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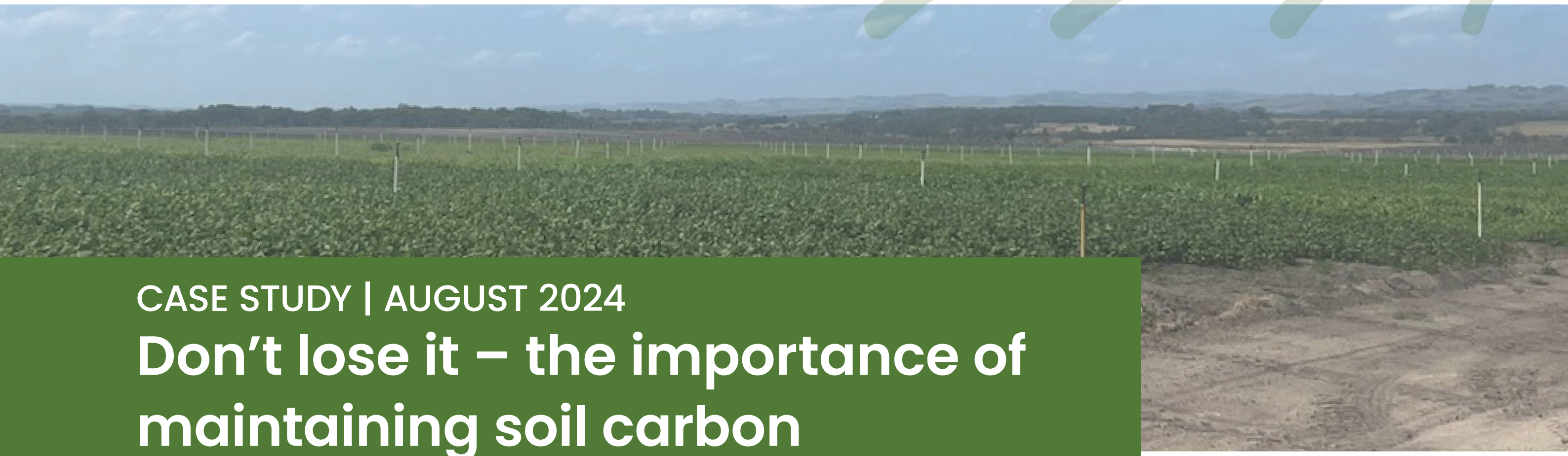

CASE STUDY | AUGUST 2024

Don't lose it – the importance of maintaining soil carbon

Tarwin VIC demonstration site

Overview and purpose

The Tarwin demonstration site in South Gippsland, Victoria is hosted by Schreurs & Sons, approximately 150 kilometres south-east of Melbourne. It aims to maintain soil carbon in a clay loam greenfield site which is gradually being converted from pasture to a vegetable production system rotation, predominantly celery, spinach and leek.

Schreurs & Sons and the Soil Wealth ICP team have worked together over many years to demonstrate how soil health can be improved through the adoption of precision agricultural technologies and to demonstrate the benefits of going back to basics by introducing cover crop rotations to the production system.

This case study outlines the importance of soil carbon in vegetable production and presents the results from Years 1 and 2 of the demonstration site.

KEY MESSAGES

- A trial is underway to maintain soil carbon at a vegetable farm in South Gippsland, Victoria by using minimum till, cover cropping and compost.
- Soil carbon is important for soil health and nutrient holding and cycling capacity for growing healthy and productive crops.
- Soil organic carbon is determined by the dynamic factors including soil type, land use, and soil management practices undertaken, including fertiliser additions that contribute nutrients other than carbon.
- Soil labile carbon is a good instantaneous measurement of soil biological activity.
- The most effective treatment in the trial has been the combination of cover cropping and minimum till that have minimised soil carbon loss through avoided bare fallow and disturbance.
- When measuring soil biota, it is desirable that their foodweb lies in the quadrant which has a high structural index and lower enrichment index with a moderate carbon to nitrogen ratio.

Hort Innovation

This project has been funded by Hort Innovation using the vegetable and melon research and development levies and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

RMCG

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Why is soil carbon so important?

