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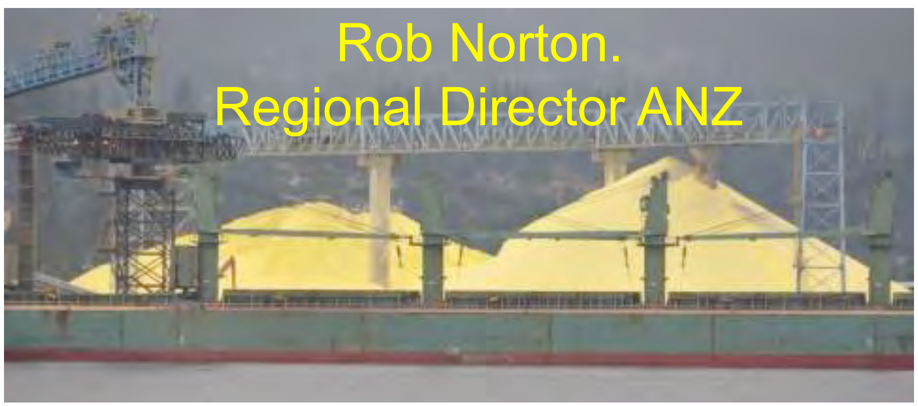
INTERNATIONAL PLANT NUTRITION INSTITUTE

Sulfur and zinc nutrition in Australia



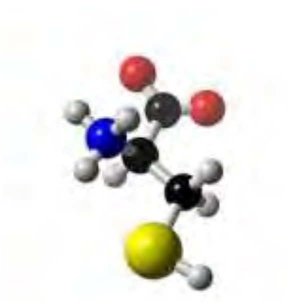
Rob Norton.
Regional Director ANZ

Better Crops, Better Environment … through Science

Dealer Meetings, Toowoomba, Wagga, Bendigo, Adelaide, October 2012.

Importance of S

- Component of essential amino acid in animal nutrition
- Key component in protein structure – disulphide bonding
- Present in several organic compounds … odours to garlic, mustard and onion, health compounds in Brassica spp.
- Part of a balanced nutrition package = Crop yields!!!!!



Cysteine

Methionine

Bread loaf on left was baked with flour made from sulphur-deficient grain.

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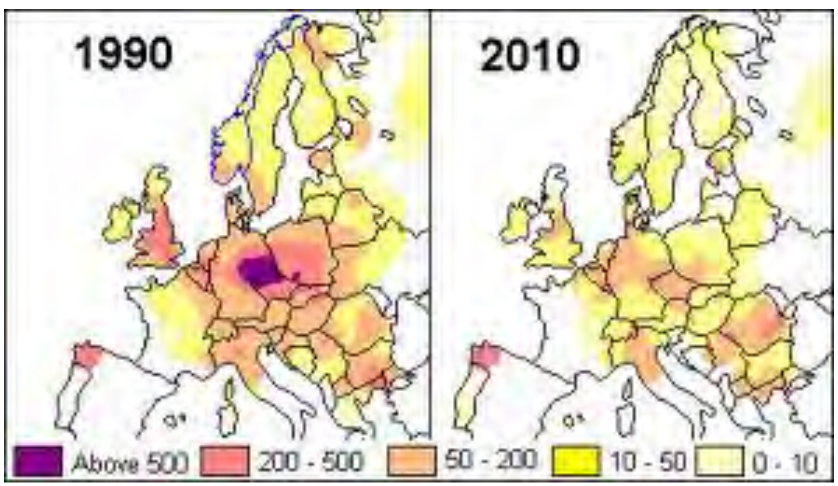
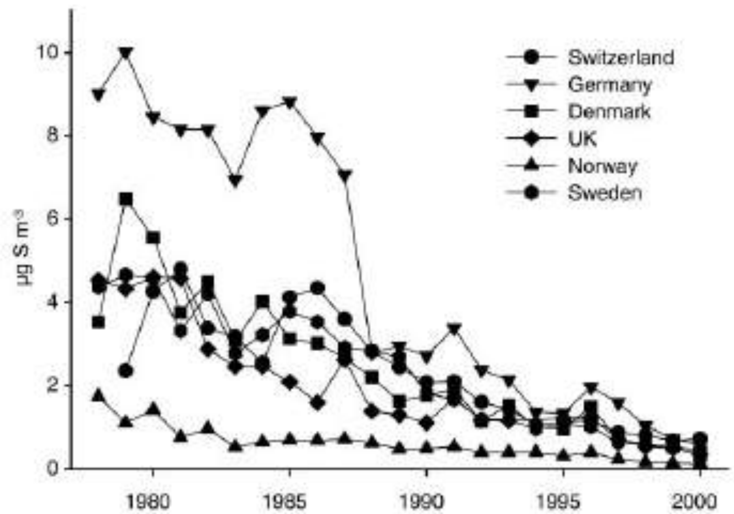
Why S and why now?

- Increased crop yields creating a higher S off-take.
- Use of high analysis fertilizers containing little incidental S
- Less use of high S fuels so less S from atmosphere.
- Slower organic matter turnover with conservation tillage
- Fewer S-containing pesticides



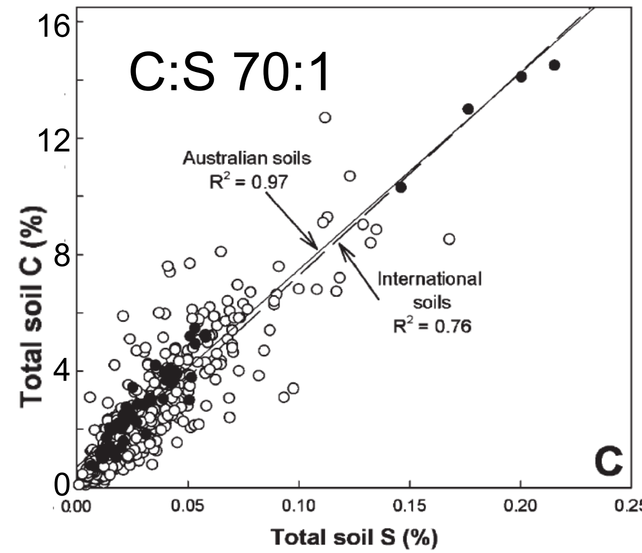


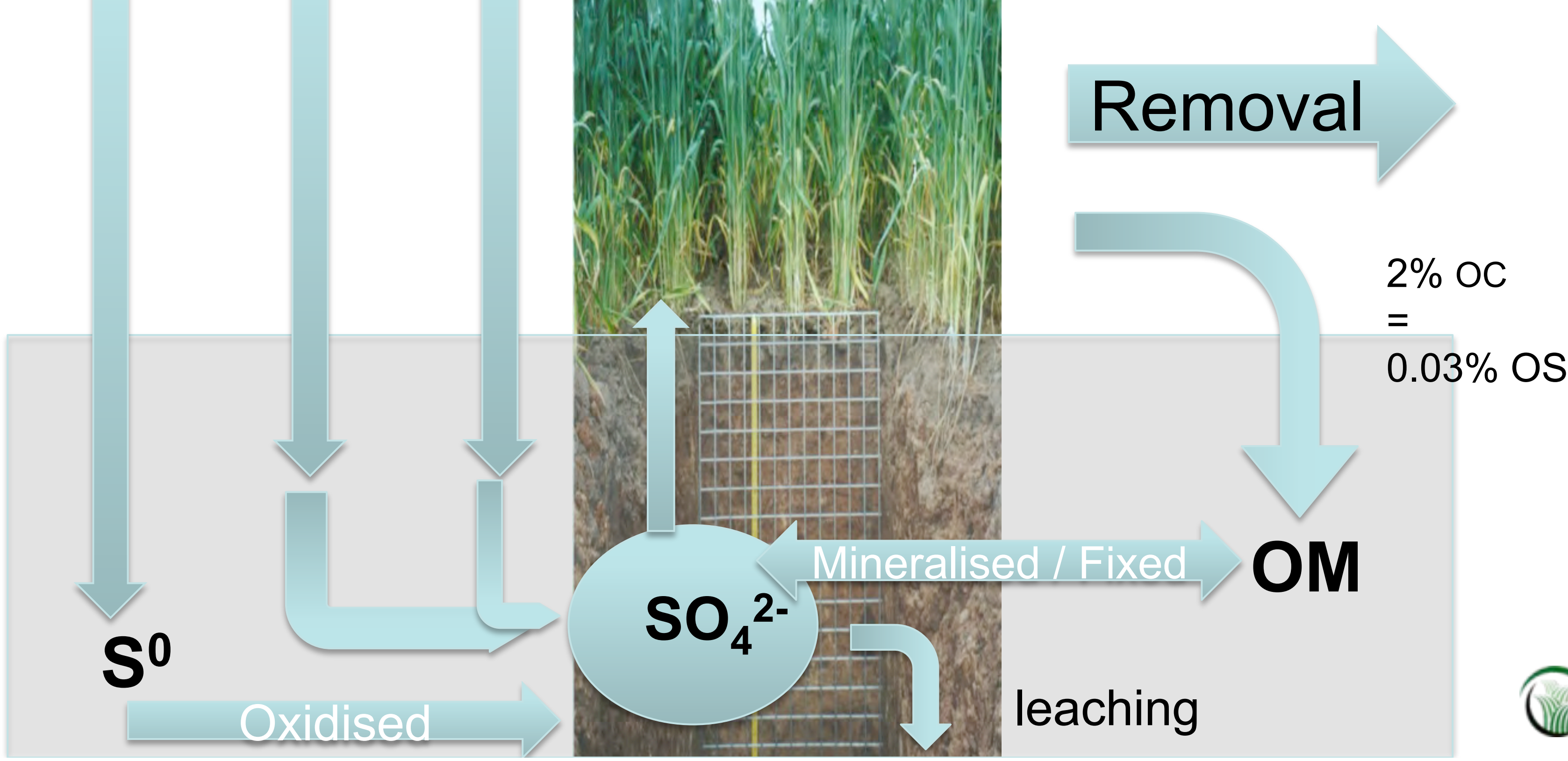
t/km^2

McNeill et al, 2005, Soil Use & Management

Sulfur cycling in the soil

Kirkby et al. (2011)





So what makes S nutrition tricky?

- Sulfate is highly mobile on the soil
  - Similar to nitrate
- Inorganic sulfate is exchanged with organic matter.
  - Similar to nitrate
- N and S can be co-limited – so one can affect the other.
- S fertilization can induce deficiencies of
  - Molybdenum, selenium – competition for uptake sites
  - Boron – mechanism uncertain
- S fertilization can increase the uptake of
  - Copper, manganese – probably through acidification in root zone.

So – again – why sulfur & why now here?

