IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

INFORMAÇÕES RECENTES PARA OTIMIZAÇÃO DA PRODUÇÃO AGRÍCOLA
Piracicaba-SP, Brazil 15-16 March 2007

Integrated Plant Nutrition for Better Soybean Quality

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Director, Northeast Region, North American Program

IPNI Mission

- "to develop and promote
  scientific information
  about the responsible management
  of plant nutrients
  for the benefit
  of the human family."

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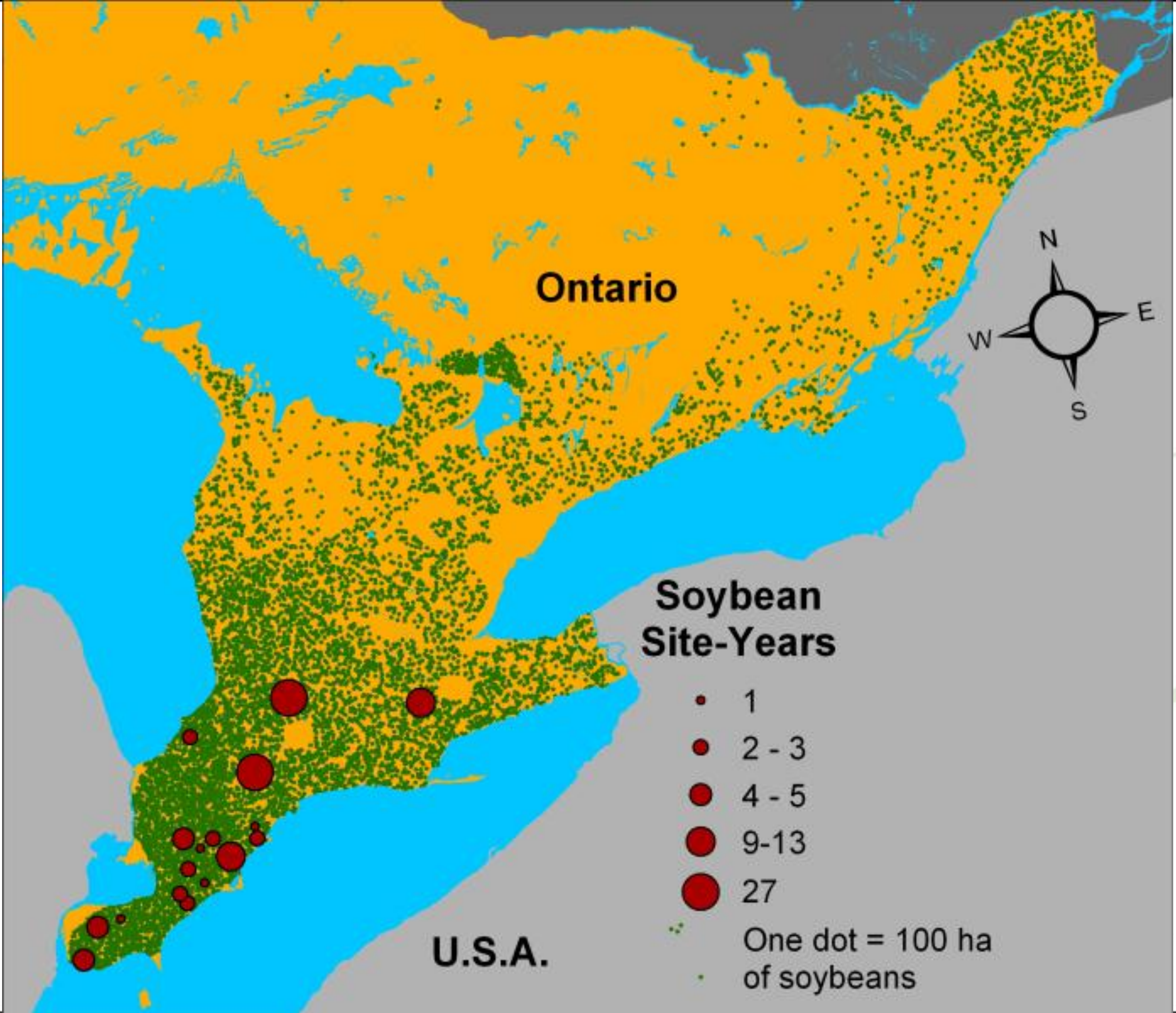
Outline – Optimal Soybean Nutrition

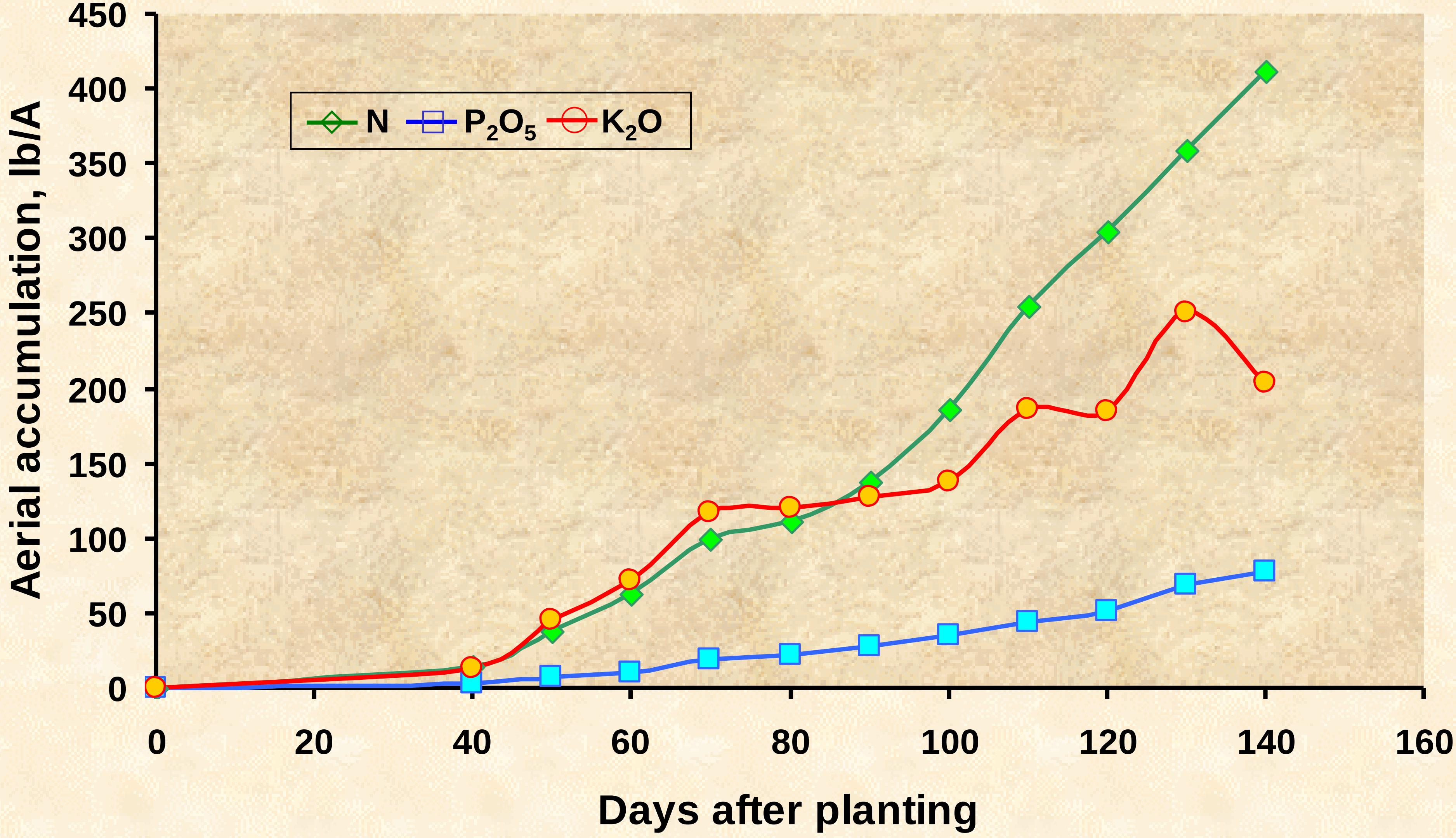
- Ontario soybean yield and K
- Functional Food Components
  - Nutraceuticals
  - Isoflavones and K
- Protein and Oil
- Plant Health

