Cropping: Using Legumes to Improve Nitrogen Efficiency

Background

This was the third and final year of a trial funded by the South Australian Grains Industry Trust (SAGIT), to evaluate the nitrogen fixation capabilities of various legume species grown on Kangaroo Island.

In 2016 four legume species – Samira faba beans, PBA Coogee field peas, Jennabillup lupins and Monti + Gosse sub clover and one non-legume species – linseed, were sown in a completely randomized design with four replicates. Each legume was inoculated with its appropriate rhizobia according to label directions. The non-legume linseed was included in the trial as a control.

In the second year (2017) the trial was sown to Clearfield canola - 46Y83 and in 2018 Kowari oats were sown. The trial was designed to answer the following questions:

- Which of the four legume species had fixed the most nitrogen (N) in the 2016 season?
- How much N did these legume crops fix?
- How much of the N fixed by the legume was utilised by the first and second subsequent crops? Concurrently, how much N was lost through leaching or denitrification?

What was done

The trial site was located for the 3 years on the Stanton's property Caledonia, 989 Timber Creek Road in MacGillivray. The soil was typical of those used for cropping on the plateau - sandy loam over clay. The site was limed in April 2016 and a soil test (0-10cm) immediately before sowing in May revealed a pHCaCl2 6.1, Colwell P 27mg/kg, PBI 195, Colwell K 176mg/kg, Sulphur 26mg/kg and Organic Carbon 2.6%.

In 2016, two paired 80cm soil moisture probes, (SMP's) were installed in a faba bean and linseed plot connected to a weather station. Accompanying these SMP's, was a Hydra Probe installed at 80cm, which measured ion content, soil temperature and soil moisture. These Hydra Probes tracked and logged the nitrate movement through the 80cm profile.

In order to monitor the nitrate released into the soil water by the various crop species, ceramic water collecting tubes Sentek SoluSAMPLERs, were installed to a depth of 30cm in 2017. These were removed at the end of the 2017 growing season.

Weather data was also recorded at the site using a rain gauge, air temperature & humidity and wind speed & direction sensor. These sensors were logged and the data uploaded every 15 minutes.

The site received 812mm of rain in 2016 (Decile 10), 515mm in 2017 (Decile 2-3) and 518mm (Decile 2-3) in 2018 compared to the long-term average of 530mm.

Measurements taken during the project included: nodule scores, dry matter, starting deep soil nitrogen, soil water nitrate, biomass nitrogen uptake and grain yield and quality.

Results

Table 1: 2016 Measurements

2016 Crop	Nodule Score	Dry Matter (t/ha)	Grain Yield (t/ha)
Linseed	0	1.98 c	0.7
Faba Beans	2.5 b	2.74 bc	3.27
Peas	3.3 a	6.53 a	3.18
Lupins	3 ab	3.81 b	NA
Sub Clover	3.4 a	2.58 bc	NA

2016 Results

The peas, lupins and sub clover shared similar nodulation scores (**Table 1**). A score over 3 is deemed adequate. The nodulation score of the faba beans although not statistically different from the lupins, fell shy of the adequate threshold of 3. It was likely that the pHCaCl2 4.8 at the 4-8cm sowing depth was the reason behind the lower nodulation score.

Due to the wet conditions, linseed was unable to compete against the tirade of waterweeds that overtook the plots. Consequently it gave the lowest biomass yield of 1.98t DM/ha and grain yield of 700kg/ha.

The PBA Coogee field peas had significantly higher biomass than the other legume species (**Table 1**). This variety and its associated Group E rhizobia, were well suited to the soil at the trial site as its nodulation score was above adequate.

Due to wildlife eating the 4 lupin plots before harvest, a lupin yield was not obtained.

