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Section 7

Soils

Can soil organic matter be increased in a continuous cropping system in the low to medium rainfall zone?

RESEARCH

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Key messages

- **Eight trial sites were established across SE Australia to investigate whether soil carbon levels can be increased in no-till farming practices, inclusive of adding nutrients to aid the biological breakdown of stubble into soil organic matter. After 3 and 5 years of treatments no increase in soil carbon could be demonstrated.**
- **We demonstrated that soil carbon is unlikely to increase with current cropping practices over a period of 5 years. But we do know that no-till and stubble retention protects the soil from wind and water erosion and over a longer time-frame the soil carbon levels may increase.**

Why do the trial?

Soil organic matter has physical, chemical and biological functions in soil. Increasing soil organic matter levels may improve the capacity of these functions in the soil, thereby improving the soils' resilience to degradation and possibly improving the soil productivity. Increasing soil organic matter also sequesters atmospheric carbon dioxide which can mitigate greenhouse gas emissions.

Increasing soil organic matter on broad-acre farms in the Australian wheat-sheep zone has been difficult to achieve. Soil organic matter content is typically measured by determining the content of organic carbon in a soil. Long term trials have showed little or no increase in soil carbon regardless of management practices imposed. Recent research undertaken by CSIRO at a medium to high rainfall site in NSW, demonstrated that increasing soil organic carbon was possible if residues were pulverised and incorporated with a rotary cultivator together with an application of sufficient fertiliser nutrients (nitrogen N, phosphorus P and sulphur S) to enhance soil biological activity to break down the crop residues into soil organic matter (Kirkby *et al*. 2016). This innovation was adapted to broadacre farming methods and tested over a three and five-year cropping rotation with grower groups at eight sites across the southern grain belt. The sites were located at Minnipa - EPARF, Hart, Birchip - BCG and Temora - Farmlink for five years, and Winchelsea - SFS, Cressy - SFS, Condobolin - CWFS and Ouyen - MSF for three years#.

Three fractions of soil organic carbon are recognised – Particulate (POC), Humus (HOC) and Resistant (ROC). The three fractions have different physical, chemical and biological functions in sandy loam soils. The proportions of the three fractions as components of the soil organic matter were measured and are reported in these results.

POC:

- Reducing soil crusting and improving infiltration,
- Improving soil friability,
- Lowering the soil bulk density,
- Increasing Plant Available Water (note – POC has a small effect on the Drained Upper Limit of the soil but because sandy loam soils in dry environments such as the upper Eyre Peninsula are rarely at Drained Upper Limit, this benefit is only minor),
- Storage and cycling of nutrients,
- Food source for soil micro-organisms.

 # EPARF = Eyre Peninsula Agricultural Research Foundation; BCG = Birchip Cropping Group; SFS = Southern Farming Systems; CWFS = Central West Farming Systems; MSF = Mallee Sustainable Farming

HOC:

- Improving soil friability,
- Storage and cycling of nutrients,
- Soil pH buffer (reducing acidification),
- Improving the Cation Exchange Capacity (CEC),
- Food source for soil micro-organisms,
- Mineralisation of ammonium and nitrate (plant available N).

ROC:

- Binding detrimental ions (such as aluminium),
- Some effect on the CEC.

It is clear that if soil organic carbon levels can be increased, the benefits for improving the soil physical, chemical and biological condition would be significant.

How was it done?

Eight sites were established in SE Australia to test whether soil organic carbon levels could be increased by retaining stubble and applying additional nutrients to enhance soil biological activity to breakdown the stubble into soil organic matter. Four of these sites were maintained for three years, the other four sites for five years. The site at Minnipa was maintained for five years.

The trial compared stubble retention versus stubble removal, with the application of additional fertiliser nutrients to aid the breakdown of stubbles into soil organic matter over a cropping rotation. Each season the stubble load of the previous crop was determined, and additional nutrients were applied to match the stubble load as a treatment to enhance the breakdown of stubble into soil organic matter.

Soil microbes use stubble as a food source and convert stubble into humus. Stubble is carbon rich relative to the other essential nutrients required by microbes and additional nutrients are required by the soil microbes to convert stubble into humus. The amount of NPS required by the microbial population to break down stubble into humus is worked out from:

- 1 tonne of carbon as humus contains 80 kg N, 20 kg P and 14 kg S
- 1 tonne of wheat stubble contains 450 kg carbon, of which 70% is lost to the atmosphere (hence 135 kg carbon is retained for every tonne of stubble)
- For the soil microbes to convert this amount of stubble carbon into humus requires 10.8 kg N, 2.7 kg P and 1.9 kg S
- 1 tonne of wheat stubble already contains 5 kg N, 0.5 kg P and 1 kg S
- Hence for every tonne of wheat stubble an additional 5.8 kg N, 2.2 kg P and 0.9 kg S is required to enable the soil microbes to break down stubble into humus.

The trial was established on behalf of EPARF at the Minnipa Agricultural Centre in 2012. Treatments were replicated 4 times and consisted of:

Stubble: (i) retained and left standing; (ii) cultivated and incorporated prior to sowing; (iii) removed prior to sowing.

Nutrients: (i) normal application of NPS to optimise production; (ii) additional nutrients applied at sowing to enhance microbial activity to breakdown stubble into soil organic matter. (Note – the Yield Prophet model was used to optimise N requirements in-crop).