Fertilizing Soybeans

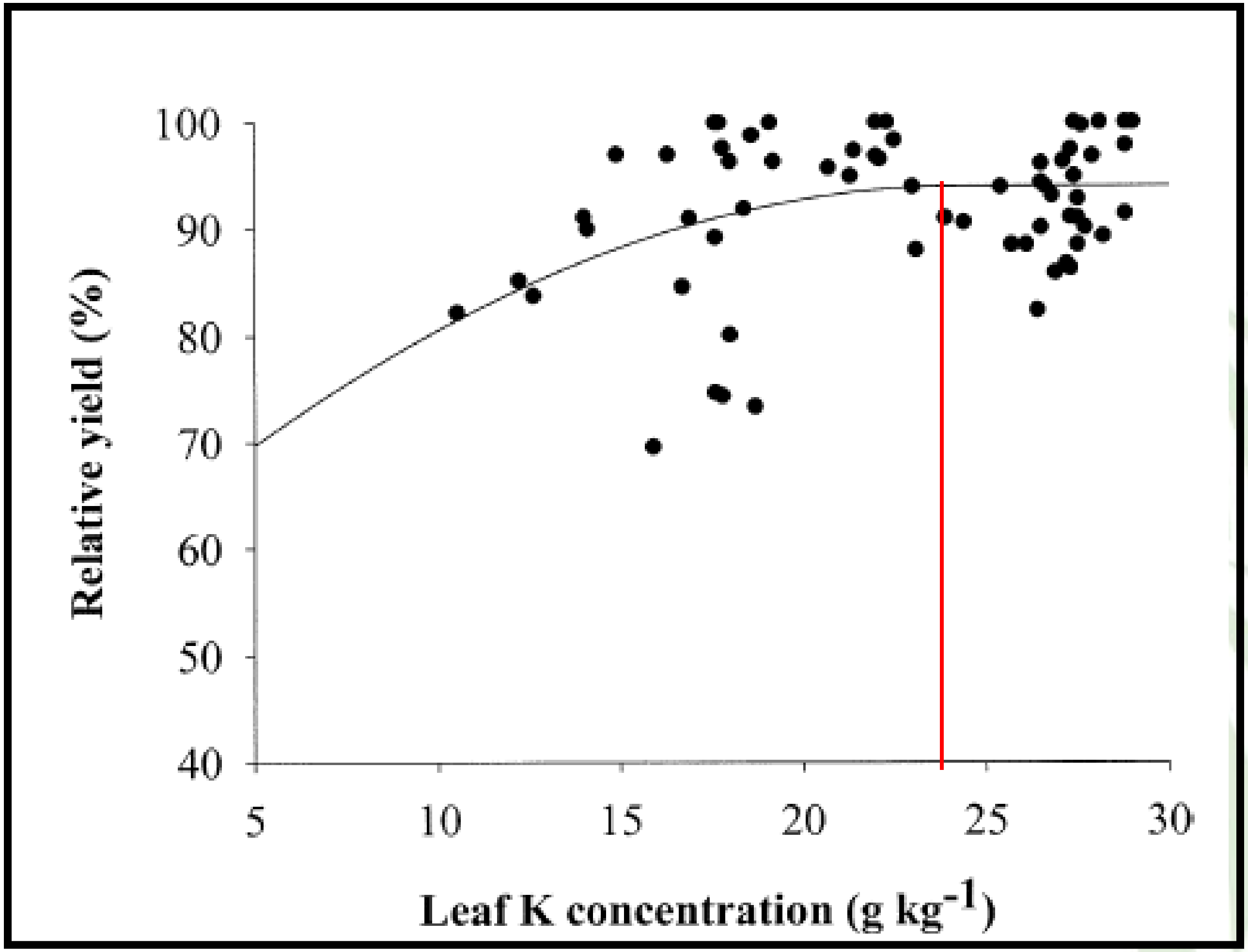
- N – legume
- P & K – often sufficient following corn
- Responses infrequent, compared to corn
- Removal rates:
  - N: 4.0 lb/bu
  - P_2O_5: 0.8 lb/bu
  - K_2O: 1.4 lb/bu
  - S: 0.34 lb/bu


Ontario
N
E
W
S
Soybean
Site-Years
1
2 - 3
4 - 5
9-13
27
One dot = 100 ha
of soybeans
U.S.A.

Aerial accumulation of N, P, and K by soybeans (80 bu/A)



Critical Level for Maximum Yield



Example from Ontario:

Leaf K in Soybean

Yin and Vyn, 2004

Table 1. Corn and soybean response characteristics in four soil test categories[1].

Soil test level[2]	Corn		Soybeans	
	Probability of response, %	Mean optimum P_2O_5, rate, lb/A	Probability of response, %	Mean optimum K_2O rate, lb/A
Low	85	45	44	48
Medium	59	25	49	35
High	19	7	15	12
Very high	25	7	24	10

[1]Based on 99 and 128 site-years of data for corn and soybeans, respectively. Analysis was weighted based on number of replications involved in each site-year.

[2]Soil test levels dividing the four classes for corn are 9, 20, and 30 parts per million (ppm) Olsen-P, and 60, 120, and 150 ppm ammonium acetate K

Table 3. Impact of soil texture class on mean optimum rates, in lb/A, for K_2O applied to Ontario soybeans.

Soil test level	Soil texture	
	Sandy to loamy	Loamy to clayey
Low	50	
Medium	16	45
High	0	13
Very high	2	14