- Declining soil organic matter levels
- Change to AP fertilizers

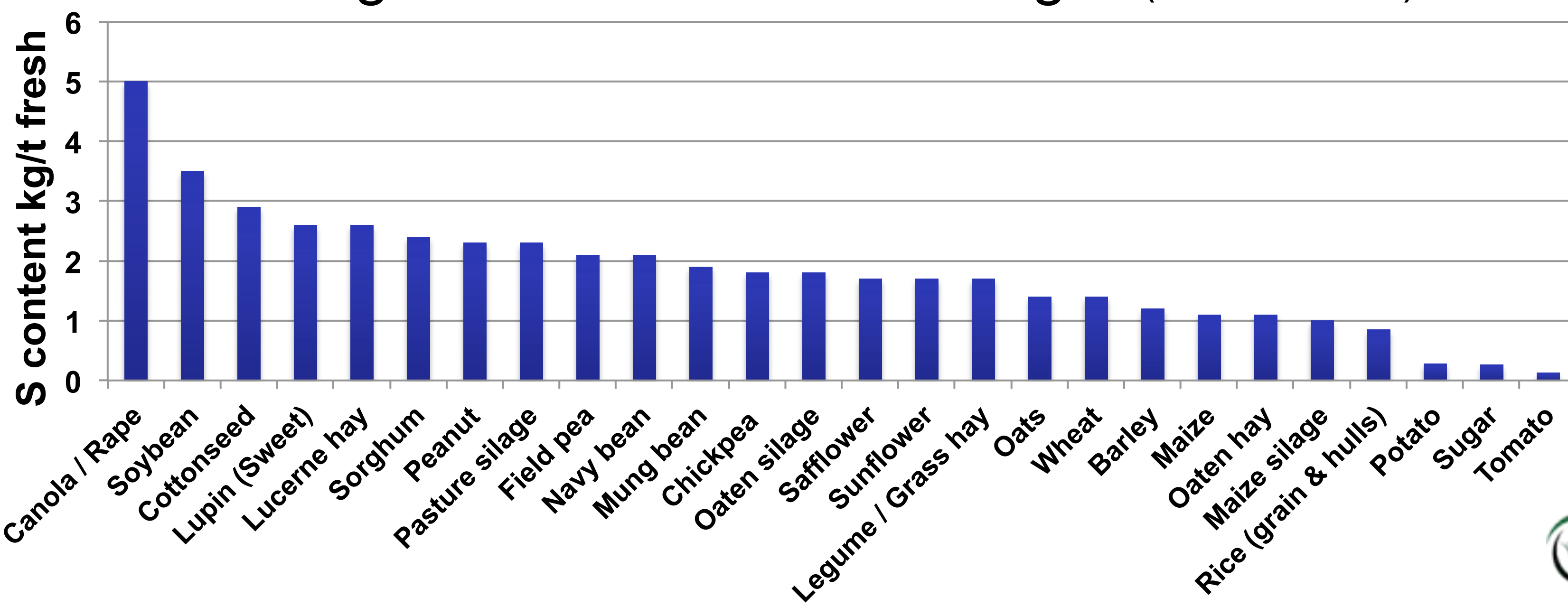
Fertilizer	% S	kt / year	kt S /y	% Change*
SOA	24	291	70	+2%
SSP	11	636	70	-37%
MAP	1.5	715	11	+2%
DAP	1.6	410	7	-25%
TSP	1.0	47	5	-50%
SOP/BentS			40	-43%
Total S			**201**	**-43%**

- New high S demanding industries – esp. Canola.

* % change over the past decade

S removal in crops & livestock products

- Milk – 0.4 g S/L – 4.4 kg/ha (Gourley et al. 2012)
- Wool – 22 g S/kg g @ 5 kg/hd*5 sheep/ha = 0.5 kg/ha
- Live cattle 0.4 gS/kg LW @ 400 kg*1 /ha = 0.16 kg/ha
- Canola – 5.0 kg S/t - 2 t/ha = 10 kg S/ha
- Wheat – 1.4 kg S/t – 3 t/ha = 4 kg S/ha
- Cotton – 1 kg S/bale – 10 b/ha = 10 kg S (Cotton CRC)



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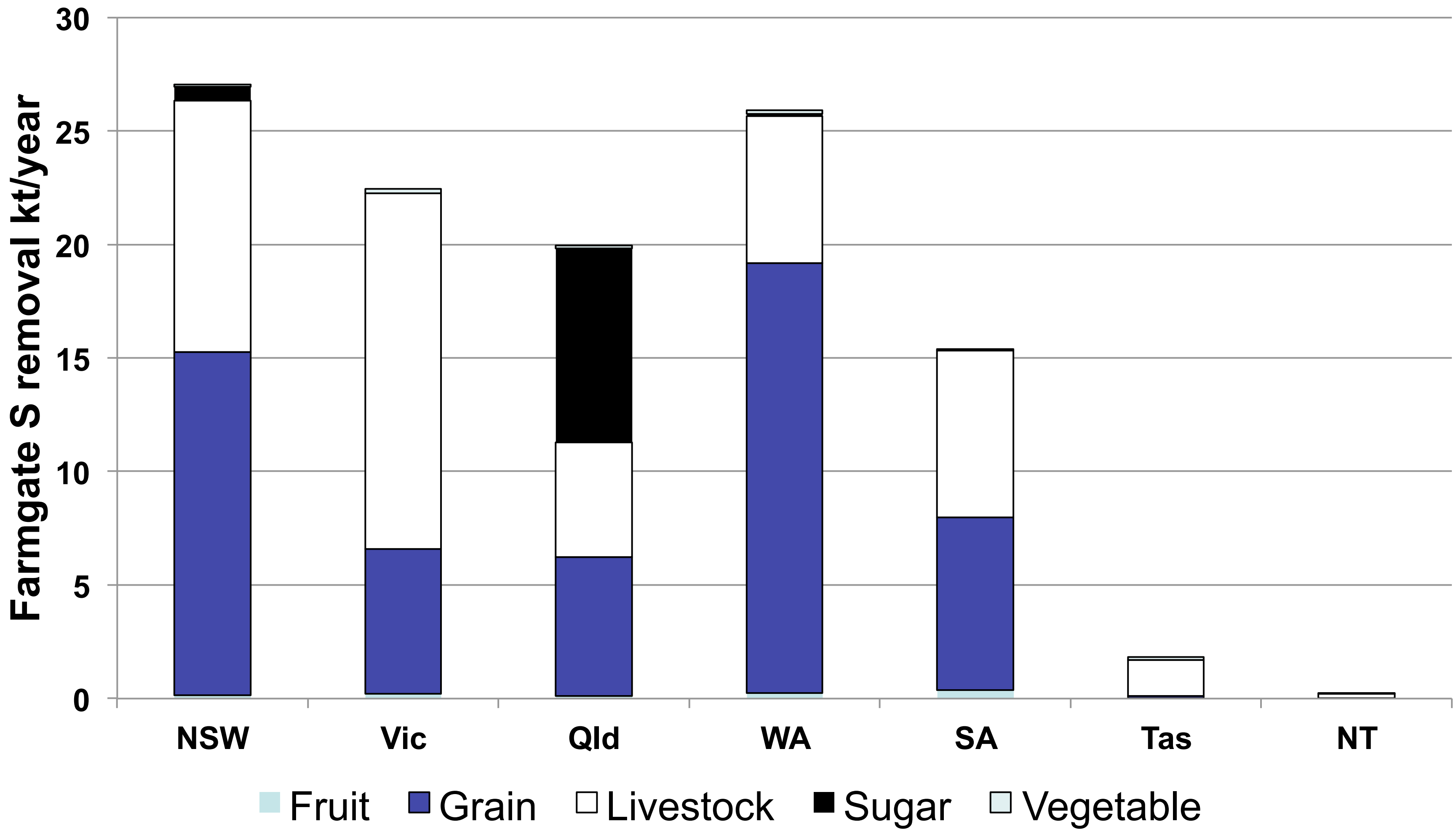
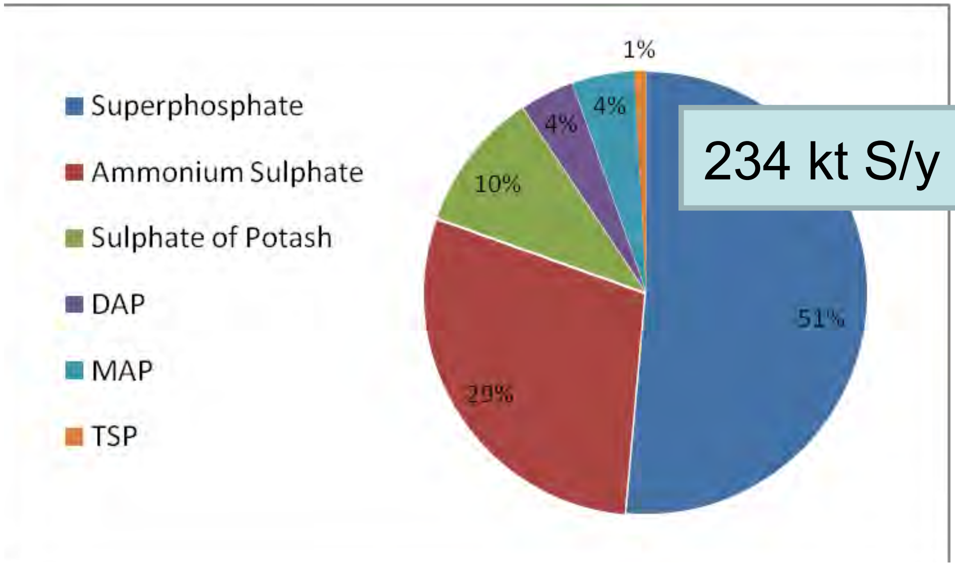
Sulfur removal by state (2002-2009)



