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COTTON RESEARCH COUNCIL

FINAL REPORT

Project number: DAN 2L

Project title: PHYSIOLOGY OF COTTON GROWTH AND DEVELOPMENT

Field of Research: AGRONOMY Field code 3

Organisation: Department of Agriculture, NSW
P O Box K220
HAYMARKET NSW 2000

Principal Researcher: Dr G A Constable, M.Sc.Agr.,Ph.D.
Senior Research Scientist
Agricultural Research Station
PMB Myall Vale Mail Run
NARRABRI NSW 2390 (067) 931105

Administrative Contact: Mr G M Mohr, Research Coordinator
(02) 2175130

Objectives

- Determine optimum nitrogen rates for cotton under a range of conditions.
- Determine the best time to apply this nitrogen.
- Measure the pattern of nitrogen uptake in relation to rate and timing and hence calculate fertiliser recovery.
- Examine the relationship between soil nitrate test and subsequent nitrogen extraction by a cotton crop.
- Measure cotton crop requirements of the trace elements zinc, copper, iron and manganese.
- Measure the effects of plant spacing, temperature and light on leaf growth in cotton.
- Measure the penetration of light through cotton canopies.
- Map the production and survival of cotton fruit.
- Use the leaf growth, light interception and fruit map data to develop simulation models for cotton.

Some success was achieved in all objectives. A summary of results from the major projects follows. More comprehensive results of all topics are attached. Difficulties encountered are outlined in the projects where they occurred.

RESULTS

Nitrogen fertiliser

Nitrogen is the main fertiliser element required on cotton in Australia and high rates are sometimes required for maximum yield. However, excessive nitrogen fertiliser can create production problems such as delayed maturity and reduced fibre quality. Therefore there is a definite optimum rate required. This optimum rate for any field varies with season, rotation, soil type and soil condition. This project aimedto improve the methods of deciding on nitrogen rates so that fertiliser efficiency and crop returns could be optimised.

In each of the three seasons up to 1985/86 there has been a large experiment at the Research Station with N fertiliser rates and timing as treatments. These experiments were extensively sampled for N uptake and yield. In addition, a total of nine experiments on commercial farms were also sampled, but less intensively.

N fertiliser rates which allowed the crop to extract a total of about 100 to 110 kg N/ha gave maximum lint yield. There are two components of N response which have great importance: 1. Available 'native' soil N
2. Recovery of fertiliser N

It has been found that crop history has a strong influence on available native soil N. For example unfertilised cotton can extract about 70 kg N/ha from soil which has had a short fallow after wheat, but only 50 kg N/ha from soil which had cotton the previous summer. A soil nitrate test taken in September to a depth of 30 cm can give a fairly reliable indication of how much N a cotton crop can extract from that soil over the next season. A correlation coefficient of 0.87 has been obtained for this relationship, indicating that the industry can use this soil test as a guide to N fertiliser rates.

Recovery of fertiliser N averages about 45%. Earlier reserch has established that waterlogging and water stress can reduce fertiliser recovery. Experiments in this project have clearly demonstrated that fertiliser recovery can also be reduced for late (after flowering) N applications.

A summary of N fertiliser recovery from the major experiments in this project are as follows:-

(% of added fertiliser N taken up by cotton crop)

Season and site	Application time		
	Presowing	Post sowing	
		Nov or Dec	Jan
1983/84	39	48	27
1984/85	36	22	28
1985/86 A	33	31	
1985/86 B	56	19	
Mean	41	29	

As a rule of thumb, sites which require a total N fertiliser rate in excess of 140 kg N/ha will benefit from having the N application split, with approximately $^2/3$ before sowing and the last $^1/3$ before flowering.

The benefits to the industry of the refinement of N fertiliser rates and strategies are that maximum benefit will be obtained from the N, without any problems associated with excessive rates.

The results now have direct application in the cotton industry. A computer program NRATE has been written and installed in the SIRATAC system where information on crop history, location and soil or plant test values can be entered to obtain a suggestion on N rate for cotton.

Trace elements

Questions are often raised about whether trace elements are required on cotton. Zinc deficiency has been confirmed in areas where topsoil has been removed, and zinc application is common in many areas, despite a lack of evidence for a general response.

