Focus paddock project soil survey results of south-western Australia

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Key messages

Grower's fertiliser practices are maintaining fertility by the use of fertilisers because there is low frequency of soil test values below critical values in the 0-10 cm soil layer, 29% for P, 15% for K, 10% for S, 24% for Cu and 13% for Zn. The relatively high frequency observed for P is argued to be misleading because on average the soil had PBI between 41-55 and there has been accumulation of P in the soil layer below 10 cm. As illustrated by 91% of samples having soil P test in the 10-20 cm soil layer > 4 mg P/kg.

In contrast, growers need to increase their lime use because 75% of samples were observed to have soil test values below critical soil pH_{Ca} values.

Soil inorganic N profile levels are high (83 - 96 kg N/ha), when sampled in autumn, in a cropping system dominated by growing of wheat and canola under a conservation farming practices (no-till with stubble retention).

There was a high frequency (70%) of paddocks with soil Mn test <10 mg Mn/kg. Hence, additional, plant testing should be undertaken to determine Mn fertiliser requirements, especially when lupins are grown on limed soils. Also, 46% of samples had soil boron levels below the critical values however, grain yield response to boron application have not been reported due to application of boron with P fertiliser and input in rainfall.

Aims

To report the GRDC Focus paddock project soil nutrient survey results which are derived mainly from the medium rainfall cropping region of south-western Australia.

Method

Productive paddocks which consistently perform well were selected across the wheat belt to provide a range of crop and pasture sequences over the sampling years 2010 to 2013. The number of paddocks surveyed was 70 from the northern agricultural region (NAR) and 64 from the central agricultural region (CAR) in 2010. An additional 50 paddocks from the southern agricultural region (SAR) were included in 2012. The paddocks were spread over ten grower groups from Yuna to Ravensthorpe, most of the paddocks were in the medium rainfall zone (annual rainfall 325 to 450 mm). Wheat was grown in all paddocks in 2010 followed by farmer rotation in sequence in the following years. This gave percentage of paddocks in wheat or canola accounted for 57% in 2011, 63% in 2012 and 69% in 2013.

Soil samples were collected prior to sowing in autumn between 2010 and 2013. The 0-10 cm samples were obtained by collecting 44 'pogo' samples these were combined into a single sample for analyses. Soil profile samples were derived for depths of 10-20 cm, 20-30 cm, 30-50 cm and 50-90 cm using three cores per the 1 hectare site. These were combined into a single sample for analysis. The exception was for 2010 and 2011 where soil profile where divided into horizon which gave variable sampling depths. The number of paddocks sampled was 136 in 2010, 129 in 2011 and 184 in 2012 and 2013.

Soil measurements conducted included 0.01 M $CaCl_2$ extractable ammonium and nitrate (mg/kg), 0.5 M $NaHCO_3$ extractable P and K, Phosphorus buffer index (PBI), 0.25 M KCl (heated) extractable S (mg/kg), total carbon (%), conductivity (d S/m), soil pH measured using H_20 and 0.01 M $CaCl_2$, with 0.01 M $CaCl_2$ soil pH (pH_{Ca}) used in this report, DTPA extractable B, Cu, Fe, Mn, and Zn (mg/kg) and exchangeable Al, Ca, Mg, K, Na expressed as % of cation exchange capacity (Rayment and Lyons 2011). A detection limit 0.1 cmol Al/kg was applied to the data to account for the presence of colloidial material in the soil extractants. However, centrifuging and filtration techniques should be investigated to remove these colloidial materials before analysis by ICP is conducted.

Critical levels were used to represent a threshold between no risk and possible soil and plant dependent risk of yield loss. Commonly used soil critical values for wheat using 0-10 cm sampling depth are as follows, soil pH_{Ca} 5.5 in the 0-10 cm soil layer, 4.8 in the soil layer below 10 cm, P soil test of 25 mg P/kg, K soil test of 45 mg/kg, S test soil of 5.9 mg S/kg for wheat and 7.7 mg S/kg or canola, Cu and Zn soil test 0.4 mg Cu/kg, Mn estimated at 10 mg Mn/kg. For Boron soil test a critical value of 0.5 mg/kg using the 0-10 cm sampling depth. For soil layers below 10 cm values of greater than 3 mg B/kg were considered indicators of risk of B toxicity. The S critical values are more accurately defined using a 0-30 cm sampling depth with 5.3 mg S/kg for wheat and 7.5 mg S/kg for canola.

It is important to note that the risk of nutrient deficiency increases, and aluminium/boron toxicity decreases, below these critical values, but the critical level at which yield loss occurs depends on soil chemical reactions, seasonal conditions, yield potential, soil type and plant species being grown. Additional information on critical soil test values for P, K and S can be obtained from a recently published special issue of Crop and Pasture Science Volume 64 (Peverill et al. 2013).

