Trialling biochar potential

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In 2010 the Australian government announced a commitment to give farmers voluntary access to domestic and international carbon markets through the Carbon Farming Initiative (CFI).

The CFI legislation has since passed through the House of Representatives and currently awaits passage through the Australian Senate.

Incentives to plant trees, improve nitrogenous fertiliser efficiency and increase soil organic carbon have all been incorporated in the CFI. Another welcome inclusion is the use of biochar as a carbon sink for agricultural soils.

Biochar is resistant to microbial breakdown in the soil and is relatively unaffected by farming practices; characteristics that enable it to persist in soils for hundreds and even thousands of years. These attributes mean biochar should be a relatively low-risk carbon credit option for farmers.

However, depending on the market price for carbon, applying biochar solely for the purpose of generating carbon credits is unlikely to be a viable option. For biochar application to be economical for farmers it will need to do much more than just lock up carbon.

Background

The South Australian No-Till Farmers Association (SANTFA) has been investigating biochar's agronomic potential since 2006 and preliminary field trials commenced in 2008.

The 2008 trials were carried out at Sheaoak Log and Templers, in the Lower North, in neutral to slightly acidic clay-loam soils with reasonable fertility and ample cation exchange capacity (CEC). Four fertiliser treatments were assessed; a nil treatment, a low rate of DAP* (35 kg/ha), a high rate of DAP (70 kg/ha) and a treatment consisting of the low rate of DAP (35 kg/ha) where biochar was spread over the soil surface at a rate of 750 kg/ha and incorporated by sowing with knife-point tines.

The yield results were not statistically conclusive, however a trend towards increased DAP efficiency in the presence of biochar was observed at the Templers site (**Figure 1**).

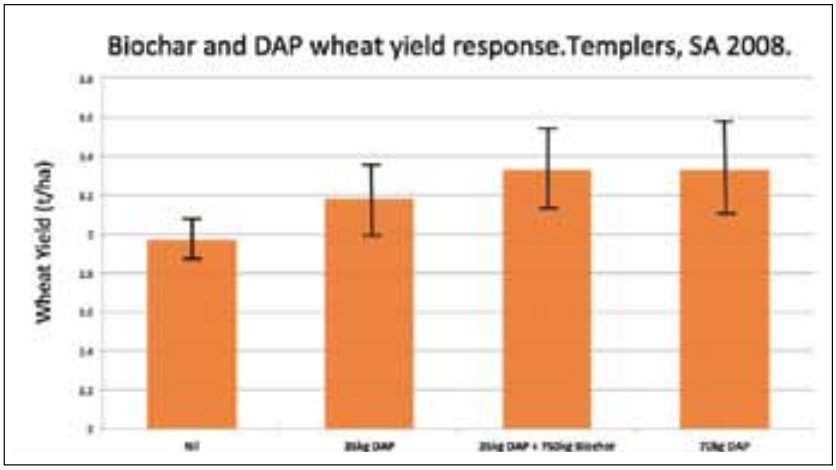

Figure 1. Wheat yield response to biochar and DAP fertiliser at Templers, 2008 (SANTFA)

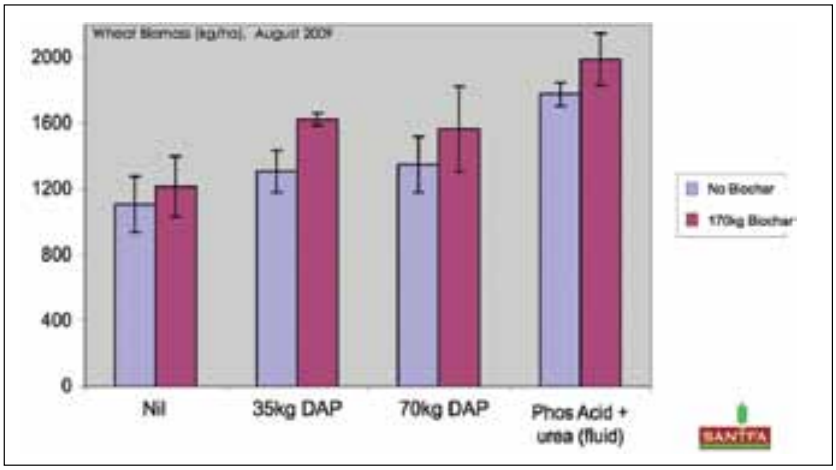

Figure 2. Biomass production response to biochar and fertiliser at Pt Kenny, 2009 (SANTFA)

Phosphate efficacy is not a big problem in the Lower North but is a major issue in the highly-alkaline calcareous soils that dominate much of SA's cropping zone. For this reason the focus of the biochar field-work shifted to calcareous soils and in 2009 a field trial was established on an alkaline calcareous soil at Pt Kenny on Eyre Peninsula.