With this background it was decided to sample soil and plants from a number (35) of cotton fields from Warren to Boggabilla. The soil was sampled to 30 cm depth as near to planting time as possible. Leaf and whole plant samples were taken from the same fields during flowering. These samples were analysed for zinc, copper, iron and manganese. In addition plant samples were taken at regular intervals from experiments at Narrabri to determine the pattern and extent of uptake of each trace element.

The precise aims of the project were to determine the timing and amount of trace element uptake by cotton and to measure the range of trace element levels in soils. The extent of any deficiency and methods of correcting the deficiency can then be approached in a scientific fashion. For example, timing of uptake could indicate the best application times, and the survey may indicate the most responsive sites.

Samples were taken during the 1984/85 season, and other than slow emergence at some sites, the climate was ideal for high cotton yields. It must be emphasised that this was not a random sample of fields. On most occasions, the owner/manager/agronomist was asked to nominate some field(s) from which samples could be taken. Most people nominated fields which they had an interest in, or a suspicion about. There were only two instances where soil test values were less than the corresponding nominal critical value. There were no occasions when plant tissue levels indicated deficiency.

In terms of total uptake of trace elements, iron was taken up in greater amounts (600 g/ha), followed by manganese (450 g/ha), zinc (60 g/ha) and least for copper (20 g/ha). To put these values into perspective, the desired uptake of nitrogen by cotton is about 110 kg/ha; or more than five thousand times the copper uptake.

Of equal interest was the relationship between soil test and plant test: at best there were only slight correlations for zinc, iron and manganese. The DTPA (eg CFL test) extraction was best for zinc and iron; the EDTA (eg Quantum test) extraction was best for manganese. There were no statistical correlations between copper soil tests and copper levels in the plant.

The best relationships for zinc, iron and manganese were between soil test and trace element uptake rather than the content in the leaf blade. In fact the site with the lowest zinc content in the leaf blade, actually had large plants and a very high yield.

The timing of uptake presented some surprising trends. Copper and zinc appeared to be taken up throughout the season. By contrast, iron was taken up early in growth with the peak iron uptake occurring before flowering. The timing of manganese uptake was intermediate.

It must be concluded that the sites sampled in this season were not deficient in any of the trace elements measured. Zinc status was relatively lower than copper, iron or manganese. It is therefore impossible to suggest that the nominal critical values for soil and plant tests are adequate, or even whether soil or plant tests are adequate. The survey indicated lowest soil and plant zinc levels in the Garah area of the Gwydir Valley. This would appear to be the most likely area to experiment with zinc.

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RECOMMENDATIONS FOR FUTURE RESEARCH

Movement in the cotton industry towards alternative methods of tillage means that there can be many instances when different N practices are required. Research is required on N response to urea either applied in the solid form or applied in the irrigation water. Most cotton growers apply N fertiliser during the winter before a crop is grown. This is earlier than the ideal date to sample for soil nitrate so research is required on the factors affecting transformations of N in the soil, so that soil samples taken in winter can be interpreted better. These gaps in our knowledge are being addressed by the new CRC project number DAN 25L "Effect of Tillage Practice on Nitrogen Fertiliser Strategy and Soil Structure".

LIST OF PUBLICATIONS

Scientific:

Constable, G.A. (1986). Growth and light receipt by mainstem cotton leaves in relation to plant density in the field. Agric. For Meteorol. 37, In press.

Conference and extension:

Constable, G.A. (1984). The growth of cotton: temperature, solar radiation and nitrogen fertiliser. Australian Cotton Growers Research Conference, Toowoomba, December 1984. pp 303-309.

Constable, G.A. (1986). Fertiliser inputs-rationalising costs. Australian Cotton Growers Research Conference, Surfers Paradise, August 1986. pp 15-22.

Constable, G.A., Rochester, I.J. and Cook, J.B. (1986). A survey of soil and plant levels of trace elements in NSW cotton areas. Australian Cotton Growers Research Conference, Surfers Paradise, August 1986. pp 31-35.

Constable, G.A. (1986). Nitrogen nutrition of cotton. The Australian Cotton Grower. 7, 4-6.

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APPENDIX. More detailed results of each sub-project

1. Nitrogen fertiliser

Site and climate conditions in each season had a strong influence on the results. The 1983/84 season was noteable in that the weather was cool and wet. In fact this site had floodwater on it for a short time at one stage. A light hail storm also caused some loss of leaf a short time later. These factors combined to produce relatively low yields, in common with commercial crops in the area. Another strong factor influencing results was soil condition. Wet weather meant that soil preparation was delayed and perhaps conducted in conditions wetter than ideal. Therefore, fertiliser recovery was relatively better when applied as a sidedressing in November, when the soil condition was improved over that in early September when the presowing N was applied.

