Key messages

- Alkaline soils can have high concentrations of dissolved organic C and the concentration is sensitive to pH.

Increasing carbon storage in alkaline sodic soils

Ehsan Tavakkoli¹, Suzanne Holbery², Pichu Rengasamy¹, Roy Latta² and Glenn McDonald¹

¹University of Adelaide, Waite; ²SARDI, Minnipa Agricultural Centre

• Soil organic C was strongly related to soil pH suggesting accumulation and retention of organic C in alkaline soils will be limited by high pH.

• Relatively small changes in pH may have a significant effect on the retention of organic C and a reduction in dissolved organic C.

• A gypsum application of between 2.5 and 5 t/ha reduced soil pH by 0.2-0.5 pH units over a year.

Why do the trial?

• After rainfall, soil pH has been suggested to be a major influence on the amount of organic C in soils. Under high pH the solubility of organic C changes and the amount of water soluble C increases.

• Ultimately the amount and form of organic C influences important soil processes such as nutrient cycling, microbial biomass and diversity and soil structure.

• Much of the detailed work on soil C has been done on neutral to acidic soils and there is little research to understand organic C accumulation in alkaline soils and the influence of high pH on the changes in the chemical form of organic C in alkaline soils.

• Under acidic conditions soil pH can be changed by adding lime. Under alkaline conditions, the use of legumes and gypsum can potentially lower pH.

• The aim of the project is to improve our understanding of the accumulation and retention of soil organic C under high pH and to investigate ways of directly managing pH.

• Detailed studies of soil chemistry and buffering capacity are being conducted in the laboratory and glasshouse and field trials are being used to investigate these changes in the field.

Paddock survey

Surveys of soils conducted in three areas where alkaline soils occur – the upper Eyre Peninsula, western Victoria and the lower North of South Australia. These are being conducted to provide a benchmark of current levels of dissolved organic C. Initial sampling was conducted on upper Eyre Peninsula during autumn 2013. Samples were taken at 0-10, 10-20 and 20-30 cm depths, dried and sieved and analysed for pH (1:5 soil: water), total C, total organic C and dissolved organic C.
Table 1: Summary of a preliminary survey of pH, organic C and dissolved organic C (% of organic C) in paddocks on upper Eyre Peninsula in 2012. Values are shown as means ± standard error of the mean and the coefficient of variation (CV%).

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>pH</th>
<th>Organic C (%)</th>
<th>Dissolved organic C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 10</td>
<td>7.79 ± 0.143</td>
<td>1.25 ± 0.152</td>
<td>0.78 ± 0.097</td>
</tr>
<tr>
<td>CV (%)</td>
<td>4.5</td>
<td>24.3</td>
<td>24.9</td>
</tr>
<tr>
<td>10 - 20</td>
<td>8.34 ± 0.123</td>
<td>0.95 ± 0.203</td>
<td>1.07 ± 0.214</td>
</tr>
<tr>
<td>CV (%)</td>
<td>3.6</td>
<td>42.8</td>
<td>40.1</td>
</tr>
<tr>
<td>20 - 30</td>
<td>8.66 ± 0.096</td>
<td>0.90 ± 0.247</td>
<td>1.04 ± 0.158</td>
</tr>
<tr>
<td>CV (%)</td>
<td>2.7</td>
<td>54.7</td>
<td>30.2</td>
</tr>
</tbody>
</table>

Rotation trials
Two short term rotation trials were established at Minnipa and Birchip in 2012 to examine the effects of legume, legume productivity and gypsum rate on soil pH. At each site three legumes [medic (a mixture of Herald, Paraggio, Caliph, Parabinga), peas (cv Morgan) and vetch (cv Morava)] were grown under standard and high inputs (doubled sowing rates and P fertiliser rates). The purpose of the high input treatment was to increase biomass production and hence the amount of N₂ fixation. Each legume treatment was grown at three treatments (0, 2.5 t/ha and 5 t/ha of gypsum; gypsum quality ~60% CaSO₄). The treatments were replicated 3 times. Soil was sampled to a depth of 30 cm in May 2013, dried and sieved, and analysed for pH (1:5 soil: water), total C, total organic C and dissolved organic C. The trial was sown to wheat in 2013 and biomass production at stem elongation (GS 32), anthesis (GS 65) and grain yield and grain quality measured.

What happened?

Paddock survey
Soil organic C decreased with depth and there was a corresponding increase in the proportion of C found as dissolved organic C. These trends followed the increases in pH with depth. The high CV (%) indicates the high level of variability among the seven surveyed paddocks. The amount of dissolved organic C measured in these profiles was relatively high.

