Year 2: Improving nitrogen use efficiency via legumes in high rainfall cropping

Background

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

As a refresher, 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 this second year, the trial was set up 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 following crop? Concurrently, how much N was lost through leaching or denitrification?

What was done

The trial site was located at the same location as 2016, on the Stantons' 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 sown by the landholder on the 28th April with 1.7kg 45Y91 Clearfield® canola + 42kg MAP + 8.5kg humate granules. The site also received 5kg slug bait applied on the same day.

Post sowing the site was sprayed with 1.8L Roundup ULTRA®MAX + 0.2% Li700 + 1L Pyrinex®Super + 1% AMS on April 30th.

In-crop fertiliser comprised of 100kg urea (applied 2/6), 50kg sulphate of ammonia (23/6) and 100kg 38:0:0:8 blend (27/7). An additional 18L Easy N® was foliar applied with the in-crop grass, and crop protection applications.

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 measures ion content, soil temperature and soil moisture. These Hydra Probes track and log the nitrate movement through the 80cm profile.

In order to monitor the nitrate released into the soil water by the various crop species, Sentek SoluSAMPLER™ – ceramic water collecting tubes, were installed to a depth of 30cm under each plot on May 18th.

Weather data was also recorded at the site with a rain gauge, air temperature & humidity and wind speed & direction sensor. These sensors are logged and the data uploaded every 15 minutes. Logged data can be viewed at http://120.150.31.37:8080/custdata/agbyte/sagit/ki/weather.html

The site received 515mm of rain for 2017 compared to the long term average of 530mm with 386mm falling in the growing season (April-October) being ideal for growing canola.

Measurements taken during the growing season included: deep soil nitrogen to 35cm (26/4), soil water nitrate readings beneath each plot taken on a fortnightly basis and canola grain yield and associated quality parameters.

Results

***TABLE 1**: Measurements*

2016 Crop	Deep Soil N (kg/ha)	Canola Grain Yield (t/ha)	Canola Oil (%)
Linseed	16.8b	2.16b	47.3
Faba Beans	43.8a	3.13a	45.9
Peas	39.4a	3.63a	45.8
Lupins	38.8a	3.13a	47.2
Sub Clover	37.7a	3.04a	46.4

All the legumes sown in 2016 shared similar starting soil nitrogen levels to 35cm depth compared to the linseed control (Table 1) inferring that they all fixed a similar amount of N last year. 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 man power versus B horizon heavy clay)

Similarly, the canola grain yield of the four legume species was statistically different from the linseed control. 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 1, it could be surmised 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 means 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 means 258.4kg of N was utilised by the canola. If 53kg N was supplied from the bag, the remaining 205.4kg 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, which happens to be approximately the amount of N required to grow 1ton of canola. Isn't it great when the numbers align!

Soil Water Nitrate Readings

Soil water nitrate (NO_3) readings were taken fortnightly from each plot from June 1st ceasing on October 2nd which was the last time water could be extracted from the SoluSAMPLERS™.

The NO_3 levels decreased throughout the season for all crop types (FIGURE 1). In agreement with the results of the starting deep soil N, linseed had statistically lower soil water NO_3 readings than the other crops until the second to last reading on 19th September.

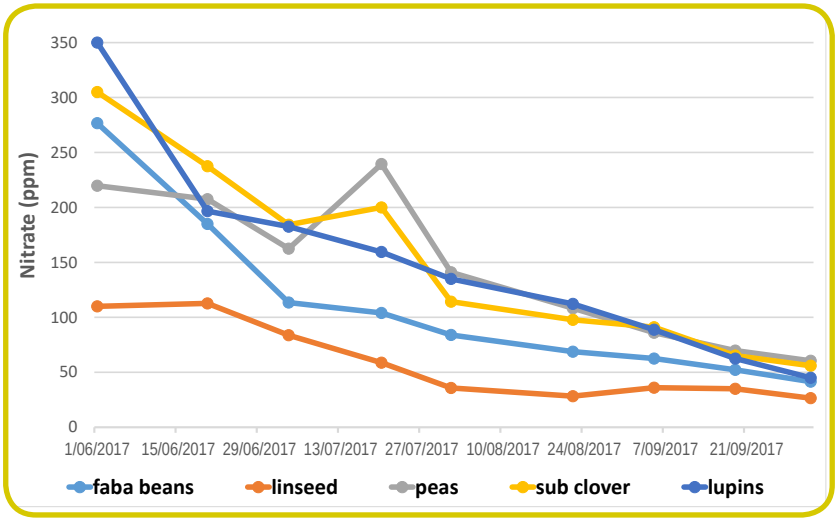

FIGURE 1: Soil water nitrate readings taken throughout the year.