Statistical analyses conducted on the data included calculating the average, median and frequency distribution.

Results and discussion

Carbon

Focus paddocks measures are consistent with other reports which indicate soil carbon content of south-western Australia is strongly related to rainfall or biomass production (National Land and Water Resources Audit 2001). Average soil carbon was lower in the NAR and CAR (0.9-1.0%) compare to the SAR (2.4%). There was a higher frequency of soils with carbon levels below 1.0% in the NAR (73%) compared to the CAR (26%) and SAR (1%). The frequency of soils with carbon levels >2.0% were 3% in the NAR, 10% in the CAR and 59% in the SAR.

Acidity

Paddocks with pH_{Ca} < 5.5 in the 0-10 cm soil layer accounted for 63% of paddocks sampled. With paddocks with pH_{Ca} < 4.8 in the 10-20 cm soil layer accounted for 30% of paddocks sampled. The combination of pH_{Ca} < 5.5 in the 0-10 cm and/or pH_{Ca} < 4.8 in the 10-20 cm soil layers accounted for 75% of the paddocks sampled. Regional differences were observed. SAR paddocks with 90% of soils acidic in the 0-10 cm layer compared to 67% CAR and 50% NAR. However, the frequency of acid soil in the soil layers below 10 cm was lower in the SAR (5%) compared to the CAR (28%) and NAR (48%).

The frequency of soils with Alex(%) >5% was 37% of paddocks for the 20-30 cm soil layers in the NAR, 28% of paddocks for the 10-20 cm soil layer in the CAR and for no paddocks in all soil layers in the SAR which were located in mainly in the medium rainfall zone.

Inorganic N

Soil carbon content, seasonal condition and rotation history result in large variation of both the 0-10 cm concentration (mg/kg) and amount of inorganic N (kg/ha) within the soil profile. In general, both levels will be higher when there is summer rainfall, poor seasonal condition in the previous year and following legume crops and pastures.

Inorganic N in the soil is in the form of nitrate and ammonium with soil ammonium rapidly converted to nitrate. Hence, most of the inorganic N presence in the soil is nitrate. Currently, a sampling depth of 0-10 cm is used to measure inorganic N content of the soil. However, there can be significant leaching of nitrate into the soil which, depending on seasonal conditions and soil properties, can be available to the current season crop. A sampling depth to 30 cm will provide better estimates for soil levels of inorganic N. Hence, both the 0-10 cm and the soil profile N content to 90 cm inorganic N levels are reported.

Soil surface measurements

Soil surface concentration of soil inorganic N was mainly assessed used the NO_3 soil test measured using a sampling depth 0-10 cm. Soil NO_3 concentration was highest in the 0-10 cm soil layer with a rapid decline in concentration with increase sampling depth. This was because there was insufficient rainfall to have leached the mineralised N to the deeper soil layers. These results indicate that fallow period mineralisation had a higher impact on soil inorganic levels than the carryover of inorganic N levels from poor seasonal conditions.

The average NO_3 soil test in the 0-10 cm ($NO3_{0-10}$) cm soil layer of the focus paddocks was lower in 2010 (15 mg N/kg) compared to 2011-12 with values ranging between 26-30 mg/kg due to no significant fallow period rainfall in 2009/2010. Soil $NO3_{0-10}$ concentration < 10 mg/kg was more frequent (30%) in 2010 compared to the other years 4-11%. While, soil $NO3_{0-10}$ concentration >30 mg/kg was more frequent (30-44%) in other years compared to 2010 (7%).

Soil profiles measurements

Soil profile inorganic amount (kg N/ha) of the focus paddocks was high with average values ranging from 83 to 96 (kg N/ha) for the four sampling years. Soil profile N content (kg N/ha) of < 60 kg/ha was more frequent in 2012 (30%) and 2013 (39%) compared to 2010 (20%) and 2011 (19%). While, profile N content >100 mg/kg was more frequent (30-44%) in other years compared to 2010 (7%) due to no significant fallow period rainfall in 2009/2010. All paddocks were in wheat in 2010, so the impact on legumes is only measured in soil profiles collected in 2012 and 2013. In 2012, paddocks following legumes grown in 2011, on average had 14 kg N/ha higher soil profile N content than paddocks following wheat or canola grown in 2011. In 2013, this difference was not observed. Legumes grown in the previous year also have an impact on growing season mineralisation. Soil profile measurements at the start of the growing season underestimate the N benefits of grown legumes because legumes contribute to growing season mineralisation.

