FINAL REPORT 2018

For Public Release

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: Du1603

Project Title: Optimising the management of manure in southern cotton

Project Commencement Date: 1/07/2015 **Project Completion Date:** 30/9/2018

CRDC Research Program: 1 Farmers

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Part 3 – Final Report

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

Cotton is now a significant crop in the irrigated Riverina region of southern NSW, Australia, increasing in area from approximately 39,000 ha in 2013 to 90,050 ha in 2018 and contributing from between 10-30% of Australia's total cotton production (Cotton Info, 2018). Many cotton crops and processing facilities in the region (Whitton, Hay, Carathool) are located in close proximity (< 50 km) to chicken production (meat and eggs), which has also increased significantly in recent years. Around Griffith, NSW, it is estimated that poultry production is currently generating approximately 10,000 m^3/week of manure and chicken litter (raw manure + bedding material which is usually rice hulls or sawdust). There is quite significant variability in the nutrient content and dry matter mass of manures and wastes that are cleaned out of chicken sheds (Griffiths, 2007). However, considering average values of plant total nutrients as 2.9%N, 1.2% P, 2.8 % K and 60% dry matter, our estimates suggest that on an annual regional basis, there maybe 5400 tonnes of TN, 2246 tonnes of total P and 5200 tonnes of total K. These are sizeable amounts of nutrient resources which have the potential to be relatively easily reused for productive purposes in an economically attractive way for farmers. Coincidentally, this re-use may contribute to offsetting the amount of artificially produced fertilizers that are applied regionally, which offers positive environmental outcomes.

A significant number of growers (> 50%) are applying the available chicken wastes to their land, mainly with a view to maintain or enhance yield through the soil fertility benefits that organic amendments can offer (nutrient efficiency and biological and physical property maintenance and improvement). Typically application rates are between 2-5 t/ha, spread and surface incorporated early in the winter when field conditions are optimal and nutrient mineralisation and losses are minimised due to low microbial activity under relatively cold winter conditions. When temperatures start to increase in spring, mineralisation of nutrients and other physical and biological beneficial effects of manure amendments are considered to potentially become available from planting through the growing season and long term.

The organic materials are not usually applied to fields by growers as fertilizer replacements, rather, in addition to conventional fertilizers as there is a lack of adequate manure management recommendations for use in cotton production under different soil types and cropping systems. The usual rates of 2-5 t/ha of animal manure applied are convenience based rather than research based and can't be relied upon in high yield cotton systems without supplemental N and other nutrient fertilization. Application rates of chemical N and other fertilizers are determined from field tests, petiole tests and experience. However, there are few detailed studies on how amendments impact on soil processes and thus effect crop production (Flavel and Murphy, 2006). The productivity responses of cotton crops in major irrigated soil types of the Australian southern region to organic amendment types, rates and frequency and placement of application, alone or in combination with fertilizers is unknown. The nutritional value, extra profit and soil sustainability measures that the organic products provide in the short and long term compared with fertilizers are ambiguous and difficult to predict. One particular reason for this is that manures vary greatly in their composition and degree of stabilization. Chicken litter available N, P, K composition and moisture content can vary by 2-10 times from one batch to another (Griffiths, 2007, Azeez and Averbeke, 2010). To successfully manage nutrient cycling from chicken litter it is necessary to know their decomposition rate and the influence that may have on the biogeochemical processes in the soil to which they are being applied.

Overall, there is a large body of research that shows that application of organic amendments improves soil fertility (see reviews of Murphy, 2014, Macdonald and Baldock, 2010 and Krull, 2004). Soil organic matter affects water holding capacity, nutrient retention, cation exchange capacity, aggregate stability and buffering capacity to acidification. It has a clear effect on nutrient supply, nutrient cycling, soil strength and compaction, water infiltration and gaseous exchange. A number of studies have reported the positive effect of soil organic carbon on cereal, potato, corn and rice in tropical and sub-tropics, Russia, China, Argentina (Johnston et al, 2009, Lal, 2010, Chen et al 2018). However, there are now several reputable publications detailing rigorous meta-analysis of well-known long term crop trials that conclude, on average there are insignificant increases in yield which can be attributed to organic inputs (Edmeades, 2003; Oelofse et al, 2014; Hijbeek et al 2017). The major finding that came out of the original work of Rothamstead was that organic fertilizers gave the same yield as farmyard manure, not that synthetic fertilizers were necessarily better than organics or vice versa (Johnston and Poulton, 2018). Johnston et al (2015) has countered some of the misconceptions surrounding the effects of SOM by finding that as crop cultivars with increased yield potential have been introduced, yields in many Rothamstead long term experiments are now larger on soils with more SOM. In contrast, Oelofse et al (2014), argues that the evidence from a lot of published organic amendment trials is quite variable and obtained from one location and therefore generalisations are difficult. In many studies, the analyses are dependent on, or fail to account for other factors that can affect yield such as the mineralizable C fraction, soil fertility status and managerial inputs such as nutrients and water (Lal, 2010).

Favourable agronomic, profit and soil conditioning effects for poultry litter application in cotton production have been documented within 3-5 years, in Alabama and Mississippi on silt loam soils (Reddy et al 2007; Tewolde et al, 2007; Tewolde et al 2016) and degraded upland soils in Louisiana (Lofton et al 2014). In other studies, the benefit of poultry litter to cotton production was stated as far exceeding the nutrient concentrations through soil conditioning (Tewolde et al 2010). Mitchell and Tu (2005) found broiler litter increased cotton yield in both no till and conventional till over a 13 year period in silty clay loam non-irrigated soils and residual effects in the year after application were found to be beneficial to yield. Fertilizer replacement value of manure is affected by a number of factors including the form of nutrients, organo-metallic complexes, in the amendment, soil type and pH, crop type, application method, timing and manuring history (Jensen, 2013). It is well known that organic amendments including chicken litter cannot be depended on in commercial situations as a soul source of crop nutrients, even when applied at high rates due to nutrient imbalances and asynchronic release of nutrients that do not match plant requirements. Supplementary synthetic fertilizers are necessary in commercial food and fibre crops but little systematic research has been undertaken to evaluate the fertilizer replacement value of organic amendments and any improvements in nutrient use efficiency they may offer.

The current project has aimed at more thoroughly establishing how to optimise the management and application of manure that is available in the southern cotton growing region for tangible productivity and nutrient use efficiency benefits. Field experiments have focussed on incorporating the use of chicken manure and litter into farmer agronomic practise and specific site issues. One focus has been on the fertilizer replacement value of the organic wastes when used in combination with chemical fertilizers for N, P and micronutrients Zn, Mn and Cu. A second focus has been on the effects that supplementary chicken litter or manure application may have to rectify productivity and nutrient deficiencies in newly developed land formed fields where 'cuts' can have a significant effect on productivity for several years.

Replicated cotton field trials on two soil types, red and grey chromosols with a range of chicken manure and litter amendment rates, have been established to evaluate productivity, nitrogen efficiency and macro and micro-nutrient uptake. The trials have been used to assess crop responses, examine the contributions and availability of important nutrients other than nitrogen (P, K, S, Zn, Cu) water stable aggregates and any negative or inconsequential impacts according to manure rate treatments. The work has provided regionally specific information which can be used to refine existing general manure management guidelines developed for broad acre cereals. These may assist cotton growers in the Murrumbidgee Valley to better estimate how manure may be applied to reduce synthetic fertilizer inputs without compromising yield and quality outcomes.

Objectives

2. List the project objectives and the extent to which these have been achieved, with reference to the Milestones and Performance indicators.

2.1. Estimate the balance and availability of nitrogen in manure sourced from livestock production in the Murrumbidgee and Lachlan Valleys.

For this objective, the project has mainly focussed on the balance and availability of nitrogen in poultry manure and litter for the region around Griffith as this was determined to be the major and increasing source of waste organics in the Murrumbidgee Valley. The resource is concentrated in a fairly small area close to gins and where it was common for growers to be applying these wastes. Direct access to manure production data from the major poultry producers in the region has not been possible and so project information is based on figures obtained from agricultural re-sellers that are distributing the materials.

Local and regional use of manure has been reviewed through project steering meetings held annually and other conversations with growers and the industry and through literature review.

The project has thoroughly documented the variability in composition of different organic waste resources in the region including cattle manure, pig manure, poultry manure, poultry litter and cotton gin trash. These have been obtained through literature review and project sampling and analysis. The losses of nitrogen from manure piles stored on farm for different times (fresh vs aged) have been investigated. During field spreading operations measurements indicated that nitrogen losses from raw poultry manure between delivery from sheds, to on site, to 7 days after field application (a total of 37 days) were minor, likely caused by TN mainly being in the form of organic N (uric acid and urea) with only trace levels of nitrate. Ammonium-N losses of only 1.3% occurred during spreading likely due to pH remaining mildly acidic which prevents volatilisation. Following spreading and incorporation weather conditions were warm and dried the material which also tends to 'fix' organic derived nutrients and reduces losses.

2.2. Conduct on-farm field trials to test different manure application strategies (including potentially cotton gin trash compost/manure mixes) for crop response and nutrient availability.

The project has been able to establish trial sites either at small plot size or on commercial scale to test crop and soil responses in the following scenarios:
Combinations of urea:chicken manure – Whitton 2015/16 and 2017/18 2018/19
Placement of manure: banding vs incorporation – Deakin Research Station 2016/17 and 2017/18
Combinations of chicken manure:urea on cut and no cut areas in land formed fields – Widgelli 2017/18 and 2018/19

A major project drawback occurred in 2016/17 (mid year of the project), when cotton was not grown at the Whitton commercial field site nor a new site planned on farm at Widgelli. As a contingency the small plot trial was established at the Deakin Research Station. In 2017/18 the Whitton field site came under new management and a direct follow on of the 2016/17 trial was not possible. A new trial was established but was off-set spatially from the 2015/16 trial due to different machinery and practises. This has led to each manure application strategy in the commercial situations in the project only being tested for 1 year and 2 years for the research station trial. Generally, although there has been significant differences with control plots, there has been a lack of strong yield responses in each of the sites which has led to limited understanding of how manure:chemical fertilizer combinations affect productivity after a single year. At the Whitton site, yields maximised at 209 kg N/ha derived from a combination of pre-plant DAP, anhydrous ammonia and 2t/ha chicken manure but there were insignificant differences between this and higher rates supplemented with 4 t/ha manure up to 370 kg N/ha. No significant differences were observed in any treatment from N being supplied by top dressing urea compared without. Additional urea-N applied as top dressing made insignificant difference to any of the productivity measures and in fact for yield and NUE caused significant decline. The plant growth parameters, N uptake and macro and micro nutrient uptake tended to maximise when the total amount of N applied was 240 kg N ha^{-1} which included 4 t/ha of chicken manure in combination with 177 kg ha^{-1} of chemical fertilizer, all pre-sown. At this stage it is difficult to ascribe the manure was a critical factor in causing this maxima. In the 177 kg N/ha + 4 t/ha treatment manure treatment, nitrate and Colwell-P values throughout the season tended to be elevated but other soil parameters such as soil dispersion, water retention and potential N mineralisation were unaffected.

Post-harvest mineral N, Colwell P and major cations trended upwards compared with pre-trial baseline soil, with significant ($p \leq 0.05$) increases in treatments supplemented with 4t/ha. ECEC, TN and TOC, bulk density and dispersion showed insignificant change within the period and pH declined in all but the highest rate of manure. There was a significant ($p \leq 0.05$) increase in post-harvest nitrate in the treatment that had received the highest amount of applied N (370 kgN/ha).

At the Deakin University small plot research trial, there was no significant ($p \leq 0.05$) improvement in yield performance when litter was applied by sub-surface banding compared with equivalent broadcast rates after one year of application generally caused by this fertile site being non-responsive. The minor insignificant positive yield response was obtained from broadcast compared with sub-surface banded treatments and suggested that banded treatment litter rates would need to be increased by up to 40% to equal the performance of broadcast and incorporated litter. The Deakin research trial facilitated Deakin PhD candidate, Ms Anika Molesworth who is currently continuing to write up the results of the second year of data which will be reported in the second phase of the research.

At the Widgelli site at high rates (14 and 22t/ha) chicken manure treatments significantly (≤ 0.05) increased vegetative growth compared with fertilizer alone or urea:chicken manure combinations but substituting mineral fertilizer with CM did not increase yield or cotton productivity after one year.

There was no significant increase ($p \leq 0.05$) in yield between the different fertilizer treatments including the control, according to cuts or interaction between the two factors suggesting a non-responsive site to N. The insignificant trends according to cut indicated the area that had not been cut had the highest yield and the area of heaviest cut had the lowest yield despite top soiling. The interaction of the two factors indicated that the lowest yield was obtained using only mineral fertilizer in the heavily cut area and the highest yield was recorded using 100% manure in the area that had not received cuts.

Notwithstanding the limitations of non-responsive sites, the project has developed a comprehensive database of cotton plant growth and yield, nutrient uptake (macro and trace nutrients in plants, bolls and seeds), soil nutrient depletion information for crops and soils typical of the Murrumbidgee Valley in situations comparing chemical only fertilizer application with chemical fertilizer supplemented with poultry industry organic wastes. The project has identified the relevance and importance of the need for better understanding of manure application in landformed fields which will be continued and refined in the next work phase.

2.3.Nutrient release and decomposition of chicken litter in soil

The project field trials have facilitated a Deakin University PhD candidate, Ms Anika Molesworth's research has involved project work that included an in situ litter bag experiment to determine chicken litter decomposition and nutrient release rates in two soil types: Hanwood Loam and Griffith clay loam. Small bags of chicken litter in combination with different ratios of urea fertilizer were buried to 10 cm in contrasting soil types at Widgelli and the Hanwood research station and excavated around three cotton crop irrigation events over a period of 70 and 50 days. The main results indicated that the decomposition of chicken litter in soil occurs through a two stage process involving a fast phase where approximately 35% was lost over 27 days followed by a slower phase whereby a further 3-10% was lost over 20-40 days. Half-lives for dry matter of approximately 450 days were calculated for the Hanwood loam and 333 days for the Griffith clay loam There was no obvious chicken manure:urea treatment effect and soil type had a stronger influence on decomposition rates than the fertilizer source ratio. Half-lives (the amount of time it takes for half of the original concentration to be released) for nitrate, ammonium and available P were 4, 21 and 72 days respectively in Hanwood loam and 27, 23 days and a growth rather than decay for P for the clay loam. The data indicate that year on year application of chicken manure would lead to an overall increase over time of dry matter with the effect being more substantial in the lighter soil type. Mineral-N in both soil types is lost rapidly, within 4-6 weeks of application suggesting little value for crop N nutrition when manure is applied in winter. The different soil types affected P release from the chicken litter quite differently. In the Hanwood loam, P release continued to occur for 140 days and therefore may act as a form of slow release. However, if application occurred in mid-winter, the duration of release may be within the cotton season until end of February, around early maturity. Unexpectedly, available P tended to show a growth relationship in the buried chicken litter in the Griffith clay loam rather than decay. Available phosphorus increase between post plant and first flower soil samplings was also a consistent feature observed in the main field trial and suggests remineralisation of organic P or accumulation of loosely held available P on organic and/or clay surfaces.

2.4. Evaluation of tests to determine the value of soil quality improvement.

In the first year of the project the evaluation of tests was begun with data collection on Solvita testing for amino-nitrogen as an indicator of soil quality improvement. Subsequently this activity was not progressed as the steering committees and feedback from R&D updates deemed this of less importance than research to determine the decomposition of chicken litter and the timing of available nutrient release.

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

The research component of the project has been focussed on field research using both small plots and commercial scale strips.

Field experiments were established at sites on commercial farms under flood irrigation in the Murrumbidgee Valley, at Whitton and Widgelli near Griffith, NSW. A small plot trial site was established at the Deakin University site in Hanwood in the 2016-17 season when commercial sites were not planted due to extremely wet winter and spring conditions. The sites explored the following: i) the productivity and nutrient use efficiency of cotton in response to combinations of poultry litter/poultry manure:urea application rates compared with manure alone and

chemical fertilizer alone. ii) the productivity and soil quality benefits of using chicken manure:urea combinations in 'cut' field areas. iii) the interaction between productivity and manure placement (banding vs. mixed into soil with tillage). Data collection and analysis of all the sites is still ongoing to obtain satisfactory multi-year datasets and so the studies reported here are the most developed data. The datasets will be reported in their entirety in the next phase of the manure management in southern cotton, Project DU1903.
The sampling and analytical methods used were as described in Australian Standard (AS 4454) or using modified soil analysis standard methods (Rayment and Lyons, 2011) mainly conducted by commercial laboratories such as Incitec Pivot or Environmental Analysis Lab, Southern Cross University.
The potential mineralisation and nutrient release of C, N, P and Zn availability to irrigated cotton in two soil types amended with chicken litter and urea under field conditions has been investigated using an in-field incubation using a litter bag technique described by Chami et al (2016). One site was located within the cotton research trial site at the Centre for Regional and Rural Futures (CeRRF), Deakin University at Hanwood, NSW (34 .19°S; 146.04°E). A second site was located approximately 10 km further East at Widgelli, NSW (34.20 °S; 146.1°E). Throughout the experimental period, daily temperatures, humidity and precipitation were considered to be the same, measured by an Australian Bureau of Meteorology standard weather station located on-site at Hanwood (Figure 1 1).

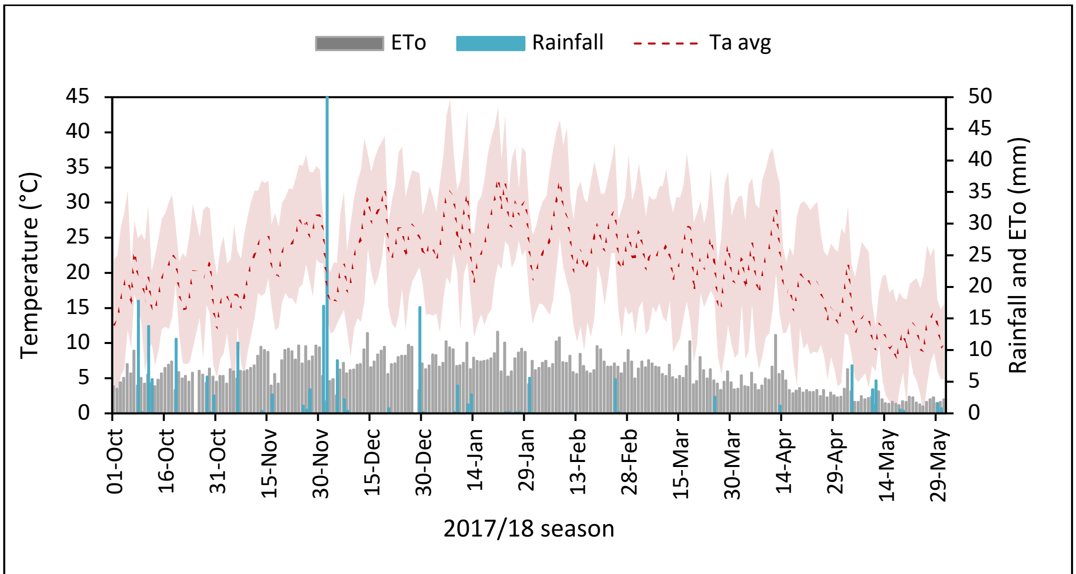


Figure 1 1 Meteorological conditions for 2017/18 summer cropping season.

