



**Frontiers  
of Potassium**  
*an International Conference*

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# How can resins be utilized to improve K rate recommendations?

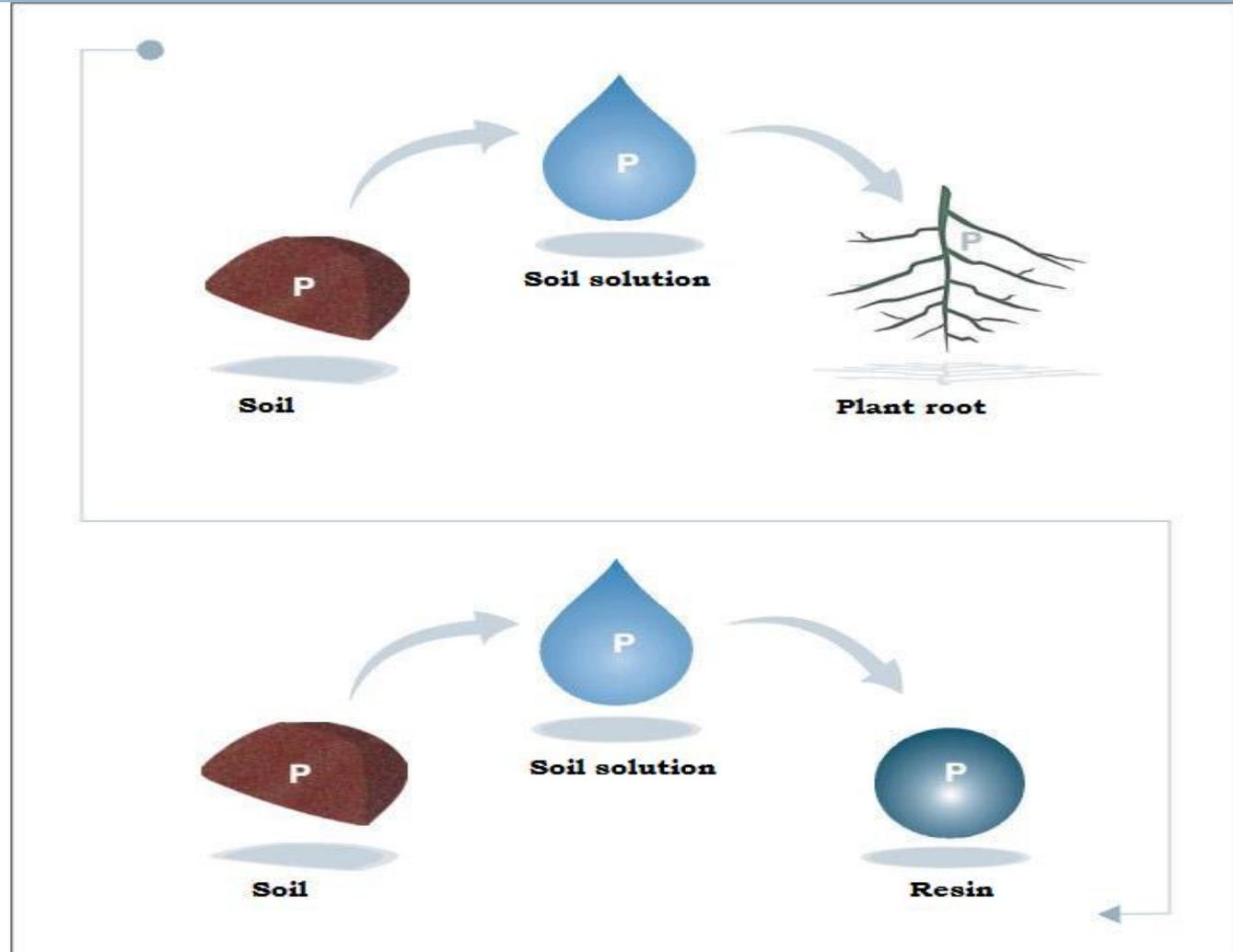
**H.Cantarella, J.A.Quaggio, L.I.Prochnow, B.van Raij**  
**Agronomic Institute of Campinas (IAC); IPNI Brazil**



