Soil characteristics and cultural practices that influence potassium recovery efficiency and placement decisions

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THE RIGHT RATE OF THE RIGHT PRODUCT, IN THE RIGHT PLACE AT THE RIGHT TIME…

- The variable (but generally low) mobility of K in soil and the lack of root response to K-rich ‘patches’ are key considerations
- Failure to contextualize the K application situation (crop, soil, climate) can make or break a K fertilizer application strategy

KEY CONSIDERATIONS FOR MAKING A SENSIBLE FERTILIZER DECISION

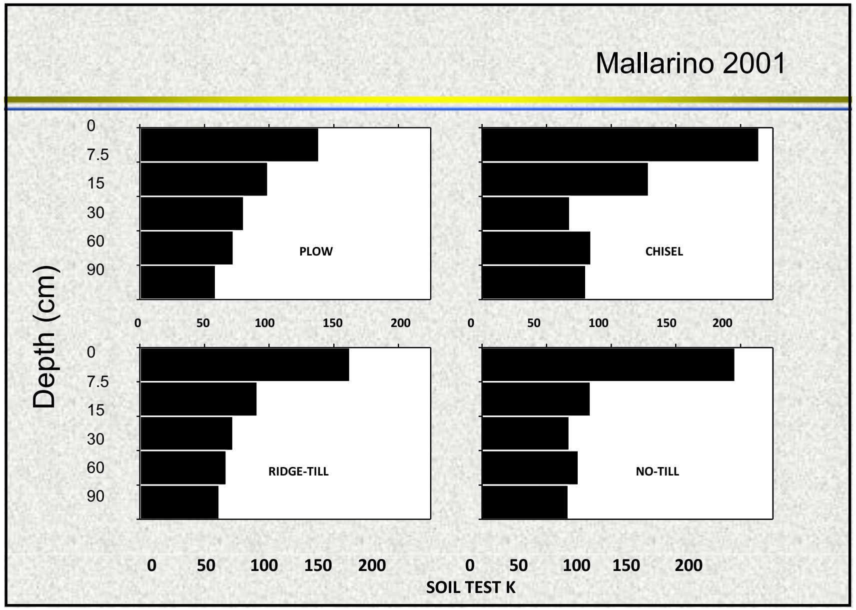
1. Understand the K status of the field you are working in
2. Understand the soil characteristics that will influence the fate of applied K and crop K availability.
3. Understand the root system of the crops in the rotation and the response to nutrient-rich patches or zones
4. Understand the crop K uptake dynamics and identify the periods where adequate K supply is critical
5. Understand the soil, management and climatic factors that will modify root access to soil/fertilizer K and potential K recovery

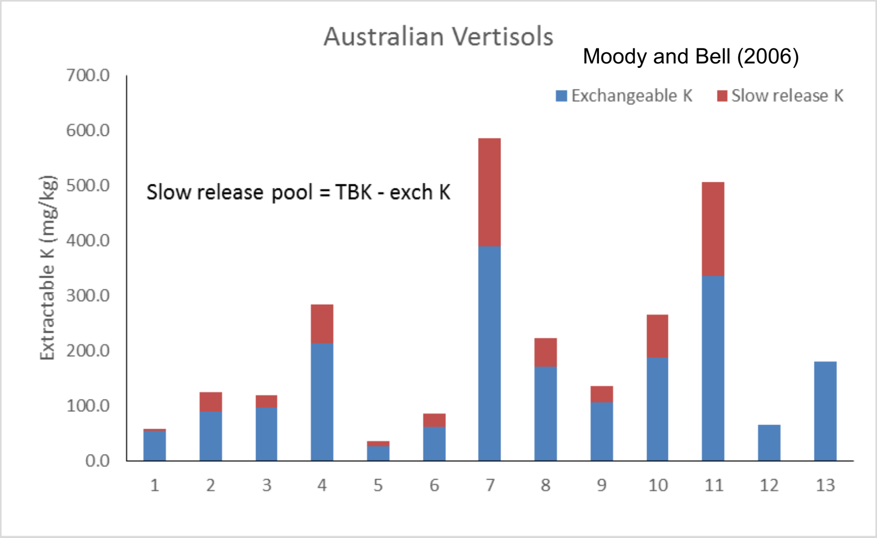
1. UNDERSTANDING K STATUS

- **Will dictate the approach to K application** – *triage* (meeting demands of the next crop in a responsive soil), *building fertility s*tatus (as previous, + component for build up) or *maintenance* (replacing crop removal to maintain current acceptable K fertility).
- Need to consider
  - **Distribution of K within the effective root zone**, with the appropriate sampling depth(s) likely to vary with soil and climate/management
  - **The fraction of K that is bioavailable**, the time frame and predictability of release (over the fallow, during the next crop season or over the next year or two)
  - **Other mitigating factors** that will affect root distribution and activity and K diffusion processes (soil solution concentration and activity, tortuosity/path length)
- One soil sample and 1 analytical test are unlikely to do it all

