
# Calcium:
# Its role in crop production

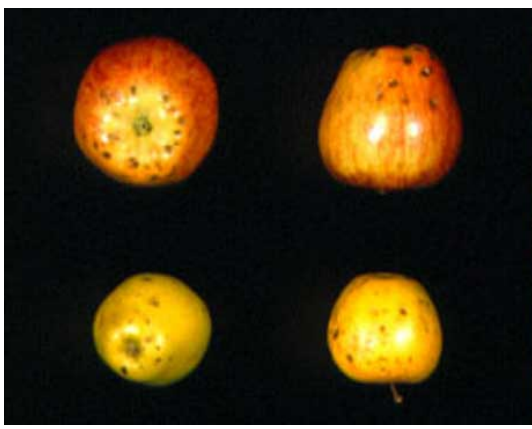
Rob Norton,
Regional Director
IPNI Australia & New Zealand

GRDC Advisor Update, Ballarat, 6 Feb, 2013

# Classic calcium deficiency -

Blossom-end rot in tomato caused by Ca deficiency

Bitter pit/cork spot in apples




“pops” in peanuts

Lettuce

Sugar beet

Soybean

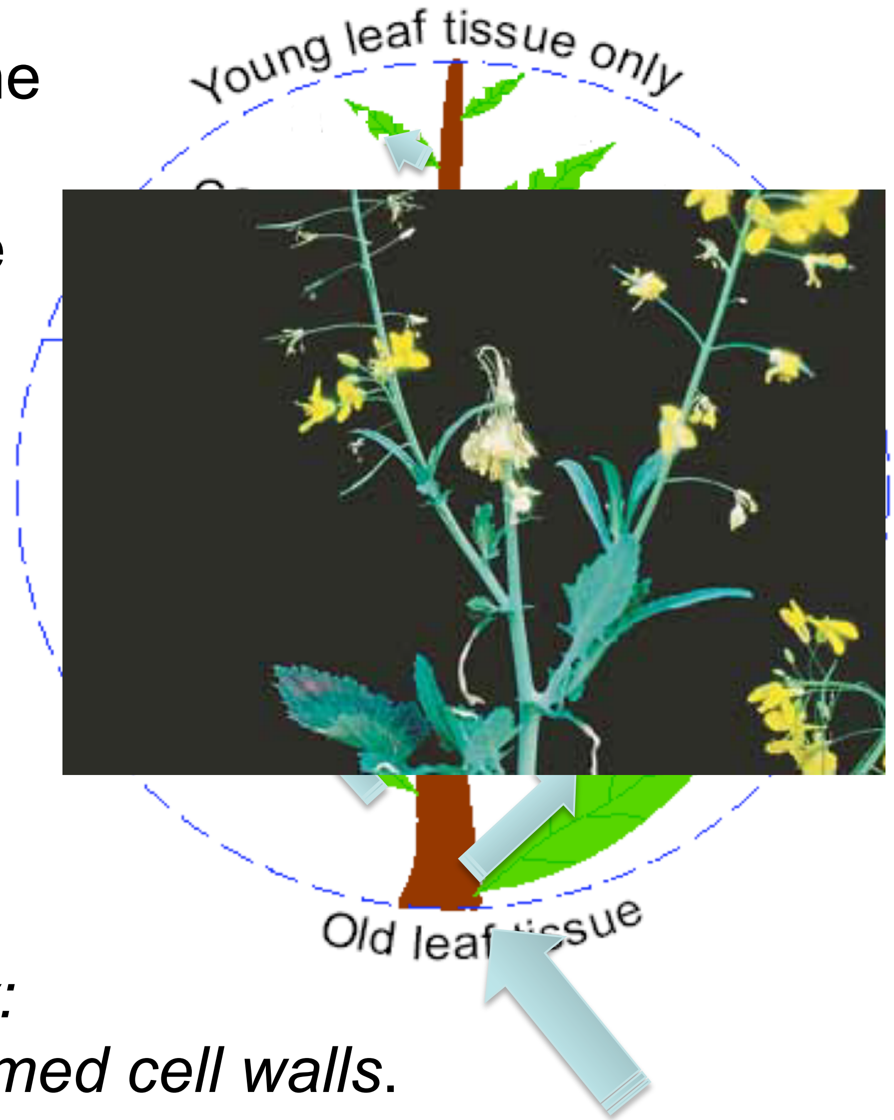
Corn

Canola

Wither-tip, Tipple-top

# Calcium in plants

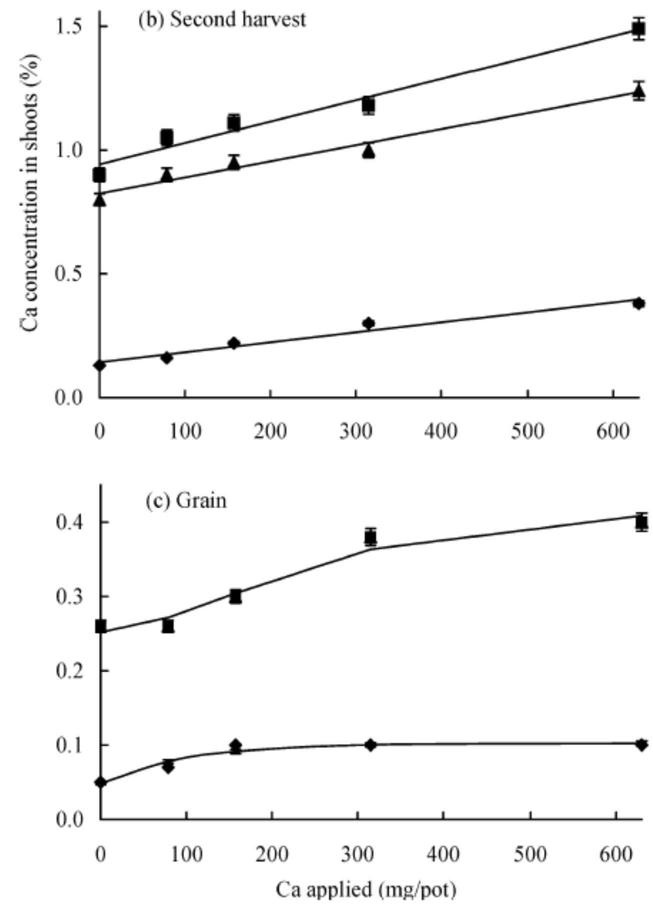
- Enters through roots in the transpiration stream.
- Moves up the plant to the ends where water evaps.
- Not remobilized.
- Poor supply to low transpiring tissues
- Ends up mainly as calcium pectate in cell walls.




*Symptoms of deficiency:*
*Breakdown in newly formed cell walls*.

# Calcium demand by different species:

- Top lines are canola, bottom line is wheat.
- Critical values for Ymax.
  - Wheat – 150 mg/pot
  - Canola - ~400 mg/pot