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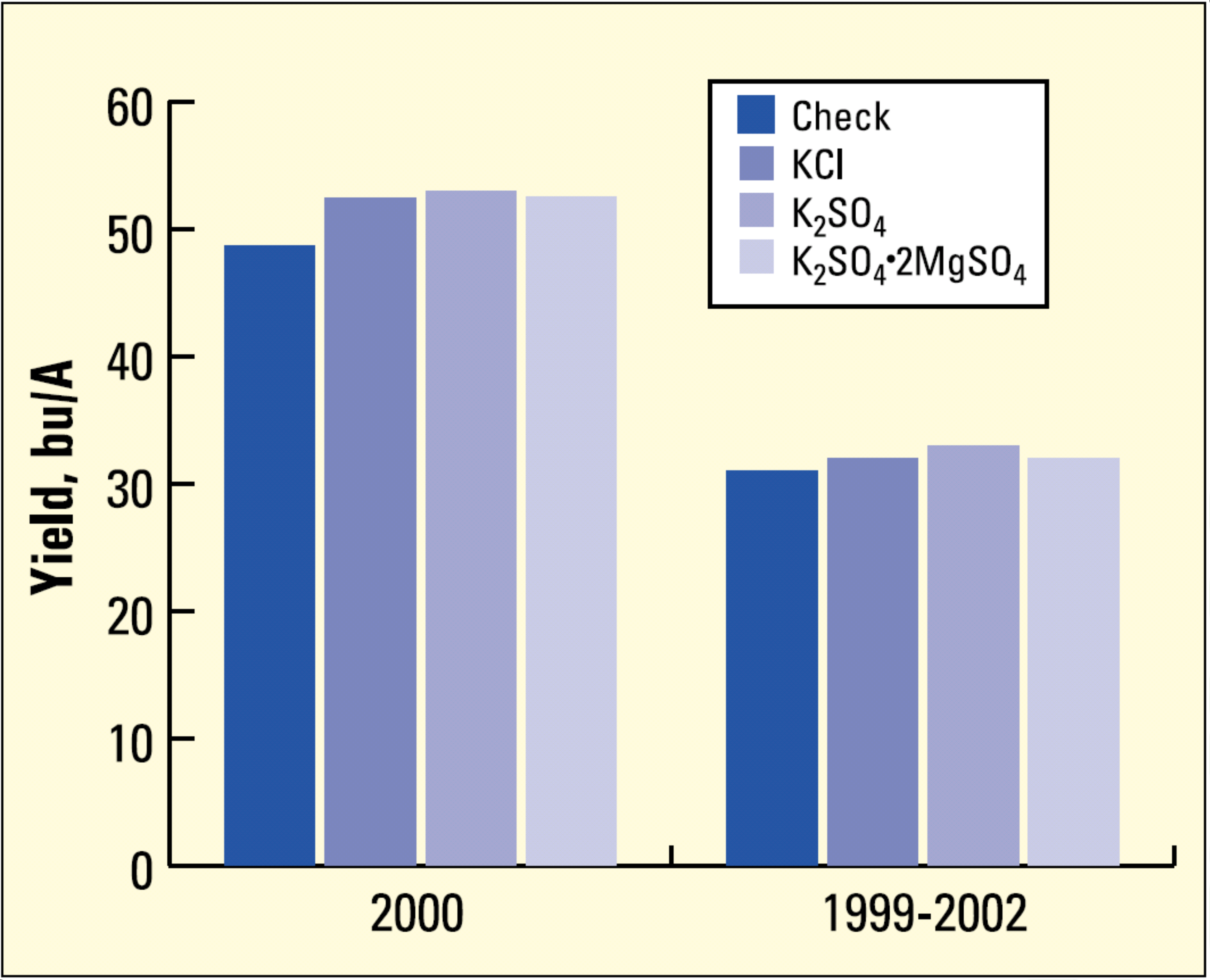
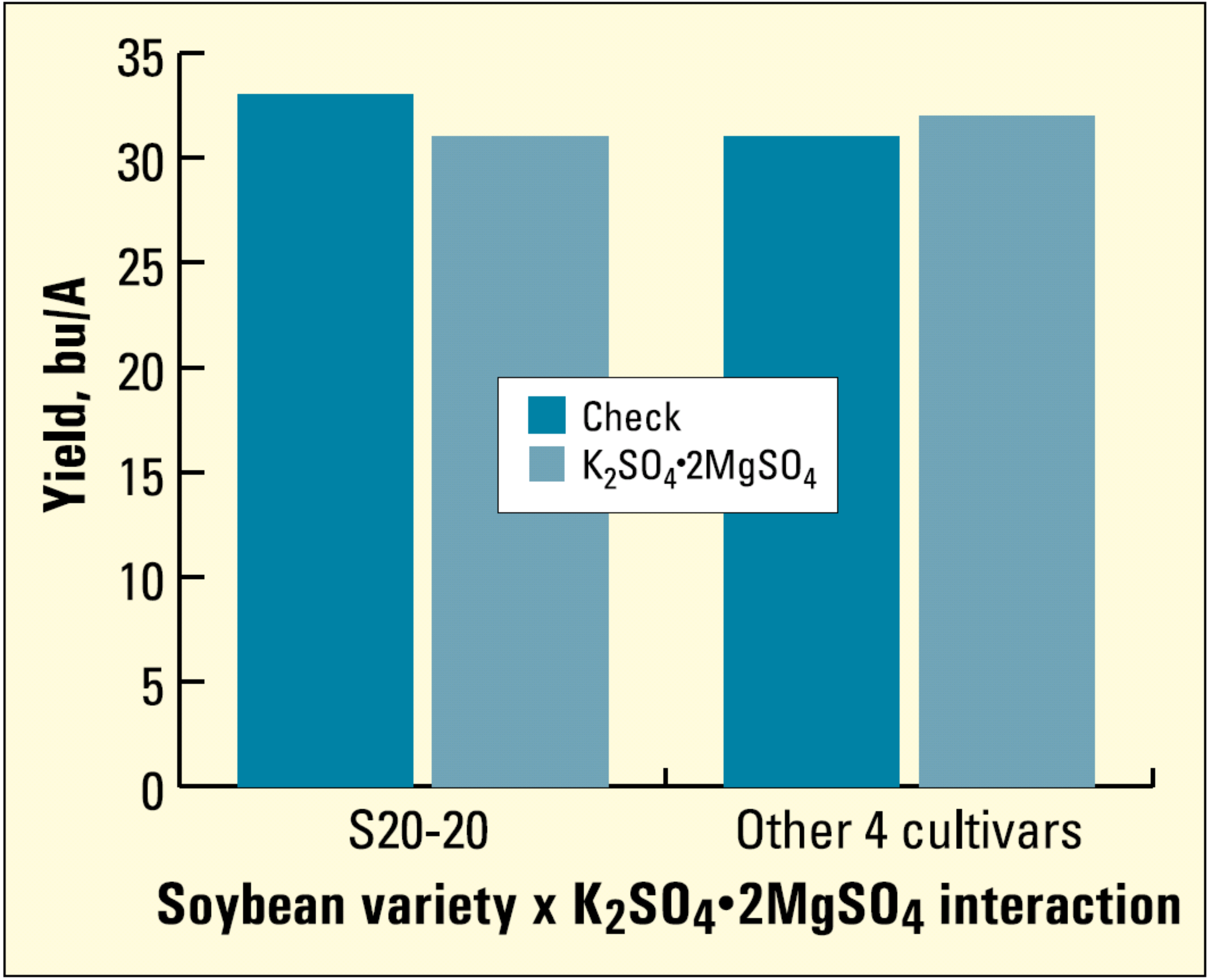


Zhang et al., 2003. Better Crops Vol. 87 No. 4

Soybean yield response to K was economic only in 1 of 4 years. Mean of 5 cultivars, Harrow, Ontario, Canada.



Zhang et al., 2003. Better Crops Vol. 87 No. 4

Cultivar S20-20 responded differently to sulfate of potash magnesia than the other four cultivars. Mean of 4 years, 1999-2002.