MULTIPLE SAMPLE DEPTHS, TWO (OR MORE) DIAGNOSTIC TESTS

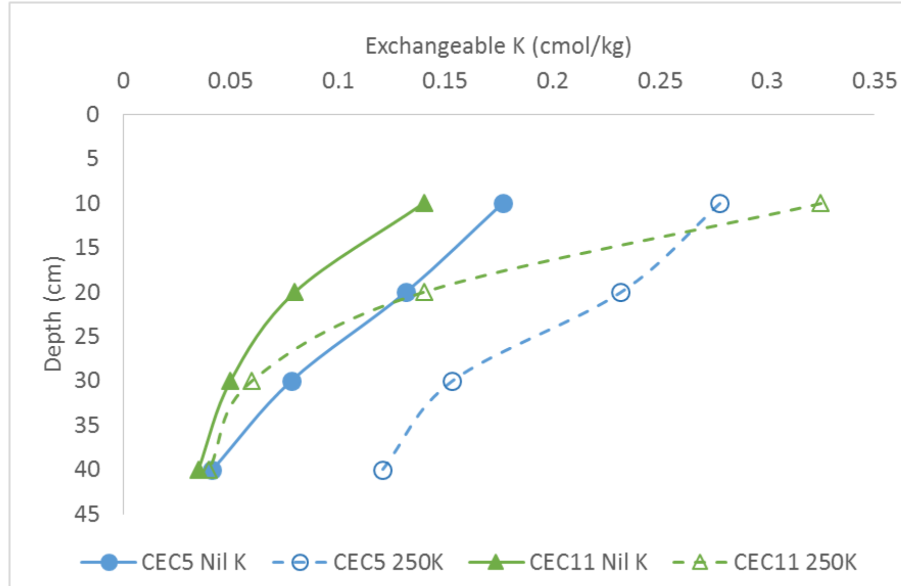
- Different tillage systems and mobility of K between soil types mean at least top soil (0-10cm) and the next layer (10-30cm?) should be quantified
- Different soil tests provide information about K in different pools (exchangeable and slow release K)

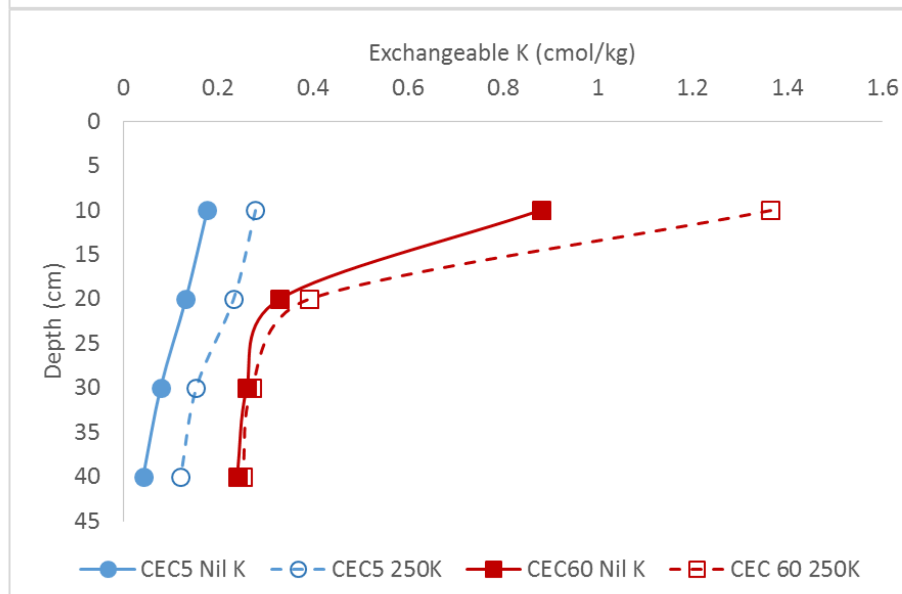




2. SOIL EFFECTS ON FATE OF APPLIED K AND CROP RECOVERY

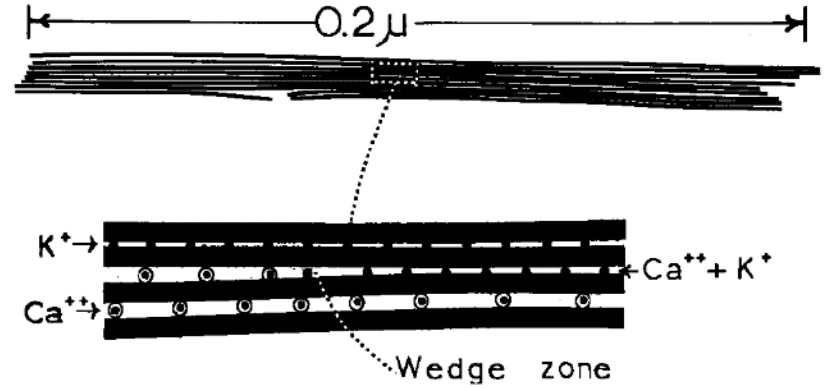
- Important considerations include –
  - *The CEC and number of K-specific sorption sites* (how much K can the soil retain before being leached – see examples)
  - Presence of mineralogy that causes K fixation



