GRDC Development and Extension to Close Economic Yield Gap and Maximise Farming System Benefits from Grain Legume Production in South Australia (Lower EP)

PULSE AGRONOMY D&E Project

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2025 Growing Season Lower Eyre Peninsula Paddock Investigations - Summary Report

Key messages

- Areas of poor growth were observed in some Lower Eyre Peninsula grain legume crops despite the season starting with very dry soil profiles.
- Wet conditions in July saw short term surface waterlogging in some paddocks.
- Despite this, pulse paddocks with underlying soil constraints (including shallow dispersive layer, high boron, or salinity), saw these expressed as continued poor crop growth and vigour into late spring.
- Whilst high exchangeable sodium and potassium are present in many of these soils, field dispersion is often confounded by elevated salinity, and response to gypsum application on these soils is highly variable.
- On the ironstone gravelly sites at Edillilie and Wangary poor pulse performance seemed to be mainly driven by low soil pH, and salinity.

Introduction

Extremely dry conditions during summer and autumn of 2024/25 resulted in very dry soil profiles on Lower Eyre Peninsula at the start of the 2025 winter cropping season. April and May rainfall was well below average, with only 41 mm received at Cummins to the end of May compared to an average of 73 mm for this period. Despite this dry start to the growing season, average rainfall in June and well above average rainfall in July (97 mm at Cummins compared to long term average of 70 mm) resulted in GSR (April to October growing season rainfall) around the long-term average (which is 339 mm).

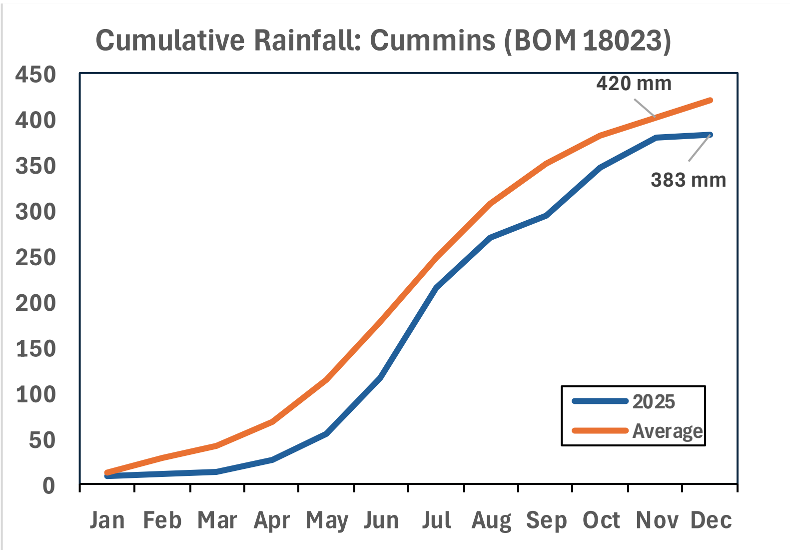


Figure 1. Cumulative rainfall in 2025 at Cummins (BOM 18023) compared to the long-term average.

Whilst these wet conditions resulted in some observations of surface waterlogging in Lower Eyre Peninsula paddocks in late winter, this was generally only short term or in small areas of paddocks. However, despite the temporary nature of surface waterlogging in these paddocks in 2025, reduced crop vigour and biomass production were reported on many of these areas going into spring (mostly in lentils, however there were several examples of affected faba bean crops).

As part of the Pulse Agronomy project investigations were undertaken on several Lower EP sites where landholders had observed particularly poor growth of lentils or faba beans during winter, which by mid spring had not sufficiently recovered compared to areas of "good" growth within the paddock. Seven sites were identified, with 4 sites growing lentils in the Cummins/Cockaleechie/Yeelanna district and 3 sites growing faba beans south of Cummins at Edillilie, Wangary, and Louth Bay.

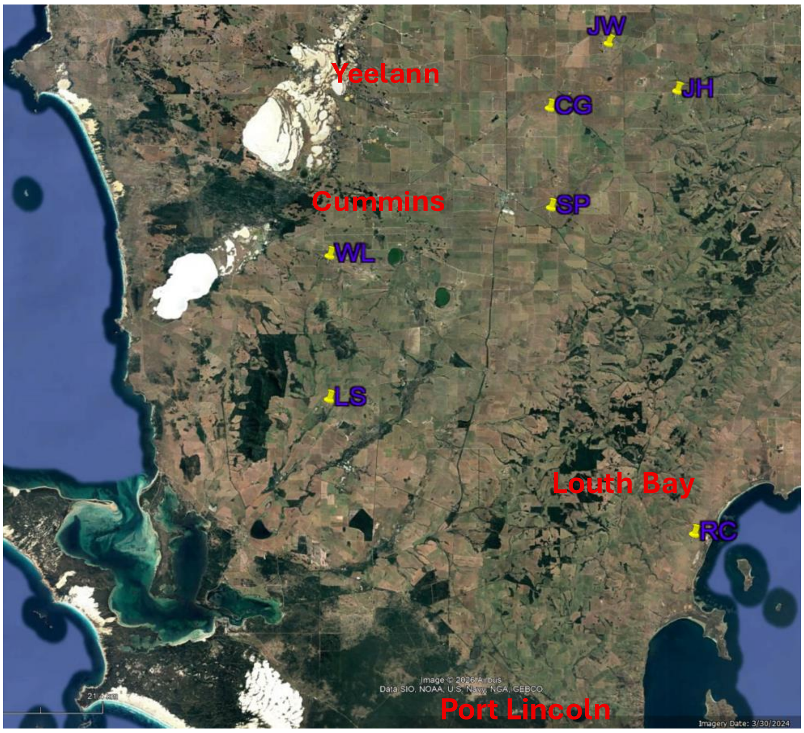


Figure 2. Map of paddock investigation sites.

Paddock investigations at each site included; observation of crop growth on an area of "poor" and "good" growth, plant biomass and tissue tests and soil sampling to depth. These investigations aimed to determine the key drivers behind the differences in pulse crop growth at each site, assess whether there were common themes across the sites, and to identify management opportunities to address these for future pulse crops grown on the site, with the learnings from these sites able to be applied more broadly across the Lower EP cropping region.

Soil Sample: Methodology and Analysis Results

Soil cores were taken (with either a gauge or 'jarret' style auger) on both the 'poor' and 'good' growth areas to a depth of 60 cm, and bulked by depth (0-10, 10-30 and 30-60 cm). Note that sampling transects were taken in areas which were *representative* of the poor crop growth, not in the barest areas of the paddock. Field analysis of texture, pH, slaking, dispersion, and reactive carbonate ("fizz" test) were undertaken (Appendix 1). Subsamples were sent to a laboratory for analysis of key chemical properties including pH$CaCl_2$, Phosphorus Buffering Index (PBI), salinity (EC1:5, ECe and Chloride), Exchangeable Cations, Boron (B) major nutrients, and trace elements (Appendix 2).