Soil carbon refers to the measure of carbon contained within soil organic matter, which is around 50% on average. It plays a key role in soil health.

Vegetable growers can maintain or build soil carbon to improve soil health, crop resilience and productivity, and reduce greenhouse gas emissions.

"Without soil carbon there the soil is dead to me. It's just so important to grow. We've seen areas where our soil carbon is depleted and things struggle to grow," host grower Adam Schreurs said.

High organic carbon levels are associated with higher soil microbial populations, good nutrient-holding capacity and nutritional cycling ability. Understanding the role of carbon will assist vegetable growers to remain profitable and sustainable in the future.

Soil carbon and organic matter play a number of beneficial roles in biological functions and support productivity through:

- Providing a slow release of nutrients
- Improving cation exchange capacity and nutrient-holding ability
- Reducing erosion risk
- Assisting soil water holding capacity
- Buffering against soil acidity
- Increasing soil biota and diversity.

Site conditions and treatments

Existing conditions prior to the cover crop

Baseline soil measurements were taken in June 2023 (Year 1). Similar results were found across the site. Organic carbon levels ranged from 5.5-5.9%. The soil structure which is measured by the calcium to magnesium ratio as an indicator of stability was relatively stable in the control area (block 14) and unstable in the trial area (block 15) which could have been due to the deep ripping and cultivation which occurred in the trial area prior to planting.

Phosphorus and nitrogen were relatively low for both blocks. The Colwell P (a measure of the phosphorus in the soil) ranged from 28–34 kg/ha in the control and treated blocks respectively and for nitrogen were 28 kg/ha and 23 kg/ha respectively. Micronutrients including zinc, manganese and boron were at adequate levels across the two bocks whilst iron levels were high.

Photo: Young celery crop at the Tarwin demonstration site control area, Schreurs & Sons (June 2023)

Treatments and inputs

Cover crops were sown in mid-January 2024. Buckwheat and common vetch were terminated a month later in late February and Japanese millet was terminated in early March 2024 (Table 1 and Figure 1). Fertiliser inputs were applied to the control area prior to spinach being sown as the first cash crop (Table 2). The spinach crop was harvested in late March and a celery and leek rotation was planted in the trial area in early May 2024. Some of the minimum till treatments trialled the use of new strip tillage equipment to maintain cover crop trash and ground cover (Figure 2 on page 4).

Treatment	Practice	Cover crop
1 (block 15)	Grower standard practice, composting, minimum till	Japanese millet
2 (block 15)	Grower standard practice, cover crop, cultivation	Buckwheat-vetch mix Japanese millet
3 (block 15)	Grower standard practice, composting, cultivation	Compost
4 (block 15)	Grower standard practice, cover crop and minimum till	Buckwheat-vetch mix Japanese millet
5 (block 14)	Control area (grower standard practice: base fertiliser and cultivation)	Cereal ryegrass
6 (east of block 15)	Reference area – undisturbed and uncropped area, remains under pasture with no treatments	None

Table 1: Different treatments in the trial area

Fertiliser	Input units	Kg/ha applied
Di-ammonium phosphate (DAP)	18–46–0	-
Muriate of potash (MOP)	10–21.9–0–1.5	1,000
Potassium sulphate	42 K, 18 S	200–300

Table 2: Inputs

Figure 1: Trial area treatments at Tarwin

Figure 2: Crop growth comparison after two months (May to June 2024)

Measuring soil carbon and other nutrients over time

To measure mass of carbon stored in the soil it is important to know the bulk density. Different analytical methods are used by labs to measure soil carbon. The soil carbon test was measured by a complete combustion of a sub-sample of soil by furnace method. This technique uses high temperatures to "burn-off" the carbon which then gets measured as carbon dioxide.

Measuring bulk density is important to understand changes in soil carbon over time. The percentage of soil organic carbon in the soil layer at 10cm-30cm needs to be adjusted to bulk density over the same period. If the soil becomes compacted due to cultivation practices, this can increase the bulk density and cause a discrepancy in the soil carbon sequestration and falsely indicate an increase in soil carbon.