At Pt Kenny, 170 kg/ha of biochar was banded below the soil surface with the fertiliser during the seeding process; an application rate significantly less than the 750 kg/ha used in the 2008 surface-spread trials.

Biochar rates being trialled around the world are often in the 'tons per hectare' range but the lower rate used in the Pt Kenny trials was considered appropriate for the district's relatively low rainfall and moderate soil CEC. Moreover, an attempt was being made to band the biochar as part of the normal no-till sowing process.

Results from this trial demonstrated a trend towards increased mid-season biomass production when DAP was applied in the presence of biochar (**Figure 2**).

The treatments did not translate into yield advantages, most likely due to nitrogen limitations in a relatively high-rainfall (decile 8) season but the trial generated more interest in the potential

role for modest biochar rates in SA no-till farming systems.

The Pt Kenny site is now a long-term biochar monitoring site where samples can be extracted from the soil to determine the longevity of biochar and hence its suitability as a carbon sequestration method in this soil type. For this reason, no fresh biochar is added to the Pt Kenny site.

Streaky Bay trial - 2010

Building on the knowledge gleaned in 2008 and 2009, a more intensive biochar field experiment was established for the 2010 growing season at Streaky Bay on western Eyre Peninsula.

Biochar was banded below the seedbed at two rates (35 kg/ha and 175 kg/ha) and spread on the surface at a significantly higher rate of 5 t/ha.

There were 12 treatments in total and various combinations of fertiliser, biochar and nil treatments were tested.

To provide a completely independent assessment, the trial design was developed with the CSIRO biochar team at the Waite Institute and the trial was sown in conjunction with SARDI (Minnipa), with all treatments statistically randomised and replicated.

On June 10, 2010, the trial area was sprayed with grammoxone (1L/ha) and trifluralin 480 (1L/ha) ahead of sowing to 56kg/ha of Axe wheat using knife-point tines.

On September 6, 12 L/ha of EasyN (42.5% N w/v) was applied in-crop across the whole the trial site to ensure nitrogen limitations did not affect the results.

The trial was harvested in mid December, again in conjunction with SARDI (Minnipa) and the data analysed in conjunction with CSIRO's biochar team. The yield results from this work are shown in **Figure 3**.

Results

Results from the Streaky Bay trial highlighted the importance of balancing fertiliser and biochar applications.

The yields from Treatment 1 (T1 = nil), T2 (35 kg DAP) and T3 (70 kg DAP) show that DAP does promote yield in highly calcareous soils but there are diminishing returns with increasing application rates.

Results from T3 (70 kg DAP) and T5 (70 kg DAP plus 5 t/ha of spread biochar) demonstrate that yield improvements may be achieved by combining DAP with biochar on calcareous soils.

Comparison of yields from T1 (nil), T10 (35 kg/ha banded biochar), T11 (175 kg/ha of banded biochar) and T12 (5 t/ha of spread biochar) indicates that biochar can reduce yield, at least in the first season, if fresh biochar is not applied in conjunction with fertiliser.

Hart trial - 2010

A phosphate and biochar response trial was also established at the Mid North Hart field site in 2010.

Flagship barley at 80 kg/ha with urea at 35 kg/ha was sown with various biochar and phosphate treatments on June 11. Biochar was applied on the surface at 500 kg/ha and the phosphorous (P) treatments - 5 kg/ha of P or 10 kg/ha of P - were applied at sowing using single superphosphate.

On August 10, 50 kg/ha of urea was applied to all plots.

The soil in the Mid North is less hostile than the soil at Streaky Bay and the influence of the biochar on phosphate efficiency was much less pronounced.

Discussion

SANTFA's 2010 field trial in calcareous cropping country near Streaky Bay demonstrated the strongest evidence yet for biochar's capacity to influence fertiliser efficacy and crop yield in SA's cropping system.

The biochar data collected from the 2010 trials is analogous in many ways to what we would expect from spreading clay on non-wetting sands: little response at very low rates, an excellent response at the appropriate rate and a potential problem if the soil is over-clayed or the wrong clay (such as a limey clay) is applied.