Litterbags were made from organza nets with 0.5 mm mesh size, and were between 156–520 cm^2. A total of 288 litterbags (144 at each field site) were filled with three differing combinations of manure and mineral fertiliser; 30:70; 70:30 and 100:0 aimed to achieve a target N rate of 250 available N/kg/ha. The equivalent total mass of material in each litterbag was between 13–20 g. The manure was spread thinly inside the bag to maximize contact between the incubated material, urea and soil particles outside the bag, and buried to a depth of 10 cm. The litterbags were laid 60 cm apart in a row on a raised bed in an unplanted area surrounded by a cotton crop, in a randomised complete block design. Excavation of the litterbags occurred around three irrigation events of the surrounding cotton crops at pre-watering and then 1, 2 and 3 days after watering over a 50 day period at the Hanwood loam site and a 70 day period at Widgelli clay loam site. At each excavation event four replications from each treatment were excavated at each field site. Gravimetric soil moisture content (%) of soil close to the litterbag placement was determined by taking two 0–15 cm soil cores at

the site when sampling the litterbags. These cores were combined to make a composite sample, which was then oven-dried at 105°C until the weight remained constant.
Previous soil nutrient studies in Hanwood cotton fields applied with PL have shown that in the first 20 days of PL application there is a great change in soil mineral N and P availability. From 20 days onwards, there is a slower gradient of change. This research corresponds to studies by Pitta et al. (2012), who likewise reported the highly-labile component of N and P having a half-life of 9.70 and 8.14 days respectively. This is followed by a slower rate of nutrient release by a more recalcitrant compartment of the litter.
In modelling decomposition, expressions are desired that are realistic in terms of both mathematical and biological behaviour. Due to limited observation points, calculation was made to estimate the percentage change between day 0 and the first extraction, 25 days after incubation (DAI) on the loam at 27 DAI at clay loam. A single exponential model was then used from first extraction to last extraction (50 DAI on the loam and 70 DAI on the clay loam), with the following equation recommended by Wieder and Lang (1982):
$y=A_0e^{kt}$
Where A_0 is equal to the value at time zero, *e* is Euler's constant, and *k* is a positive or negative constant that determines the rate of growth or decay per day, and *t* is time.

The exponential decay function was used to estimate half-life ($N(t) = N_0\left(\frac{1}{2}\right)^{\frac{t}{t_{\frac{1}{2}}}}$ where N_0 is initial quantity and N_t is the remaining quantity after time, t).
Nutrient release and decomposition were averaged by treatments recordings for statistical analysis. All data were analysed using SPSS software (SPSS 24, SPSS Inc., Chicago, USA). Analysis of variation (ANOVA) tests were conducted to assess the significance of the treatment effects, followed with a post-hoc Tukey Test to determine which specific group's means (compared with each other) were different using a significance level of 0.05.
Better understanding of nitrogen uptake using drone acquired imagery has been a significant activity of the project as the manure amendment field trials provided an ideal opportunity to acquire drone spectral data to determine N uptake at different N application rates at a commercial scale.
Drone (UAV) images were collected using a DJI Inspire drone flying at approximately 100m above ground level. The sensing camera consisted of a micasense multi spectral camera collecting images in the green, blue, red, near infrared and red edge bandwidths. These aerial surveys were undertaken in a grid based pattern using drone automation software (drone deploy) which resulted in approximately 3500 images of the field. These were then processed using orthomosaic software into a single high resolution image of the field giving band data of approximately 5cm resolution on ground which was used to create the NDVI and NDRE maps.

Field Sites
Irrigation Research and Extension Committee (IREC), Stott Road, Whitton.

The productivity and nutrient use efficiency of cotton in response to combinations of poultry litter/poultry manure:urea application rates compared with manure alone and chemical fertilizer alone.

2015-16
Replicated commercial scale field experiments were established in September, 2015 and separately in September 2017 at the Whitton Field Site, NSW (146°18'E, 35°54'S) in collaboration with CRDC, the Irrigation Research and Extension Committee (IREC) and Cotton Seed Distributors (CSD). The land (30 ha), was laser levelled and an automated (Rubikon) bankless channel irrigation layout was installed in winter

2015, comprising 6 roll over blocks with flat terraces. Prior to trial establishment, cut and fill maps were considered and the site was EM 38 surveyed to assess site uniformity (Figure 1 1).

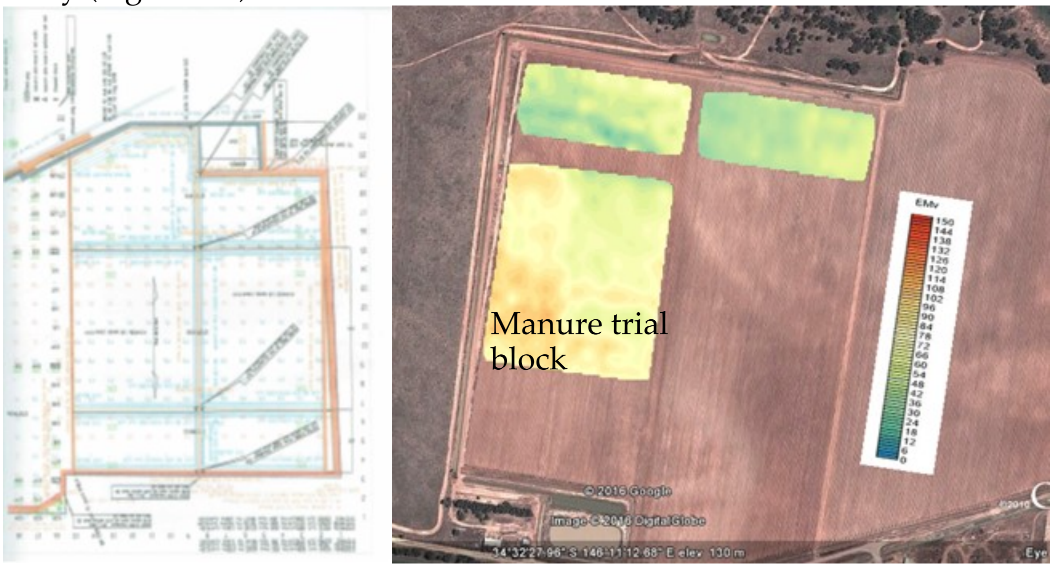


Figure 1 Whitton, NSW field trial site 2015-16

Fertilization treatments based on organic fertilizers (poultry manure), pre-plant inorganic fertilizers [diammonium phosphate (DAP), anhydrous ammonia (NH_3-N) and top dressed urea or both were applied to give the equivalent of 0, 130, 177, 209, 240, 307, 339 and 370 kg N/ha (Table 1). The manure available N was calculated according to the method of Bitzer and Sims (1988) using the manure TN%, dry mass, mineral-N (NO_3-N+NH_4-N) and assuming 50% of the organic N was mineralised in the first year:

Available manure N/kg = ((TN/100 x 1000) - mineral N) x 0.5)) + mineral-N

The farm was sown on October 14th, 2015 with the cotton variety Sicot 74BRF. Due to the weather conditions experienced during winter and spring in 2015, manure was spread and incorporated into the soil in the respective treatments later than usual, at only 2 weeks before seeding at rates of either 2 t/ha (treatments NM-209 and NM-339) or 4 t/ha (treatments NM-240 and NM-370). Pre-planting inorganic fertilizer was also applied two weeks before seeding as DAP and anhydrous NH_3-N in all the treatments with the exception of N-130, where N was only applied as top dressed Urea on December 10th, and the control treatment (N-0), where fertilization was not applied (Table 1).

Table 1 Total nitrogen (N) applied to each treatment and contribution and date of application of the four fertilizer products used in the Whitton 2015 trial: poultry manure, diammonium phosphate (DAP), anhydrous ammonia (NH_3-N) and urea. The number of replicates used for each treatment are also indicated.

Treatment	DAP 23-09-2015	NH_3N 23-09-2015	Poultry manure 23-09-2015	Urea 10-12-2015	N Ratio Fert:PM	Total N applied (kg/ha)	Replicates
N-0	0	0	0	0	-	0	3
N-130	0	0	0	130	-	130	3
N-177	27	150	0	0	100:0	177	4
NM-207	27	150	31.5	0	10:1	207	4
NM-240	27	150	63	0	5:1	240	4
N-307	27	150	0	130	100:0	307	4
NM-339	27	150	31.5	130	46:1	339	4
NM-370	27	150	63	130	9:1	370	4

In all the cases, treatments were replicated 3-4 times with each replicate consisting of 3-9 beds of either 100 m or 200 m length.

The soil type is known as a transitional red brown earth (Chromosol), locally known as a Mundiwa Clay Loam. The undisturbed profile has a 15 cm sandy clay loam A horizon over a dense clay B horizon. Soil and manure properties properties are shown in Table 2.

Table 2 Pre-trial soil and manure chemical characteristics at Whitton, 2015.

Depth	Soil type	pH $CaCl_2$	EC (dS/m)	Colwell-P mg/kg	NO_3-N mg/kg	NH_4-N mg/kg	TC (%)	BD (g/cm^3)
	Clay Loam							
0-30		7.7	0.16	21.2	1.6	3.9	0.8	1.2
30-60		8.9	0.31	6.0	2.5	2.6	1.1	1.5
60-90		8.9	0.53	27.9	1.4	1.7	1.1	1.5
	Manure	Dry Matter (%)	TN%	P (%)	K (%)	Ca (%)	Zn (mg/kg)	Cu (mg/kg)
		62	5.1	1.4	2.4	10.6	414	56

In crop measurements and sampling was completed in accordance with standard protocols.
Specific activities included:

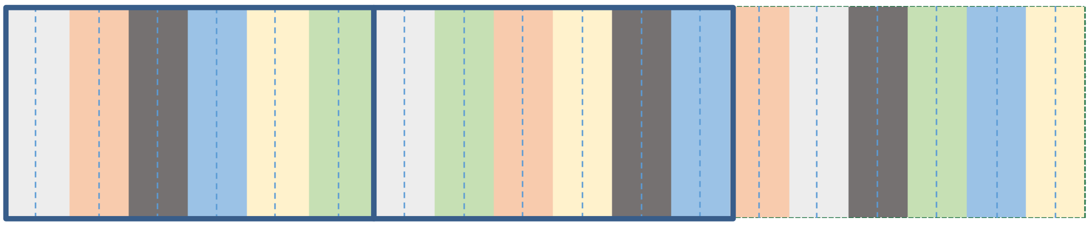
- Soil sampling (0-30) to determine starting and ending soil nutrition status, soil biological activity and biomass and physical properties including, bulk density, water stable aggregates and dispersion.
- Plant establishment counts
- Plant growth measurement characteristics
- Petiole sampling for plant N status
- Total biomass for nutrient uptake.
- Fruit mapping and seed nutrient uptake and export
- Yield – hand picking and commercial pick.

2017-18

The replicated field experiment established in 2017 comprised 6 treatments replicated 3 times in a randomised blocked design in the same mid-west section of the IREC field station as in 2015 but spatially offset compared to the previous trial The layout and N application regime is shown in Table 3 and Figure 2.

Table 3 Type and availability rate of fertilizers used in the experiment.

Treatment	Soil-N 0-30 cm (kg/ha)	Pre-plant urea N (kg/ha)	Granulok-N (kg N/ha)	Manure available N (kg N/ha)	Top dressed urea-N (kg N/ha)	Total available applied-N (kg N/ha)
0N+P	70	0	15.4	0	0	15.4
N+P (180)	70	92	15.4	0	69	176
N+P (150)	70	92	15.4	0	46	153
N+P +4t/ha	70	92	15.4	53	46	207
N+P 8t/ha	70	92	15.4	106	46	259
16t/ha	70	0	15.4	213	0	228



216 m

Figure 2 Layout of RCBD field trial at IREC field station Whitton in 2017-18. Each treatment plot comprised 6 x 2m beds with 12 rows of cotton/treatment.

Manure was applied on the 25th August, 2017 using tractor and muck spreader which was calibrated prior to spreading using a density measured on site of 360 kg/m^3. Pre-planting inorganic fertilizer was applied on the 4th September inside and outside plant line banded at 3-20 cm depth. The crop was planted on October 13th, 2017 with the cotton variety Sicot 743BRF. The first irrigation occurred on the 14th October. First flower occurred on the 3rd January, 2018 when biomass was sampled and at first defoliation on the 28th March, 2018. The crop was hand-picked for maturity assessment on the 9th and 20th March and the 19th April, 2018 and classed for quality and turn out using a hand gin. The crop was commercially harvested on the 20th April, 2018, each module was weighed using a weigh trailer and commercial ginning determined average turn out for the field.

Soil sampling 0-30 cm was undertaken at planting, first flower and post-harvest in each treatment plot.

Final results from the Whitton 2017 trial will be reported in the follow on project DU1903 after 2 years of continuous data collection.

Amberley Farms Inc., Widgelli, 2017/18
The productivity and soil nutrient release and quality benefits of using chicken manure:urea combinations in 'cut' field areas.

A replicated field experiment were established in June, 2017 at Widgelli, NSW Australia (34.20 °S; 146.1°E) at 'Yarran Park' in collaboration with Amberley Farms Inc. The trial followed a crop of wheat and long fallow and then newly developed for cotton. The soil is classified as a Chromosol, locally known as a Griffith clay loam. Cut and fill maps were utilised to determine a comparative small plot trial within a commercial field comprising a high cut (17 cm) a low cut (4cm) and no cut (0cm) areas. The soil properties for each area are shown in

Table 4

Table 4 ***Soil characteristics in the different cut areas at the Widgelli field site, 2017***

	NO CUT	LIGHT CUT	HEAVY CUT
pH	7.8	7.5	9.1
EC (dS/m)	0.09	0.09	0.13
ESP	3.2	2.4	6.9
WHC %	57	52	58
Colwell-P mg/kg	27	34	12
Mineral-N mg/kg	10	21	0.13
Colwell-K mg/kg	720	735	590

The trial layout is shown in Figure 3. It consisted of 5 treatments (Table 5) replicated 3 times in a complete randomised design on each soil cut area. Each plot was 10 m long x 4x 36" hills.
The area of each plot was 36.4 m^2

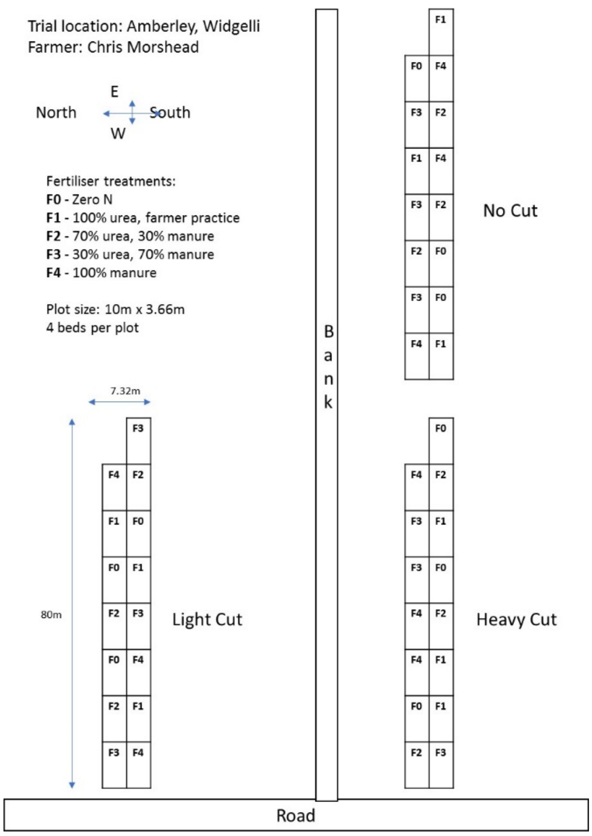


Figure 3 ***Trial Layout in 2017-18 at Widgelli, NSW in cotton.***

Table 5 ***Source and rate of fertilizers applied to meet a total N application of 250 kg N/ha. MF = mineral fertilizer. CM = Chicken manure***

Treatment	CM (kg/ha)	Urea broadcast pre-plant (kg/ha)	Soygran Super-P mix 50:50 (kg/ha)	Urea broadcast top dressed (kg/ha)
Control Zero	0	0	0	0
100:0 MF-CM	0	360	371	182
70:30 MF-CM	6592	252	0	127
30:70 MF-CM	13186	108	0	55
0:100 MF-CM	21976	0	0	0

.

The application of fertilizers and organic amendment is shown in Table 5 and the chemical properties of the chicken manure in Table 6

Table 6 ***Composition of the chicken manure applied to the trial at Widgelli, 2017***

Chicken manure (layers)

pH		6.6
TC	%	34
TN	%	5.1
Nitrate-N	(mg/kg)	<50
Ammonium-N	(mg/kg)	3900
Phosphorous	(mg/kg)	4200
Potassium	(mg/kg)	20000
Manganese	(mg/kg)	12
Zinc	(mg/kg)	20
Iron	(mg/kg)	55
Copper	(mg/kg)	15
Dry matter	%	45.8

Data Analysis

Statistical analysis was conducted using SPSS v. 24.0 (IBM Corp., Armonk, NY, USA). Mean values of dry mass, nutrient uptake and lint yield for each treatment were compared by means of a multiple comparison analysis using the Tukey's Honest Significant Difference test at a significance level of 0.05.

Results

4. Detail and discuss the results for each objective including the statistical analysis of results.

4.1. Estimate the balance and availability of nitrogen in manure sourced from livestock production in the Murrumbidgee Valley.

Overall, in the Murrumbidgee Irrigation Area (MIA), poultry manure and litter is the most readily available, particularly around Griffith, NSW. There is a consistent supply of about 250 m^3/week of raw manure, but this constitutes a relatively small amount compared with poultry litter which includes rice hulls or wood shavings. The poultry industry is rapidly expanding in the Riverina and it is estimated that poultry litter production will be at 10000 m^3/week when all new chicken sheds are complete from April, 2017 (more than double 2016 production, Table 7). Bulk density, determined on 10 samples of freshly delivered raw manure at Whitton in 2015 was 560 kg/m^3 (±0.04) and on piles of poultry litter at farms near Griffith was 381 kg/m^3 (± 0.01). A typical application rate currently for manure is 2-4 t/ha, indicating that the approximate land area that may be able to receive manure application would be up to approximately 50 000 ha from 2017.

Table 7 Estimate of volumes of chicken litter and chicken manure in the vicinity of Griffith, NSW, bulk density of the products, approximate costs and the potential area of crop land in the region that chicken waste application could cover at typical spreading rates. Source: Yenda Producers (pers. comm).

Poultry manure	Volume (m^3/week)	Wet Bulk density (kg/m^3)	Annual Mass (tonnes)	Freight (\$/m^3)	Manure cost (\$/m^3)	Approximate land area for 4 t/ha
Raw manure	250	560	7280	5-6	7-10	1820
Poultry litter (2016)	4,000	381	79248	5-6	6	19812
Poultry litter (2017)	10,000	381	198120	5-6	10	49530

As an example of the economic value of manure, from composition in Table 8, the available N (ammonium-N+ 50% of organic N) in raw chicken manure may be estimated as approximately 30.5 kg/dry tonne. Bulk density was measured as 560kg/m^3 wet wt/v, dry weight is 55.2%; total available N of wet wt is 16.8kg/t. Freight is approximately \$15/m^3 wet weight and so manure available N is valued at ~ \$1.99/kg. This compares with current urea-N prices of ~\$1/kg. The P in manure may be estimated as ~ 2.3 kg/m^3, therefore P is approximately \$6.5/kg compared with approximately \$3.52/kg for P in generic DAP (http://fertsmart.dairyingfortomorrow.com.au/).
Chicken manure contains significant amounts of potassium (approximately 20 kg/tonne) and it is considered that most of it becomes available within the first year. The irrigated soil types of the Riverine Plain are naturally loaded with available K and so K in manure has not usually factored in as an economic consideration, although views may be changing in most recent times on the availability of K. Therefore, in the direct financial assessment of nutrient value, manure is relatively expensive compared with inorganic fertilizers. The critical question is what added value does it provide in terms of increasing fertility in the longer term through other benefits such as physical biological and other chemical attributes that can overcome soil constraints and provide soil resilience for multi-year intensive cropping systems?