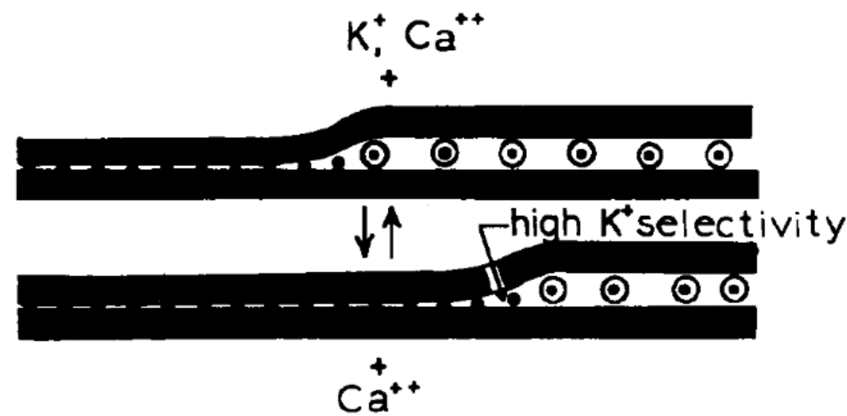


K FIXATION HAS BEEN STUDIED FOR DECADES

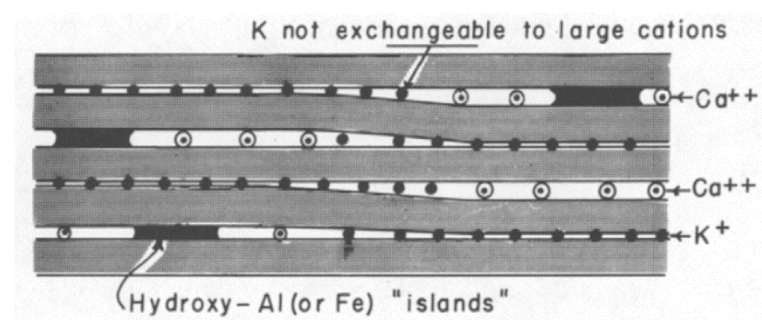
- Vermiculite fixes K



- Sites in wedges and at frayed edges of “micas” are selective for K



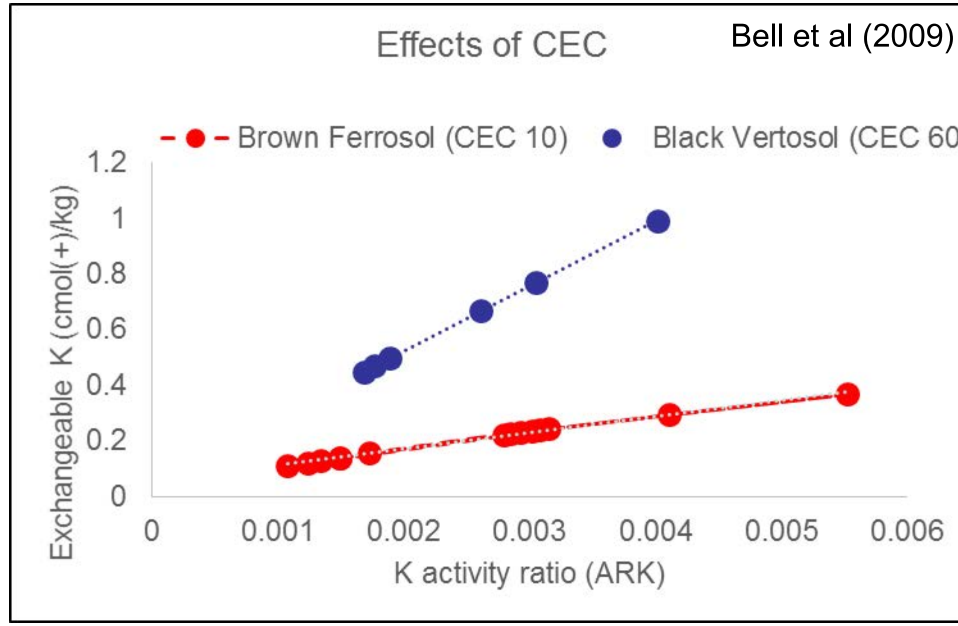
- Al-hydroxide interlayer islands may limit K

