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GOONDIWINDI CIRUCLAR COTTON PROJECT

TRIAL RESULTS

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GOONDIWINDI CIRCULAR COTTON PROJECT

Introduction

In December 2019 the Transition to Action (T2A) program visited Goondiwindi to scope possible circularity projects in this regional town of Queensland. Transition to Action was a collaborative program between circularity specialists Coreo, the Queensland Government's Department of Environment and Science (DES) and the local people of Goondiwindi. From this T2A program the Goondiwindi Circular Cotton Project was born.

The project became a collaboration between Coreo, the Queensland Government, local brand Goondiwindi Cotton, cotton farmer Sam Coulton, Sheridan, Cotton Australia and Cotton Research and Development Corporation supported soil scientist Dr Oliver Knox of the University of New England (UNE).

The mission was to to test whether shredded cotton products at end of life could be returned to the cotton fields, offering both benefits to cotton soil health, and a scalable solution to textile waste.

Although the formal phase of T2A wrapped up in October 2021 the momentum that the Queensland Government catalysed has continued. This report outlines the results of field trials conducted at "Alcheringa Farm" during the 2021-22 cotton season, and gives an outline of future plans for this groundbreaking work.

Our Story

Phase 1: lab tests

Back in 2020, Phase One of the project involved lab-based testing cotton fabrics to assess what might happen during the biodegradation process, in terms of potential benefits such as carbon and water retention in soils.

The experiment involved burying two centimetre squares of cotton fabric in about 40 grams of moist Goondiwindi soil and incubating it at 20oC for 24 weeks. The buried material equated to between 400-3000 kg of material applied to a hectare of farmland, the equivalent of removing 2,500 to 20,000 t-shirts from landfill (based on average T-shirt weight of 150g).

The results of the Phase One lab tests, analysed by Dr Oliver Knox with support from the Cotton Research and Development Corporation, showed:

- Adding cotton fabric samples to soil increased levels of microbial (bacterial and fungal) activity in all but one sample.
- When added to soil all but the tightest weave of cotton material broke down significantly in about 24 weeks.
- Cotton seeds germinated just as well in soil to which cotton fabric had been added as it did in soil to which no material had been added.

These results encouraged the team to move to a field trial which was implemented during the 2021-22 cotton season.

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Our Story

Phase2: field trial

In June 2021 around two tonnes of cotton textiles, garments and end of life State Emergency Service coveralls were processed at Worn Up in Sydney, transported to “Alcheringa” farm, and spread onto a cotton field by local farmer, Sam Coulton.

The field was being prepared for planting the next cotton crop in October 21. It was hoped the fabrics would break down in the soil, increase microbial activity, lock in carbon and provide cover to improve soil moisture.

Projections showed 2,250kg of atmospheric Carbon Dioxide equivalents (CO_2 e) would be mitigated through the breakdown of these garments in soil rather than landfill.

The trial looked at the breakdown process at different application rates, and assessed effects on soil nutrition, respiration/CO_2 and microbial biomass.

The trial was concluded at cotton harvest in May 2022, with initial results reported here, although it’s expected the real benefits for cotton yield and long-term soil health may not be known for many years.

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Next Steps

There is much interest in further collaboration from industry groups, government, farmers, brands and potential investors. In order to establish the feasibility of this approach as a scalable solution to cotton textile waste, more research is required as a next step.

Any group or individual interested in collaborating can contact the team via Cotton Australia by emailing cotton2market@cotton.org.au

Replicated Trial in 2022-23 Cotton Season

Due to Covid and floods we recognise that the first trial wasn't perfect. We're excited to announce that the trial will be replicated during the 2022-23 cotton season, with an additional farm in Gunnedah NSW added as a trial site. Sheridan is providing at least 8 tonnes of shredded cotton textiles for these trials. This will give us further confidence that the results we've already seen can be replicated across time and geographies.

CRDC Committed to Textiles Composting Research

The Cotton Research and Development Corporation (CRDC) has committed to funding cotton textiles composting research that will further investigate the effects of dyes and finishes and look at ways to pelletise cotton textiles so it can be spread on fields using existing farm machinery.

This is a three year commitment from CRDC with approx $300,000 investment.

Identify Further Challenges and Actions

Proof of concept is one thing, but there are a range of other challenges to be solved before this can evolve into a scalable solution. Logistics, collection points, blending sorting, dismantling, shredding, cost, business models and investment requirements are just some of the non-technical related questions that still need to be answered.

The group is committed to progressing this, in collaboration.