Soil analysis results indicated that the sites could be divided into two common themes which were:

1. Soils with shallow sodic (and often calcareous) subsoils in the Cockaleechie/Yeelanna districts, as well as the Louth Bay site, which constituted 71% of sampled sites (5). The soil in the poor growth areas of these sites exhibited moderate to severe field dispersion at relatively shallow depths, except where dispersion was inhibited by high salinity in heavier textured clay layers. Several of these sites also had very high levels of boron in these clays.
2. Ironstone gravelly soils with low pH surface and/or subsurface layers in the Edillilie/Wangary district (2 out of the 7 sites) in the Edillilie district. At one of these sites, salinity (EC and chloride) levels were elevated where faba bean growth was poor. On the other site faba bean growth seemed to be affected in an area which was deep ripped several years ago. This area had very low pH (4.4 $CaCl_2$) in conjunction with high aluminium (9.5% of CEC) in the 0-10 cm layer. This area also had dispersive

clay at 10-30 cm, compared with the ‘good’ and ‘very good’ growth areas which have deeper sandy A horizons to 30 cm.

A summary of the soil analysis results (field and laboratory) for each site is provided in Table 1 below, with laboratory values for key soil chemical analyses in appendix 2.

Table 1. Site location and soil description

SITE ID	Location/ District	Crop	Soil type in poor production zone	Soil type in good production zone
RC	Louth Bay	Faba bean	Alkaline sand on clay loam from 10-60 cm. Very high Colwell P and K. Very high salinity (EC1:5 0.61-0.97 dS/m and 260-730 mg/kg chloride) in subsurface layer. Very high exchangeable sodium in 10-60 cm layer (sample results perhaps dominated by soluble Na)	Alkaline loamy sand on clay at 30 cm. Salinity (EC and chloride) relatively low throughout sampling depth High Colwell P but K low in 0-10 cm layer. ESP and Exch. K relatively low at 0- 30 cm but increasing in 30-60 cm layer.
SP	Cummins	Lentil	Gravelly alkaline clay loam to depth of sampling. Very high Colwell P (93 mg/kg) with high PBI (180) somewhat restricting availability. Very high available K (440 mg/kg) at surface. Salinity and chloride are low.	Gravelly alkaline clay loam on neutral clay on rock at 30 cm. Adequate Colwell P (43 mg/kg) but high PBI (143) is likely to restrict availability. Very high available K (310 mg/kg) at surface. Elevated salinity (0.63 dS/m) in the 10-30 cm layer. Chloride and boron levels are relatively low with low ESP and exch. K indicating low dispersion potential.
JW	Yeelanna	Lentil	Highly alkaline heavy clay. High Colwell P (65 mg/kg) in surface soil but very high PBI (189). Salinity and chloride increasing with depth (EC1:5 0.51-0.99 dS/m, Chloride 160-310 mg/kg). Field dispersion likely to be restricted by salinity. Boron high at surface (6.3 mg/kg) and increase with depth (16-33 mg/kg).	Alkaline loam to 10 cm on alkaline clay. Colwell P in 0-10 cm layer marginal (27 mg/kg) with PBI104. Very high available clay at the surface (600 mg/kg). Salinity is low (0.15-0.16 dS/m) to sampling depth. ESP low, but elevated exch. K (5% of CEC) in 0-10 cm layer could result in some field dispersion.
JH	Yeelanna	Lentil	Highly alkaline (pHw 8.2-8.5) clay loam to 60 cm. Colwell P adequate (48 mg/kg) but very high PBI (171) would restrict availability. Very high available K (630 mg/kg). Salinity is generally low (0.22-0.27 dS/m) with low chloride (28-63 mg/kg in subsoil). Boron concentration is slightly elevated (3-4 mg/kg) in subsurface layers and might have some impact on sensitive crops such as lentils. ESP+K at 5-6% of CEC saw some field dispersion.	Neutral loam-clay loam on clay at 30 cm. Colwell P (52 mg/kg) adequate with some tie-up expected due to PBI (102). High available K (350 mg/kg). Salinity, chloride (16-18 mg/kg), and boron (1.3-1.5 mg/kg) low in subsoil layers. Moderate ESP+K (5-7% of CEC) saw some field dispersion.

CG	Yeelanna	Lentil	Highly alkaline clay throughout sampling depth (0-60 cm). Colwell P (43 mg/kg) marginal given very high PBI (190). Very high available K (710 mg/kg) Salinity generally low (0.2 mg/kg) in 0-30 cm but slightly elevated EC (0.44 dS/m) and chloride (120 mg/kg) in 30-60 cm layer. ESP + exch. K very high throughout (7 -14% of CEC), with field tests showing very high dispersion.	Neutral sandy loam/loam to 30 cm on alkaline clay. Colwell P moderate (39 mg/kg) with low PBI (36) and high available K (320 mg/kg). Generally low salinity (0.1-0.22 dS/m) and chloride (18 mg/kg) in subsoil layers. Whilst exch. K is elevated (5-7% of CEC) in the 0-30 cm layer lighter soil texture would restrict field dispersion. However, ESP+K % (10% of CEC) at 30-60 cm is likely to result in some dispersion of this layer.
WL	Edillilie	Faba bean	Acidic (pHca 5.6) loamy sand surface soil on alkaline loamy sand to 60 cm. Elevated salinity (0.3 dS/m) and chloride (200-230 mg/kg) throughout sampling depth. High Colwell P (74 mg/kg) with low available K (55 mg/kg) in topsoil. Despite elevated ESP+K values (as % of CEC) the light soil texture limits field dispersion.	Acidic (pHca 5.5) loamy sand surface soil on neutral (pHCa 6.8-7.1) sandy loam to sampling depth. Adequate Colwell P and K at the surface. Subsurface salinity (0.23-0.28 dS/m) and chloride (<10 mg/kg) are low. Despite elevated ESP+K values (as % of CEC) the light soil texture limits field dispersion.
LS	Wangary	Faba bean	Acidic sandy loam topsoil (pHCa 4.4) on neutral pH clay from 10 cm (ESP +exch K 6% at 10-30 and 11% 30-60 cm). High exchangeable Aluminium (Salinity low in surface and subsurface layers	**Good production area -** Slightly acidic (pHCa 5.6) loamy sand on clay at 30 cm. Generally low salinity. Moderate Colwell P and high Colwell K (140 mg/kg). **Very good production area –** Well drained neutral pH sand to 60 cm. Low salinity. High Colwell P (61 mg/kg) but very low K (28 mg/kg) in surface layer).

3. Crop growth observations

Plant samples were taken along the soil sampling transect, from within both the 'poor' and 'good' production areas. These samples were assessed for total biomass production (Table 2 and Figures 3 to 5) and plant tissue nutrient concentrations (Figures 7 to 9, and appendix 3). Assessment of normalised difference vegetation index (NDVI) were also taken prior to taking biomass cuts at the three Yeelanna sites (high values between 0.6 and 1.0 indicate heathy green growth, whilst values in the range 0.2-0.5 indicate sparse vegetation or crops under stress).

Biomass on the areas of good growth was more than 7.5 x higher than the poor growth areas on the lentil sites and more than double that of the poor producing areas on the faba bean sites (Table 2).

Table 2. Spring NDVI and biomass (dry matter t/ha) in early October 2025.

		Mean NDVI		Dry Matter (t/ha)	
Site ID	**Crop type**	**Poor**	**Good**	**Poor**	**Good**
CG	**Lentil**	0.14	0.83	0.14	4.19
JH	**Lentil**	0.36	0.83	0.46	3.54
JW	**Lentil**	0.33	0.84	0.38	3.65
SP	**Lentil**	*	*	0.52	6.44
RC	**Faba Beans**	*	*	3.01	6.79
LS	**Faba Beans**	*	*	1.10	3.21

a) b)

Figure 3. Lentil growth at site CG, Yeelanna on the poor (a) and good (b) growth areas.

a) b)

Figure 4. Lentil growth at site JW, Yeelanna on the poor (a) and good (b) growth areas.


a)

b)

Figure 5. Lentil growth at site JH, Cockaleechie on the poor (a) and good (b) growth areas.