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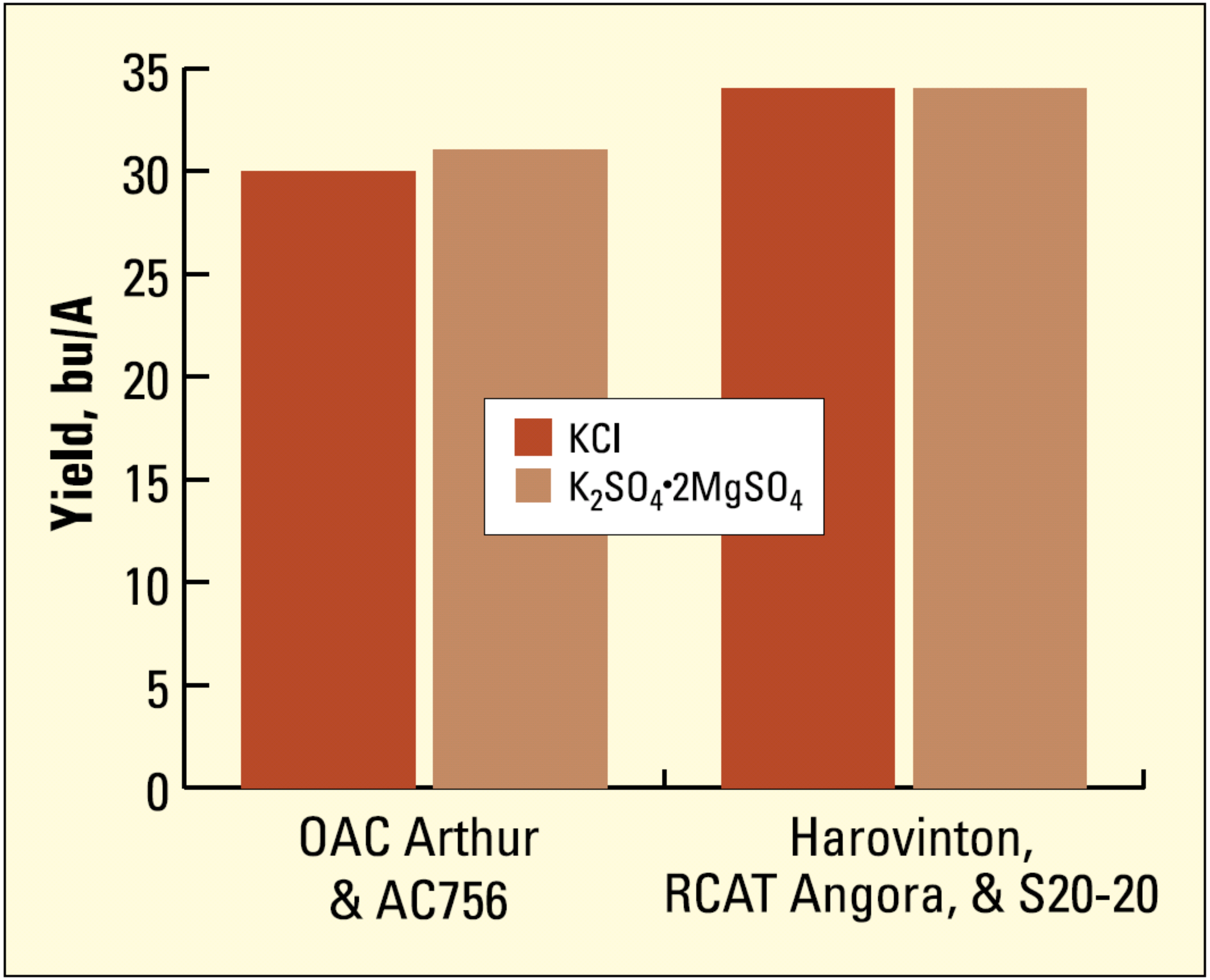
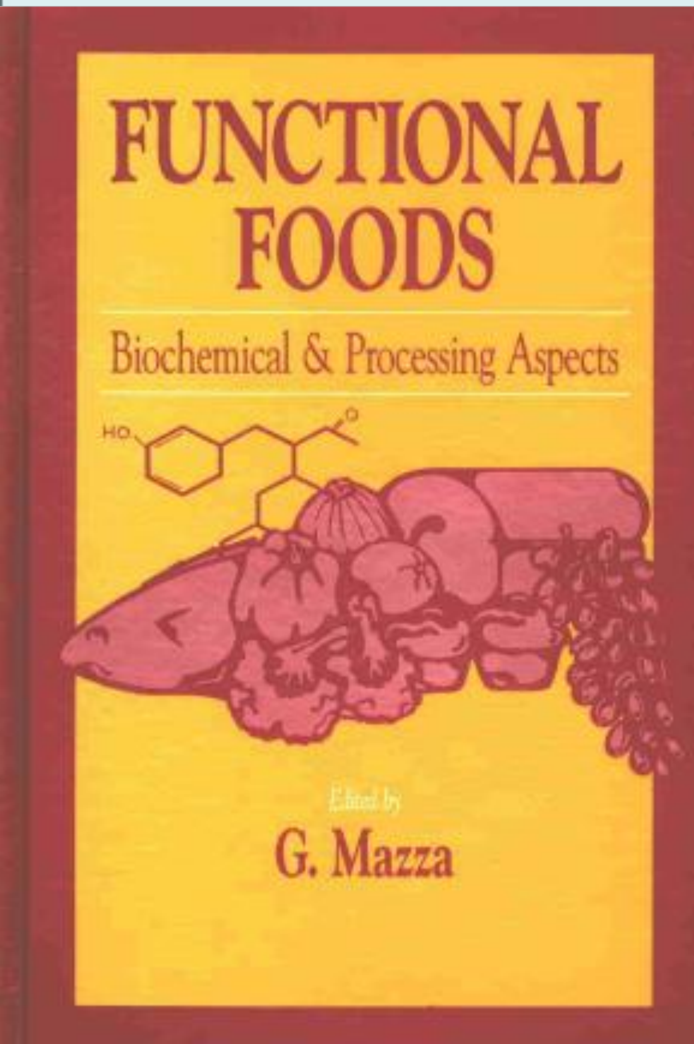
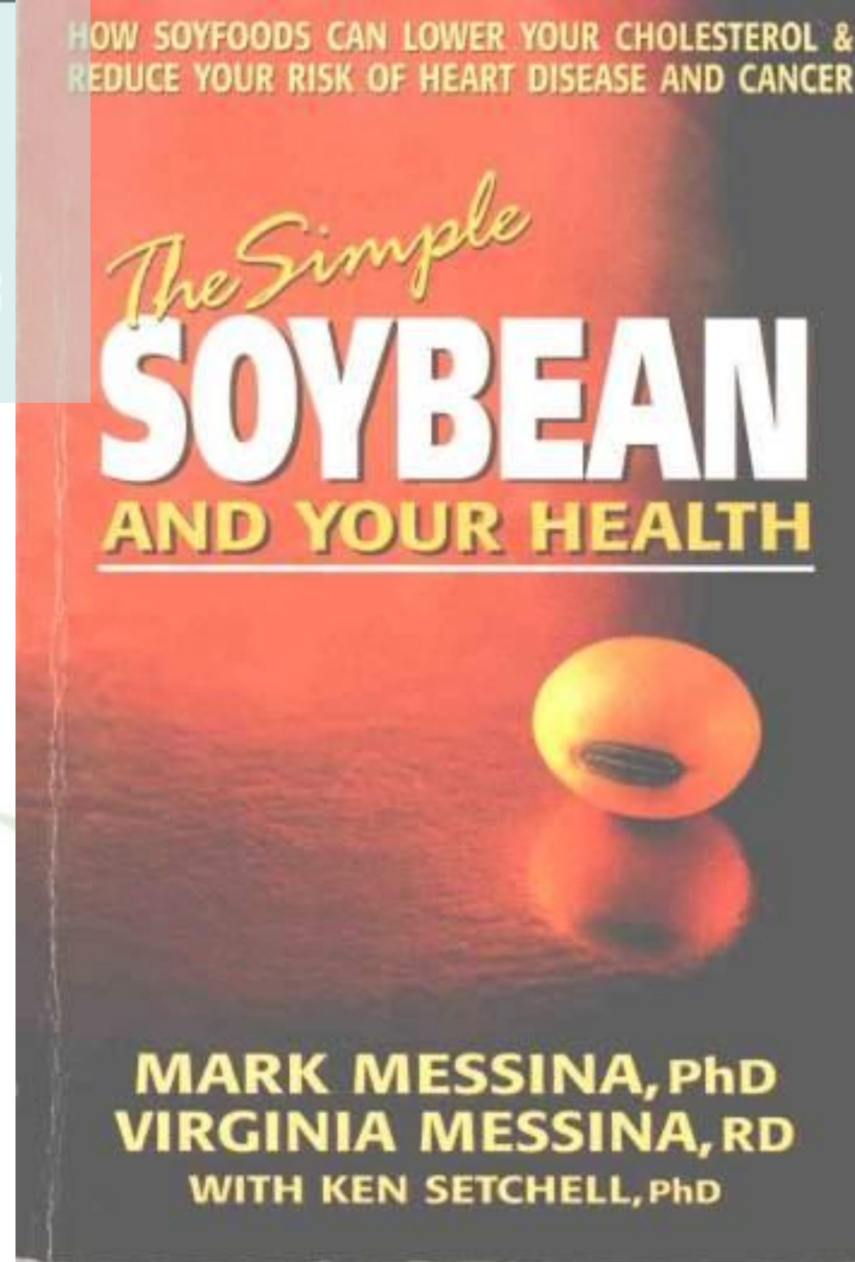


Zhang et al., 2003. Better Crops Vol. 87 No. 4

Soybean cultivars showed slight differences in preference for Cl or sulfate sources. Mean of 4 years, 1999-2002.