In Crop Evaluations of the Goondiwindi Circular Cotton Project

Highlights

• Compost and cotton shod application had no effect on plant stand emergence.
• Soil properties were influenced, but only slightly in most cases and with positive trends for plant production, by the compost and shod application.
• Plant development was consistent across the treatments.
• Soil microbes responded to nutritional addition from composts.
• There were no down sides to disposing of cotton waste to a cotton field observed during this trial, with rates as high as 50t/ha used.

A Reminder

The Goondiwindi Circular Cotton Project escalated to a field trial for the 2021/22 cotton season. This saw the application of 1.5, 3, 4 and 6 tonnes of cotton waste (prepared as shod) applied in demonstration plots to a cotton field at 'Alcheringa' in September, ahead of cotton planting in October.

Composted cotton gin trash was used as the carrier material to spread the cotton shod. The remaining material was also used to create a strip of approximately 50 tonnes per hectare in an adjacent cotton field as well as to a small patch of stock route. Although these were not the primary focus of the demonstration trial, monitoring these sites was also undertaken.

Samples were taken in field at the time of spreading, post planting from most of the plots and in late January – as the crop was approaching cut out.

The purpose of the demonstration plots were two fold. To firstly show proof of concept, that cotton waste can be successfully applied to the cropping system and, secondly, that there was no impact on the crop. Part of the reason for this is that long term benefits from the application of bulky organic fertilisers is known to generally take five to ten years to result in measurable changes.

Some Caveats

COVID placed several limitations on the demonstration trails. The set up was undertaken against a plan, but application challenges addressed on the day were not well captured. The initial in-crop sampling was conducted with assistance from a third party, due to COVID travel restriction, and only three of the five demonstration plots were sampled.

In December there was extensive flooding in the area, which will have contributed to movement and loss of mobile elements. During the January recovery it was noted that the crop had been damaged by hail with a lot of the growing tips damaged or removed.

Soil observations

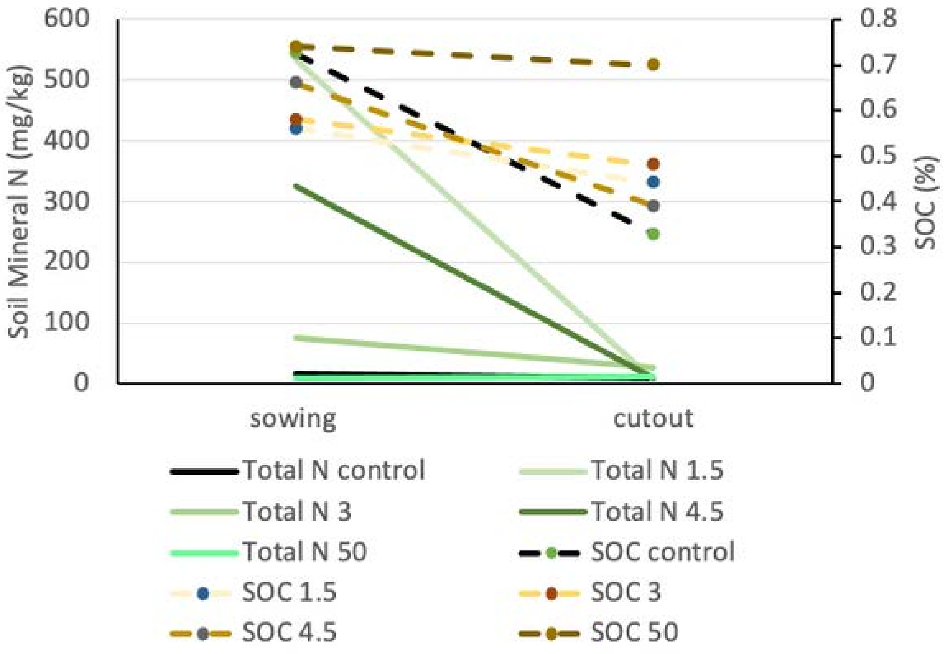
The application of the compost to the demonstration plots did not result in any notable changes in the soil samples taken at the onset of the project. The same was true in the first in crop recovery, where there was notably higher levels of nitrogen on two of the plots. These did not correspond to cotton application and were attributed to sampling having managed to recover some of the applied in crop fertiliser (Figure 1).