# Topics

- **Proper K fertilization depends on adequate diagnosis of soil K**
- **Soil testing for K is a matter of debate, especially for soils with fixed or nonexchangeable K**
- **Well succeeded experience of ion exchange resin in Brazil**
- **Comments on experiences with resin for K soil testing elsewhere**

# Resin extraction mimics root nutrient uptake: based on diffusion of ions through the soil solution



# Resin for nutrient extraction from soils

## □ Pioneer work of Amer et al. (1955)

CHARACTERIZATION OF SOIL PHOSPHORUS  
BY ANION EXCHANGE RESIN ADSORPTION  
AND P<sup>32</sup>-EQUILIBRATION \*)

F. AMER, D. R. BOULDIN, C. A. BLACK and F. R. DUKE  
Plant and Soil VI, no 4 August 1955

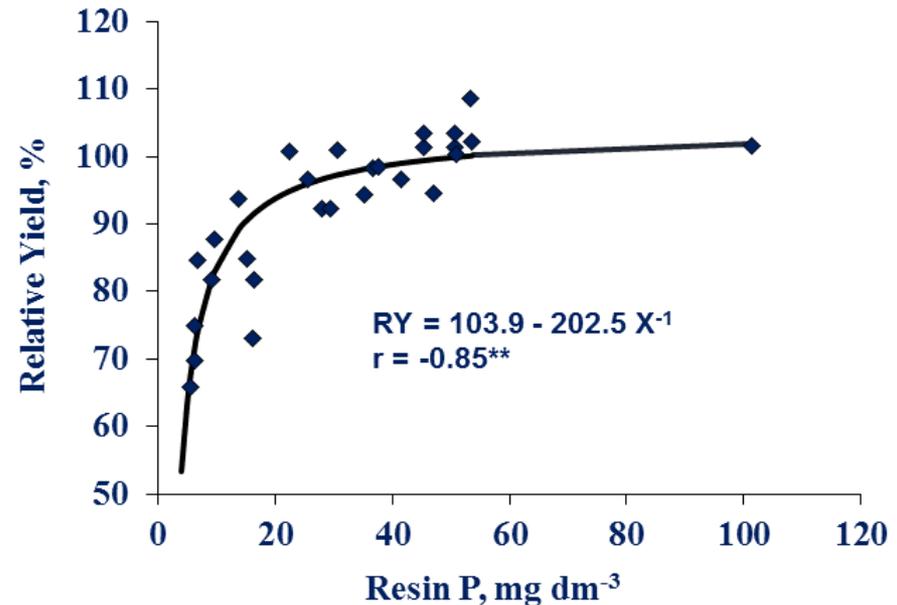
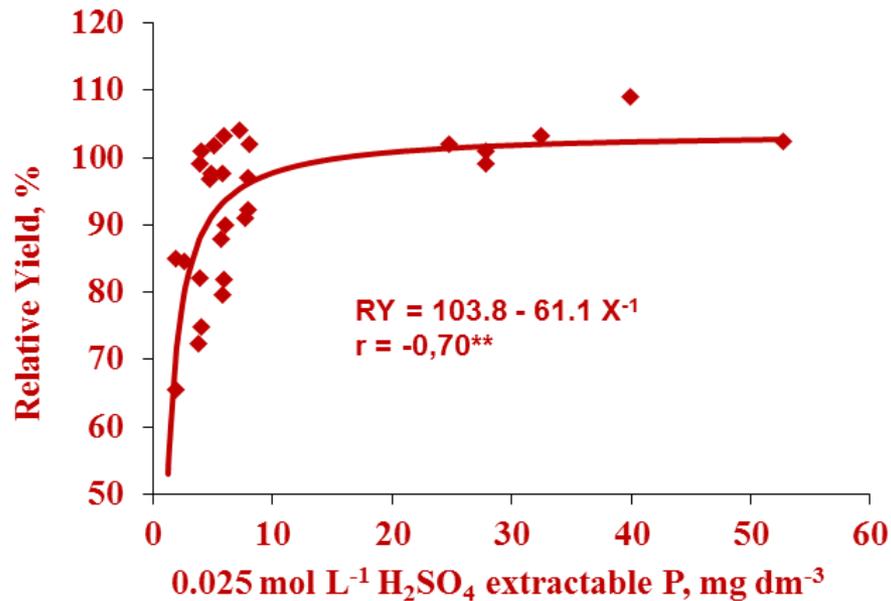
## □ Many studies followed (Intl. literature)