- Nutrient densities & removal
  - Wheat – 400 mg/kg (0.4 kg/t)
  - Canola – 4000 mg/kg (4 kg/t)
  - Pulses – 1000 mg/kg (1 kg/t)




Brennan et al. 2007, JPl.Nutr. 30:1167

# Values for critical tissue Ca levels

| Crop | Stage | Part | Adequate | Ref |
|---|---|---|---|---|
| Canola | Pre-flow | YML | 1.4-3.0% | Weir, 1983 |
| | Pre-flow | 1,2,3 RML | 1.4-3.0 | Weir, unpub. |
| Wheat | 2-3 leaf | YEB | 0.3-0.8% | Peverill, unpub. |
| | Mid-late Till | YMB | 0.2-0.4% | Weir, 1983 |
| Field pea | Pre-fl | YML | 0.9-2.0% | Weir & Cresswell, 1994 |

Source, Reuter & Robinson, Plant Analysis.

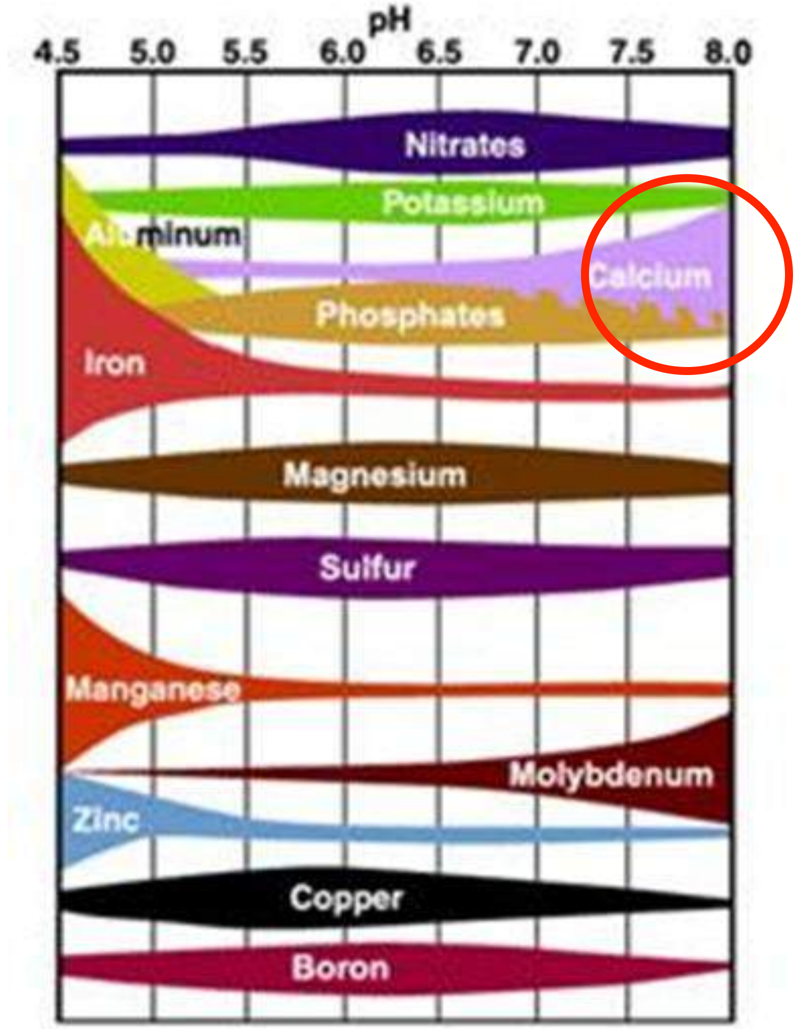
# A transport problem?

- Ca moves in the xylem so goes to the actively transpiring tissues (ie leaves).
- Ca is nearly all supplied in this new stream.
- Tissues with low transpiration rates (eg fruits) will lack Ca.
- Uneven water supply can result in poor Ca transport
- So – in most cases it is a transport problem!