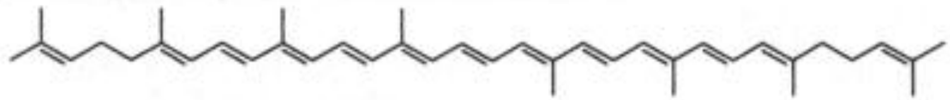
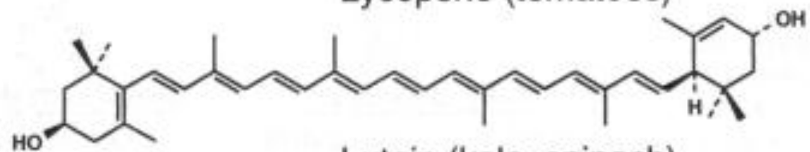
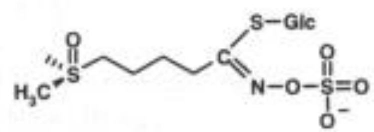
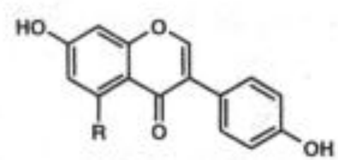
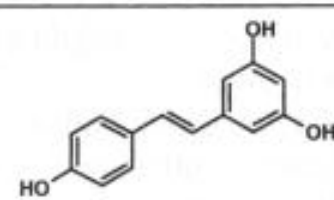
Functional Foods: lead the list of consumer trends - market opportunities for crop producers (Successful Farming; @g Online; Better Homes & Gardens)





Phytochemical Examples

Table 2. Selected phytochemical classes, health-promoting properties, example active compounds, and good plant sources.

Phytochemical Class (no. of compounds)	Diseases ameliorated or prevented	Example active compound and plant source
Carotenoids (>700)	Prostate, esophageal and other cancers, cardiovascular disease, macular degeneration (*14*)	 Lycopene (tomatoes)  Lutein (kale, spinach)
Glucosinolates (>100)	Cancers (*12*)	 Glucoraphanin (broccoli and broccoli sprouts)
Phytoestrogens (>200)	Cardiovascular disease, osteoporosis, breast, prostate and colon cancers (*13*)	 Genistein (R=OH); Daidzein (R=H) (soybeans, tofu, soy products)
Phenolics (>4,000)	Cardiovascular disease, cancers (*42*)	 Resveratrol (red wine, red grapes)

Science 285:377, 1999

Cargill Health & Food Technologies - Soy Isoflavones - Microsoft...

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Products > Soy Isoflavones

Cargill Health & Food Technologies manufactures and markets AdvantaSoy™ soy isoflavones. Our soy isoflavone concentrates can be formulated into foods, dietary supplements, beverages or other nutraceuticals. At Cargill Health & Food Technologies, we offer a broad spectrum of support in helping to develop your soy isoflavone products.

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Our Platforms

Heart Health

Women's Health

Joint Health

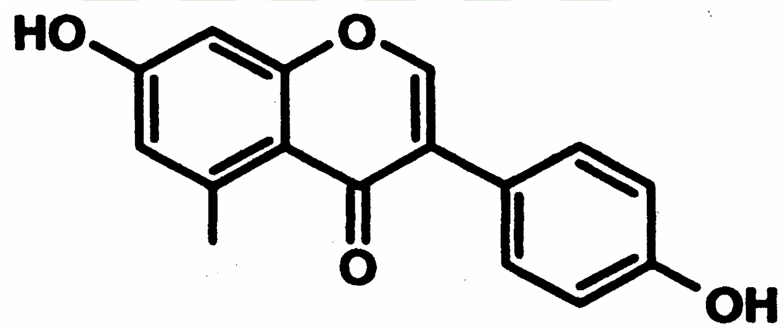
NovaSoy

The Power of Soy

Internet

FDA & the Soy Health Claim

- 20 Oct 1999: foods containing soy protein
  - Reduced risk for heart disease
- Isoflavones - genistein, daidzein
  - CVD, cancer, antioxidant, phytoestrogen
  - Isoflavone market year ending March 2001 was worth $118 million – Cargill & ADM
  - Possible role in animal feeds: increased muscle % in swine (Iowa State University, 1998)



Factors Influencing Isoflavones in Soybean

- Temperature
- Variety
  - Maturity Group
- Irrigation
- Yield

Walt Fehr,
Iowa State University,
2001

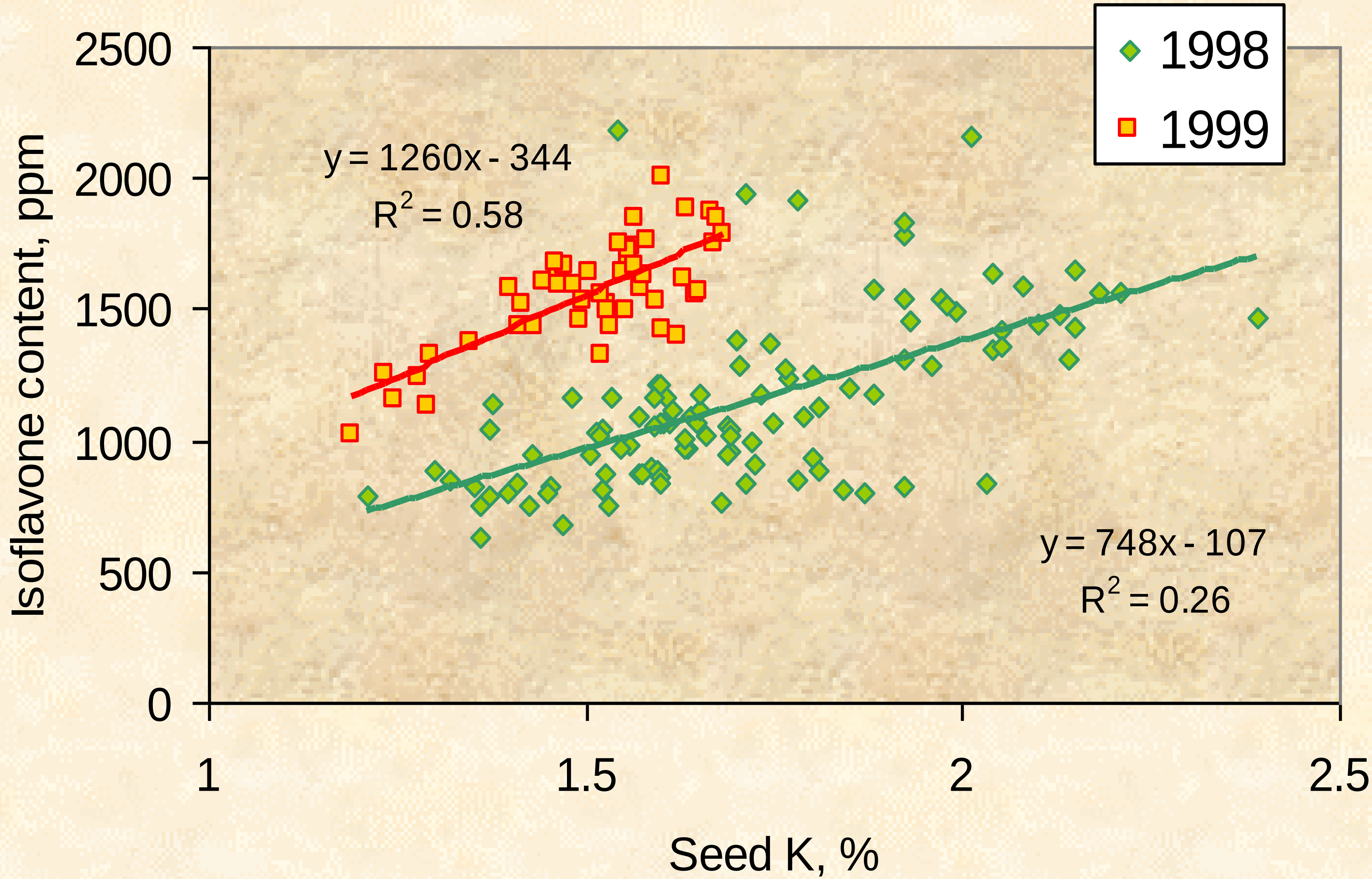
Temperature	Isoflavones (ppm)
38/28 ºC	**103**
25/10 ºC	**1667**

