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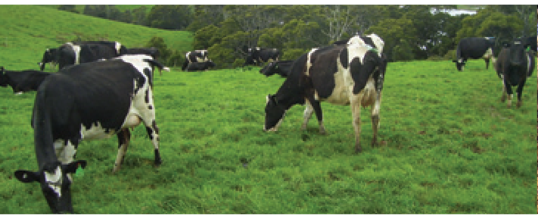  

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Re-defined soil test–grain yield response relationships can give better fertiliser decisions for P, K and S with wheat, canola and lupin in the cropping systems of Western Australia

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Abstract

Soil test P, K and S – response relationships for wheat, lupin and canola can be used to make better fertiliser decisions for the cropping systems of Western Australia. A database of N, P, K and S experiments conducted in Western Australia was compiled. Relationships were then defined between soil test value and per cent maximum yield. Data sets were partitioned according to soil properties and sampling depths to improve the accuracy of the fitted regression equations. Sampling of the surface 0-10 cm soil layer provided suitable predictions of P relationships when separated into soil types with different P sorption capacities. In contrast, soil sampling to 30 cm depth improved the relationship for K soil tests for wheat and canola when the impact of soil acidity and potential yield on root distribution was taken into account. In contrast, deeper soil sampling to 30 cm improved the relationship for S for canola but not for wheat where rate of S leaching and potential yield appear to be important. The N soil test relationships for wheat and canola were not significant and critical levels could not be defined.

Introduction

Phosphorus (P), potassium (K), sulphur (S) and nitrogen (N) fertilisers are key inputs to maintain a profitable cropping industry in Western Australia (WA). However, excessive fertiliser use or inappropriate application practices can lead to nutrient pollution of land, water and air. Adoption of best management practices (BMP) is required to achieve high agronomic effectiveness with low environmental impact. This paper is directed at defining fertiliser nutrient requirements for wheat, canola and lupin as determined from the soil test results and crop grain yield response. This is achieved by soil sampling to various depths, analysis of the soil for nutrient concentrations using standard extraction techniques and defining a relationship between soil test measurement and crop response to applied nutrient, referred to here as the soil test – crop response relationship. These relationships need to be calibrated to account for differences in crop demand, soil types and climatic conditions. Once defined, these relationships can be used to determine whether to apply or to not apply a nutrient and assist with calculating the rate of nutrient required. 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.

Materials and Methods

Database

A database 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, duplex soils 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 as follows:

- P soil test or bicarbonate extractable P (Colwell 1963),
- K soil test or bicarbonate extractable K (Wong *et al*. 2000),
- S soil test or KCl-40 extractable S (Blair *et al*. 1991),
- N soil 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 soil samples were collected down the soil profile 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. Nutrient content of the soil can be expressed in units of mg of nutrient/kg of soil (mg/kg). Alternatively, nutrient content can be expressed in units of kg of nutrient/ha to a specified sampling depth. This value is obtained by multiplying nutrient concentration (mg/kg) by depth of soil layer (mm) and by bulk density divided by 100. As bulk densities were not measured for most experiments, they were assumed to be related to soil texture with sands having bulk density of 1.5 g/cm^3 and loams having bulk density of 1.3 g/cm^3. The results from gravelly soils were not presented using this approach because gravel content of the soil reduces the nutrient content of soils and unfortunately gravel content was not reported in most experiments. 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 c coefficient in the exponential root distribution with depth equation was initially set to 0.065. However, most wheat and canola experiments examined were affected by surface and/or sub-soil acidity. The c coefficient was hence increased to 0.100 when the 0-10 cm soil layer pH was less than 5.5 and 10-20 cm layer pH was less than 4.5. Also when the wheat grain yield was less than 1.5 t/ha the c coefficient was increased to 0.150.

Soil test – crop response relationships

Nutrient rate experiments were conducted to derive crop grain yields (t/ha). Nutrient rates used and the number of rates applied varied widely among the experiments. The database 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 nil nutrient rate treatment 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 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. A modified Mitscherlich equation, $PMY=a-b \exp(-c^d)$, where; a, b, and c are coefficients; and d is the soil test value, was fitted. The *a* coefficient was set to equal 100. The *b* coefficient was derived from the fitted equation or estimated so that the predicted critical levels are consistent with the approach used by the BFDC Interrogator (Chris Dyson, personal communication). Critical soil test levels were calculated to correspond to 95% *PMY.* The confidence interval around the critical value was calculated from the standard errors associated in defining the 95% PMY using the statistical package R version 2.15.0 (http://www.r-project.org/ downloaded 17/04/2012).

Results

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

When using the 0-10 cm sampling depth (mg/kg), the K soil test - wheat grain yield response relationship was poor, when data was pooled across all soil types (Table 1). In contrast, the K soil test – canola yield response relationship defined a critical value of 57 mg/kg (confidence interval 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 (confidence interval 24-39 mg/kg) compared to yellow sands, gravels and loams, with defined critical value of 59 mg/kg (confidence interval 51-67 mg/kg). Duplex soils had a poor relationship and neither the critical value nor the confidence interval could be defined. The relationship for lupin grown on grey sands defined a critical value of 27 mg/kg (confidence interval 23-30 mg/kg).

