Project Catalyst Trial Report

Mixed Species Fallow into Sugarcane

Grower Information	
Grower Name:	Denis Pozzebon
Entity Name:	The Trustee for POZZEBON FARMING TRUST
Trial Farm No/Name:	BKN-09462A
Mill Area:	Pioneer/Kalamia
Total Farm Area ha:	117.97
No. Years Farming: (Grower Experience)	
Trial Subdistrict:	Mt. Kelly
Area under Cane ha:	117.97

Trial Status

COMPLETE

Background Information

Aim:
To utilise planted mixed species in a fallow block to improve and increase natural soil health. This will be done by improving beneficial biology and bacteria, water retention and drainage, as well as reduce sediment loss from runoff and inorganic Nitrogen inputs for the subsequent sugarcane crop.

Background: (Rationale for why this might work)
It is widely accepted that breaking the monoculture of sugarcane with a fallow crop has many advantages, this has now become common practice in the Burdekin region with legumes such as mungbeans and soybeans. The ability of these cover crops to fix nitrogen means reduced inputs and potentially higher yields for subsequent sugarcane crops, but these fallow crops are still a monoculture and therefore still have many of the issues associated with monocultures (i.e. pests and disease build up and resilience, organic matter levels, water usage and soil compaction). It is proposed that some of these issues can be alleviated by planting a mixed species fallow crop, with benefits associated with reducing tillage and soil compaction, increasing soil OM, greatly improving soil biology (e.g. increasing beneficial nematode numbers) and increasing the available nutrients.

There has been documented success of mixed species fallow crops in the Wet Tropics (Mossman and Tully regions) but a trial of this nature has never been conducted in the Dry Tropics (Burdekin region).

Potential Water Quality Benefit:
- An increase in overall organic matter in soil
- Improvement in soil biology (more specifically a reduction in parasitic nematodes)
- Increased soil aeration and access to deeper subsoil nutrients and moisture
- Reduce soil compaction (reducing tillage),
- Improved drainage and soil structure
- Increase the availability of plant available nitrogen.
- Reduce sediment loss and erosion.

By reducing the amount on N applied to the subsequent sugarcane crop, we are reducing the amount of potential Nitrogen runoff, and by providing structure and cover for the fallow block, there will be a reduction in sediment loss to adjacent water courses. In addition, improving drainage and water retention within the soil will improve irrigation efficacy, limit overall losses of chemical and nutrient to run off and deep drainage.

Expected Outcome of Trial:
The required Nitrogen rate for the subsequent cane crop will be reduced, there will be an increase in beneficial nematodes, organic matter level will increase and yield will be higher for the subsequent cane crop.

Service provider contact: Mika Rowston, Farmacist (Mobile: 0429 165 046 Email: mikar@farmacist.com.au)

Where did this idea come from: Denis Pozzebon approached Farmacist

Plan - Project Activities	**Date : (mth/year to be undertaken)**	**Activities :(breakdown of each activity for each stage)**
Stage 1	Sept 19-Nov 19	Harvest of paddock and appropriate working of fallow block to prepare for planting of mixed species fallow. Collect Baseline app data + P2R Data, create Nutrient Management Plan.
Stage 2	Oct 19-Jan 20	Take baseline measurements including; Nematode counts, Soil biology measurements, soil compaction measures, soil tests, soil profile assessment.
Stage 3	Dec 19	Buy & Plant Mixed species fallow.
Stage 4	Jan 20-Mar 20	Monitor mixed species progression. e.g. Plant counts, biological assays, nematode counts, Soil compaction etc.
Stage 5	Mar 20	Finish mixed species either by green manuring.
Stage 6	Mar 20-Apr 20	Work paddock and plant cane.
Stage 7	Mar 20-Jun 21	Monitor plant cane crop.
Stage 8	Jan 21	Plant second mixed species fallow trial.
Stage 9	Jan 21-Apr 21	Monitor mixed species progression. e.g. Plant counts, biological assays, nematode counts, Soil compaction etc.
Stage 10	Apr 21	Finish second mixed species fallow either by green manuring.
Stage 11	Jun/Jul 21	Harvest plant cane on first mixed species fallow trial.

Project Trial site details	
Trial Crop:	Soybean, Mungbean, Cowpea, Sorghum, Tillage Radish, Shirohie Millet, Sunflower, Sunn hemp
Variety: **Rat/Plt:**	Fallow to Plant
Trial Block No/Name:	Trial 1: 13-2 Trial 2: 2-1
Trial Block Size Ha:	Trial 1: 9 Trial 2: 19
Trial Block Position (GPS):	Trial 1: -19.670335°, 147.334097° Trial 2: -19.656987°, 147.340228°
Soil Type:	Trial 1: 4Ucc Deep coarse sand and sandy loam with bleached A2 horizon AND 4Gnb Red and brown podozolic soil with loamy sand to light sandy clay loam A horizon and colour A2 horizon. Trial 2: BUfc Deep, neutral, dark-brown friable clay. Buried sandy layers, if present are below 1.2m.