Table 8 ***The composition of fresh and aged manure stockpiles sampled from 5 farms and comprising 3 different manure types: poultry manure, poultry litter, pig manure and a cotton trash compost (Source: Southern Cotton) were determined.***

Analysis	Units	Fresh Poultry manure delivered	Poultry Manure Pre-spreading	Poultry litter	Aged poultry litter	Windrowed Pig:poultry litter	Cotton gin trash compost
pH		6.38	6.5	7.3 - 7.6	5.9	7.8	8.3
EC	dS/m	13.38	11.9	7.4/8.6	6.0	5.5	4.5
Chloride	%	0.5	0.5	0.2-0.9	0.14	0.2	
TC	%	35	33.3	30.4-32.4	30	14.5	14.6
C/N		7.3	6	10-14.6	11	6.4	9.6
DM	%	54.32	61.6	71.4-84.3	58.6	78.3	
		Total Nutrients/ Water Soluble Nutrients					
TN	%	4.8	5.3	2.1-3.3	2.8	2.3	1.52
Nitrate	mg/kg	<50	51	57.4-628	2700	55	
Ammonium	mg/kg	8920	8000	3960-8700	4200	5550	
Phosphorous	mg/kg	14000	16000	8780-14000	0.4	2.6	0.4%
Available-P		3740	3800	2260-3640	0.15	0.14	
Potassium	mg/kg	24000 19600	23000 18000	16200-18600	4000 15000	11000 5400	1.99%

Available-K	mg/kg	24000	23000	12600-13600	4000	11000	1.99%
Sulphur	mg/kg	19600	18000	5000-5420	15000	5400	0.2%
Available S	mg/kg	6980	7366	2860-3140	4000	6000	0.2%
					900	2500	4.1%
Calcium	mg/kg	106800	101333		14000	88000	
Available Ca	mg/kg	3360	2433	418-688	2000	400	4.1%
		5840	5633	4880-5720	2000	6000	0.72%
Magnesium	mg/kg	2100	1800		600	300	
Available Mg	mg/kg	5840	5633	568-640	2000	6000	0.72%
Sodium	mg/kg	2100	1800	2000-5280	600	300	0.07%
		4800			2000	2000	
					1500	1100	
Available Na	mg/kg	4800	4866	1580-4140	2000	2000	0.07%
Copper	mg/kg	4200	4233	52.2-132	1500	1100	16%
		56	57		140	485	
		15.8	17		2.7	36	
Available Cu	mg/kg	56	57	10.5-29	140	485	16%
Zinc	mg/kg	15.8	17	322-426	2.7	36	40
		414	427	15.5-36.8	450	1450	
		20.4	18		3	14	
Available Zn	mg/kg	414	427	322-426	450	1450	40
Iron	mg/kg	20.4	18	15.5-36.8	3	14	13987
		1052	2500	2080-4860	9400	16000	
		55.4	65		24	150	
Available Fe	mg/kg	1052	2500	52.5-70.2	9400	16000	13987
Manganese	mg/kg	55.4	65	476-57	24	150	286
		460	457	6 8.7-26	540	800	
		18	13		23	5.3	
Available Mn	mg/kg	460	457	476-57	540	800	286
	mg/kg	18	13	6 8.7-26	23	5.3	82
		31	28	15-33.8	17	20	
		20.4	18		5.3	4.8	

The process for considering the use of manures and calculating the loading of different nutrients associated with applying manure is well laid out in Primefact 1008 (NSWDPI, Dorahy et al, 2010). However, the calculation used for the estimation of different applied nutrients is usually only a rule of thumb as there is inherent variability in each load of manure and assumptions have to be made on the nutrient losses from the system during storage, handling and field application and the availability of nutrients in the first and subsequent years after application.

At best, for management recommendations and nutrient budgeting, it seems that other than sampling and analysing manure piles on farm for the particular application year, a range of nutrient availability must be accepted, based on manure surveys as in Table 8.

A summary of different manures is provided in Table 9 and a comparison available from previous literature sources are provided in Table 10.

Table 9 ***Summary of manure composition and amounts that are applied in kg/ha or g/ha (Zn and Cu) when one tonne of dried manure is applied to land. The available nutrients are a conservative estimate of what may be available in the first year of application as any available nutrients that are mineralised from organic matter are not included in this estimate. The values are those provided as 'available' in a standard Incitec Pivot Analysis report***

Analysis	Layer Manure	Poultry Litter	Piggery / Poultry	Feedlot
pH	6.5	7.4	7.8	7
C:N ratio	6	30	15	8

Moisture	40-48	30	22	20-54
Total N Mineral-N	51 9	30 4-9	23 5	21 4
Total P Available P	14 4	11-13 3	26 2	7 4
Total K Available K	23-26 18-20	28 18	11 5	26
Total S Available S	7 5	5 3	6 2.5	6
Total Zn Available Zn	0.4 0.02	0.3-0.4 0.02	1.5 0.01	0.2-0.7 0.08
Total Cu Available Cu	0.05 0.02	0.05-1 0.01-0.03	0.5 0.02	0.05 0.001

Table 10 ***Comparison of previously published nutrient composition of manures sourced locally around Griffith or regionally in NSW***

Analysis	Poultry* litter – rice hulls		Fresh poultry** litter	Poultry*** manure	Cattle Feedlot ****	Piggery
pH_w	6.0	6.7	5.8 -8.1	7.8	7	7.3
EC (dS/m)	5.9	10.03	6.8-16	7.5	7-12.4	7.6
Dry matter (%)	81	56.4	64-79	59	45-80	5.1
C (%)	33.9	31	29-36	33	11-44	65
N (%)	4.57	3.8	2.6-5	5.8	2.1	1.6
P (%)	1.2	1.3	1.2-2.6	2.2	0.71	0.7
K (%)	2.1	3.2	1.0-2.8	1.68	2.6	1
Ca (%)	2.25	2.0	1.6-4.4	9.2	1.8	0.9
Na (%)	0.35	0.39	0.4-0.9	0.36	0.26	0.2
Zn (mg/kg)	469.3	510	239-580		690	170
Cu (mg/kg)	117.5	170	25-160		53	200

*Warne. 2014, **Dorahy et al, 2010, *** Griffiths, 2013, ****Dorahy et al, 2005, 2010 and Beecher and Dunn, 2013.

4.2. Conduct on-farm field trials to test different manure application strategies (including potentially cotton gin trash compost/manure mixes) for crop response and nutrient availability.

IREC, Whitton Field Trial, 2015-16 and 2017-18

Yield and Nitrogen Use Efficiency

Treatment yields of the synthetic fertilizers at 177 kg N ha^{-1} applied pre-plant (green bars) alone or at 307 kg N ha^{-1}, applied by 177 kg N ha^{-1} pre-plant and topped dressed with 130 kg N ha^{-1} (grey bars) in combination with 2t ha^{-1} or 4t ha^{-1} chicken manure ranged between 9.3 -12.9 and were all statistically similar ($P \leq 0.05$) (Figure 4). This indicated that there was no yield advantages of either applying chicken litter compared to chemical only fertilizers, nor top dressing compared with pre-plant fertilizer only, in the 2015-16 cropping season (Figure 4). Clearly, the crop was not N constrained by > 177 kg N/ha applied fertilizer N and the manure offered no additional soil quality effects which might have increased yield further compared with the fertilizer in this first trial year.

The number of bales tended to decline slightly with fertilizer applications > 240 kg N/ha and this was reflected in the applied fertilizer NUE (kg of lint/kg fertilizer-N applied) which reduced from 16 at 130 kg N/ha to <8 at 370 kg N/ha. From previous research, the optimum value for applied NUE is considered to be 15. This value was achieved using the pre-plant fertilizer and 2 t/ha chicken manure (209 kg

N/ha). This was also the treatment that had the highest yield of 12.9 bales/ha. The ratio of fertilizer N:manure N in this treatment was ~5:1, suggesting that a mineral N budget with an additional 20% of N provided by chicken manure may optimise, yield and applied NUE. The optimum range of applied fertilizer NUE has been determined previously to be 13-18 kg lint/ kg N applied which was achieved in the treatments that received no top dressing.

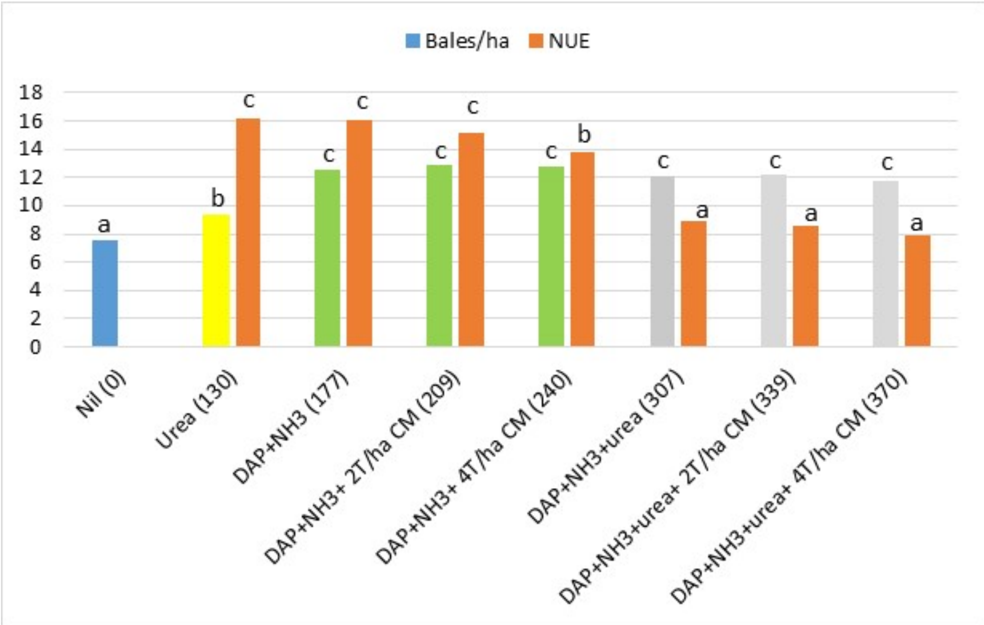


Figure 4 ***Lint yield response and applied NUE to chicken manure/fertilizer treatments 2015-16. Bales/ha - Blue bar: zero fertilizer, yellow bar: top dressed only, green bars: pre-plant fertilizer-N only, grey bars: pre-plant and top dressed N. Figures in parantheses are equivalent N (kg/ha). CM = chicken manure.***

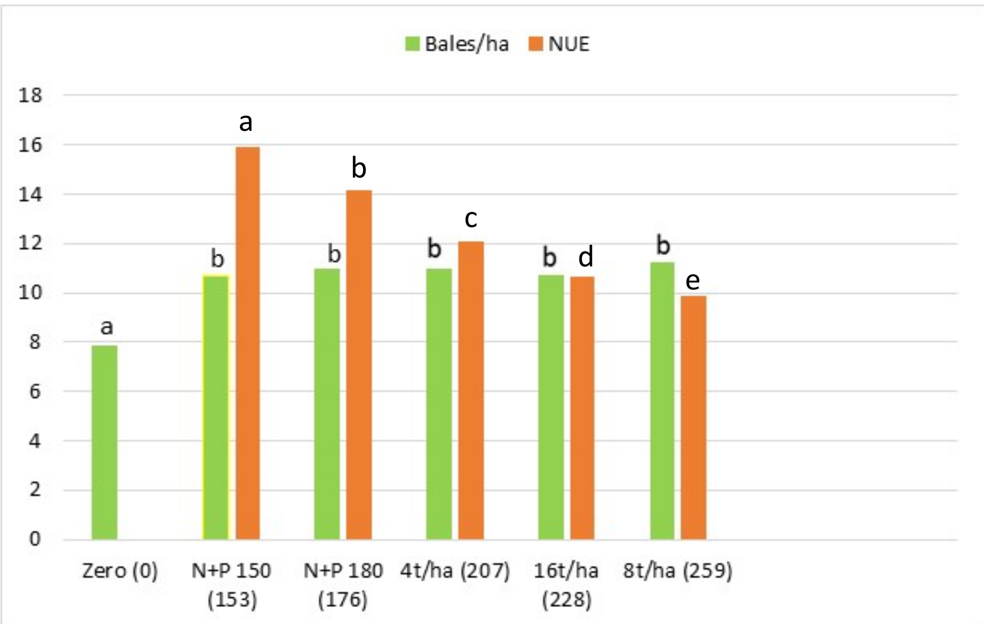


Figure 5 ***Lint yield response and applied NUE to chicken manure/fertilizer treatments 2017-18. Figures in parantheses is total available N from mineral fertilizer + manure.***

In the 2017-18 cropping season the newly established set of treatments, which followed a season of faba beans did not overlay the 2015-16 were not responsive to nitrogen. Yields ranged from 10.7-11.3 bales/ha and showed no significant difference ($p \leq 0.05$) from 150 – 259 kg applied N/ha (Figure 5). Agronomic conditions were not as favourable in the 17/18 season as in 15/16 with generally more pest pressure and very hot conditions over the flowering period. During these hot periods the irrigation deficit apparently led to slight water stress which

potentially limited yield by 1.5 -2 bales. Increased amounts of nitrogen and chicken litter had no effect on offsetting the effect of mild water stress which are most likely to have capped the yield.
Because the yield was so constant, the applied NUE consistently decreased as the amount of applied N increased (Figure 5). Because the crop was not responsive to N, it is not possible to formulate conclusions on optimal nitrogen:manure rate application according to treatment. Chicken manure rates at 4t/ha, 8t/ha in combination with 150 kg N/ha of chemical fertilizer did not affect yield compared with the 150 kg N/ha of mineral fertilizer alone. The 16t/ha chicken manure treatments received no synthetic fertilizer and apparently performed no differently to the mineral fertilizers at equivalent N rates suggesting that chicken litter can potentially completely replace chemical fertilizer for short term nutrient supply. Further analysis of plant data and soil data for the 2017-18 season will be reported in the following manure research project (DU1903) since a second season 2018-19 has been established at the time of this reporting.

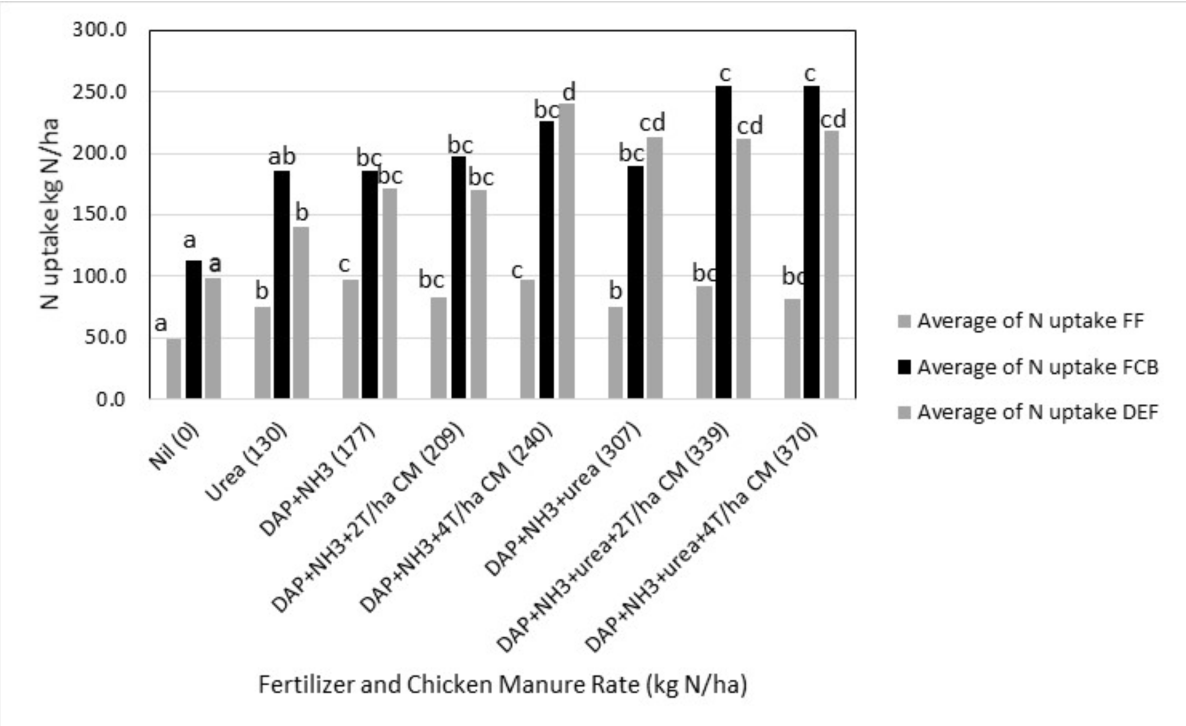


Figure 6. ***Total N uptake at first flower, first cracked boll and defoliation 2015-16 according to mineral fertilizer and chicken manure (CM) combinations.***

At first flower the N uptake of the crop was generally similar across all the treatments ranging between 74.5 – 97.1 kg N/ha in the fertilizer/manure treatments compared with 48.3 kg N/ha in the zero control (Figure 6). At first cracked boll total N uptake ranged between 186-255kg N/ha in all the treatments that had received DAP and anhydrous NH_3-N pre-plant. The mean values provided a linear increase with application rate up to 339 kg N/ha (Figure 6). The higher rate mineral fertilizer treatment (307) did not perform as well as might be expected, tending to generally lie outside the trend but this lower value was consisten int eh treatments throughout the blocked experimental design. The higher N application rates had the maximum uptake rates but were only significantly different ($p \leq 0.05$) compared with the treatment that had received only 130 kg N/ha as top dressed urea and the zero control. Therefore, although N uptake tended to be marginally higher at the higher application rates, this did not translate to yield benefit. The reason for this may be explained by the distribution in N uptake. The seed N content ranged between 138-154 kg N/ha in the fully fertilized treatments but there was high variability and no significant difference was obtained between the treatments. However, vegetative growth N mimicked total N uptake, increasing linearly as application rate increased suggesting that more available N was being used to increase vegetative growth and that in this case in-crop broadcast applied N had little effect on reproductive growth (Figure 7).