*Take care with tissue sampling*

# pH and nutrient availability

- Soil acidity (pH) drives much of the chemistry in the soil
- Reactions to free or to bind nutrients driven by soil pH
- At pH < $5.5_W$ calcium becomes less available.
  - Cation substitution & losses
- At pH >$8.5_W$ calcium becomes less available
  - Insoluble calcium carbonates
  - Solubility of $CaCO_3$ is decreased at higher soil pH.




Note $pH_w$ is 0.7 to 1.0 greater than $pH_{CaCl2}$

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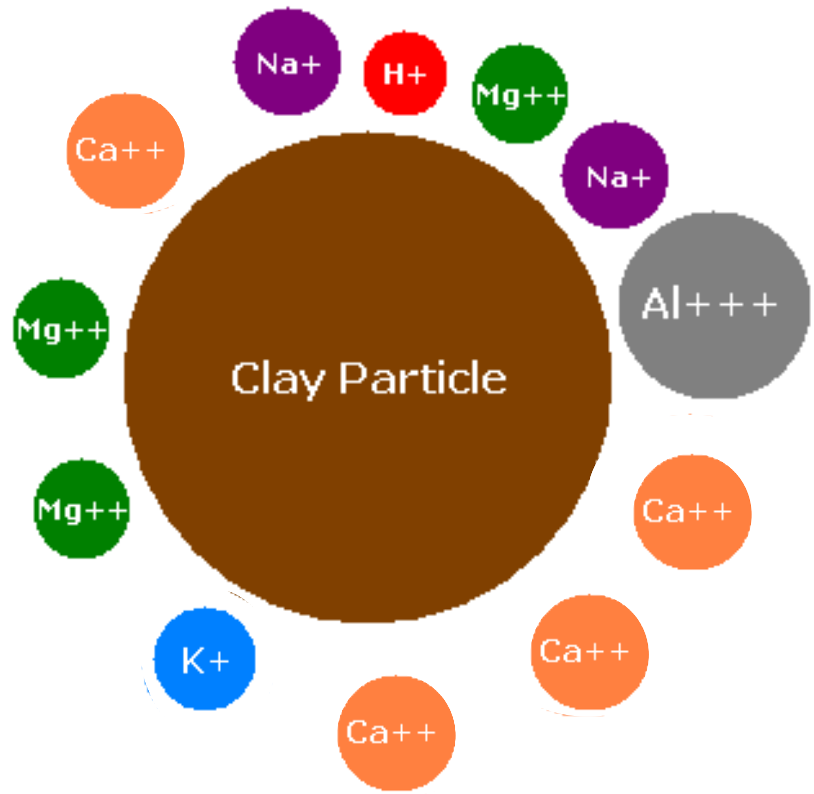
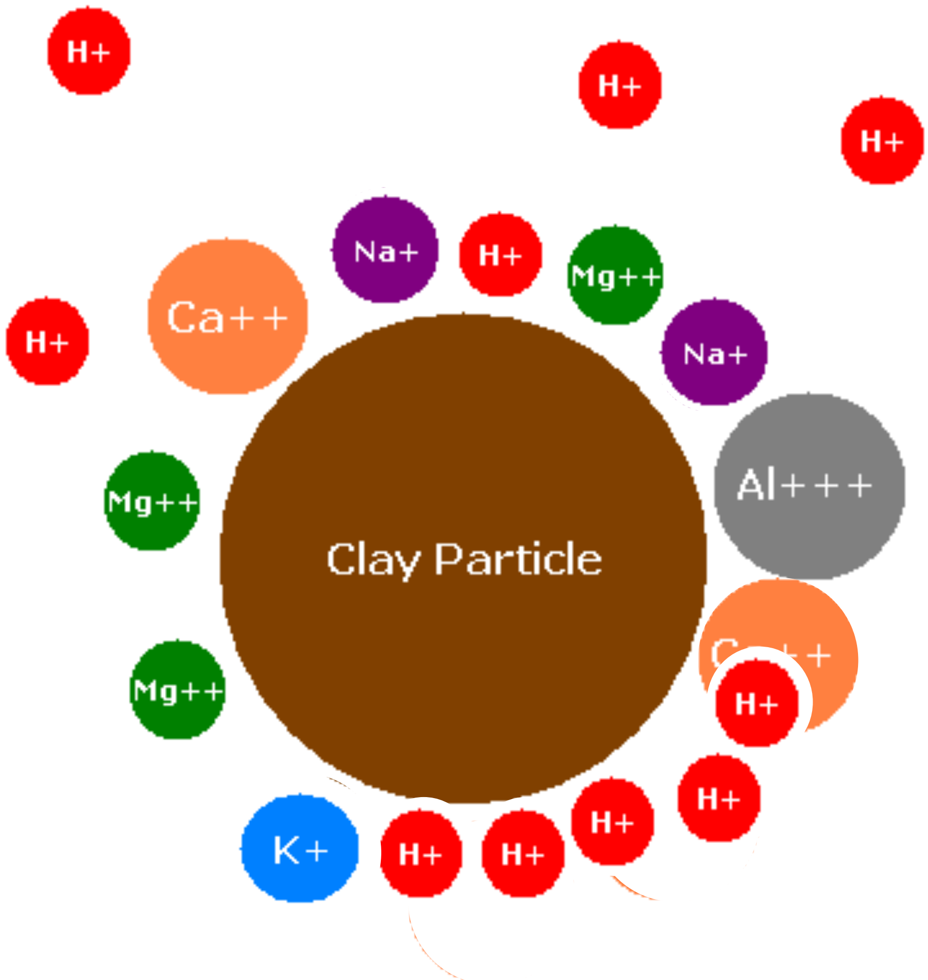
# Clay colloids 101:

- Clays are negatively charged
- Electrostatically attract cations
- Strength depends on the charge and size of the cations (hydrated diameter – Table 1 incorrect)
- A small ion (eg 300 pm $K^+$) is held more strongly than a large ion (eg 450 pm $Na^+$).
- Charge number is also important.