Block History, Trial Design:

This trial ran over two years on two separate blocks in the Delta growing region in the Burdekin (fully flood irrigated). The first trial (2019-2020) was installed on a sloping, light, sandy block. The second trial (2020-2021) was installed on a 19ha heavier clay block. Some mixes trialled were utilised based on the grower's experience and some mixes were chosen based on their potential agronomic benefit. Apart from one mix in the second trial, all seed was purchased separately and mixed by the grower prior to planting. All legume seed that required incolulation were treated with the appropriate rhizobium at planting.

The fallows were planted using the grower's existing bean planting equipment, a three row John Deere Max-Emerge XP planter. The mix species were planted in dual rows along the drill, the furrow/inter-row was not planted as the grower operates a zonal tillage system and maintains a permanent drill and inter-row. Seeds were pre-mixed and inoculated using a cement mixer and direct drilled into preformed beds (2 bean rows per 1.55m sugarcane beds).

The fallow crops grew for 3 months (First trial: Dec 2019 – March 2020, Second trial: Jan 2021 – Apr 2021). Ground preparation activities were as follows: Ploughed out cane, disced twice, bed-formed, 2 pre-plant irrigations, sprayed, plant mix species, 2-3 in-crop irrigations, sprayed out, mulched and incorporated, wavy coultered, planted cane. Preparation was the same for both blocks with the only difference being that in the first fallow, treatments with forage sorghum planted were slashed half-way through the fallow to prevent seed set.

Planting ratios for seeds were calculated using standard seeding rates and adjusted accordingly, traditional seeding rates were halved for the mixed treatments as there will was three times as many plants growing per square metre. Planting density and depth was adjusted on the planter to suit the mix that was being planted.
Based on results and learnings from the first fallow trial, mixes were modified for the second trial.

Treatments:

Trial 1 (Fallow growing period Dec 2019 – Mar 2020)

Trial Area:	5.6ha
Treatments:	5
Replicates:	3
	Treatments
Control:	Bare/Weedy Fallow
Soybean:	Leichhardt Variety (very poor germination)
Mix 1 (Biomass):	Ebony cowpea, Leichhardt soybean, Jumbo sorghum (forage)
Mix 2 (Nitrogen Building):	Ebony cowpea, Leichhardt soybean, Jade mungbeans
Mix 3 (Soil Health):	Tillage radish, A6785 Soybean, Sunflower, Shirohie millet, Jumbo sorghum (forage)

trial area	T1R1	T2R1	T3R1	T4R1	T5R1	T1R2	T4R2	T2R2	T5R2	T3R2	T1R3	T5R3	T2R3	T3R3	T4R3	trial area
GUARD	REPLICATION 1					REPLICATION 2					REPLICATION 3					GUARD
12 Rows Guard	CONTROL Bare (weed free)	Soybeans Only	Mix 1	Mix 2	Mix 3	CONTROL Bare (weed free)	Mix 2	Soybean Only	Mix 3	Mix 1	CONTROL Bare (weed free)	Mix 3	Soybeans Only	Mix 1	Mix 2	43 Rows Guard
	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	6 Rows	

Trial 2 (Fallow growing period Jan 2021 – Apr 2021)

Trial Area:	6.7ha
Treatments:	4
Replicates:	4
	Treatments
Control:	Bare/Weedy Fallow
Soybean:	Hayman variety
Mix 1 (Biomass/Nitrogen):	Ebony cowpea, Jade mungbeans, Sunn hemp
Mix 2 (Variety):	Lablab, Linseed, Vetch, Soybean, Triticale, Ryecorn, Tillage radish, Sunflower, Cowpea, Buckwheat, Sunn hemp

	T1R1	T2R1	T3R1	T1R2	T3R2	T2R2	T1R3	T2R3	T3R3	T2R4	T1R4	T3R4	
Remainder of Paddock NQDT **T4R1** Bare Fallow 3 Rows X 10m 46.5m2 **T4R2** Bare Fallow 3 Rows X 10m 46.5m2 3ha	**Soybean**	**Legume Mix**	**NQDT Mix**	**Soybean**	**NQDT Mix**	**Legume Mix**	**Soybean**	**Legume Mix**	**NQDT Mix**	**Legume Mix**	**Soybean**	**NQDT Mix**	Remainder of Paddock NQDT **T4R3** Bare Fallow 3 Rows X 10m 46.5m2 **T4R4** Bare Fallow 3 Rows X 10m 46.5m2 10ha
Rows	6	6	6	6	6	6	6	6	6	6	6	6	