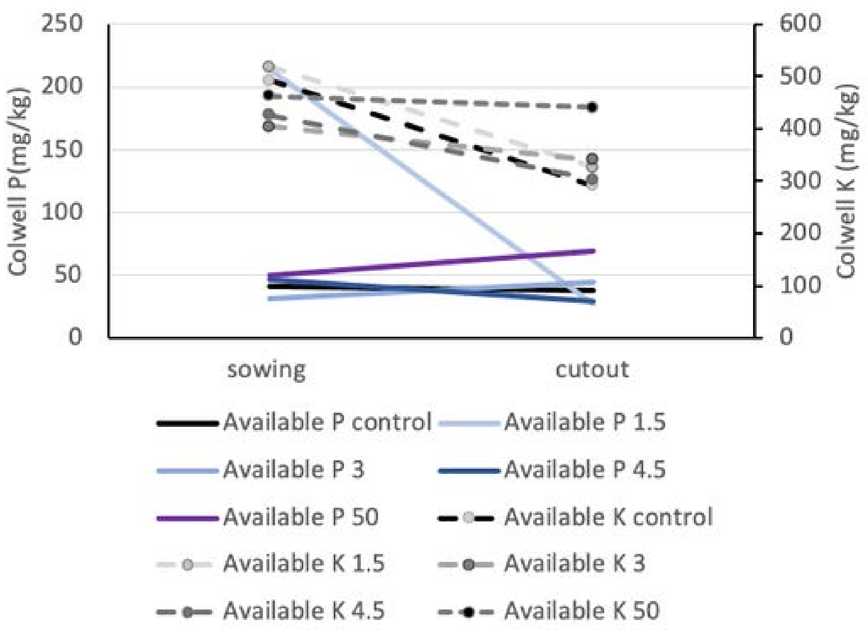
The 50 t/ha cotton strip also showed a large reduction in the amount of available N (7 versus other plot average of 152 mg/kg nitrate). This is believed to have occurred due to the carbon load deposited on the field in the compost and cotton immobilising the available N as the C:N ratio of the soil adjusted. It should be noted that this N would become available later in the season as the C is lost through microbial processes and as such this could be considered as a method to protect N fertiliser application from losses.

The levels of sulphur also appeared to increase with the application of most of the treatments. Again the pattern was not quite as expected. The 1.5 t/ha treatment had less than the control plot (4.8 vs 6.7 mg/kg), whilst the 3 t/ha plot had the highest levels of sulphur (12.3 mg/kg), which exceeded the 11.1 mg/kg of the 50 t/ha plot in the adjacent field. It needs to be remembered that sulphur can be mobile, so flooding across the field in December may have resulted in this anomaly, and that we did not get a full set of plot samples pre-sowing for comparison.

Figure 1

Figure 1 Changes in the soil N, SOC (top) and available P and K (bottom) in the cotton shod and compost plots over the course of the 2021/22 season. The higher elevated early measurements of the 1.5 t/ha plot were thought to have been due to fertiliser being captured in the initial sample. The run down is as expected, given the size of the crop grown on the field, with only the 50 t/ha treatment consistently remaining less depleted. (Note: the sowing data is assumed to correspond to these plots based on discussions with the sampling team, but cannot be confirmed)





Soil test results are presented in tables 1 and 2, with changes indicated by colour. The amount of green in table 2 after the crop has undertaken most of its vegetative growth and given the impacts of water over the season are interesting and perhaps indicative of what long term application of a compost cotton organic fertiliser could achieve in this system over time

Table 1 Summary soil test data for the field and stock route pre application of the compost and shod and again in October, which was pre-sowing. Colour changes indicate where the level of element went up (green) and down (red). The effect on the stoke routs has also been presented as a ratio of change. The application rates are based on information provided by the sample team and are assumed to be correct.

		Pre application field	pre sowing 1.5 tonnes/ha	pre sowing 3 tonnes/ha	pre sowing 4.5 tonnes/ha	pre sowing 50 tonnes/ha	Pre application stock route	pre sowing Stock route	
Colour		DKGR	GRBR	GR	GR	DKGR	DKGR	DKGR	change ratio
Ammonium Nitrogen	mg/kg	154.25	306	25	147	3	3.5	5	1.4
Nitrate Nitrogen	mg/kg	121	227	51	179	7	2.5	3	1.2
Phosphorus Colwell	mg/kg	127.75	214	31	47	50	11	7	0.6
Potassium Colwell	mg/kg	505	518	406	427	463	200	262	1.3
Sulfur	mg/kg	14.6	23.9	9.3	15.0	16.2	3.8	2.9	0.8
Organic Carbon	%	0.6425	0.56	0.58	0.66	0.74	0.88	0.77	0.9
Conductivity	dS/m	0.379	0.655	0.181	0.422	0.097	0.0535	0.062	1.2
pH Level (CaCl2)		5.65	5.5	5.7	5.6	5.9	5.85	5.6	1.0
pH Level (H2O)		6.55	6.2	6.5	6.3	6.9	7.2	7.0	1.0
PBI		88.125	85.6	80.3	88.9	83.6	72.7	78.8	1.1

Table 2 Soil test data collected in January of 2022 as the crop was approaching cut out. Colour has again been used to indicate change with comparisons made between starting (Sep) and updated (Jan) samples in muted shades and between the treatment applications and the corresponding control (all Jan) in more vibrant colours.

