Queensland Journal of Agricultural and Animal Sciences Vol. 45 (2), 129-138 (1988)
Published by the Queensland Department of Primary Industries

Modification by crop rotations of the nitrogen fertiliser requirements for irrigated cotton and soil test calibration

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Abstract

Benefits of rotational cropping were investigated in the Emerald Irrigation Area, central Queensland. A site cropped with cotton (*Gossypium hirsutum* L.) in 1983–84 was subdivided into areas left fallow or nitrogen fertilised and sown with wheat. In November 1984 each area was subdivided for five cropping treatments, fallow, dryland soybean (*Glycine max.*) with nil and 180 kg N/ha, and cotton (Deltapine 61) with 60 and 180 kg N/ha. Subsequently, in November 1985, each plot was sown with cotton (Deltapine 90) receiving 25 or 175 kg N/ha. Soil was sampled in April and October 1984 and in August 1985.

Mean soil nitrate at 0 to 0.6 m after wheat or fallow in 1984 was 11 kg N/ha. Seed cotton yields in 1985 were 3200 (fallow + 180 kgN/ha), 3400 (wheat + 180 kg N/ha), 2600 (fallow + 60 kg N/ha) and 2100 kg/ha (wheat + 60 kg N/ha). Soil nitrate levels after the 1984–85 treatments were 91 (soybean + 180N), 65 (fallow), 55 (soybean + 0N) and 19 kg N/ha (cotton + 60N, cotton + 180N).

Seed cotton yields in 1986 were 2400 kg/ha when 25 kg N/ha was applied to the 1984–85 cotton plots: seed cotton yields from all other treatments were about 4000 kg/ha, fallow and soybean being equivalent to 175 kg N/ha. Corresponding lint yields were about 1000 and 1600 kg/ha. Lint yields approached an asymptote at lower pre-plant soil nitrate than seed yields; thus as nitrate increased, ginning percentage decreased.

Mitscherlich curves closely related pre-plant soil nitrate at 0 to 0.4, 0 to 0.6 or 0 to 0.8 m with lint, seed and seed cotton yields. From similar curves relating fertiliser nitrogen and yield for Deltapine 90 conversion constants were derived: one unit of profile nitrate nitrogen was equivalent to three to four units of fertiliser for lint yield and two to three units of fertiliser for seed yield. Nitrogen fertiliser recommendations based on soil nitrate levels before planting are reported.

INTRODUCTION

Cotton production from irrigation farms in the Emerald area of central Queensland was well established by 1977. Since then some farmers have grown cotton continuously while others have included alternative crops (Hamilton 1980). By 1984 farmers were asking about the merits of rotational and continuous cropping.

Information was available from other environments and soil types. Hipp and Gerard (1971) showed no response by cotton to nitrogen fertiliser (to 150 kg N/ha) after a seven month fallow on a fine sandy loam in Texas. They related this result to an increase in soil nitrate during the fallow. Turner *et al.* (1972) recorded increased yields for cotton following lucerne (*Medicago sativa* L.) and cotton following corn (*Zea mays* L.) over continuous cotton plots on a sandy loam soil in California. Moreover, nitrogen fertiliser increased the yields of continuous cotton, of cotton following corn and cotton the second year after lucerne but not of cotton the first year after lucerne. They noted that rotation crops improved soil structure and the release of soil nitrogen. Hearn (1986) reported that the response of cotton to fertiliser nitrogen was least after wheat or fallow, greatest after cotton or sorghum: the effect of soybeans was intermediate on a grey cracking clay (Vertisol) in the Namoi Valley of New South Wales.

The experiment reported here investigated the nitrogen contribution from rotational cropping to cotton production and soil nitrate on a cracking clay (Vertisol) in the Emerald Irrigation Area. Cotton, wheat, fallow and a legume crop (soybean) were incorporated in cropping sequences from 1984 to 1986. Using soil nitrate, relative cotton yields and data from a complementary fertiliser rates experiment, we developed fertiliser recommendations based on profile nitrate before planting.

MATERIALS AND METHODS

Site

The experiment was located on a dark cracking clay of basaltic origin, Soil Profile Class BUg-2, Taxonomy Sub-group Mollic Torrert and classified according to Northcote (1979) as Ug 5.12. This was on Farm 164 of the Emerald Irrigation Area. Soil analyses in Table 1 complement those of the earlier site no. 1 description by McDonald and Baker (1986).

Table 1. Mean site analyses*

Depth (m)	pH 1:5	Conductivity 1:5 (dS/m)	Chloride (mg/kg)	Bicarbonate extractable P (mg/kg)	Organic carbon (% (W. and B.))	Replaceable K (m.eq./100 g)	Air dry moisture (%)	Bulk density † (g/cm³)
0–0.1	7.7	0.11	40	16	0.9	0.41	12.9	0.86
0.1–0.2	7.8	0.07	30	11	0.8	0.35	13.2	1.02
0.2–0.4	8.1	0.08	20				13.2	1.14
0.4–0.6	8.3	0.14	20				13.6	1.16
0.6–0.8	8.6						11.0	1.20

* Methods—Bruce and Rayment (1982). † D. F. Yule (pers. comm. 1987).

The climate at Emerald is subtropical and subhumid with a concentration of rainfall in summer months and a fairly high degree of rainfall variability (Anon 1965). Climatic conditions from 1984 to 1986 were typical of normal seasons (G. D. Keefer, pers. comm. 1988). Data for specific periods of the experiment are given in Table 2.

