Importance of timing N application for meeting irrigated cotton demands

Tim Weaver[1*], Ian Rochester[1], Kellie Gordon[1], and Michael Bange[2]

[1] CSIRO Agriculture & Food, 21888 Kamilaroi Highway, Myall Vale, NSW 2390, www.csiro.au, Email: tim.weaver@csiro.au

[2] GRDC, 214 Herries St, Toowoomba, QLD 4350, www.grdc.com.au Email: Michael.Bange@grdc.com.au

Abstract

Nitrogen strategies used in the Australian cotton industry include: a single, split, fertigation, and foliar applications. All strategies usually start with a single application early; however, all involve several additional in-crop applications as a "peace of mind" strategy to ensure every chance is given to reach optimum yield. Five field experiments were undertaken from 2013 to 2016 to investigate N timing application strategies. The experiments included single applications (200 kg N/ha) in either July, September, December, January or February, or split applications applying nitrogen firstly in September with further applications in either December, January or February. Yield, N uptake, and internal nitrogen use efficiency (iNUE - kg lint/ kg N Uptake per ha) were captured from the experiments. The results showed that there was no yield penalty across the various N application strategies over the three seasons, however, N uptake was highest for split applications (>300 kg N/ha) and lowest for late single applications (111 kg N/ha). The iNUE was highest (19) for the late single application in February and lowest (9) for split applications, where the second application was higher (120 kg N/ha) than the first application (100 kg N/ha). Varying the timing of N (single or split) did not impact yield and suggests that adequate mineralisation was occurring. These factors, combined with an adequate single application (e.g. 200 kg N/ha in September), suggests that no additional N would be required. Later applications of N are not critical when levels are adequate and mineralisation is occurring, highlighting the need to sample for N with plant-based techniques to avoid over-fertilisation and to improve efficiency.

Keywords

Timing of nitrogen, cotton, irrigation, nitrogen use efficiency.

Introduction

Nitrogen application strategies are possibly one of the most researched topics in agriculture, yet we continue to research optimum timing for in-crop applications to ensure we reach peak yield (Constable and Bange 2015; Khan et. al 2017). Strategies in the cotton industry have included various methods with different products, e.g. anhydrous ammonia, urea granular (slow-release urea such as ENTEC®, liquid run urea – Easy N) and blends. Strategies to apply N have varied from all applied in a single pre-season to split application, and applied using different technologies such as fertigation (applying N through irrigation – liquid run urea or anhydrous gas), side dressing and foliar (applied using aircraft or ground rigs).

Much conjecture exists about the need to have multiple applications of N to achieve high yields (Rochester and Bange 2016; Rochester and Constable 2015)). Fertiliser use efficiency is an important issue for growers in optimising cost and for environmental considerations regarding greenhouse gas emissions (Antille and McCarthy 2016; Macdonald et. al 2018; Maraseni et. al 2010;). As such, cotton research has a strong responsibility to improve nutrient use efficiency: from fertiliser to soil, soil to crop, and from crop to yield. This study was undertaken to improve and understand the impact of N timing on yield and nitrogen use efficiencies.

Methods

Site description

The experiments (Exp.) were located in Field 6 at the Australian Cotton Research Institute, Narrabri (149.68E, 30.28S), New South Wales, Australia. The soil is a fertile alkaline dark greyish brown cracking medium clay, classified as a fine, thermic, montmorillonitic Typic Haplustert. Annual rainfall averages 645 mm but is highly variable (420 and 870 mm for first and ninth deciles) and is slightly summer-dominant. The experiments were established with a randomised complete block design with four replicates for the N applied split application trials and six replications for the N applied single application experiments. Nitrogen was applied using a Gessner-Walker rig fitted with a Simplicity air seeder box delivering urea through John Shearer double disc openers. The urea was side dressed in-crop ~10 cm each site of the plant line.

Experiments and treatments

The five experiments and their nitrogen timing treatments are shown in Table 1. Experiments 1 and 4 addressed single applications of 200 kg N/ha from July to February and experiments 2, 3 and 5 addressed split applications from September to February. The split applications reflected industry practice and to better understand the efficiencies of various timings during the season and the value for improving yield.

Table 1. Experiments and Nitrogen timing and rate treatments (kg N/ha) undertaken from 2013 to 2016 in Field 6 at the Australian Cotton Research Institute, Myall Vale NSW. Controls had no N fertiliser applied.