		Sep-21 field	Jan-22 Control	Jan-22 1.5 T/Ha	Jan-22 3 T/Ha	Jan-22 4.5 T/Ha	Jan-22 6 T/Ha	Jan-22 50 T/Ha	Sep-21 SR Control	Jan-21 SR Control	Sep-21 SR applied	Jan-21 SR applied
Texture		3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Ammonium Nitrogen	mg/kg	2.5	4	4	7	3	4	2	3.5	2	5	2
Nitrate Nitrogen	mg/kg	15	5	4	20	7	10	9	2.5	3	3	3
Phosphorus Colwell	mg/kg	41.5	38	27	44	29	37	69	11	11	7	10
Potassium Colwell	mg/kg	492	292	326	341	304	326	441	200	233	262	248
Sulfur	mg/kg	5.3	6.7	4.8	12.8	7.5	9.8	11.1	3.8	1.7	2.9	2.8
Organic Carbon	%	0.725	0.33	0.44	0.48	0.39	0.42	0.70	0.88	0.63	0.77	0.92
Conductivity	dS/m	0.103	0.064	0.053	0.105	0.072	0.094	0.086	0.0535	0.037	0.062	0.046
pH Level (CaCl2)		5.8	5.0	5.5	5.1	5.5	5.5	6.0	5.85	5.8	5.6	6.0
pH Level (H2O)		6.9	6.1	6.6	6.0	6.5	6.7	6.7	7.2	7.1	7	7.0
ESP	%	2%	2%	2%	3%	2%	3%	2%	3%	2%	2%	2%
Boron Hot CaCl2	mg/kg	1.345	1.04	1.07	1.07	1.34	1.20	1.38	0.775	0.63	0.68	0.48
PBI		90.65	68.9	75.1	68.8	69.0	90.2	76.9	72.7	89.9	78.8	70.1

The presence of flakes of the shod were evident in the samples collected in October, ahead of sowing. These flakes were only evident in the soil of the 50 t/ha applications during the January sampling, but were not evident during a visual inspection of the 50 t/ha cotton and stock rout plots during a return visit ahead of cotton picking in late April. This suggests that the applied material is incorporated into the system, even from a broadcast surface application within a few months.

Plant observations

Plant establishment and mapping was undertaken during the January visit to the trial site. For each plot ten meter long plots were assessed with one plant mapped in each plot for height, nodes, white flower position.

The first reportable observation was that application of the compost and cotton shod had no effect on stand emergence (Figure 2, ANOVA p=0.84). With regard to all subsequent crop measurements it is important to remember that the top of the crop had evidence of hail damage, which looked as if the top of the crop had been cut off. As such, interpretation of these differences should treated with care.

Crop height was observed to be different, due to the 50 t/ha treatment having taller plants than the 3 and 6 t/ha and control treatment (Figure 3, ANOVA p=0.04). However, this could have been due to the location of the plots in the field and from uneven hail damage.

The number of nodes on each plant were observed to only differ between the 1.5 and 3 t/ha treatments, but again this could have been due to the aforementioned reasons. White flowers and their position with regard to the top of the plant were noted, but all this indicated was the crop was yet to cut out. The hail damage was perhaps the biggest limitation to making more of these plant determinants (Figure 5).