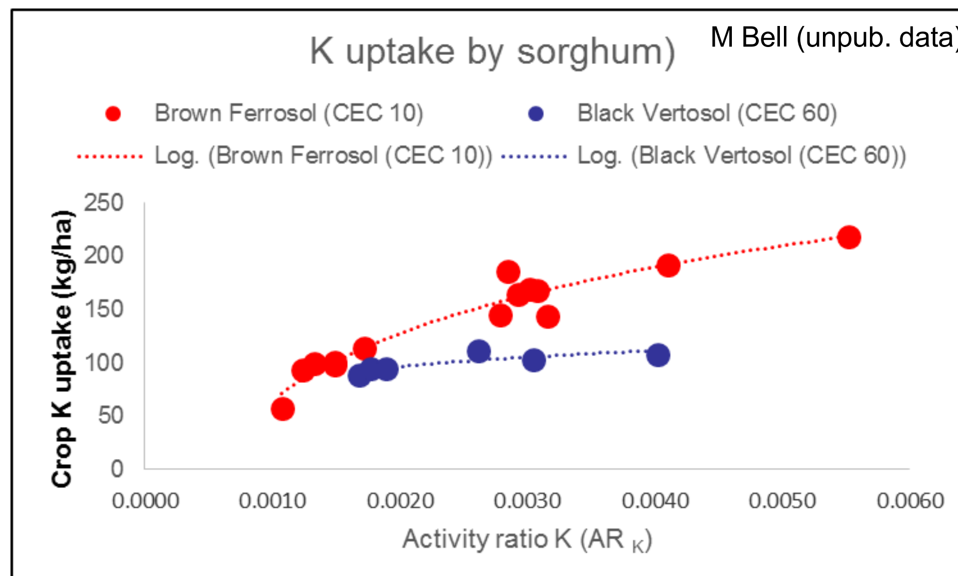


Rich, C.I. 1968. Mineralogy of Soil Potassium. p. 79-108. The Role of Potassium in Agriculture. Kilmer, V.J., S.E. Younts, and N.C. Brady (eds.) ASA, CSSA, SSSA, Madison, WI. doi:10.2134/1968.roleofpotassium.c5

OTHER MITIGATING FACTORS

- CEC is a good indicator of K buffer capacity, which impacts on soil solution K and K activity
- Soils with high CEC have lower K and AR_K for the same exchangeable K
- High CEC soils also typically have high clay contents and more tortuous K diffusion pathways.
- The combined effect is less efficient accumulation of K by the same crop as CEC increases.



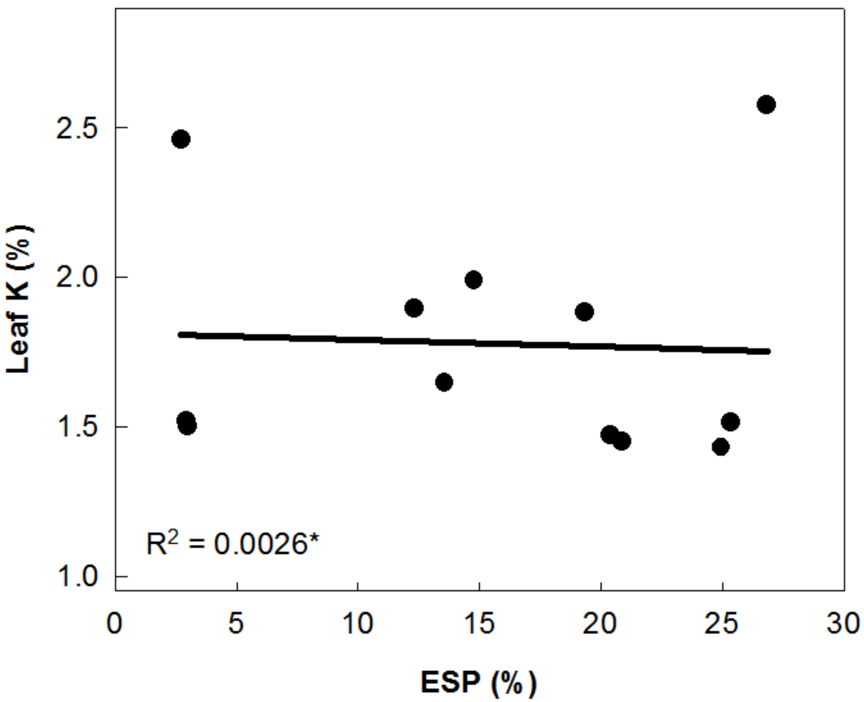


OTHER MITIGATING FACTORS (CONT).