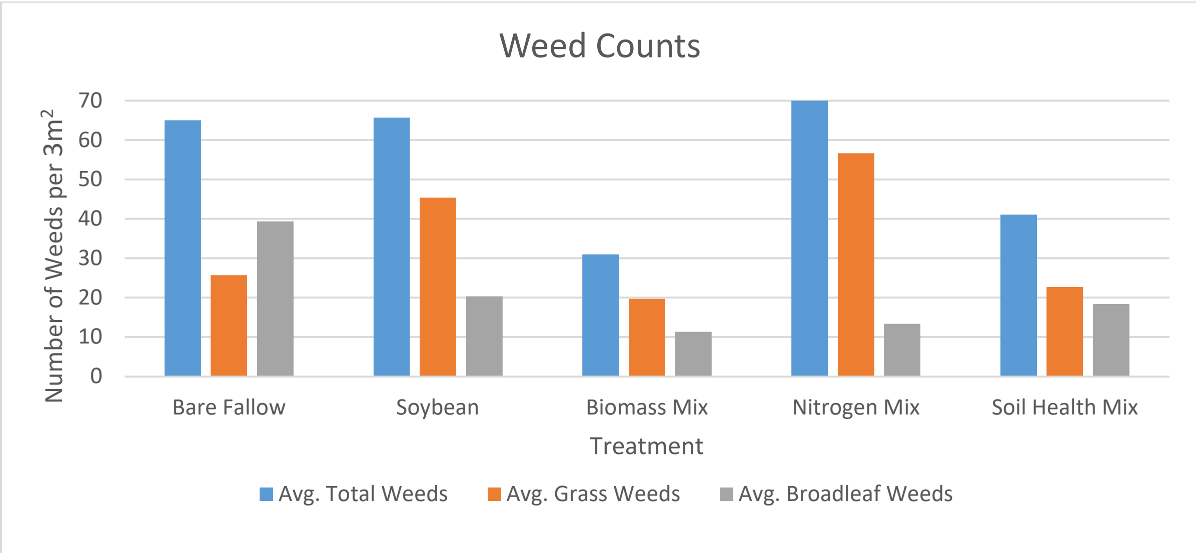
Sampling and Analysis:

Nematode counts, full chemical soil analysis, labile carbon analysis, Solvita burst analysis, nitrate testing and biomass assessments and plant counts, commercial harvest of cane following fallow (only trial 1).

Results:

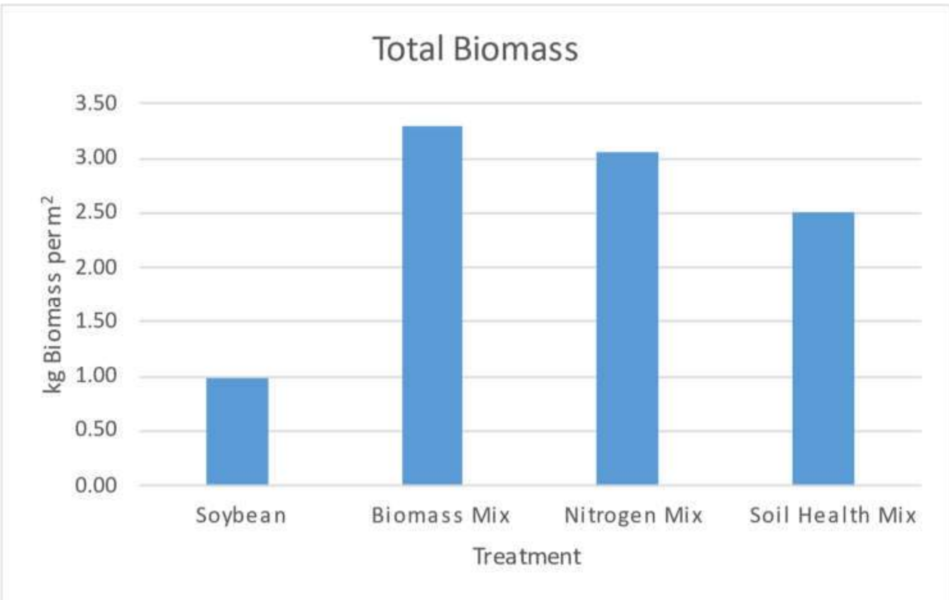
Trial 1:
Sampling and analysis occurred in each plot, with exact georeferenced locations. Sampling locations where chosen based on soil and EC zones to reduce natural variation. Results are shown below.

Weed Suppression



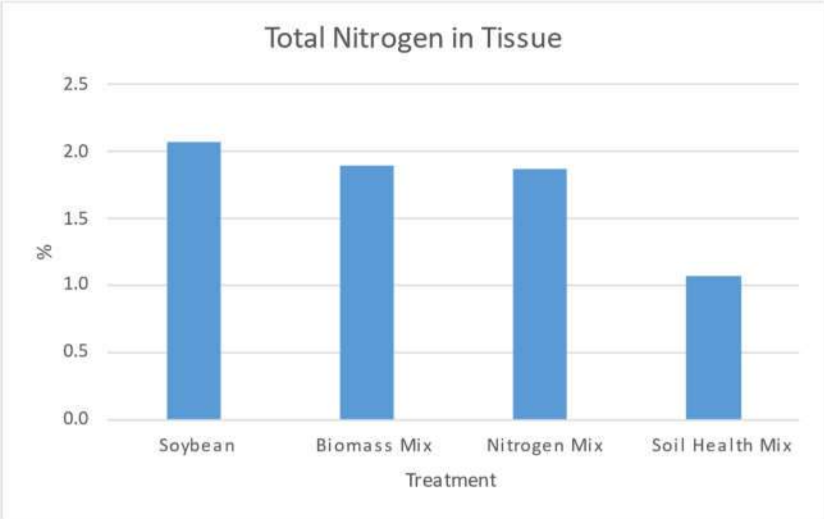
The above figure shows the weed control in relation to treatment, weed counts were conducted approximately three weeks prior to the mixed species fallow termination. These results show that the more cover/biomass present, the less space there is for weeds to compete, and this is to be expected.