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

A small spike in NO_3 readings was observed on the 20th July for the peas and sub clover, which may have been caused by leaching of the 50kg of sulphate of ammonia applied on the 23rd June coinciding with the site receiving 107mm of rain between the 29th June and 20th July. However, the NO_3 spike wasn't evident for the other three crops.

Soil Probes

It appears from the summed comparison graphs (FIGURE 2), that there has been more net moisture extracted from the 2016 faba bean plot compared to the 2016 linseed plot. Observing moisture extracted from 1st May 2017 to 1st December 2017 shows ~66mm of moisture extracted out of the 2016 faba bean profile compared to ~44mm out of 2016 linseed plots. This is likely due to the fact that there was more moisture available in the faba bean 70cm profile residual from last year which meant there was more for the roots to extract with less energy. (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.)

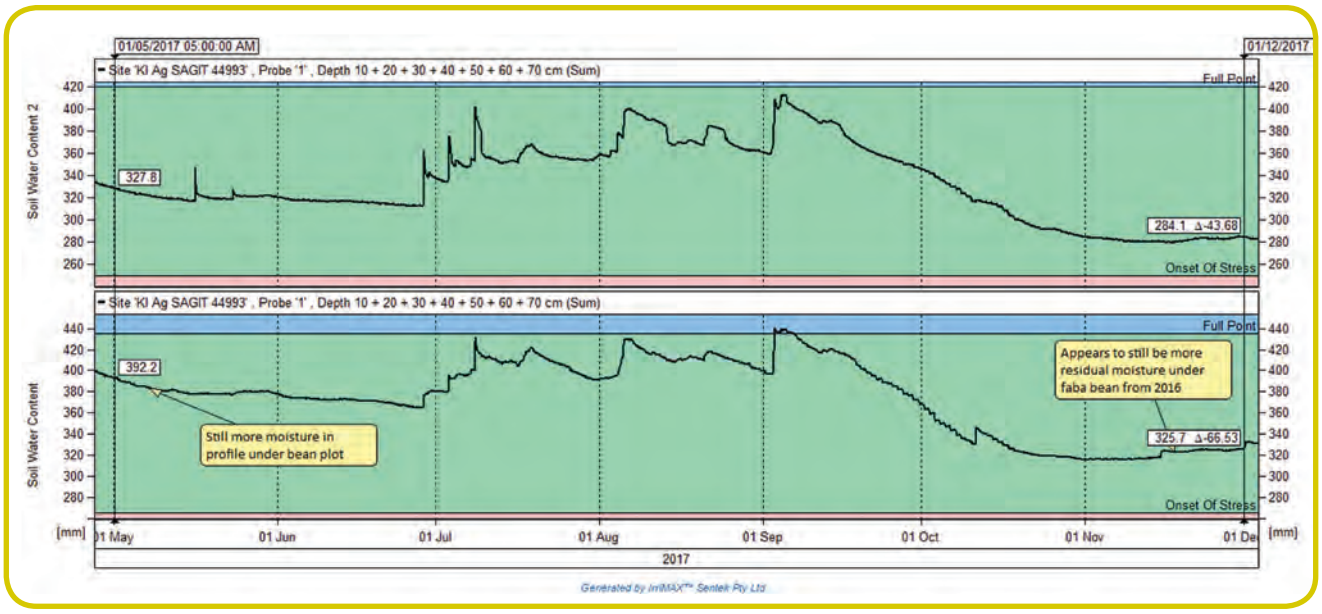

FIGURE 2. Soil moisture graphs. Top: Linseed. Bottom: Faba Beans.