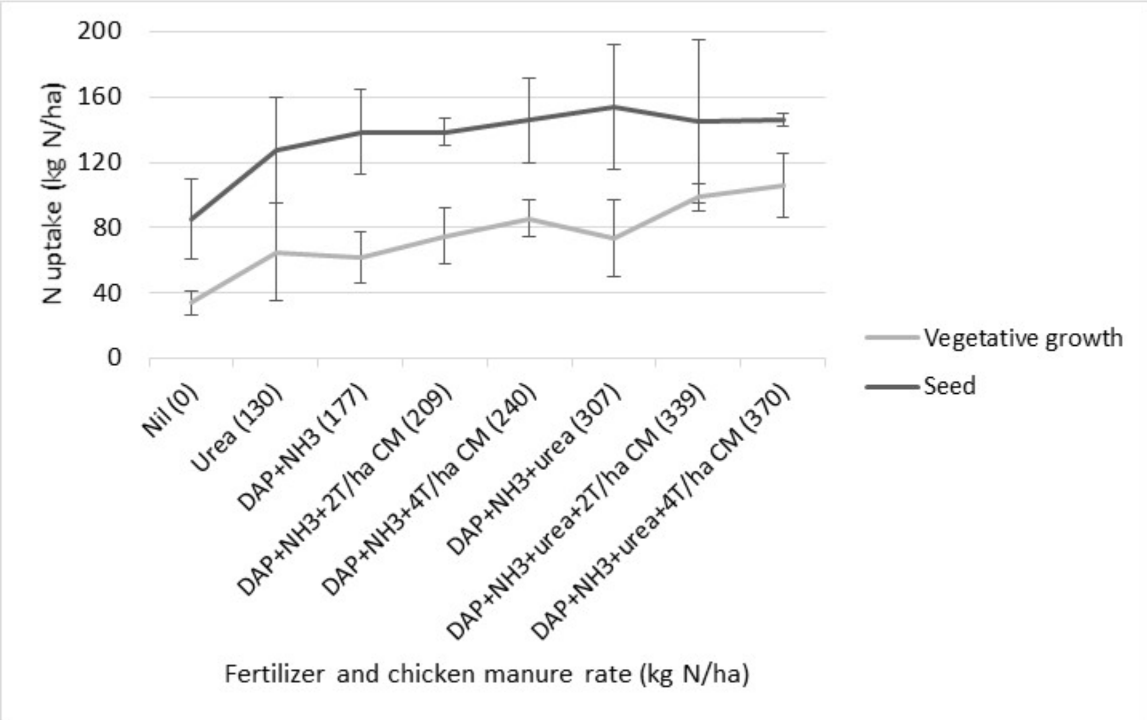


Figure 7 ***Nitrogen uptake in seed and in vegetative plant material according to fertilizer and chicken manure (CM) combinations.***

Internal nitrogen use efficiency indicated that the 240 kg N/ha with mineral fertilizer, no top dressing and 4t/ha chicken manure treatment was optimal (Figure 8). This is consistent with the nutrient uptake data and plant growth parameters. Although this treatment did not provide a significantly higher yield, the apex of the best fitted yield response curve falls at this treatment (Figure 9).

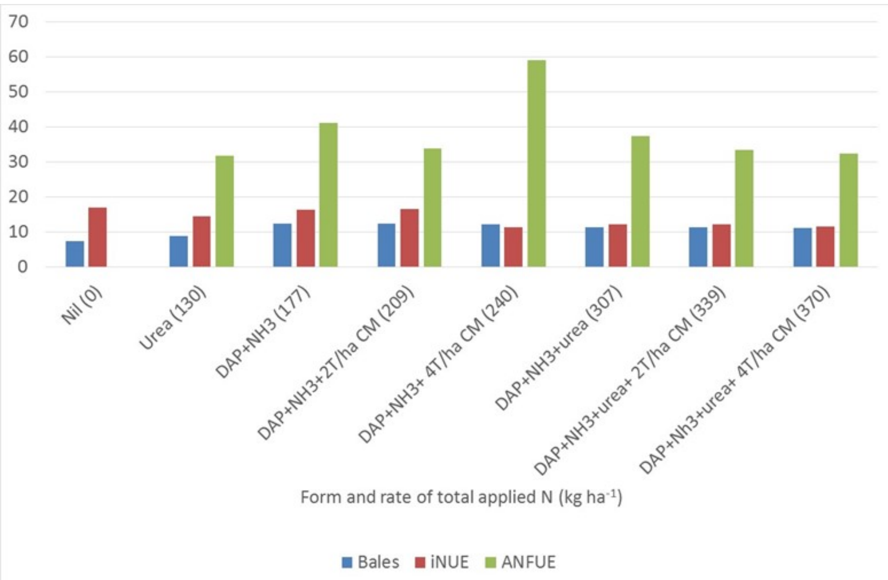


Figure 8 ***Internal nitrogen use efficiency and actual applied nitrogen use efficiency for the treatments***

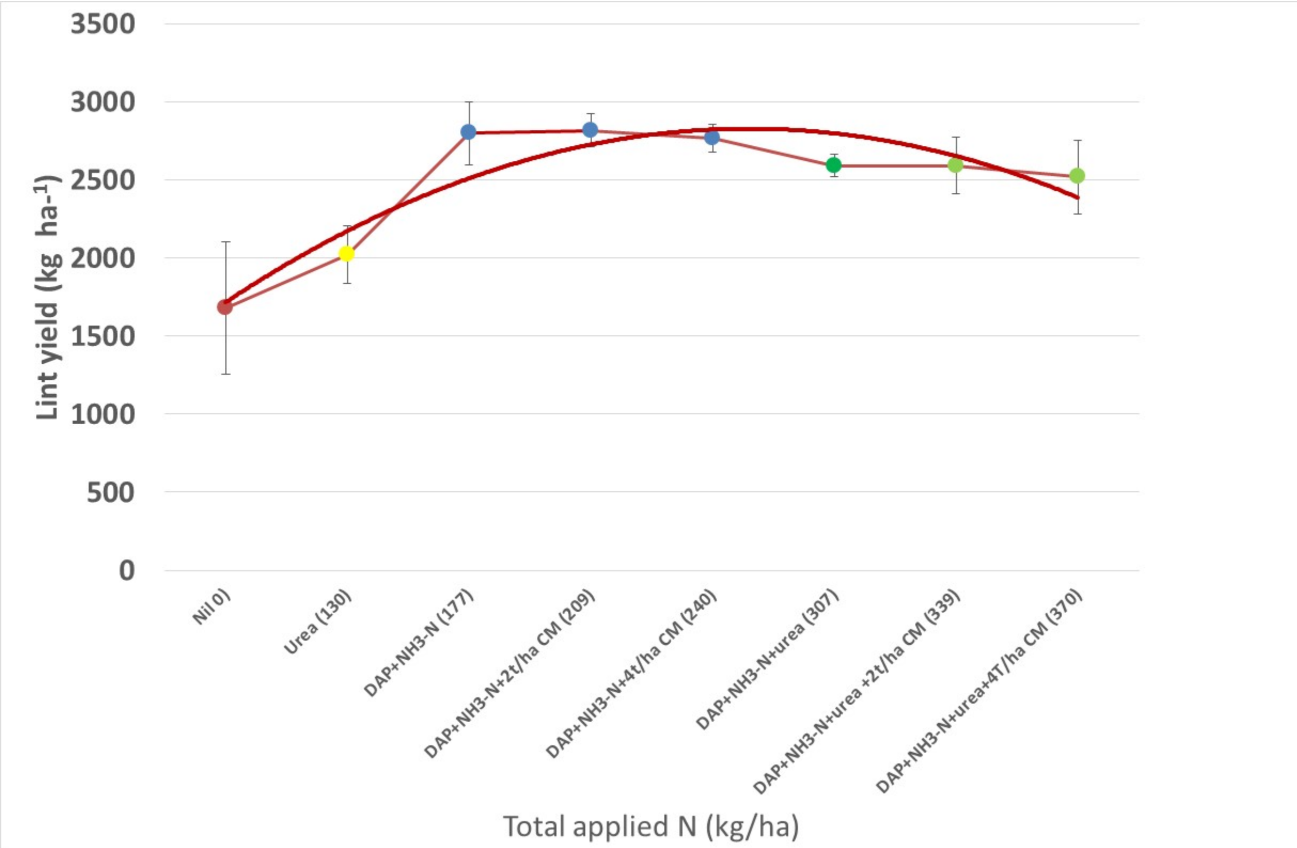


Figure 9 ***Response of lint yield to nitrogen applied N in fertilizer alone and in combination with 2 t ha^{-1} and 4 t ha^{-1} chicken manure***

Nitrogen recovery efficiency ranged from 23% to 45% across the trial with the lowest value occurring in the high rate of mineral fertilizer applied alone, although insignificantly. The highest values were observed in the 240 kg N/ha treatment with pre-plant and 4t/ha chicken manure. It was postulated that chicken manure: mineral fertilizer combinations may synergistically increase the uptake efficiency of N compared with the mineral fertilizer alone but there was no indication of this between the different treatments.

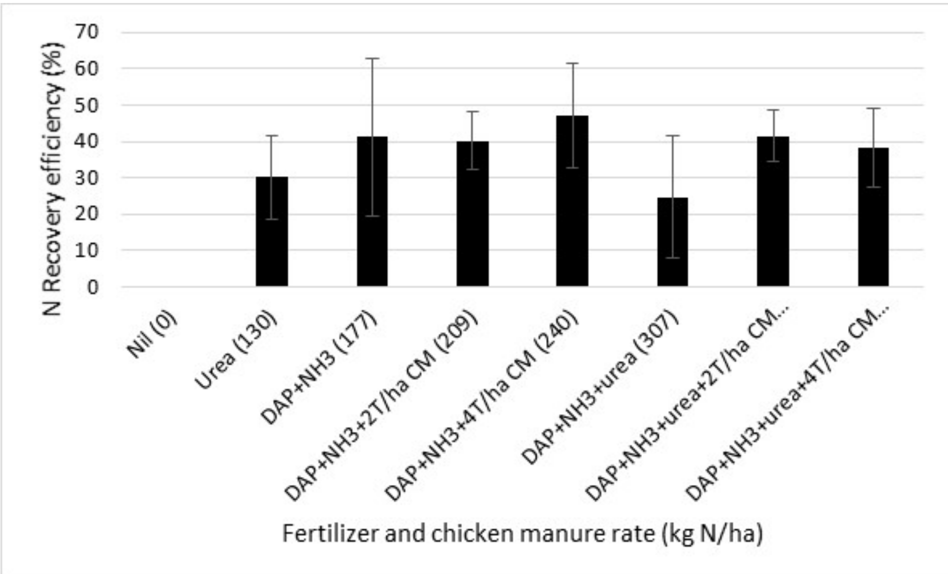
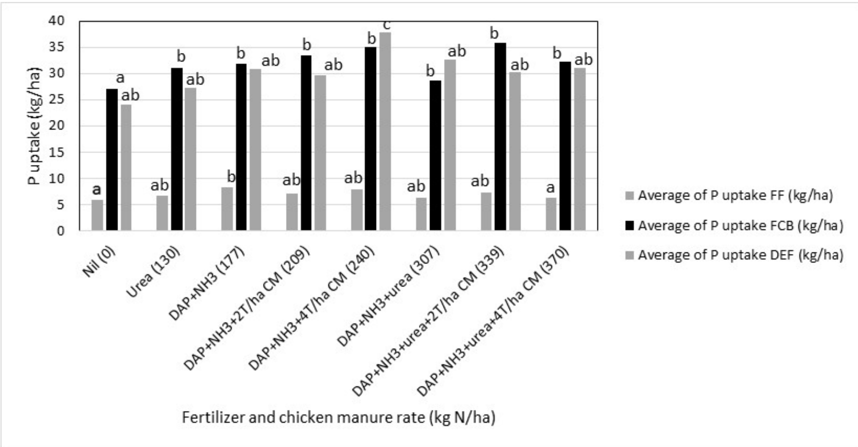
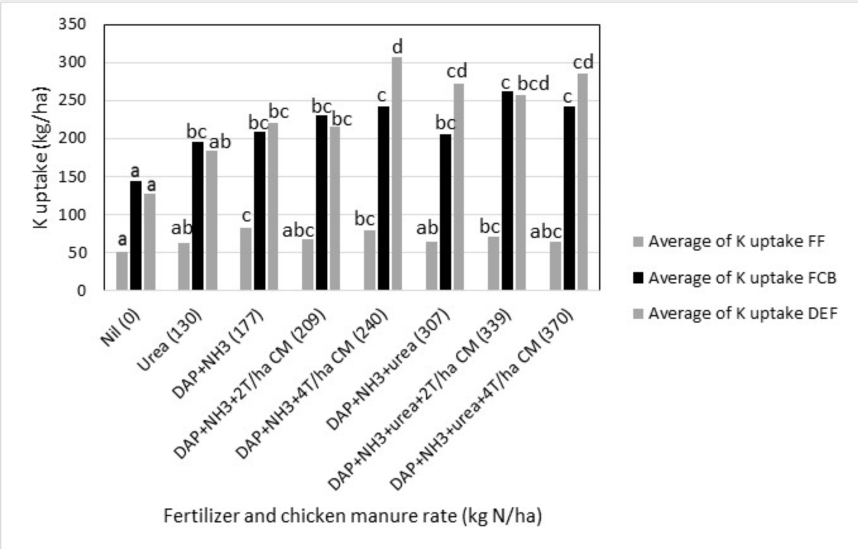


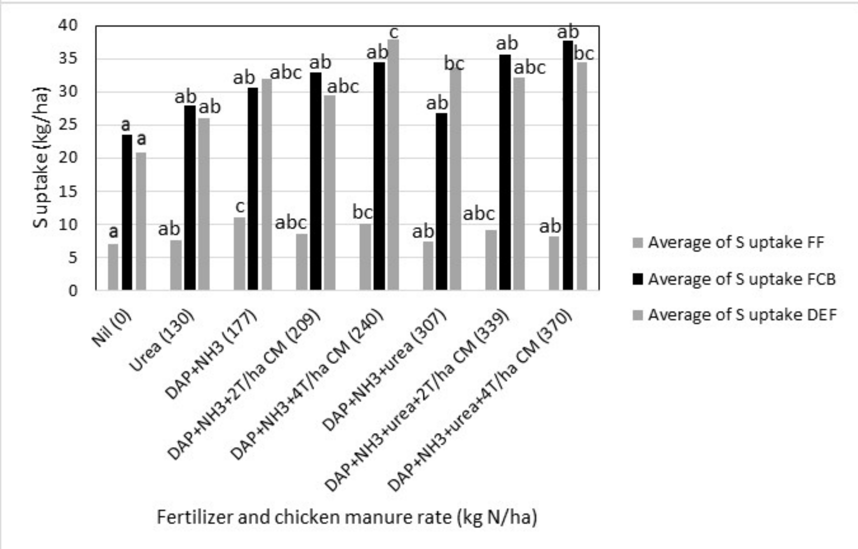
Figure 10 ***Nitrogen recovery efficiency according to fertilizer and chicken manure (CM) combinations.***

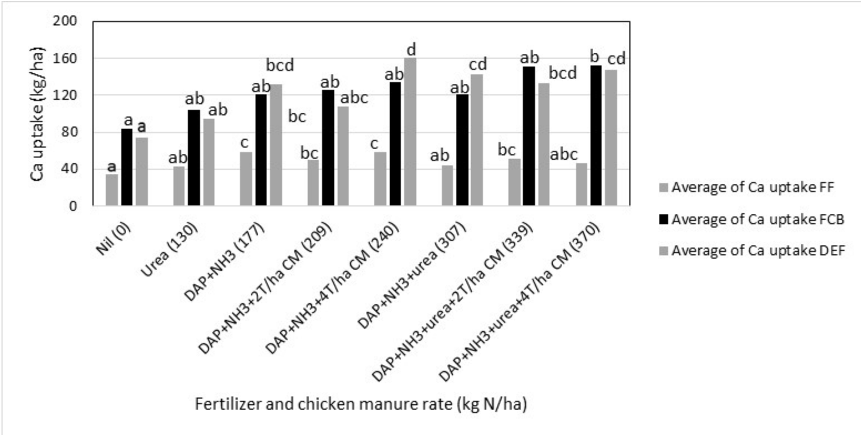
Uptake of nutrients other than nitrogen at different stages of crop growth

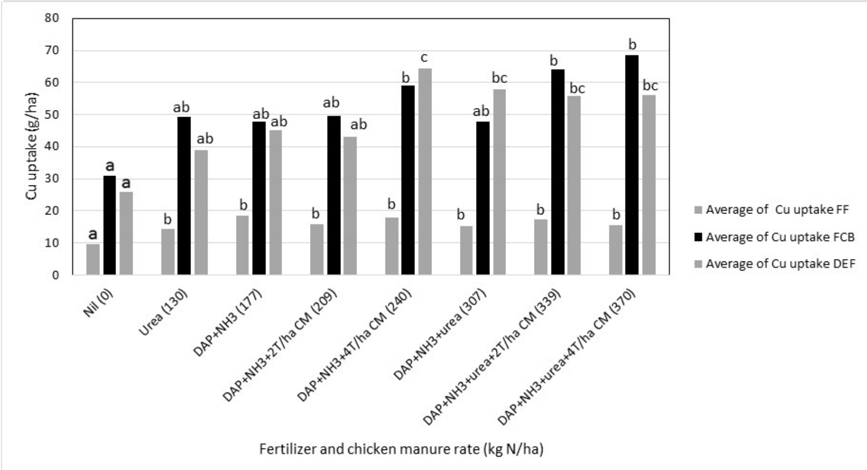
Nutrients other than nitrogen, including P, K, S, Ca, Cu, Zn, Mn, Fe, B analysed in biomass from three crop stages are presented in Figure 11 . Generally, they all trended in a similar way to N uptake according to treatment. P was non-responsive due to the application of DAP pre-plant. Zn, Fe, B and S were also relatively non-responsive compared to the control. Overall uptake including P was consistently significantly ($p \leq 0.05$) greatest in the 240 kg N/ha treatment with pre-plant and 4t/ha chicken manure suggesting an apparently comparatively greater fertility status for this treatment within the complete block trial design.