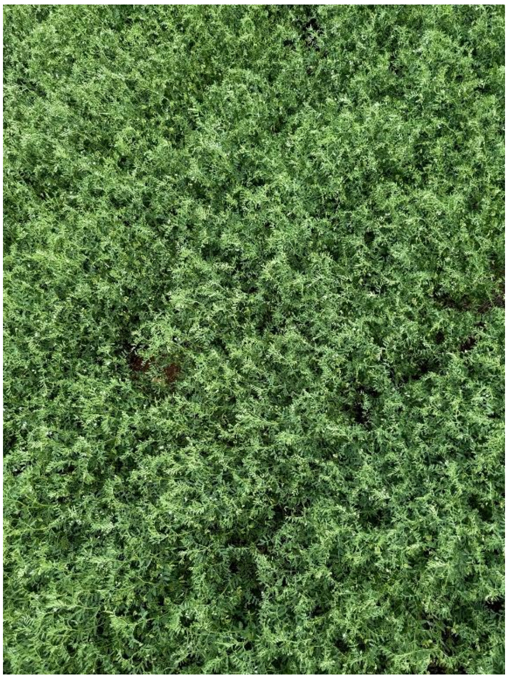

a)

b)

Figure 6. Lentil growth on site SP, Cummins on the poor (a) and good (b) growth areas.

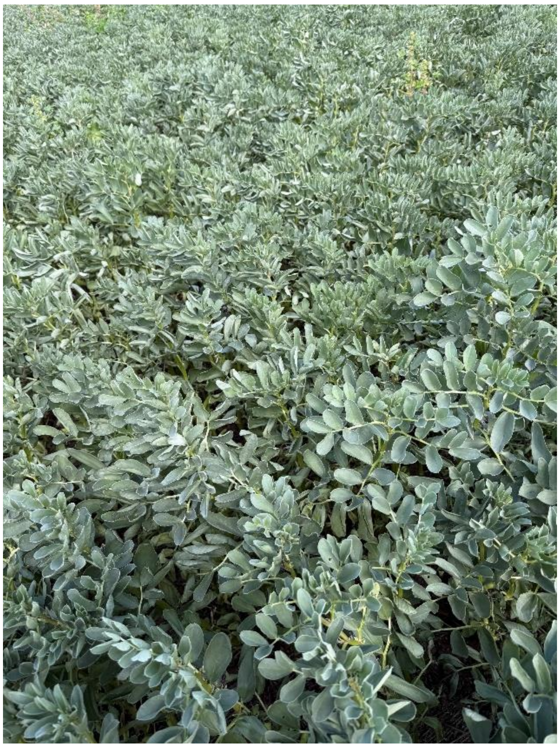

a)

b)

Figure 7. Faba bean growth on site RC, Louth Bay on the poor (a) and good (b) growth areas.

Plants were dug up to inspect to inspect root nodulation (one shovel width along crop row at 3 locations) (Figure 8). There did not appear to be any difference in root nodulation between the good and poor production areas. Plants taken from both production zones had adequate levels of healthy root nodules, though the lentil roots in the poor production zone seemed to be shorter and less healthy when compared to those in the 'good' growth area.

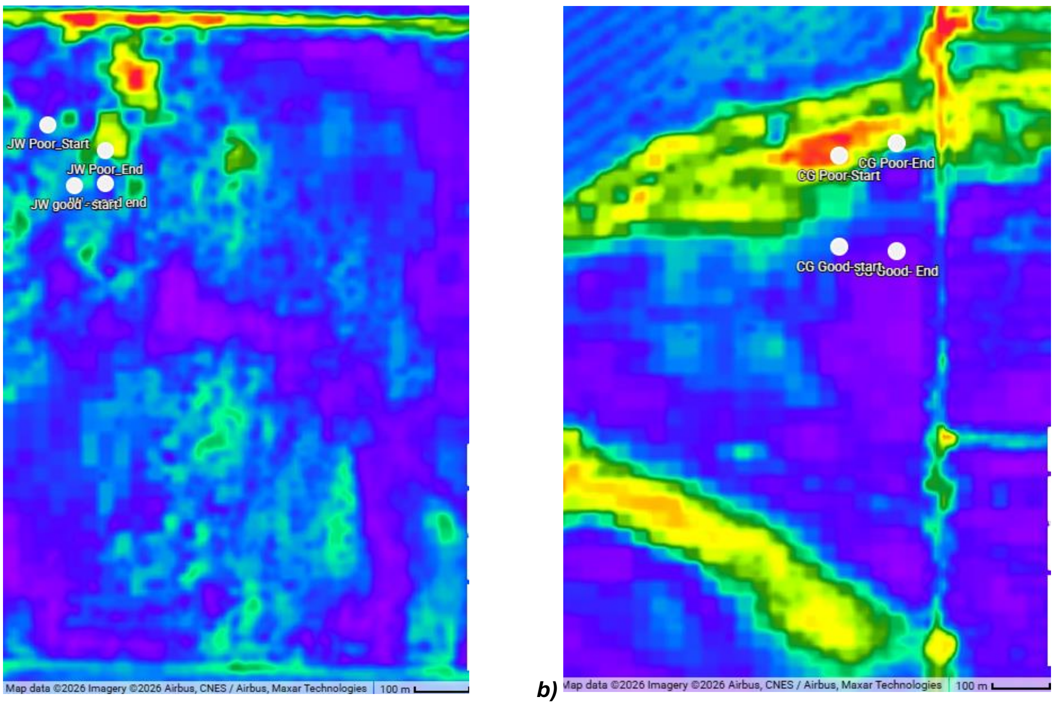
a) b)

Figure 8. Root nodulation and above ground biomass site CG, Yeelanna on the poor (a) and good (b) growth areas.

