Canola and subsoil constraints

Technical Bulletin

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During the 1990’s and prior to the millennium drought, the yields of canola were documented as having declined compared with wheat (Mead et al. 2005, Kirkegaard et al. 2006). This could be the result of an increased frequency of canola in rotations during this period, which would have lead to two possible causes for the perceived canola yield decline: increased disease pressure (Lisson et al. 2007), and/or the spread of canola onto less suitable soils. The aim of this project was to assess the relative contribution of subsoil constraints to the decreased relative performance of canola.

This bulletin summarises the results of three years of field trials (Figure 1), funded by the Grains Research and Development Corporation, on the impact of subsoil constraints on the vegetative growth and grain yield of canola. The bulletin assumes a basic understanding of the issues associated with hardpans (plough pans, compaction), acidity (low pH), salinity (high electrical conductivity) and sodicity (high sodium levels). These constraints can occur in the surface soil but also in the subsurface or subsoil. ‘Subsurface’ soil is defined as A-horizon soil either below the plough layer or below 10 centimetre depth, and ‘subsoil’ is defined as the B-horizon.

This document focuses on:
1. The diagnosis of each constraint.
2. The impact of each constraint on canola growth and yield.
3. Recommendations for management.

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Recommendations

**Hardpans:** A biological response by canola to deep ripping is not expected when penetration resistance in a hardpan is less than 3MPa (measured at field capacity). Where resistance is greater than 3MPa a biological response is possible but the economic value of the amelioration will depend on the residual value of the ripping. Soil penetration resistance measured at Morven from 2007-2009 indicates that ripping has a positive residual value after three seasons.

**Acidity:** Lime injection is not recommended where pHca is greater than 4.2 and exchangeable aluminium (Alca) is less than 20 percent in the acidic throttle layer (10-20cm). The use of liming to increase soil pHca to 5.5 in the surface 10cm of soil provides adequate protection for canola growth unless the subsurface soil contains elevated concentrations of manganese (Mn). This appears to be an uncommon occurrence but has been observed on red earth (red kandosol) soils.

**Sodicity:** Amelioration of subsoil sodicity by deep placement of gypsum is not recommended for canola even for soils with exchangeable sodium levels in the subsoil (Naex-ESP) greater than 15%. But interpretation of the site data in the context of variable soil moisture conditions suggests this recommendation might not be valid in seasons where there is subsoil moisture and a dry surface soil. Other research (Armstrong et al. 2007) indicates there may be value in the placement of organic matter in circumstances where this is economically feasible.

**Salinity:** EM38 surveys accompanied by strategic soil sampling to a depth of one metre are recommended to determine the likely presence of subsoil salinity. But the best strategy for canola is to avoid sowing into saline soils. Despite the tolerance of canola to salinity in the presence of adequate moisture, the combined effect of salinity and low matric potential severely restricts canola grain yield. This is particularly the case in seasons of low spring rainfall.
Diagnosis of soil constraints

**Hardpans**: The presence of a hardpan (compacted layer in the soil profile) can be diagnosed with a cone penetrometer, by inspection in a pit, or by carefully excavating plants and inspecting for ‘J-roots’. The advantage of a penetrometer is the ability to quantify the constraint; the disadvantage is that the measured value depends on the water content of the soil. So it is necessary to undertake measurements of penetration resistance in the soil profile at a specified water content, ideally at field capacity. Assessment of a hardpan in a soil pit is qualitative but has the advantage of allowing assessment of the presence and extent of cracks and root channels that allow roots to bypass hardpans.

**Acidity**: Sampling soil to a depth of 20cm is recommended when assessing soil pH status. It is recommended that surface (0-10cm) soil samples are taken in conjunction with subsurface samples at 10-20cm depth with separate analyses for each depth. Acidity can extend deeper than 20cm, which can be semi-quantitatively determined by taking samples either using an auger or from a pit face and using a pH indicator kit. Acidified subsurface soil is usually paler in colour than the surface soil above or subsoil below. These “acid throttles” can be concurrent with hardpans.

**Sodicity**: Diagnosis of subsoil sodicity requires sampling the clay layer of the soil profile to distinguish sodicity from a hardpan. The clay subsoil usually begins at a depth of about 20cm and can be sampled by hand auger, a pit, or a hydraulic corer. Laboratory analyses for Na is desirable but simple dispersion tests can be used on site. As poor structure in subsoils can be due to high concentrations of magnesium (Mg) laboratory tests are required to determine the relative contributions of Na and Mg. In some soils the sodic layers may overlay saline soil.