Equally, adding extra clay to a clay soil doesn't do much and, as indicated by the results from the Templers and Sheaoak Log experiments in 2008 and Hart in 2010, there seems to be little phosphate efficiency benefit from adding biochar at modest rates to soils with ample CEC, good organic matter and relatively high nutrient pools. Comparing these results with those from the trials on EP suggests there is greater potential for improving phosphate efficiency from adding biochar to soils with low CEC, less organic matter and poor nutrient pools.

Applying higher and higher rates of phosphate to highly calcareous soils has relatively little yield benefit. Plant-available phosphate is precipitated and locked up by the abundant calcium in high-pH soils so the pool of plant-available phosphate is generally quite low.

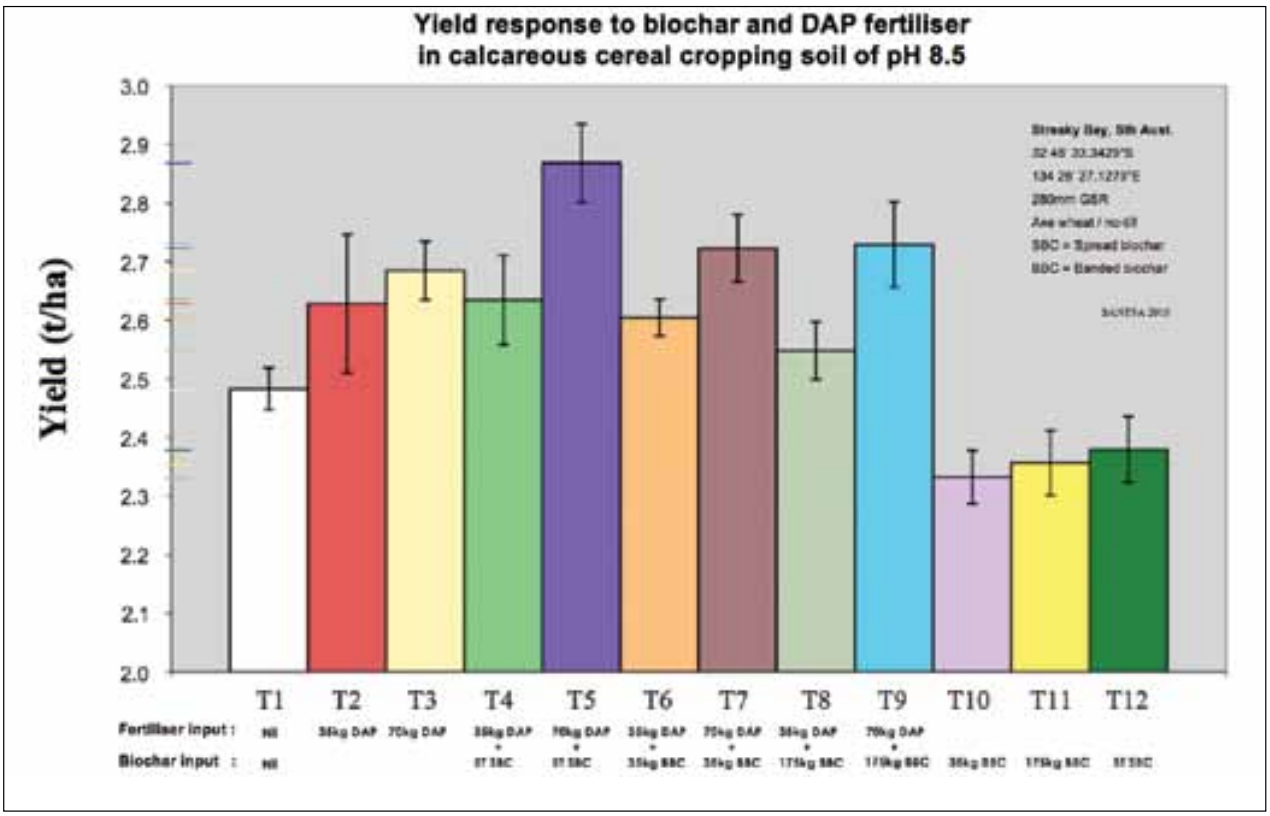

Figure 3. Yield response to biochar and DAP fertiliser at Streaky Bay, 2010 (SANTFA)

It is well-known that increasing organic matter and clay content can improve the water and nutrient-holding capacities of poor cropping soils and biochar could be thought of as a hybrid between organic matter and clay in terms of its effect on the soil.

