# Improving fertiliser management: redefining the relationship between soil tests and crop responses for wheat in WA

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## Key Messages

- The derived critical level for the Colwell soil phosphorus test for wheat increases with the clay content of the soil being tested.
- In soil types with less than 5% clay the critical level for the Colwell-soil phosphorus test for wheat was 21 mg/kg, while for soil types with more than 5% clay the critical level was 35 mg/kg. More research is needed to refine the relationship between the critical test value for Colwell soil phosphorus and the level of soil phosphorus adsorption across different soil types in WA.
- For wheat crops grown on non-duplex soils, the derived critical value for the Colwell soil potassium test was 80 mg/kg. More research focussing on sub-soil potassium is needed to define the critical values for the Colwell soil potassium test on duplex soils.

## Background and Aims

Most soils in Western Australia (WA) are highly weathered with very low levels of phosphorus. WA soils initially contained adequate indigenous soil potassium for cropping but removal of potassium over time in harvested grain has gradually resulted in the some soils becoming potassium-deficient for grain production.

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crop yield responses for both nil and fertilised treatments across different soil types and seasons from published or unpublished sources, and (2) to critically analyse soil test-crop response relationships to derive better critical soil test values in soils and environments suitable for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

## Methods

### Database

Data were obtained from 266 phosphorus experiments carried out between 1966 and 1999. The data set was divided into the two periods:

- First period - 160 experiments over the period 1966 to 1979
- Second period - 106 experiments over the period 1980 to 1999

Over the second period only, soils were identified using the WA soil classification system.

A database of 109 experiments was developed by compiling data from DAFWA potassium fertiliser experiments between 1988 and 2002.

### Data analysis

A soil test calibration for a specific crop type is the relationship between the measured yield to an applied nutrient at a range of experimental sites and the soil test value for each trial site. In this study, relative crop yield was used to estimate yield responsiveness to reduce variations in yield response to applied nutrient due to site and seasonal conditions, and was calculated using the following equation:

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

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:

$$Y = a - be^{-cx}$$

Where y is relative yield; a, b, and c are constants; and x is Colwell-P or Colwell-K soil test. For each nutrient, the critical value was calculated based on the soil test values (0-10 cm) corresponding to 95% of the maximum predicted relative yield. The critical value is defined as the critical soil test value below which deficiency is likely to reduce crop grain yield.