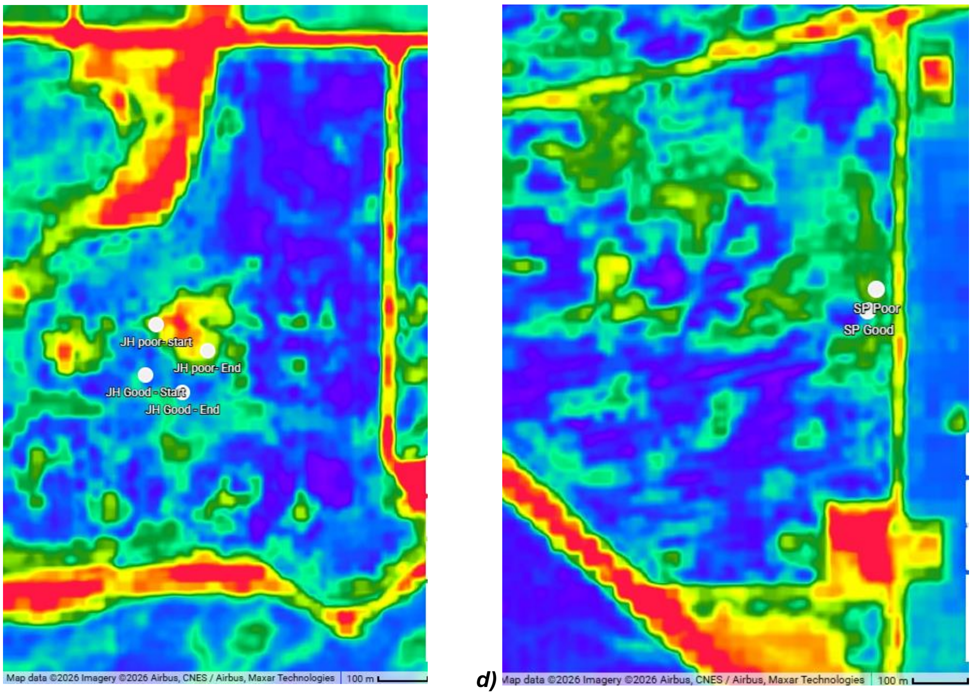
Satellite NDVI – October 2025

Site sampling locations/transects were geolocated and checked against publicly available Satellite NDVI for October 2025 using the *Decipher Ag* platform (Figures 9 to 11). Imagery display parameters were set to capture the highest plant densities for the month of October, to ensure that the contrast in growth between the poor and good areas observed in the field at the time were reflected.

Figure 9. Legend for Decipher Satellite NDVI imagery maps for October 2025.



a) *b)*



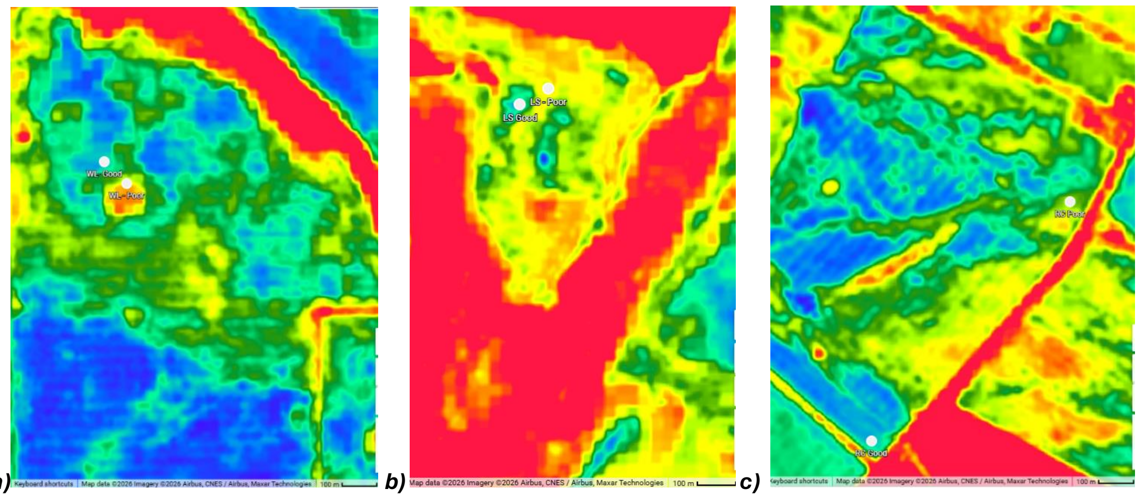
c) d)

Figure 10. October 2025 satellite NDVI imagery for Cummins/Yeelanna sites a) JW, b) CG, c) JH and d) SP

The NDVI imagery reflected the poor growth at the Yeelanna sites (JW, CG and JH) well, showing that although the growth at these sites was significantly poorer in some areas, these were generally confined to isolated patches or constituted small areas of the paddock (Figure 10a, b and c). At the SP site at Cummins there was a more even distribution of poor and good crop growth throughout the paddock (Figure 10d). Gravimetric moisture in the subsoil of the poor area (31% in October) was much higher than that of the good growth area (23%) (Appendix 1). The poor lentil growth, and coinciding with poorer NDVI, reflects the impact of microrelief and underlying rock on drainage at this site (Appendix 1).

At the Edillilie site (WL) the poorer faba bean growth in the lower lying areas, reflected in the satellite NDVI, corresponds to the lower lying area which drains into a saline swamp (Figure 11a). Elevated soil salinity levels from the poor growth area compared to the good were reported in soil analysis results (appendix 2). At the Wangary site (LS) the growth of faba beans was severely restricted by very low surface pH associated with high aluminium (9.5% of CEC) (Appendix 2). Growth of the faba bean in these areas was so poor that the landholder ended up spraying out a large proportion of this paddock for weed control (Figure 11b).

Lower NDVI values along the eastern portion of the paddock at Louth Bay (Figure 11c) reflected poorer faba bean growth in the lower lying areas of the paddocks. Soil analysis from the poor growth area showed that there was not much difference in soil moisture between the good and poor growth areas in October 2025 (Appendix 1), but salinity levels were highly elevated (EC1:5 0.6-0.97 dS/m) on the poor growth area, which is likely the driving fact for poor crop growth (Appendix 2).



a) b) c)

Figure 11. October 2025 satellite NDVI imagery for faba paddocks south of Cummins at a) WL- Edillilie, b) LS- Wangary and c) RC-Louth Bay

Plant tissue tests

Plant tissue samples (whole tops) were sent for complete nutrient analysis (Figure 12). Results showed that there was little difference in plant tissue nitrogen (N) or phosphorus (P) concentrations from the good or poor growth areas at most sites (Figures 12a and 12b). At two sites (SP, Cummins and RC, Louth Bay) there were slightly higher concentrations of N and P in the samples from the area of poor growth, despite soil test results not showing large difference in soil concentrations of these nutrients. This might result from initial accumulation at establishment with poor plant growth following because of extended waterlogging on these sites.

There seemed to be a trend of slightly higher potassium in the areas of good growth Yeelanna (Figure 12c). This might be a function of the healthier plant roots in these areas being better able to take up the high concentrations of readily available potassium in subsoil clays at these sites. The inverse was true at SP (Cummins) and RC (Louth Bay), with plants from the poor growth area having higher K than the good growth.

At Yeelanna, the areas of good growth had generally lower magnesium (Mg) concentrations, which might reflect the antagonistic relationship of high K on Mg availability.

Plant tissue sulphur was higher on the poor growth areas at SP, RC, and CG where waterlogging was observed for extended periods (Figure 12d).