What does labile carbon tell us?

Labile carbon is the carbon most readily available as a carbon and energy source to microorganisms.

While changes in practice may not demonstrate changes in total soil carbon, they may increase labile carbon, making it a better indicator of improved soil quality. Labile carbon is often a good 'leading indicator' of soil biological activity.

The labile carbon field test is useful for comparing management practices that influence organic carbon. A labile carbon test was undertaken across the different treatments within the trial and compared to the control area.

The relative results in Figure 3 showed:

- **Very good labile carbon** in the areas with the warm season cover crops (Japanese millet-vetch mix and buckwheat) combined with minimum till
- **Good labile carbon** in the areas with cover crops and cultivation, in both the trial and control that included grower standard cereal rye
- **Poor-average labile carbon** in the areas with composting and cultivation, or minimum till, without cover crops.

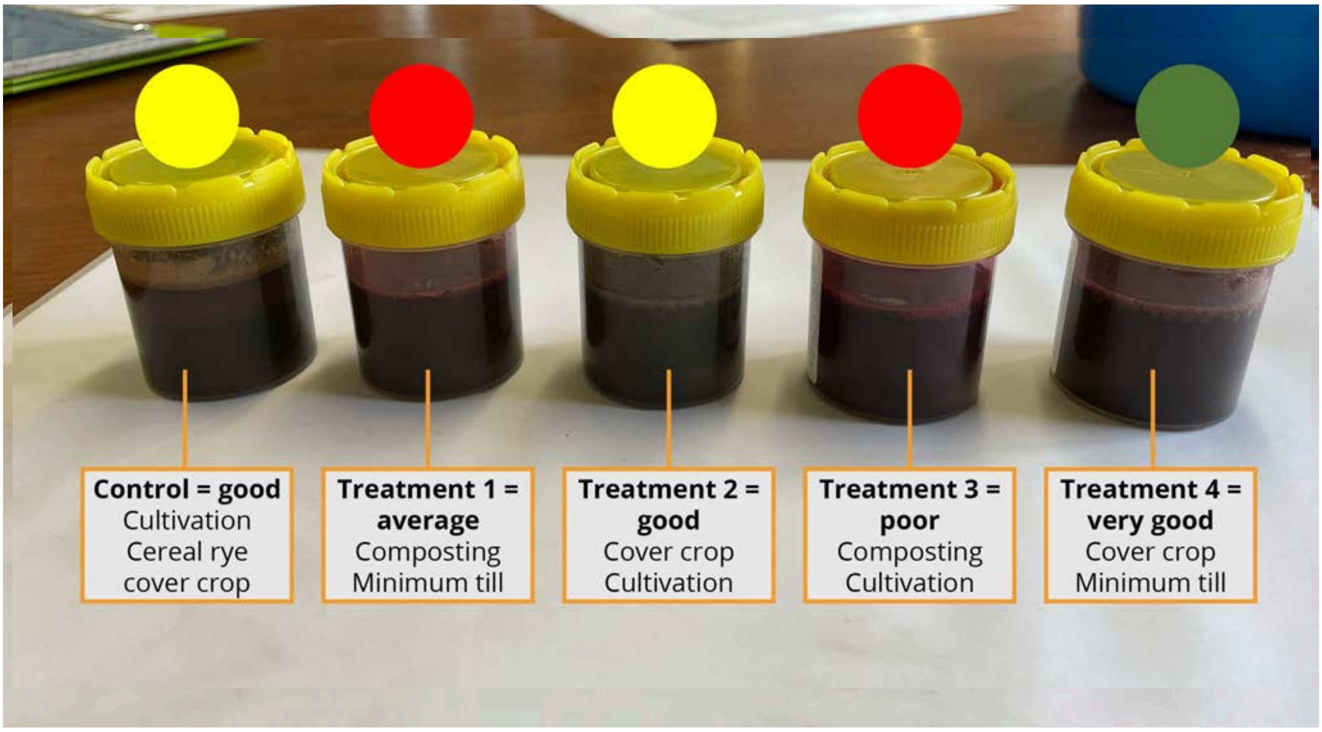

Figure 3: Labile carbon field test results with soil health 'traffic light' indicators