When using the 0-30 cm sampling depth (kg/ha), the K soil test - wheat grain yield response relationship was also poor for soil sampled in the 0-30 cm layer (Table 1). In contrast, the K soil test – canola yield response relationship defined a critical value of 55 kg K/ha (confidence interval 35-75 kg/ha). Application of the Wong *et al*. (2000) root distribution approach improved the relationships when the c coefficient was increased to account for reduced root growth 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 (confidence interval 29-35 mg/kg) and for canola was defined as 40 mg/kg (confidence interval 36-44 mg/kg).

Table 1: Critical values, confidence intervals and regression coefficients for soil test – crop response relationships by nutrient, crop, soil type and soil depth.

Nutr-ient	Crop	Soil depth	Soil type	No of experiments	Critical values[G]	Confidence intervals[H]	r^2
P	Wheat	0-10 cm[A]	Grey sands	22	15	12-17	0.63
		0-10 cm[A]	Other soils[D]	67	29	28-31	0.86
	Canola	0-10 cm[A]	All	31	20	17-25	0.72
	Lupin	0-10 cm[A]	Grey sands	22	14	11-16	0.37
		0-10 cm[A]	Yellow sands[E]	46	24	18-30	0.89
K	Wheat	0-10 cm[A]	All	139	na	na	0.05
		0-10 cm[A]	Grey sands	13	32	24-39	0.42
		0-10 cm[A]	Other soils[F]	76	59	51-67	0.63
		0-10 cm[A]	Duplex	48	na	na	0.08
		0-30 cm[B]	All	62	na	na	0.02
		0-30 cm[B]	Yellow sands, Duplex	59	na	na	0.33
		0-30 cm[C]	Yellow sands, Duplex	33	32	29-35	0.57
	Canola	0-10 cm[A]	All	182	52	48-56	0.67
		0-30 cm[B]	All	91	55	35-75	0.51
		0-30 cm[C]	All	182	40	36-44	0.72
	Lupin	0-10 cm[A]	Grey sands	22	27	23-30	0.82
S	Wheat	0-10 cm[A]	All	61	na	na	0.00
	Wheat	0-30 cm[B]	All	55	na	na	0.00
	Canola	0-10 cm[A]	All	126	na	na	0.15
	Canola	0-30 cm[B]	All	126	43	39-46	0.57

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

The soil S test - grain yield response relationship was poor for both wheat and canola and critical levels could not be defined when the sampling depth was 0-10 cm. Better fits for the soil S test values for canola were obtained by summing the extractable soil S content to 30 cm depth. The critical level for canola was 38 kg S/ha (confidence interval 35-40 kg/ha). There are only 7 lupin fertiliser experiments in the database with only one responsive site which had an extractable S level of 3.7 mg/kg (data not presented).

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.

Discussion

Phosphorus sorption in known to have a large impact on the availability of soil P to crops particularly when P is extracted using the sodium bicarbonate solution (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 of 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 higher critical levels of 29 mg/kg for wheat on grown on all other soils. 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 greater than 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 (confidence interval 17-25 mg/kg). The P soil test increases with higher fertiliser applications and this differs in relation to PBI, production history and the rate of P input (Weaver and Wong 2011). The impact of P fertilisation history on defined P soil test – crop response relationships needs to be investigated.

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. 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, 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).

Acknowledgments

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References

Anderson GC, Fillery IRP, Dolling PJ, Asseng S (1998) Nitrogen and water flows under pasture–wheat and lupin–wheat rotations in deep sands in Western Australia. 2. Drainage and nitrate leaching. *Australian Journal of Agricultural Research* **49**, 345–361.

Blair GJ, Chinoim N, Lefroy RDB, Anderson GC, Crocker GJ (1991) A soil sulfur test for pastures and crops. *Australian Journal of Soil Research* **29**, 619-626

Colwell JD (1963) The estimation of phosphorus fertilizer requirements of wheat in Southern New South Wales by soil analysis. *Australian Journal of Experimental Agriculture and Animal Husbandry* **3**, 190–97.

Helyar KR, Spencer K (1977) Sodium bicarbonate soil test values and the phosphate buffering capacity of soils. *Australian Journal of Soil Research* **15**, 263-273.

Rayment GE, Lyons DJ (2010) Soil Chemical Methods – Australasia. Australian Soil and Land Survey Handbook Series, (CSIRO Publishing: Melbourne).

Weaver DM, Wong MTF (2011) Phosphorus balance efficiency and P status in crop and pasture soils with contrasting P buffer indices: scope for improvement. *Plant and Soil* **349**, 37–54.

Wong MTF, Edwards NK, Barrow NJ (2000) Accessibility of subsoil potassium to wheat grown on duplex soils in the south-west of Western Australia. *Australian Journal of Soil Research* **38**, 745–751. doi:10.1071/SR98117