Potassium dynamics are affected by sodicity

+PAM Treatments

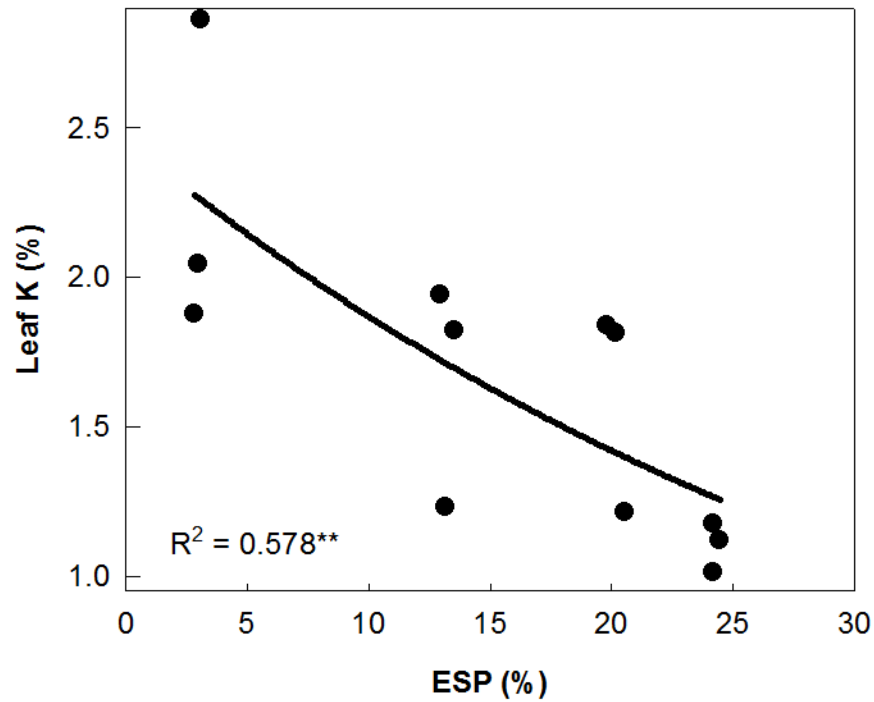
- Isolating the Chemical Impacts



There is no effect of sodic soil solution chemistry on the potassium nutrition of cotton, despite the extreme ratios of Na: K that exist at high ESP levels

Control Treatments

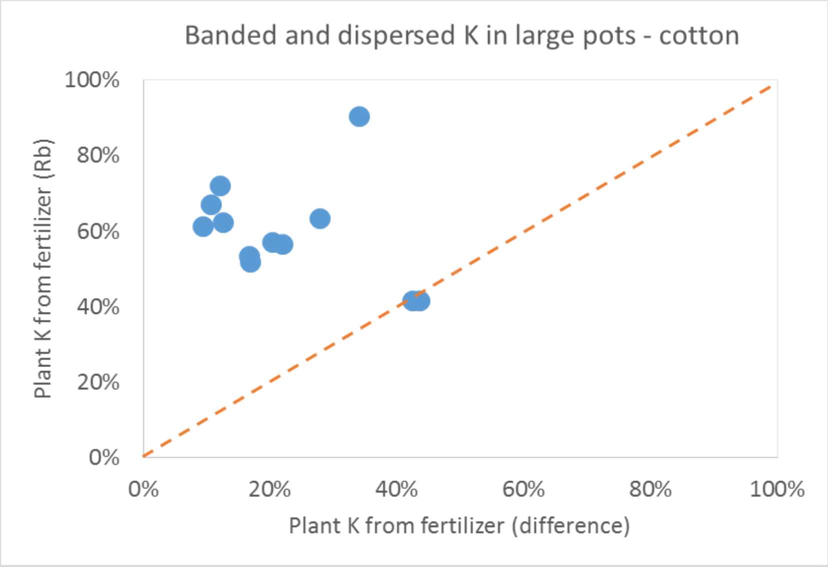
- Physical and Chemical Impacts

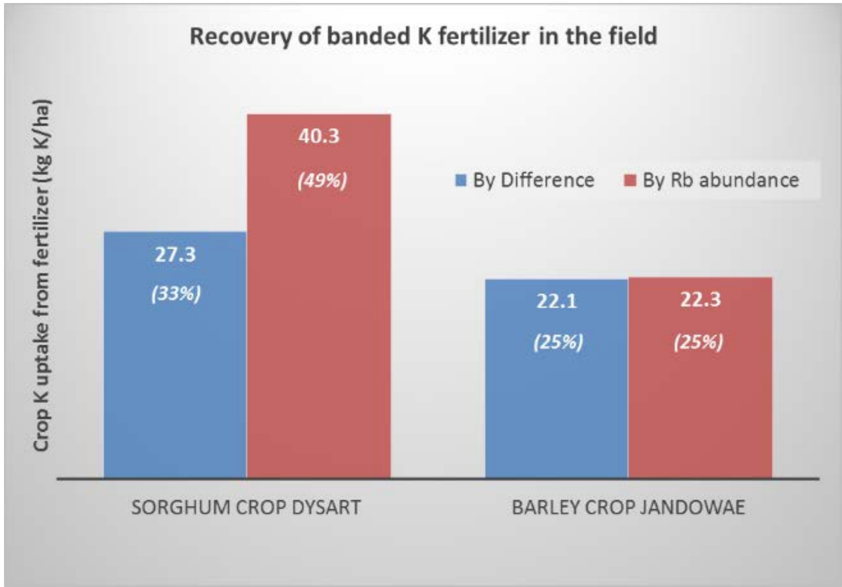


The potassium concentration of cotton decreases with increasing soil sodicity, due to adverse soil physical conditions

HOW WELL DO WE ACTUALLY MEASURE K RECOVERY?