It is important to recognise that the ability of organic matter and clays to hold water and nutrients is based on an electromagnetic attraction, which we measure in the soil as cation exchange capacity (CEC).

A magnet holding paper clips is an analogy for a particle of clay, organic matter or biochar holding onto water and nutrients. The paper clips closest to the magnet are held quite firmly and chains of paper clips can be built until the magnetic force is so weak that no more paper clips can be added. When this occurs with a clay or organic matter particle, the CEC is saturated.

In the Eyre Peninsula trails, adding biochar (the magnet) on its own, without any fertiliser, reduced yield in the first year. This is most likely because the biochar is drawing water and nutrients (the paper clips) from the available soil pool and effectively competing with the crop for these resources. However, the effect of this competition is much less than that of the tie-up due to calcium precipitation of phosphate, which is extremely strong and more akin to welding the paper clip to the magnet.

'applying higher and higher rates of phosphate to highly calcareous soils has relatively little yield benefit'

Several studies have shown that biochar stimulates populations of soil micro-organisms, which rely on soil and plant resources for their nutrition, so stimulating soil-micro-organisms by adding biochar without complimentary fertiliser may also create biological competition for available nutrients. If this occurs in a soil with low pools of available nutrients the plant yield may be decreased, at least in the short-term.

Experience tells us, however, that increasing the overall water and nutrient-holding capacity of a hostile or poor soil delivers many medium and long-term benefits. And the results achieved from banding just 35 kg/ha of biochar at the Streaky Bay trial site clearly shows that biochar at modest rates can have a significant effect on soil condition and nutrient status. If managed properly this might be used to advantage.

We speculate that the extra yield increase achieved from adding biochar with the higher rate of DAP can be attributed to the biochar acting as a buffer by binding excess fertiliser that the emerging plant is unable to take up immediately. We surmise that the biochar binding sites are being saturated with nutrients that would otherwise be lost to calcium precipitation. The relatively high influx of nutrients from the higher fertiliser rate also means the biochar binding sites can be saturated with little or no competition with the crop.

Once the plant has processed the nutrients immediately available from the soil pool the crop roots can comb the biochar for the nutrients buffered there. We suspect that the buffering or 'slow release' results in more of the nutrients from the fertiliser being available to the

