Critical values for soil P, K and S for near maximum wheat, canola and lupin production in Western Australia

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KEY MESSAGES

Soil test P, K and S – yield response relationships for wheat, lupin and canola can be used to make better fertiliser decisions. Soil test using 0-10 cm soil samples provided reliable predictions of yield response to P when separated into soil types with different P sorption capacities. In contrast, soil sampling to 30 cm depth improved wheat and canola yield response prediction with the K soil test when the impact of soil acidity and potential yield on root distribution was taken into account. The deeper soil sampling to 30 cm improved the relationship for S canola but not for wheat where rate of S leaching and potential yield appear to be important. The N soil test-response relationships for wheat and canola were not significant and critical values could not be defined.

AIMS

The aim of this paper is to define the soil test–grain yield response relationships for P, K, S and N with wheat, canola and lupin grown in WA.

METHOD

Data base

A data base of 1824 fertiliser experiments conducted by the Department of Agriculture and Food (DAFWA) was developed. All data accepted in the database met rigorous quality assurance criteria. Since minimum tillage practices are currently used in WA, only trials conducted post 1990 were selected to define the soil test – crop response relations. The exception was when the data base was small, for example K soil test – lupin response where all years were included in the analysis. This limited the analysis to 1237 experiments. Soil types were separated into grey sands, coloured (yellow, brown and red) sands, gravels, duplexes and loams. The data are available on the web as an interactive data base “Making Better Fertiliser Decisions for Cropping Systems in Australia Interrogator” (www.bfdc.com.au).

Soil test measurements

Techniques used to measure plant available nutrients in Western Australia are; soil P test or bicarbonate extractable P (Colwell P), soil K test or bicarbonate extractable K (Colwell K), soil S test or KCl-40 extractable S and soil N test or KCl extractable nitrate and ammonium (Rayment and Lyons 2010). Other soil measurements undertaken to improve nutrient assessment of the soils include soil pH, total carbon content, clay content and P sorption capacity. Various P sorption measurements have been conducted and include reactive iron, phosphorus retention index (PRI) and phosphate buffer index (PBI).

Sampling layer

Soil samples were collected prior to conducting the experiments. The surface sampling layer was to 10 cm depth, except for N experiments where the surface sampling layer was to 15 cm. Additional deeper soil samples were collected for many sites. The most commonly used sub-soil sampling depth was to 30 cm for K, S and some P experiments and to 45 cm for N experiments. For the 0-30 cm layer, concentration was calculated by averaging the concentration of the 0-10, 10-20 and 20-30 cm soil layers. Soil N supply was calculated as amount of N extracted by soil test to depth of 45 cm plus predicted growing season N mineralisation based on levels of soil organic N (Anderson, unpublished data). The root distribution weighting approach of Wong et al. (2000) was used to examine the impact of root distribution on availability of soil K to wheat and canola.
to a depth of 30 cm. The root distribution was slowed when the 0-10 cm soil layer pH was less than 5.5 and 10-20 cm layer pH was less than 4.5 and also when the wheat grain yield was less than 1.5 t/ha.

**Soil test – crop response relationships**

Nutrient rate experiments were conducted to derive crop grain yields (t/ha). Fertiliser rates used and the number of rates applied varied widely among the experiments. The data base mainly contains multiple nutrient rate treatments which generally produced a yield plateau to provide the most accurate assessment of maximum yield. Percentage of maximum grain yield (PMY) was calculated by dividing the yield obtained for the nutrient rate used by the maximum yield observed among the nutrient rate treatments. In some experiments, the maximum yield was observed for the nil rate treatment. By definition, for each trial maximum percent yield is 100. This approach allows comparison of across experiments on different soil types and under different seasonal conditions that produce differences in maximum crop grain yield.

Soil test values were plotted on the x axis and PMY was plotted on the y axis. Critical soil test levels were calculated to correspond to 95% PMY. The critical range around the critical value was calculated from the standard errors associated in defining the 95% PMY.