**Salinity**: Electromagnetic (EM 38) surveys provide a measurement of apparent electrical conductivity (EC). The weakness of the EM procedure is that the raw data can be influenced by variations in soil water content, depth to clay and rock, and soluble salt content. The EM reading therefore needs to be calibrated to EC measured by conventional soil testing at each site. However, the use of conventional soil sampling to depth, followed by lab EC methods on their own is time consuming and potentially misses ‘hotspots’. The EM procedure is advantageous as it provides a good spatial resolution of where the apparent salinity is distributed, which allows followup with targeted soil sampling and analyses.

Impact of subsoil constraints on canola growth and grain yield

The impacts of subsoil constraints on the growth and grain yield of canola was investigated at a number of sites in south-eastern NSW and northern Victoria. The summary of the experimental results are presented in the following sections.
A. Impact of hardpans and acidity on canola growth and grain yield

**Example 1: Impact of hardpans and acidity on canola growth and grain yield (Morven, NSW 2007-2009).**

The impact of a hardpan (compaction) and an acidic throttle (Figure 2) on canola growth was investigated at the Morven site east of Culcairn. The soil was a grey loam grading into yellow clay (yellow kandosol).

Treatments included deep ripping to 30cm and deep ripping to 30cm plus a lime injection at 10-30cm depth. All plots were limed on the surface at a rate of 1t/ha, eliminating surface soil acidity. The first trial commenced in 2007 (canola, wheat, canola), with the second trial commencing in 2008 (canola, barley).

Deep ripping successfully broke up the hard layer producing soil with low penetration resistance to 30cm depth as shown in Figure 3.

Figure 4 highlights the impact of the ripped + lime treatment that produced vertical slots of high pH (blue) between very acidic (red) bands of soil. Interestingly, while not shown here, ripping alone increased subsurface soil pH by mixing clay from the B-horizon into the acid throttle.

Although dry matter cuts in August 2009 (the second year after ripping) showed responses by barley to the ripped and ripped + lime treatments, neither canola cultivar showed a response to either treatment (Table 1). This indicates that canola was more tolerant of the hardpan and the acid throttle than barley when soil water supply was adequate. But final grain yields in the dry season of 2009 showed no response to the treatments for either crop species (Table 2).

![Figure 2. The initial pH and penetration resistance profile at Morven, NSW (2006).](image)

While solution culture experiments in the glasshouse have shown that canola is moderately tolerant to aluminium (Al) (Figure 5), its sensitivity to manganese (Mn) toxicity is well known. But the lack of response to subsurface liming from barley contradicts research from the 1980s and 1990s, which showed large responses in a range of cereals to amelioration of subsurface acidity (Scott et al. 1997).

The impact of seasonal conditions on apparent tolerance may explain this anomaly. In conditions of adequate subsoil moisture combined with a drier surface soil, as was common in late spring periods during the 1980s and 1990s, plants rely on root development in the subsoil. The run of dry seasons from 2001 to 2009 resulted in drying of subsoils. In 2009, although the subsoil was dry, regular showers provided adequate surface moisture, so even for sensitive crop species such as barley there was no apparent benefit of ameliorating the acid throttle. It follows there will be seasonal interactions between the treatment of subsoil constraints and a likely response in grain yield.
Example 2: Impact of hardpans and acidity on canola growth and grain yield (Young district, NSW 2007–2008).

The impact of a hardpan (compaction) and acidity on canola growth and grain yield was investigated at sites near Young (Greenethorpe and Milvale). These experiments indicated that deep ripping can breakdown hardpans and also increase the evaporation of water from the soil profile. In very dry years the loss of water can have a greater impact on yield than the impact of the hardpan on root development. For example, following relatively low rainfall in 2008 the untreated control at the Greenethorpe site (loam over red clay (red chromosol)) had an additional 30mm of stored water in the profile compared to the ripped treatments, resulting in an additional 0.2–0.3t/ha of grain. However, this increase in grain yield did not reach statistical significance.