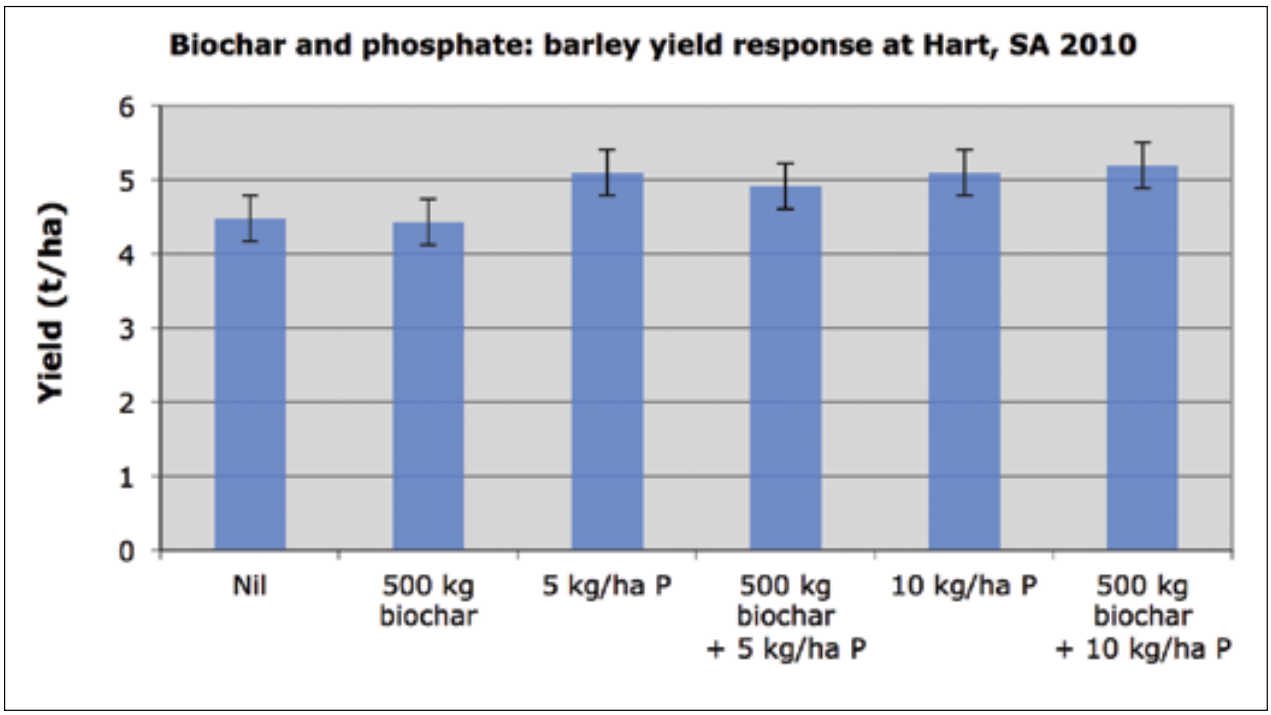

Figure 4. Barley yield response to biochar and phosphate fertiliser at Hart, 2010 (SANTFA)

crop, with their availability spread over an extended period. However, more research is required to confirm this interpretation.

The interactions between the lower rates of DAP and the various biochar additions (T2, T4, T6 and T8) can be explained by the initial competitive buffering of nutrients by the fresh biochar and the later release of those nutrients for uptake by the crop roots. This results in more or less the same yield in the short-term but may increase the available nutrient pool for subsequent seasons.

The buffering effect of biochar is likely to persist into the future, but biochar already in the soil is less likely to compete with emerging crops in following seasons because its binding sites will be partially saturated from the previous year; a bit like comparing the sticking potential of new velcro to used velcro that already has some fluff stuck to it.

The costs and benefits of agricultural products and farming practices are often calculated on an annual basis but this approach is not always valid. As with stubble retention and clay spreading, the true benefits of biochar additions should be assessed over several years following the first treatment.

Future

The Streaky Bay trial site has been set up for long-term analysis, with the existing plots used to assess long-term carry-over effects of biochar application and the impact of adding fresh biochar in successive years.

It is anticipated that new concepts will also be introduced, with one of particular interest being the banding of biochar pre-saturated with phosphorous solutions (liquid DAP, phosphoric acid) so the biochar is pre-buffered and the phosphate it carries is physically separated from the soil calcium and therefore at lower risk of permanent lock-up.

Nitrous oxide resulting from the use of nitrogenous fertilisers is the largest greenhouse gas liability associated with cropping enterprises. Results from several pot and pasture studies indicate that additions of biochar may mitigate nitrous

oxide production from soils in certain conditions. It is reasonable to conclude that preventing losses of nitrogen (N) derivatives to the environment keeps more nitrogen in the farming system and increases the availability of N to plants over a longer period, thus offering better N use efficiency and a better return on fertiliser investments.

SANTFA is keen to explore the potential to inoculate biochar with free-living nitrogen-fixing bacteria as a means of reducing nitrogen input costs, reducing the risk of high percentages of screenings in dry finishes and minimising environmental losses.

Another area of interest is the potential to use the sorption capacity of fresh biochar to reduce greenhouse gas emissions from manures and composts. Manures and composts do release volatile nutrients as greenhouse gases as they mature. Precursors of these gases should bind to fresh biochar added to manure or during the composting process, in theory reducing the greenhouse footprint and retaining more nutrients in the final product.

Some scientists have been working on ways to 'value add' biochar and improve the benefits it can provide by manipulating the pyrolysis process. SANTFA has incorporated a value-added biochar, Biochar Mineral Complex (BMC) into its 2011 trial program. It is hoped that increasing biochar's potency through improved manufacturing will enable application rates to be reduced.

In 2011, SANTFA has biochar trial sites on Eyre Peninsula (Streaky Bay and Pt Kenny), on Yorke Peninsula (Warooka) and in the Mid North (Hart and the Mid North High Rainfall Zone trial site).

Summary

Adding phosphate fertilisers to high-pH calcareous soils is not very efficient.

Using biochar to improve the availability of applied phosphate could be a viable commercial option, particularly if it also reduces nitrous oxide emissions, carries carbon sequestration credits and improves overall soil health.

Biochar rates need to be balanced with land capability and the aims of the farming system.

* *DAP = Diammonium Phosphate (N: 18.0% P: 20.0% S: 1.6%)*

References

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