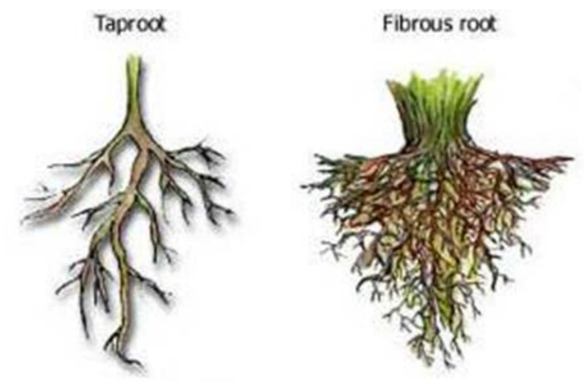
- Often don't measure fertilizer recovery – simply agronomic response (kg additional grain/kg applied K)
- If crop recovery is measured it is typically done by difference (kg K $uptake_F$ minus kg K $uptake_{Unf}$)
- This does not account for any preferential uptake of fertilizer
- Tracers like Rb provide useful insights, and suggest recovery can be better than we think. **(Bell et al, unpub. data)**

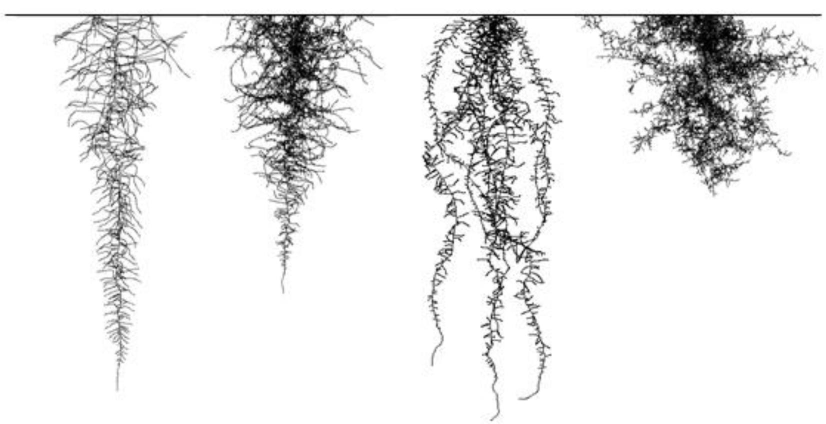




3. UNDERSTANDING THE IMPACT OF VARIATION IN CROP ROOT SYSTEMS

- Root system morphology differs between crops in a rotation.
- Differences in root exudates allow access to different K pools by different species (and genotypes?).
- Climate and water management influence root system distribution.
- Differences in root proliferation response to banded or dispersed K, with or without other nutrients (e.g. P)
- These factors will have a big impact on the need to apply K, the product used and the application strategy.





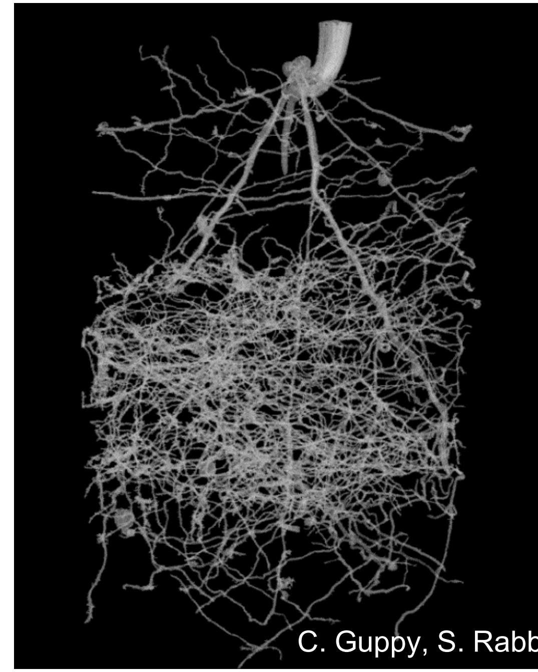
AN EXAMPLE OF MANAGEMENT – ROOT SYSTEM INTERACTIONS AFFECTING P AND K RECOVERY

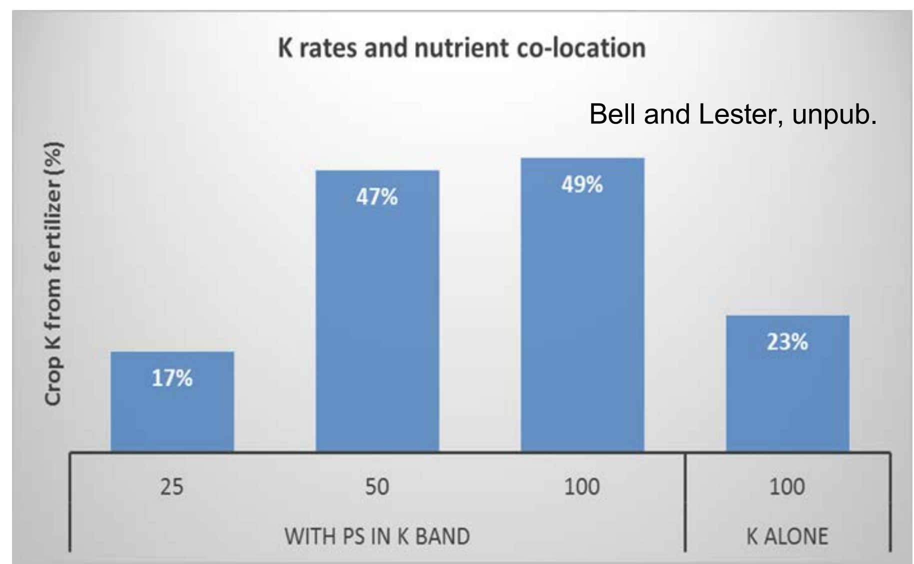
Well developed laterals in the fertilized mound