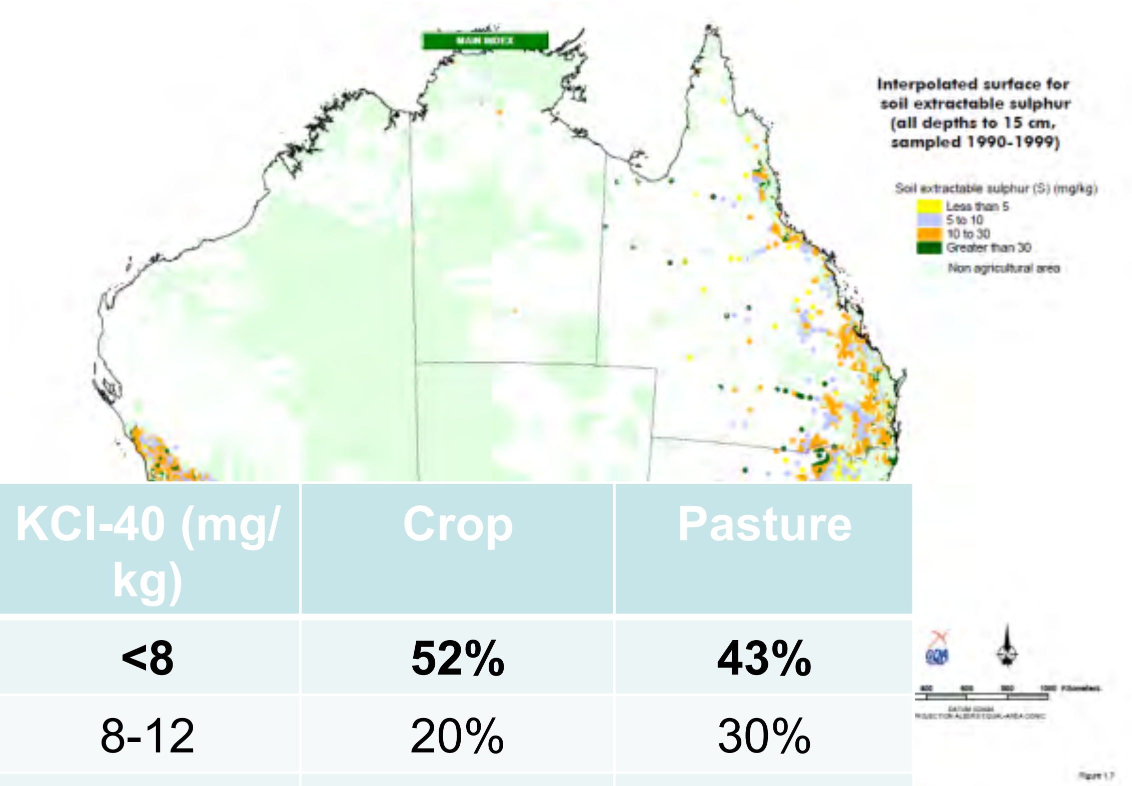
Notional farm gate S balance

- S inputs from current fertilizers – Most superphosphate applied to pastures. DAP/MAP used for grain
- Notionally Australia is in positive S balance
- Not included in this balance
  - Added S from mined/by-product gypsum (4 Mt mined)
  - Atmospheric input 4.5 ± 2.1 kg S/ha/y (NLWA 2001)
  - S input from irrigation – depends on watershed position



2002-2009 means

Soil S levels – ANRA Audit 2001



KCl-40 (mg/kg)	Crop	Pasture
<8	**52%**	**43%**
8-12	20%	30%
>12	28%	27%

2010 Soil S test values (top 10 cm) for Victoria, South Australia, New South Wales (~1200 tests)

- Nationally

11% < 5 mg/kg

- Queensland

2% < 5 mg/kg

- New South Wales

25% < 5 mg/kg

- South Australia

20% <5 mg/kg

- Victoria

3% < 5 mg/kg

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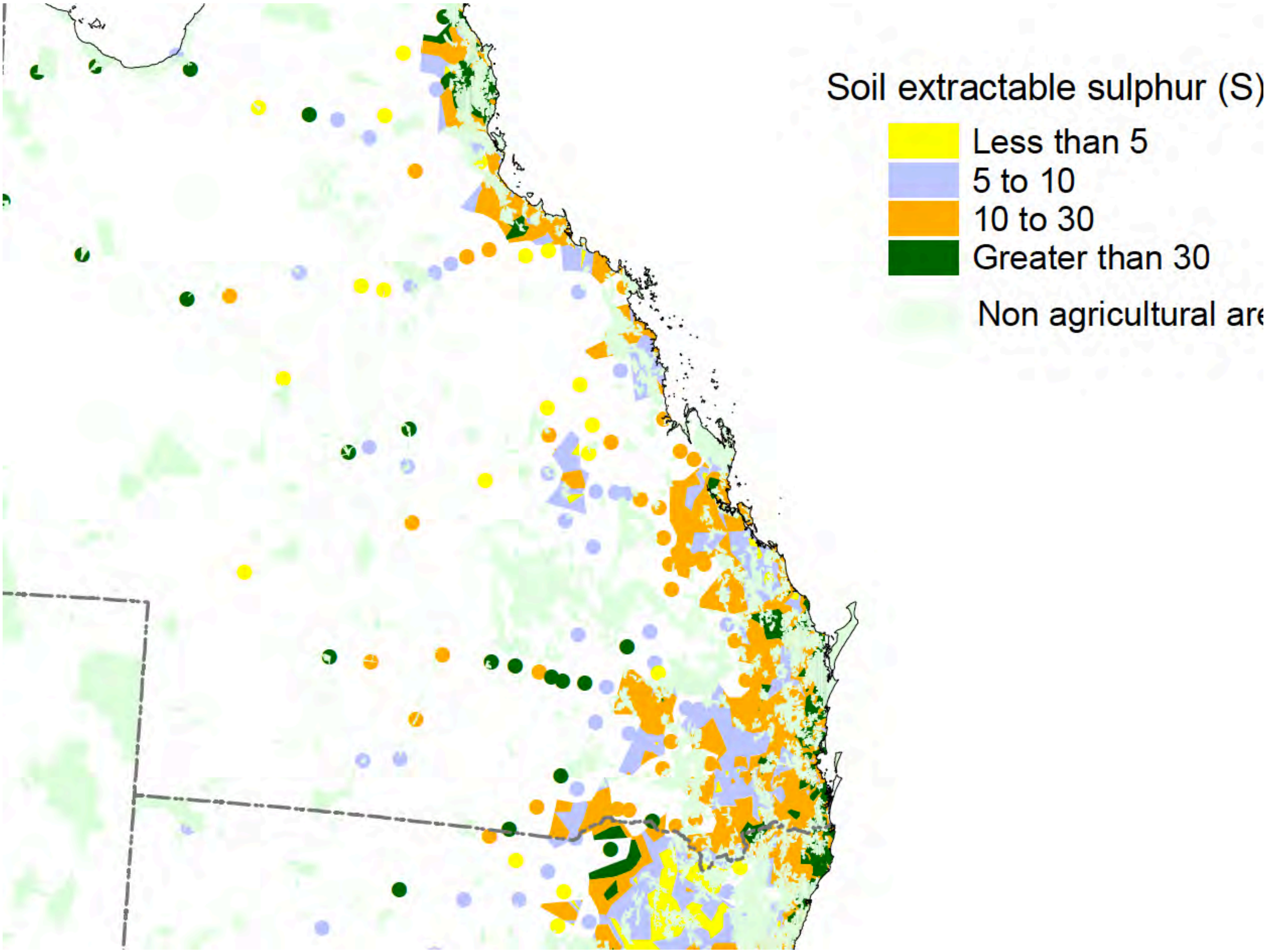
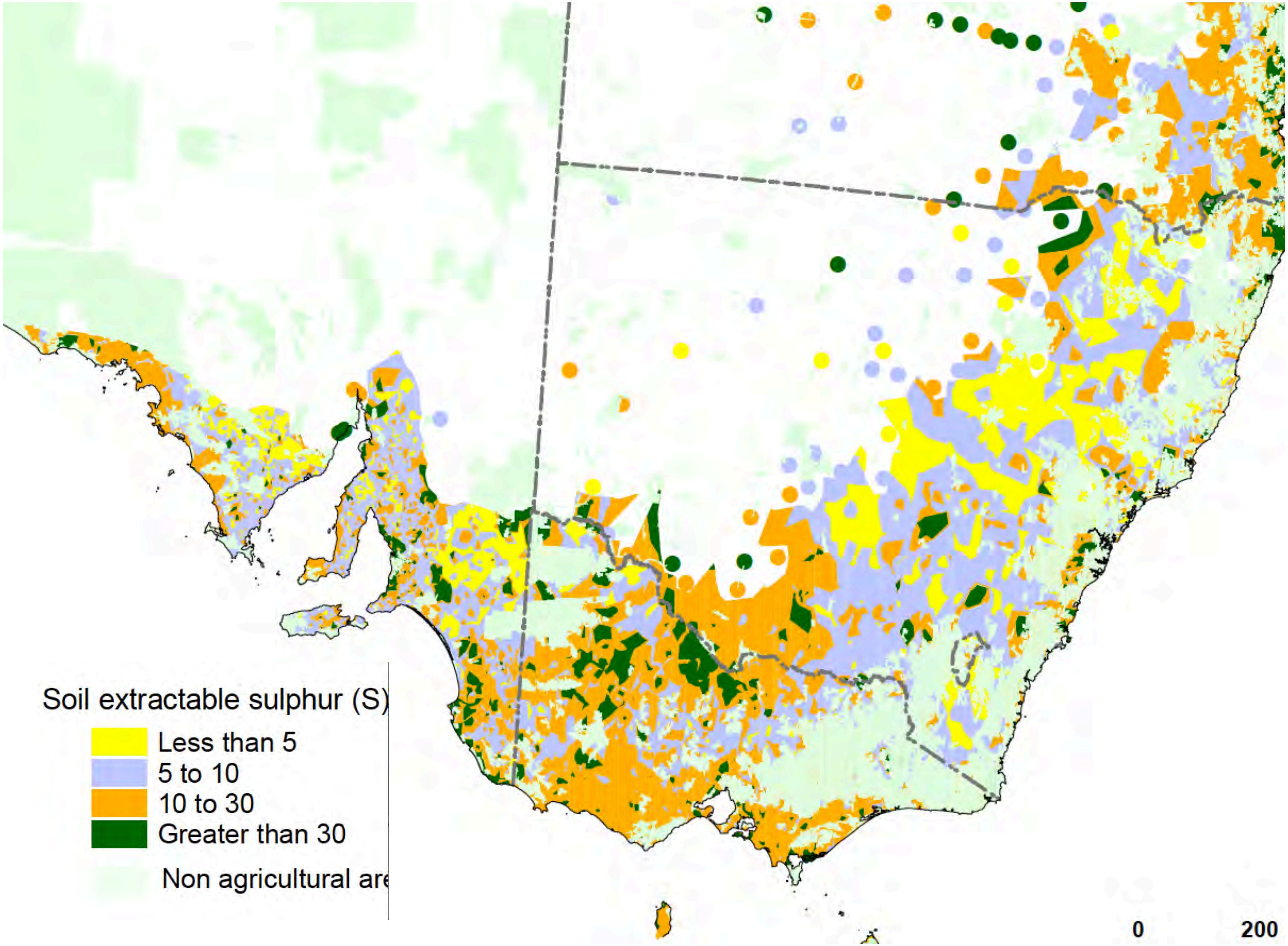


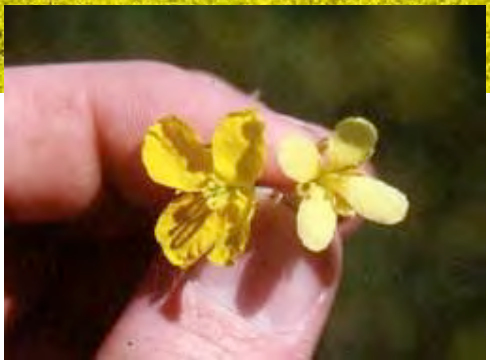
Soil extractable sulphur (S)
Less than 5
5 to 10
10 to 30
Greater than 30
Non agricultural are


Soil extractable sulphur (S)
Less than 5
5 to 10
10 to 30
Greater than 30
Non agricultural are
0
200

Seen first in the golden canola era.