Total Biomass (Fallow Crop)



This graph shows the total biomass in kilograms per square meter, the soybean treatment is markedly lower than the other treatments and was underrepresented in the trial. Seed quality for the soybean planting was poor (an issue faced by many growers this season across the Burdekin), and this is shown in the these results. It is expected that the biomass mix would yield the highest amount of organic matter and this is seen in these results.

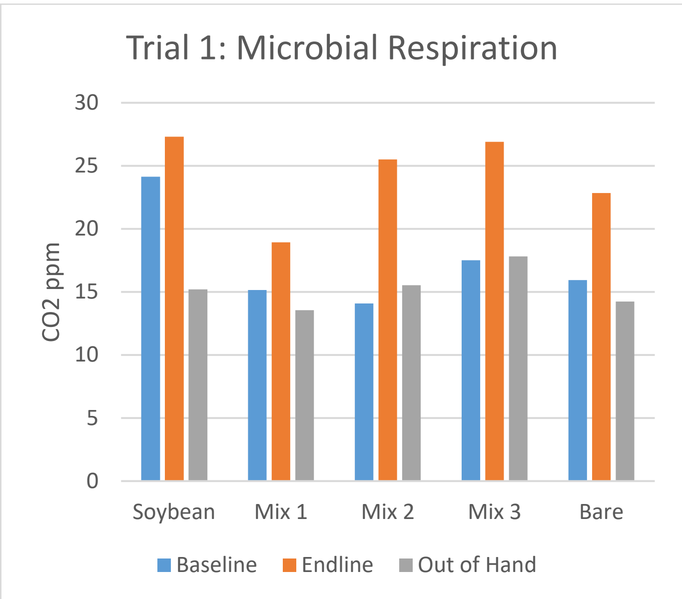
Total Nitrogen in Tissue (Fallow Crop)

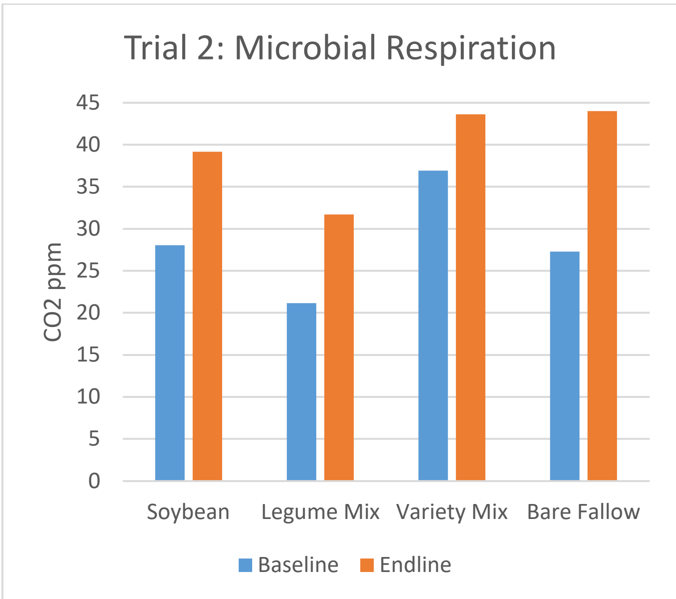


The above graph shows the total Nitrogen in tissue samples collected from each treatment. As expected, the treatments that contain Nitrogen fixing legumes contain the highest perecentage of N. The soil health mix comprised of only one legume species, whereas the other treatments were primarily legume based or only contained legumes.