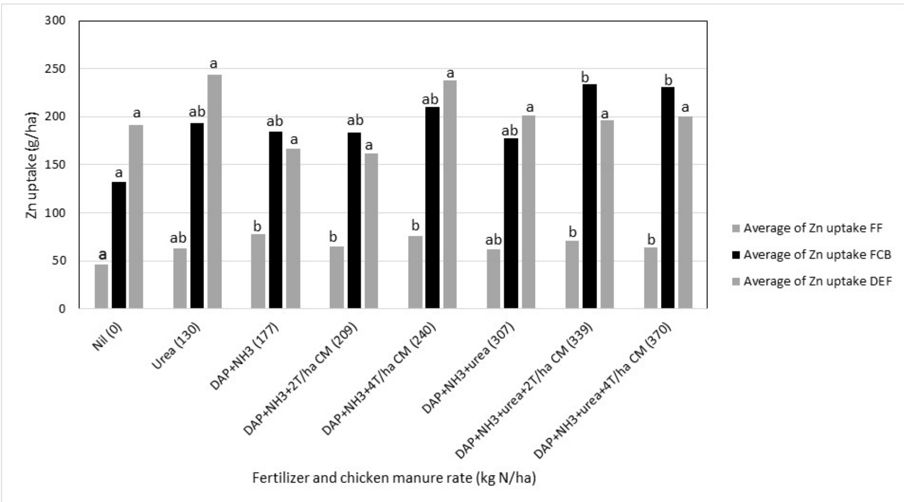







Ca uptake (kg/ha)
Average of Ca uptake FF
Average of Ca uptake FCB
Average of Ca uptake DEF
Nil (0)
Urea (130)
DAP+NH3 (177)
DAP+NH3+2T/ha CM (209)
DAP+NH3+4T/ha CM (240)
DAP+NH3+urea (307)
DAP+NH3+urea+2T/ha CM (339)
DAP+NH3+urea+4T/ha CM (370)
Fertilizer and chicken manure rate (kg N/ha)


Cu uptake (g/ha)
Average of Cu uptake FF
Average of Cu uptake FCB
Average of Cu uptake DEF
Nil (0)
Urea (130)
DAP+NH3 (177)
DAP+NH3+2T/ha CM (209)
DAP+NH3+4T/ha CM (240)
DAP+NH3+urea (307)
DAP+NH3+urea+2T/ha CM (339)
DAP+NH3+urea+4T/ha CM (370)
Fertilizer and chicken manure rate (kg N/ha)


Zn uptake (g/ha)
Average of Zn uptake FF
Average of Zn uptake FCB
Average of Zn uptake DEF
Nil (0)
Urea (130)
DAP+NH3 (177)
DAP+NH3+2T/ha CM (209)
DAP+NH3+4T/ha CM (240)
DAP+NH3+urea (307)
DAP+NH3+urea+2T/ha CM (339)
DAP+NH3+urea+4T/ha CM (370)
Fertilizer and chicken manure rate (kg N/ha)

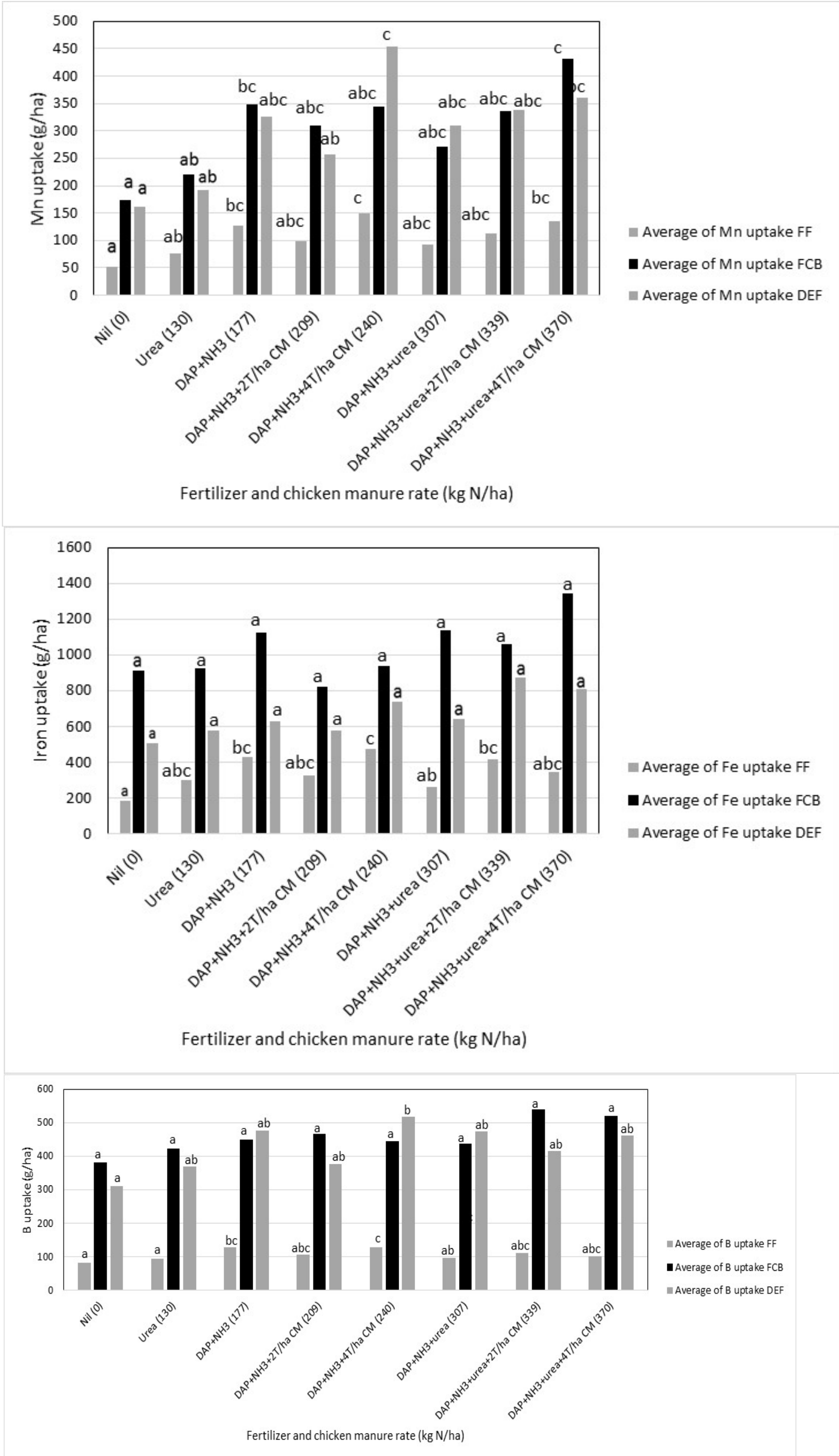


Figure 11 ***Uptake of nutrients other than N according to treatment at Whitton, 2015. Letters denote different significance at p≤0.05.***

Export of nutrients other than nitrogen, Whitton 2015-16

Analysis of nutrients in seed indicated significant amounts were being exported off farm in high yielding cotton. These are higher than previously reported in the soils at ACRI, Narrabri and suggest luxury nutrient conditions and an over use of inorganic fertilizers with associated inefficiencies.

Table 11 ***Export of nutrients off-farm from Whitton at 12 bales/ha and previous work in northern region at 10 bales/ha. In order to arrest soil fertility decline these levels indicate the replacement of nutrients necessary. Although applying K and P does not necessarily give a single season productivity response it is necessary to maintain these major nutrients to ensure the optimal co-uptake of nitrogen.***

Nutrient	Rochester (2007) Lint 2200 (kg/ha)/*(g/ha)	Whitton (2015) Lint 2800 (kg/ha)/*(g/ha)
N	93	141
P	18	31
K	29	37
S	8	10
Ca	4	7
Mg	*12	*17
Zn	*96	*177
B	*41	*68
Fe	*136	*241
Cu	*20	*36
Mn	*21	*68

Plant growth, Whitton, 2015

Plant establishment

Sowing was conducted at 130,000 seeds/ha. DAP was applied at 150kg/ha as the site was newly landformed and there was some concern over Colwell P levels. According to the analysis here Colwell-P was adequate at 21 mg/kg in 0-30 cm, although dropped to low levels across the entire site at 30-60 cm compared with the 60-90 cm interval (Table 2). At establishment stage, there was no significant difference between any of the treatments ($p<0.05$) regardless of manure or DAP application.

Effect of N rates on plant growth

Application of N affected plant height differently according to growth stage. Prior to flowering, the tallest plants were observed in the zero control treatments and the treatments that had more than 300 kg N ha^{-1}were significantly shorter than all the other treatments (Figure 12). By first flower, all treatments had evened out, irrespective of source and N rate and just prior to first defoliation the tallest plants occurred in the middle of the N rate range with a significant decline in the highest N rate. There was no correlation between plant height and lint yield at first flower but became highly significant at maturity (R^2=0.86, P< 0.01). Vigorous plant growth has been claimed to contribute to higher yields (Reddy et al 2007).

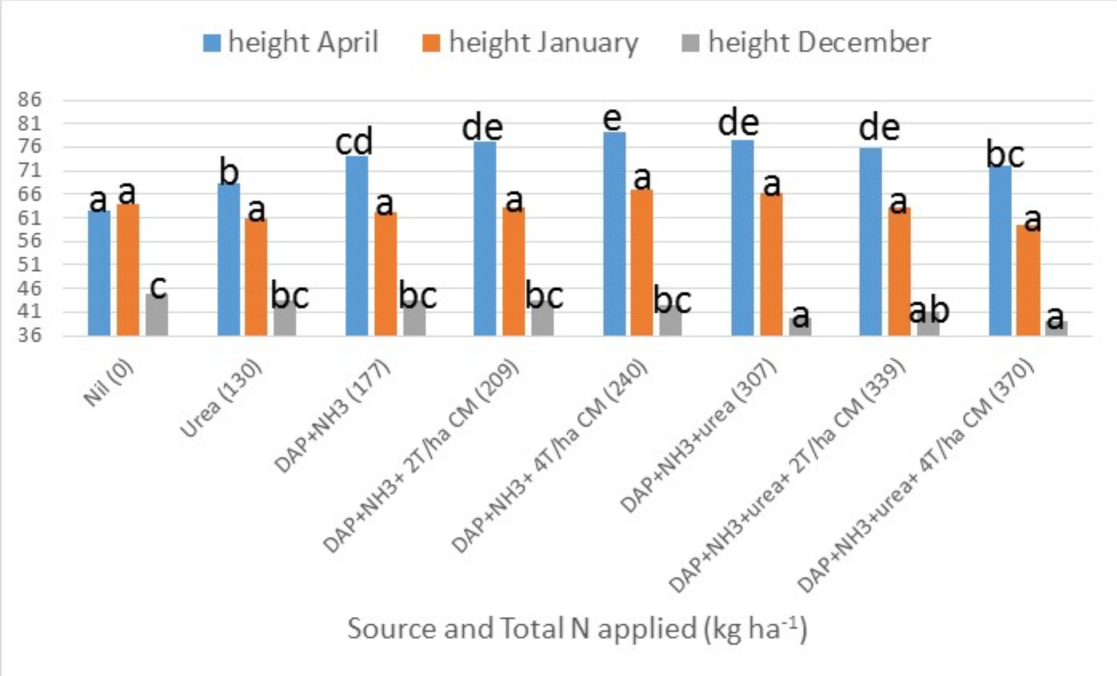


Figure 12 Response of cotton plant height to N in fertilizer alone and in combination with 2 t ha^{-1} and 4 t ha^{-1} chicken manure at different growth stages.

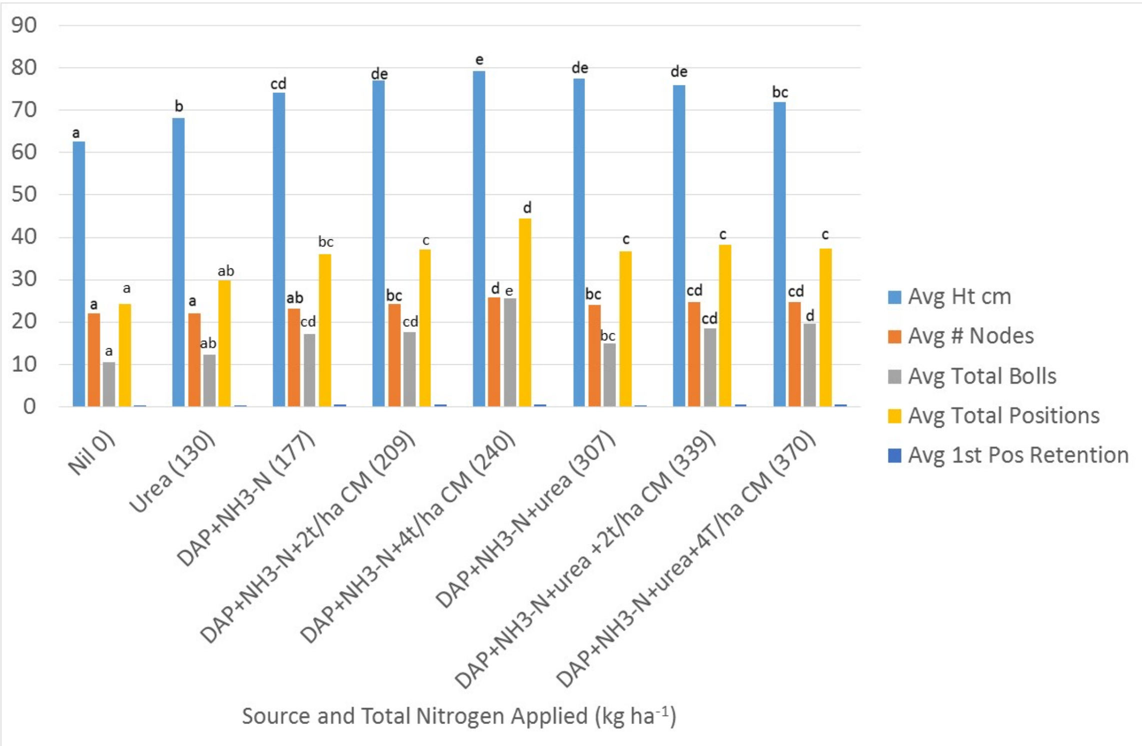


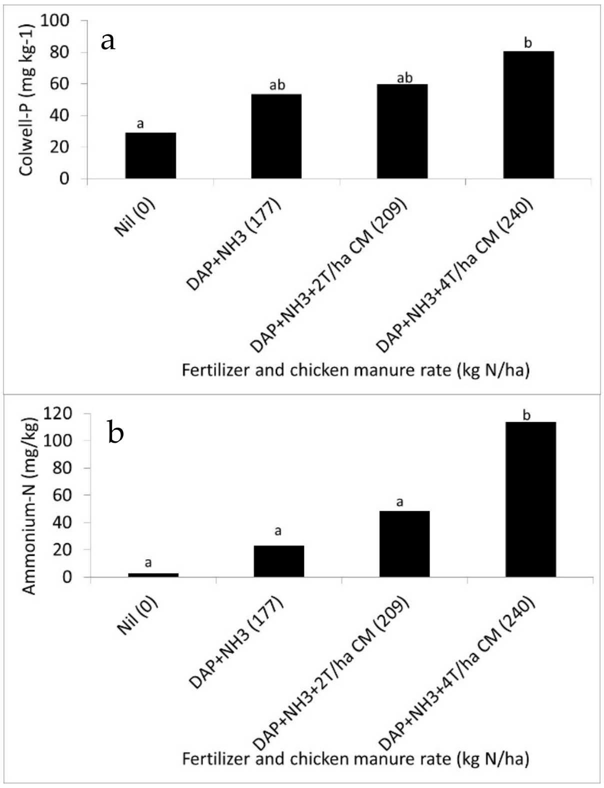
Figure 13 Response of plant assessment parameters: plant height, number of main stem nodes, total positions and total bolls to N in fertilizer alone and in combination with 2 t ha^{-1} and 4 t ha^{-1} chicken manure at maturity.

At the time of defoliation plant height, number of nodes, total bolls and total positions generally increased as N rate increased up to a maxima at 240 kg ha^{-1} N in which the source of N included pre-sowed DAP, anhydrous NH_3 at sowing and 4t t ha^{-1} of chicken manure. At higher rates (in excess of 300 kg ha^{-1} of applied N) which included a urea broadcast top dressing, there was a slight decline in these parameters (Figure 13). A similar pattern was observed in lint yield with a fitted curve (Figure 9).

Soils at Whitton, 2015

Effect of chicken manure on selected soil properties at application

Soils (0-10 cm) sampled two weeks after manure and anhydrous fertilizer application in October confirmed increases in major and minor nutrients C and N and significantly (P≤ 0.05) increased ammonium-N, Colwell-P and available K above the zero control (Figure 14 a b d). As might be expected the increases in this surface horizon were most significant for the 4 t/ha chicken manure treatment. No differences were observed in nitrate concentrations (Figure 14 c) explained by only trace levels of nitrate in raw chicken manure and insufficient time for the conversion of ammonium to nitrate. Although minor increases occurred in total C, total N, and a decrease in bulk density (data not shown), no significant (P≤ 0.05) differences were observed for these parameters in any of the treatments at application (Figure 14e,f).



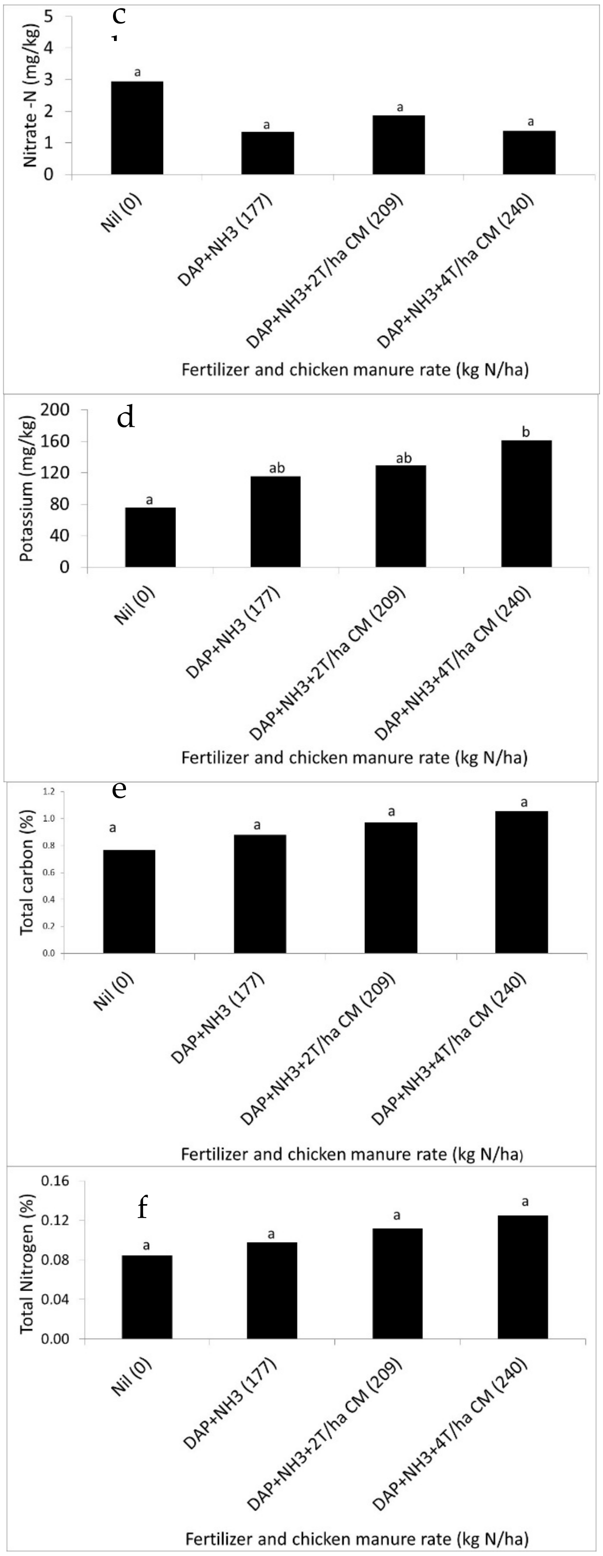


Figure 14 ***Soil nutrients (0-10 cm) in pre-sowed trial immediately following manure amendment compared with fertilizer only and control.***

Significant ($p \leq 0.05$) elevation in major nutrients over the period 9/9/2015-3/1/2016 from the amendment additions compared to control and mineral only fertilizer in periodic surface (0-30) soil samples (Figure 15). However, by the time first flower had been reached there were insignificant differences between the treatments including the control, for nitrate. For ammonium-N, by first flower, there was a significant difference ($p \leq 0.05$) for the amended treatments compared with the control but not between the amended treatments and the mineral fertilizer only treatments. In 0-10 cm surface samples, differences in ammonium-N according to treatment had disappeared by 60 DAS (Figure 16). Colwell-P in the 4t/ha treatment always remained significantly higher compared with the other treatments. Colwell-P trended in a similar fashion to that which was observed in the Widgelli soils in the main trial and in the litter bag experiment (discussed below). An elevated spike occurred around the first irrigation after sowing followed by a decline but then a gradual maintenance or increasing trend as the season progressed. The Colwell-P data suggests remineralisation of soil P is occurring with release from either organic or other inorganic P soil pools and absorption to soil surfaces. The zero treatment Colwell-P indicated the clearest consistent increasing trend from 21.2mg/kg to 36.7 mg/kg over the 104 day period.

