Management of ‘hostile subsoils’ depends on correctly identifying the problem, then either doing something about it or learning to live with it.

You need to know what and where your subsoil constraint (SSC) is and to know your soil’s ‘bucket size’ (plant available water capacity) – and manage accordingly. Otherwise your crop and soil management decisions may not have the expected harvest results. By illustration, there were a series of SSC trials in northern NSW in 2006, across soils categorised by their ‘good’ or ‘bad’ subsoils, with surprising results.

Trials at the ‘bad’ site (that is, constrained by high chloride levels) at Garah, out-yielded those at the ‘good’ site due to the soil’s bucket being almost full at the bad site and only half to two thirds full at the good.

Cereals performed best on soil with high concentrations of subsoil salts (barley better than faba beans better than wheat = durum = triticale better than canola = mustard better than field pea better than chickpea = lentil = linseed).

Northern NSW trials, 2006

Soil profile distribution of chloride concentration (Cl) for each of the sites is shown in Figure 1. Chloride levels at Garah were up to 2440 mg per kg at 140 cm depth in the constrained (bad) and 1750 mg per kg at 160 cm depth in the unconstrained (good) site.

Chloride levels at Liverpool Plains were up to 2920 mg per kg at 120 cm depth in the constrained (bad) and 1240 mg per kg at 160 cm depth at the unconstrained (good) site.

Other workers on this project have determined a tentative threshold for soil chloride of greater than 600 mg per kg, when...8[>
root growth in some species is restricted. This threshold was exceeded at Liverpool Plains (1540 mg per kg) and Garah (1370 mg per kg) bad sites at 50 to 70 cm depth; Garah good site (730 mg per kg) 70 to 90 cm; and, 110 to 130 cm depth at the Liverpool Plains (1110 mg per kg) good site.

Soils at both Garah and Liverpool Plains (Figure 2) good and bad sites are sodic (Exchangeable Sodium Percentage (ESP) greater than six per cent) in the surface layers (0–10 cm) and strongly sodic (ESP greater than 15) at 30 to 50 cm depth at Liverpool Plains good and bad, and Garah bad, and 50–70 cm depth at Garah good.

**Plant available water capacity**

Plant available water capacity (PAWC) was determined for each 2006 trial site as the difference between soil moisture contents, at drained upper limit (DUL), measured after drip irrigation, and crop lower limit (CLL), measured under rain exclusion tents set up on additional plots of wheat (Baxter), chickpea (Jimbour) and canola (Ripper).

- Wheat PAWC was 168 mm (to 115 cm) at Garah Bad, 221 mm (to 140 cm) Garah Good (Figure 3), 135 mm (to 90 cm) at Liverpool Plains Bad and 263 mm (to 180 cm) at Liverpool Plains Good (Figure 4).
- Chickpea PAWC was 121 mm (to 105 cm) at Garah Bad, 198 mm (to 160 cm) Garah Good, 67 mm (to 90 cm) at Liverpool Plains Bad and 152 mm (to 160 cm) at Liverpool Plains Good.
- Canola PAWC was 123 mm (to 110 cm) at Garah Bad, 218 mm (to 140 cm) Garah Good, 122 mm (to 100 cm) at Liverpool Plains Bad and 210 mm (to 160 cm) at Liverpool Plains Good.

**TRIAL DESIGN AND LOCATIONS IN 2006**

- In winter 2006, paired un-constrained and constrained species and variety trials were conducted on vertosols near Garah, and near Spring Ridge on the Liverpool Plains. The un-constrained soil is referred to as ‘good’ and the constrained soil as ‘poor or bad’. Paired trials sites were within 2 km, were of similar soil type, and experienced very similar weather conditions.
- The trials were fully replicated small plots (each plot 2 m wide by 12 m long).
- The trials aimed to rule out all other yield limiting factors such as nutrition, insects and disease (where possible).
- There were 28 treatments consisting of the following species: 5 bread wheat, 2 durum wheat, 5 barley, 3 chickpeas, 2 field peas, 2 faba bean, 2 lentil, 2 canola, 2 mustard, 2 safflower and 1 linseed. Two varieties of triticale were sown as demonstration plots to try and understand how it handles subsoil constraints (SSC).
- With the dry start to the season at Garah, the early sown species and varieties were sown deep into variable moisture, resulting in patchy plots. Areas of reasonable growth in the patchy plots were hand harvested, while the remainder of the site was machine harvested.
- On the Liverpool Plains the sowing date was late for faba beans. There was useful in-crop rain early in the season but the flowering/grainfill period was very dry.
Starting soil water