**RESULTS**

**P**

Critical soil test P value for crops (wheat, canola and lupin) differed among soil types (Table 1) due to differences in P sorption properties. For wheat, on grey sands, it was 15 mg/kg (critical range 12-17 mg/kg) and for other soils it was 29 mg/kg (critical range 28-31 mg/kg). The critical canola soil P test value was 20 mg/kg (critical range 17-25 mg/kg) across a wide range of soil types. The critical lupin soil P test for grey sands was 14 mg/kg (critical range 11-16 mg/kg) and for yellow sands it was 24 mg/kg (critical range 18-30 mg/kg).

**K**

When using the 0-10 cm samples, the soil K test - wheat grain yield response relationship was poor, when data was pooled across all soil types (Table 1). In contrast, the soil K test – canola yield response relationship defined a critical value of 57 mg/kg (critical range 53-61 mg/kg). The relationship for wheat was improved when soils were separated into different soil types. Grey sands had lower critical values of 32 mg/kg (critical range 17-47 mg/kg) compared to yellow sands, gravels and loams, with defined critical value of 59 mg/kg (critical range 44-74 mg/kg). Duplex soils had a poor relationship and the critical value was 53 mg/kg with a large critical range of 43-63 mg/kg. The relationship for lupin grown on grey sands defined a critical value of 27 mg/kg (critical range 23-30 mg/kg).

When using the 0-30 cm sampling depth (mg/kg), the soil K test - wheat grain yield response relationship was also poor (Table 1). In contrast, the soil K test – canola yield response relationship defined a critical value of 39 mg K/kg (critical range 37-41 mg K/kg). Application of the Wong et al. (2000) root distribution approach improved the relationships when the rate of root growth was decreased due to soil acidity and low yield potential. The weighted critical soil K test for wheat (0-30 cm) was defined as 32 mg/kg (critical range 29-35 mg/kg) and for canola was defined as 40 mg/kg (critical range 36-44 mg/kg).
Table 1. Critical Colwell P, Colwell K and KCl40-S values, critical ranges and regression coefficients for soil test – crop response relationships by nutrient, crop, soil type and soil depth.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Crop</th>
<th>Soil depth</th>
<th>Soil type</th>
<th>No of experiments</th>
<th>Critical values(^D) (mg/kg)</th>
<th>Critical ranges(^E) (mg/kg)</th>
<th>(r^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Wheat</td>
<td>0-10 cm</td>
<td>Grey sands</td>
<td>22</td>
<td>15</td>
<td>12-17</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-10 cm</td>
<td>Other soils(^B)</td>
<td>67</td>
<td>29</td>
<td>26-31</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>Canola</td>
<td>0-10 cm</td>
<td>All</td>
<td>31</td>
<td>20</td>
<td>17-25</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>Lupin</td>
<td>0-10 cm</td>
<td>Grey sands</td>
<td>22</td>
<td>14</td>
<td>11-16</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-10 cm</td>
<td>Yellow sands(^C)</td>
<td>46</td>
<td>24</td>
<td>18-30</td>
<td>0.89</td>
</tr>
<tr>
<td>K</td>
<td>Wheat</td>
<td>0-10 cm</td>
<td>All</td>
<td>139</td>
<td>na</td>
<td>na</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-10 cm</td>
<td>Grey sands</td>
<td>13</td>
<td>32</td>
<td>17-47</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-10 cm</td>
<td>Yellow sands, gravel, loams</td>
<td>76</td>
<td>59</td>
<td>44-74</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-10 cm</td>
<td>Duplex</td>
<td>48</td>
<td>53</td>
<td>43-63</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-30 cm</td>
<td>All</td>
<td>108</td>
<td>na</td>
<td>na</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-30 cm(^C)</td>
<td>Yellow sands, Duplex</td>
<td>33</td>
<td>32</td>
<td>29-35</td>
<td>0.57</td>
</tr>
<tr>
<td>Canola</td>
<td>0-10 cm</td>
<td>All</td>
<td>130</td>
<td>57</td>
<td>53-61</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-30 cm</td>
<td>All</td>
<td>100</td>
<td>39</td>
<td>37-41</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-30 cm(^C)</td>
<td>All</td>
<td>127</td>
<td>40</td>
<td>36-44</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>Lupin</td>
<td>0-10 cm</td>
<td>Grey sands</td>
<td>22</td>
<td>27</td>
<td>23-30</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Wheat</td>
<td>0-10 cm</td>
<td>All</td>
<td>70</td>
<td>na</td>
<td>na</td>
<td>0.00</td>
</tr>
<tr>
<td>Wheat</td>
<td>0-30 cm</td>
<td>All</td>
<td>70</td>
<td>na</td>
<td>na</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Canola</td>
<td>0-10 cm</td>
<td>All</td>
<td>130</td>
<td>na</td>
<td>na</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Canola</td>
<td>0-30 cm</td>
<td>All</td>
<td>130</td>
<td>9</td>
<td>8-10</td>
<td>0.41</td>
<td></td>
</tr>
</tbody>
</table>