Cotton Seasons		July	Sep	Dec	Jan	Feb
2013/14 Exp. 1	Control	-	-	-	-	-
	Tr. 1	200	-	-	-	-
	Tr. 2	-	200	-	-	-
	Tr. 3	-	-	200	-	-
2014/15 Exp. 2	Control	-	-	-	-	-
	Tr. 1	-	100	120	-	-
	Tr. 2	-	100	-	120	-
	Tr. 3	-	100	-	-	120
2014/15 Exp. 3	Control	-	-	-	-	-
	Tr. 1	-	200	-	-	-
	Tr. 2	-	200	60	-	-
	Tr. 3	-	200	120	-	-
	Control	-	-	-	-	-
2015/16 Exp. 4	Tr. 1	-	200	-	-	-
	Tr. 2	-	-	200	-	-
	Tr. 3	-	-	-	200	-
	Tr. 4	-	-	-	-	200
	Control	-	-	-	-	-
2015/16 Exp. 5	Tr. 1	-	200	-	-	-
	Tr. 2	-	120	80	-	-
	Tr. 3	-	120	-	80	-

- denotes zero applied N

Lint Yield and Biomass

Lint yield was determined using a CASE 1822 single row plot picker. The plots were 4 rows wide and 16 metres in length. The total of one 16 metre row was picked for yield. Aboveground biomass was collected (2 metres) from each plot with a subsample dehydrated at 70ºC and analysed for Total N to calculate plant N uptake.

Internal Nitrogen Use Efficiency (iNUE)

N uptake was calculated using the analysis from whole plant samples. Total N was determined using Kjeldahl Distillation method (Rayment and Lyons 2011).

The iNUE was calculated as: kg lint / kg crop N uptake per hectare. Genstat 14 (Payne et. al 2011) was used to test differences in N Uptake, iNUE and Lint Yield.

Results

N Uptake

There were no significant differences in N Uptake for Experiments 2, 3 and 5 where splitting N applications occurred. It did not matter how the split occurred, with either 100, 120 or 200 applied in September with further applications added in either December, January or February (Table 2). The only significant differences were shown in experiments 1 and 4 (Table 2) where N applications were not split. In experiment 1, the control was the only treatment that was significantly different. In experiment 4, the very late application of 200 kg N/ha in February and pre-season application were significantly different to treatments 2 and 3. Applying a single application of 200 kg N/ha very late in the season was shown to have the lowest N Uptake (Table 2). The maximum uptake was observed in treatments 2 and 3 where 200 kg N/ha was applied in December or January, the optimum time when cotton plants take up N. The highest N uptake observed from all five experiments was during the 2014/15 season for treatments 1 and 2 where 100 kg N/ha was applied in September followed by a further 120 kg N/ha applied in either December or January; similarly the optimum time when cotton plants take up N.

iNUE

The only experiment to show a significant difference in iNUE was Exp. 4, where 200 kg N/ha was applied as a single application in either September, December, January or February. The highest iNUE was for treatment 4 (Table 2) at 19 kg of lint per kg of N/ha taken up. The actual nitrogen fertiliser use efficiency (NFUE = kg lint per kg N/ha applied) was only 10 (the mean for all treatments was 11 compared to the industry target of 13-18 kg lint/kg of fertiliser N applied).

Table 2. The nitrogen uptake (kg N/ha), internal nitrogen use efficiency (iNUE) and yield (bales/ha) for the five (5) timing of N experiments from 2013 to 2016. A bale is 227 kg of lint.

Cotton Seasons		N Uptake (kg N/ha)	iNUE	Yield (bales/ha)
2013/14 Exp. 1	Control	134a**	14ns	8a***
	Tr. 1	245b	12ns	13b
	Tr. 2	251b	12ns	13b
	Tr. 3	278b	10ns	12b
2014/15 Exp. 2	Control	271ns	10ns	12ns
	Tr. 1	313ns	9ns	12ns
	Tr. 2	335ns	9ns	13ns
	Tr. 3	299ns	9ns	12ns
2014/15 Exp. 3	Tr. 1	205ns	11ns	16ns
	Tr. 2	209ns	10ns	16ns
	Tr. 3	208ns	10ns	16ns
2015/16 Exp. 4	Tr. 1	156ab	15ab	10ns
	Tr. 2	185b	12a	10ns
	Tr. 3	187b	12a	9ns
	Tr. 4	111a**	19b**	9ns
2015/16 Exp. 5	Tr. 1	233ns	14ns	13ns
	Tr. 2	211ns	14ns	12ns
	Tr. 3	186ns	15ns	13ns

Note. ns = not significant and a & b indicate statistical differences between treatments and the level of significance indicated as P<0.01**, P<0.001***. Tr. = Treatment. Exp. = Experiment.