Table 2: Starting Deep Soil N

2016 Crop	2017 N (kg/ha)	2018 N (kg/ha)
Linseed	16.8b	23.2a
Faba Beans	43.8a	32.4a
Peas	39.4a	25.8a
Lupins	38.8a	39.0a
Sub Clover	37.7a	35.0a

Table 3: Grain Yield, N Uptake & Quality

2016 Crop	2017 Canola (t/ha)	2018 Biomass N (kg/ha)	2018 Oat Grain Protein (%)
Linseed	2.16b	92a	11.15a
Faba Beans	3.13a	104a	11.85a
Peas	3.63a	100a	11.70a
Lupins	3.13a	108a	12.05a
Sub Clover	3.04a	108a	11.80a

2017 Results

All the legumes sown in 2016 shared similar starting soil nitrogen levels to 35cm depth compared to the linseed control (**Table 2**), inferring that they all fixed a similar amount of N in 2016. The average starting N of the four legumes was ~40kg/ha being ~23kg/ha higher than the linseed control. (Soil was sampled to 35cm due to constraints of manpower versus B horizon heavy clay).

Similarly, the canola grain yield at the end of the season from the plots of the four legume species was statistically different from the linseed control (**Table 3**). There are two likely reasons for this outcome. Obviously, the linseed being a non-legume did not fix any N in 2016 and thus the 2017 canola crop had less available N. Secondly, the 2016 linseed plots had a higher ryegrass burden attributable to the poorly competitive nature of linseed which consequently allowed numbers to build up. In high numbers ryegrass is a strong competitor and therefore stole nutrients, moisture and sunlight from the canola crop, reducing yield.

Based on the canola grain yields in **Table 3**, it could be concluded that growing any of the four legumes conferred, ~1t/ha canola yield advantage over the linseed control.

The site received 106kg N/ha as in-crop fertiliser, which assuming a 50% efficiency meant the crop took in 53kg N. Typically 80kg N is required to grow 1 tonne of canola. The average yield of the canola grown on the legume stubbles was ~3.23t/ha, which meant 258kg of N was utilised by the canola. If 53kg N was supplied from the bag, the remaining 205kg came from the soil N pool.

Likewise, the canola grown on the 2016 linseed stubble yielded ~2.16t meaning it required a total of 172.8kg N with 53kg applied from the bag = 119.8kg N came from the soil N pool.

Therefore, it could be deduced that the difference between the linseed and the legume soil N pool was the amount of N fixed by the legumes (205.4kg – 119.8kg) = 85.6kg N [= 186kg urea], which happens to be approximately the amount of N required to grow 1 tonne of canola. Isn't it great when the numbers align!

2018 Results

The starting deep N tests taken two years after the legumes were sown, showed large variability amongst the different legume plots but no statistically significant differences (**Table 2**). This was also reflected in the in-crop biomass nitrogen uptake measurement taken in August (**Table 3**). Unfortunately, strong wind in December laid the oat crop flat in a westerly direction, making it impossible to harvest with the host organisations plot harvester to produce a reliable grain yield. Instead, grain was collected from each plot and analysed for protein (**Table 3**), but once again no statistical differences could be found.

Soil Water Nitrate Readings

Soil water nitrate readings were taken fortnightly from each plot from June 1st 2017 ceasing on October 2nd 2017.

The soil water nitrate (NO3) levels decreased throughout the season for all crop types (**Figure 1**). In agreement with the results of the starting deep soil N in 2017, (**Table 2**) linseed had statistically lower soil water NO3 readings, than the other crops until the second to last reading on 19th September.

With the exception of the first soil water nitrate reading taken on 1st June, the remainder of the season nitrate readings for the lupins, sub clover, peas and faba beans were statistically similar.

Soil Moisture Probes

2016

Linseed used significantly more moisture from a greater depth, than the faba bean plots. Linseed roots reached 60cm, whilst the faba beans only reached 40cm at most. Saturation of the profile occurred for many weeks of the season, and the lower layers in the faba bean plots were still near on saturation in December 2016. Despite 2016 being a Decile 10 rainfall year, by years end, linseed had essentially dried out the profile.

2017

More moisture was extracted from the 2016 faba bean plot, compared to the linseed plot. This was likely due to the fact there was more moisture available in the faba bean profile residual from 2016. Interestingly, at the time of the deep N soil sampling, the faba bean plots appeared to have the wettest soil samples whilst the linseed had the driest soil.

At the end of the growing season there was more total moisture still left in the faba bean plots compared to the linseed, i.e. the canola did not extract all the residual moisture left from 2016, so there was in effect, still residual moisture left for crop in 2018.