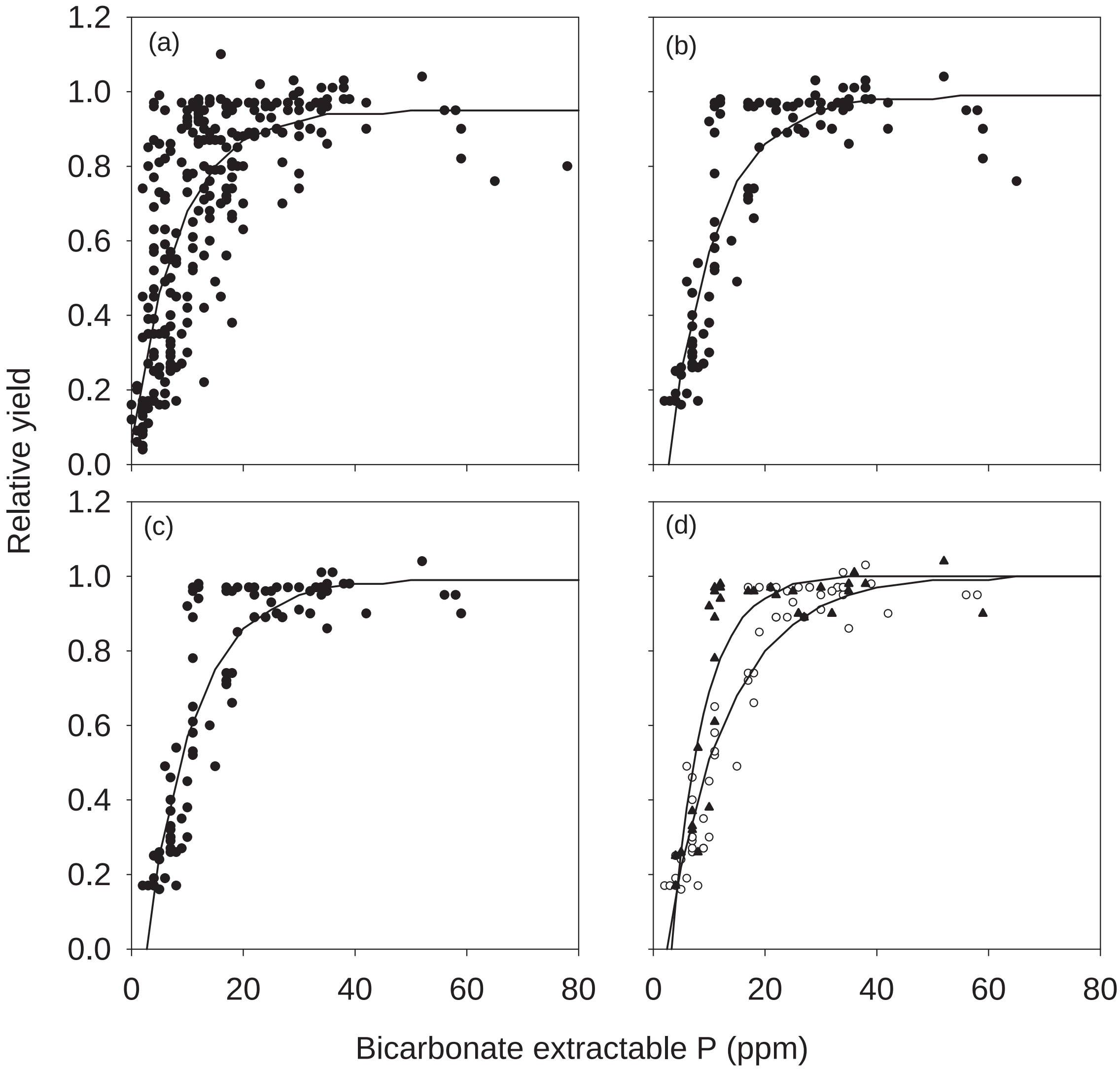


**Figure 1. Mitscherlich regression lines fitted to (a) the whole data set (b) experiments carried out since 1980, (c) experiments carried out since 1980 with acid sites removed and (d) experiments carried out since 1980 on grey sand (▲) and other soils (○) with acid soil sites removed.**

## Results

### Phosphorus

The calibration relationship between relative yield and Colwell soil phosphorus test (Figure 1a and Table 1) was poor when the regression was fitted to all data. However, when the data from experiments carried out before 1980 were removed (due to insufficient soil information), the relationship improved significantly (Figure 1b and Table 1). The derived critical level for the Colwell soil phosphorus test for wheat across all 106 trials was 29 mg/kg (Table 1).

The critical level also varied depending on soil groups (Figure 1d and Table 1). For grey sands (less than 5% clay) the critical level for the Colwell soil phosphorus test for wheat was 21 mg/kg, while for soils with more than 5% clay the critical level was 35 mg/kg (Table 1).

Table 1. Summary of Colwell-soil P test calibrations for wheat

| Experiments | Number of observations | $r^2$ | Soil test critical level (mg /kg) |
|---|---|---|---|
| All experiments | 266 | 0.00 | - |
| Post-1980 experiments | 106 | 0.81 | 29 |
| Grey sand or soils with < 5 %clay | 38 | 0.73 | 21 |
| Other soils or soils with > 5 % clay | 60 | 0.90 | 35 |

### Potassium

Across all experiments, the Colwell soil potassium test was not related to relative wheat yield (Figure 2a). There was a small improvement in the calibrations when the data on low nitrogen treatments were removed (Figure 2b). When the data were separated according to soil type, there was a significant relationship between the Colwell soil potassium test and relative wheat yield (Figure 2d). For wheat crops grown on soil types other than duplex soils, the derived critical level for wheat was 80 mg/kg (Table 2).

Table 2. Summary of Colwell-soil K test calibrations for wheat

| Experiments | Number of Observations | $r^2$ | Soil test critical level (mg/kg) |
|---|---|---|---|
| All experiments | 152 | 0.00 | |
| Minus low N treatments | 113 | 0.25 | |
| Soil type | | | |
| Duplex soils | 42 | 0.00 | |
| Soils other than duplex soils | 71 | 0.54 | 80 |

## Conclusion

The derived critical level for the Colwell soil phosphorus test for wheat across all 106 trials was 29 mg/kg. However, the critical levels varied depending on soil type (due to the differences in soil phosphorus adsorption). For the soil types with < 5% clay, the critical level for Colwell-soil phosphorus test for wheat was 21 mg/kg, but for soil types with > 5% clay, the critical level was 35 mg/kg. More trials are needed to refine the relationship between critical Colwell soil phosphorus test value and soil phosphorus adsorption across different soil types.