Lint yield

There were no significant differences in yield for all experiments from 2013 to 2016, apart from the control in experiment 1 (Table 2). The highest yield was achieved in the 2014/15 season (16 bales/ha) and lowest in the 2015/16 season (9 bales/ha). There was no yield penalty under all the timing of N experiments.

Discussion

Although there were N uptake differences for some seasons, they did not impact yield. The mineralisation in Field 6 in all seasons provided enough N to sustain growth until the applied N became available. The more sustainable and higher efficiencies were the single applications in December or January, allowing time for the N to be taken up maintaining yield. Splitting applications did not provide better efficiencies. The high yields that were achieved in the 2014/15 season (16 bales/ha) showed that it did not matter if N was supplied as a single or split application. There was no yield gain either by adding the extra N in December or January for the 2014/15 season.

The outcome from the five experiments would suggest that single pre-season applications of N (200 kg N/ha) will supply enough N for the remainder of the season. To alleviate concerns, it would be suggested to monitor in-crop N status up to January for deficiencies and supply any shortfall. The outcome from this research, however, would suggest that further N applications when there is already adequate N and mineralisation occurring would not provide any yield benefit. The positive of a single application has other implications for the possible reduction in nitrous oxide emissions and would reduce extra labour and machinery costs and losses during delivery through fertigation practices.

Conclusion

Single or split applications of N in irrigated cotton systems did not impact yield. There were no benefits for splitting applications of N and mineralisation was providing enough from previous seasons. To ensure optimum crop health and to have “peace of mind”, it is suggested that in-crop monitoring is the best strategy as is currently practiced. As this study highlights, it is important to know whether the crop is showing deficiencies, hence the reason for monitoring the crop in-season and knowing the N status of the soil. It is important in our high yielding systems to maintain fertility. A single application of N annually followed by in-crop monitoring could provide many economic and environmental benefits.

Acknowledgement

Support from the Cotton Research and Development Corporation is gratefully acknowledged. Australian Cotton Research Institute farm staff for managing the experiments. Dr Ian ‘Rocky’ Rochester may you rest in peace.

References

Antille DL and McCarthy A (2016) Field scale evaluation of furrow fertigation using liquid nitrogen. our fibre, our focus, our future. In: Cotton Research and Development Corporation, 17th Australian Cotton Conference. 5–7 August 2016, Gold Coast, Australia.

Constable GA and Bange MP (2015) The yield potential of cotton (*Gossypium hirsutum* L.). Field Crop Research 182:98–106.

Khan A, Tan DKY, Munsif F, Afridi MZ, Shah F, Wei F, Fahad S and Zhou R (2017) Nitrogen nutrition in cotton and control strategies for greenhouse gas emissions: a review. Environmental Science and Pollution Research 24, 23471-23487.

Macdonald BCT, Latimer JO, Schwenke GD, Nachimuthu G and Baird J (2018) The current status of nitrogen fertiliser use efficiency and future research directions for the Australian cotton industry. Journal of Cotton Research 1:15. (https://doi.org/10.1186/s42397-018-0015-9)

Maraseni TN, Cockfield G, Maroulis J (2010) An assessment of greenhouse gas emissions: implications for the Australian cotton industry. Journal of Agricultural Science 148:501-510.

Payne RW, Murray DA, Harding SA, Baird DB, Soutar DM (2011) An introduction to GENSTAT for Windows. 14th Edition (VSN International: Hemel Hemstead, UK).

Rayment GE and Lyons DJ (2011) Soil Chemical Methods – Australasia. CSIRO Publishing. Collingwood. Vic.

Rochester IJ and Bange M (2016) Nitrogen fertiliser requirements of high-yielding irrigated transgenic cotton. Crop and Pasture Science 67:641–648.

Rochester IJ and Constable GA (2015) Improvements in nutrient uptake and nutrient use-efficiency in cotton cultivars released between 1973 and 2006. Field Crop Research 173:14–21.