By the second year following ripping, one would expect that the loss of soil water from the ripping operation would not be significant and there would be subsequent yield benefits from deep ripping. But no carry-over benefit of ripping in 2007 on dry matter or grain yield of canola in 2008 at the Milvale site (Table 3) was observed.

Similarly, as shown in Table 4, wheat in 2008 following ripping in 2007 did not show any yield response at either of the Greenethorpe sites (i.e. Finns or Hodges).

B. Impact of sodicity on canola growth and grain yield


The impact of sodicity on canola growth was investigated at three sites – near Rand and Lockhart, NSW, and Brimpaen, western Victoria.

Sodicity can be ameliorated with applications of gypsum. There are two mechanisms by which gypsum can ameliorate sodic soils:

1. The calcium (Ca) from gypsum displaces sodium (Na) in the soil, which then leaches down the profile.
2. Calcium sulphate (CaSO4), the main component of gypsum, flocculates clays due to its mild salinity.

It is unlikely that the first mechanism can make a significant contribution to the amelioration of soils with a sodic clay layer at a depth of 20-30cm. The displaced Na is unlikely to be leached from this depth without heavy irrigation or flooding. In most seasons there is limited potential for amelioration of subsoil sodicity in the dryland systems of the 350-550mm rainfall belt. The quantity of gypsum required might also be prohibitive.
Ripping with and without surface applied gypsum was trialled at two sites in NSW and one in Victoria. The NSW sites were EM surveyed and the paddock yield mapped according to both the soil type and apparent salinity level.

**Rand 2008**

There were three soil types across this riverine plains paddock, ranging from a red loam to a black clay. As at Morven, treatments were applied in 2007 and again in adjacent plots in 2008. Only 2008 results are described here.

Neither ripping or gypsum application had any effect in 2008 on canola plant density, but yield was reduced on ripped plots in 2008 due to increased evaporative losses in these plots (Table 5).

Although it might be expected the effects of ripping and gypsum application may be delayed in dry seasons, there was no carry-over effect of ripping or gypsum application in 2007 on the subsequent 2008 wheat crop, which had a mean yield across all treatments of 1.2t/ha.

**Lockhart 2008**

The site at Lockhart produced similar results to the Rand site, with no carry-over effect of the ripping or gypsum applied to the 2007 canola on the growth and yield of the subsequent 2008 wheat crop. The mean site wheat yield at the Lockhart site was 2.74t/ha.

### Table 3. Canola grain yield (t/ha) response to ripping and lime injections in 2008*.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Greenethorpe</th>
<th>Milvale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weevil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plants/m²</td>
<td>Yield (t/ha)</td>
</tr>
<tr>
<td>Control</td>
<td>47</td>
<td>2.40</td>
</tr>
<tr>
<td>Ripped</td>
<td>43</td>
<td>2.20</td>
</tr>
<tr>
<td>Ripped + Lime</td>
<td>40</td>
<td>2.10</td>
</tr>
<tr>
<td>LSD</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>


### Table 4. Wheat grain yield (t/ha) response to ripping and lime injection in 2008*.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Greenethorpe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Finns (t/ha)</td>
</tr>
<tr>
<td>Control</td>
<td>3.50</td>
</tr>
<tr>
<td>Ripped</td>
<td>3.40</td>
</tr>
<tr>
<td>Ripped + Lime</td>
<td>3.40</td>
</tr>
<tr>
<td>LSD</td>
<td>ns</td>
</tr>
</tbody>
</table>

2.6t/ha (var. Beacon) and 1.7t/ha (var. Marlin) for the two years respectively. The lack of response to deep ripping was considered to be the result of inherent seasonal cracking observed within the subsoil as it dried. Significant cracking enables advancing root tips to penetrate the subsoil, allowing water extraction at depth. However the minimal quantity of subsoil water limited yield responses in these two seasons.

C. Impact of salinity on canola growth and grain yield


As salinity cannot be removed experimentally, the experimental design used for investigating salinity is different to the design used to investigate other subsoil constraints. Using the natural variability within the paddock a regression approach was applied to assess the impact of salinity on canola. The trial paddocks at Yuluma, west of Lockhart, were on red earths (red kandosols), mapped using EM38 (wet and dry soil) and plants harvested for dry matter, rooting depth and yield. Plant samples were taken from areas of 1-3 square metres, representing different EM zones, all with plant densities of 15 plants/m². Soil cores were removed from the areas and EC (and ions) measured.