Tsukamoto et al., 1995

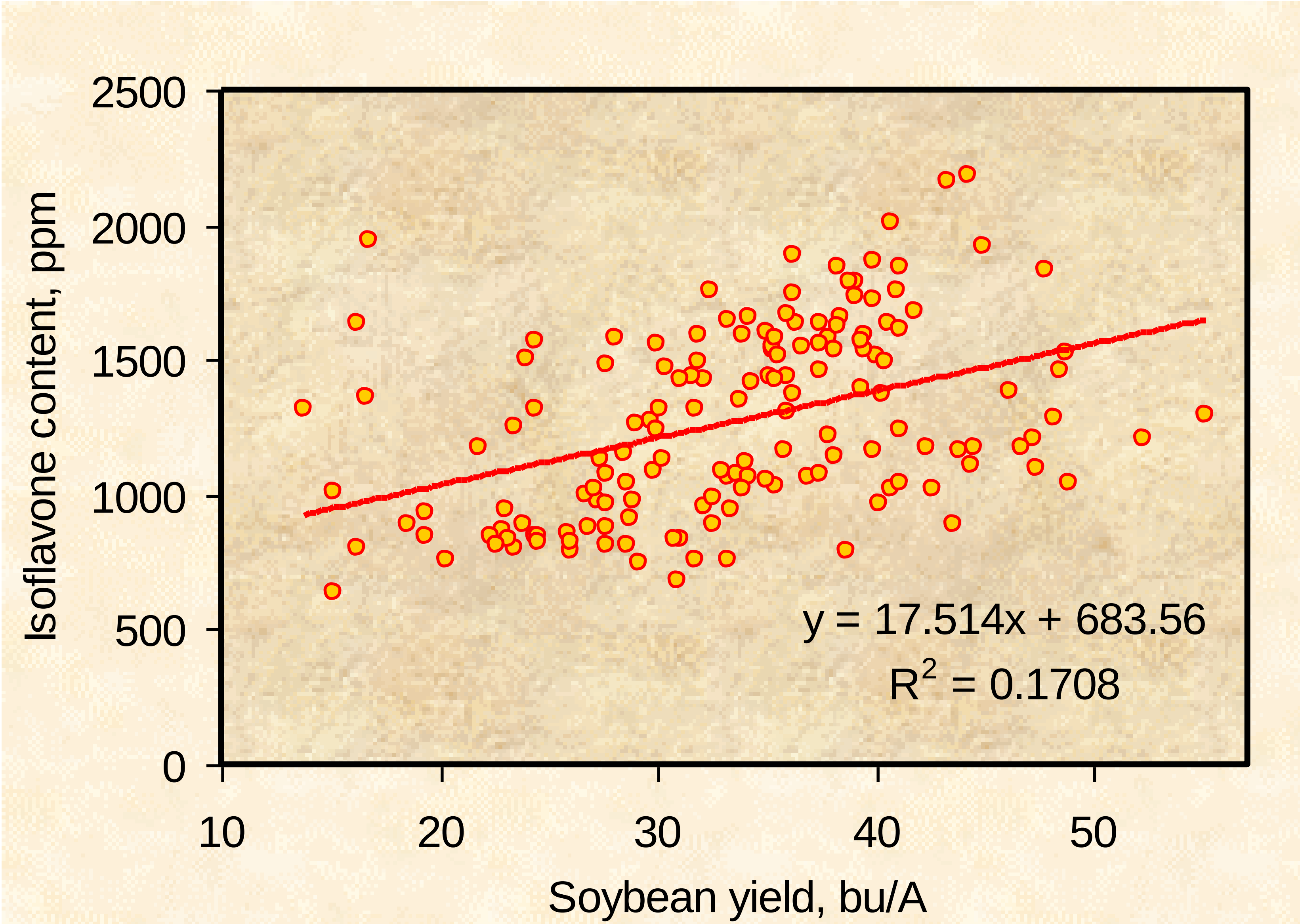
Irrigation	Isoflavones (ppm)
With	**7550**
Without	**4500**

Dayde & Lacombe, 2000 (France)

Isoflavone levels in relation to soybean seed K content Ontario, Canada.



Isoflavone levels in soybean seeds in relation to yield. Ontario, 1998-1999

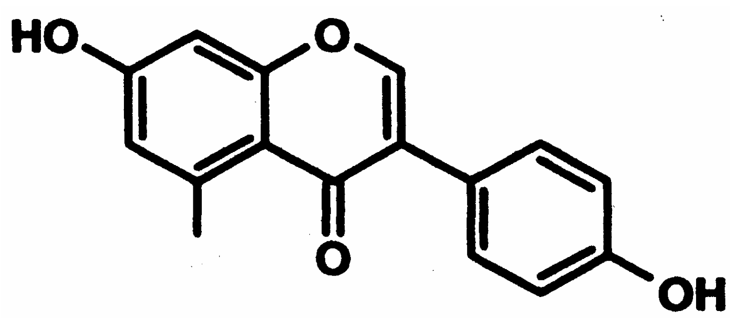


Concentration of isoflavones in soybean seeds in response to applied K fertilizer (two sites, three years, 1998-2000).

K_2O application	Genistein	Daidzein	Glycitein	Total[1]
Spring banded	938	967	146	2,051
None	831	854	130	1,851
Increase due to K, %	13	13	12	13

[1] Total isoflavone concentration expressed as aglycone; sum of three components; parts per million (ppm)

Vyn et al., 2002. Journal of Agricultural and Food Chemistry, 50: 3501-3506.



Impact of stratification of soil test K on critical values of leaf K for maximum levels of yield, seed K, oil and isoflavones in soybeans (adapted from Yin and Vyn, 2004).

Attribute	Critical Value (g K kg^{-1} leaf tissue dry matter)	
	KSC<2	KSC>2
Yield	19.1	22.8
Seed K	21.2	22.4
Oil	21.6	24.7
Isoflavones	21.9	25.9

KSC = soil test K stratification coefficient (0-5 cm depth divided by 10-20 cm depth).

Two Responsive Sites

Potassium treatment	Isoflavones (ppm) Lambton	Paris
Spring Banded K	2635	1453
No K	2384	1248
difference	11%	16%

No-till soybeans, 3-year average, 1998-2000
Lambton: High soil test K, clay loam soil
Paris: Low soil test K, sandy loam soil

T.J. Vyn & Xinhua Yin

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Residual K effect

Potassium applied to corn (110 lb K2O /A)	'97-'98 Corn Yield (bu/A)	'98-'99 Soybean Isoflavones (ppm)
Spring Banded K	130	1838
No K	116	1527
difference	12%	20%

No-till soybeans, 2-year average, 1998-1999
Paris: Low soil test K, sandy loam soil
T.J. Vyn & Xinhua Yin

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Harrow, Ontario, 2000 Perth clay loam