Deficiencies first seen in NSW at Lockhart.

- Soils naturally low in S.
- Declining soil OM levels
- Picture shows an S trial in central NSW
- Variation in flower colour – pale flowers



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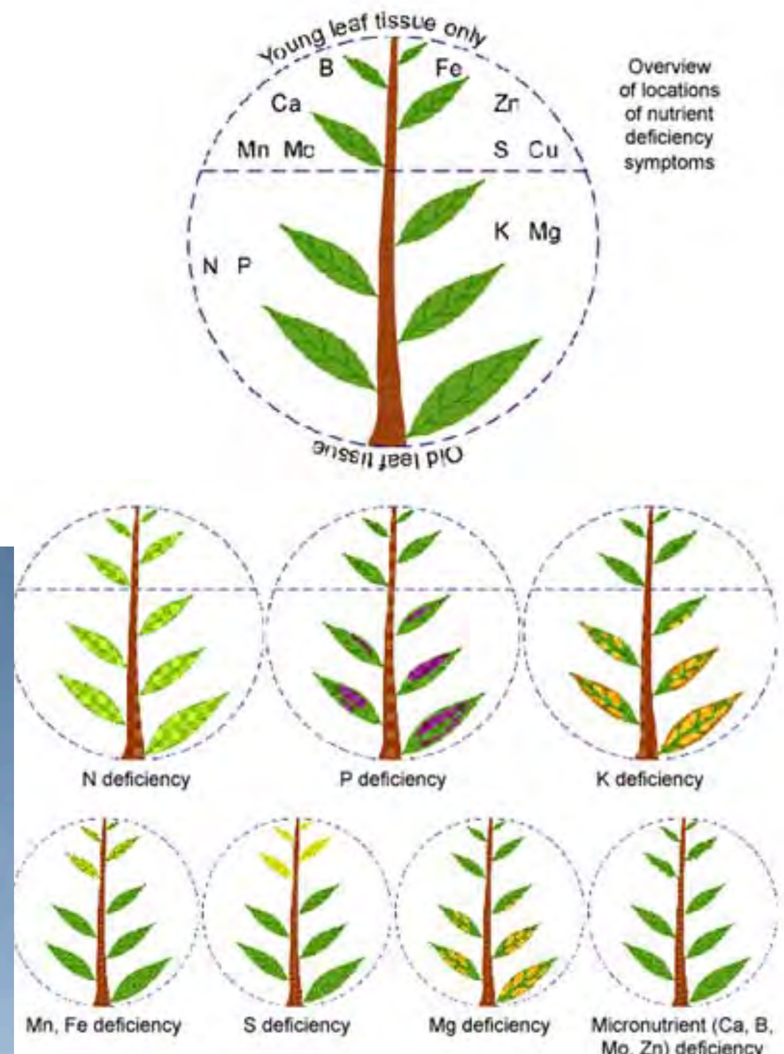
S deficiency in wheat



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Cotton, Maize, Sorghum

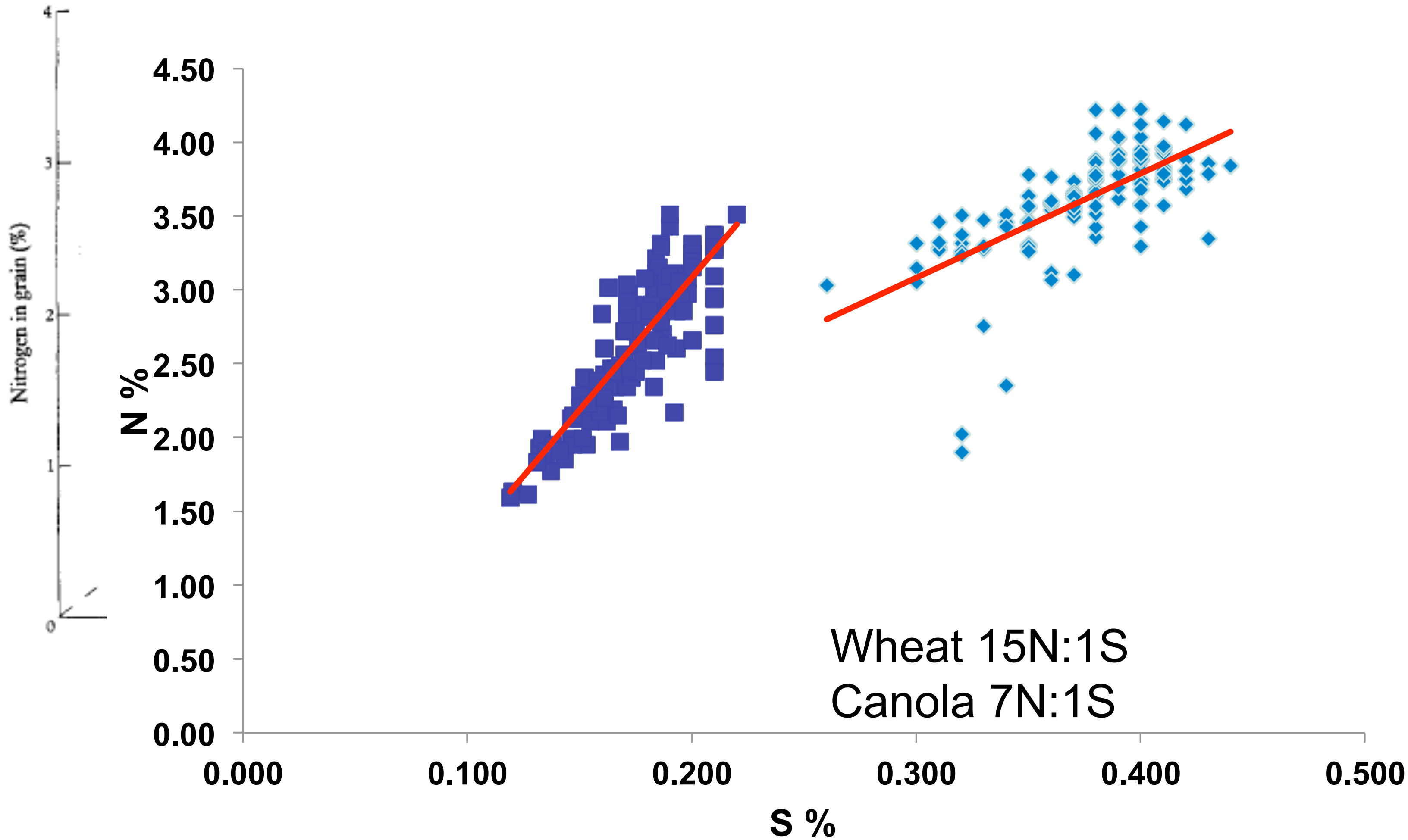
Response to S

Rate of S fertilizer (kg/ha)	Canola Yield (t/ha) after:	
	Cereal	Pasture
0	2.63	3.25
10	2.74	4.12
20	2.82	4.38
40	2.91	4.53
LSD	0.24	

Importance of balanced nutrition

- S is only one part of a balanced nutrition package
- Benefits to the crop come when all nutritional limitations are met.
- Co-limitation studies
  - N:P – 7:1 (Duivenbooden et al, 1996)
  - N:S – 15:1 (Randell et al, 1981)

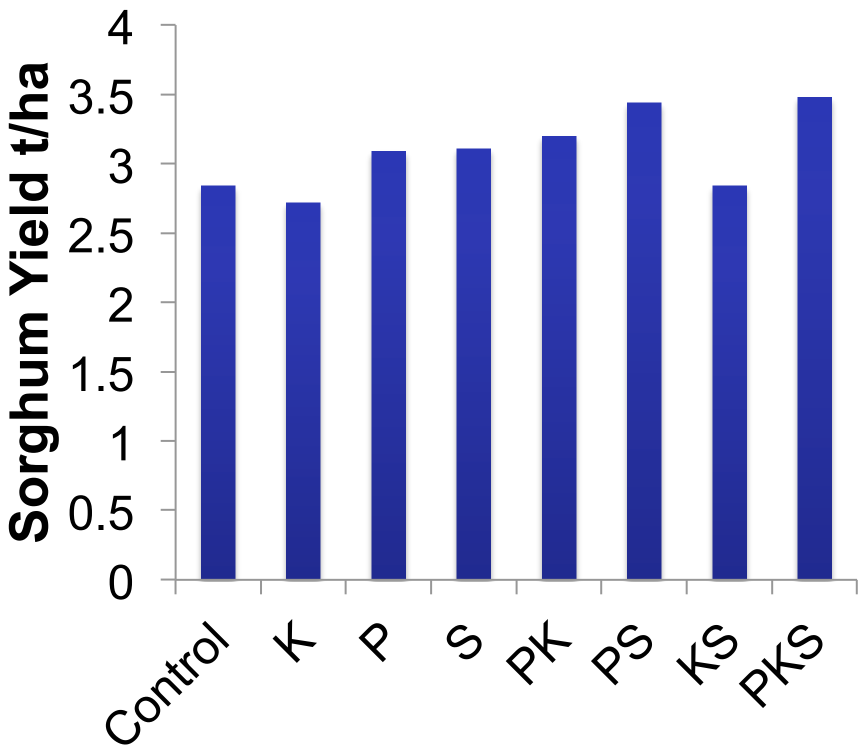
Wheat grain N:S ratio



SE Australian N/S 2009
n=140 (2*70)

Randell et al. (1981) AJAR 32, 203-212

Importance of balanced nutrition (Northern grains)



- Sorghum @ Bendee south of Emerald
- 20% to P or K
- No individual S reponse
- 38% with P and S
- Data of M Bell QAAFI

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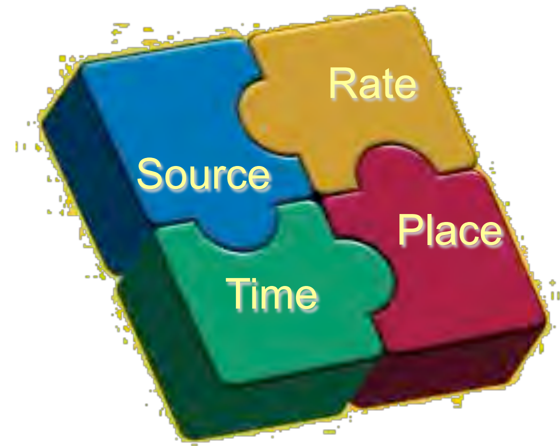
Principles for Fertilizer Management