Both the control and the treatment blocks started with high organic carbon levels in year 1. Soil carbon reduced from year 1 to year 2 the least in treatment 4 (-0.1%; cover crop with minimum till) and the most in treatment 1 (-2%; composting with minimum till), demonstrating the importance of ground cover and avoiding bare fallow between cash crops. Treatment 4 with the buckwheat and millet planted as a cover crop which was minimum tilled outperformed the control which had a slightly larger reduction in soil carbon (-0.5%) and was similar to the reference area (-0.2%; undisturbed and uncropped pasture) (Figure 4 on page 6).

"You can really see the difference in bed stability between the minimum tillage and conventional tillage. We've had a lot of recent heavy rain and the beds that were conventionally tilled [in the control] are slumping in some areas," Adam noted.

These treatment areas had better soil structure and crop growth after two months to late June 2024 compared to the control areas too, which was shown by visual inspection of soil pits, rooting depth and remaining cover crop biomass (Figure 5 on page 6). This is promising with the planned harvest of celery and leeks in late September 2024.

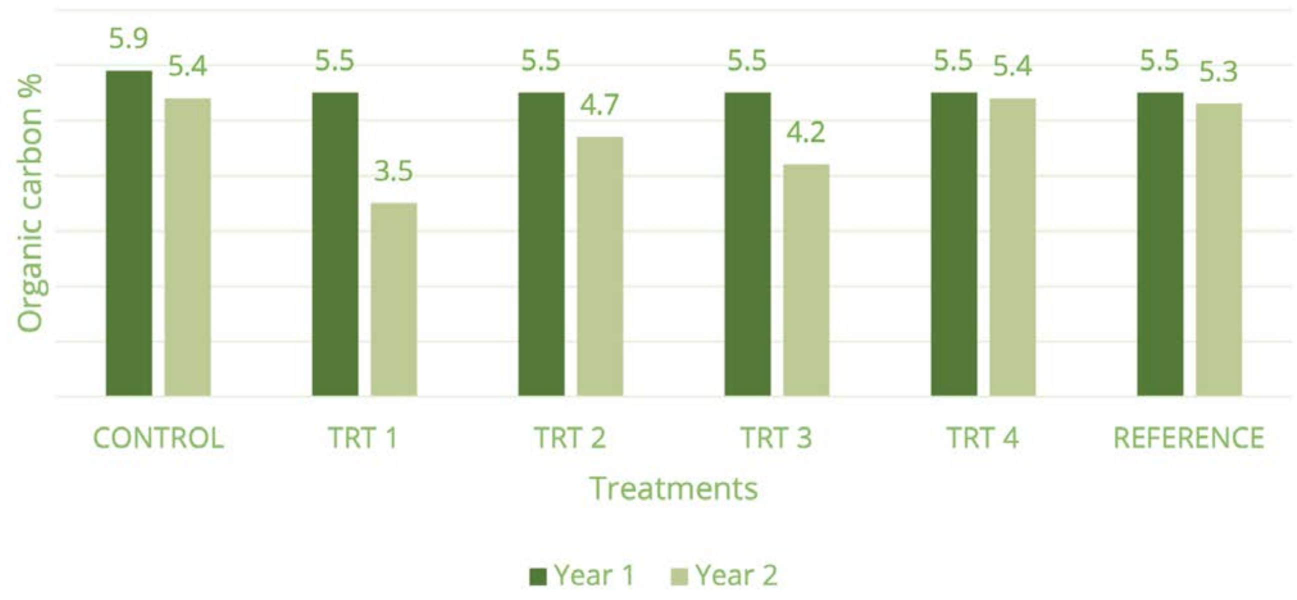

Figure 4: Organic carbon percentage

Figure 5: Cover crop biomass, three months after termination

Soil nitrogen levels significantly increased in the second year for the control and treatments which received one tonne mono-ammonium phosphate (MAP) (10-21.9-0-1.5) and di-ammonium phosphate (DAP) (18-46-0). Units of nitrogen applied were calculated to be approximately 280 kg/ha. Although the cover crop biomass was not measured, treatment 4 seemed to return an excess amount of nitrogen to the soil post-cultivation to that applied. All other treatments measured lower units of nitrogen than that applied, however, this could be influenced by the rate of breakdown (Figure 6). The buckwheat was terminated in late February and the soil test was taken one month later in late March 2024.