Few laterals in the fertilized mound

CO-LOCATING NUTRIENTS TO IMPROVE K RECOVERY

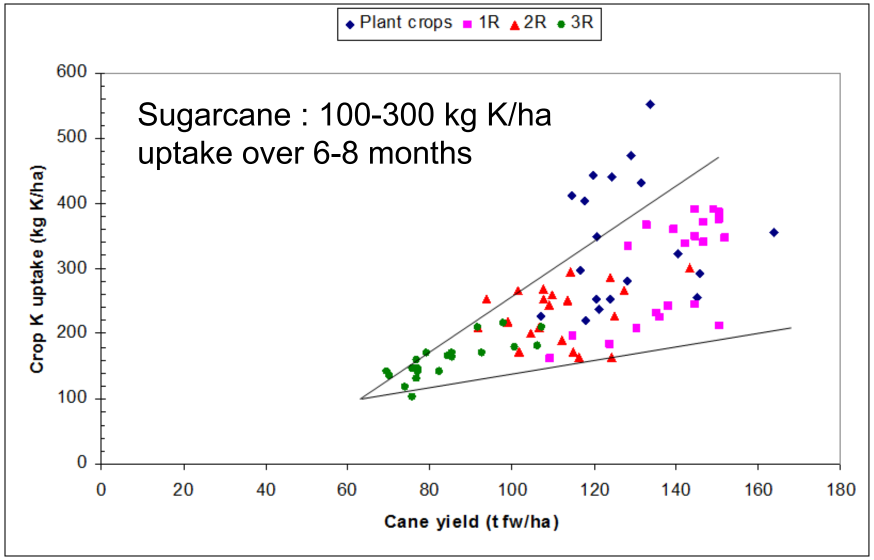
- Bands enrich a limited soil volume, especially in soils with high clay content
- There is little evidence of root proliferation in a K-enriched soil patch/band
- There is well documented evidence of roots proliferating in and around bands of P fertilizer.
- We can utilize this by co-locating some P with K in

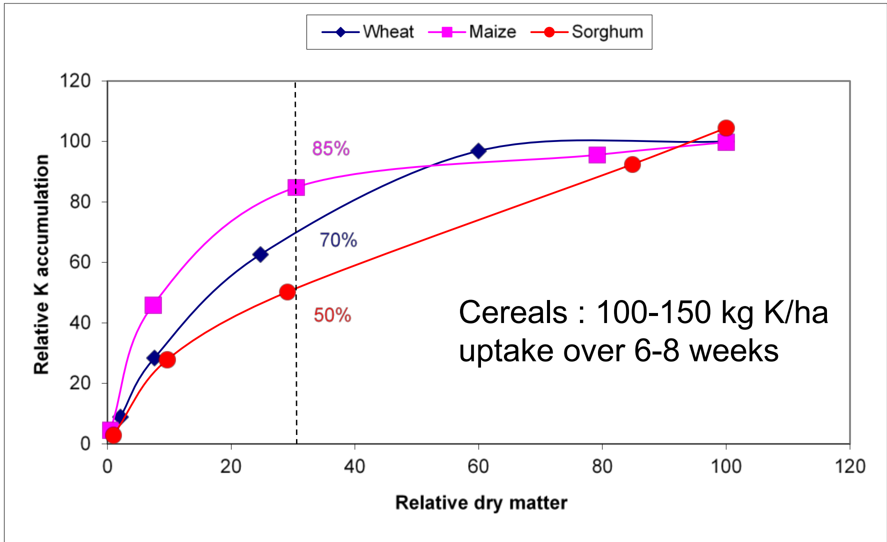




4. UNDERSTANDING THE QUANTUM AND DYNAMICS OF CROP K DEMAND

- The larger the crop K requirement the larger the demand on the soil K supply.
- Dynamics of that K accumulation can impact on the soil volume exploited and the intensity of K demand.
- Compare K uptake in sugarcane (6-8 months) versus cereals (6-8 weeks) and vegetables (3-4 weeks)
- Demand intensity and volume exploited will affect the ability of crops to modify the rhizosphere and exploit different K pools.





5. SOIL TYPE * CLIMATE * CROP TYPE

- The best laid plans can go awry, when you are dependent on getting good fertilizer recovery.
- Dry seasonal conditions can limit recovery of K fertilizers in shallow soil layers
- Large rainfall events can leach K deep into the profile, or restrict access to K bands
- Root pathogens can constrain root development or reduce fine roots/root hairs
- Dynamic crop rotations (in response to price signals) may mean the crop species sown may not be compatible with the fertilizer application strategy

K APPLICATION STRATEGIES

- ***Surface spreading***, with and without incorporation by tillage
- ***Banding*** in or near the seeding row (low rates), removed from the seeding row and at seeding depth, or deep placed (typically prior to sowing).
- ***Foliar applications*** typically complimentary to soil applied K, but rates are low and sources chosen carefully.
- **Forms** of K typically MOP or SOP, with PotNitrate used in some high value horticulture
- **Granular forms predominant**. No real evidence of improved recovery efficiency with liquid K, but used in specific situations.