Trial 1 and 2:

Microbial Respiration





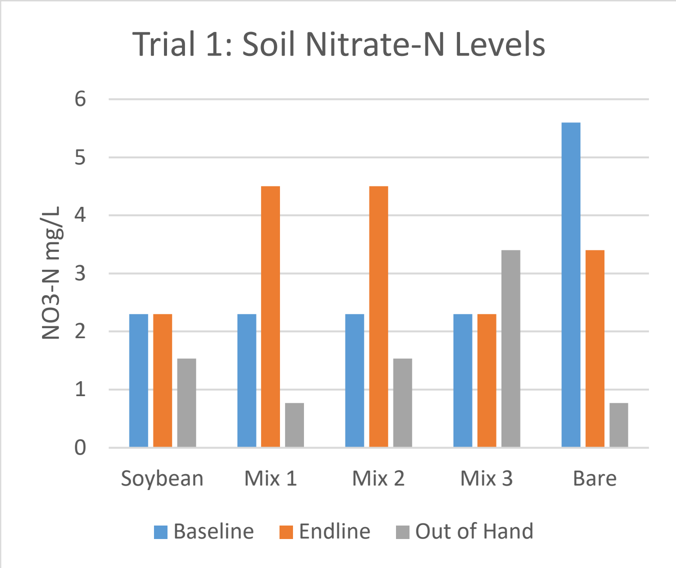
This figure outlines the change in microbial respiration over the course of the mixed fallow, measured as carbon dioxide in parts per million over 24hrs. Microbial respiration can be used as an indicator for soil health, as the more CO_2 that is produced by the soil, the more live organisms, and the greater the detritus food web. This food web plays a vital role in nutrient cycling and the water holding capacity of the soil. Microbial respiration was measured using the 24hr Solvita© Burst method.

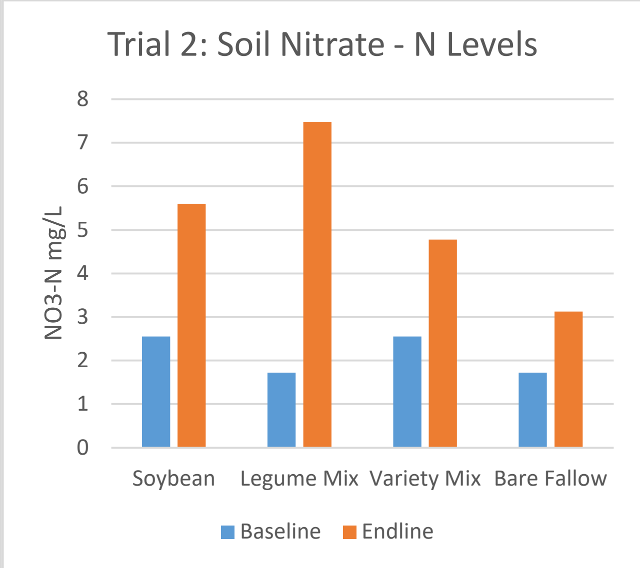
The above results show that bacterial respiration has increased over the fallow period for all treatments, including substantially in the bare fallow. Indicating that any kind of fallow is beneficial for microbial growth, with no treatment necessarily having an advantage over another. The first trial results also has the subsequent out-of-hand cane results, which shows that the microbial respiration has generally returned to the pre-fallow levels across all treatments. This could be an indicator that microbial activity is driven by other factors such as moisture or heat in association with the particular species planted. The limitation of this method of analysis is its ambiguity, the test does not allow us to identify which organisms are producing the CO_2. Being able to identify specific microbial communities may present differences in the results above, i.e will a greater diversity of plants and root systems lead to a greater diversity in micro-organisms?