- Right Product@Right Rate,

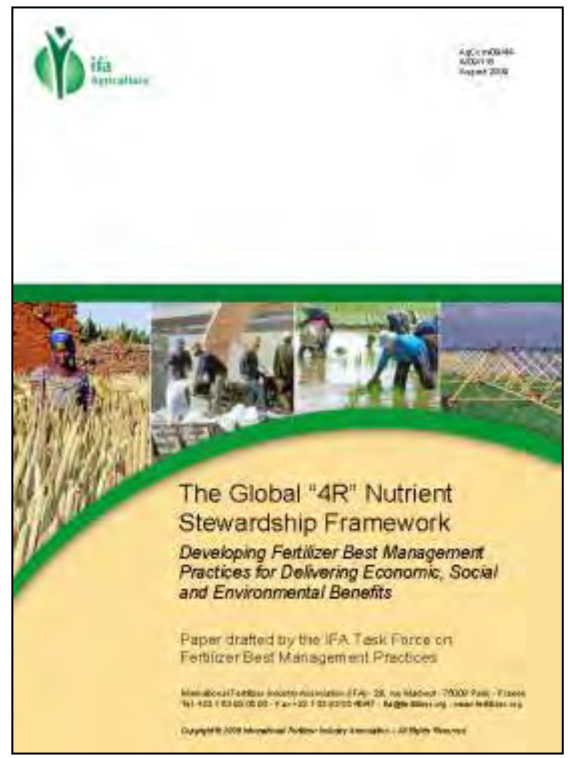
Right Time, Right Place™ system

- 4 R's approach as a summary


A Global Framework for Fertilizer BMPs

The concept was further developed by IPNI scientists (Bruulsema et al. 2008)

Series in Crops & Soils 2009



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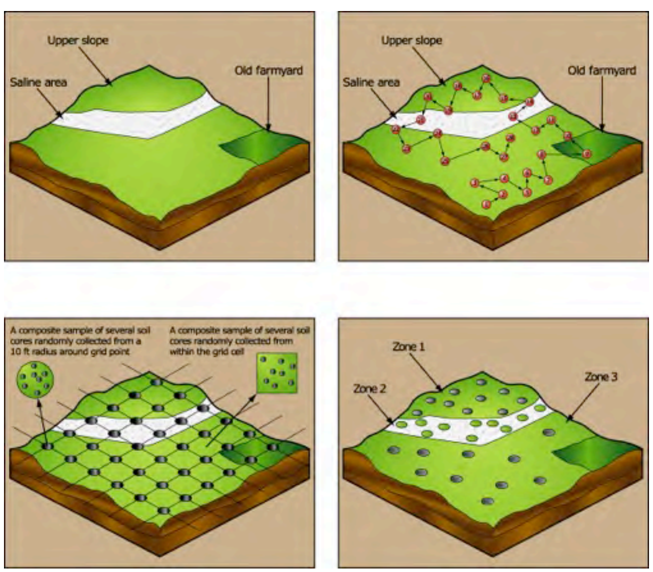
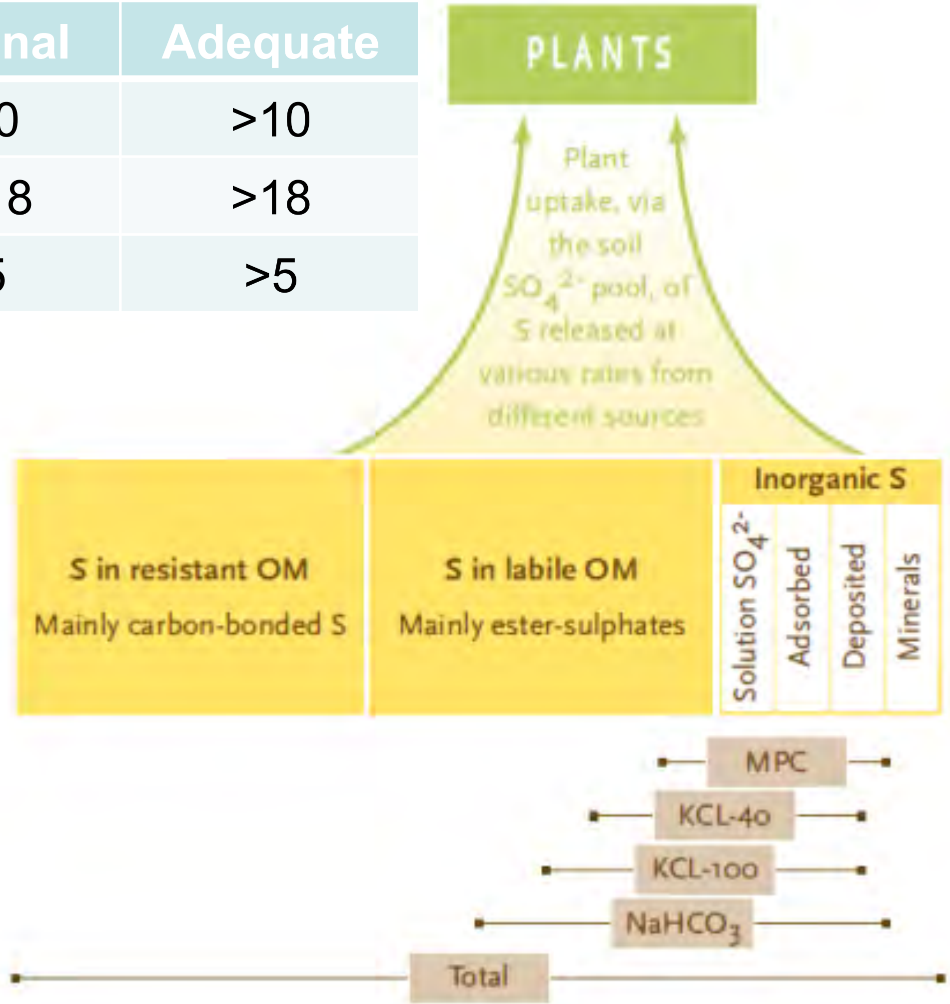
The Right Rate - Soil test

Crop	Deficient	Marginal	Adequate
Pasture	<5	5-10	>10
Canola	<12	12-18	>18
Wheat	<3	3-5	>5