## □ Brazil: main interest was P

### □ Acid extractants: poor P diagnosis

- Soils high in Fe, Al oxides
- Soils fertilized with rock phosphates
- **INADEQUATE FERTILIZER P RECOMMENDATIONS**

# Cotton response to P: acid extractant vs ion exchange resin (n=28 field experiments)



# Comparing methods of P extraction: International literature (n=70)

Method	Coefficient of determination (%) for soils		
	Acid	Alkaline/ Neutral pH	Not Specified
Resin	84	83	69
Olsen	47	52	58
Mehlich 1	56	39	41
Bray 1	53	25	48

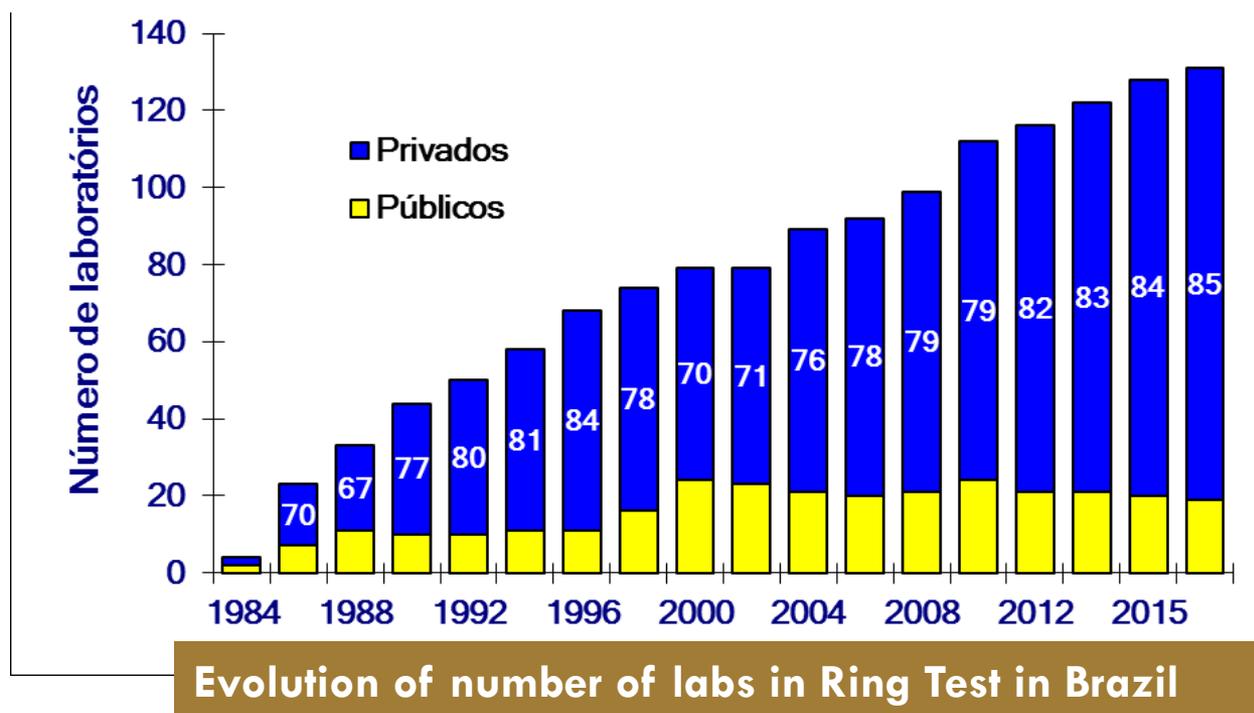
DISPONIBILIDADE DE FÓSFORO EM SOLOS  
AVALIADA POR DIFERENTES EXTRATORES<sup>1</sup>