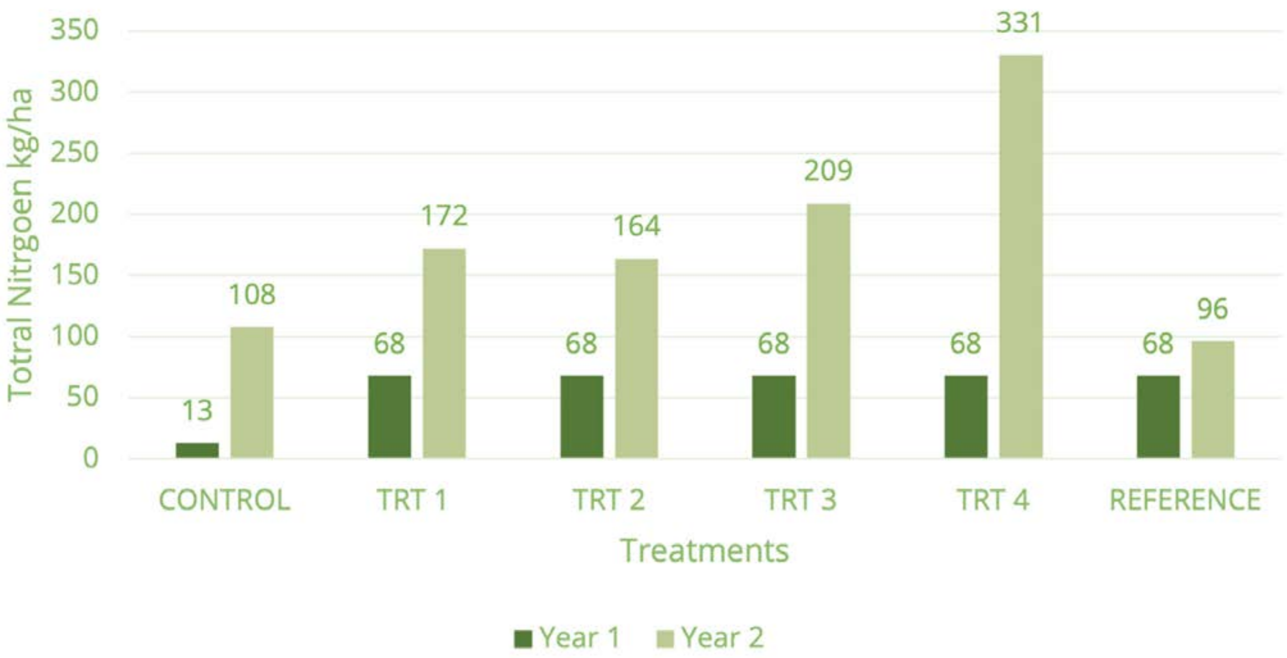

Figure 6: Total nitrogen (kg/ha)

Photo: Pre-bed forming at the Tarwin demonstration site, Schreurs & Sons (May 2023)

The carbon to nitrogen ratio indicates whether nitrogen will be fixed or released when microorganisms breakdown the organic matter. The carbon to nitrogen ratio is in the medium range between 11 and 24. The carbon to nitrogen ratio increased for all the treatments containing cover crops compared to the reference area (undistributed and uncropped pasture). The carbon levels are in a good range to allow for the breakdown of nitrogen by soil microbes.