The ion sensors showed there was more net extraction of ions from the 2016 faba bean plots compared to the 2016 linseed plots.

2018

The oats drew both the linseed and faba bean sites, back to a level playing field. There appeared to be no increased soil moisture or ion content in either plot. During August however, there was a saturation event that saw the highest levels of soil moisture since the project began. Since that point, a dry spring saw the moisture extraction in both plots, draw down to a similar level. Interestingly, the oats did not extract as much moisture out of the profile as the linseed did at the end of 2016.

In regards to the ion content, it is a similar story with the levels being the same in either plots throughout 2018; in effect showing that there was no residual elevated ion content left over from the 2016 faba bean plots.

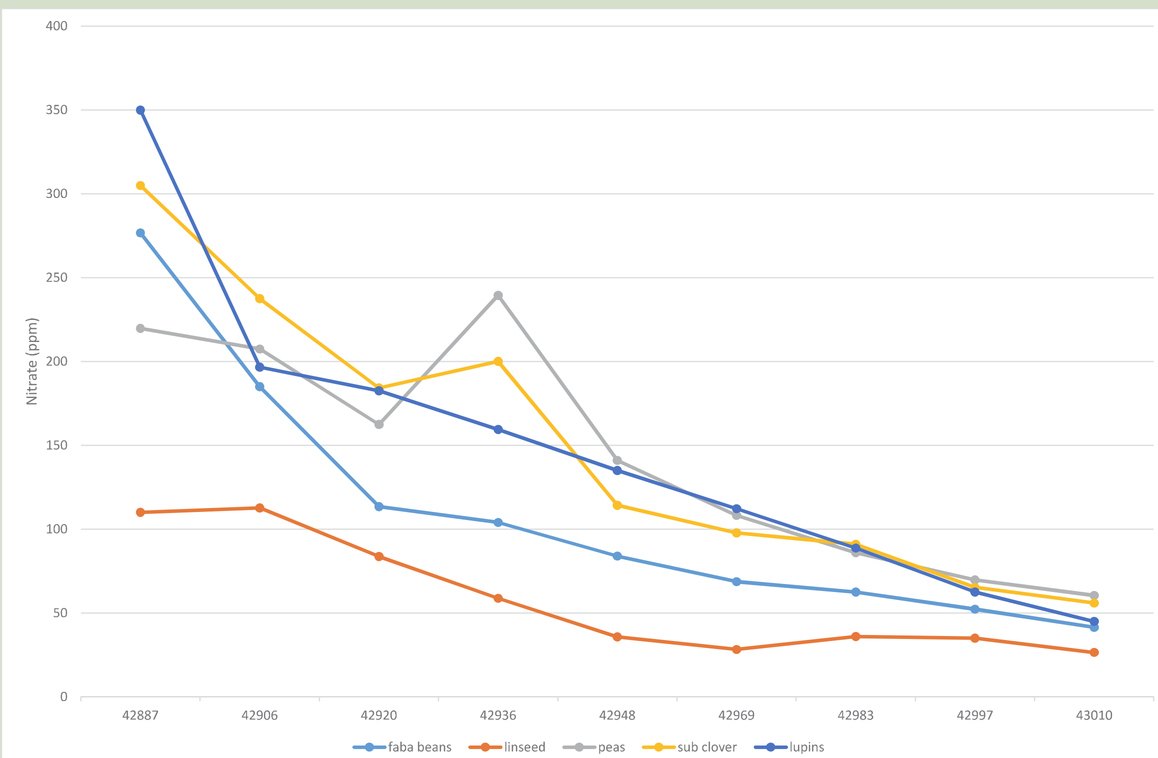
Soil Probes Summary

There were differences between the faba bean and linseed in regards to both soil moisture and ion content. Looking at the summed graph from the start of 2018 (**Figure 2**), it appears that there were slightly elevated levels of moisture still residual from the faba beans in 2016, even after the canola in 2017. This goes in line with the thinking that faba beans are not as deep rooted as linseed and thus the faba beans left behind soil moisture. The canola crop of 2017 had a good growing season with enough winter precipitation to allow it to reach maturity without extracting all of the deep soil moisture reserves. It takes the second season's crop of oats following the faba bean plots to see the moisture levels even out when compared to the linseed plots.

