Implications of minimum till dryland cropping systems for diagnostic P and K soil tests

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Abstract
Dryland broadacre cropping systems on Vertosols in northern Australia are presenting challenges to diagnostic soil testing methodologies. Because water availability is often limited in the surface soil during the growing season, the P and K status of the 0.10-0.30 m layer needs to be assessed to determine the likely availability of these nutrients to meet crop growth requirements, especially during peak growth periods pre- and post-anthesis. Furthermore, the widely adopted commercial soil tests do not appear to be appropriate to assess the P or K status of these soils because they are not correlated with the slow release nutrient pools (i.e. with acid-extractable P or tetraphenyl borate-extractable K). Re-assessments of soil sampling depth and soil P and K tests are necessary to develop diagnostic tools that are applicable to these soils and cropping systems.

Key Words
Soil sampling depth, Vertosols.

Introduction
Stubble retained systems are becoming the norm for broadacre grain cropping in the subtropics and dry tropics of northern Australia. This is because minimum or zero tillage systems improve water use efficiency by reducing runoff and erosion and effectively store subsoil moisture for subsequent use by the crop.

Minimum or zero tillage contrasts to the conventional tillage practices under which P and K soil tests were calibrated against grain yield in the 1970s and 1980s to serve as diagnostic indicators of the need for fertilisers. Conventional tillage regularly re-distributed nutrients through the plough zone and diagnostic soil samples were taken from 0-0.10 m to assess soil nutrient status. It is likely that with continued minimum or zero tillage systems, nutrient stratification will occur in the surface few centimetres, and the availability of these nutrients to the crop is then dependent on this zone retaining sufficient plant available water to allow active root growth. Modelling of plant available water during the growing season using long term weather data indicates that the 0-0.15 m soil layer is drier than the lower limit for 14-51% of the post-anthesis sorghum period and 17-65% of the post-anthesis wheat period. Similar regional variability is evident in the pre-anthesis period for both crop seasons, but soil moisture status is higher. These results indicate that, following establishment, the crop is likely to be dependent on soil nutrient reserves below 0.10 m for a substantial proportion of the growing season. This observation is supported by soil P data from a Vertosol at Colonsay in south-eastern Queensland following prolonged dryland cropping (Wang *et al*. 2007). Without P fertiliser addition, continuous cropping caused a decline of 55%, 35% and 10% in total P from the 0-0.10, 0.10-0.30 and 0.30-0.60 m layers respectively, compared to an uncropped reference soil.

For broadacre, dryland grain cropping, the Colwell (1963) soil test (0.5 M $NaHCO_3$ extractant; soil:extractant 1:100; extraction period 17 h) is generally used as a diagnostic soil test to determine whether or not soil P is adequate (Moody and Bolland 1999). However, at the Colonsay site, sequential extraction of the soil P with a range of extractants (Guppy *et al*. 2000) indicated that the greatest decrease in soil P in the 0.10-0.30 m layer due to cropping occurred in the M HCl extractable fraction, not the bicarbonate extractable fraction. These results raise doubts about the efficacy of the Colwell soil test to adequately reflect the availability of subsurface P under conditions where acid-extractable P is making a large contribution to available P. A similar situation applies to the assessment of K availability. While exchangeable K is generally used to identify K-responsive soils, K-depletion glasshouse experiments indicated that the amounts of K taken up by successive crops growing in Vertosols were better correlated with changes in tetra-phenyl borate extractable K (TB-K) than changes in exchangeable K (Moody and Bell 2006). Available soil K reserves are therefore not being assessed by the exchangeable K method.

In dryland wheat, P supply prior to anthesis sets yield potential, but realisation of this yield is dependent on the crop accessing further P after anthesis (Fischer 1979). Given that the above findings indicate a major source of this post-anthesis P (and probably K) supply is obtained from deeper than 0.10 m, it is apparent that basing soil fertility assessment solely on the 0-0.10 m layer is questionable. Also questionable is the usefulness of a bicarbonate soil test for assessing available P when acid-extractable P appears to be a major source. Likewise, exchangeable K may not be the appropriate diagnostic soil test in soils such as Vertosols which often have considerable TB-K reserves.

This paper presents data on the stratification of P and K in grain cropping soils of northern Australia and the relationship between Colwell-P and acid extractable P and between exchangeable K and TB-K in these soils. The implications of these data for diagnosing the need for P and K fertilisers is discussed with reference to an appropriate soil sampling depth and an appropriate soil test.

Methods

Soil sampling and analyses

Soil samples (0-0.10 m or 0-0.15 m) were collected from 169 sites from the northern grains region of Australia which occupies approximately 4 Mha across northern New South Wales, southern and central Queensland. The soils comprise Vertosols, Chromosols and Sodosols (Isbell 1996). Soils were analysed for Colwell-extractable P, acid-extractable P (0.005 M H_2SO_4), and M NH_4Cl exchangeable K (Methods 9B2, 9G2 and 15A1, respectively: Rayment and Higginson 1992). Tetra-phenyl borate extractable K was determined using the method of Carey *et al*. (2000) with a 1 h extraction period. In addition, 15 cropped and uncropped paired sites on Vertosols were identified in this suite and 0.10-0.30 m samples from these sites also analysed by the above methods.