Standard tests
0-10 cm KCl-40 S
0-10 cm MCP S

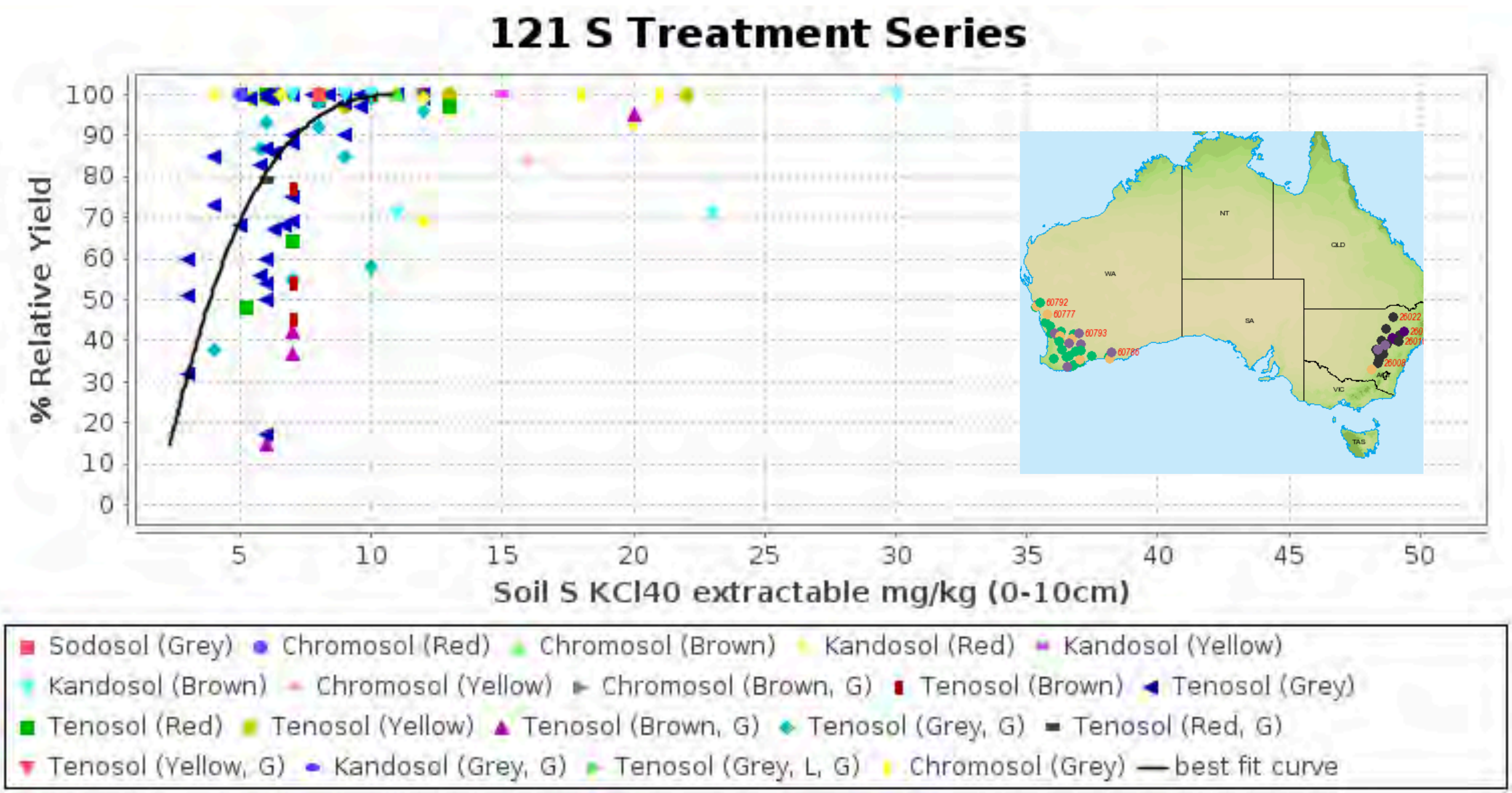




Blair 1993 P&S

Better Fertiliser Decisions for Crops –

Canola calibration curve



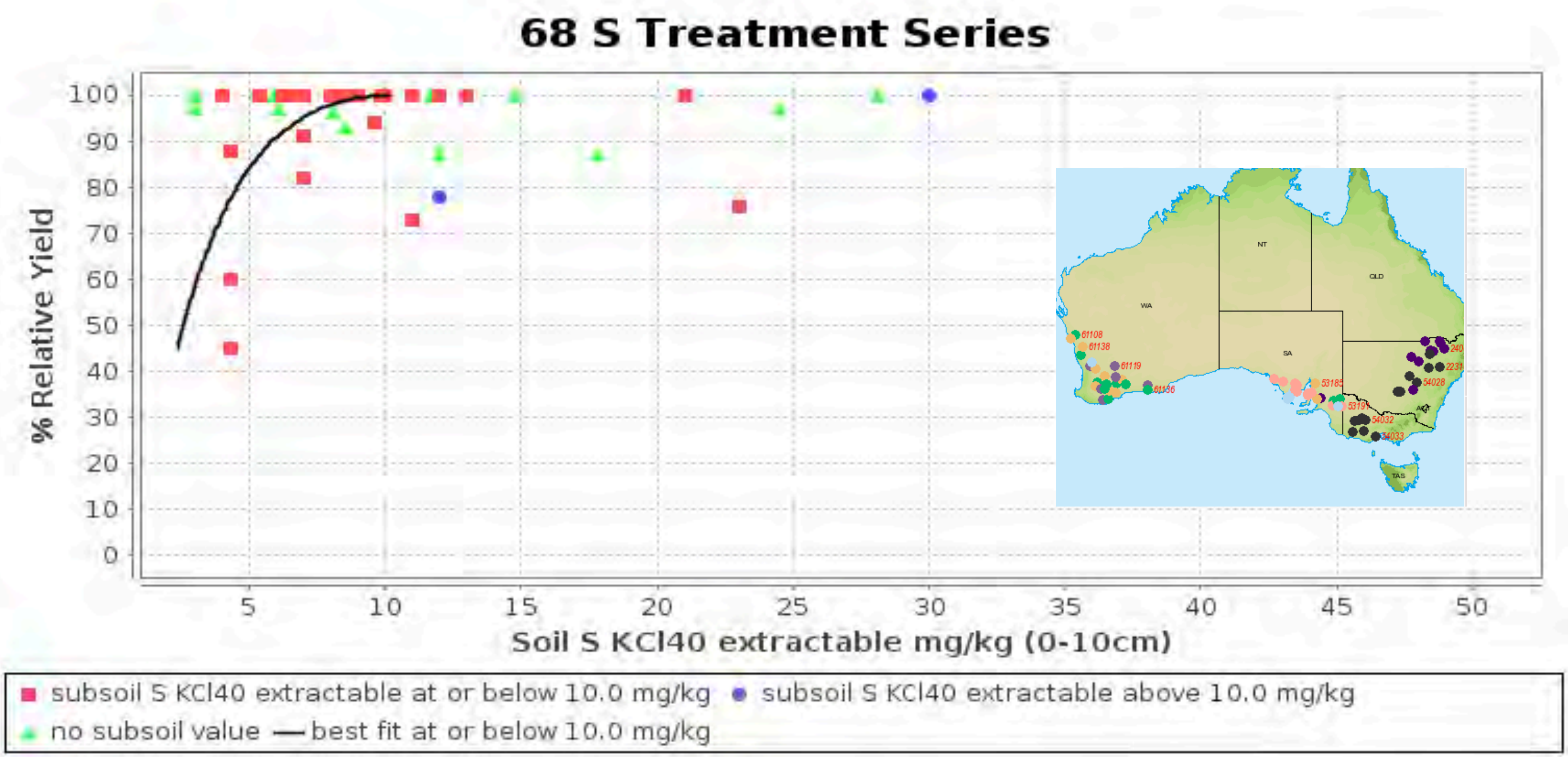
Soil test calibration:

80% Relative Yield: 5.9 (4.6 - 7.5)
90% Relative Yield: 7.1 (5.8 - 8.8)
95% Relative Yield: 8.1 (6.6 - 9.9)

Correlation R: 0.35
Range soil test values: 3.0 - 30.0
Slope RY(50-80): 7.7 (-15.0 - 30.0)

>1 t/ha

Better Fertiliser Decisions for Crops –
Wheat calibration curve (account for deeper S)



Soil test calibration:

80% Relative Yield: 4.5 (1.5 - 14.0)

90% Relative Yield: 5.8 (2.6 - 13.0)

95% Relative Yield: 6.9 (3.6 - 13.0)

Correlation R: 0.23

Range soil test values: 4.0 - 23.0

Slope RY(50-80): poorly defined

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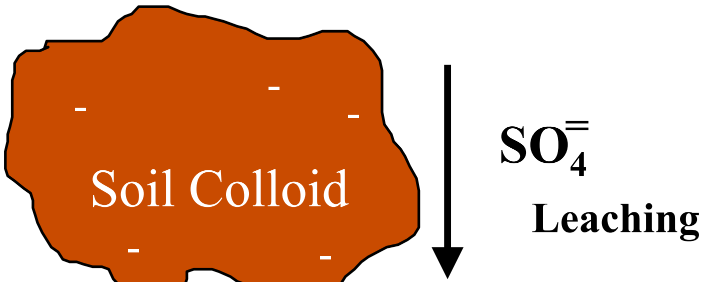
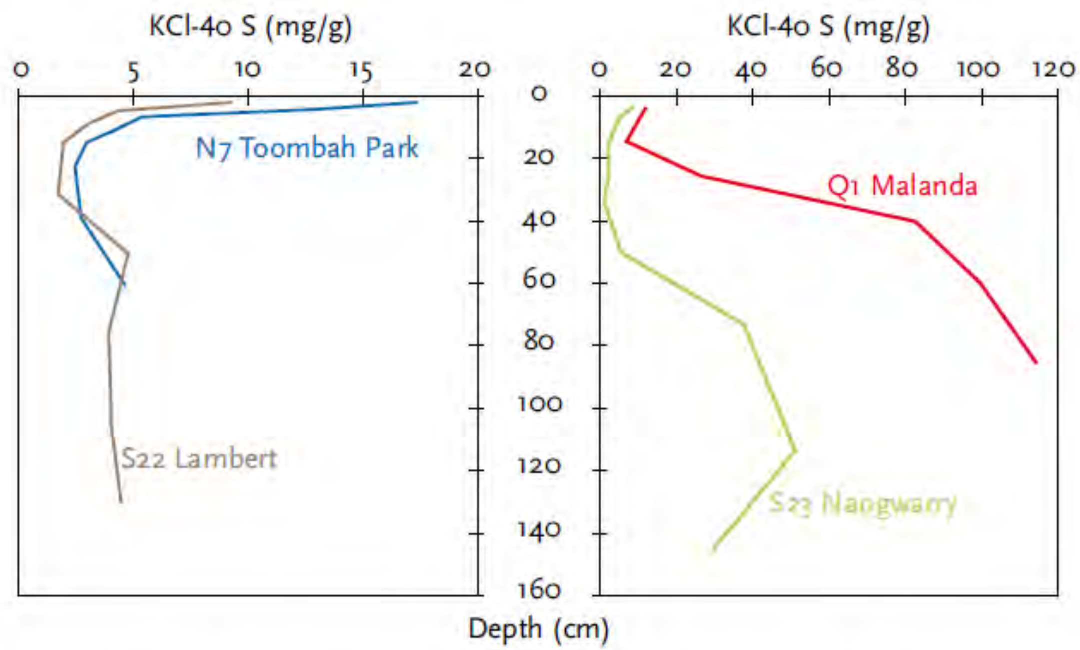
Problem with leaching & deep S



- sulfate mobile
- Improved tests;
  - Appropriate depth
  - Take account of some part of the other S sources
    - Organic S esp.
  - DGT – S



Sulphur distribution down the profile for some New South Wales soil sites (Blair *et al.*, 1997).

Establishing an appropriate S rate

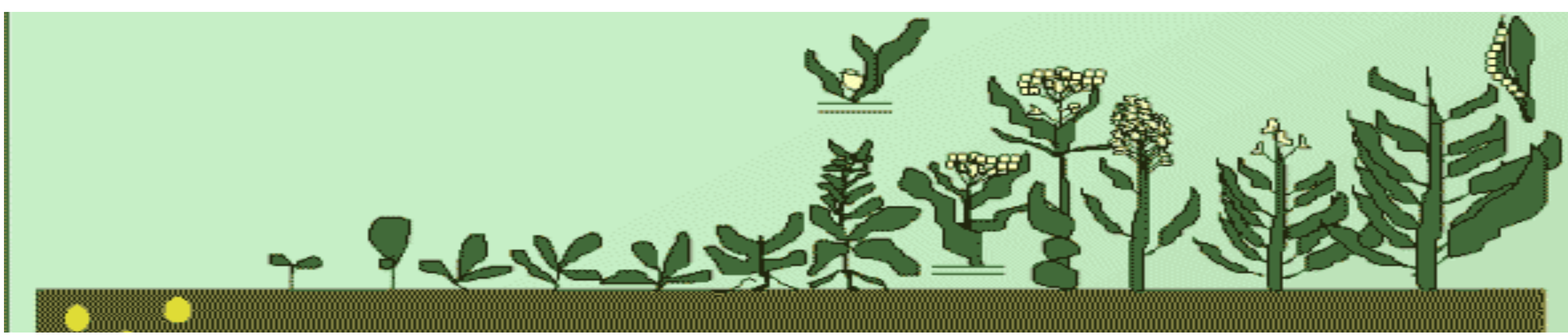
- Assess the soil supply – deep soil test
- Set to balance S removal in product
  - Similar to N budget but fewer losses.
  - Wheat – 0 -10 kg S/ha
  - Canola – 0 – 20 kg S/ha

- Consider both N and S (and all others)
  - Cereals – 6-8 kg S/ 100 kg N
  - Canola – 12-15 kg S/ 100 kg N
  - Cotton – 10-12 kg S/ 100 kg N

Right place & right time

- Where the plant can get it –
  - Root zone – control release rates to avoid leaching
  - Available sulfate in the root zone
- In synchrony with plant demand – most crops show good ability to recover from nutrient stress – *eg Canola*

S applied Kg/ha	Sowing	5-6 Leaf	Buds Visible	Stem Elongation	
10	1.73	1.62	1.56	1.41	*LSD*
40	2.15	2.26	2.11	2.19	*0.43*



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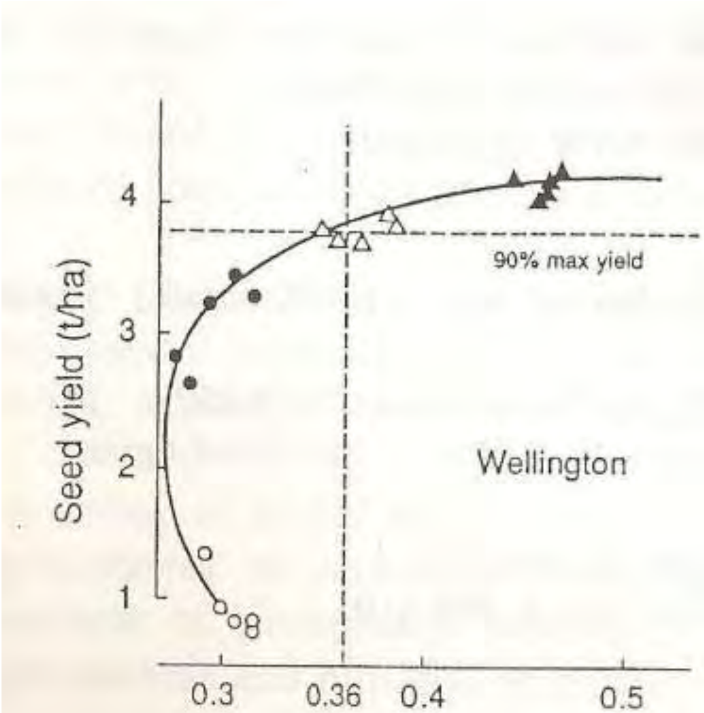
Tissue Tests for Diagnosing S deficiency

- *eg* Canola - 0.36% S in whole shoots at start of flowering



Wheat	YEB Critical	Cotton	YML %S
FS 4-5	0.28%	Flow'ing	<0.2%
FS 5-6	0.32%		

Critical S values lower in N deficient plants
Reuter & Robinson 1997

- Highly dependant on GS/tissue.
- Need rapid tests
- Root penetration when sampled
- Grain analyses for retrospective diagnosis

Pinkerton A. PJ Hocking, A Good, J Sykes,s RBD Lefroy, GJ Blair. (1993) A preliminary assessment of plant analysis for diagnosing S deficiency in canola. Proceedings of 9th Australian Research Assembly on Brassicas, Wagga Wagga, p21-28.