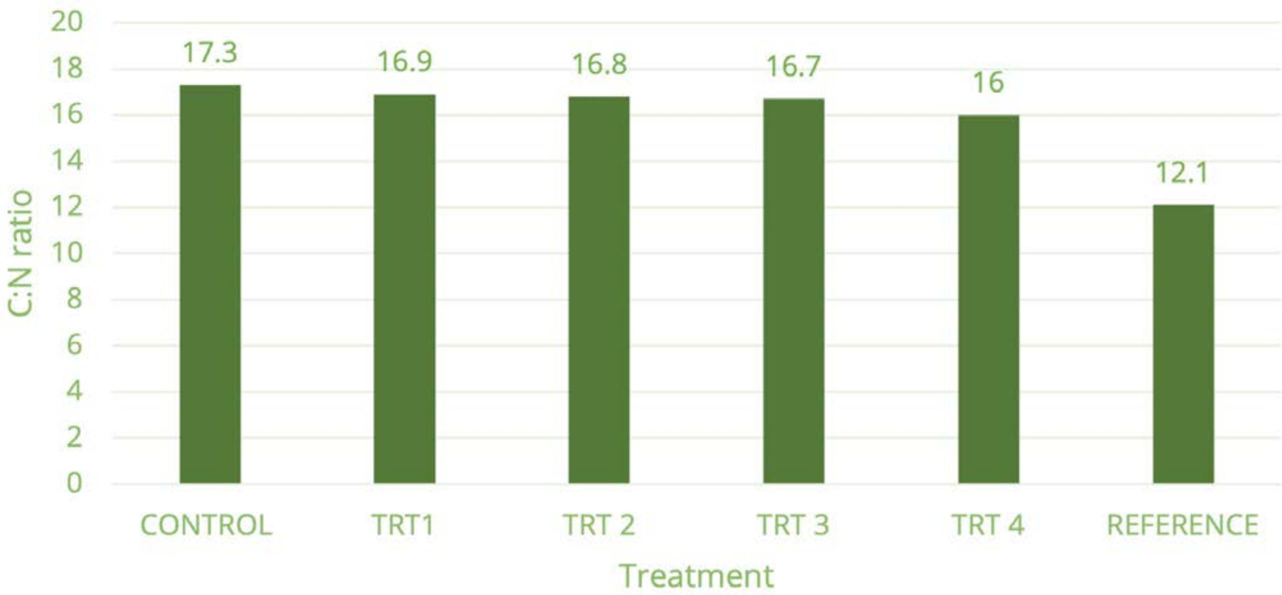

Figure 7: Carbon to nitrogen ratio

Soil biota and diversity

Soil health samples were taken and the DNA analysed by two laboratories – Metagen and the South Australian Research and Development Institute (SARDI).

Very little arbuscular mycorrhizal fungi (AMF) abundance was identified in the control and trial area. The control sample had three different genera of AMF detected including *Glomus, Acaulospora* and *Ambispora* comprising of nearly 1% of the total fungal population. The trial area had a single species of AMF detected (*Ambispora*) at a low abundance of <0.1% of the total fungal population.

In the control area, pest suppressing microbes were detected including Trichoderma and entomopathogenic fungi, and a very high proportion of soil borne pathogens including sclerotia. The trial area seemed to have the highest abundance of soil borne pathogens including sclerotinia, verticillium and rhizoctonia despite a moderate detection of entomopathogenic fungi.

The trial area (block 15) had low biodiversity, however a high proportion of microbes were identified which have plant associations including: actinobacteria, firmicutes, endomycorrhizal fungi and ectomycorrhizal fungi.

Overall, the soil health rating was highest for the reference area (undisturbed and uncropped), followed by the trial area (block 15) and lastly the control area (block 14) which considered the population of AMF, bacteria, fungi, mesofauna and protists (Figure 8 on page 9). This could be explained by the limited disturbance in the reference area compared to cultivation and deep ripping in the cropping area (blocks 14 and 15).

Further assessments will see how the AMF population can be influenced over time by measuring soil borne disease, organic carbon, soil structure and yield.