FÁBIO CESAR DA SILVA<sup>2</sup> e BERNARDO VAN RAIJ<sup>3</sup>

Pesq. agropec. bras., Brasília, v.34, n.2, p.267-288, fev. 1999

# Resin: time-consuming for routine

- Equipment & procedures developed (Raij et al., 1986)
- Adopted in 1983 in Brazil (P, K, Ca, Mg). Today 114 labs

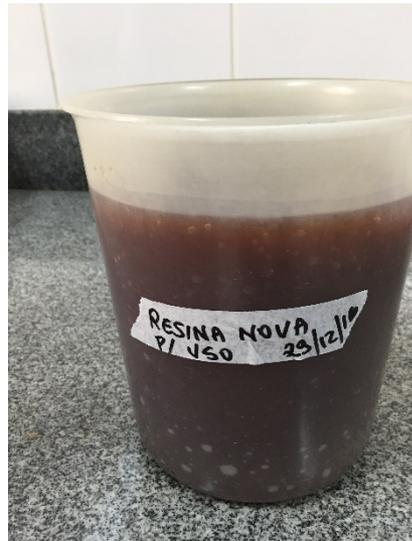


# Resin procedure for routine laboratories



**Anion Exchange Resin:**  
strong base, Amberlite  
IRA-400 or similar.

**Cation Exchange Resin:**  
strong acid, Amberlite IR-  
120 or similar



Equipment for resin preparation before  
use and to recover resin after use

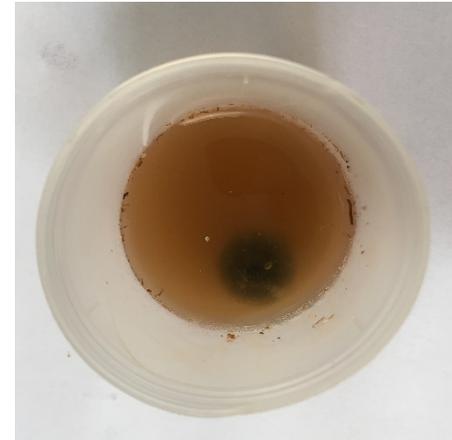
# Grinding soil samples before addition of resin



**Trays (30 samples) for routine**



**Glass marbles for grinding soil**



# Resin extraction



**Shaker (up to 210 samples)  
Grinding (15 min), Resin extraction  
(16h), Nutrient recovery from resin (1h)**

**Simultaneous extraction of P, K, Ca, Mg  
Shaking time: 16h; 4 h enough for K<sup>+</sup>**



**Resin (2.5 cm<sup>3</sup>) added to soil  
suspension (2.5 cm<sup>3</sup>)**

# Separating resin from soils by sieving



# Resin transferred to new flask: nutrients are now extracted from the resin



**Resin separated from the soil is transferred to a new flask. Nutrients are removed by ion exchange with a salt solution and determined by various procedures**