Na 450, K300, Mg 800, Ca 600, Al 900.

## $Al^{3+} > H^{+} > Ca^{2+} > Mg^{2+} > K^{+} = NH_4^{+} > Na^{+}$



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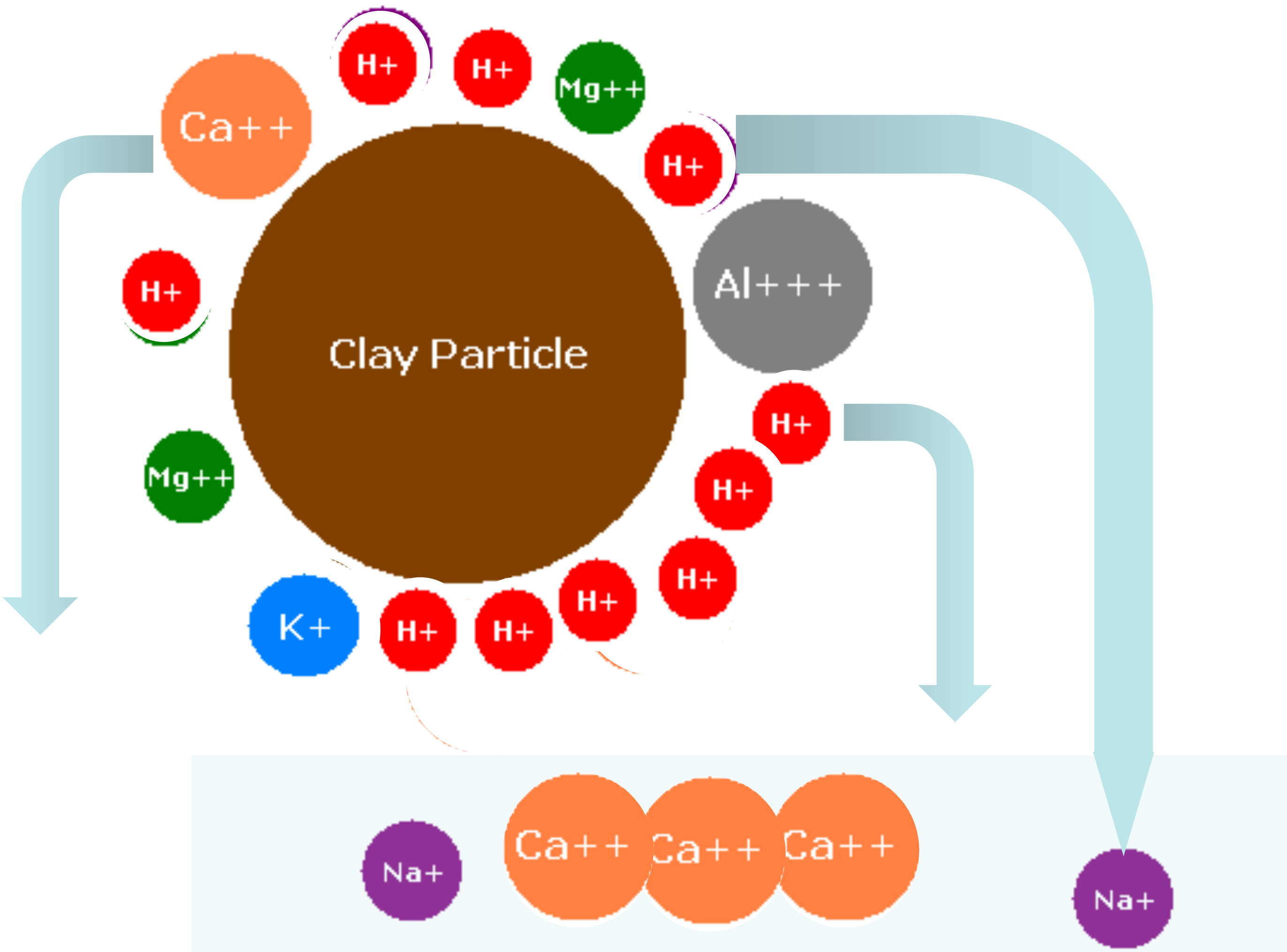
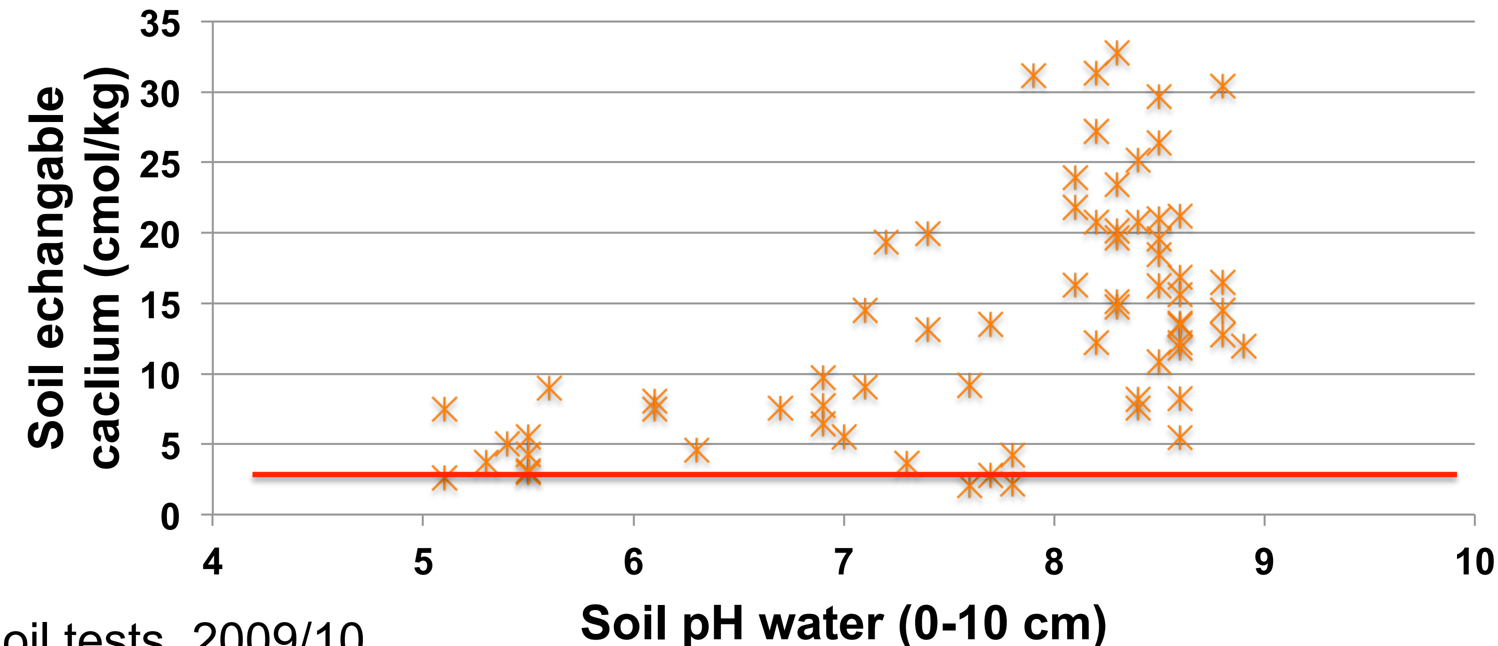