As shown in Figure 6, there was a good relationship between EM reading (apparent ECa) and rooting depth.

Table 5. Canola grain yield (t/ha) responses to ripping and gypsum on soil types at Rand, 2008.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Red loam (low EC)</th>
<th>Black clay (med EC)</th>
<th>Brown clay (high EC)</th>
<th>Brown clay (low EC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.70</td>
<td>0.41</td>
<td>0.41</td>
<td>0.35</td>
</tr>
<tr>
<td>Ripped</td>
<td>0.32</td>
<td>0.09</td>
<td>0.22</td>
<td>0.20</td>
</tr>
<tr>
<td>Ripped + Gypsum</td>
<td>0.28</td>
<td>0.06</td>
<td>0.22</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Recommendations for amending soils with hardpans and low pH

It is recommended that the diagnostic criterion of penetration resistance for canola be increased from the generally accepted 2MPa to 3MPa. But care needs to be taken with interpretation of penetrometer data, as (i) penetrometer resistance varies with soil water content. The 3MPa recommendations apply to soil near field capacity, but at lower soil water content the equivalent penetration resistance will be greater than 3MPa; and (ii) penetrometers travel in a straight line while plant roots explore and exploit the slightest opening.

Many soils of southern NSW appear to have sufficient cracks and biopores to enable root penetration through all but the hardest compaction layers. Deep ripping is not recommended as a standard tool for overcoming hardpans prior to sowing of canola crops. The data presented here and in previous studies have rarely found significant yield response to deep ripping.

If contemplating deep ripping it is recommended the resistance in the hardpan should be greater than 3MPa when measured at near field capacity, and, where possible, the ripping operation should be conducted in spring prior to cropping so the soil moisture profile has a chance to refill before sowing. This lag allows time for the seed bed to resettle and reduce the risk of evaporative loss noted at the Greenethorpe site (Table 3). Those undertaking deep ripping need to be aware of the potential yield penalty from loss of stored soil water.

Brimpaen 2007-2008

The Brimpaen site in the southern Wimmera of Victoria is an alkaline, duplex, sodic soil (sodosol). Treatments were applied in both years. There was no dry matter or grain yield response by canola to deep ripping (to a depth of 40cm), with or without gypsum, in either 2007 or 2008. Mean canola grain yields were 2.6t/ha (var. Beacon) and 1.7t/ha (var. Marlin) for the two years respectively. The lack of response to deep ripping was considered to be the result of inherent seasonal cracking observed within the subsoil as it dried. Significant cracking enables advancing root tips to penetrate the subsoil, allowing water extraction at depth. However the minimal quantity of subsoil water limited yield responses in these two seasons.

Figure 5. Comparison of wheat (W) and canola (C) tolerance to aluminium stress. Source: Moroni et al. (2006).
in both 2008 and 2009. Soil extracts showed that most salt was below 20cm depth. The salts extracted included sodium chloride (NaCl) and calcium sulphate (CaSO4), magnesium (Mg) and bicarbonate (HCO3) salts. Although the different salts occurred at different spatial locations and different depths, this bulletin only reports the aggregated impact of salinity on canola. In 2008 the impact of aggregated salinity on rooting resulted in a loss of dry matter (Figure 7) and grain yield (Figure 8) with increasing EC levels. This was not the case in 2009. The late spring rainfall in 2009 may have allowed the crop to finish on surface moisture, avoiding the impact of subsoil salinity. So, the impact of subsoil salinity on canola is likely to vary with the seasonal availability of water.

The yield losses observed in high ECa zones of the 2008 trial was surprising given that canola is known to be tolerant of salinity in solution culture experiments. This may be explained by considering the impact of changing water potential on canola plants.

Water potential, a measure of the effort required by plants to uptake water, is the sum of the gravitational potential (i.e. draining tendency), matric potential (retaining ability) and osmotic potential (salinity) of the soil water. At a given depth, the ease of uptake of water depends on the sum of the matric and osmotic potentials. As a soil dries, the impact of salt exaggerates the lack of moisture.

The salinity response observed in 2008 is potentially a response to the declining sum of the matric and osmotic potentials. That is, the tolerance of canola to salinity in wet soil declines significantly as the soil dries out.

Bibliography