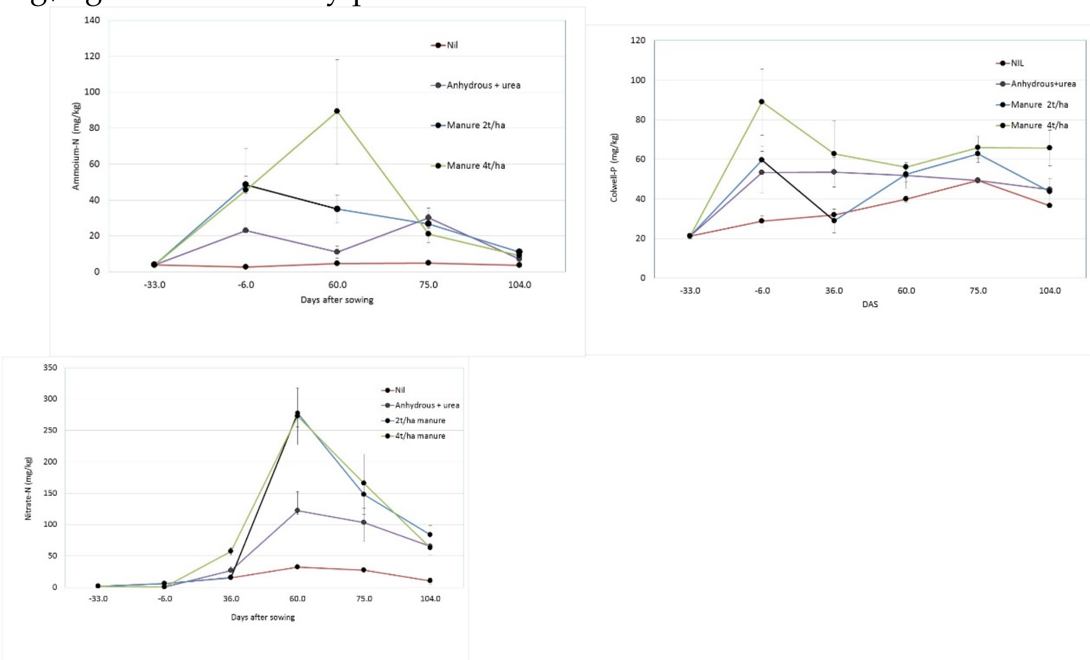


Figure 15 ***Changes in 0-30 soil ammonium-N, Colwell-P and nitrate-N with DAS at Whitton, 2015.***

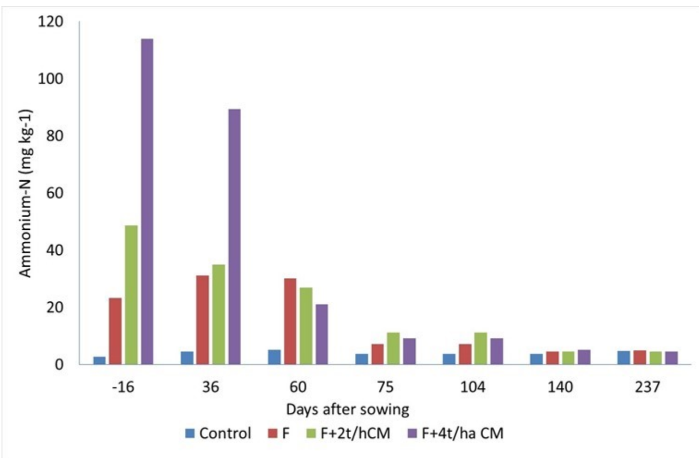


Figure 16 ***Changes in soil 0-10 cm ammonium-N up to 217 days after sowing.***

Soils sampled post-harvest (0-30 cm) had increased mineral N, Colwell P and major cations compared with the same sampling undertaken early season (36 DAS), but significant ($p \leq 0.05$) increases were only observed in 4t/ha manure treatments. ECEC, TN and TOC, bulk density and dispersion showed insignificant change within the period and pH declined in all but the highest rate of manure. There was a statistical increase in post-harvest nitrate in the treatment that had received the highest amount of applied N indicating an over-supply and alternative factor, likely soil compaction was constraining nutrient uptake. Therefore, although there were some minor beneficial effects on soil nutrient status obtained from amending with 4 t/ha chicken manure, effects on soil physical properties were not observed. After a single season the manure amendment did not alleviate any soil productivity constraint.

Yarran Park, Amberley Farms Inc. Widgelli, NSW

Chemical characteristics of manure and soil.

The soil type at Widgelli is a Chromosol with a clay loam texture with red and grey characteristics, locally known as a transitional red brown earth, Griffith Clay Loam. It has a heavier texture and more sodicity compared with the soil at Whitton (Table 4).

Yield and Nitrogen Use Efficiency

There was no significant increase (p≤0.05) in yield between the different fertilizer treatments including the control, according to cuts or interaction between the two factors suggesting a non responsive site to N or nutrients held in the manure. Irrespective of the source of N or even in the control plots a yield difference was not observed. Without statistical significance, the general trends according to the fertilizer treatments indicated that the mineral fertilizer had the lowest average yield and 100% manure had the highest average yield. The insignificant trends according to cut indicated the area that had not been cut had the highest yield and the area of heaviest cut had the lowest yield despite top soiling. The interaction of the two factors indicated that the lowest yield was determined using only mineral fertilizer in the heavily cut area and the highest yield was recorded using 100% manure in the area that had not received cuts (Table 12). The seed yield showed a similar pattern consistently increasing (but insignificantly (≤0.05) as the proportion of manure increased according to fertilizer treatment and as the level of cut reduced (Table 12).

Table 12 ***Cotton lint yield, seed yield and applied NUE in 2017.***

	Low Cut (4cm)			High Cut (17 cm)			No Cut (0cm)		
	Lint Yield (b/ha)	Seed Yield (kg/ha)	aNUE	Lint Yield (b/ha)	Seed Yield	aNUE	Lint Yield (b/ha)	Seed yield	aNUE
Control Zero	11.9±1.5	3436±477	10.8 ±1.4	11.5±1.6	3262±381	10.4±1.5	12.8±2.1	3653±647	11.6±1.9
100:0 MF-CM	13.2±1.7	3840±511	10.7±1.4	10.3±1.1	3022±257	7.8±0.9	11.9±0.9	3400±261	10.8±0.8
70:30 MF-CM	12.0±0.5	3571±270	10.9±0.7	12.1±0.5	3480±145	11.0±0.5	11.9±2.7	3530±786	10.8±2.4
30:70 MF-CM	11.3±2.4	3339±645	10.3±2.1	12.7±1.0	3689190	11.6±0.9	12.4±0.2	3552±94	11.3±0.2
0:100 MF-CM	11.2±0.8	3274±212	10.2±0.7	12.4±1.5	3579±453	11.2±1.4	14.2±0.6	4093±148	12.9±0.5
Mean	11.9	3492±435	10.5	11.9	3406±358	10.4	12.6	3646±472	11.5
	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

MF = mineral fertilizer; CM = chicken manure. Ratios used to meet 280 kg N/ha.

At first flower aboveground biomass, and plant height had increased as the proportion of manure had increased, with significant differences (p≤0.05) between the mineral only fertilizer and the manure only treatments (Table 13). The treatments with 100% MF and 70:30 MF:CM did not outperform the control (p≤0.05) whilst the higher ratios of CM outperformed both the control and the 100% MF treatment. Plant height was also greater in the 30:70 MF-CM treatment at this stage compared to the 70:30 MF:CM. There was no significant difference in the number of nodes according to the fertilizer regime. At first flower the cotton productivity data suggests that the chicken manure had a significant impact on vegetative growth when applied at 15 t/ha and 22 t/ha, which was the mass required to meet a manure N supply of 170 and 250 kg N/ha in the 30:70 MF-CM and the 100% CM treatments respectively (Table 13).

At defoliation, aboveground biomass in the treatments with MF only and lower proportions of CM had caught up with and exceeded the treatments dominated by organic fertilizer (Table 13). For example, the MF 100% treatment had 27 % more bolls than the CM 100% treatment. The shortest plants (p≤0.001) were still observed in the treatments that contained no manure and there was no difference in the number of nodes. The number of bolls was greater in the treatments with the lower

proportions of CM with the MF 100% treatments being significantly ($p \leq 0.05$) higher than all the other treatments and all treatments being significantly higher than the control ($p \leq 0.001$).
The results demonstrate that at high rates the CM treatments increased vegetative growth but substituting mineral fertilizer with CM did not increase lint yield, seed yield or cotton productivity after one year. This finding is inconsistent with the findings of Tao et al (2017) who reported cotton productivity increased when cattle manure was used to supplement MF compared with MF alone. However, that study was in the final 2 years of a 4 year drip irrigated trial.

Table 13 ***Cotton productivity components in 2017***

	Productivity Components							
First Flower	AGB	Plant Height	Nodes	**Defoliation**	AGB	Plant Height	No. Nodes	bolls/plant
Control Zero	2220.86a	54.778ab	21		6192.9a	87.3a	26	8.0a
100:0 MF-CM	2157.75a	52.333a	20		7911.6b	86.6a	26	16.3c
70:30 MF-CM	2528.31ab	53.956a	20		7573.4ab	88.6ab	26	15.2bc
30:70 MF-CM	2536.42ab	59.2bc	21		7065.0ab	90.0ab	25	10.7ab
0:100 MF-CM	3185.08b	62.378c	22.		7243.8ab	91.4b	27	11.9abc
Fertilizer	**0.005	***0	0.161		*0.03	***0.001	0.081	***0.001
No cut	2741.02b	57.573b	21		7883.1b	90.9b	26	13.1
Low cut	2609.75ab	58.48b	21		6518.6a	89.8b	26	12.0
High cut	2226.28a	53.533a	21		7190.3ab	85.6a	26	12.3
Cut	*0.048	***0	0.759		**0.008	***0.001	0.514	0.685
Fertilizer x Cut	0.511	0.181	0.462	**Fertilizer x Cut**	0.251	*0.032	0.074	*0.035

In spite of topsoiling, cotton productivity including the aboveground biomass and plant height at first flower and defoliation were significantly ($p \leq 0.05$) reduced in landformed cut areas of 17 cm compared with no cut areas (Table 13). However, the no of nodes and number of bolls/plant were not affected by soil cuts.
Analysing interaction of the factors, plant height at defoliation significantly increased when 100% manure was used in cut areas compared with the effect in the lighter cut or no cut soils. However, boll numbers were greatest (insignficantly) when MF was used in no cut or light cut areas compared with manure substitution. Otherwise there was no clear interaction between the factors (Table 13).

Cotton Nitrogen Uptake
Cotton nitrogen uptake ranged between 92 -131 kg/ha at first flower and between 305-380 kg N/ha Overall, cotton N uptake analysed with Two Way Anova in the three cut areas at first flower (a total of 9 reps for the field), showed increases in N uptake as manure as a proportion of the applied fertilizer, increased and this was significant ($p=0.007$) in the 100% manure treatment compared to the 100% MF treatment (Table 14). It is usually accepted that interactive effects of mineral fertilizer

and organics increases nitrogen uptake and efficiency caused by improved soil physical properties and a more synchronous supply of nutrients to plants by slower release (Tao et al, 2017). However, we observed no difference when using 70:70 MF-CM or vice versa suggesting that in this case combination mineral:organic fertilizer does not offer synergism in the short term and that manure does not offer additional properties for enhancing mineral N uptake within the time period. By defoliation, significant treatment differences in N uptake had been lost including the control. The insignificant trends according to fertilizer regime indicated N uptake in the order 100:0MFCM>0:100MF:CM>30:70MF:CM>70:30MF:CM>ControlZero.

Table 14 Two way ANOVA analysis of N uptake at first flower and defoliation in the three different cut areas at Widgelli, 2017-18.

	First Flower N uptake (kg/ha)	Defoliation N uptake (kg/ha)
Cut (cm)	*0.027	0.218
0	115.906b	359.1
4	109.91ab	338.8
17	93.111a	331.6
Fertilizer	**0.007	0.1
Control Zero	91.844a	305.7
100:0 MF-CM	93.109a	381.9
70:30 MF-CM	109.775ab	330.9
30:70 MF-CM	106.154ab	346.9
0:100 MF-CM	130.663b	350.6
cut*fert	0.5	0.516

At first flower cotton N uptake increased as the depth of cut decreased (p=0.027) but the plants apparently compensated and the relationship was lost at defoliation although similar insignificant trends were present (Table 14,Figure 1

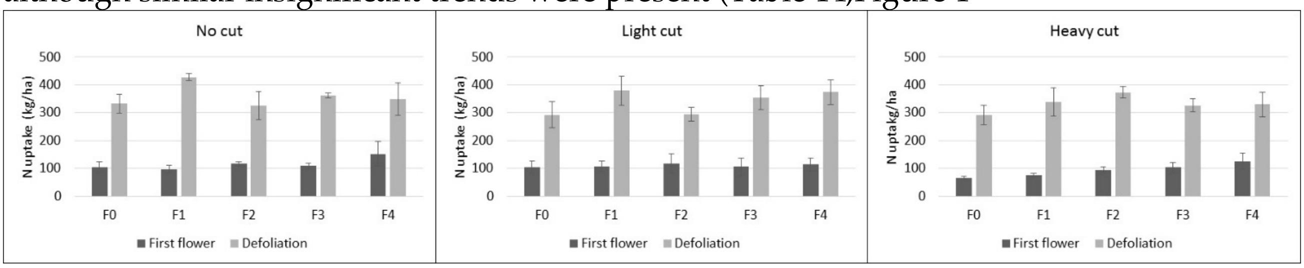


Figure 17 Nitrogen uptake according to cut at first flower and defoliation. F0= Control zero, F1=100:0 MF-CM, F2=70:30 MF-CM, F3= 30:70 MF-CM, F4=0:100 MF-CM

The first flower N uptake data and the trends at defoliation in the cotton productivity components (Table 13) and the N uptake data according to fertilizer regime, indicate some increasing trends in productivity as the proportion of applied N as manure increases. However, at this stage of 1 year into the trial, there is no indication that there is a synergistic effect from integrating mineral and manure N that enhances yield or N uptake.

Soils, Yarran Park, Widgelli

The total N contents in 0-30 cm soils ranged between 0.05 - 0.14% across the trial with the lowest recorded in the post-harvest control and the highest in the post plant 100% mineral fertilizer. The TN was not significantly ($p \leq 0.05$) different according to *treatment in any of the plant growth stages: post plant stage in the last week of October, first flower and post-harvest (Figure 18). The dispersion of data around the mean was greater for the low cut and no cut areas compared with the high cut area with CVs of 21%, 20% and 17% respectively. The data indicated that seasonal drawdown of total nitrogen was significantly (p<0.05) lower (14%) in the high cut area compared with the low cut and no cut soils (20-28%) and that >80% removal occurred between first flower and post-harvest (*

Table 15).

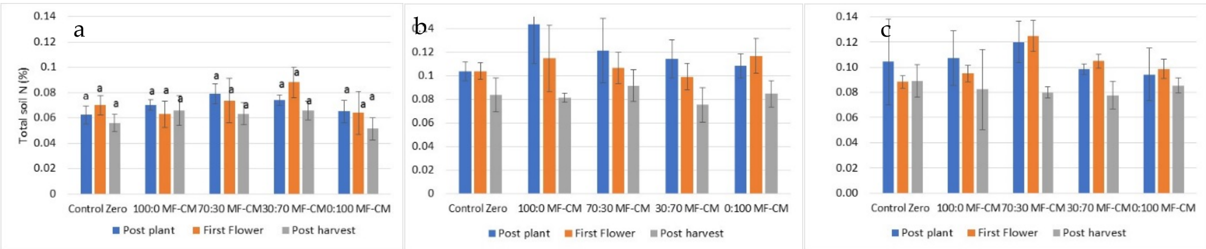


Figure 18 Changes in total soil N of 0-30 cm soil in cotton field receiving mineral fertilizer or chicken manure on a) high cut (17 cm), b) low cut (4cm) and c) no cut (0 cm) at post planting (October), first flower (January) and post harvest (May) in 2017-18.

Total Colwell P contents ranged between 17 mg/kg in post-harvest high cut soils to 419 mg/kg (100% MF treatment) in post plant no cut soils (Figure 19). Colwell-P was not significantly (p≤ 0.05) different according to treatment with the exception of the 100% MF treatment which tended to be approximately 150-200 mg/kg higher in Colwell-P compared with the other treatments caused by the 150 kg/ha of DAP applied. Minor but insignificant increases in Colwell-P were observed according to the proportion of chicken manure in the low cut and no cut soils but not in the high cut. Seasonal drawdown of Colwell-P ranged from 13-17mg/kg (51-66 kg/ha) in controls and the 100% manure treatment of the high cut area and increased as mineral fertilizer increased to as high as 245 mg/kg in the 100% MF treatment (

Table 15). The 100% manure treatment performed no differently to the control.

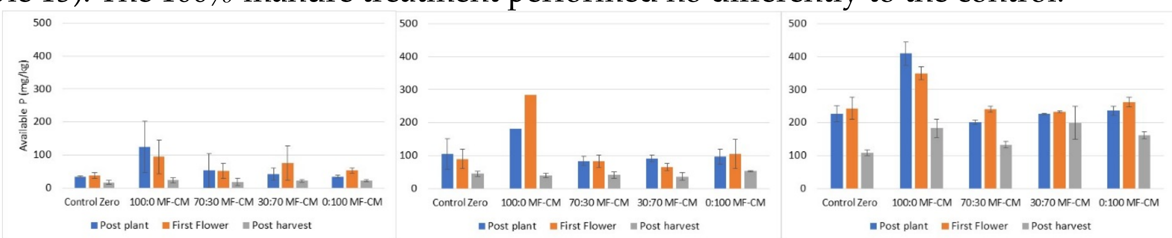


Figure 19 Changes in available P of 0-30 cm soil in cotton field receiving mineral fertilizer or chicken manure on a) high cut (17 cm), b) low cut (4cm) and c) no cut (0 cm) at post planting, first flower and post-harvest in 2017-18. Non-normal distribution in the 100MF treatment not included.

In luxury Colwell P conditions the plants apparently removed extra P but without significantly affecting yield or productivity.

The soil concentrations of Colwell-P consistently increased in all the soil areas between post plant and first flower, by on average 4-5% in the no cut and low cut and by 22% in the high cut areas. The greatest gains in Colwell-P over the season were made in the high cut of up to 76 mg/kg in the 30:70 MF:CM and the 100% CM treatment. The reason for the comparatively greater increase in the high cut soils is unclear and the consistency seen in the data indicates it unlikely to be caused by measurement error. The microbial activity and microbial biomass data indicated significantly ($p \leq 0.05$) less biological mass and activity in the high cut area which suggests microbially mediated phosphorus remineralisation is unlikely as a reason for the increases of Colwell P with time (Figure 20). Therfore, it seems that Colwell P maybe being supplied from other less available pools of soil by abiotic processes. There were no changes in the microbial indicators that soil quality had been improved by chicken manure amendment (data not shown).