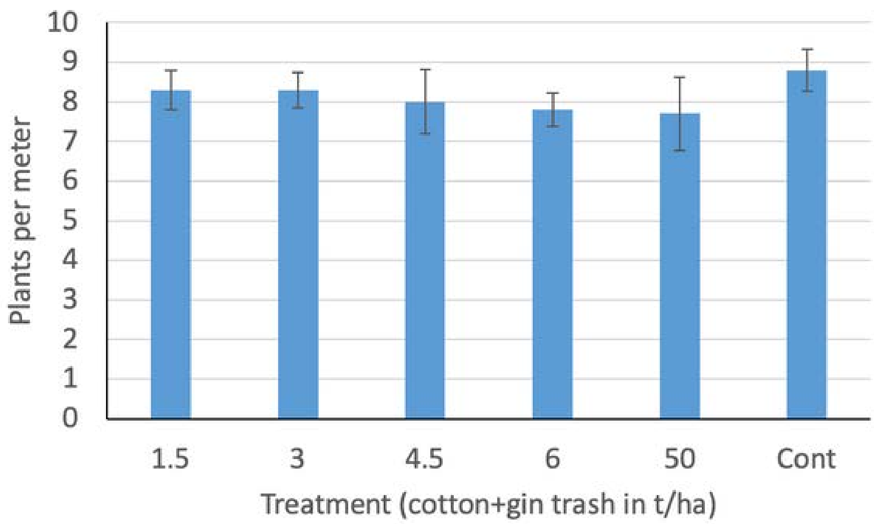


Figure 2 Mean plants per meter, scored over ten 1 metre regions of each plot, with standard errors of the mean plotted. There was no statistical difference in emergence.

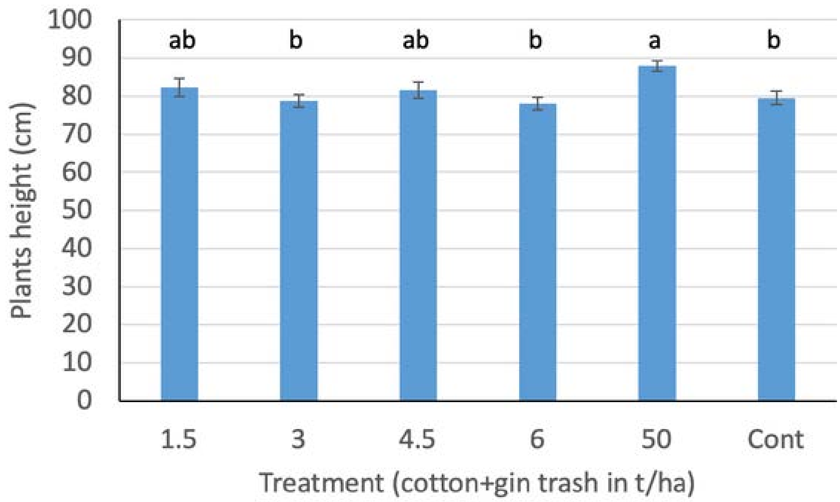


Figure 3 average plant height from ten plants assessed in each plot. Similar letters indicate similar means, based on ANOVA. Although the 50 t/ha treatment is taller than the 3, 6 t/ha and control plot, the hail damage and single plot location may have attributed to this.

In light of the plant observations made and the damage that was witnessed in January as well as the flooding of the field in December, any repeat trial should consider taking more plant measurement, mapping the first position fruit retention and considering yield at the end of the season.

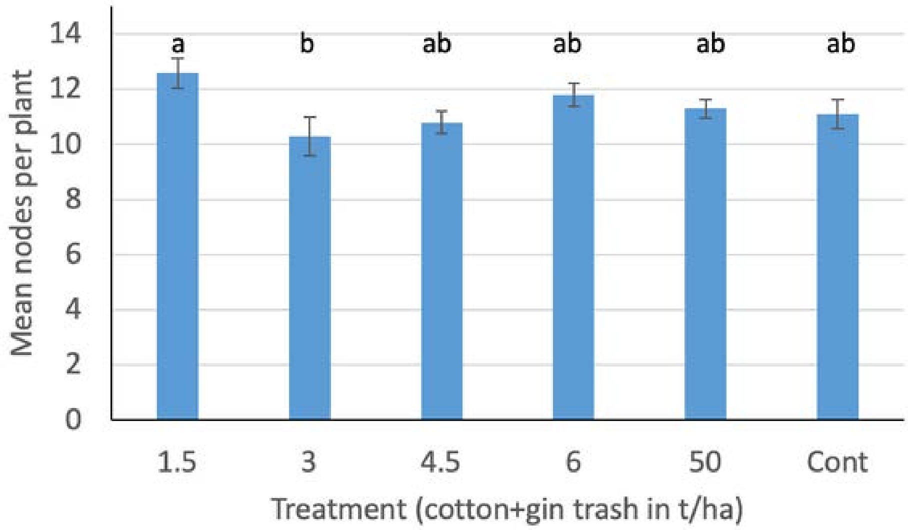


Figure 4 Average nodes per plant (scored on ten plants) with standard errors also plotted. Similar letters indicate similar means.