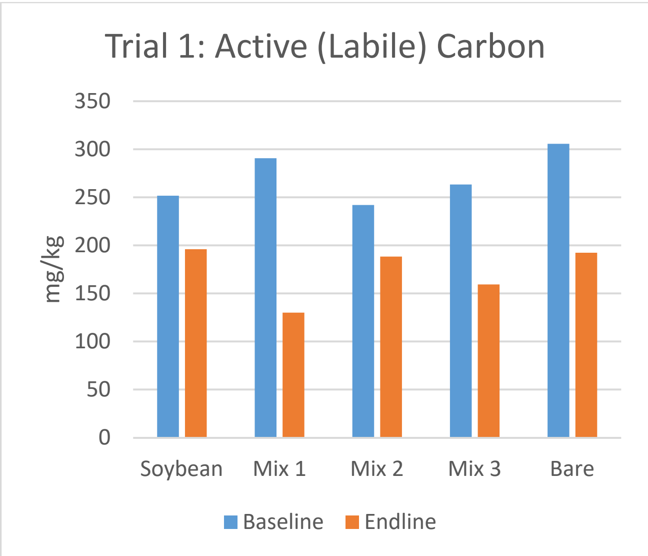
Soil Nitrate Nitrogen

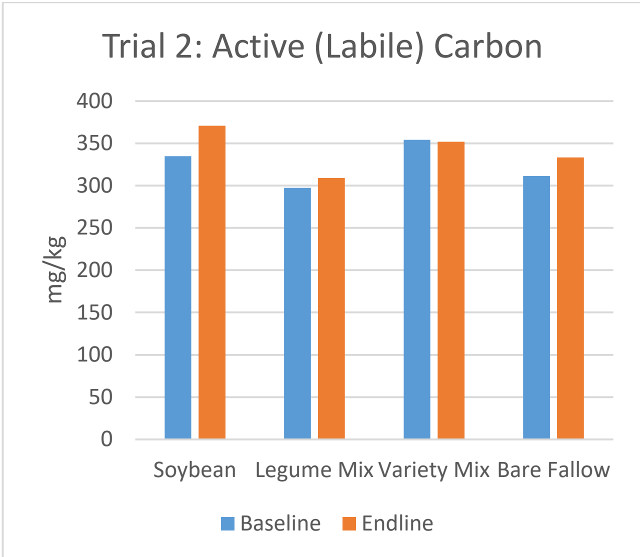
The results presented below are based on nitrate strip testing, before and after the treatments were installed. Nitrate N increased in most treatments across both sites, except for the soybean and soil health mix in trial 1. The low level of nitrate N leftover from the soybean treatment is attributed to the poor germination after planting, the soybean only treatment would have been considered a failure in a commercial cropping sense and would have not gone to harvest, plants were small and spread out, almost emulating a bare fallow. The issues with this variety of soybean seed were anecdotally poor throughout the district in 2020. Other treatments that were majority legumes saw substantial increases in nitrate N.

The discrepancy between the bare fallow treatments could be attributed to the plot size and location. In trial 1 the control bare fallow treatments were paddock long strips the same size as the other treatments. In trial 2, as a result of flood risk, we could not have such large sections of the paddock left bare, consequently we installed four 47sq metre sections in the guard rows of the paddock to simulate bare fallow areas. As these treatments were surrounded by legume species, irrigation could have lead to nitrate N accumulating in the treatments.





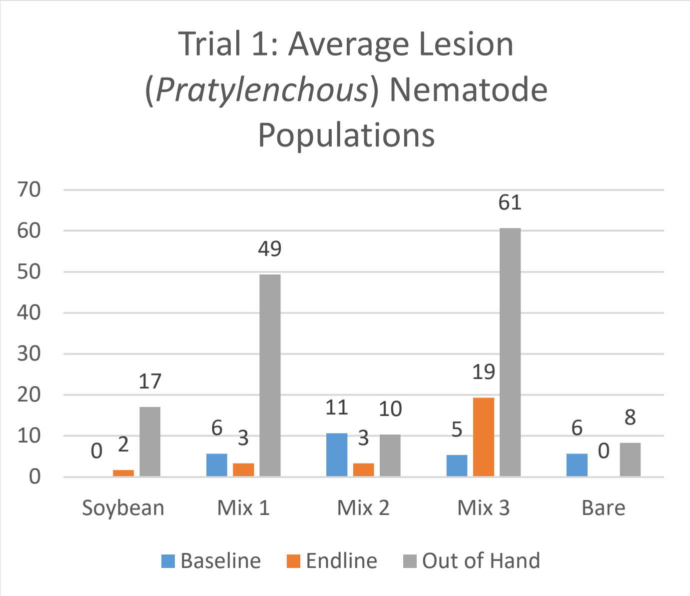


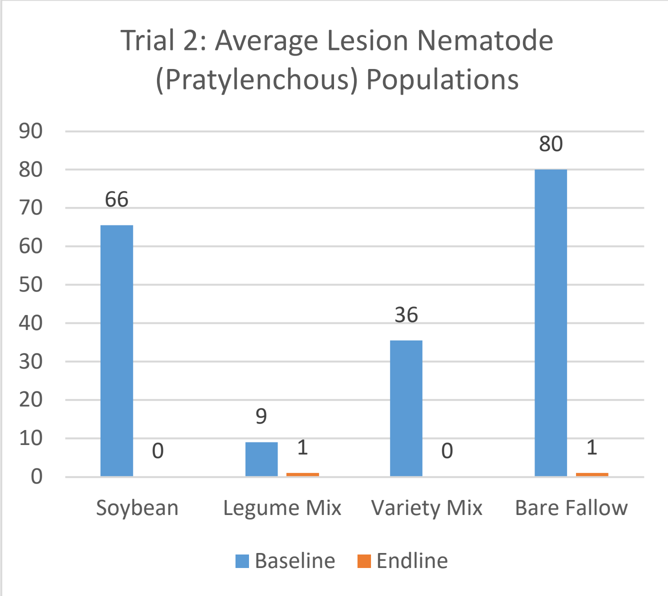


This figure presents some interesting results, one of the main expected outcomes from this trial is an increase in organic carbon in the soil. These results show somewhat of a contrast, in trial 1 all treatments organic carbon levels decrease quite significantly, even though all biomass was incorporated into the soil. Potentially this is because the organic matter produced by the mixed species fallow has not had enough time to decompose/breakdown to become readily available, so timing of sampling and decomposition/nutrient cycling rate is important for measuring changes in labile carbon. Measuring changes in organic carbon is difficult to do over a short period of time and it is expected that changes may not be measurable until a fallow of this nature is practiced for several crop cylces.

Nematodes

Populations of nematodes were very low in each block during all sampling events (six events). Overall, the results suggested a decrease in parasitic nematodes and an increase in free-living nematodes, but results were highly variable, and it was difficult to draw quantifiable conclusions from the data collected.