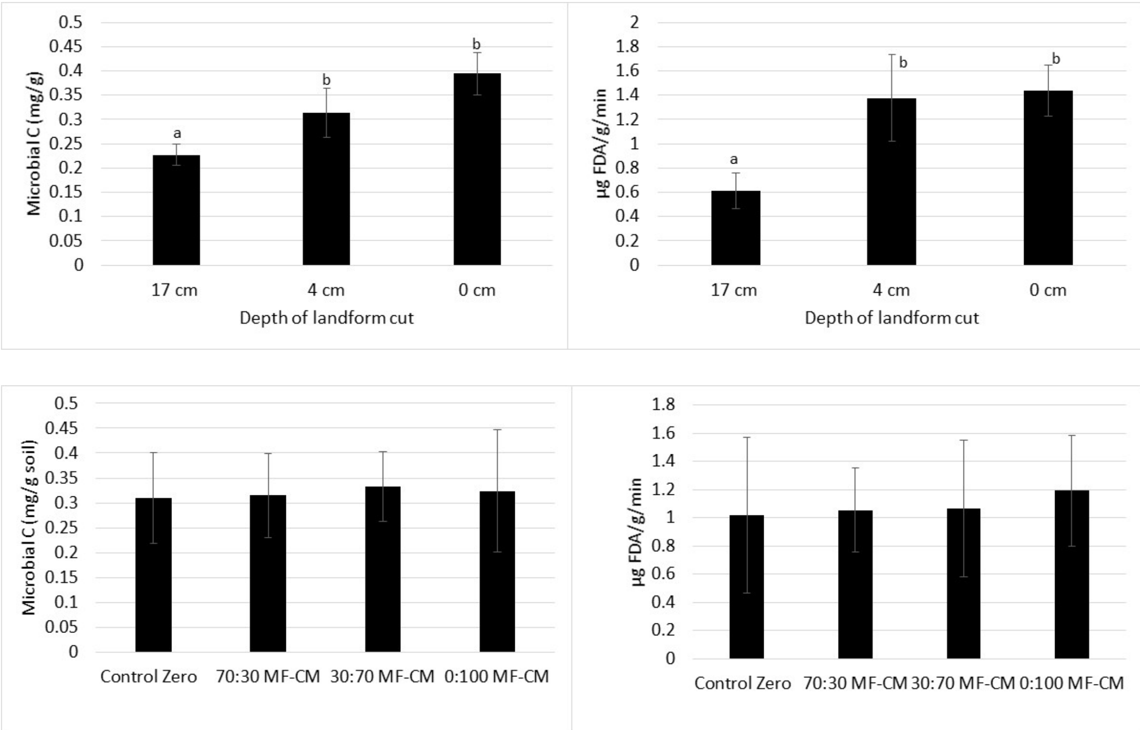


Figure 20 Microbial biomass and activity according to treatment.

Nevertheless, by post-harvest average seasonal depletion had occurred in all areas and across all treatments (mean of 37% in the no cut to 78% in the high cut of post plant Colwell-P). The manure applied treatments performed with no significant ($p \leq 0.05$) difference compared with the control whilst there was significantly greater decline in soil Colwell-P concentration in the 100% MF (DAP applied) treatments and according to cut depth; 103 mg/kg in no cut, 69 mg/kg in low cut and 38 mg/kg in high cut. Similar to nitrogen decline, 70->100% was removed between first flower and post harvest.

At post plant, available Zn concentrations in high cut soils were 1-4 mg/kg in control and manure amended treatments and not significantly different (Figure 21). Nominal critical value or Zn at which deficiency may occur is 4 mg/kg, therefore the soil Zn status was relatively poor. The 100% MF treatment was significantly ($p \leq 0.05$) higher than the control and manure amended treatments due to the farmer practise of applying Soygran. By post-harvest available Zn in the soil was essentially completely depleted in all of the treatments in the high cut and low cut areas with only trace amounts remaining in the 30:70 MF:CM and the 100% CM treatments. On average the controls and manure amended treatments diminished from 2.1 mg/kg at post plant (8 kg/ha), to 0.6 mg/kg (2.3 kg/ha) at first flower to 0.2 mg/kg (0.78 kg/ha) at post-harvest. Most if not all of the soil Zn that was available was depleted between post plant and first flower and distributed to bolls thereafter. For example 100% MF treatments in the high cut soil at post plant contained 7 mg/kg of Zn which was depleted to undetectable by first flower. In the no cut soils, where some Zn remained after first flower, there was none or only minor further removal between first flower and post- harvest. Generally poor correlations between soil tests and plant uptake have been found (Constable et al, 1988) who calculated that it was necessary for Zn to be continued to be taken up throughout the season as redistribution from leaves was insufficient to sustain boll requirements. Further data analysis around soil available Zn and plant uptake will be undertaken in the follow on manure project.

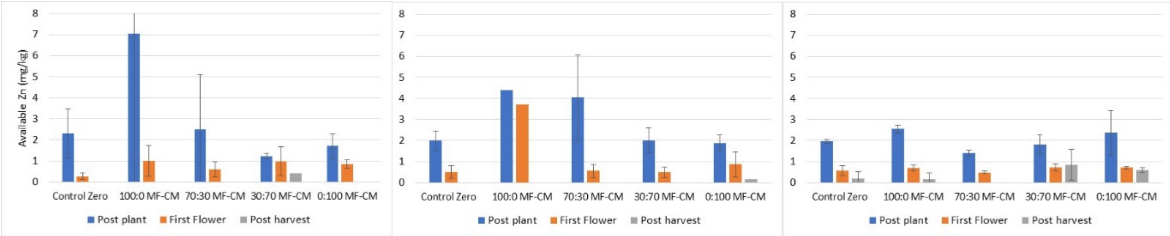


Figure 21 Changes in available Zn of 0-30 cm soil in cotton field receiving mineral fertilizer or chicken manure on a) high cut (17 cm), b) low cut (4cm) and c) no cut (0 cm) at post planting, first flower and post-harvest in 2017-18. Non-normal distribution in the 100MF treatment not included.

Averages of available manganese in all treatments in high cut, low cut and no cut areas at post plant were 34 mg/kg, 78 mg/kg and 55 mg/kg respectively (Figure 22). Available manganese concentrations in the different soil cut areas were significantly (p≤ 0.05) higher in the low cut area compared with high cut and no cut soils which were statistically similar. There was no differences according to treatments. Overall seasonal drawdown occurred relatively evenly between post-plant, first flower and post-harvest. By post-harvest manganese depletion of 74-80% of post plant concentrations had occurred with no significant difference in drawdown between the cut areas (

Table 15).

Nominal critical values that indicate a potential deficiency maybe 2 mg/kg for cotton although reliability of soil tests is low due to availability being affected by redox state, metallo-organic complexes, extraction from a number of different soil pools and moderating influences of pH. Plant uptake values have previously been determined as 236 g/ha. Therefore available soil N is 3 orders of magnitude higher than plant uptake. The early season average values indicated here fall within the range or somewhat higher than other cotton growing soils, vertisols from between Warren and Boggabilla, surveyed in 1984-1985 season (Constable et al, 1988). These produced no deficiency in plant tissues indicating these soils here are unlikely to offer limitation with respect to manganese. Although the absolute decline in manganese was 21-58 mg/kg, by the end of the season soil manganese values ranged between 6-19 mg/kg which is still above the nominal critical value, However, manganese tends to remain in boll walls rather than being predominantly redistributed to the seed and exported with only 2-5% of total uptake being exported by crops (Rochester 2007). Therefore, the decline is likely to be offset by the return of plant residues to the soil.

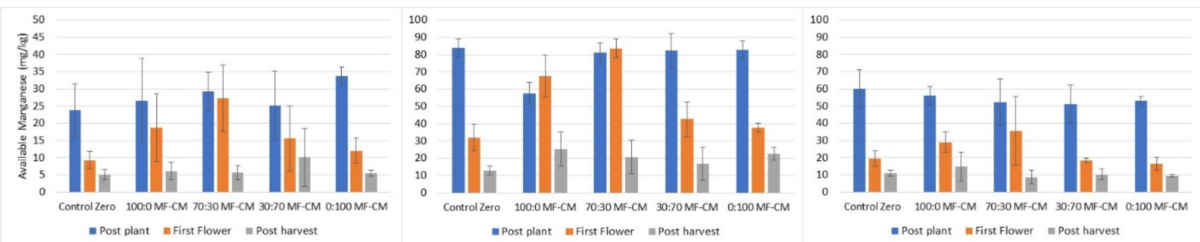


Figure 22 Changes in available Mn of 0-30 cm soil in cotton field receiving mineralfertilizer or chicken manure on a) high cut (17 cm), b) low cut (4cm) and c) no cut (0 cm) at post planting, first flower and post harvest in 2017-18.

Available copper ranged from 2.6-3.7 mg/kg across the entire trial area (Figure 23). Treatment affects for copper were insignificant (p≤0.05) in high cut, low cut and no cut soils. Measurement variability of soil copper was low compared with the other metal ions (Figure 23). Like manganese, the low cut soil had significantly (p≤0.05) higher available copper concentrations compared with the other two cut soil areas suggesting this area overall offers the highest inherent fertility and marginally higher than the no cut area. Depletion of soil available copper predominantly occurred between post plant in October and first flower (43-50%) compared with first flower to post-harvest (13-20%). The high cut area depletion was lower in the first flower to post harvest stage compared with the other two soil areas which may indicate a reduction in the availability of copper, or ability for root exploitation in this less fertile area, despite initial concentrations being similar.

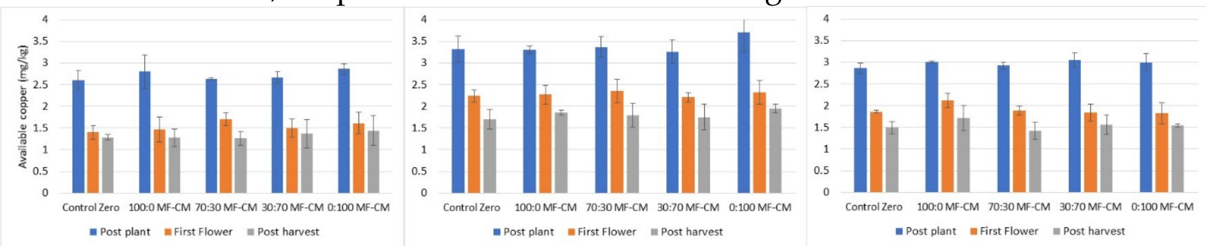


Figure 23 Changes in available Cu of 0-30 cm soil in cotton field receiving mineral fertilizer or chicken manure on a) high cut (17 cm), b) low cut (4cm) and c) no cut (0 cm) at post planting, first flower and post-harvest in 2017-18.

Table 15 Seasonal drawdown expressed as % in soil (0-30 cm) of selected macro and micronutrients at different plant growth stages in high, low and no cut soil areas, Widgelli, 2017

		Seasonal Drawdown (%)								
		Post plant-first flower	First flower-Post harvest	Post plant-Post Harvest	Post plant-first flower	First flower -Post harvest	Post plant-Post Harvest	Post plant-first flower	First flower-Post harvest	Post plant-Post Harvest
Element	High Cut				Low cut			No Cut		
TN	Control	-12.3	20.0	10.2	0.0	19.6	19.6	15.3	-1.1	19.6
	100:0 MF-CM	10.4	-4.5	6.4	20.3	29.1	43.5	11.5	13.3	43.5
	70:30 MF-CM	6.8	14.3	20.0	12.1	14.2	24.6	-4.2	36	24.6
	30:70 MF-CM	-18.9	25.3	11.3	13.1	24.2	34.1	-6.4	26.0	34.1
	0:100 MF-CM	1.5	19.8	21.0	-8	27.6	21.8	-4.6	13.5	21.8
Colwell-P	Control	-6.9	55.3	52.3	14.4	49.5	56.8	-8.5	55.2	51.4
	100:0 MF-CM	14.5	47.8	55.4	-56.5	86.1	78.3	24.4	75.5	81.5
	70:30 MF-CM	-19.7	44.7	33.8	1.4	50.0	50.7	4.09	65.6	67.0
	30:70 MF-CM	-3.0	14.6	12.0	29.5	43.9	60.4	-76.0	72.0	50.8
	0:100 MF-CM	-11.2	38.7	31.8	-8.3	49.4	45.3	-53.0	59.4	38.1
Zinc	Control	88.4	100	100	74.3	100	100	71.8	65.8	90.4
	100:0 MF-CM	85.9	100	100	15.7	100	100	73.1	75.4	93.4
	70:30 MF-CM	76.0	100	100	86.3	100	100	65.6	100	100
	30:70 MF-CM	20.6	58.4	66.9	75.6	100	100	59.7	-16.6	53.0
	0:100 MF-CM	50.0	100	100	54.1	80.3	91.0	69.9	15.5	74.6
Manganese	Control	61.4	44.8	78.7	61.9	60.3	84.9	67.5	43.7	81.7
	100:0 MF-CM	29.7	67.1	76.9	-17.4	62.7	56.2	48.3	49.0	73.7
	70:30 MF-CM	6.7	78.9	80.3	-3.2	75.2	74.4	31.9	75.3	83.2
	30:70 MF-CM	38.0	35.6	60.1	48.2	60.8	79.7	63.8	44.4	79.9
	0:100 MF-CM	64.5	54.2	83.8	54.5	40.2	72.8	69.2	42.1	82.2
Copper	Control	46.2	8.2	50.7	32.7	24.1	48.9	34.9	20.0	47.9
	100:0 MF-CM	47.9	12.6	54.4	31.3	18.2	43.8	29.4	19.2	43.0
	70:30 MF-CM	35.4	25.9	52.1	30.3	23.6	46.8	35.2	25.1	51.5
	30:70 MF-CM	43.6	9.0	48.7	32.2	20.8	46..3	39.7	15.3	49.0

	0:100 MF-CM	43.7	10.7	49.7	37.3	16.1	47.4	39.1	15.6	48.6

Decomposition and nutrient release of chicken manure using an in situ litter bag technique.

Poultry litter dry matter (DM) decomposition and nutrient release has been reported to follow a double-exponential model, as describe by Wider and Lang (1982) (*RDM and RN* = $Ae^{-kat}+(100-A)e^{-kbt}$). Decomposition in the initial period is usually rapid (Phase 1) due to a rapid increase in microbial population soon after application to the soil and easily decomposable components are released. This is then followed by a slower decomposition process (Phase 2) of more recalcitrant components (Figure 24) attributed to the stabilization of microbial population and activity. As observation in this study was centered around the DM changes and nutrients transitions in the first few weeks of Phase 2 – in the slower decomposition and nutrient release phase a single exponential model has been used in analysis (Figure 25).

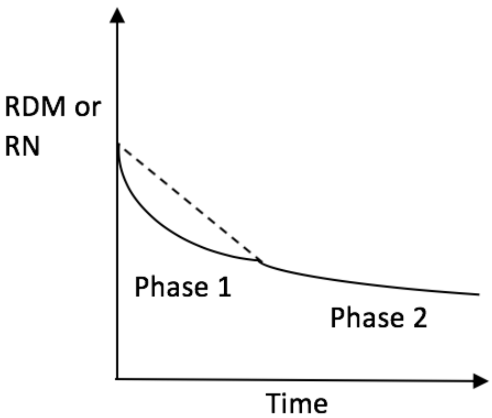


Figure 24 Remaining dry matter (RDM) or remaining nutrient (RN) graph.

The differences between the two soil types for available N release is minor. However the data indicates that combining PL with urea at a 30:70 manure:urea ratio resulted in an additional N release of 3.7% from PL on the loam and 2.43% from PL on the clay loam. The addition of urea narrowed the C:N ratio by the addition of a higher N content and may have promoted N mineralization within the manure. On the loam the 70:30 treatment had the equivalent of 24.477 kg/ha accumulated mineral N release (1% additional N release compared to 100:0 treatment) and on the clay loam this treatment had the equivalent release of 24.079 kg/ha (-0.8% less N than 100:0 treatment).

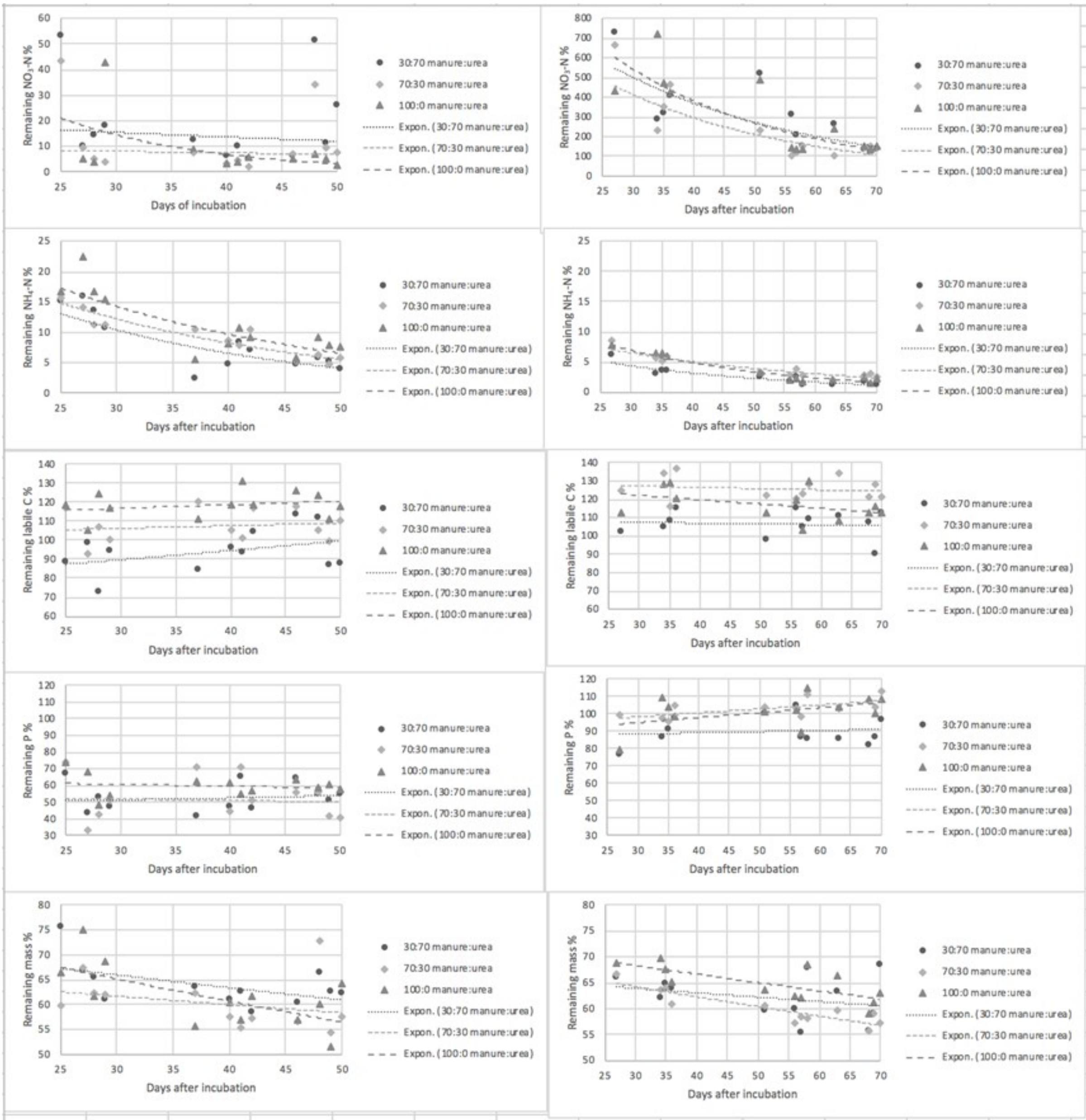


Figure 25 ***Remaining % of NO3 (a), NH4 (b), C (c), P (d) and dry mass (e) in poultry litter after field incubation in litterbags on loam and clay loam soils. Note differences in X and Y bounds.***

On the lighter loam soil higher proportions of manure:urea (100:0 and 70:30) resulted in a decline of Colwell-P from litter bags, whilst in the 30:70 manure:urea ratio an increase in the excavated litter Colwell-P was observed. Similar to the seasonal Colwell-P increasing soil trends at Whitton (Figure 15) and the main field experiment at Widgelli (Figure 19), increases occurred in the contents of the litter bag Colwell-P over time from all of the treatments buried in the heavier transitional red brown earth soil 20, 14 and 29% increase in P in 30:70, 7:30 and 100:0 manure:urea ratios respectively Figure 25. Half-lives for dry matter of approximately 450 days were calculated for the Hanwood loam and 333 days for the Griffith clay loam There was no obvious chicken manure:urea treatment effect and soil type had a stronger influence on decomposition rates than the fertilizer source ratio. Half-lives (the amount of time it takes for half of the original concentration to be released) for nitrate, ammonium and available P were 4, 21 and 72 days respectively in Hanwood loam and 27, 23 days and a growth rather than decay for P for the clay loam. The data indicate that year on year application of chicken manure would lead to an overall increase over time of dry matter with the effect being more substantial in the lighter soil type. Mineral-N in both soil types is lost rapidly, within 4-6 weeks of application suggesting little value for crop N nutrition when manure is applied in winter. The different soil types affected P release from the chicken litter quite differently. In the Hanwood loam, P release continued to occur for 140 days and therefore may act as a form of slow release. However, if application occurred in mid-winter, the duration of release may only last within the cotton season until end of October and not accumulate season on season. The growth relationship of Colwell-P in the buried chicken litter in the Griffith clay loam rather than decay suggests remineralisation of organic P and accumulation of loosely held available P on organic and/or clay surfaces.