Figure 1: The effect of gypsum application rate in 2012 on soil pH and dissolved organic carbon in 2013 at Minnipa. Means within each depth with different letters are significantly different; where there are no letters means are not significantly different.
Figure 2 The relationship between pH and dissolved organic carbon in soils from Minnipa gypsum trial 2013

Rotation trial

In 2012, biomass production of legumes was not significantly affected by gypsum rate but it was increased by 50-60% when sowing rate and P rate were increased.

In 2013 both pH and dissolved organic C increased with depth (Figure 1). Applying gypsum in 2012 significantly reduced the pH at 10-20 cm by 0.2-0.5 pH units in 2013 and there was a corresponding reduction in the amount of dissolved organic C. There was no influence of the type of legume or the level of inputs on soil pH. The variation in dissolved organic C was proportional to the changes in pH within the profile (Figure 2). Comparable results were observed at Birchip.

While there were significant changes in pH from the 2012 gypsum treatments there were no measurable effects on the yield of wheat in 2013, the only effect of gypsum at Minnipa was a small reduction in grain protein concentration from 11.3% with no gypsum to 11.0% with 5 t/ha gypsum. In two similar experiments at Birchip, one showed a 12% increase in wheat yields from the 2012 gypsum treatment, while the other showed no effect of gypsum.

What does this mean?

- High soil pH can increase the solubility of organic carbon which is susceptible to washing out.
- Dissolved organic carbon leached from decomposing organic matter is important in the leaching of nutrients from the root zone.
- Application of gypsum can significantly lower pH and reduce dissolved organic carbon over a single growing season. The effect of these changes on subsequent productivity of crops and whether the changes are long-lasting needs further investigation.

Acknowledgements

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Stubble and nutrient management trial to increase soil carbon

Trent Potter\textsuperscript{1}, Harm van Rees\textsuperscript{2}, Amanda Cook\textsuperscript{3}, Wade Shepperd\textsuperscript{4} and Ian Richter\textsuperscript{5}

\textsuperscript{1}Yeruga Crop Research, Naracoorte; \textsuperscript{2}CropFacts Pty Ltd, Mandurang; \textsuperscript{3}SARDI, Minnipa Agricultural Centre

No-Till stubble retention systems are adding to the partially broken-down particulate organic carbon fraction but are not contributing to the stable humus fraction. Without an increase in soil humus the important functions of soil organic matter (i.e. improved soil water holding capacity, increased nutrient supply (N and cations), pH buffering capacity and better soil structure) are unlikely to be realised.

What is humus and how can it be increased?
Humus consists of the remains of bacteria and other micro-organisms that consume and break down plant material returned to the soil from a crop or pasture. This plant material consists mainly of carbon (C). For soil microbes to consume this material they also need nitrogen (N), phosphorus (P) and sulphur (S) otherwise they cannot thrive and multiply. Australian soils are inherently low in nutrients and in most soils there is insufficient N, P and S for soil micro-organisms to rapidly break down the plant material returned to the soil. If we want to break down plant material such as stubble to form humus, we need to supply soil microbes with additional N, P and S - this may have to be supplied as extra fertiliser.

How much N, P and S need to be supplied to stubble to form humus?
Dr Clive Kirkby, from CSIRO, has been working on this question and found that:
- In humus 1000 kg of C is balanced with 80 kg N, 20 kg P and 14 kg S.
- Wheat stubble has a lower nutrient:C ratio and 1000 kg of C is balanced with 11 kg N, 1.1 kg P and 2.2 kg S.

Dr Kirkby argues that for soil micro-organisms to breakdown stubble and form humus, we need to add sufficient nutrients (N, P and S) to feed the micro-organisms.

This DAFF funded national trial will examine existing, new and alternative strategies for farmers in the cereal sheep zone to increase soil carbon. The trial will be used as base line data for carbon accumulation in soils and to:
- discuss the various forms of soil organic carbon (plant residues, particulate, humus and recalcitrant)
- investigate how management affects each of these pools and how humus can be increased over the medium to long term
- communicate how soil organic matter affects soil productivity (through nutrient and water supply, and improvements in soils structure).

Identical trials are being run by eight farm groups in SE Australia (Victoria: Mallee Sustainable Farming, Birchip Cropping Group, Southern Farming Systems; NSW: FarmLink, Central West Farming Systems; SA: Hart and Eyre Peninsula Agricultural Research Foundation, both through Ag Ex Alliance; and Tasmania: Southern Farming Systems) so information can be collected nationally across the southern cereal zones.
How was it done?