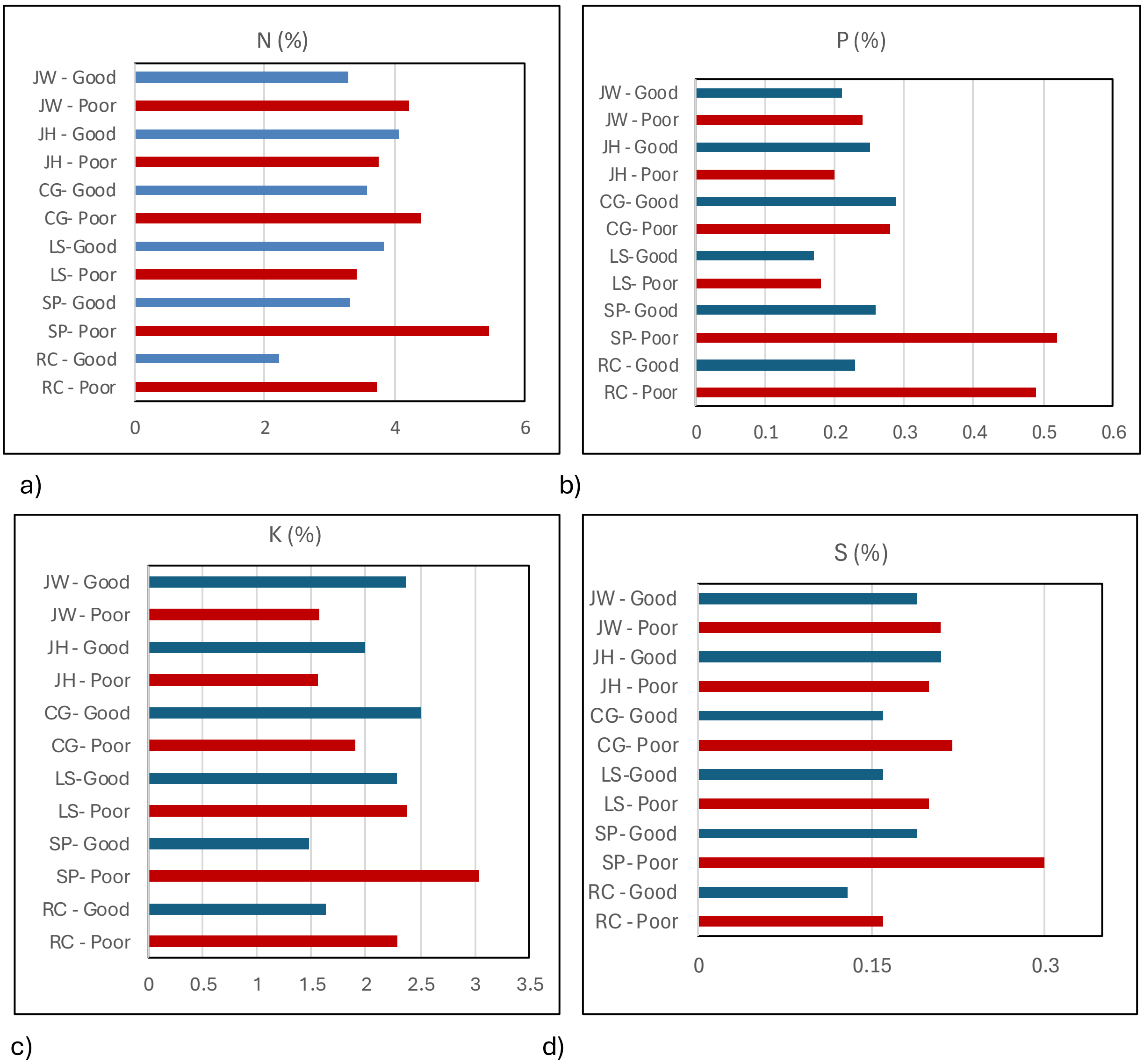


__Figure 12. Plant tissue concentrations of major nutrients; a) Nitrogen (N), b) Phosphorus (P), c) Potassium (K) and d) Sulphur (S).__

There were higher concentrations of calcium in the poor growth areas compared to the good in all sites except SP (Figure 13). It is difficult to determine the significance of this beyond the fact that most sites had high soil calcium levels which might have accumulated in the smaller stunted plants on the poor production areas.

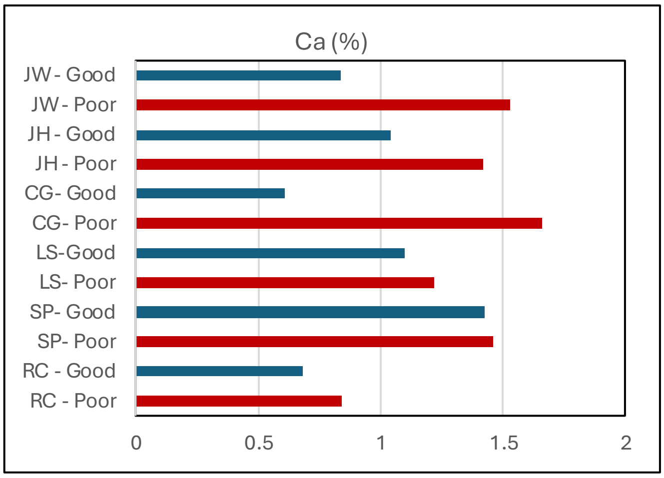


Figure 13. Plant tissue calcium concentration.

At the Yeelanna/Cockaleechie sites (CG, JH, and JW) boron (B) concentration was much higher in the plant tissue samples taken from the poor growth areas than the good (Figure 14a). This reflects the higher soil B concentrations reported in the soil analysis and is likely to be a driving factor for poor lentil growth at these sites.

Plant tissue concentrations of Aluminium were also much higher in the samples from the poor growth areas compared to the good at all sites except SP (Figure 14b).

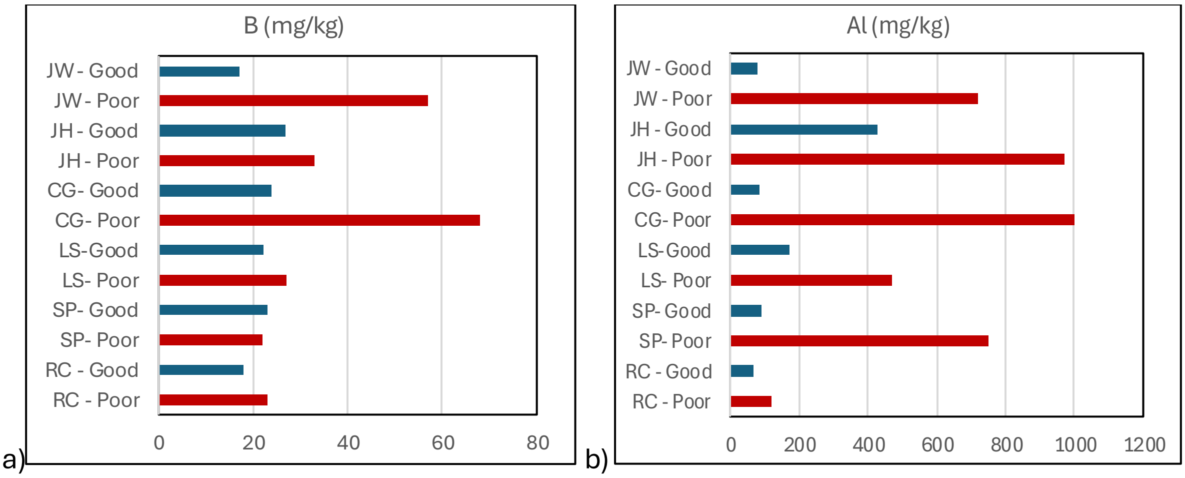


Figure 14. Plant tissue concentrations of a) boron and b) aluminium.

There was little difference in the concentration of zinc in samples from the poor area compared to the good area (Appendix 3). At all sites iron levels were at higher concentrations in the poor growth area compared to the good. Where paddocks experienced waterlogging for longer (CG, SP, LS and RC) plant tissue copper concentrations were higher in the poor growth area compared to the good (Appendix 3). Again, the most likely explanation for this is that these plants were able to accumulate these nutrients prior to their growth being impacted by subsoil issues including waterlogging and chemical constraints.