Broadcast K in crop in UK


Deep K Banding for Ridge-Till, Strip-Till, or No-Till in Iowa


K applied as a liquid via trickle tape, Australia

MANIPULATING K APPLICATION STRATEGIES TO SUIT SOIL TYPE

Proposed hierarchy of factors influencing K application strategy –

1. Soil test to determine if K application is needed and where in the soil profile it should be placed.
2. Soil CEC used as an indicator of capacity to retain applied K in the crop root zone and the K buffer capacity (mineral soils only?). Classes of low, moderate, high and very high. Implications for rate, frequency and method of application.
3. Within CEC classes, develop K fixation index. This will influence efficiency of fertilizer K recovery (at least in the short term), with implications for application method.
4. Consider CEC class and K fixation index to derive the most effective application method and the need to co-locate K with other nutrients.

STEP 1. SOIL TEST DEPTHS AND ANALYTICAL METHODS

- Conventional till - initial depth is the cultivated layer (0-10cm or 20cm, depending on tillage equipment)
- No till systems - typically 0-10cm.
- Subsequent depth intervals determined by root distributions and ability to address any observed deficits. In most cases this will be a 10-30cm or 20-40cm increment.
- Deeper layers (i.e. to 60cm) useful for interest only, except in free draining sands, as root length density limits role in K acquisition.

STEP 2. SOIL CEC CLASS

- ***CEC low … <5 cmol(+)/kg***. Limited ability to retain applied K on exchange complex. Leaching risk in high rainfall/irrigated situations. Low K buffering and efficient diffusion means small K applications can be used very efficiently.
- ***CEC moderate … 5-15 cmol(+)/kg.*** Reasonable retention capacity for applied K, with limited risk of leaching loss. Some K buffering but diffusion still quite rapid in most situations. Larger, less frequent K applications still recovered efficiently, but may result in luxury uptake and accelerated removal in forages and sugarcane.
- ***CEC high … 15-30 cmol(+)/kg.*** Large retention capacity for applied K and no leaching risk. Increasing K buffer capacity and less efficient diffusion process will slow the rate of recovery of applied K and reduce risk of accelerated removal rates.
- ***CEC very high … >30 cmol(+)/kg.*** Very large retention capacity for applied K and no leaching risk. High K buffer capacity and relatively inefficient diffusion process will dramatically slow the recovery of applied K.

STEP 3. K FIXATION INDICES FOR EACH SOIL CEC CLASSES

- ***CEC low … <5 cmol(+)/kg***. Low clay content or low activity clays and greater reliance on organic matter for cation retention. K fixation index typically low.
- ***CEC moderate … 5-15 cmol(+)/kg.*** Increasing clay content increases the possibility of significant K fixation. Extent determined by mineralogy.
- ***CEC high … 15-30 cmol(+)/kg.*** Typically high clay contents and potential for significant K fixation. Extent determined by mineralogy.
- ***CEC very high … >30 cmol(+)/kg.*** High clay contents with large proportions of reactive clays (high charge density), but extent of fixation determined by mineralogy. Important to distinguish between K fixation and strong K buffer capacity.

IMPLICATIONS FOR APPLICATION STRATEGY

CEC < 5

- Non fixing: All strategies effective. Small rates, frequently.

CEC 5-15

- Non fixing: All strategies effective. Less frequent applications with higher rates may accelerate K removal.
- Fixing: Reduce volume fertilized? Apply more frequently, but high rates may be used inefficiently.

CEC 15-30

- Non fixing: Reduce volume fertilized or increase rates. Co-locate nutrients for root proliferation?
- Fixing: Banding increasingly effective, but root proliferation needed. Apply K to maintain fixn – release balance.

CEC > 30

- Non fixing: Maintain K status where possible. Banding most effective, but co-location essential.
- Fixing: Banding and nutrient co-location essential. Apply K to maintain fixn – release balance.

CONCLUSIONS

- Effective application strategies require a coincidence of K-enriched soil with a significant proportion of the active root system.
- The same K rate and application method will vary in effectiveness between soil types, so a clear understanding of the soil and climatic factors at each site are important.
- Better quantification of the plant-available K pool, and the ability of a soil to retain applied K in that pool, are needed to improve K application guidelines.
- Particular challenges exist in developing effective K application strategies for soils with high K buffer capacities and where there is limited ability to predict the dynamics of K fixation and release.
- A better understanding of species (and genotype?) response to K-rich patches, and to collocation of K with other nutrients to encourage root proliferation, are required.

ACKNOWLEDGEMENTS

- We would like to thank IPNI for their role in promoting this international K initiative, and for supporting this conference and subsequent activity.
- We acknowledge the support of our respective host organizations, and the funding support of the agricultural industries in our respective home countries.
- We look forward to a resurgence in interest in K nutrition, and to opportunities to collaborate with participants internationally to advance the cause of efficient and effective K management in sustainable agricultural systems.

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