In regards to the ion content, the sensors showed a slightly elevated ion content following the faba bean plots towards the end of 2016 (**Figure 3**). The coarseness of these readings, makes it a bit hard to confidently assess the differences, but there was an apparent increase in ion reduction of the faba bean plots (extraction of nitrates?) from the canola crop from mid-September to early November 2017. At the start of 2018 the ion levels were very similar, and then mirrored each other during the 2018 season.

In short, faba beans left behind more moisture and ions (nitrates), compared to linseed. This was of apparent benefit to the following canola crop and in the case of the soil moisture, may have been of benefit in the second year crop.

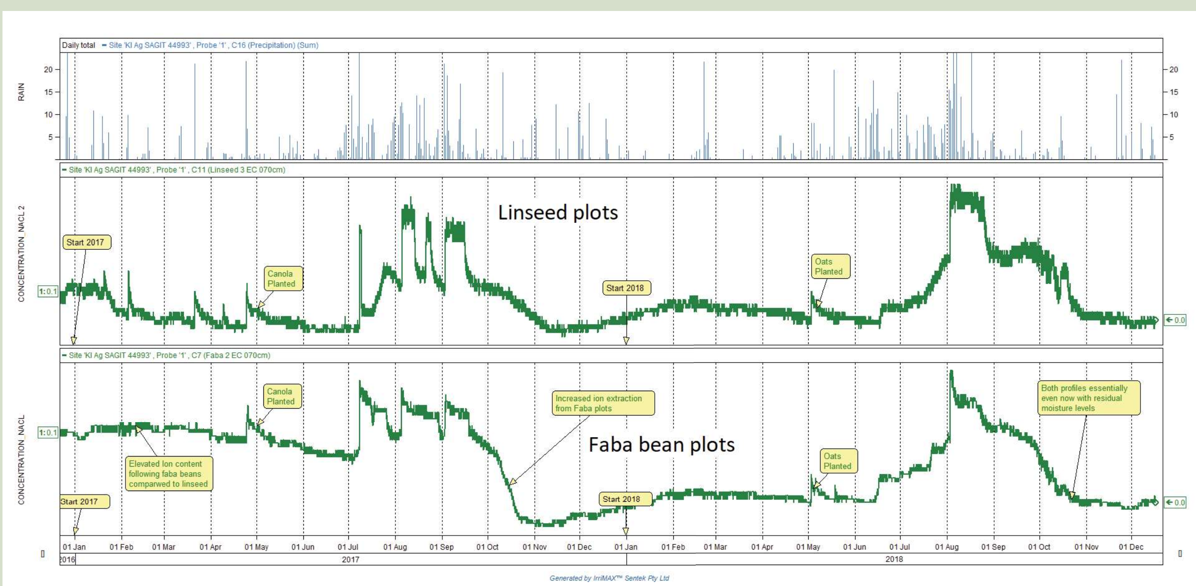
Figure 1: Soil water nitrate readings



Using Legumes to Improve Nitrogen Efficiency (cont.)

Figure 2: Three years of Soil Moisture Graphs. Top Linseed. Bottom Faba Beans

Figure 3: Three years of Soil Moisture Graphs. Top Linseed. Bottom Faba Beans.



Take home messages

- All the legumes sown - peas, lupins, sub clover and faba beans - were equal in terms of their nitrogen fixing capabilities, reflecting the importance of having well nodulated legumes.
- The average amount of N fixed by the legumes was calculated at ~86kg/ha (~187kg urea).
- In year 2, this residual N gave rise to a ~1t/ha canola yield advantage.
- In year 3, no differences in residual nitrogen from the legumes was measured.
- Linseed extracted more moisture, from a greater depth, than the faba beans in the same year and all subsequent crops – canola and oats.
- The linseed was able to dry the soil profile in a decile 10 year (812mm rainfall). This is a potential solution for farmers wanting to dry out their soil profile.
- Two years after growing linseed, soil moisture levels were even.

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