Stratification Index

A stratification index for Colwell-P, Acid-P and exchangeable K was calculated as the soil test value (0-0.10 m)/ soil test value (0.10-0.30 m).

Results and Discussion

Nutrient stratification

Colwell-P, Acid-P and exchangeable K were all stratified, with Colwell-P showing the greatest tendency for this (Table 1).

Table 1. Stratification index [value (0-0.10 m)/value (0.10 m-0.30 m)] for extractable P and K in some Vertosols of northern Australia.

	Median	**Range**
Colwell-P (mg/kg)	2.5	1.7-5.0
Acid-P (mg/kg)	1.6	1.0-4.0
Exchangeable K (cmol(+)/kg)	2.1	1.3-3.3

The pronounced stratification confirms that P and K tend to accumulate in the surface 0.10 m, presumably as a result of nutrients being cycled by the plant via subsoil absorption to deposition on the soil surface as plant residues. The 0-0.10 m layer is the standard soil sampling depth used to assess soil P and K sufficiency in the grains industry. It is apparent that analysing this soil layer would generally over-estimate the available P and K content of deeper soil layers, yet it is these layers that are likely to be a major source of available nutrient to the crop during significant proportions of cropping seasons.

The importance of subsurface P and K supply to dryland cropping of these soils has implications for fertiliser placement. While starter P (and K) fertiliser application at sowing will assist the crop to rapidly develop a root system, it is likely that this nutrient source will become inaccessible when the surface soil dries out. Complementary deeper application of fertiliser will also be necessary when P and/or K status of the subsoil is not sufficient to meet crop demands. Yield responses to deep fertiliser application have been obtained by Singh *et al*. (2005) in this environment.

Correlation between soil tests

Across both sampling depths there was no correlation between Colwell-P and Acid-P ($r = 0.35$; $P > 0.10$). This lack of correlation is highlighted by the Acid-P to Colwell-P ratio in the 0.01-0.30 m layer ranging from 1.5 to 82.5. Some of the soils had large amounts of Acid-P despite Colwell-P values being rated as very low. For example one soil from Clermont had 6 mg/kg Colwell-P and 495 mg/kg Acid-P in the 0.10-0.30 m layer. Data cited above from the Colonsay site show that acid extractable P is plant available, so although the Colwell-P value for the Clermont site suggests that site might be P-deficient in the subsoil, the Acid-P indicates a contrary conclusion.

There was no correlation between exchangeable K and 'apparent slow release K' (calculated as TB-K minus exchangeable K) and some soils had 4 times more slow release K than exchangeable K (Figure 1). Therefore, for both P and K, the current diagnostic soil test does not give an indication of nutrient reserves; nor can it be used to estimate the reserves.

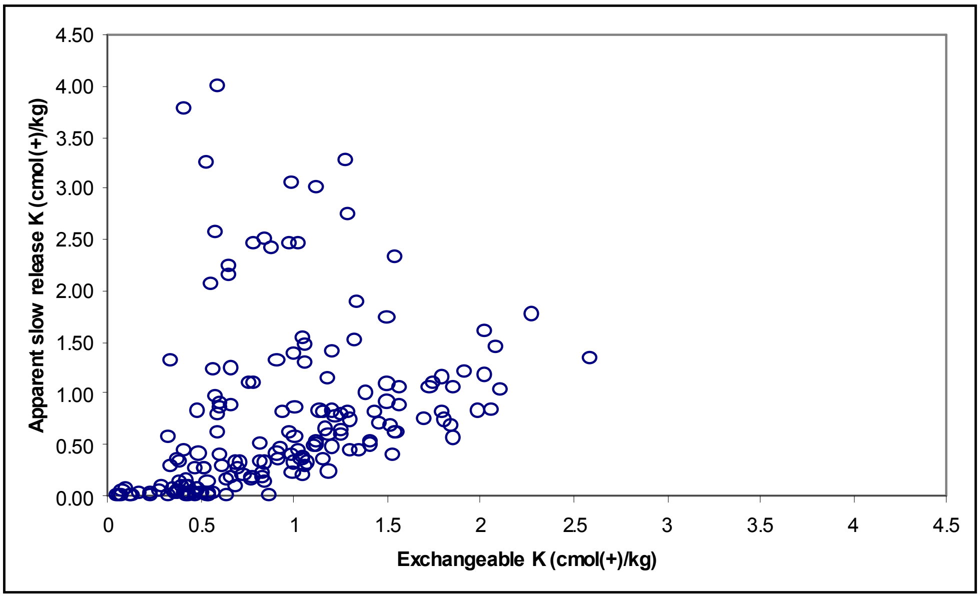

Figure 1. Variation in exchangeable K and apparent slow release K for soils of the northern grains region.

Conclusion

Dryland broadacre cropping systems on Vertosols in northern Australia are presenting challenges to diagnostic soil testing methodologies. It is apparent that the P and K status of the 0.10-0.30 m layer needs to be assessed to determine the likely availability of these nutrients to the crop post-anthesis. Furthermore, the widely adopted Colwell-P and exchangeable K soil tests do not appear to be appropriate to assess the P or K status of these soils because they are not correlated with the slow release P and K pools in these soils. Re-assessments of soil sampling depth and soil P and K tests are necessary to develop diagnostic tools that are applicable to these soils and these cropping systems.

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