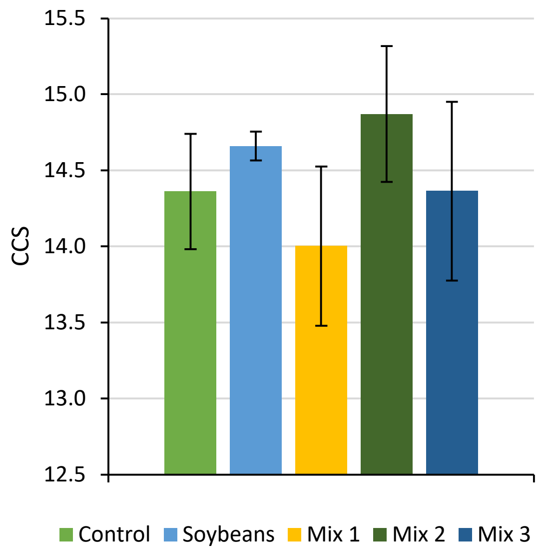


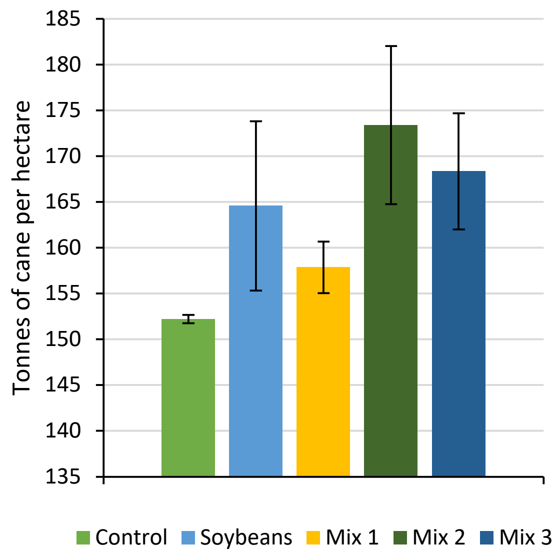
Parasitic populations in all samples were well below economic thresholds. Quantitatively monitoring changes in nematode populations proved to be extremely difficult in a commercial cropping scenario, nematode populations varied greatly within a few metres. Their presence or absence in the soil profile is also heavily influenced by moisture levels and other environmental factors, so conclusive repeated temporal sampling proved to be very difficult in this trial.

Cane Yield Results

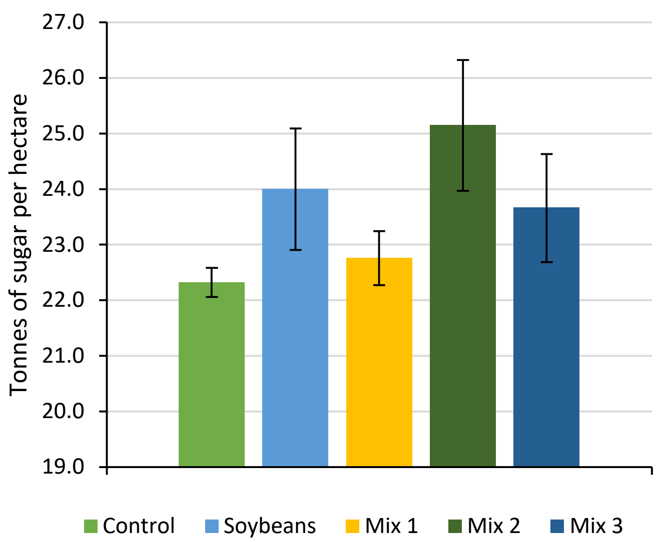
Yield Results (First Trial Block)

Commercial plant cane yields were recorded for each treatment for the first trial block (second trial has not been harvested at the writing of this report). The variety is KQ228 and the six easy steps soil test recommendation was used to calculate fertiliser inputs. Nitrogen fertiliser rates were not adjusted for sources of nitrogen provided by any of the fallow crops, to limit variability. Statistical analysis was undertaken for CCS, tonnes of cane per hectare (TC/Ha) and tonnes of sugar per hectare (TS/Ha), but no significant difference is present at a 95% confidence interval ($p=0.05$) for any variable. It is important to note that there is a quite a lot of variation between replicates in these results, but when statistical analysis is run at an 85% confidence interval ($p=0.15$), results are significantly different for TC/Ha and TS/Ha. Mix 2, mix 3 and soybeans were all significantly greater than the bare fallow control for TC/Ha ($p=0.12$) and mix 2 and soybean treatment significantly increased the TS/Ha ($p=0.11$).





Some of the variation in these yield results could be attributed variation across the paddock, this trial block has a substantial cross-slope and is very sandy, the change in yield could be driven by the water holding capacity of the soil and slope can affect this dramatically.