At the RC (Louth Bay) site there was a common trend of higher concentration of all nutrients (major nutrients and trace elements) in the plant samples taken from the poor area compared to the good. Given that the site was in faba beans (which are better able to handle waterlogging), rather than lentils, it might be that salinity was the biggest driving factor with nutrients and aluminium concentrating in the stressed plants of the poor growth area.

Crop Yield

In discussions with growers the difference in crop yields at the site at the end of the season largely reflected the differences in spring biomass, with yields in the good areas more than double that of areas of poor growth. One grower at Yeelanna stated that he has observed this trend in the yield maps of lentil crops from the paddock over several seasons. This has been particularly true since he changed from a crop rotation which included canola to a lentil wheat rotation.

Discussion

Field observations and soil and plant analysis results on the 7 Paddock Investigation sites indicated that the poor pulse crop growth observed in spring of 2025. Soil profiles identified by sampling the areas of poor pulse crop growth could be broadly grouped into two main themes which were; a) shallow sandy to clay loam surface on B horizons with significant soil structure or chemical constraints (i.e. dispersive clays, elevated salinity or boron), and b) ironstone gravelly soils with acidic sandy A horizons.

The best management approach for the ironstone gravels is to address the low soil pH with lime applications and address high soil strength layers by deep ripping (being careful to consider the impact of bringing high amounts of dispersive clay, or toxic aluminium or salt to the surface).

Addressing the constraints limiting pulse production on the sites near Yeelanna/Cockaleechie with shallow poorly structured B horizons is more problematic. Whilst gypsum can be effective in improving the structure of dispersive soil resulting from high relative concentrations of exchangeable monovalent cations (sodium and potassium), the response is less predictable where soils also contain high levels of salt. Additionally, many of these sites contain high amount of boron in subsurface soil layers which impacts the growth of sensitive crops such as lentils. There are no practical solutions for removing boron from these soil layers.

On the Edillilie site (WL) there might be opportunities to re-engineer soils to drain some of excess soil water toward the discharge zone. This is also a potential solution for the CG site at Yeelanna, where soil chemical constraints are low, but poorly structured subsoils inhibit drainage and the area affected by poor growth is mostly concentrated in the northern part of the paddock adjacent to drainage area.

Despite the significant impact on crop health in the area affected by these issues, they tended to be concentrated in certain areas of the paddock and only constituted a small proportion of the paddock area. However, it was evident from soil sampling that the poor crop growth in these areas resulted in significantly reduced crop water use with a large amount of residual water left following a poor pulse crop. There is a danger that if this is a regular occurrence (i.e. such as in a lentil-cereal rotation) excess water in the system could result in longer term issues such as increased areas at risk of salinisation.

Appendix 1. Soil Field characterisation

***Not analysed/or nil value**

1.1 RC, Louth Bay

Sample ID	Sample	Sample Depth	Field texture	Colour	Field pH	reaction (Fizz test)	Slaking/Dispersion	Gravel % of total dry weight	Gravel adjusted gravimetric moisture (%)
RC1	Poor	0-10	Clay loam	Light brown	6.00	Nil	*	0	4
RC2	Poor	10-30	Light Clay	Dark brown	7.50	Nil	Nil slaking/Highly dispersive	0	13
RC3	Poor	30-60	Light Clay	Dark brown	8.00	Slight	Slight slaking/Highly dispersive	0	21
RC4	Good	0-10	Clay loam	Light brown	7.50	Nil	*	0	3
RC5	Good	10-30	Light Clay	Light brown	8.00	Nil	Nil slaking/Highly dispersive	45	6
RC6	Good	30-60	Light Clay	Dark brown	8.00	Nil	Nil slaking/Highly dispersive	0	21

1.2 SP, Cummins

Sample ID	Sample	Sample Depth	Field texture	Colour	Field pH	reaction (Fizz test)	Slaking/Dispersion	Gravel % of total dry weight	Gravel adjusted gravimetric moisture (%)
SP1	Poor	0-10	Clay loam	Dark brown	8.50	Very High	*	0	21
SP2	Poor	10-30	Carbonate marl	Yellowish grey	9.00	Very High	Moderately slaking/Highly disperisve	0	31
SP3	Poor	30-60	Carbonate marl	White	9.00	Very High	Moderately slaking/Slightly disperisve	0	31
SP4	Good	0-10	Clay loam	Dark brown	8.50	High	Slight slaking/Nil dispersion	22	17
SP5	Good	10-30	Clay loam	Dark brown	9.00	Very High	Moderately slaking/Nil dispersion	19	23

1.3 CG, Yeelanna

Sample ID	Sample	Sample Depth	Field texture	Colour	Field pH	reaction (Fizz test)	Slaking/Dispersion	Gravel % of total dry weight	Gravel adjusted gravimetric moisture (%)
CG1	Poor	0-10	Clay loam	Dark brown	8.00	Very High	*	0	18
CG2	Poor	10-30	Light Clay	Dark brown	8.50	Very High	Highly slaking/Highly dispersive	0	23
CG3	Poor	30-60	Light Clay	Dark brown	8.50	Very High	Slightly slaking/Moderately dispersive	0	25
CG4	Good	0-10	Sandy clay loam	Light brown	7.50	Nil	*	0	5
CG5	Good	10-30	Clay loam	Light red brown	8.00	Slight	Highly slaking/Highly dispersive	0	7
CG6	Good	30-60	Clay loam	Red brown	8.50	Nil	Highly slaking/Highly dispersive	0	22

1.4 JH, Cockaleechie

Sample ID	Sample	Sample Depth	Field texture	Colour	Field pH	reaction (Fizz test)	Slaking/Dispersion	Gravel % of total dry weight	Gravel adjusted gravimetric moisture (%)
JH1	Poor	0-10	Clay loam	Red brown	8.50	Very High	*	17	18
JH2	Poor	10-30	Carbonate marl	Mottled carbonate marl	8.50	Very High	highly slaking/slight dispersion	47	39
JH3	Poor	30-60	Carbonate marl	Mottled carbonate marl	9.00	Very High	Highly slaking/nil dispersion	46	34
JH4	Good	0-10	Sandy clay loam	Dark red	6.50	Slight	*	23	12
JH5	Good	10-30	Clay loam	Dark red	7.00	Slight	Highly slaking/nil dispersion	29	12
JH6	Good	30-60	Clay loam	Red brown	7.50	Slight	Moderately slaking/high dispersion	20	17

1.5 JW, Yeelanna

Sample ID	Sample	Sample Depth	Field texture	Colour	Field pH	reaction (Fizz test)	Slaking/Dispersion	Gravel % of total dry weight	Gravel adjusted gravimetric moisture (%)
JW1	Poor	0-10	Clay loam	Dark yellowish brown	8.50	Very High	*	0	20
JW2	Poor	10-30	Light Clay	Light brownish yellow	9.00	Very High	Very High slaking/Highly dispersive	0	26
JW3	Poor	30-60	Light Clay	Yellow with red mottles	9.00	Very High	Very High slaking/moderately dispersive	0	31
JW4	Good	0-10	Clay loam	Dark brown	8.50	Moderate	*	21	14
JW5	Good	10-30	Clay loam	Dark red brown	8.50	Moderate	Highly slaking/nil dispersion	26	17
JW6	Good	30-60	Carbonate marl	Light yellowish brown	9.00	Very High	Highly slaking/nil dispersion	33	18