# Details of the methods:

13

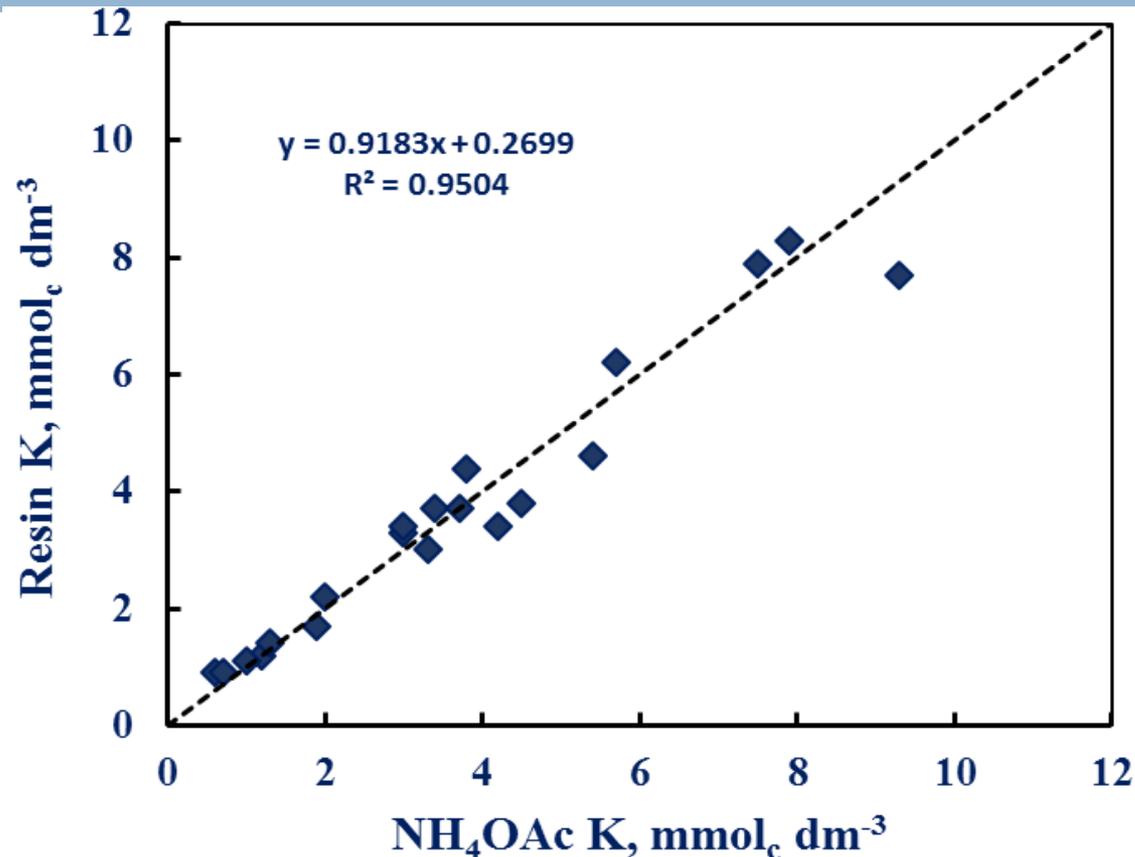
B. van Raij, J. C. de Andrade, H. Cantarella & J.A. Quaggio (2001). **Chemical analysis for evaluation of the fertility of tropical soils** (In Portuguese). Campinas, Agronomic Institute. 285p.