Consistently, Mix 2 (Ebony cowpea, Leichhardt soybean, Jade mungbeans) appears to outperform all treatments, although we cannot conclusively state that any mix is better than the monoculture soybean fallow. It can be said that, overall, planting some sort of cover crop during the fallow period is beneficial to subsequent yields compared to a bare fallow. We would however expect to see a potential CCS penalty in the legume dominated treatments, but results don't reflect this, potentially this is a result of the light and sandy nature of the soil. The soil has a reduced capacity to store nutrients and therefore any excess N is unavailable to the plant during its maturing phase, allowing it to maintain reasonable CCS.

Conclusions and comments

There have been several important learnings developed during the course of this trial. Before developing a plan to implement a mixed species fallow, it is important to step back and determine why we fallow ground to begin with. One major advantage of fallowing ground is the unselective control of weeds and reducing the weed seed bank in the paddock to reduce the pressure of weeds in the subsequent crop. In addition, to control volunteer cane to reduce the carry-over risk of diseases.

In the first fallow trial two treatments had grasses present in the mix, jumbo forage sorghum and shirohie millet. Ordinarily in a broadleaf fallow crop, such as soybean, growers have the opportunity to use grass selective herbicide to control grasses and volunteer cane. As a result of the grasses being planted in the mixed species fallow we did not have this option, and volunteer cane and grass weeds remained uncontrolled in some treatments which can be a risk for the subsequent crop. In addition, as the mixed species crop matured, some species set seed (forage sorghum and millet), the grower attempted to control this by slashing the treatments with grasses but there was still weed escapes. This caused forage sorghum and millet to germinate in the subsequent plant cane crop, which prompted the grower tod significantly more on herbicide in crop than the grower would normally use, at quite an expense.

Seed quality was also an issue with some treatments, particularly where soybean was planted. In the first trial, the soybean seed was of poor quality and this showed with germination and also vigour. This fact basically rendered the soybean only treatment a failure, therefore it is difficult to draw comparisions with this treatment and the others. In addition, as we wanted to maintain permanent beds and plant in rows we were only able to plant at one depth, each species has dramatically varying seed sizes which changes the ideal depth for germination. Compromises on seed planting depth were made and this will affect the germination of each species dramatically.

In terms of measurable soil health outcomes , it is apparent that measuring quantifiably in this space is quite difficult and what defines a healthy soil is very ambiguous. Measuring changes in soil intensivley over a 12 month period has also shown that there is a large of amount of within paddock variation (even within soil type and EC zone). Temporal and elevation changes can also influence results quite dramatically and eliminating this variation is very difficult. In relation to nematode sampling, developing a robust sampling program proved to be difficult, especially when changes in moisture is a key driver in nematode mobility and activity, drawing quantifiable conclusions from the nematode data is difficult as nematodes exist in clusters and without identifying where clusters exists it is near impossible to accurately measure changes in their populations.

The underlying idea behind the success of a mixed species cover crop is developing ecosystem and biological synergies between the different species (this includes many groups of plants: brassicas, legumes, grasses and many others). If these relationships do not develop because we have selectively chosen to remove grasses from the mix, then perhaps we may not see all of the potential benefits a mix species cover crop can offer. We intend to continue testing a number of other mixes over the next year on Denis's farm to determine what is most easily managed in the cane rotation so we can maximise yield without compromising soil health and the sustainability of the system.

To conclude, the results from this trial show that planting some sort of cover crop during the fallow period is beneficial to subsequent yields compared to a bare fallow, which is well documented.

Advantages of this Practice Change:
If practiced for several crop cycles, the grower hopes to see improvements in irrigation management and soil water holding capacity especially on very sandy paddocks. In addition, improvements in soil microbial activity should lead to improved productivity and a reduction in soil borne diseases and parasitic nematodes.

In mixes that have a significant contribution of nitrogen due to legume nodulation, there is the capacity to reduce nitrogen rates. When determing how much we can reduce by, it is very important to determine how much the cover crop is actually contributing and how much is actually available for plant uptake, especially after significant decomposition and mineralisation of the fallow crop residues.

Disadvantages of this Practice Change:
As mentioned aboved there were issues with grass control during the fallow and also in the subsequent cane crop, and this needs to be considered.

Adopting this type of practice change also means that you are not able to grow a cash cover crop during the fallow period. As the Burdekin region is fully irrigated, growers do have greater control of their fallow crops and have the potential to make substantial profits from cover crops if commercially harvested, this will be a significant barrier for broader adoption of this practice.

Depending on timing of fallow crop planting and termination, it can delay the planting of the subsequent cane crop, which could lead to a yield decline for the subsequent harvest. Depending on the type of mixed species fallow, the biomass material can be be substantial, which needs to be sufficiently broken down by the time can is planted. Depending on the fallow termination method, this can take anywhere from 4-10 weeks.

Will you be using this practice in the future:
Yes, as a result of these trials, the grower has refined the mix that is planted and is implemented across his fallow blocks.

Other growers in the productivity group have also adopted planting of mixed species fallows, with mixes informed by some of the results from these trials.

% of farm you would be confident to use this practice:
100% of fallow ground – 20% of farm area