Phosphorus

Soil P levels have increased with the use of P fertiliser application rates higher than the P removed by crops (Weaver and Wong 2011). Average P soil test was 36 mg/kg in the 0-10 cm soil layer with a higher average for paddocks located in SAR (48 mg/kg) compared to the CAR (38 mg P/kg) and the NAR (30 mg P/kg). The average PBI was 41-55 in the soil layers 0-10 cm, 10-20 cm and 20-30 cm. These average values are consistent with values reported in a 100,000 data base reported by Weaver and Wong (2011). There was low frequency (29%) of P soil test <25 mg/kg in the 0-10 cm with the lowest frequency in the SAR (7%) compared to the CAR (26%) and the NAR (37%). Average P soil test was 11 mg P/kg in the 10-20 cm soil layer with levels higher in the NAR (13 mg P/kg) compared to the CAR (12 mg P/kg) and the SAR (9 mg P/kg). There were 9% of samples containing <4 mg P/kg in the soil layers 10-20 with frequency

in NAR of 3% compared to 7% in the CAR and 16% in the SAR. The frequency of PBI<20 was lowest in the SAR (2%) compared to the 12% in the CAR and 23% in the NAR. The higher PBI in the SAR is the main reason for the low P levels in the 10-20 cm soil layer.

Potassium

Average soil K test (mg/kg) was 132 mg/kg within the 0-10 soil layer with average for NAR paddocks of 134 mg/kg, CAR paddocks 140 mg/kg and SAR paddocks 121 mg/kg. There were 15% of paddocks with K soil test values <50 mg/kg with lower frequency in the SAR (3%) compared to the CAR and NAR (15-18%).

Sulfur

The average S soil test across all paddocks sampled was 20 mg/kg for the 0-10 cm soil layer with a lower average of 16 mg/kg observed for the NAR compared to the CAR value of 22 mg/kg and 24 mg/kg for the SAR. Across the state 10% of paddocks had soil a S test within the 0-10 cm soil layer <6 mg/kg.

Micro-nutrients

The median micro nutrient concentration was 0.6 for B, 0.5 for Cu, 0.8 for Zn and 7.3 mg/kg for Mn. The median values were reported for micro nutrient because the data set contains a few very high values which increase the value when the average value is calculated. Boron deficiency B soil test <0.5 mg/kg was predicted to occur 46% of paddocks. The occurrence of low levels of Boron soil test values on the Northern sand plain country is consistent with the mapping risk approach used by Wong et al. (2005). Copper deficiency Cu soil test values <0.4 mg/kg occur for 24% of paddocks when measured using the 0-10 cm soil layer. However, 90% of paddocks had sub soil Cu with 90% having values > 0.2 mg Cu/kg. Zinc soil test values <0.4 mg/kg occur for 13% of paddocks. Manganese soil test values <10 mg Mn/kg occur for 70% of paddocks.

Conclusion

Application of soil amendments (fertiliser and lime) are used to maintain soil fertility in cropping systems because nutrients and alkalinity are removed when crops are harvested. The Focus paddock survey indicates there is a low frequency of paddock with P, K, S, Cu and Zn below critical soil test values. This indicates that grower's fertiliser practices are maintaining fertility of the soil. However, there is a high frequency of acid soils, determined using soil pH_{Ca}, indicating growers need to increase their lime use. But there is a need for greater measurement of Al status of soil layers below 10 cm. In situations when soil Al_{ex}(%) is above 5% growers need to select Al tolerant crops and varieties to maximise yield. Although, there is a high frequency of soil with low boron grain yield response to boron application has not been reported due to application of boron with P fertiliser and input in the rainfall.

There was a high frequency (70%) of paddocks with soil Mn test <10 mg Mn/kg. With increased lime use the high frequency of paddocks with low Mn will be an important issue for lupin growers. Measured soil inorganic N profile levels of 83 - 96 (kg N/ha) represent a relative high inorganic status of the soil in a cropping system dominated by growing of wheat and canola under a conservation farming practices (no-till with stubble retention). There is a need to re-examine fallow mineralisation routines used in models to account for these high levels of inorganic N. There is also a need for improve understanding of the role of non-symbiotic N_2 fixation in conservation cropping farming systems.

Key words

Soil testing, Acidity, Boron, Carbon, Copper, Phosphorus, Potassium, Sulfur, Nitrogen and Zinc

References

Rayment GE, Lyons DJ (2011) 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.

National Land and Water Resources Audit (2001) Australian Agriculture Assessment Nutrient Management in Australian Agriculture, National Land and Water Resource Audit, Canberra

Peverill K, Reuter D, Conyers M, Norton R (2013) Making Better Fertiliser Decisions for Cropping Systems in Australia Crop & Pasture Science Special Issue, Volume 64, Number 5

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