Four wheat stubble samples from 2012 were collected from the Minnipa Agricultural Centre farm in paddock south 2/8 in February across the trial site and dried at 40°C for 24 hours to calculate the stubble load.

Soil samples were collected 14 March for Yield Prophet (0-10, 10-40, 40-70, 70-100 cm) for soil available nitrogen and soil moisture.

In March the stubble management treatments: (i) stubble left standing, (ii) stubble worked in with single operation of the seeder before sowing (1 March) and (iii) stubble raked and burnt (2 March) were imposed.

Nutrient application treatments at seeding were: (i) normal practice for P at sowing and N in crop as per Yield Prophet and (ii) normal practice PLUS extra nutrients (N, P, S) required to break down of the measured wheat stubble. The extra nutrient requirement applied (N, P and S) on 23 April with a rainfall event to break down the stubble load was 3.8 units P, 10.2 units N and 1.6 units S, which was applied as DAP (18:20:0:0) @ 19 kg/ha, ammonium sulphate (21:0:0:24) @ 16 kg/ha and urea (46:0:0:0) @ 7.5 kg/ha. The treatments were replicated 4 times.

The trial was sown on 6 May with Mace wheat @ 60 kg/ha and base fertiliser of DAP (18:20:0:0) @ 50 kg/ha. Pre seeding chemical applications were sprayspray @ 1.5 L/ha, trifluralin @ 1.5 L/ha and a wetter. Using Yield Prophet predictions, UAN was applied @ 50 L/ha on 28 July using the broadacre boom on all the trial plots.

Emergence counts, flowering date, grain yield and grain quality were measured.

What happened?

The mean stubble load calculated from 2012 was 1.76 t/ha so additional nutrient treatments were applied as above.

Emergence counts were taken on 27 May with an average of 133 plants/m². There was no difference between treatments with plant emergence (range 118-144 plants/m²). There was no difference in flowering date (GS 65 (when 50% of heads have anthers)) which occurred between 30 and 31 August. The trial was harvested on 24 October.

Table 1 Grain yield and quality as affected by stubble treatments and additional nutrients at Minnipa 2013

<table>
<thead>
<tr>
<th>Stubble treatment</th>
<th>Nutrition treatment</th>
<th>Yield (t/ha)</th>
<th>Protein (%)</th>
<th>Test weight (kg/hL)</th>
<th>1000 Grain weight (g)</th>
<th>Screenings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stubble removed</td>
<td>DAP @ 50 kg/ha</td>
<td>2.58</td>
<td>11.1</td>
<td>80</td>
<td>35.7</td>
<td>3.2</td>
</tr>
<tr>
<td>Stubble removed</td>
<td>normal practice PLUS N,P&amp;S</td>
<td>2.54</td>
<td>11.4</td>
<td>80</td>
<td>35.0</td>
<td>3.4</td>
</tr>
<tr>
<td>Stubble standing</td>
<td>DAP @ 50 kg/ha</td>
<td>2.56</td>
<td>11.3</td>
<td>80</td>
<td>34.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Stubble standing</td>
<td>normal practice PLUS N,P&amp;S</td>
<td>2.54</td>
<td>11.4</td>
<td>80</td>
<td>33.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Stubble worked</td>
<td>DAP @ 50 kg/ha</td>
<td>2.60</td>
<td>11.2</td>
<td>80</td>
<td>34.2</td>
<td>3.6</td>
</tr>
<tr>
<td>Stubble worked</td>
<td>normal practice PLUS N,P&amp;S</td>
<td>2.63</td>
<td>11.6</td>
<td>80</td>
<td>33.8</td>
<td>3.7</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td></td>
<td>ns</td>
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<td>ns</td>
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<td>ns</td>
</tr>
</tbody>
</table>

Yield Prophet was used early in the season (22 July) to predict if extra nitrogen fertiliser was required to achieve potential yield. UAN @ 50 L/ha was applied on 28 July using the broadacre boom over all the trial plots. The mid-flowering date was 30 August and harvest date 24 October.

On 22 July Yield Prophet predicted a 50% probability of yield greater than 3 t/ha, however a dry spring prevented this potential being achieved.

There was no difference in grain yield or quality for all treatments in 2013 (Table 1). The trial at Hart in 2013 also showed the same results.

What does this mean?

It is expected that the imposed treatments to increase soil organic matter will take a few years to become noticeable. The trial will be repeated on the same site next year.

Acknowledgements

Funding provided from DAFF, and project management through Ag Ex Alliance and EPARF. Yield Prophet is an on-line modelling service based on APSIM that provides simulated crop growth based on individual paddock information and rainfall, and is registered to BCG.