Figure 5 Cotton plant with missing upper nodes and end of first visible branch in the foreground. A similar damaged plant can be seen in the back left of the photo. This damage was evident across all of the trial plots. Its extent was not assessed within the scope of this trial, but it looked as if the tops of the plants had been cut off. Lower leaf damage was minimal, given the destruction to the top of the crop.

Microbial Responses

The soil biota was monitored using a system that identifies how the biological community responds to different substrates. The data is captures as respired CO_2, which is an indication of activity with higher generally considered to be better. The results were analysed against the substrates presented and then with the inclusion of the nutrition that was added with the compost and cotton shod (Table 3).

		Tonnes applied per hectare				
Compost	UNIT	**1.5**	**3**	**4.5**	**6**	**50**
Total Nitrogen	kg	26	52	77	103	860
Total Carbon	Tonnes	4	7	11	15	124
Total P	kg	5	11	16	22	180
Total S	kg	9	17	26	34	285
Compost Soluble NH4N	g	14	27	41	54	450
Compost Soluble NO3N	kg	2	5	7	10	82
Compost Soluble PO4P	g	18	36	54	72	600
Compost Sat Paste K	kg	13	27	40	54	448
Compost Sat Paste Na	kg	1	2	3	4	32
Compost Sat Paste NH4N	g	126	252	378	504	4200
Compost Sat Paste NO3N	kg	12	24	36	48	404
Compost Sat Paste P	g	28	56	83	111	925
Compost Sat Paste S	kg	3	6	9	11	95
Compost Sat Paste Zn	g	0	0	0	1	5

Table 3 Conversion of compost measures to indicate the levels of nutrients applied to the trial plots. Totals indicate what is present in the compost, with the saturated pastes giving an indication of what might be available and the compost soluble measures what is instantly available. Note units change with different determinants.

Analysis of the microbial activity suggested that there was some grouping of the microbial responses within the experimental plots, with the stock route samples behaving similarly, while almost all of the compost and cotton shod treatments varied from the untreated control (Figure 6).

The 1.5 and 3 t/ha applications did not follow the same sort of associated grouping as was observed with the 4.5, 6 and 50 t/ha treatments and also differed from each other. The reasons for this are not obvious from the microbial preferences for substrate (Figure 7), but when the soil analysis data is included it became apparent that the higher SOC and pH of the stock routes were responsible for them behaving differently from the other trial sites, while the 3 t/ha treatment appeared to be particularly responsive to nutrition, and N nutrition in particular (Figure 8).

One of the limitations of these analysis is that each plot sample was only run as three technical replicates. Five would allow better interpretatin of the data and ideally fewer treatments with more independent field plots would be preferential, however, the constraints of undertaking this at the field level are recognised.