The trial ran for five cropping seasons (2012 to 2016). At the end of the trial, in March 2017, all treatment plots were soil sampled to 30 cm depth with three replicate cores taken in each plot. Each core was divided into 0-10 and 10-30 cm sections. Each sample was air dried and analysed for bulk density, total soil carbon (Leco) and the fractions of soil organic matter – Particulate (POC), Humus (HOC) and Resistant (ROC) using mid infrared (MIR) spectroscopic techniques.

Treatment crop yields were recorded.

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Table 1. Crop rotation and yield over five years of treatments (2012 to 2016) at Minnipa.

Stubble treatment	**Nutrition treatment**	**Yield (t/ha)**				
		2012	**2013**	**2014**	**2015**	**2016**
GSR (April to October rainfall mm)		185	237	290	249	261
Crop type		Wheat	Wheat	Wheat	Wheat	Canola
Variety		Scout	Mace	Grenade	Mace	TT
Stubble removed	Normal practice	1.3	2.6	3.8	2.6	1.0
Stubble removed	“ plus NPS	1.4	2.5	3.9	2.9	1.0
Stubble standing	Normal practice	1.3	2.6	3.6	2.7	1.0
Stubble standing	“ plus NPS	1.2	2.5	3.6	2.8	1.1
Stubble incorporated	Normal practice	1.3	2.6	3.8	2.9	0.9
Stubble incorporated	“ plus NPS	1.2	2.5	4.0	3.0	1.2
	LSD (P=0.05)	*ns*	*ns*	*ns*	*ns*	*ns*

Table 2. Soil organic carbon stock (t/ha, 0-30 cm) after five years of treatments (2012 to 2016) at four trial sites.

Stubble treatment	Nutrition treatment	Soil C (Leco) 0-30 cm (t/ha)			
		Minnipa	Hart	Birchip	Temora
Stubble removed	Normal practice	38.1	50.5	31.8	42.9
Stubble removed	" plus NPS	38.3	53.0	29.8	44.0
Stubble standing	Normal practice	37.0	49.7	32.0	42.5
Stubble standing	" plus NPS	35.7	49.7	31.9	44.5
Stubble incorporated	Normal practice	37.9	51.9	30.9	39.8
Stubble incorporated	" plus NPS	39.0	53.0	31.4	41.5
Double stubble	Plus NPS		52.6*		
	LSD (P=0.05)	*ns*	*ns*	*ns*	*ns*

*Annual application of double the stubble load plus additional NPS at Hart only

What happened?

Trial rotation and crop yield

Over the five-year trial there were no differences in yield between treatments (Table 1). This result implies that the additional nutrients applied as a treatment were not used by the crop for yield but were available to the soil microbes for potential stubble breakdown into humus.

At the other three sites with a five year rotation (Hart, Birchip and Temora) there were no differences in crop yield between treatments.

Change in soil organic carbon after five years of treatments

The average soil organic carbon content of the topsoil (0-10 cm) at Minnipa was 1.2% and 0.8% in the subsoil (10-30 cm). After five years of trial work there was no difference in total soil organic carbon (t/ha, 0-30 cm) at Minnipa (Table 2) nor at the other three trial sites. (Note: in this study soil organic carbon was measured with the Leco technique, these values are generally 20% higher than the more traditionally used analysis for soil organic carbon with the Walkley Black technique).

At the Hart site an extra treatment was included – each year the stubble load was doubled and the required additional nutrients were applied. This treatment did not result in higher soil carbon levels (Table 2) after five years of experimentation.

Soil carbon fractions

At Minnipa and the other three trial sites the treatments did not result in changes in the soil organic matter fractions. After five years of treatment applications the soil carbon fraction proportions were: 15% POC, 55% HOC and 30% ROC.

What does this mean?

In the SE Australian low to medium rainfall zone it is difficult to increase soil organic carbon levels using current cropping techniques, even if additional nutrients are applied to enhance soil microbial activity for the breakdown of stubble into soil organic matter. The previous research undertaken in southern NSW where significant increases in soil organic carbon were measured (Kirkby *et al*. 2016), included pulverising the residues with a flail mulcher followed by incorporation with a rotary cultivator – this treatment was not applied in our trials because we regarded it unlikely that farmers could be persuaded to pulverise stubbles and cultivate the soil, increasing the risk of soil erosion in low rainfall environments, to see a potential increase in soil organic carbon.

Eight sites in SE Australia undertook the trial work outlined in this paper, four of the sites were maintained for three years, and four sites – including Minnipa – for five years. At all sites the result was the same – an increase in soil organic carbon could not be demonstrated with the treatments outlined in this paper.

The take home message in relation to soil organic carbon is that it is unlikely to increase with current cropping practices through stubble and fertiliser management. We do know that no-till and stubble retention protects the soil from wind and water erosion and over a longer time-frame soil organic carbon levels may increase. However, based on these results it is likely that any potential increases in soil organic carbon will be small.

References

Kirkby CA, Richardson AE, Wade LJ, Conyers M, Kirkegaard JA (2016). Inorganic nutrients increase humification efficiency and C-sequestration in an annually cropped soil. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0153698

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