Starting soil water was determined from a selection of plots and averaged across each trial site. Figure 4 shows the volumetric soil water of Garah good and bad DUL and starting soil water. The graph shows that Garah bad plots had more water stored in the profile from 65–180 cm than at the good site – this equates to an extra 48 mm PAW in the lower root zone (80–140 cm depth). This difference in starting soil water likely explains why some species yielded less on the good site when compared to the bad. Liverpool Plains Good had more water stored in the profile than the bad, which equates to 38 mm from 0–180 cm (or an extra 64 mm in root zone 0–120 cm).

Rooting depth of species

Approximate rooting depth for each of the species is the lowest depth where the soil water measurements at maturity are still the same as they were at sowing. Figure 5 shows the rooting depth for all species at Garah good and bad sites with little difference between bread wheat (GB 103 cm & GG 104 cm), durum wheat (GB 100 cm & GG 96 cm), triticale (GB & GG 102 cm), mustard (GB & GG 110 cm) and safflower (GB & GG 151 cm).

But the chart shows there is a difference between the good and bad sites for barley (GB 98 cm & GG 114 cm), canola (GB 108 cm & GG 122 cm), linseed (GB 86 cm & GG 96 cm), chickpea (GB 79 cm & GG 96 cm), faba bean (GB 82 & GG 101 cm), field pea (GB 83 & GG 97 cm) and lentil (GB 78 cm & GG 98 cm).
This suggests that these species were more constrained by the salt or specific chloride concentrations at the bad site than by the lesser available water at the good site.

Much greater differences were found in 2005 when starting water contents were not as different between the trials sites as they were in the 2006 season.

At the Liverpool Plains site in 2006, most species showed a reduction in rooting depth and no species stands out as being able to extract moisture from depth in constrained subsoils.

2006 YIELD RESULTS

Figures 6 and 7 show yields obtained at Garah and Liverpool Plains sites for 2006.

Yields at Garah did not go as expected in 2006 with the bad site out-yielding the good site. Barley and triticale were the only two species to have higher yields on the good site when compared to the bad. This is due to the lack of plant available water at depth in the good soil (that is, the ‘bucket’ was full on the bad site and only half to two thirds full on the good site).

Crop access to subsoil water is crucial during grain filling, especially when in-crop rain is limited as in 2006. The yields received were in line with commercial crop yields in the region.

IN SUMMARY

Yield is not always the best way to look at SSC trial results – yield can mask a constraint. A good example of this is the faba bean yield data for Garah which shows yields of 2–2.4 tonnes per hectare in a highly constrained soil.

The results from the 2006 Garah site may have performed to their maximum yield potential for the constraint present. But as the unconstrained soil performed well below its maximum yield potential.

The season plays a big role in setting up yield – especially how and when rain falls. On constrained soils crop production is more reliant on in-crop rainfall refilling the smaller bucket, so there is a smaller safety margin of stored water for plant use.

At Garah, 2006 seemed to be a favourable season for early planted species and varieties. It is important to know the PAWC for paddocks and starting soil water to guide planting decisions and rotations. But this was the second consecutive year that faba bean had been the highest yielding pulse, and may mean that the crop is better able to convert water into grain than the other, later sown, pulses.

Rooting depth of faba beans was no different to chickpea, field pea or lentil crops grown at the same sites.

On the Liverpool Plains most of the crops suffered significant reduction in water use and yield at the bad site compared to the good. Faba beans suffered little yield loss between good and bad sites, but this may be due to the lateness of sowing and the fact that the faba beans yielded well below potential on both sites.

Know your PAWC

It is important to understand PAWC and to measure it in paddocks with SSC. This will aid in planning a rotation. Once PAWC has been determined, starting soil water needs to be known or estimated to aid in species and/or varietal selection for the SSC paddock. As seen at Garah in 2006 – when the SSC paddock has a full profile and limited rain falls, the SSC paddock may (depending on how and when rain falls) outperform an unconstrained paddock with a dry subsoil.

An ideal winter crop rotation on a constrained paddock like the one of the trial at Garah may look like this:


Further research is required to look at SSC in a farming systems context, not just one-off species trials.

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