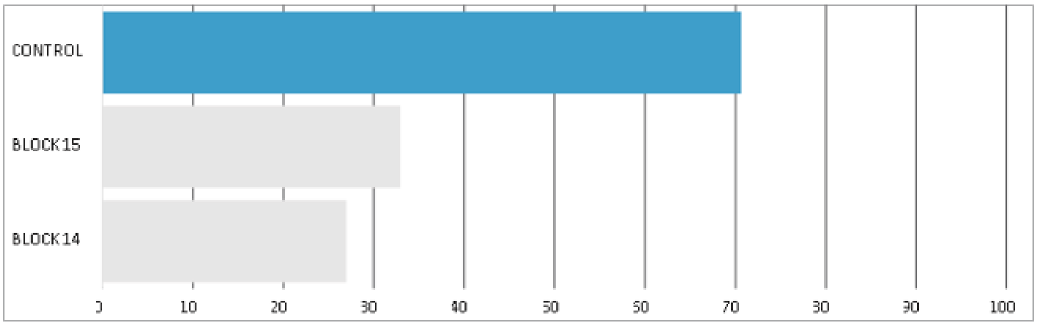

Figure 8: Overall soil health score comparison (Metagen analysis of test September 2023)

The SARDI Predicta Soil DNA test shows pythium as a moderate–high rating, with sclerotinia, rhizoctonia and botryosphoria as low across both the control and trial areas (Table 3). The Predicta Soil DNA test for pathogens is still in development for horticultural crops.

The most important pathogens affecting celery include *Rhizoctonia spp* and *Pythium spp* which cause damping off infection resulting in poor seedling emergence and stunting. White mould caused by Sclerotinia sclerotiorum is another important disease of celery which produces water–soaked roots. This SARDI DNA test results shows multiple species of pythium present in both blocks and sclerotinia and rhizoctonia in the trial area (block 15).

Table 3: Soil pathogens from the SARDI Predicta Soil DNA test (KDNA g/sample)

Pathogen	Control (block 14)	Trial (block 15)
Sclerotinia sclerotiorum	0	1
Rhizoctonia solani (AG2.2)	0	2
Pythium Clade F (multiple species)	148	135
Botryosphoria (sampling off, seedling blight, collar rot, stem rot, charcoal rot)	3	6

Low	Moderate	Moderate-high	High

Free living nematodes and how their composition and abundance can help inform soil health

The free living nematodes (FLN) analysed in the SARDI Predicta Soil DNA test showed a combination of fungivores, bacterivores and predators which is indicative of the food sources in the soil microbial population. The numbers of each family of nematodes in Table 4 was transposed to loge+1 and analysed using the NINJA: Nematode INdicator Joint Analysis application developed by Wageningen University & Research to provide soil health rating indices which are shown in Figure 9 on page 11.

Table 4: Living nematodes from the SARDI Predicta Soil DNA test (KDNA g/sample)

Free living nematodes	Feeding type	Control (block 14)	Treatment (block 15)
Aphelenchoididae	Fungivores	77	18
Aphelenchidae	Fungivores	2	0
Cephalobidae	Bacterivores	227	104
Dorylaimida	Omnivores	68	118
Mesorhabditis	Predators	98	4
Monochida	Predators	1	0
Panagrolaimidae	Bacterivores	281	26
Total		**754**	**270**

Low	Low-moderate	Moderate	Moderate-high	High

Photo: Japanese millet cover crop after termination at the Tarwin demonstration site, Schreurs & Sons (March 2024)

The Structure Index (SI) correlates with the degree of maturity of an ecosystem and Enrichment Index (EI) parallels the intensity of nutrient enrichment. Figure 9 presents a 'foodweb analysis' which correlates SI and EI with various soil health parameters including maturity, nitrogen enriched, carbon to nitrogen ratio and bacterial to fungal ratio. A foodweb analysis with a high enrichment and structural index with mature and fertile soil, and a moderate carbon to nitrogen ratio with a combination of bacterial and suppressive fungal populations, is desirable .

