Improving fertiliser management: Redefining soil test-crop response relationships for canola in Western Australia

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KEY MESSAGES

Derived critical Colwell soil test values (mg/kg) of 52 for K and 25 for P in the top 10 cm of soil adequately indicated when canola crops were likely to respond to fertiliser K and P applications on most soils in the region.

However, for some soil types or soil type/climate situations further testing of the 10–20 and 20–30 cm horizons may also be required when the top 10cm soil test values are marginal to more accurately indicate the likelihood of canola responses to fertiliser K and P applications.

For sulphur the derived critical KCl_{40} soil test value was 10 mg/kg in the top 10 cm of soil. In sandy duplex soils further testing of the subsoil horizons was required when the soil S test value fell below this critical value, However, grain yield responses to applied fertiliser S were unlikely if the soil S test value in either of these two lower horizons was above the critical value.

AIMS

Canola (*Brassica napus*) has become a major crop grown in rotation with spring wheat and lupins in Western Australia (WA) since the mid 1990s. Most soils in WA are highly weathered with very low levels of phosphorus (P). The WA soils initially contained adequate indigenous soil potassium (K) for cropping but removal of K over time in the harvested grains has gradually resulted in the some soils becoming deficient in K for grain production. The sulphur (S) status of WA soils was maintained when single superphosphate (containing about 11 per cent S) was widely used as P fertiliser. The increased and widespread use of fertilisers containing lower S levels than single superphosphate, such as DAP and MAP is likely to increase S deficiency in canola. Furthermore, S deficiency has more frequently been identified in canola crops (compared with wheat and lupins). Consequently fertilisers containing P, K and S are now applied to most canola crops.

Fertiliser costs represent a significant part of the variable costs of growing crops in WA. Chen et al. (2009) identified the need for improved soil test interpretation for making fertiliser recommendations due to substantial changes in farming systems, fertiliser practices and crop yield potential since earlier calibrations were developed. The aims of this study were (1) to compile experimental data containing the standard soil test measurements and observed canola crop yield responses for both nil and fertilised treatments across different soil types and seasons from published or unpublished sources, and (2) to critically analyse soil test-crop response relationships to derive better critical soil test values in soils and environments suitable for canola grain production in WA.

METHOD

Data from experiments on the application rates of P, K and S across different sites, locations and years were collected from published and unpublished DAFWA sources (Table 1). Most experiments were conducted during 1993–2005 so should be relevant for the current cropping systems. The sites chosen for the experiments represent the major soil types used for canola production in WA.

The relationship between the measured yield increase to an applied nutrient at a range of the soil test value and experimental sites is analysed to derive critical soil test value for a specific crop type. In this study, relative crop yield (as a per cent of maximum) was used to estimate yield responsiveness to reduce variations in yield response to applied nutrient between sites and seasonal conditions, and was calculated using the following equation:

$$\% \text{ Relative Yield} = 100 \times (\text{Yield of unfertilised treatment } (Y_0) / \text{maximum yield obtained } (Y_{max})$$

Table 1 **Summary of the datasets used for analysing soil test-crop response relationships and deriving critical soil test values**

Nutrient	Standard soil test	Number of experiments	Sources
K	Colwell K	131	Brennan and Bolland 2006a; Brennan and Bolland 2007a; Brennan unpublished data
P	Colwell P	31	Brennan and Bolland 2007b; Brennan unpublished data
S	KCl_{40} S	104	Brennan and Bolland 2006b; Brennan and Bolland 2008; Brennan unpublished data

Historically, several yield response functions (linear-linear, linear-plateau and Mitscherlich) have been used to fit relationships between % relative yield and soil test value. The Mitscherlich model used was:

$$Y=A\,[1-Be^{-cx}]$$

where Y is the predicted relative yield (%), A is the maximum attainable yield (%), B is the yield response relative to A, c estimates rate at which the curve approaches the maximum yield plateau, and x is the soil test value. The model was fitted using GenStat 12. For each nutrient, the critical value was calculated based on the soil test values (0–10 cm) correspond to 95 per cent of the maximum predicted relative yield increase and its standard deviation was also calculated. The critical value is defined as the critical soil test value below which deficiency is likely to reduce crop grain yield.

