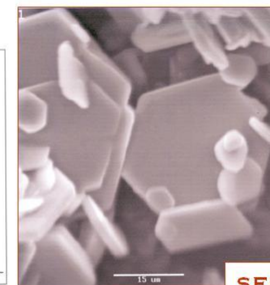
Calculated Formula:

$Fe_{2.8}K_{1.1}H_8(PO_4)_6$!$6.1H_2O$

$Fe_3KH_{14}(PO_4)_8.4H_2O$

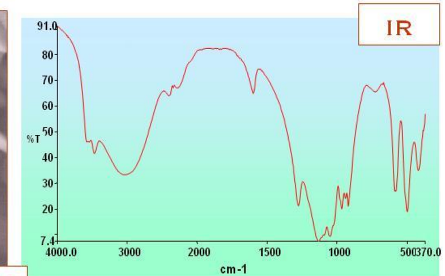
EDX



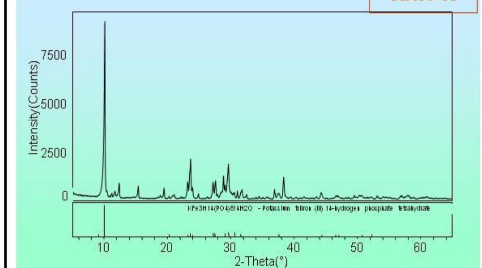


SEM

IR



Raio X



Análise química para P total, Fe, K, S e água de hidratação

Fórmula calculada:

$Fe_{3.0}K_{0.9}H_{14}(PO_4)_{8.}4.3H_2O$

Source: PROCHNOW, L.I.; CHIEN, S.H.; et al. Soil Science Society of America Journal. 67:1551-1563, 2003.

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STUDY 3

Synthesis, characterization and agronomic evaluation of iron phosphate impurities in superphosphates

P Source	Crop	Segmented Regression Model			WSP (%) required to reach §	
		Quadratic Equation	SE†	Plateau	Plateau	90% of Plateau
H8-syn	Upland Rice	$Y=7.81+0.28X-6.2x10^{-3}X^2$	1.59	35.3	66.6	42.7
H14-syn	Upland Rice	$Y=22.83+0.398X-2.8x10^{-3}X^2$	2.36	36.9	70.9	34.6
H8-syn	Flooded Rice	$Y=14.52+1.168X-20.0x10^{-3}X^2$	2.15	31.6	29.3	16.7
H14-syn	Flooded Rice	$Y=25.08+0.299X-3.8x10^{-3}X^2$	1.45	30.9	39.1	10.6

† Standard error for comparing predicted values.
§ Percentage water-soluble P needed to obtain the plateau or 90% of the plateau of the segmented model.

Source: PROCHNOW, L.I.; CHIEN, S.H.; et al. Soil Science Society of America Journal. 67:1551-1563, 2003.

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Statistical Group Experiment Analysis
16 Field Experiments

Tratament	P source	Average RAE	
1	SSP GCA (High WSP)	96.1	A
2	SSP RCA (Low WSP)	95.3	A
3	SSP GCA/RCA	94.5	A
4	SSP Patos (Low WSP)	95.5	A

C.V. = 10.4; dms = 4.2.
1 Conjunto de dados = experimentos 01 sulco, 01 lanço, 02 sulco, 02 lanço, 04 sulco, 04 lanço, 07 granulado, 07 pó, 08-01 RSP, 08-01 RCP, 08-02 RSP, 08-02 RCP, 11, 12 M1, 12 M2, 12 M3.

It is believed that it will be possible to utilize PR in the future in a more cost-effective way by:

- ✓ Being able to access the weight percent <u>chemical compounds of the fertilizers</u> (modal analysis),
- ✓ Understanding the <u>behavior of the impurity compounds in soils and as a P source for different plant species</u>,
- ✓ Having more accurate processes of <u>controlling the impurities formed</u> in the production of acidulated P fertilizers.