# Soil Ca levels:

- Usually expressed as ammonium acetate exchangeable calcium in cmol/kg of soil.
- 1 cmol/kg top 10 cm equates to ~400 kg of ex-Ca.
  - ie it is in an ionic and plant available form!
- 2-5 cmol/kg (about 0.5 mmol/l)




NVT Soil tests, 2009/10

# Exchangable cations and interpretations (cmol/kg)

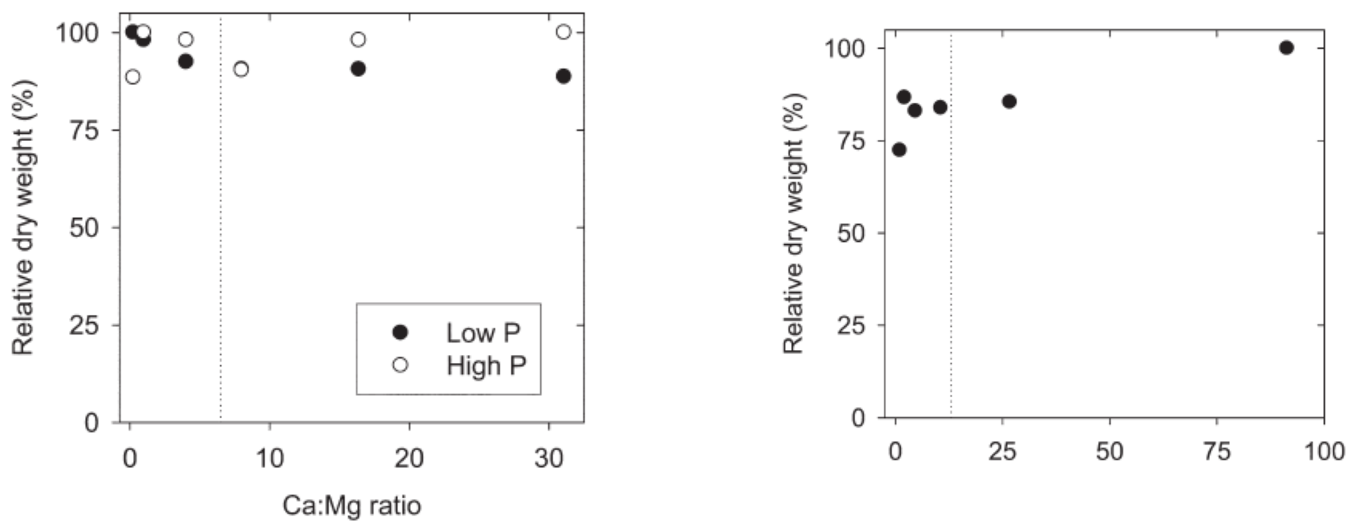
| | Sodium | Potassium | Calcium | Magnesiu m |
|---|---|---|---|---|
| Very Low | <0.1 | <0.2 | <2 | <0.3 |
| Low | 0.1-0.3 | 0.2-0.3 | 2-5 | 0.3-1.0 |
| Moderate | 0.3-0.7 | 0.3-0.7 | 5-10 | 1-3 |
| High | 0.7-2.0 | 0.7-2.0 | 10-20 | 3-8 |
| Very High | >2 | >2 | >20 | >8 |

Hazelton & Murphy 2007, Interpreting soil test results, CSIRO Publishing.