1.6 WL, Edillilie

Sample ID	Sample	Sample Depth	Field texture	Colour	Field pH	Gravel % of total dry weight	Gravel adjusted gravimetric moisture (%)
WL1	Poor	0-10	Sandy loam	Dark brown	6.50	13	14
WL2	Poor	10-30	Sandy loam	Dark grey	7.00	45	18
WL3	Poor	30-60	Clay loam	Dark grey	7.50	79	38
WL4	Good	0-10	Light sandy clay loa	Dark brown	6.50	22	6
WL5	Good	10-30	Light sandy clay loa	Orange brown	6.00	43	11
WL6	Good	30-60	Sandy clay loam	Dark red brown	7.00	27	19

1.7 LS, Wangary

Sample ID	Sample	Sample Depth	Field texture	Colour	Field pH	Gravel % of total dry weight	Gravel adjusted gravimetric moisture (%)
LS1	Poor	0-10	Loamy sand	Dark grey	6.00	14	10
LS2	Poor	10-30	Loamy sand	Dark grey	6.50	64	13
LS3	Poor	30-60	Loamy sand	Dark grey	7.00	34	24
LS4	Good	0-10	Loamy sand	Dark brown	5.50	12	11
LS5	Good	10-30	Loamy sand	light grey	6.00	6	20
LS6	Good	30-60	Clayey sand	light orange	7.00	0	21
LS7	Very good	0-10	Loamy sand	Dark brown	6.50	59	12
LS8	Very good	10-30	Loamy sand	Dark brown	6.50	75	22
LS9	Very good	30-60	Loamy sand	Dark brown	7.50	62	25

Appendix 2. Soil chemical analysis results

				pH and Aluminium			Major Nutrients						Salinity and Toxicities				Trace Elements				Exchangable Cations (*NB: not prewashed)					Exch. Cations % of CEC			
Sample	Depth (Cm)	Org. C (%)	Texture (MIR)	pH(water)	pH(CaCl)	Aluminium (% of CEC)	NO3 (mg/kg)	NH4 (mg/kg)	Col. P (mg/kg)	PBI	Col. K (mg/kg)	S (mg/kg)	EC1:5 (dS/m)	Ece (dS/m)	Chloride (mg/kg)	Boron (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Iron (mg/kg)	Mn (mg/kg)	Exch. Ca (cmol/kg)	Mg (cmol/kg)	Exch. K (cmol/kg)	Exch. Na (cmol/kg)	CEC (cmol/kg)	Ca (% CEC)	Mg (% CEC)	Na (% CEC)	K (% CEC)
RC - Poor1	0-10	1.37	Sand	6.5	5.7	0	1.6	9.2	150	47	130	13	0.11	2.5	*	0.63	0.75	3.1	160	2.8	4.51	0.924	0.254	0.479	6	73	15	8	4
RC - Poor2	10-30	*	Clay loam	8.5	7.8	0	*	*	*	*	*	*	0.61	5.2	260	3.9	*	*	*	*	14.8	6.57	0.713	4.45	27	56	25	17	3
RC - Poor3	30-60	*	Clay loam	8.9	8.2	0	*	*	*	*	*	*	0.97	8.3	730	6.8	*	*	*	*	15.1	9.26	0.931	8.05	33	45	28	24	3
RC - Good1	0-10	1.14	sand	6.9	6.5	0	2.4	7.9	130	44	55	16	0.08	1.8	*	0.51	1.2	5.9	67	4.9	5.14	0.42	0.129	0.078	6	89	7	1	2
RC - Good2	10-30	*	sand	7.6	7.3	0	*	*	*	*	*	*	0.18	4.1	13	0.43	*	*	*	*	6.3	0.904	0.17	0.241	8	83	12	3	2
RC - Good3	30-60	*	Clay	8.3	7.7	0	*	*	*	*	*	*	0.30	1.8	29	1.3	*	*	*	*	15.6	7.38	0.811	2.19	26	60	28	8	3
SP- Poor 1	0-10	1.64	Clay loam	8.2	7.7	0	16	9	93	180	440	40	0.19	1.6	*	1.7	0.46	0.42	13	1.9	32.7	2.07	1.19	0.314	36	90	6	1	3
SP- Poor 2	10-30	*	Clay loam	8.4	7.7	0	*	*	*	*	*	*	0.18	1.5	13	1.2	*	*	*	*	28.5	2.05	0.462	0.273	31	91	7	1	2
SP- Poor 3	30-60	*	Clay loam	8.6	7.9	0	*	*	*	*	*	*	0.24	2.1	65	1.6	*	*	*	*	27.1	4.55	0.411	0.697	33	83	14	2	1
SP- Good1	0-10	1.94	Clay loam	8.2	7.7	0	10	6.6	43	143	310	7.7	0.20	1.7	*	3.2	0.43	0.72	16	1.5	33.4	2.58	0.979	0.555	38	89	7	2	3
SP- Good2	10-30		Clay	7.8	7.6	0							0.63	3.6	98	1.8					42.2	1.66	0.652	0.554	45	94	4	1	1
WL- Poor1	0-10	1.1	sand	6.3	5.6	0	12	3.7	74	44	55	25	0.32	7.4	*	0.47	0.35	1.2	160	<0.3	2.79	1.07	0.159	1.18	5	54	21	23	3
WL- Poor2	10-30	*	Sand	8.1	7.6	0	*	*	*	*	*	*	0.31	7.0	200	0.31	*	*	*	*	10.9	0.765	0.209	0.693	13	87	6	6	2
WL- Poor3	30-60	*	sand	8.2	7.6	0	*	*	*	*	*	*	0.31	7.1	230	0.28	*	*	*	*	4.27	0.809	0.183	0.696	6	72	14	12	3
WL-Good1	0-10	1.35	sand	6.3	5.5	0	2.5	9.9	36	42	150	10	0.05	1.2	*	0.42	0.51	0.76	85	1.4	3.36	0.332	0.359	0.049	4	82	8	1	9
WL-Good2	10-30	*	loam	7.3	6.8	0	*	*	*	*	*	*	0.23	3.2	<5	0.48	*	*	*	*	2.86	0.51	0.353	0.059	4	76	14	2	9
WL-Good3	30-60	*	Clay loam	7.4	7.1	0	*	*	*	*	*	*	0.28	2.4	9	1.2	*	*	*	*	18.6	2.93	0.763	0.204	22	83	13	1	3
CG- Poor1	0-10	1.63	Clay	8.4	7.8	0	18	6.6	43	190	710	61	0.21	1.2	*	4.5	0.66	1.6	16	3.5	32	4.91	2	0.664	40	81	12	2	5
CG- Poor2	10-30	*	Clay	8.8	8.0	0	*	*	*	*	*	*	0.29	1.7	36	8.6	*	*	*	*	28.4	7.28	1.69	2.05	39	72	19	5	4
CG- Poor3	30-60	*	Clay	9.2	8.2	0	*	*	*	*	*	*	0.44	2.5	120	16	*	*	*	*	26.2	8.99	1.72	4.09	41	64	22	10	4
CG-Good1	0-10	1.29	Loam	7.3	6.8	0	3.2	6.3	39	36	320	12	0.10	1.0	*	1.1	0.69	2.1	16	2.9	8.52	1.18	0.782	0.109	11	80	11	1	7
CG-Good2	10-30	*	loam	8.2	7.6	0	*	*	*	*	*	*	0.13	1.8	5	1.3	*	*	*	*	12.1	2.17	0.781	0.195	15	79	14	1	5
CG-Good3	30-60	*	Clay	8.8	8.0	0	*	*	*	*	*	*	0.22	1.3	18	5.1	*	*	*	*	26	9.19	1.54	2.17	39	67	24	6	4
JH- Poor1	0-10	1.95	Clay loam	8.2	7.6	0	20	6.2	48	171	630	17	0.22	1.9	*	2.7	0.51	1.3	14	2	36	3.91	1.69	0.4	42	86	9	1	4
JH- Poor2	10-30	*	Clay loam	8.5	7.9	0	*	*	*	*	*	*	0.27	2.3	63	4	*	*	*	*	29.9	6.02	0.818	1.39	38	78	16	4	2
JH- Poor3	30-60	*	Clay loam	8.4	7.8	0	*	*	*	*	*	*	0.24	2.0	28	3	*	*	*	*	32	5.12	1.03	0.849	39	82	13	2	3
JH- Good1	0-10	2.46	Loam	6.9	6.6	0	4	6.5	52	102	350	23	0.32	3.0	*	1.4	0.76	1.1	97	3.6	14.3	2.09	0.764	0.273	17	82	12	2	4
JH- Good2	10-30	*	Clay loam	7.1	6.6	0	*	*	*	*	*	*	0.19	1.6	18	1.3	*	*	*	*	11.3	2.33	0.625	0.404	15	77	16	3	4
JH- Good3	30-60	*	Clay	7.6	7.2	0	*	*	*	*	*	*	0.28	1.6	16	1.5	*	*	*	*	17.1	3.23	0.456	0.668	22	80	15	3	2
JW- Poor1	0-10	1.61	Clay	8.5	7.9	0	16	11	65	189	590	27	0.24	1.4	*	6.3	0.5	3.8	16	2.8	29.7	7.16	1.62	1.42	40	74	18	4	4
JW- Poor2	10-30	*	Clay	9.2	8.3	0	*	*	*	*	*	*	0.51	2.9	160	16	*	*	*	*	25.9	11.1	1.36	4.68	43	60	26	11	3
JW- Poor3	30-60	*	Clay	9.5	8.7	0	*	*	*	*	*	*	0.99	5.8	310	33	*	*	*	*	20.2	16	1.44	10.5	48	42	33	22	3
JW- Good1	0-10	2.24	Loam	8.2	7.6	0	7.4	6.9	27	104	600	12	0.16	1.5	*	0.98	0.56	3	13	2.5	30.7	2.13	1.68	0.191	35	88	6	1	5
JW- Good2	10-30	*	Clay loam	8.3	7.6	0	*	*	*	*	*	*	0.16	1.4	14	2.2	*	*	*	*	33.3	2.71	0.869	0.333	37	90	7	1	2
JW- Good3	30-60	*	Clay loam	8.6	7.8	0	*	*	*	*	*	*	0.15	1.3	21	1.6	*	*	*	*	31.4	3.19	0.501	0.317	35	89	9	1	1
LS - Poor1	0-10	2.02	loam	5.3	4.4	9.5	2.6	5.3	32	85	130	15	0.06	0.8	*	1	0.41	1	200	2.8	3	0.859	0.343	0.11	5	61	17	2	7
LS - Poor2	10-30	*	Clay	7.0	6.8	0	*	*	*	*	*	*	0.24	1.4	23	1.8	*	*	*	*	9.55	3.27	0.495	0.281	14	70	24	2	4
LS - Poor3	30-60	*	Clay	7.1	6.6	0	*	*	*	*	*	*	0.17	1.0	34	2.8	*	*	*	*	4.75	5.09	0.517	0.684	11	43	46	6	5
LS - Good1	0-10	1.6	sand	6.3	5.6	0	33	11	36	40	140	37	0.13	3.0	*	0.67	0.55	1.7	120	1.9	5.11	0.582	0.346	0.129	6	83	9	2	6
LS - Good2	10-30	*	Sand	7.6	7.2	0	*	*	*	*	*	*	0.23	5.2	13	0.4	*	*	*	*	11.1	0.686	0.283	0.075	12	91	6	1	2
LS - Good3	30-60	*	Clay	8.0	7.2	0	*	*	*	*	*	*	0.17	1.0	29	1.7	*	*	*	*	5.87	2.94	0.66	0.276	10	60	30	3	7
LS -Very Good1	0-10	1.17	sand	6.6	5.8	0	6.1	6.6	61	91	28	11	0.05	1.0	*	0.46	0.56	0.82	170	1.3	4.15	0.472	0.11	0.184	5	84	10	4	2
LS -Very Good2	10-30	*	sand	7.5	7.1	0	*	*	*	*	*	*	0.29	6.6	29	0.81	*	*	*	*	5.8	1.04	0.153	0.243	7	80	14	3	2
LS -Very Good3	30-60	*	Clay	7.6	7.0	0	*	*	*	*	*	*	0.24	1.4	48	1.6	*	*	*	*	4.65	2.81	0.349	0.653	8	55	33	8	4