Right product

Product	N	P	K	S
Superphosphate		8.8		11
MAP	10.0	21.9		1.5
DAP	18.0	20.0		1.6
MAP S^0/SO_4	12.0	17.6		5+5
Triple Superphosphate		20.7		1.0
Ammonium sulfate	20.2			24
sulfur Bentonite				90
sulfate of Potash			41	18
Gypsum ($CaSO_4.2H_2O$)				14-16%
Kieserite ($MgSO_4.2H_2O$)				22%
Langbeinite ($K_2Mg_2(SO_4)_3$)			17	21

Range of S coats – MAP/DAP/Urea $+S^0$,

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S product considerations

- High nutrient densities
- Deliver sulfate into the root zone
  - Care with fertilizer damage – light/dry soils/wide rows.
  - Acidification can help with availability of other nutrients (eg P)
- Controlled release of sulfate with time – leaching.
- Co-placement of nutrients can be important (eg P & S, Frisen) S^0 oxidation rapid with fine particles
  - Good for sulfate release
  - Bad for handling
- New processes that incorporate S^0 into existing products at manufacture

Particle Size μ	2 weeks	4 weeks	Supply in:
<75	80	82	*weeks*
175-400	15	36	*months*
840-2000	2	5	*years*
2000-4000	1	2	

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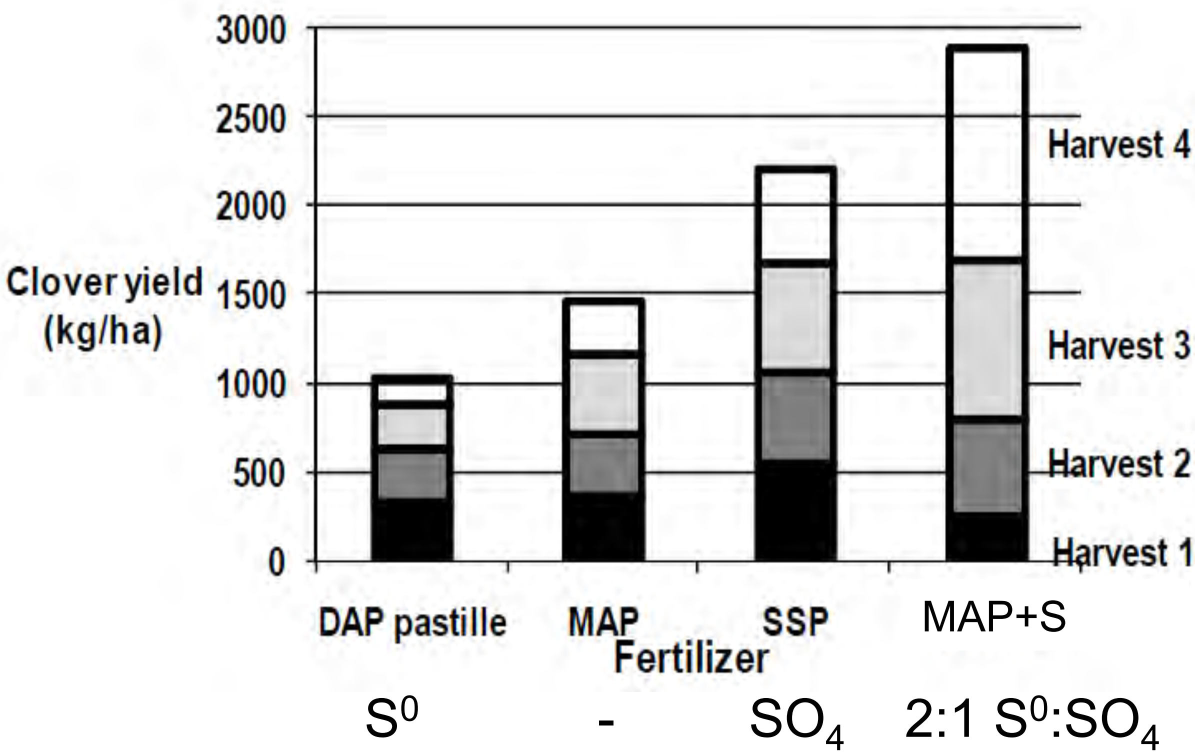
Mixtures of sulfate and elemental S

- Alter S:SO_4 ratio, even distribution in granule – alter the rate of sulfate supply to the plant. Backed up with slower release S^0

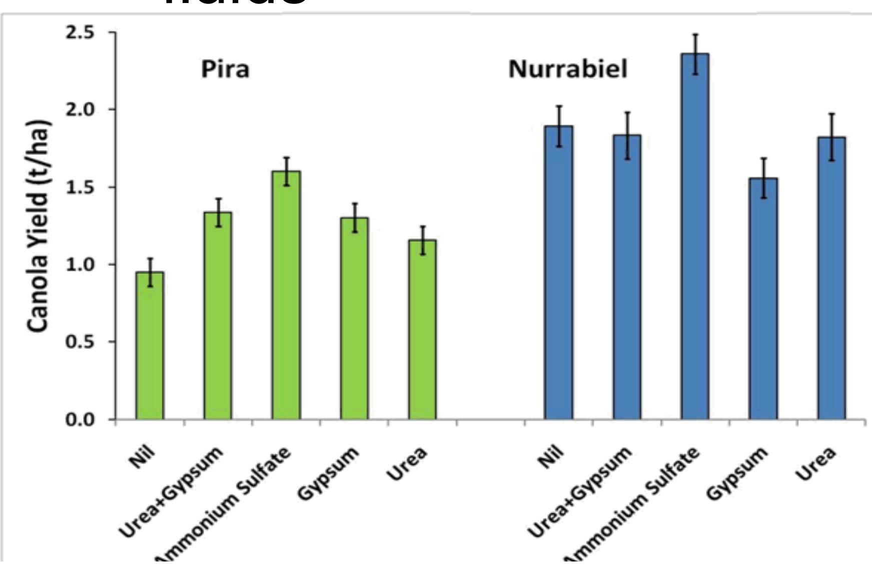


Flavel et al., 2010, ISSC.

Higher S & P recoveries with MAP+S

Ammonium sulfate - topdress

- Traditional fertilizer – all S as sulfate (soluble).
  - Root Zone acidification, Co-placement of N/S, Reduced N loss.
  - In-furrow damage potential ~ apply 50% more N from AmS in furrow compared to urea in furrow.
- As a plant fertilizer – not enough N – looking at Urea/ Ammonium sulfate fluid fertilizers, compared to fluids



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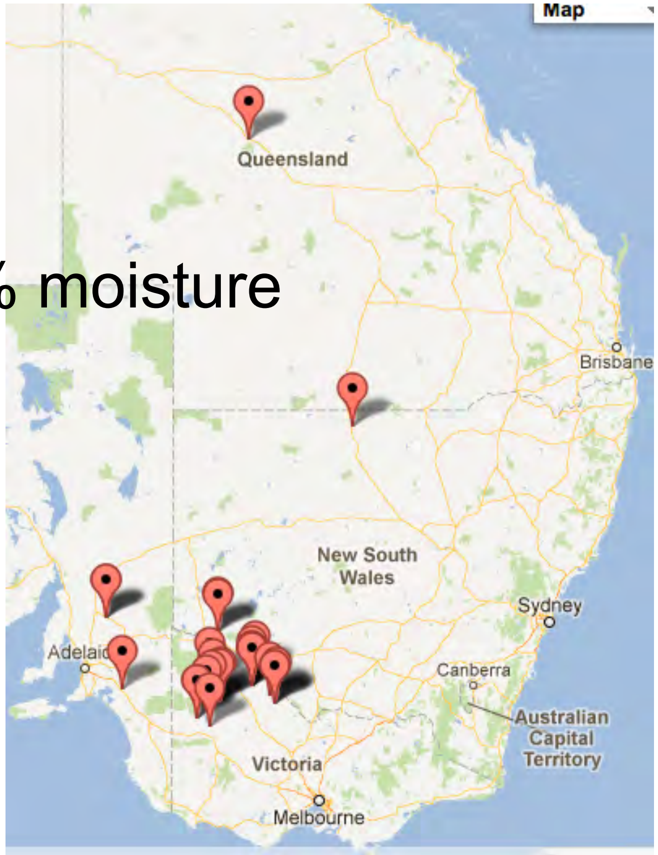
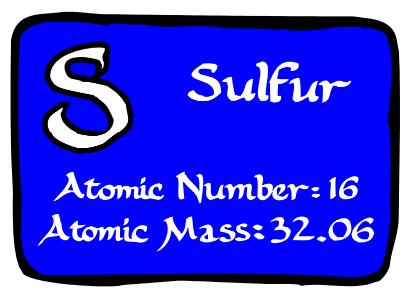
Gypsum

- Good source if available locally
- >65% $CaSO_4.2H_2O$; <0.8% Na, <15% moisture
- 14-16% S.
- Good solubility (particle size)
  - Needs rainfall to get it to the right place
  - 100-300 mm will dissolve around 1 t/ha (soil texture)



Summary

- *S is something to look out for.*
- *Spread out the needed application of S through the whole crop rotation.*
- *Deep soil test for S, the top soil can be deficient while there may be adequate in the subsoil*
- *Apply the S in a side-band or mid-row band away from the seed-row for susceptible crops.*
- *Apply a source of S that has both sulfate and fine-particle sized elemental S in the seed-row.*
- *Apply S later in the growth of the crop. Top-dressed S should be in the sulfate form.*