# Potassium

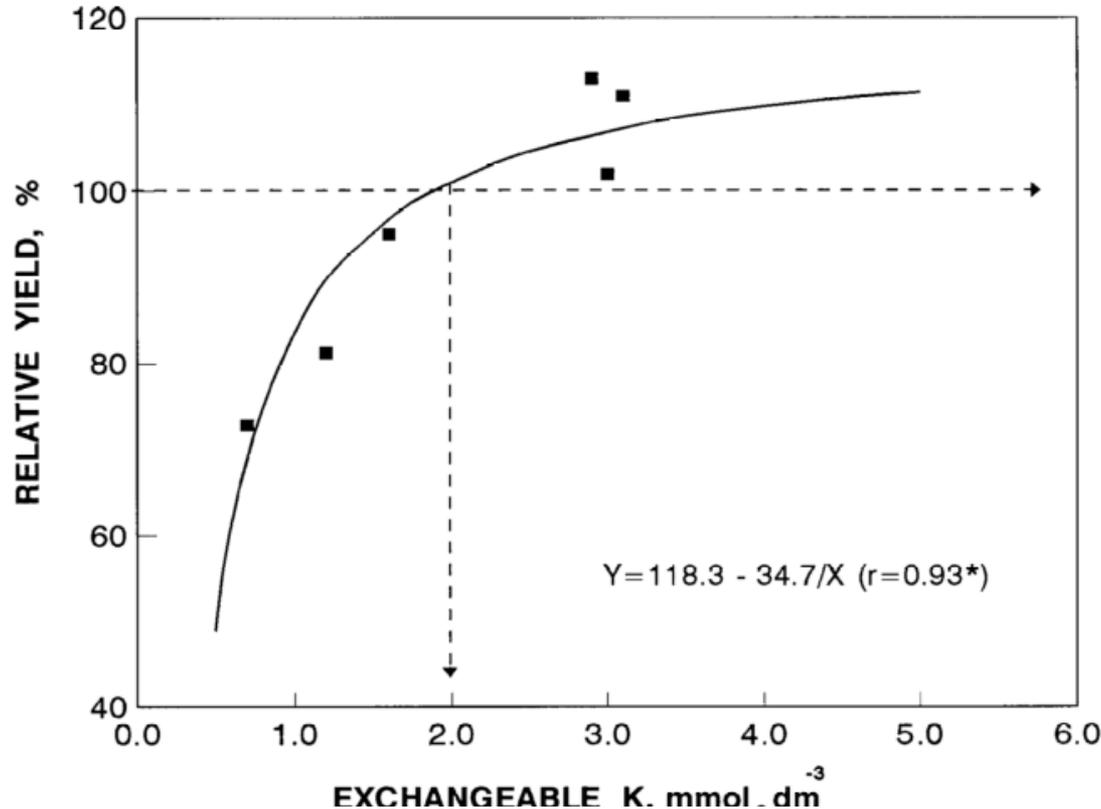
- **Brazilian soils:**
  - **Low CEC soils (1:1 clay; Fe, Al oxides)**
  - **85% topsoil samples: low K** (Lopes & Guilherme, Adv. Agron, 2016)
  - **K fertilizers are key for crop production in Brazil**
    - **More K fertilizer consumed than N and P**
  - **Exchangeable K (+ export): main criteria for fertilizer recommendation**
  - **Resin: high correlation with exchangeable K**
    - **Resin-K & exchangeable K: same class of soil analysis**
    - **Same fertilizer recommendation tables**

# Relationship between exchangeable and resin K.



20 samples representative of the soils of the State of São Paulo, Brazil

# First resin-K soil calibration. Citrus



6 sites, 4-7 harvests per site: 30 site-years of data

Phosphorus and potassium soil test and nitrogen leaf analysis as a base for citrus fertilization

J. A. Quaggio, H. Cantarella and B. van Raij

*Nutrient Cycling in Agroecosystems* **52**: 67–74, 1998.

# Equations of resin-K calibration similar to those for exchangeable K

Crop	Regression equation	Coefficient of correlation (r)	Value of P of K for maximum yield	Reference	
			mmol <sub>c</sub> /dm <sup>3</sup>		
<b>Potassium</b>					
Soybean	RY=108.0 - 17.42/K	0.54	2,1	Raij & Mascarenhas (1976)	<b>Exchangeable</b>
Cotton, beans, and sugarcane	RY=111,8 - 32.1/K	0.76	2,9	Raij (1974)	<b>Exchangeable</b>
Citrus	RY=118.3 - 34,7/K	0.93	2.0	Quaggio et al. (1997)	<b>Resin K</b>

Soil and plant analyses for lime and fertilizer recommendations in Brazil

Heitor Cantarella<sup>a</sup>, Bernardo van Raij<sup>a</sup> & Jose Antonio Quaggio<sup>a</sup>

COMMUN. SOIL SCI. PLANT ANAL., 29(11-14), 1691-1706 (1998)