\(^A\) weighted for root distribution with units in mg/kg, \(^B\) other soils - yellow, red and brown sands, loams, clays and duplex soils, \(^C\) yellow sands with PRI=1, \(^D\) Soil test value (mg/kg) at 95% of predicted maximum grain yield, \(^E\) 95% chance that this range covers the critical soil test value, na not available.

S

The soil S test - grain yield response relationship was poor for both wheat and canola and critical levels could not be defined with the 0-10 cm soil samples. Better fits for the soil S test values for canola were obtained by averaging the extractable soil S content to 30 cm depth. The critical level for canola was 9 mg S/kg (critical range 8-10 mg S/kg). There are only 7 lupin fertiliser experiments in the data base with only one responsive site which had an extractable S level of 3.7 mg S/kg (data not presented).

N

The inorganic N soil tests using both the 0-10 and 0-45 cm sampling layers – for both wheat and canola grain yield response relationships - were poor (data not presented). Soil N supply or soil profile N plus predicted N growing season mineralisation better predicted wheat grain yield response when sites were separated by rainfall zones and soil types. However, the regression coefficients for soil N – crop yield relationships were all less than 0.25. Nevertheless, some sites with N supply of 102-106 kg/ha were able to produce 4.0 t wheat/ha within the 275 to 375 mm rainfall zone.

CONCLUSION

Phosphorus sorption has a large impact on the availability of soil P to crops (Helyar and Spencer 1977). Within the wheat and canola data base, there was limited availability of P sorption data and only PRI was recorded in the lupin data base. As a result, soil type was used as a surrogate for P sorption to separate the P data. This approach resulted in wheat and lupins grown on grey sands having a lower critical value of 14-15 mg/kg compared to a higher critical value of 29 mg/kg for wheat grown on other soils examined. A critical value of 24 mg/kg was determined for lupins grown on yellow sands with PRI=1 (Table 1). For soils with PRI values > 1, P sorption reduced soil P availability to lupins but it was not possible to define a soil test – crop response relationship (data not presented). Canola appeared to be less sensitive to soil type, with the soil test values correlated to canola yield response across a wide range of soil types, giving a critical value of 20 mg/kg (critical range 17-25 mg/kg).

Sulfur soil test better predicted canola grain yield responses when using the soil sampling depth of 0-30 cm compared to the sampling depth of 0-10 cm. The improvement compared to the 0-10 cm soil sampling layer is attributed to the
utilisation of sub-soil S canola. For wheat, sampling to a depth of 30 cm did not improve the relationship as rates of S leaching and potential yield appeared to have an impact on the relationship.

Potassium soil test better predicted canola grain yield responses when using the soil sampling depth of 0-30 cm compared to the sampling depth of 0-10 cm. However, for wheat the approach required root distribution as affected by soil acidity and potential yield to be taken into account.

Nitrogen soil testing both for the 0-15 cm or 0-45 cm soil layers, even when the contribution of growing season mineralisation was estimated, had limited predictive capacity for crop yield response, presumably because of the large impact of nitrate leaching on soil inorganic N availability in WA (Anderson et al. 1998).

KEY WORDS

Soil testing, Phosphorus, Potassium, Sulfur and Nitrogen

REFERENCES


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