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Micronutrients - Zinc

- Required in small amounts by plants.
  - 4 t/ha wheat crop removes ~100 g of Zn
- Essential for healthy growth – enzyme co-factor.
- Levels are quite variable in soil and grain
  - Mallee grain Zn – 19 mg/kg (seed quality)
  - North East grain Zn – 29 mg/kg
- Difficult to pick up in soil tests due to low quantities in soil:
  - Zinc <0.5 mg/kg critical level
    - 22% Wimmera, 61% Mallee, 37% Western
  - Measured using a chelate (DTPA) mimicking the root extraction – generally poor indicator

Copper (Cu)

Iron (Fe)

Manganese (Mn)

Zinc (Zn)

Boron (B)

Molybdenum (Mo)

Chloride

Nickel

Silicon

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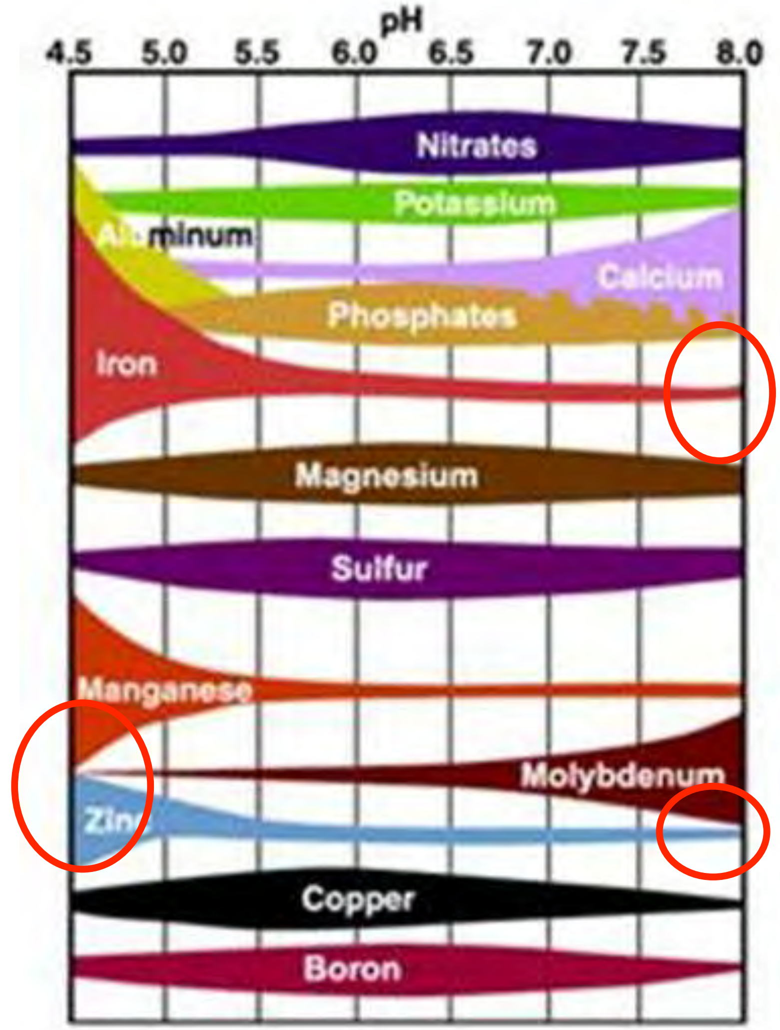
Soil pH and nutrient availability

- Soil acidity (pH) drives much of the chemistry in the soil
- Liming will change micronutrient availability
- Deficiency and toxicity (*eg* B and Mn)
- Classic deficiencies
  - Zinc and iron on alkaline soils
  - Molybdenum on acid soils
- Cereals susceptible, canola relatively tolerant, Chickpeas very good



Zinc

Classic high pH deficiency

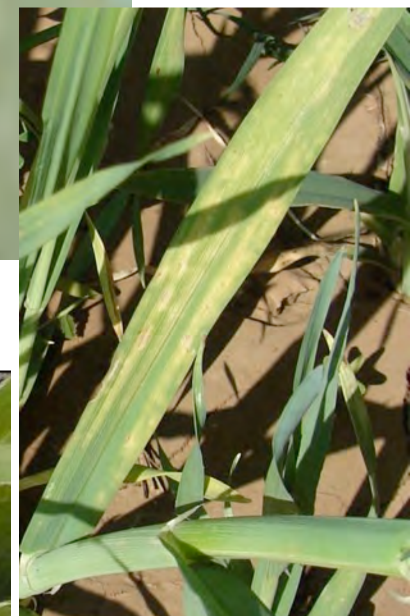
Also under high P use & high organic matter soils

Bronzing of upper surface of younger leaves

Canola relatively more efficient than wheat at getting soil zinc (Brennan and Bolland 2002)

In barley & wheat – classic inter-veinal soaked spots.

Classical symptoms in maize.



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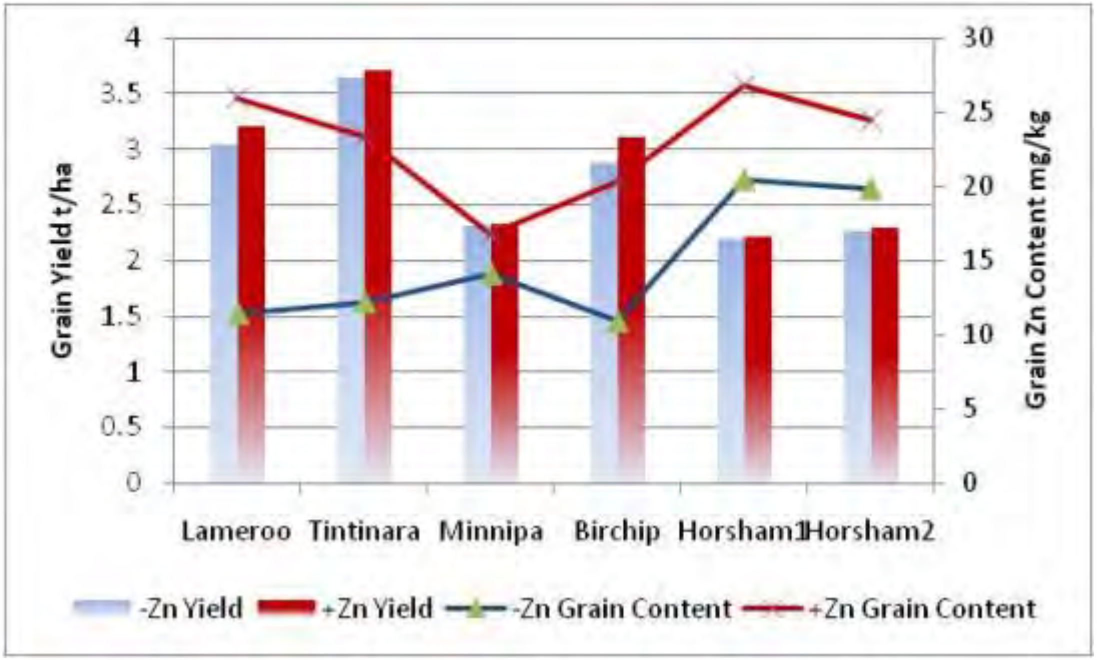
Response to Zn



Yield Response to 7.5 kg Zn – 2 of 6 sites

Grain Zn Increase on 5 of 6 sites

DTPA Zn test available but difficult to find yield responsive sites

Peck et al 2008

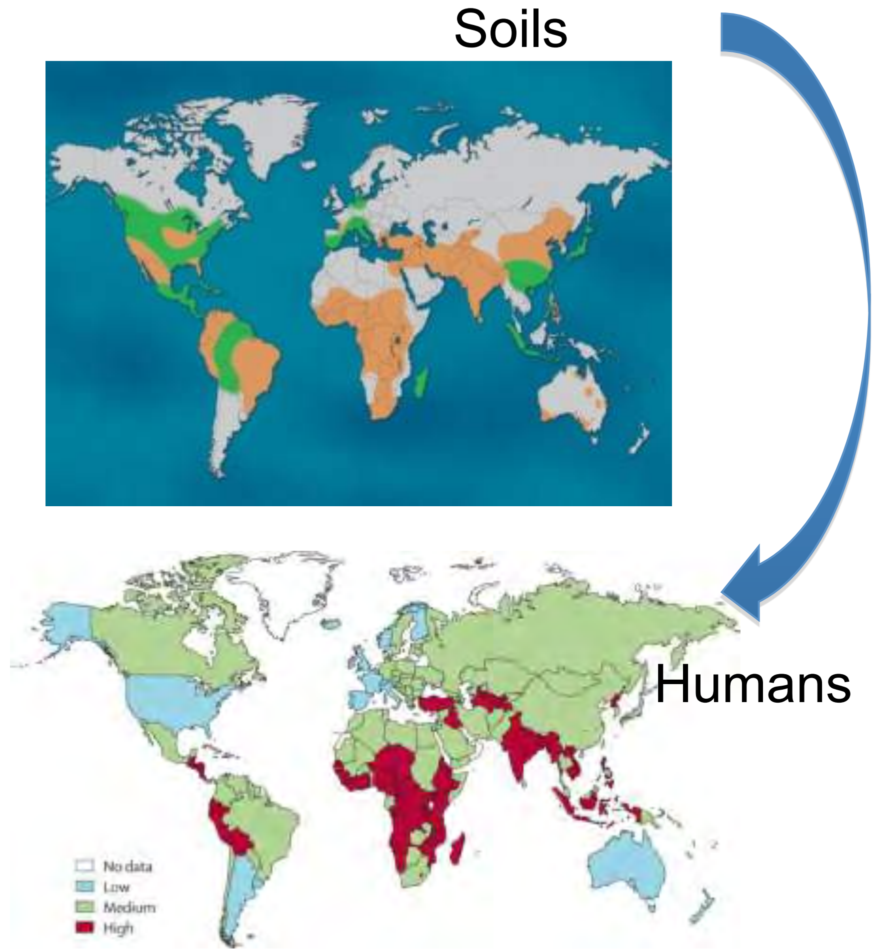
Formulation with granulated fertilizers

- Some great developments over the past few years
  - Moving from supplements tipped in to a mixer giving a surface coat.
  - Some traces sprayed onto the dry product
    - Molybdenum – sprayed on as sodium molybdate or molybdenum trioxide compunded in the granule - 0.050 kg/ha
  - Now co-granulated – with an even mixture through the granule applied in the MAP/DAP melt (form depends on substrate used).
    - This gives a more controlled release rate and a more even field distribution.
    - Zinc – zinc oxide and/or zinc oxysulphate – 1-5 kg/ha

Food security also considers food quality- Example of Zinc

There are over 450,000 deaths annually < 5 years old in the developing world due to Zinc deficiency.

Grains often low in Zn – when grown on low Zn soils, even lower:
eg Australia – 23 ± 7 mg/kg



Black et al. 2008 The Lancet Maternal and Child Undernutrition Series