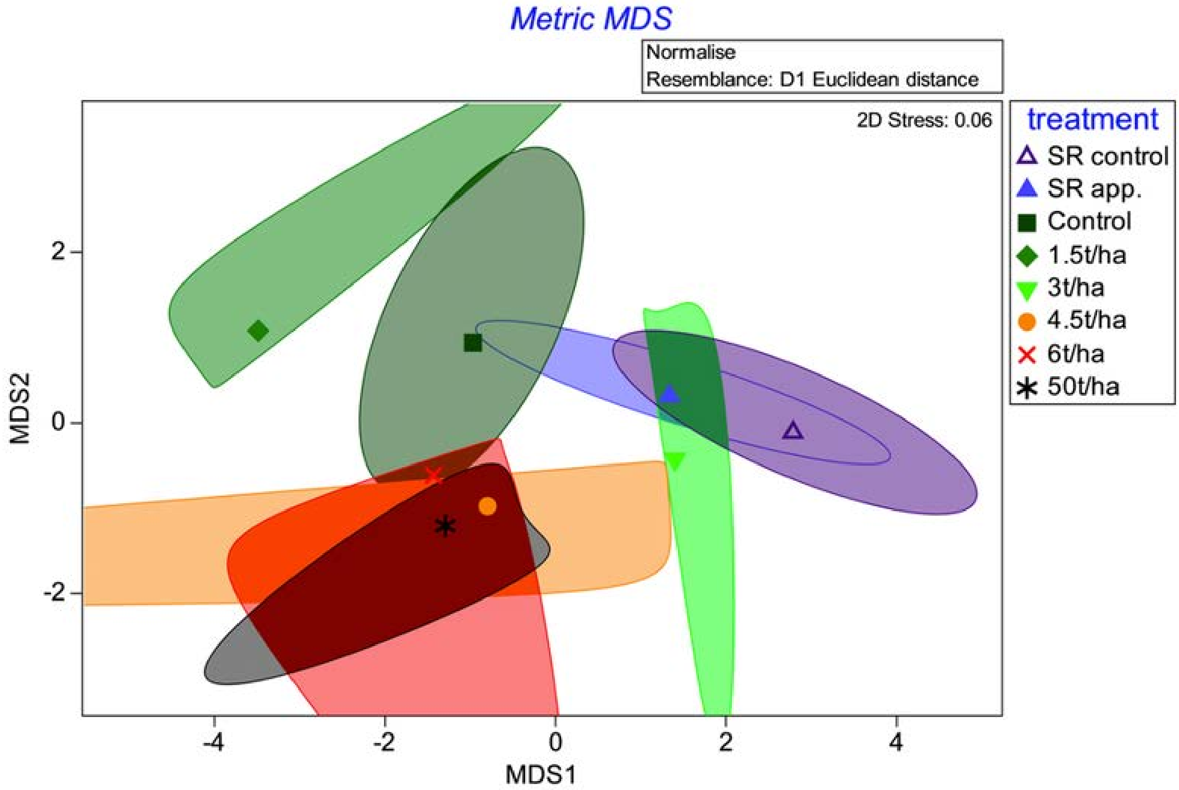


Figure 6 A bootstrapped presentation of the multi-dimension scaling (MDS) analysis of the MicroResp results from the January trial soil samples. There is some clustering of the stock route (SR) plots that have some overlap with the 3 t/ha plot. The 4.5, 6 and 50 t/ha plots overlap and these and the 1.5 t/ha plots have all responded differently to the control.

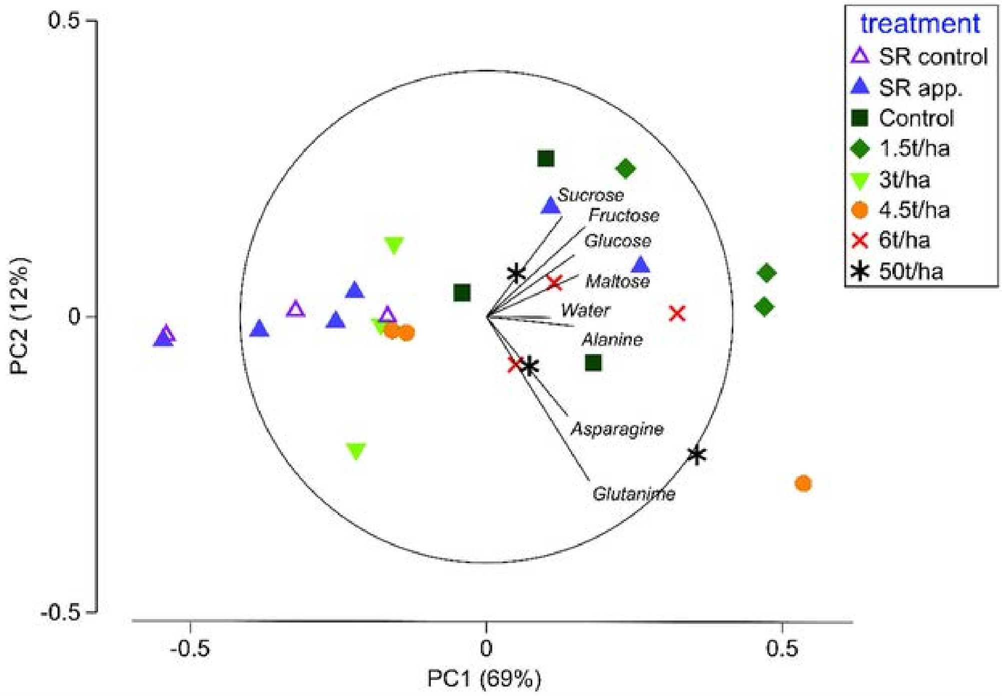


Figure 7 Principal Component Analysis (PCA) of the MicroResp soils data from the January plot samples. There is some grouping evident for some of the plots and ability to use substrate is the biggest driver of the differences in between the plots (69%) with the field plots being better suited to substrate use than the stock route soil. Other differences appear to be due to the ability to preferentially use either carbohydrate/sugars over amino acid substrates, but this difference is small (12%).