Very much a guide only.

# Base saturation cation ratios

- Have been around for 60 years, proposed that there is an optimal “balance” between Ca, Mg, Na, K (the base cations).
- See review by Kopittke and Menzies, 2007.



# Effect of Ca:Mg ratio on cotton

Table 1. Effect of soil chemical properties from a long-term field experiment on average cotton fiber micronaire, uniformity, strength, and lint yields. Table taken from Stevens et al. (2005).

| Ca/Mg ratio | $pH_{salt}$ | Cation exchange saturation | | | Cotton fiber | | | Lint yield |
|---|---|---|---|---|---|---|---|---|
| | | Ca | Mg | K | Micronaire | Uniformity | Strength | |
| | | ——— % ——— | | | | % | cN $tex^{-1}$ | kg $ha^{-1}$ |
| 7.6 | 6.3 | 76 | 10 | 9 | 4.3 | 83.6 | 27.9 | 897 |
| 7.2 | 6.2 | 72 | 10 | 8 | 4.3 | 82.9 | 28.2 | 821 |
| 7.4 | 6.4 | 74 | 10 | 9 | 4.2 | 83.4 | 28.2 | 902 |
| 6.3 | 6.2 | 69 | 11 | 9 | 4.3 | 83.9 | 28.1 | 842 |
| 4.8 | 6.1 | 67 | 14 | 8 | 4.1 | 82.7 | 27.8 | 868 |
| 4.4 | 6.2 | 66 | 15 | 8 | 4.2 | 83.6 | 28.2 | 789 |
| 2.7 | 6.3 | 59 | 22 | 7 | 4.4 | 83.1 | 28.2 | 840 |
| 2.5 | 6.1 | 57 | 23 | 8 | 4.2 | 83.4 | 28.0 | 889 |
| 2.5 | 6.5 | 60 | 24 | 9 | 4.3 | 83.5 | 27.6 | 878 |

"Our examination of the data from numerous studies (particularly those of Albrecht and Bear themselves) would suggest that, within ranges commonly found in soils, *the chemical, physical and biological fertility of a soil is not influenced by the ratios of Ca, Mg, and K*. The data do not support the claims of BCSR and continued promotion of the BCSR will result in the inefficient use of resources in agriculture and horticulture."

Kopittke & Menzies, 2007, SSSAJ, 71:259

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## Question 7
# So why do laboratories still quote BCSR and Ca:Mg ratios?

**A.** **I have no idea.**

- Dr D Edmeades, New Zealand
  - http://www.agknowledge.co.nz
  - Soil Ca, expressed as the % Ca base saturation is meaningless and misleading – Ignore it.

- What is important is the actual level of the calcium and magnesium – both should be above 0.5 mmol/l in the soil solution - 2-3 cmol/kg.

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# Lime – calcium carbonate

- It is not a fertilizer, it is a soil ameliorant.
- The calcium plays NO ROLE in amending the soil pH –it is a spectator ion.
- The carbonate/bicarbonate reacts with hydrogen ions as:

$$H^+ + HCO_3^- \longrightarrow H_2CO_3 \longrightarrow H_2O + CO_2 \text{ (quite quick)}$$

- Lime has a low solubility – 0.013 g/l (pH & temp.)
  - its solubility declines significantly with pH – above pH 9, the solubility will be about 1/20th of it at pH 7.
  - Lime usually requires incorporation to react with the soil volume.
- It takes time for lime to dissolve and dissociate to Ca.
  - Depending on soil pH – it may not dissolve or dissociate
  - At high pH, it can 'trap" ex-Ca.