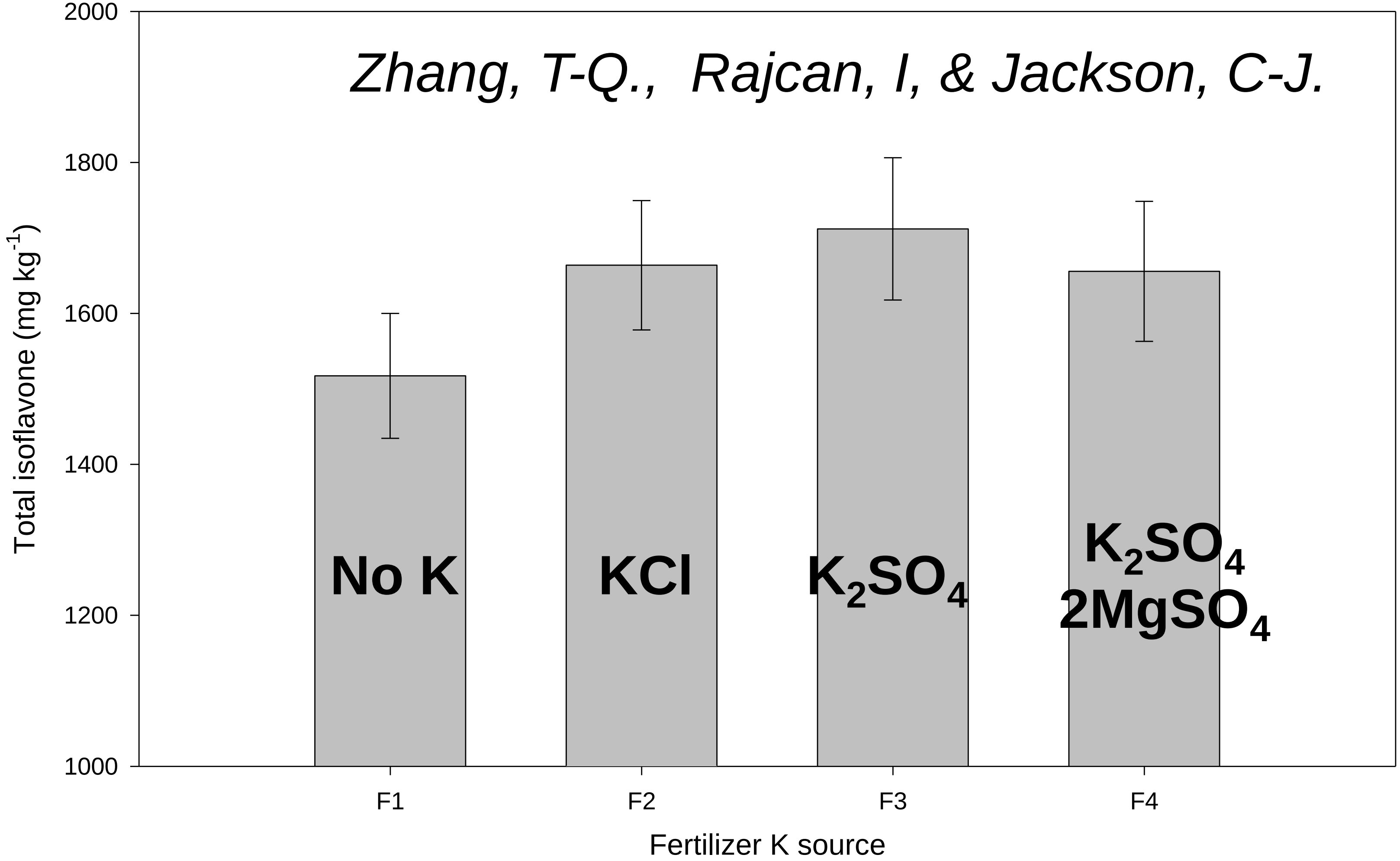

Fig. 2. Effect of fertilizer K source on total isoflavone content of soybean seeds in a Perth clay loam soil, Harrow, 2000. F1=control; F2=KCl; F3=K_2SO_4; F4=$K_2SO_4.2MgSO_4$.

Soybeans: Lambton 1999

Potassium application method	Isoflavones (ppm)	Protein (%)	Yield (bu/A)
spring banded K	3074	40.3	49
fall surface K	2878	40.1	48
no K	2535	41.0	41

Soil test K – high to very high
No-till soybeans

T.J. Vyn & Xinhua Yin

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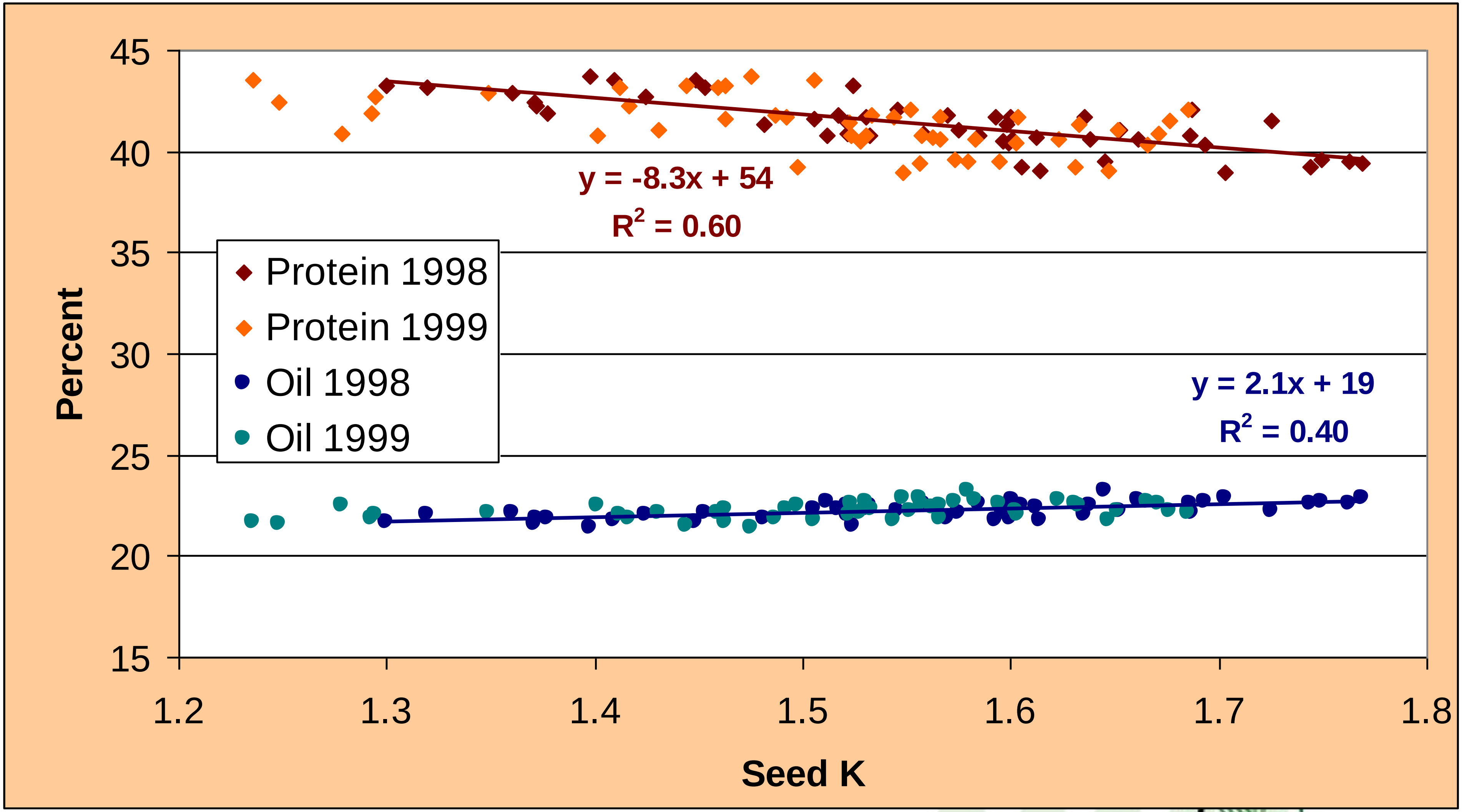
K Effect on Protein and



T.J. Vyn, Paris, 1998-1999

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P&K Effects on Soybean

P_2O_5	K_2O	Yield	Protein	Protein	Seed germination
kg/ha	kg/ha	kg/ha	(%)	kg/ha	%
0	0	1710	41.8	716	62
135	0	1770	41.8	741	70
0	135	3130	39.2	1227	85
135	135	3680	39.2	1443	95

2-year average, Virginia

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Potassium Effect on Protein, Oil and Sugar (Harrow, Ontario)

Applied K_2O, kg/ha	Protein, %	Oil, %	Sugar, %
95	**41.9**	**21.6**	**11.0**
0	**42.3**	**21.4**	**10.9**

Potassium slightly increased oil and sugar but decreased protein. Mean of five cultivars over four years, 1999-2002 (Zhang et al., 2003).