For wheat crops grown on soil types other than duplex soils, the derived critical value for Colwell soil K test was 80 mg/kg. For duplex soils, most Colwell K values were < 50 mg/kg, but yield ranged from 20-100 % of maximum with these low K values. More research on crop response in relation to sub-soil K levels is needed to develop critical values for Colwell soil K test for duplex soils.

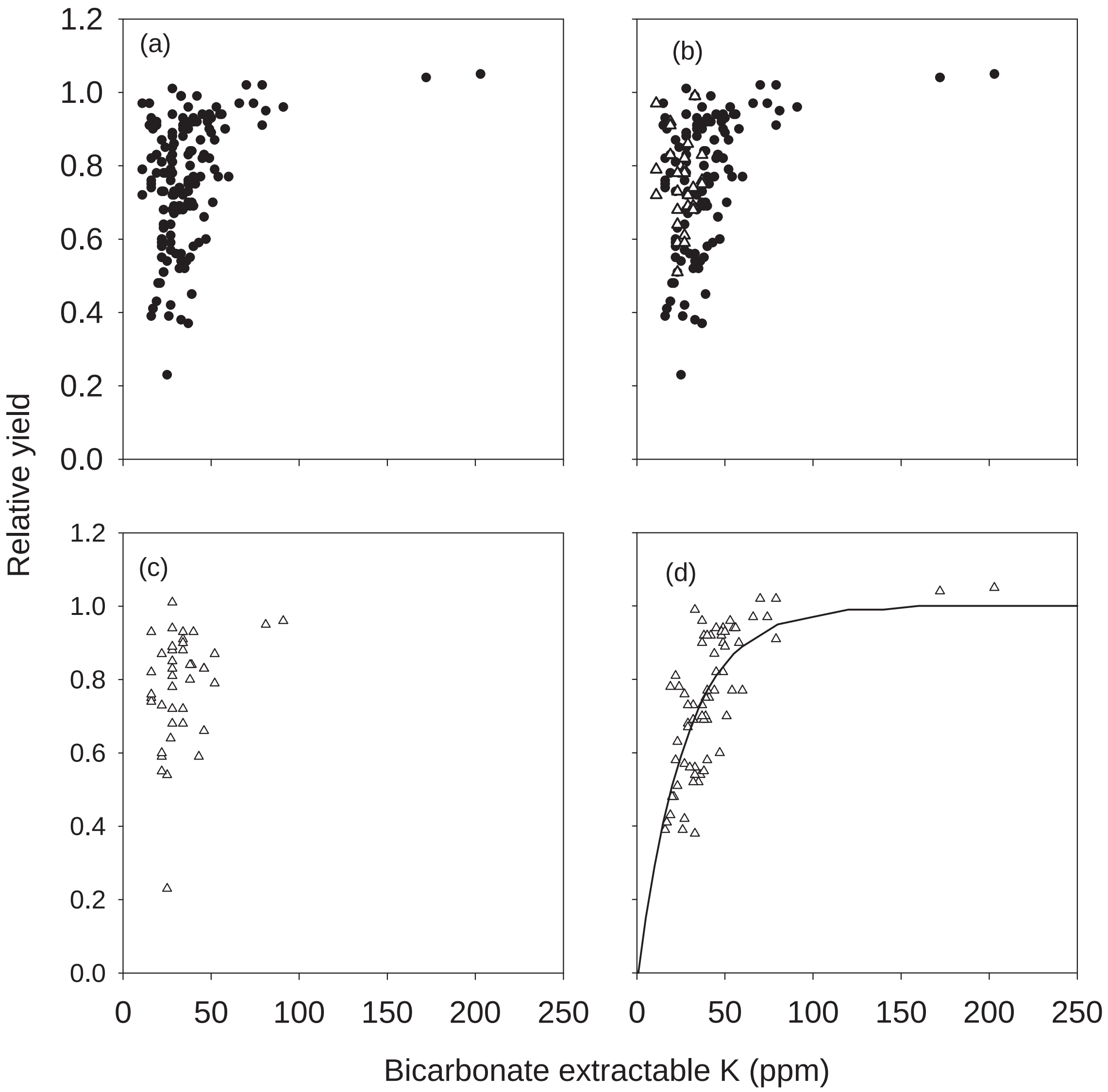


Figure 2. Mitscherlich equation fitted to (a) the whole data set (b) the whole data set with low nitrogen rates (Δ) removed, (c) duplex soils and (d) soils other than duplex soils.

## Key Words

Phosphorus, potassium, critical level, crop nutrition


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