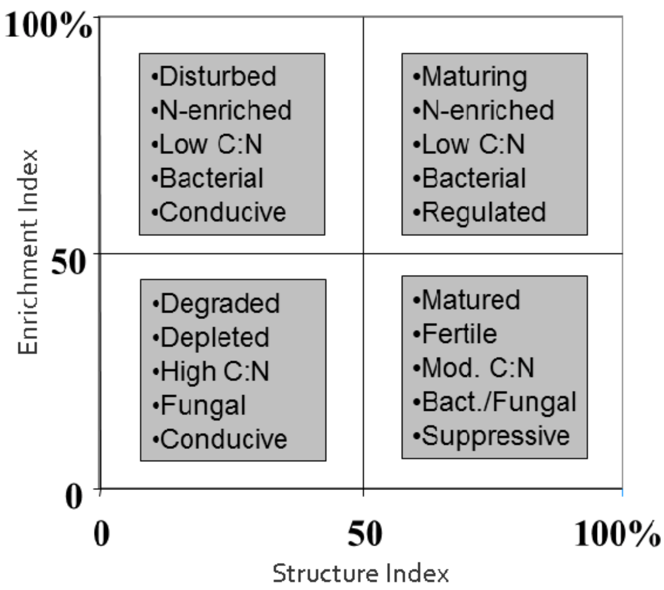

Figure 9: Foodweb analysis interpretation scheme

Photo: Inspecting soil pits at the Tarwin demonstration site, Schreurs & Sons (March 2024)

The results of the foodweb analysis show the control, trial and reference areas all exhibit a maturing, nitrogen-enriched, low carbon to nitrogen, bacterial and regulated metabolic footprint in the desirable range (Figure 10).

The SARDI Predicta DNA test for free living nematodes is still under development and is not yet a commercial service.

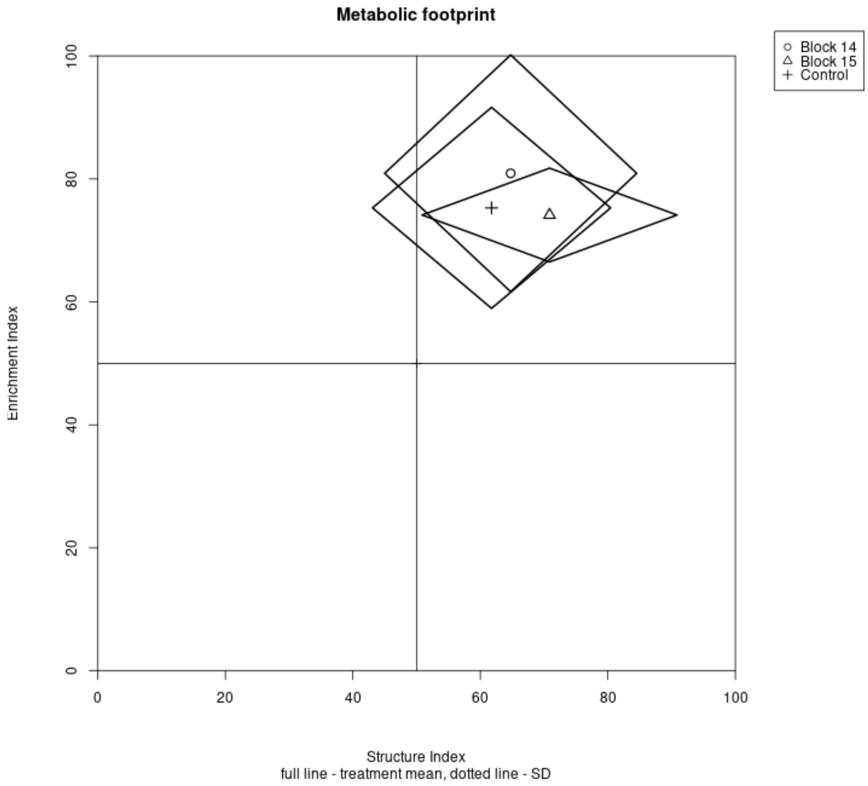

Figure 10: Free living nematode DNA test results plotted and represented as a rhombus which corresponds to the footprints of enrichment and structure components respectively

WHERE TO NEXT? FURTHER INFORMATION

You can access the following useful resources for further information:

- **Carbon storage in vegetable soils fact sheet**
- **The Carbon Series Part 2: Soil carbon and carbon sequestration global scan and review**
- **Labile carbon fact sheet**
- **How do you know your soil is healthy? Top tips for vegetable growers fact sheet**

Stay tuned for harvest in the spring (September 2024) when we'll undertake a yield assessment and crop tissue tests to determine nutrient cycling for the different trial treatments.