RESULTS

For K, the critical level for Colwell soil K test was 52 mg/kg (Table 2 and Figure 1). This value could be used to determine K deficiency or sufficiency for canola grain production using the top 10 cm soil test in most soils.

Table 2 **Critical soil test P, K and S values determined for canola grain production using the Mitscherlich equation**

Nutrient	R^2 [A]	N [B]	Soil test Critical value (mg/kg)	Standard deviation
K	0.68	131	52	2.6
P	0.81	31	25	5.3
S	0.15	104	10	1.3

[A] R^2 is the coefficient of determination for the Mitscherlich model.

[B] N is the number of observations used to fit the model.

However, further analyses of the relationship between relative grain yield response and profile soil K distribution down to 30 cm (data not shown) indicated that in the experiments where the surface soil K test values (40–50 mg/kg) were close to the critical level, K deficiency or sufficiency could only be determined if the sub-soil K test values were also taken into account (Figure 1). Identifying soil types and better quantifying the relationship between soil K profile distribution and other soil properties in the landscape where above experiments were located, would be useful to improve current K management practices through development of deep soil sampling and improved current soil test interpretations.

For the soils with adequate capacities to retain applied P near to where the fertiliser was applied in the topsoil and negligible leaching of P down the profile, soil test P for the top 10 cm of soil provides a good indication of likely deficiency or sufficiency of soil P for canola grain production. For these soils, critical Colwell soil test P was 25 mg/kg (Table 2 and Figure 2).

However, in few soil type/climate situations (deep sandy soils located in medium or high rainfall zone), the sub-soil soil test P values also needed to be taken into account in order to accurately determine P deficiency or sufficiency for canola grain production (Figure 2).

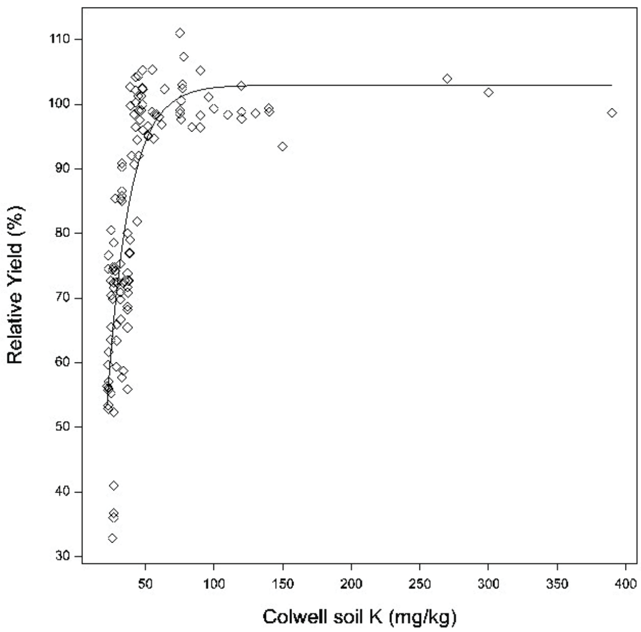

Figure 1 **Canola grain yield response to Colwell soil K (0–10 cm) for all experiments (across different sites and years) fitted by the Mitscherlich model. The solid line was the fitted line from the model.**