The 1984/85 season was ideal for soil preparation and for crop growth. Yields double that of 1983/84 were therefore obtained. The strongest influence on fertiliser recovery in this experiment was that the soil was high in available 'native' soil N as evidenced by 104 kg N/ha uptake from unfertilised treatments. Therefore only relatively low rates of N were required for maximum yield, despite surprisingly low N recoveries around 30%.

The 1985/86 season was also ideal for soil preparation and crop growth. At site A where soil N levels were low, responses to applied N were obtained up to rates of 200 kg N/ha. Responses to sidedressing were poor, presumably because the sidedressing treatments did not include a treatment with any presowing N. Results at site B where soil N levels were high, produced identical results to 1984/85.

TABLE A1. Nitrogen experiment 1983/84 Results

Nitrogen applied kg/ha			N uptake	Lint yield
Presowing	November	January	kg/ha	kg/ha
0	0	0	41	662
50	0	0	71	965
100	0	0	88	1038
150	0	0	99	1091
200	0	0	114	1066
0	50	0	53	823
50	50	0	81	994
100	50	0	112	1094
150	50	0	132	1070
0	0	50	46	779
50	0	50	60	1016
100	0	50	76	1007
150	0	50	113	1145

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TABLE A2. Nitrogen experiment 1984/85 Results

Nitrogen applied			N uptake	Lint yield
Presowing	November	January	kg/ha	kg/ha
0	0	0	104	1973
50	0	0	125	2044
100	0	0	141	2186
150	0	0	156	2121
200	0	0	176	2129
0	50	0	99	2094
50	50	0	145	2199
100	50	0	146	2142
150	50	0	126	2008
0	0	50	105	1991
50	0	50	128	2024
100	0	50	159	2036
150	0	50	137	2151

TABLE A3. Nitrogen experiment Site A 1985/86

Nitrogen applied		N uptake	Lint yield
Presowing	December	kg/ha	kg/ha
0	0	64	1316
67	0	92	1682
134	0	108	1860
200	0	124	1905
0	40	82	1660
0	80	88	1708
0	120	100	1727

TABLE A4. Nitrogen experiment Site B 1985/86

Nitrogen applied		N uptake	Lint yield
Presowing	December	kg/ha	kg/ha
0	0	82	1956
0	73	113	2174
0	146	119	2290
0	218	131	2281
50	0	122	2134
50	73	129	2293
50	146	132	2306
50	218	149	2206
100	0	114	2281
100	73	127	2180
100	146	144	2146
100	218	154	2246

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2. Trace elements

TABLE A5. Results of trace element survey of 35 cotton fields.

		Nominal Crital value	Survey results Minimum	Mean	Maximum
Soil tests					
pH in $CaCl_2$		-	6.9	7.3	7.6
EDTA extraction	Zinc	4	2.1	6.2	15.5
(ppm)	Copper	2	2.3	5.6	9.2
	Iron	80	27.8	166.3	354.2
	Manganese	-	.5	1.1	2.1
DTPA extraction	Zinc	.5	1.2	2.5	4.8
(ppm)	Copper	.3	1.8	2.2	2.9
	Iron	2	4.0	7.6	17.4
	Manganese	2	15.5	23.7	48.5
Plant tests					
Leaf blade	Zinc	11	11.6	23.0	37.2
(ppm)	Copper	2	4.8	7.1	9.5
	Iron	30	90.0	162.0	264.7
	Manganese	15	43.1	148.6	404.0
Plant uptake	Zinc	-	22.0	61.9	113.8
(g/ha)	Copper	-	9.1	19.6	49.5
	Iron	-	209.5	594.4	1122.5
	Manganese	-	55.9	449.2	1574.1

3. Simulation studies

Cool wet springs result in a wide range of planting dates in all cotton regions. During 1983/84 a study was made of the long term weather data and the likely yield in each season with varying planting dates.

Date relating temperature to crop development and day degree summations to yield were cmbined with long term meteorological data from Trangie, Narrabri, Moree and Goondiwindi. The results showed that there was considerable variation in the southern areas in te success of late (after mid November) plantings. Critical planting dates as determined by the simulation study were:

	Last planting date to achieve 2/3 yield potential	
Region	in 50% of years	in 90% of years
Macquarie	Oct 18	-
Namoi	Nov 27	Nov 9
Gwydir	Dec 2	Nov 20
Macintyre	Dec 8	Nov 30

These results indicate that planting in the Namoi should cease on Nov 27. Plantings on this date would be successful (profitable) in only half of the seasons.