ACKNOWLEDGEMENTS

- ✓ Previous researchers:

  G. Mullins, F. Sikora, B. Gilkes.
- ✓ University of São Paulo.
- ✓ IFDC:

  N. Chien, G. Carmona, R. Austin & E. Dillard.

5. FINAL COMMENTS

1. <u>Technical</u> (Speech Wrap Up)

2. <u>Polytical/Philosophical</u>:

   2.1. Sir Francis Bacon and the mistakes of the human mind

   2.2. The future

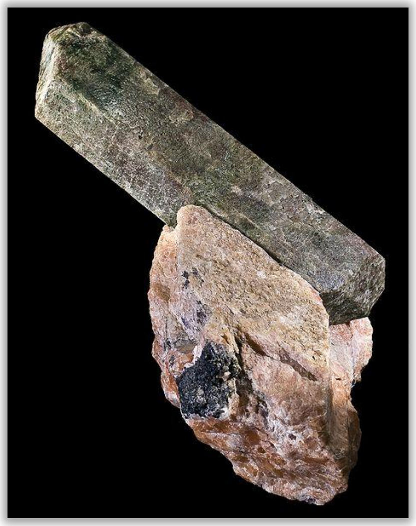
1º. FINAL COMMENT
Technical
(Speech Wrap Up)

HOW TO OPTIMIZE THE USE OF P RESOURCES?

- ✓ More adequate agronomic procedures.
- ✓ More adequate and realistic production of P fertilizers.

- ✓ Many factors interacting.
- ✓ From research to practice.

P in Agriculture = Related to Apatite = Deceiving Mineral



Apatite gets its odd name from the greek word meaning "to deceive" because its varied forms and colors caused early mineralogists to confuse it with a half dozen other minerals (Zim et al., Rocks and Minerals, 1957)

Fosfato de Rocha	Comprimento do eixo a (Å)	Formula da Apatite [a]
Kaiyang, China	9.372	$Ca_{9.98}Na_{0.01}Mg_{0.01}(PO_4)_{5.94}(CO_3)_{0.06}F_{2.02}$
Hahotoe, Togo	9.351	$Ca_{9.79}Na_{0.15}Mg_{0.06}(PO_4)_{5.39}(CO_3)_{0.61}F_{2.24}$
Pesca, Colombia	9.346	$Ca_{9.76}Na_{0.18}Mg_{0.07}(PO_4)_{5.28}(CO_3)_{0.72}F_{2.29}$
El-Hassa, Jordan	9.339	$Ca_{9.68}Na_{0.23}Mg_{0.09}(PO_4)_{5.12}(CO_3)_{0.88}F_{2.35}$
Gafsa, Tunisia	9.328	$Ca_{9.59}Na_{0.30}Mg_{0.12}(PO_4)_{4.90}(CO_3)_{1.10}F_{2.44}$
North Carolina, USA	9.322	$Ca_{9.53}Na_{0.34}Mg_{0.13}(PO_4)_{4.77}(CO_3)_{1.23}F_{2.49}$

APATITE AND IPNI MISSION

- Apatite is a limited resource.
- Amounts of high quality PR/apatite is decreasing.
- Apatite is deceiving.
- Using apatite wisely is directly related to IPNI Mission, i.e.,

"to develop and promote scientif information about the responsible management of plant nutrition for the benefit of the human family"

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VALOR DO SERVIÇO: COMO AVALIAR?

- ✓ Um técnico é chamado por uma empresa para avaliar o problema em um computador extremamente valioso.
- ✓ Após estudo detalhado do caso o técnico desliga o computador, abre um compartimento específico e dá uma volta e meio em um parafuso.
- ✓ Religa então a máquina que passa a funcionar perfeitamente.
- ✓ O dono da empresa lhe dá os parabéns e pergunta quanto é o serviço.
- ✓ Fica furioso ao ter conhecimento que o valor cobrado é de R$ 5.000. Diz que não vai pagar a menos que o técnico envie uma fatura especificando tudo o que foi feito.
- ✓ O técnico balança a cabeça e vai embora satisfeito.
- ✓ No outro dia a fatura é enviada e após leitura o dono da empresa – pessoa de bom senso - decide pagar de imediato os R$ 5.000.
- ✓ A fatura especificava:
  - Apertar um parafuso .... R$ 10,00
  - Saber qual parafuso apertar .... R$ 4.990,00

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LUCIANO PIRES
O MEU EVEST

POETA ESPANHOL

ANTONIO MACHADO

CAMINANTE, NO HAY CAMINO.

SE HACE LO CAMINO AL CAMINAR.

IPNI INTERNATIONAL PLANT NUTRITION INSTITUTE

THANKS FOR YOUR ATTENTION WITH GREAT WISHES OF:
(1) SUSTAINABLE USE OF P RESOURCES AND
(2) ENORMOUS SUCCESS TO ALL OF YOU AND TO AGRICULTURE

PLEASE DON'T FORGET:
APATITE =
<u>DECEIVING MINERAL</u>

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