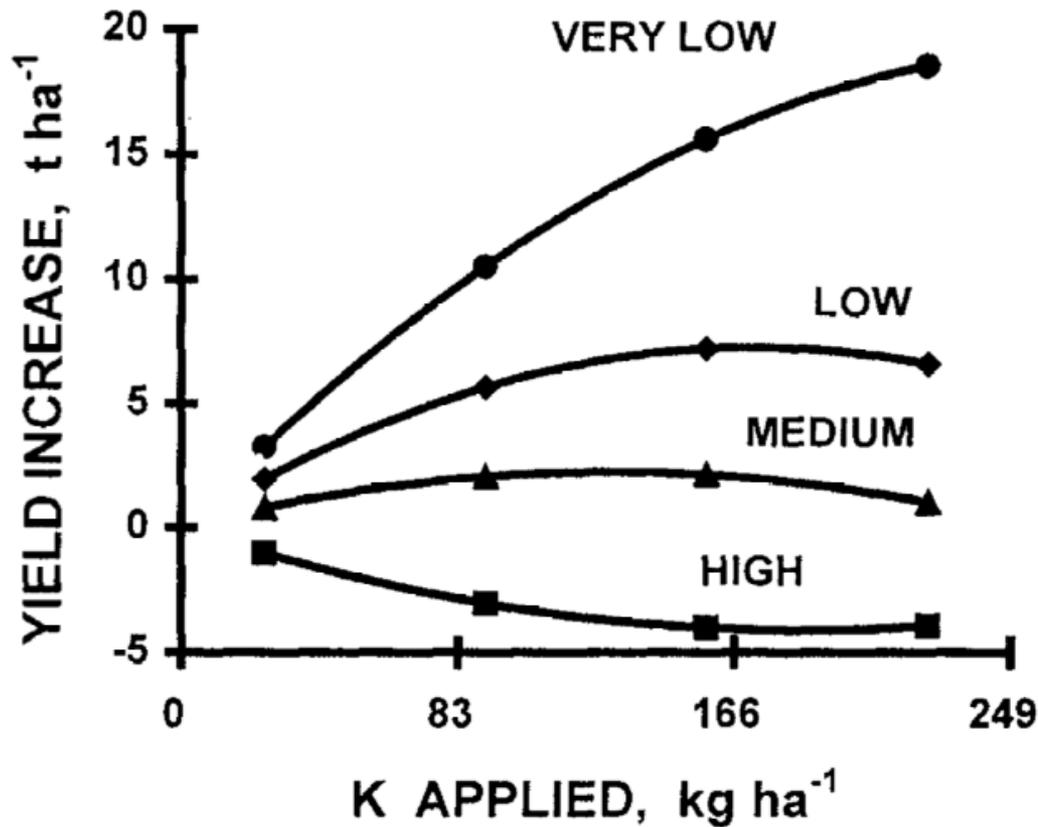
# Resin K: same class of soil interpretation; same fertilizer recommendations

Soil class	Resin K, $\text{mmol}_c/\text{dm}^3$
Very low	< 0.7
Low	0.8 – 1.5
Medium/adequate	1.6 – 3.0
High	3.1 – 6.0
Very high	> 6.0



Fertilizer recommendation tables for +120 crops  
(soil K: resin)

# Citrus response to K fertilizer based on fertility class (defined by resin K)



30 site-years of information

Phosphorus and potassium soil test and nitrogen leaf analysis as a base for citrus fertilization

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*Nutrient Cycling in Agroecosystems* 52: 67–74, 1998.