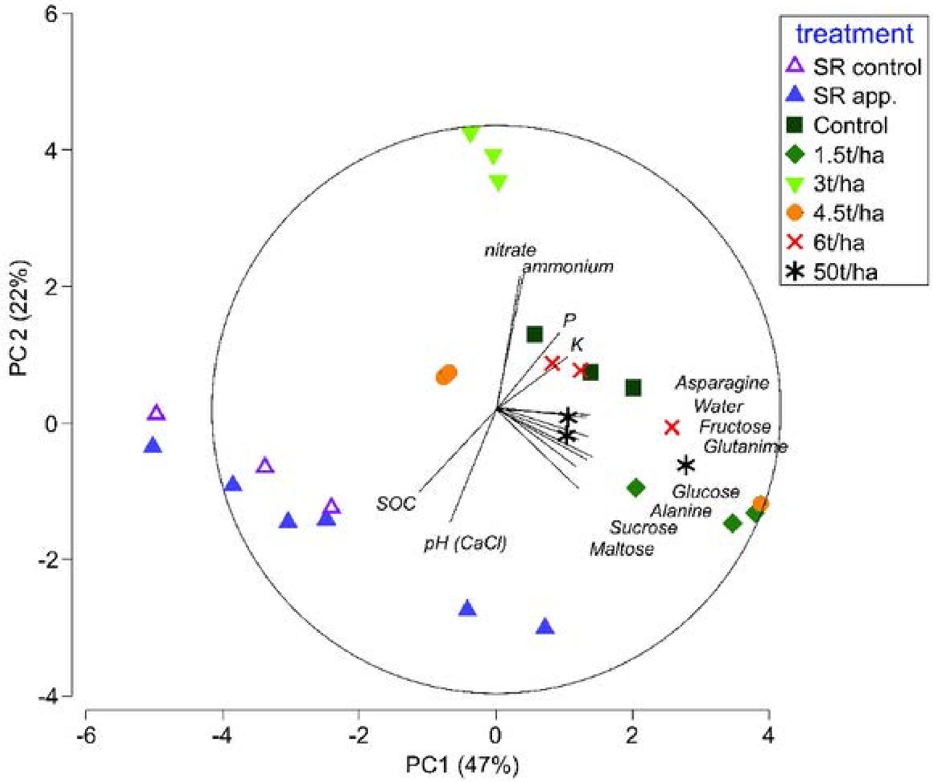


Figure 8 Principal Component Analysis (PCA) of MicroResp and chemical analysis of soils from the January plot samples. Grouping is evident for the plots with the SOC and pH of the stock route soil pulling that out. The 3 t/ha treatment appears to be responding to changes in N based nutrition more than the other plots. P and K nutrition appears to be as influential as ability to utilise substrates in driving other aspects of the system.

Acknowledgements

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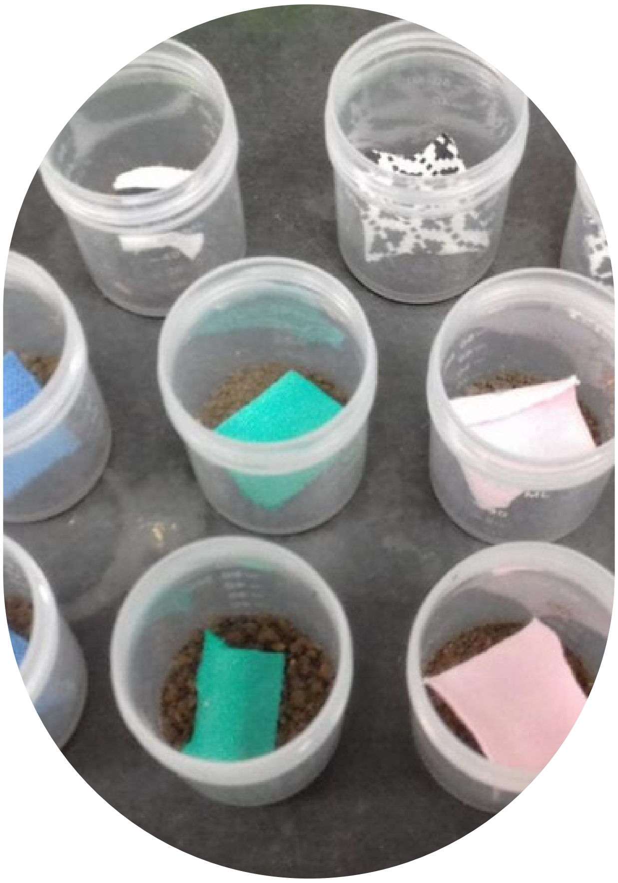
- Dr Oliver Knox, UNE (supported by the Cotton Research and Development Corporation)
- Sam Coulton and family for donating the fields on which to run the trial



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