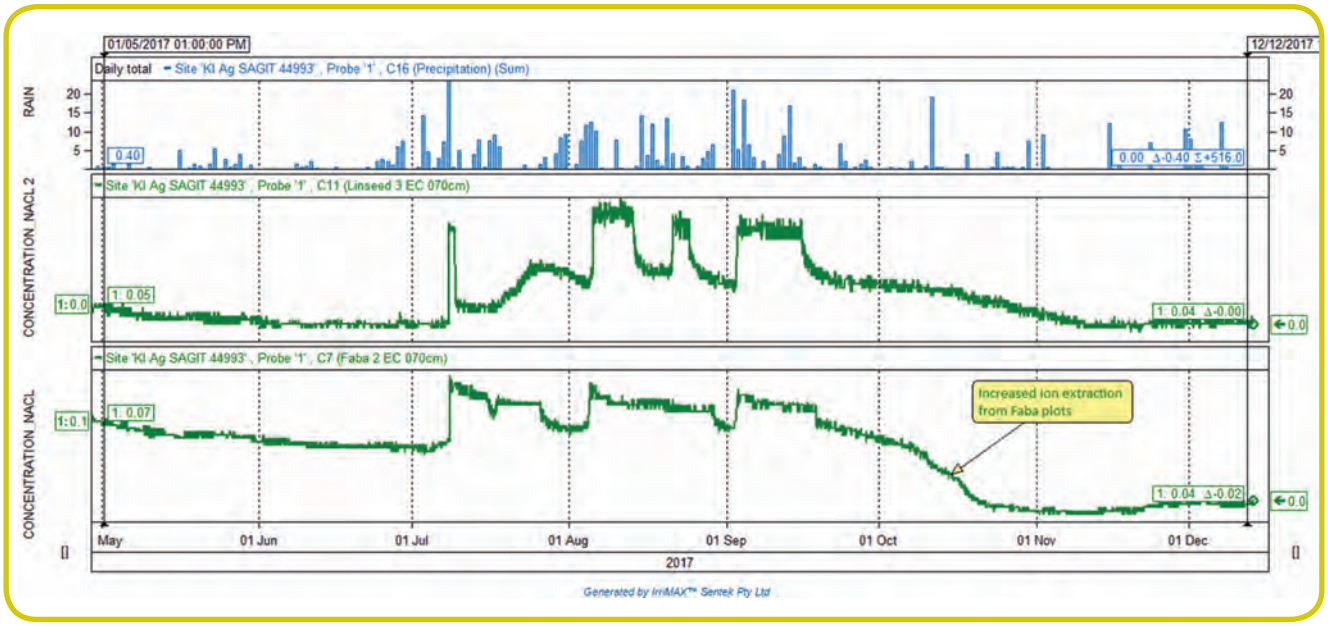

FIGURE 3. Soil ion content graphs at 70cm. Top: Rainfall. Middle: Linseed. Bottom: Faba Beans.

The canola on the linseed plots may have had to go deeper to extract the same amount of total moisture. The other reason may be that there was more nitrogen left residual under the faba bean crop and thus the canola plants there were healthier and grew a bigger root system to extract more moisture.

Observation from the 5th September (the time of greatest soil moisture during the season) to 1st December shows ~129mm extracted from linseed plot compared to ~108mm from faba bean. Possible reasons for this increased extraction could be that canola roots followed linseed roots deeper, compared to shallow rooted faba beans. Perhaps too, the canola on the bean plots was marginally more advanced compared to the linseed plots, therefore extracted more moisture earlier in the season.

There is 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 is in effect, still residual moisture left for crop in 2018.

The ion sensors still show that there was more net extraction of ions from the 2016 faba bean plots compared to the 2016 linseed plots. Observation from 1st May 2017 to 1st Dec 2017 show more next change in the faba bean plots (FIGURE 3). This is possibly due to there being an increased amount of nitrate ions under the faba bean plots and there was therefore more to extract.

Year 3 (2018)

In the third and final year of the trial, the residual nitrogen levels of the various legumes will be examined by a deep nitrogen soil test in each plot shortly before the site is sown to barley in 2018.

To protect the SoluSAMPLERS™ from damage during the sowing operation, they will be removed from the site and no further soil water nitrate levels will be measured. Instead normalized difference vegetation index (NDVI) readings of each plot will be taken during the growing season using a GreenSeeker handheld crop sensor to provide a rudimentary indication of the vegetative growth of the plots, which in turn will give an indication of how much residual nitrogen is still being released by the various crop residues. This will be verified by grain yield and protein readings at harvest.

Take Home Messages

- Near perfect growing season for canola, provided ideal opportunity to assess the residual N feeding effect of the legumes
- All legumes sown in 2016 – peas, lupins, sub clover and faba beans had similar starting soil N levels and soil water nitrate readings throughout the year which was reflected in similar grain yields inferring that all legume species were equal in terms of their N fixing capabilities
- The average amount of N fixed by the legumes was calculated as ~86kg/ha
- Growing adequately nodulated legumes can give rise to a ~1t/ha canola yield advantage compared with a non-legume
- Linseed used more moisture, from a greater depth, than the faba beans in 2016. Resultantly more moisture was extracted by the canola crop sown on the faba bean stubble in 2017, and yet there is still more residual moisture left.

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