***Not analysed/or nil value**

Appendix 3. Plant tissue analysis results

Sample Name	NO3 (mg/kg)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)	S (%)	B (mg/kg)	Cu (mg/kg)	Zn (mg/kg	Mn (mg/kg)	Fe (mg/kg)	Al (mg/kg)	Mo (mg/kg)	Cl (%)
RC - Poor	1	3.73	0.49	2.29	0.842	0.21	0.25	0.16	23	7.6	79	110	130	120	0.78	0.45
RC - Good	1	2.22	0.23	1.63	0.684	0.17	0.75	0.13	18	3	33	33	99	69	0.31	1.4
SP- Poor	529	5.45	0.52	3.04	1.46	0.27	0.084	0.3	22	13	30	8.6	490	750	0.47	0.65
SP- Good	1	3.33	0.26	1.48	1.43	0.28	0.037	0.19	23	3.2	12	12	99	92	0.66	0.74
LS- Poor	1	3.41	0.18	2.38	1.22	0.33	0.19	0.2	27	6.8	47	62	240	470	0.63	0.51
LS-Good	1	3.83	0.17	2.28	1.1	0.38	0.18	0.16	22	4.3	55	130	130	170	0.37	0.83
CG- Poor	41	4.4	0.28	1.9	1.66	0.38	0.083	0.22	68	8	38	28	590	1000	1.8	0.42
CG- Good	86	3.57	0.29	2.5	0.614	0.25	0.038	0.16	24	4.9	36	34	95	83	0.87	0.49
JH - Poor	43	3.75	0.2	1.56	1.42	0.28	0.087	0.2	33	7.3	28	18	520	970	3	0.39
JH - Good	47	4.07	0.25	2	1.04	0.28	0.079	0.21	27	7.2	30	43	320	430	1.5	0.47
JW - Poor	1	4.22	0.24	1.57	1.53	0.35	0.23	0.21	57	6.6	30	21	450	720	0.63	0.74
JW - Good	126	3.28	0.21	2.37	0.835	0.22	0.055	0.19	17	5.4	20	17	89	80	1.2	0.46