Potash Increases Yield and Seed Quality

K_2O	Yield	Shrunken, shriveled, mouldy or discoloured seed	Hundred Seed Weight
kg/ha	**kg/ha**	**%**	**g**
0	**470**	**37**	**11.2**
135	**1810**	**3**	**14.5**

Soybean cv. Ogden, North Carolina

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Fertilizer Increases Yield and Quality

Fertilizer (0-10-20) Rate	Yield	Damaged or purple seed	Germination
kg/ha	kg/ha	%	%
0	1360	17	82
450	2210	3	93

Indiana soybeans

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Nutrients Impact Diseases

- **Sudden death syndrome**
  - Reduced 36% by chloride; increased by sulfate or nitrate (Sanogo and Yang, 2001)
  - Reduced by chloride (Howard et al., 1999)
- **Phytophthora root rot, mosaic virus**
  - Reduced by NPK together, not alone (Pacumbaba, 1997)
- **Stem canker**
  - Reduced incidence with N, P, or K, in Alabama and Mississippi (Rhoton, 1989)
- **Anthracnose and Phomopsis**
  - K suppressed both; P slightly increased Phomopsis (Sij et al., 1985)

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Nutrients Impact Diseases (2)

- Phytophthora stem rot:
  - Zoospore release inhibited by application of a solution of 2.5 mM K and 5.1 mM Ca (Sugimoto et al., 2007)
- Frog's Eyespot and Downey mildew
  - *Cercospora sojina, Peronospora manshuria* in Minas Gerais (Nolla et al., 2006)
  - Reduced by application of 1.5 to 12 t ha^{-1} of calcium silicate
  - No effect on Asian rust (*Phakopsora pachyrhizi*)

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Potassium Fertilizer Reduces Disease

P_2O_5	K_2O	Yield	Pod and Stem Blight	Purple Seed Stain
kg/ha	kg/ha	kg/ha	%	%
0	0	1550	12b	14b
450	0	1760	8b	11b
0	450	2410	1a	5a
450	450	2610	1a	5a

- Virginia soybeans
- soil low in K and very high in P
- two-year averages; 1971 and 1972
- all fertilizer applied in 1969

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Soybean Stem Canker

Fertility treatment	Soil test P	Soil test K	Leaf P	Leaf K	Soybean Stem Canker
	kg/ha	kg/ha	%	%	% infection
Low	53	177	0.26	1.3	43
High	140	280	0.26	1.7	32

Influence of soil fertility on soybean leaf tissue P and K and stem canker infection (Rhoton, 1989).

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Stress Tolerance

Effect of K in nutrient solution on leaf K and water stress effect on whole leaf CO_2 uptake of wheat (adapted from Pier and Berkowitz, 1987).

K^+ in nutrient solution	Leaf K^+	Photosynthesis ($\mu mol\ m^{-2}\ s^{-1}$)	
mM		Well-watered	Stressed
0.2	55	22	7
2	195	25	11
6	315	26	17

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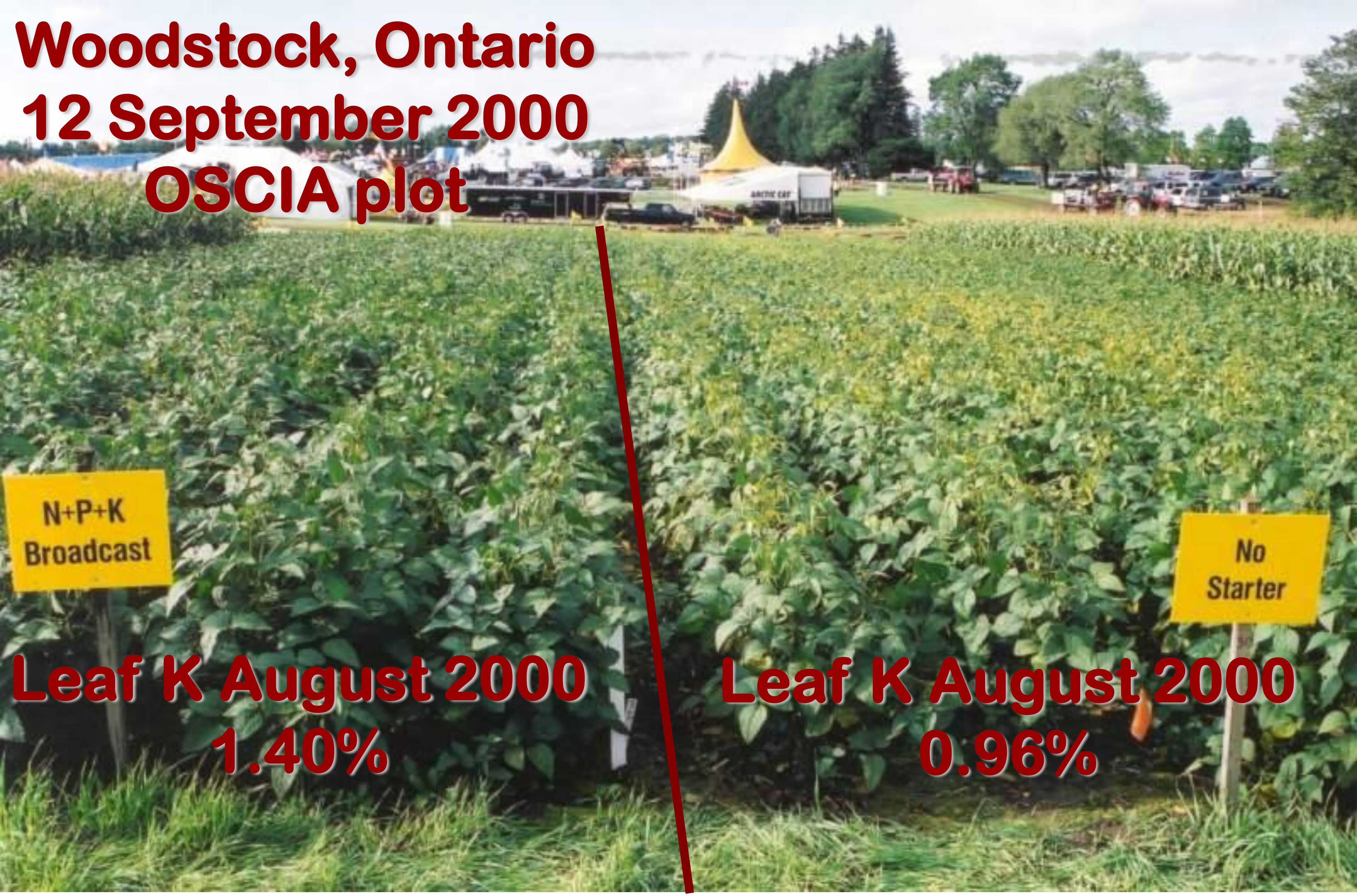

Soil Test K = 50-55 ppm; pH = 7.2


Woodstock, Ontario
12 September 2000
OSCIA plot
K deficiency symptoms
Near top of plant
Low temp or frost injury?

Summary

- While soybeans often produce high yield and quality with residual nutrition following corn, optimum nutrition cannot be taken for granted
- Managing nutrients to optimum levels improves isoflavones, protein, oil, and plant health
- Soil testing, plant analysis, and matching nutrient applications to removals are important aspects of optimal nutrient management


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