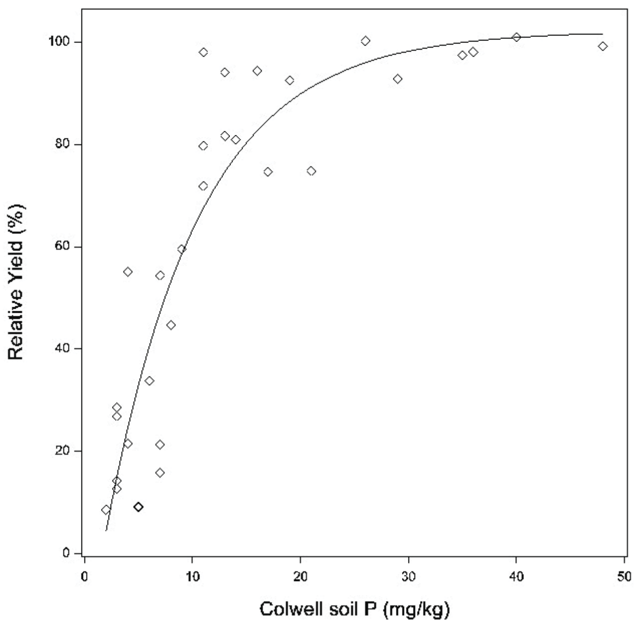

Figure 2 **Canola grain yield response to Colwell soil P (0–10 cm) for all experiments (across different sites and years) fitted by the Mitscherlich model. The solid line was the fitted line from the model.**

The derived critical level for KCl_{40} soil S test for canola was 10 mg/kg (Table 2 and Figure 3). However this value could only be used as general guideline because S deficiency or sufficiency could be predicted accurately only in half of the experiments where the surface soil S test was below the critical level of 10 mg/kg (Figure 3). These non-responsive experiments were located on sandy duplex soils where the soils could have high soil S test values down the profile due to the increase of clay and iron and aluminium contents with soil depth and thus increased capacity of the soils to retain sulphate in the sub-soil layers still explored by canola roots. Rather than only sampling the top 10 cm, deeper soil sampling to 30 cm would improve the ability of soil S testing to indicate the likelihood of S deficiency or sufficiency in soils for canola grain production.

CONCLUSION

The derived critical Colwell soil test values (mg/kg) for the top 10 cm of soil were 52 for K and 25 for P and for most soils, these values can be used to determine deficiency or sufficiency of K and P. However, in certain soil type or soil type/climate situations, in order to accurately determine whether canola crop would respond to K and P fertiliser applications, the soil test values in the sub-soils (10–20, 20–30 cm) also need to be taken into account.

For sulphur, the derived critical level for the KCl_{40} soil S test was 10 mg/kg. However this value could only be used as general guideline. In sandy duplex soils where the surface soil S test was below the critical level, the sub-soil soil test values need to be taken into account in order to accurately interpret the critical level.

This study also highlights the need to develop deep soil sampling guidelines together with better interpretation of the topsoil and subsoil soil test values to improve current fertiliser advice for canola grain production.

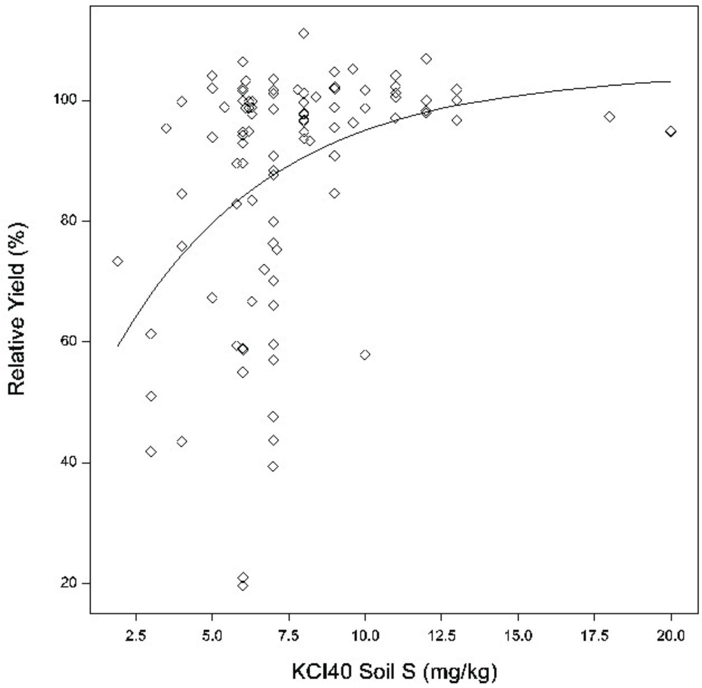

Figure 3 **Canola grain yield response to KCl_{40} soil S (0–10 cm) for all experiments (across different sites and years) fitted by the Mitscherlich model. The solid line was the fitted line from the model.**

KEY WORDS

phosphorus, potassium, sulphur, critical level

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