Outcomes

5. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

The planned project outcomes were focussed on enabling growers to better integrate manure into nutrient budgets for more predictable productivity outcomes resulting in decreased synthetic fertilizer use and gain improved understanding of the full agronomic value (NPKS and micronutrients) for longer term soil nutrient balance and quality. Overall, growers and advisors would have more confidence of the value of agronomic outcomes of using manures, be more strategic with the materials in their land management and be able to be more judicious in supplementation with mineral fertilizers with associated economic and environmental benefit. Further understanding of the nitrogen losses that can occur during the storage handling and agronomic management of manures was planned to provide more transparency on the behaviour of manure nitrogen from supplier to the farm and after spreading. The emphasis of the activities were guided by grower/advisor recommendations by way of annual meetings. The work was supported by testing in commercial field trials and at the grower group- IREC research station to facilitate rapid extension of project outcomes. The outputs which to date have included annual demonstration days, articles in industry magazines, cotton conferences and R&D updates and a science journal publication have provided information on the response of cotton in integrated mineral fertilizer and manure programmes and on performance according to manure in landformed paddocks. While not able to develop widely applicable and ready to use recommendations, the project has demonstrated the response of crops to chicken wastes in the short term and identified strategic management scenarios for where most benefit might be realised. There is a significant knowledge gap in growers knowing the nutrient composition of manure batches from load to load from the same source as well as between different suppliers and different manure types. The confusion is exacerbated by total manure concentrations

i) Relatively limited productivity and soil quality benefits of chicken wastes after single year applications at realistic application rates (2t/ha-8t/ha) in combination with mineral fertilizer on clay loam soils of the Murrumbidgee Valley compared with mineral fertilizers alone. High rates of chicken manure (16t/ha) can completely replace mineral fertilizer although limited to one season. Going forward, there should be a focus towards P and Zn rather than N as the budget of these nutrients are likely to be more affected by intensive manure regimes at practical application rates. Selection of targeted low fertility or problem soils is important to enable demonstration of what organic wastes can and cannot do especially within the limits of 3 year funding cycles and commercial crop rotations.

ii) Improved understanding of the interactions between mineral N fertilizers and manures and management practises in southern soils will provide further industry insights on the impact and value of long term use of organic wastes through trials on a number of sites in the region. These data and findings may contribute to updating industry nutrient advice such as modules in myBMP with latest information and the development of decision support tools and apps for more rational use of manures compared with inorganic fertilizers.

iii) The project has verified the large variation in the nutrient composition within and between different manure and chicken litter batches and compositional confusion for end users is exacerbated by total nutrient concentrations, available nutrient concentrations and release rates. There is a need for better linkage through the manure generation, distribution and grower value chain if there is to be a practical transformation in cotton industry reuse of quite significant regional resources of N, P and K; 5400, 2246 and 5200 tonnes respectively in chicken litter in the Murrumbidgee Valley.

iv) Losses of ammonium-N between delivery of raw chicken manure and spreading were only 1.3% in manure piles stored on farm for 37 days, likely caused by maintenance at pH 6 and almost all available N (85%) contained within organic-N such as uric acid and proteins and not yet transformed to ammonium.

v) The project has provided plant growth characteristics and rates of both macro and micro nutrient in plants at different growth stages and amounts exported in seed for nutrient budgeting. Plants with high rates of manure on heavily cut landformed areas had increased vegetative growth (plant height) but node, number of bolls and yield was unaffected. The amounts obtained from a 12 bale crops at both Whitton and Widgelli were high compared with previous studies from ACRI crops and suggest luxury crop uptake which indicates overuse of fertilizers and inefficiencies. Therefore, careful site selection and paddock history and testing the use of manure to address specific problems or on specific soil types is necessary to develop useful and valuable strategies.

vi) The project has provided some indications of the half lives of chicken litter in free draining (Hanwood Loam) and tighter (Transitional red brown earth) soil types using a buried litter bag technique. Half-lives for incorporated chicken litter dry matter mass of 450 days were calculated for the Hanwood loam and 333 days for the Griffith clay loam. There was no obvious chicken manure:urea treatment effect and soil type had a stronger influence on decomposition rates than the fertilizer source ratio. Half-lives (the amount of time it takes for half of the original concentration to be released) for nitrate, ammonium and Colwell P were 4, 21 and 72 days respectively in Hanwood loam and 27, 23 days and a growth rather than decay for P for the clay loam. The data indicate that at the high application equivalent rates used here (22t/ha), year on year application of chicken manure would lead to an overall increase over time of dry matter with the effect being more substantial in the lighter soil type. Mineral-N in both soil types is lost rapidly, within 4-6 weeks of application suggesting little value for crop N nutrition when manure is applied in winter. The different soil types affected P release from the chicken litter quite differently. In the Hanwood loam, P release continued to occur for 140 days and therefore may act as a form of slow release. If application occurred in mid-winter, the duration of release may only last within the cotton season until end of October and therefore be available around planting but not accumulate season on season. Unexpectedly, available P tended to show a growth relationship in the buried chicken litter in the Griffith clay loam rather than decay. Available phosphorus increase between post plant and first flower soil samplings was also a consistent feature observed in the main field trial and suggests remineralisation of organic P and accumulation of loosely held available P on organic and/or clay surfaces.

N release was not affected according to soil type amounting to 24 kg/ha of N from an initial equivalent application rate of 250 kg manure N/ha (included organic release of 50%). The field data suggest that over the period of the incubation experiment only mineral_N originally present in the litter was released with no transformation and release of organic N unless it occurred as small organic forms such as amino acids which were not measured here. Available P release patterns did not follow the expected exponential decay but actually maintained or increased in concentration in buried bags containing chicken litter which had undergone 3 flood

irrigation events. This pattern was more accentuated in the clay loam than the loam soil likely cause by greater leaching following irrigation in the lighter soil type.
vii) An additional outcome of the project has been an assessment of a set of spectral indices obtained from an unmanned aerial system (drone) for tracking spatial and temporal variability of nitrogen status as well as predicting lint yield. Early in the season when fertilizer is still being considered for top dressing, the simplified canopy chlorophyll content index (SCCCI) was the index that best explained the variation in N uptake and N% between treatments. SCCCI and NDRE were able to predict lint yield from 83 DAS. Overall, this study shows the practicality of using an UAS to monitor the spatial and temporal variability of cotton N status in commercial farms. It also illustrates the challenges of using multi-spectral information for fertilization recommendation in cotton at early stages of the crop.

6. Please describe any:-
- **a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);**
- **b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and**
- **c) required changes to the Intellectual Property register.**

Spatial and temporal variability assessment of nitrogen status and lint yield prediction in cotton from unmanned aerial system imagery

The work assessed the usefulness of a set of spectral indices obtained from an unmanned aerial system (UAS) for tracking spatial and temporal variability of nitrogen (N) status as well as for predicting lint yield in a commercial cotton farm. Organic, inorganic and a combination of both types of fertilizers were used to provide a range of eight N rates from 0 to 370 kg N/ha. Multi-spectral images (reflectance in the blue, green, red, red edge and near infrared bands) were acquired on seven days throughout the season, from 62 to 169 days after sowing (DAS), and data were used to compute structure- and chlorophyll-sensitive vegetation indices (VIs). Above-ground plant biomass was sampled at first flower, first cracked boll and maturity and total plant N concentration (N%) and N uptake determined. Lint yield was determined at harvest and the relationships with the VIs explored. Results showed that differences in N% and N uptake between treatments increased as the season progressed. Early in the season, when fertilizer applications can still have an effect on lint yield, the simplified canopy chlorophyll content index (SCCCI) was the index that best explained the variation in N uptake and N% between treatments. All the indices were significantly correlated with both N% and N uptake at first cracked boll and maturity, when the highest correlations were obtained. The normalized difference red edge index (NDRE) and SCCCI generally yielded the highest coefficient of determination. Treatments with the highest N rates (from 307 to 340 kg N/ha) had lower normalized difference vegetation index (NDVI) than treatments with 0 and 130 Kg N/ha at the first measurement day (62 DAS), suggesting that factors other than fertilisation N rate affected plant growth at this early stage of the crop. This fact affected the earliest date at which the structure-sensitive indices NDVI and the visible atmospherically resistant index (VARI) enabled yield prediction (97 DAS). SCCCI and NDRE were well correlated with lint yield from 83 DAS. Overall, this study shows the practicality of using an UAS to monitor the spatial and temporal variability of cotton N status in commercial farms. It also illustrates the challenges of using multi-spectral information for fertilization recommendation in cotton at early stages of the crop.

Keywords: multi-spectral imagery; nitrogen uptake; plant nitrogen content; precision agriculture

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

There are large and readily available supplies of organic materials and associated nutrients in the southern cotton growing region that are in close proximity to cotton production areas from the burgeoning poultry industry and other more minor supplies of cattle and piggery manures. This readily available supply makes manure management of great interest to growers as there is a general understanding that increasing soil organic matter improves soil sustainability in the long term. However, manure is generally applied on convenience based and a feel good factor rather than research based strategies. There are a lot of unknowns on production impacts and best application according to soil type and in newly developed areas for maximum effect and whether year on year manure application is really making any difference. The impacts and results of this project have aimed to improve understanding of how manure might be able to reduce the application of conventional synthetic fertilizers through definition of its fertilizer replacement value and avoid further over application of nutrients causing inefficiencies. To date observations in loams and clay loams have shown little impact of manure application alone or integrated with a mineral fertilizer strategy compared with mineral fertilizer on productivity or soil benefit in the short term even at high rates. Manure decomposition rates indicate that dry matter of chicken litter will accumulate over time with repeated annual applications at high rates. Short term nutrient release of mineral N last only 4-6 weeks after application and so is inconsequential, however, nutrient release of P and Zn from chicken litter may offer useful fertilizer replacements.

Extension Opportunities

8. Detail a plan for the activities or other steps that may be taken:
(a) to further develop or to exploit the project technology.

There is a need for ongoing education and training programmes around the value of applying manure long term with respect to yield benefit vs fertilizer replacement value vs soil sustainability and quality. Although there is a feel good factor in application, the actual economic value and advantages over mineral fertilizer within irrigated crop rotations and Riverina soil types remains ambiguous.

The experiments carried out to determine synergistic effects of manure:urea combinations, manure as a complete P fertilizer and effects of manure in ameliorating heavily cut areas in newly developed areas are mid-way through. Both of these will be repeated for a second year in 2018-19 in the follow on manure management project DU1903. A new site has been planned to begin in 2019 at Websters Kooba Station comparing effect of chicken litter on heavily cut areas of new cotton land compared with gypsum with commitment for a 3 year trial.

Ms Anika Molesworth, Deakin PhD candidate and Young Cotton Champion 2018 will complete her PhD thesis mid 2019 which will allow combined analysis of two years of data from the Deakin research site examining effect of banded vs incorporated chicken litter on productivity, nutrient efficiency and release rates. The work will complete the publication of the litter bag experiment and investigate the impacts of amendments on soil microbial activity.

Datasets from the project will be used in a collaborative NLP project with QUT (P. Grace et al) with the main aim of linking manure generators with analytical labs to allow more transparency for growers on the composition of organic wastes. The main outcome is the development of a farmer decision support tool in the form of an app that will enable growers to better refine the supplementation of mineral fertilizer programmes with organic amendments so that crop and soil benefits are more predictable. Nitrous oxide emissions from cotton organic amendment trial sites will also be monitored within this project.

(b) for the future presentation and dissemination of the project outcomes.

The strategy for manure application remains convenience based rather than research based. The data collection and trials in this project have begun a concerted effort to provide key learnings to focus on the aspects of nutrition that these materials can impact in Riverina soil types e.g N mineralisation, reduced fertilizer N requirement, P,K,S and Zn and cut area amelioration.

The industry needs a clear message on the response of cotton to organic amendments by presenting the findings of the trials in this project, follow on project DU1903 and the organic amendment trial in northern soils from UQ1302. The findings may temper the expectations around the use of these materials by a realistic assessment of what they can and what they cannot achieve and help identify where most benefit might be realised for strategic management. However, this may provide a conflicting message to the general positive perceptions of the effect of soil organic matter on soil sustainability.

There are a number of publications in various stages of preparation for submission to journals (for example litter bag experiment, effects of banded vs incorporated chicken litter, and integration of data from Whitton and Widgelli sites being planned.

(c) for future research.

Focus on manure phosphorus and zinc for use as a practical valuable contribution to cotton nutrient budgets

Better definition of organic amendment composition for best practise management throughout the supply chain.

Benefits of deep placement of chicken litter in sodic or problem soils.

9. A. List the publications arising from the research project and/or a publication plan.

(NB: Where possible, please provide a copy of any publication/s)

Journal Publication

Ballester, C, Hornbuckle, J., Brinkhoff, J. and Quayle, W. (2017)
Assessment of in-season cotton nitrogen status and lint yield prediction from unmanned aerial system imagery. Remote Sensing 9, 1149

Industry press articles and dissemination.

Quayle, W. (2015). Optimising the use of manures in southern cotton production. Australian Cottongrower Oct-Nov, 2017 Dec 2015-Jan 2016.

2016 IREC Field station open day. Flier. Optimising the use of manure in southern cotton.

Ballester, C and Quayle, W. (2016). Monitoring crop N status. Spotlight Spring edition, 2016. p.19.

Pirie, R., Redding, M., Quayle, W. Berg, S (2017). Realising the Poo-tential of manure derived fertiliser. Australian Cottongrower Oct-Nov, 2017.

Conferences and Meetings.

First year presentation CRDC R&D update meeting, September 2016, Yanco.

Second year presentation, CRDC R&D update meeting, August, 2017, Yanco.

Third year presentation, CRDC R&D update meeting, August, 2018, Yanco.

Molesworth, A and Quayle, W. Cotton Research Conference, Canberra
Quayle, W. A. Molesworth, C. Ballester, J. Hornbuckle. Using chicken litter to improve the performance of cotton production in laser levelled paddocks.

Future Publications in Preparation

Quayle, W.C Ballester, C and Hornbuckle, J. In prep. Effect on cotton productivity, plant nutrient uptake and soil nutrient export from the integrated use of inorganic fertilizer and poultry litter.
Molesworth, A and Quayle, W.C. In prep. Potential mineralisation of C, N and P and availability to irrigated cotton in two soil types amended with chicken litter and urea under field conditions.

B. Have you developed any online resources and what is the website address?

N/A

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

Many cotton crops and processing facilities in the southern cotton growing region of Australia are located in close proximity (< 50 km) to chicken production (meat and eggs), which has also increased significantly in recent years. Around Griffith, NSW, it is estimated that poultry production is currently generating approximately 10,000 m^3/week of manure and chicken litter (raw manure + bedding material which is usually rice hulls or sawdust). Considering average values of plant total nutrients as 2.5%N, 1.2% P, 2.8 % K, our estimates suggest that on an annual regional basis, there maybe 5400 tonnes of N, 2246 tonnes of P and 5200 tonnes of K. These are sizeable amounts of nutrient resources which have the potential to be relatively easily reused for productive purposes in an economically attractive way for farmers. Coincidentally, this re-use may contribute to offsetting the amount of artificially produced fertilizers that are applied regionally, which may reduce negative environmental impacts.
A significant number of growers (> 50%) are applying the available chicken wastes to their land, mainly with a view to maintain or enhance yield through the soil fertility benefits that organic amendments can offer (nutrient efficiency and biological and physical property maintenance and improvement). The organic materials are not usually applied as fertilizer replacements, rather, in addition to conventional fertilizers as there is a lack of adequate manure management recommendations for use in cotton production under different soil types and cropping systems. The usual rates of 2-5 t/ha of animal manure applied are convenience based rather than research based and can't be relied upon in high yield cotton systems without supplemental N and other nutrient fertilization.
The productivity responses of cotton crops in major irrigated soil types of the Australian southern region to organic amendment types, rates and frequency and placement of application, alone or in combination with fertilizers is unknown. The nutritional value, extra profit and soil sustainability measures that the organic products provide in the short and long term compared with fertilizers are ambiguous and difficult to predict. One particular reason for this is that manures vary greatly in their composition and degree of stabilization. Chicken litter available N, P, K composition and moisture content can vary by 2-10 times from one batch to

another. To successfully manage nutrient cycling and availability to crops from chicken litter it is necessary to know the decomposition and nutrient release rate in the soil to which they are being applied.

This project undertook a field research programme to determine cotton crop productivity, nutrient efficiency and nutrient export in trials comprised of different combinations of inorganic fertilizer and chicken litter or raw chicken manure compared with mineral fertilizer only nutrient programmes. Changes in soil nutrient, physical and biological responses were monitored. The trials are ongoing and so only short term implications are reported.

The research findings have been that in the short term, there are limited productivity benefits obtained from the use of integrated mineral fertilizer:chicken organic amendment combinations compared with traditional synthetic fertilizers. High rates of chicken manure as a proportion of available N increased plant height compared with inorganic fertilizer but had no effect on number of nodes, boll numbers or lint yields. First flower N uptake data and the trends at defoliation in the cotton productivity components indicate some increasing trends in productivity as the proportion of applied N as manure increases. However, at this stage there is no indication that there is a synergistic effect from integrating mineral and manure N that enhances yield or N uptake compared with mineral fertilizer only. Significant differences in uptake of a wide range of nutrients were observed according to depth of landform cut rather than treatment effects within different cut depths.

Across all treatments there was relatively high levels of macro and micronutrients exported in seed suggesting plants grew in luxury conditions, offsetting risk but with associated inefficiencies. Extra export of nutrients from manure dominated treatments were not observed.

Increases in major soil nutrients occurred over the period pre-plant to FCB from the amendment additions compared to control and mineral only fertilizer. However, by the time first flower had been reached there were insignificant differences between the treatments including the control for mineral N. For Colwell-P an elevated spike occurred around the first irrigation after sowing followed by a decline but then a gradual maintenance or increasing trend as the season progressed. The Colwell-P data suggests remineralisation of soil P is occurring with release from either organic or other inorganic P soil pools. However, the effects seem more likely to be caused by abiotic factors than microbially mediated. There were insignificant differences in soil aggregates, dispersion and biological activity as a result of treatment manure addition.

Half-lives (the amount of time it takes for half of the original amount to remain) for incorporated chicken litter dry matter mass of 333-450 days were calculated and varied according to soil type. The data indicate that at the high application equivalent rates used here (22t/ha), year on year application of chicken manure would lead to an overall increase over time of dry matter. Mineral-N in both soil types is lost rapidly, within 4-6 weeks of application suggesting little value for crop N nutrition when manure is applied in winter. Valuable contributions to cotton nutrient budgets of Colwell-P and Zn maybe gained from manure amendment and should be targeted rather than nitrogen in further investigation

Selection of targeted field sites is important to enable demonstration of what organic wastes really can and cannot do especially within commercial crop rotations.