# Variability of results in a Ring Test of laboratories that analyze resin K (n=114)

Grade of laboratory in the Ring Test (n=114 labs) †	Samples outside the confidence interval							All determinations (n=180 per lab)
	P	MO	pH	K	Ca	Mg	H+Al	
	----- % -----							
Average of all labs	12	6	5	9	10	7	9	8
Grade A labs	5	1	1	2	3	4	3	3
Grades A and B labs‡	8	3	2	4	4	5	5	5

† 114 laboratories fulfilled the Proficiency test requirements (Cantarella et al., 2017)

‡ Laboratories approved in the Proficiency test according with the rules (Quaggio et al., 1994)

# Soils 2:1 layer clay

- **Interlayer K fixation; nonexchangeable K**
  - **Not fully detected by K exchangeable methods**
  - **But exchangeable still the most common method**
  
- **Alternatives**
  - **Use exchangeable & nonexchangeable K**
  - **Estimate of nonexchangeable K (by resin) + exchangeable (Dobermann et al, 1996)**
  - **Total K (<2 to 3%) & exchangeable K (Rayment 2013)**

**(Cited literature in the Proceedings paper)**

# Nonexchangeable K

- **Hot HNO<sub>3</sub>**
- **Sodium tetraphenyl boron (NaTPB)**
  - **Methods hardly adopted in routine**
  - **K only moderately available to plants**
  - **It has being suggested that K recommendations use both exchangeable & nonexchangeable K**

# Resin & nonexchangeable K

- **Arnold (1958): nonexchangeable K**

**ARNOLD, P. W. 1958. Potassium uptake by cation-exchange resins from soils and minerals. *Nature*, 182, 1594-1595.**

- **“promising value for soil fertility evaluations”**

- **Rate of release of fixed or structural K and characterize nonexchangeable K forms**

**Feigenbaum et al (1981)/Martin & Sparks (1983)**

**Havlin & Westfall (1985)/Skogley & Schaff (1985)/Doberman et al. (1996)**

- **Good correlation with plant K uptake (some studies)**

- **Long extraction procedure (days, weeks): purpose was not routine**

- **Helmke & Sparks (1996): resin procedure for nonexchangeable K**

# Resin & K availability tests

- **PST (phytoavailability soil test) for K, P, S** (Yang et al. 1991a, b)
  - **Cationic and anionic resins (bags, capsules)**
  - **Equilibrium time relatively long**
  - **Skogley (1994): “reinventing soil test for the future”**
- **Ion Exchange membranes for N, P, S, K** (Qian et al, 1992, 1996, 1998)
  - **Equal or better than conventional methods**
  - **Led to commercial application of membrane method** (Bremer et al, 2014)

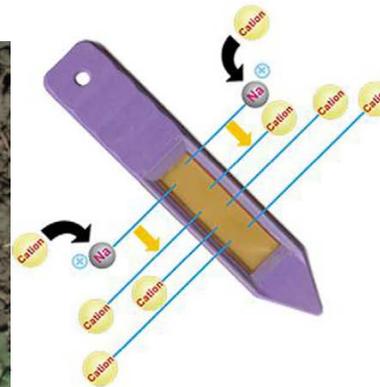
# Commercial kits for soil analysis with ion exchange resins

Use of ion-exchange resin membranes for nutrient management in western Canada 2014

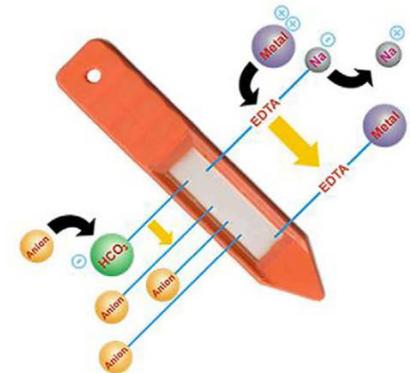
By Eric Bremer, Lindsey Andronak, and Ken Greer, Western Ag Innovations



Cation



Anion



Walla Walla, WA 99362



**Resin capsules (2.5 cm): 14 nutrients; saturated paste; 1-4 days**

**Results sometimes difficult to interpret and classify (low, medium, ...) but allow understanding of K status for turf (Woods et al, 2006)**

# Concluding remarks

- **Low CEC soils: Resin is a proven choice for K**
  - **Example of Brazil**
- **Resin for K (including nonexchangeable K) is not new**
  - **Some promising results (for other types of soils)**
  - **Brazilian model may be a starting point**
  - **Still soils with nonexchangeable K are research challenge**



**THANK YOU**

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