A similar study was made of the survival, growth and fibre quality of late flowers on cotton. This study was required to indicate the value of late irrigations. Flowers from late February and early March are generally not numerous, are small and have low fibre quality. With the wide range of planting dates in 1983/84, those growers with late plantings were tempted to set a late crop. This decision entailed late irrigation and pest control and relies on warm autumn temperatures.

4. Growth and light receipt by mainstem cotton leaves in relation to plant density in the field

The expansion of individual mainstem cotton leaves and light receipt at their natural angle of display were measured in the field to determine simple expressions for growth and light interception of cotton leaves. Plant density and planting date were varied in three seasons to generate a range of leaf and plant sizes. It was necessary to repeat the experiment three times due to hail damage in two successive seasons.

When expressed in thermal time, leaves appeared regularly at intervals of 2.9 physiological days (or 41 day degrees) and the leaves expanded for a relatively constant time of 18 p-days (253 day degrees), being insensitive to plant density and planting date. Leaf size and therefore daily rate of leaf expansion were strongly influenced by position on the plant, plant density and planting date (largest leaves in the middle region of the plant, at low plant densities and late planting dates). These effects were consistent with leaf size at initiation and relative leaf expansion rate being influenced by assimilate competition within the plant either between leaves and fruiting branches, or due to mutual shading. Planting date effects were consistent with a temperature response, in that leaves grew faster and larger from late planting dates.

Leaves faced the sun in the early morning and late afternoon, which a simulation study suggested allowed an extra 40% photosynthesis at these times. However since absolute light levels were low at these times, simulated daily photosynthesis was only increased by 9% over leaves which stayed at constant leaf display.

Plant density highly influenced light extinction coefficients (K) for mainstem leaves when measured at their natural angle of display. For plant densities of 2, 8 and $24/m^2$, K was 3.56 ± .26, 1.76 ± .08 and 1.15 ± .10 respectively. These effects were attributed to the more 'clumpy' nature of plants at low density. When measured at ground level with a linear sensor held horizontally under a medium plant density crop, K was 0.87 ± .03. Therefore, it was postulated that K for fruiting branch leaves might be substantially lower than for mainstem leaves. It was demonstrated that K could have a large effect on calculated photosynthesis of lower leaves in a crop model based at the single leaf level.

5. Fruit mapping

The appearance, survival and size of nearly 10,000 fruiting forms of cotton have been mapped in the past 3 seasons. This substantial data set is still being analysed so only a brief resume of results will be presented here. The ultimate aim is to use this mapping data in conjunction with leaf growth, light interception and leaf photosynthesis data to develop and validate complex crop models based at the process level. These models will complement the modelling work already undertaken in SIRATAC research.

The main points of interest from data analysis so far are:

1. Of all the fruiting sites which appear on a cotton plant in a season, nearly 70% are shed as young squares or as young bolls - in roughly equal proportion.

2. The survival of squares and bolls is poorly correlated with boll load on the plant.

3. The production of new squares (Y) on a crop can be described by the relationship:
   $$Y = (1- .895 * LOAD) * .659 (1- \exp (- .0112 * SITES))$$
   where LOAD is the boll load and SITES is the total number of fruiting positions ($/m^2$) on the crop at that time. This relationship is similar to that used in SIRATAC, where boll load limits the production of new squares, but SITES, a measure of crop size, generally has a positive influence on the rate of squaring.

4. Only 6.9% of the total lint yield was held above mainstem node number 16. The micronaire of lint from these bolls was 15% lower than micronaire of lower bolls - especially in a cool season.

5. The second boll on a fruiting branch averages 83% of the size of the first boll on that branch.

6. About 18% of total yield is carried on vegetative branches at a plant density of $8/m^2$.

7. The boll period (BP - days from flowering to boll opening) is related to mean temperature (T) by the following equation:
   $$BP = \exp (5.385 - .0512 * T)$$
   for example at 18°C, BP is 87 days; at 30°C BP is 47 days. Some late bolls open prematurely, an effect that cannot be related to temperature, frost, boll load or defoliant. These bolls that open early are always small and contain poor quality lint.