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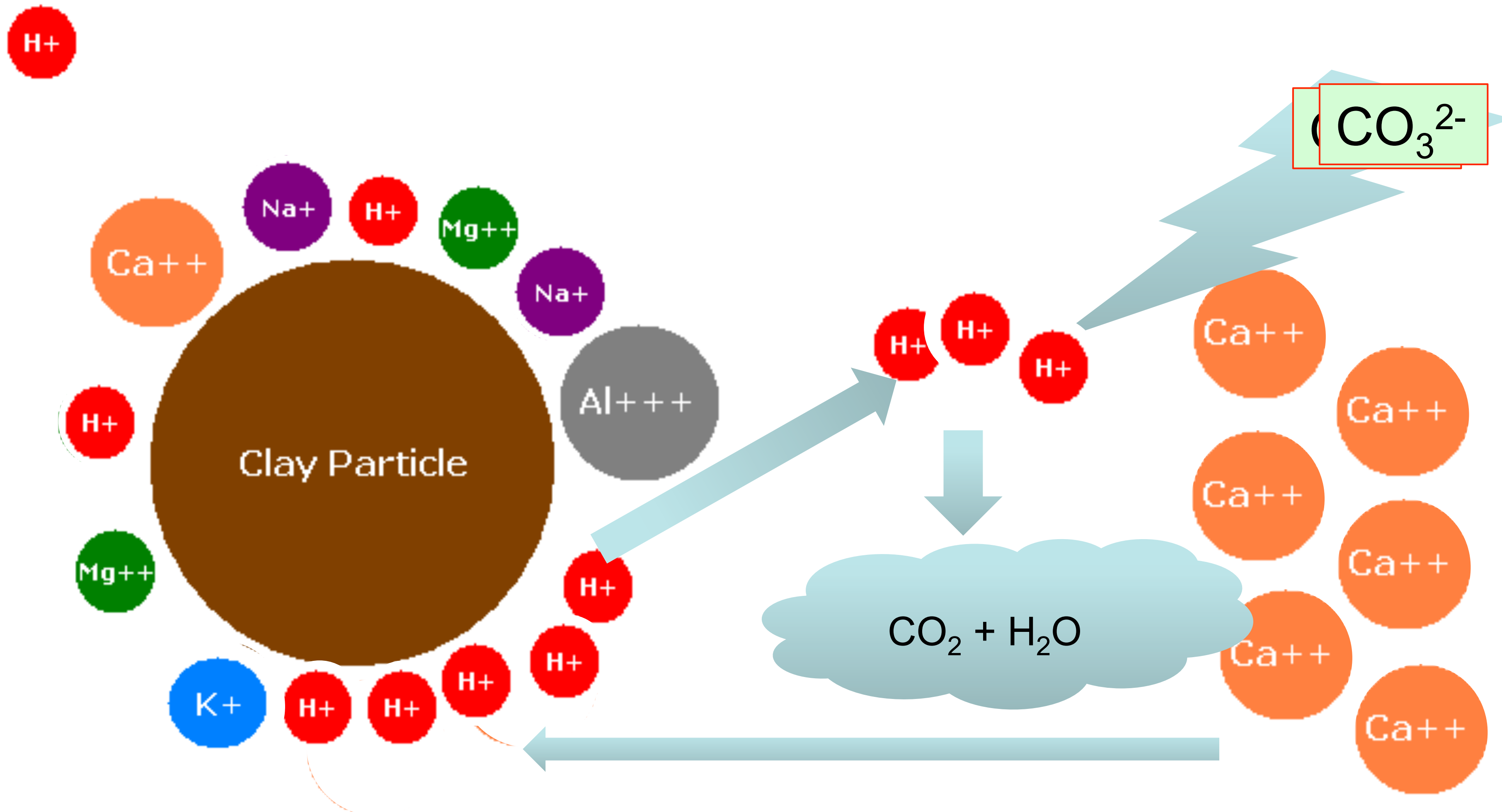
# On an acid soil…adding lime



# Gypsum – Calcium sulfate dihydrate

- It is not a fertilizer but a soil ameliorant
- The sulfate ion plays no role in the soil reactions, but it can supply S to demanding crops (eg canola).
- Calcium displaced sodium off the clay, assisting with flocculation of the clay particles.
- Gypsum has a solubility of 2.4 g/l but will still need 100 mm of rain to dissolve a tonne get into the soil
  - (burning stubbles?).
- In soils with free carbonate, calcium may be precipitated into lime.

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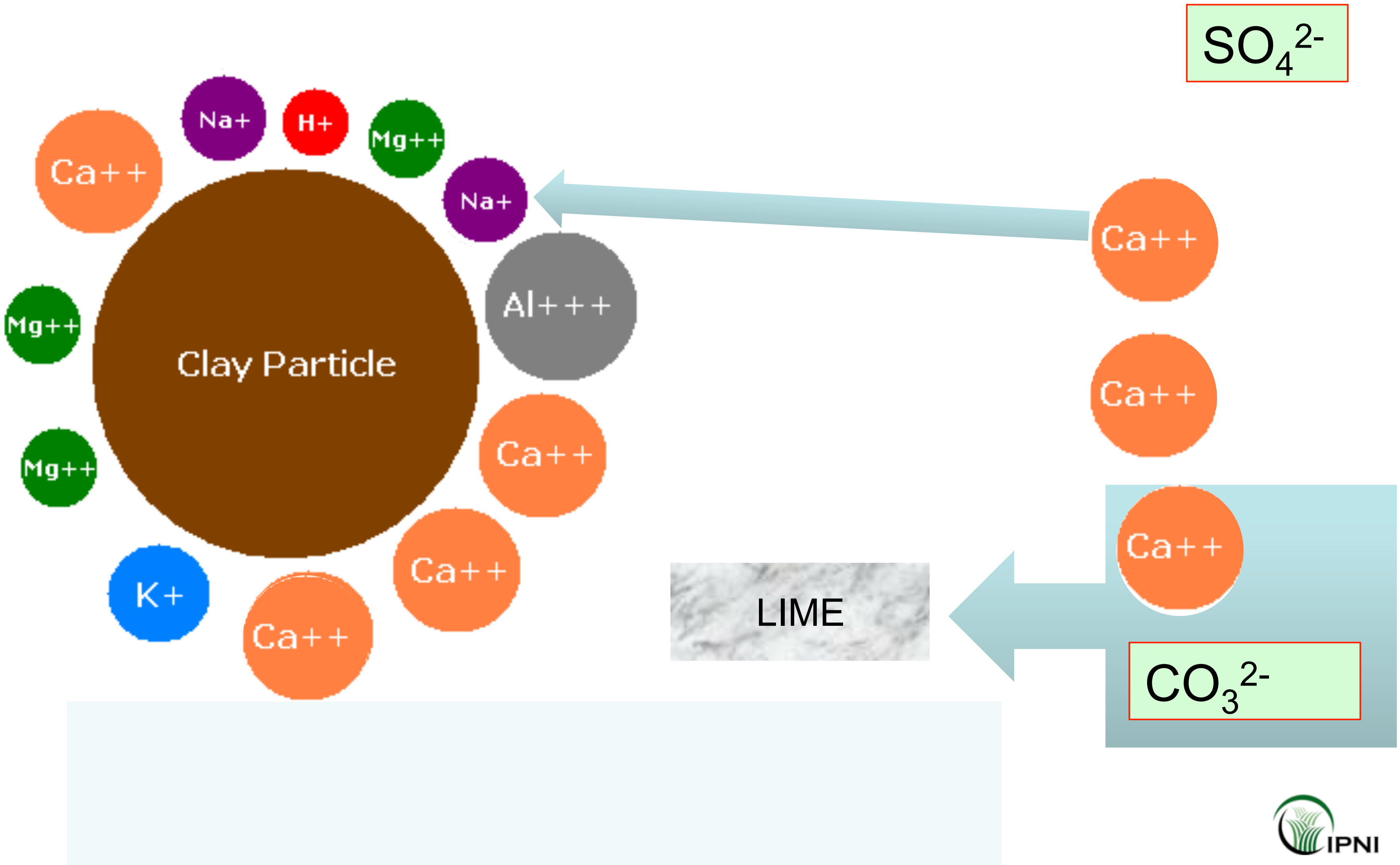
# On an alkaline soil………adding gypsum

Sodic clay to a calcic clay



# Gypsum & Lime (Rengasamy, pers.comm.)

- Up until pH 8.5, Ca is derived from the dissolution AND dissociation of lime or gypsum.
- These are equilibrium reactions based on the $K_s$:
  - **$CaCO_3 \rightleftarrows Ca^{2+} + CO_3^{2-}$** (100 mm)
  - 1 tonne of lime (40% Ca) → g's of $Ca^{2+}$ + carbonate (replenished)
  - **$CaSO_4 \rightleftarrows Ca^{2+} + SO_4^{2-}$** (100 mm)
  - I t of gypsum (15% Ca) – kg's of Ca (all dissolved)

- Supply is not about solubility alone – it is rate * solubility in an equilibrium reaction.
  - A low rate of a "highly soluble" product may not supply as much as a high rate if a "poorly soluble" product.
  - High rate of low soluble means a back up supply over time.

# Do you have any now?

- Soil test? 1 cmol/kg = 400 kg/ha Ca

- Using gypsum on sodic soils?
  - Good quality gypsum has >15% Ca

- Do you use/recommend lime –
  - Raise soil $pH_W$ above 5.5, will provide adequate Ca.

- Do you use SSP or TSP?
  - 100 kg/ha SSP (20% Ca) = 20 kg/ha Calcium
  - 40 kg/ha TSP (15% Ca) = 6 kg/ha Calcium
  - DAP/MAP = nil

# Using fluid calcium sources?

*As a nutrient source* (eg Ca Nitrate/ Ca Ammonium nitrate):

- Clearly done in horticulture as foliar sprays – high value crops for storage disorders.
- Most often the problem in canola is transport, low transpiration rate and/or dry soil.
- Trials?

Kandle & Porter, Minnesota

| Crop | Without Calcium | With Calcium | L.S.D. 0.05 |
|---|---|---|---|
| **Alfalfa** | | | |
| Yield (lb/a) | 2736 | 2561 | N.S. |
| Protein (%) | 22.8 | 23.4 | N.S. |
| Relative Forage Quality | 173 | 189 | N.S. |
| Milk per Ton (lb/ton) | 2521 | 2704 | N.S. |
| **Oats** | | | |
| Yield (bu/a) | 122 | 119 | N.S. |
| Test weight (lb/bu) | 36.8 | 37.1 | N.S. |
| **Wheat** | | | |
| Yield (bu/a) | 32.3 | 30.8 | N.S. |
| Test weight (lb/bu) | 61.8 | 61.5 | N.S. |
| Protein (%) | 13.1 | 13.0 | N.S. |
| **Soybean**[1] | | | |
| Yield (bu/a) | 7.3 | 6.4 | N.S. |
| Height (inch) | 17.4 | 16.3 | N.S. |
| **All Crops Combined** | | | |
| Yields expressed as % of non treated crop | 100 | 98.3 | N.S. |

# Using fluid calcium sources?

*As a structural amendment*:

Calcium to displace sodium off the colloid.

Solubility is not the issue – it is the amount of Ca supplied.

<u>To halve ESP from 7% - 400 kg/ha of Ca (1 cmol/kg)</u>

- 1 t/ha of gypsum will supply ~100 kg/ha of Ca ions with 100 mm of rain.
- A 5% calcium nitrate solution would need to be applied at 2000l/ha to achieve the same supply of Ca ions.
  - Maybe there is a "localized" effect where applied – but this strip would be under "chemical siege" from the surrounding Na.

Summary

# Where will added Calcium be a benefit

- Where pH <5 – why not add lime anyway

- Where pH>9 – grow a legume/use elemental S
  - Is a degree of uncertainty about this area.

- When growing sensitive crops (almonds, peanuts, apples) on acid soils.
  - Canola and added Ca? No reliable replicated data on this.
  - Adding to N efficiency. No reliable replicated data on this.

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