Table 2. Climatic data for selected periods during the experiment

Period*	Rainfall (mm)	Pan evaporation (mm)	Range of mean weekly temperatures (°C)	
			Maximum	Minimum
1	259	724	16.4 - 29.6	2.4 - 14.1
2	235	1312	29.9 - 37.5	15.9 - 23.2
3	256	1117	19.6 - 33.2	5.0 - 17.5
4	282	1175	31.9 - 37.1	18.4 - 24.5
5	486	2030	19.6 - 37.5	5.0 - 23.2

*1 Wheat/fallow, May to October 1984. 2 Cotton/soybean/fallow, November 1984 to April 1985.
3 Pre-planting period, April to October 1985. 4 Cotton, November 1985 to March 1986.
5 Second to third soil sampling, October 1984 to August 1985.

Treatments

The sequence of treatments is summarised in Table 3. Each was replicated twice to give a 2 × 2 × 5 × 2 double split plot factorial experiment for the analyses of variance in 1986. Results are reported as significant ($P < 0.05$) unless otherwise stated.

Cotton (*Gossypium hirsutum* L.) had been grown on the farm site in 1983–84. An area 250 m × 30 m was divided into four main plots each 56 m × 30 m separated by laneways for farm equipment; two were left fallow and two were planted on 9 May 1984 with wheat receiving 120 kg N/ha as urea (46% N) and 30 kg P/ha as high analysis superphosphate (19.2% P, 1.6% S, 16% Ca). The wheat was harvested on 5 October 1984 and the stubble was removed.

Table 3. Key to crop rotations and fertiliser treatments (kg N/ha)

1983–84	1984 May to October	1984–85 November to April	1985–86 November to March
		Fallow	
	Fallow	Soybean (0N)	Cotton † (25N)
Cotton ×	x	Soybean (180N) ×	
	Wheat (120N)	Cotton * (60N)	Cotton † (175N)
		Cotton * (180N)	

* Irrigated Deltapine 61. † Irrigated Deltapine 90.

Main plots were subdivided into seven plots 8 m × 30 m. Two treatments, cotton with 180 kg N/ha and stubble incorporated, and soybean with 180 kg N/ha and stubble removed, were planned but were not finally included. The remaining five treatments are reported in this paper. All except the fallow subplots received 40 kg P/ha and urea was banded 0.1 m below the surface at sowing time. Cotton (Deltapine 61) was sown in rows at 1 m spacing on 30 October 1984 with 60 and 180 kgN/ha. Soybean (*Glycine max.* Merrill var. Canapolis) with nil and 180 kg N/ha was sown at the same time. The cotton was flood irrigated when a soil water deficit of 70 mm was reached, as predicted by a crop factor/pan evaporation model (Yule and Keefer 1984). Datum rows were harvested on 9 April 1985. Due to circumstances beyond our control, the soybean was not irrigated. The crop nodulated poorly and exploratory estimates of yield were less than 500 kg beans/ha so the entire crop was ploughed in on 3 May 1985. At the same time trash was raked off the cotton plots and burnt.

In September 25 kg N/ha and 30 kg P/ha were applied as a mixed fertiliser (14.2% N, 17.3% P, 7.1% S) over all the site. By 1985 Deltapine 90 was the recommended variety for the Emerald Irrigation Area because it had a 5 to 10% yield advantage over Deltapine 61 and higher fibre quality (P. K. Lawrence, pers. comm. 1987). Each subplot was sown to cotton (Deltapine 90) planted on 8 November 1985 and split for further applications of nil and 150 kg N/ha as urea, giving 25 and 175 kg N/ha in total. The crop was defoliated with thidiazuron on 13 March 1986 and datum rows (2 × 10 m) were harvested on 26 March for seed cotton yield and ginning percentage.

Soil samples and analyses

Soil profile samples were taken from each main plot in April 1984 after the 1983–84 cotton crop and on 8 October 1984 after the winter treatments. Each of the 1984–85 subplots was sampled on 13 August 1985. Composite samples were obtained from each plot or subplot, 30 cores from 0 to 0.1 m, 10 cores from 0.1 to 0.2 m and 6 cores from 0.2 to 0.4, 0.4 to 0.6 and 0.6 to 0.8 m, below which there was weathered basalt. These provided separate samples from each treatment and each replicate.

Each sample was dried (40°C), ground (<2 mm) and then a subsample was dried at 105°C to determine the moisture factor correction. These samples were for site characterisation (Table 1) and nitrate determination (extraction in 2M potassium chloride and an autoanalyser procedure). Results were converted to kg N/ha by multiplying by the moisture factor and soil bulk density value for the appropriate depth (Table 1).

Relationship between soil nitrate and fertiliser nitrogen

To convert soil profile nitrate to a fertiliser equivalent requires the relationships between nitrate and relative yield and between nitrogen fertiliser and relative yield. Although a nitrogen rates experiment was not run on a low nitrate area adjacent to the rotation experiment, data (unpublished) from the cotton variety × irrigation × nitrogen rate experiment of E. A. Clarke in 1986–87 under similar conditions at Emerald is available.

Let y % be the relative yield of lint, seed cotton or seed, let x_1 kg N/ha be soil nitrate at 0 to 0.4, 0 to 0.6 or 0 to 0.8 m and let x_2 kg N/ha be the rate of fertiliser in the 1986–87 experiment. The Mitscherlich equation for the present experiment is:

$$y = \mathrm{m}\,(1 - \mathrm{e}^{-(\mathrm{a}_1 + \mathrm{b}_1 x_1)})$$

and for the fertiliser experiment is:

$$y = \mathrm{m}\,(1 - \mathrm{e}^{-(\mathrm{a}_2 + \mathrm{b}_2 x_2)})$$

Both equations approach an asymptote at $y = \mathrm{m} = 100$. Therefore

$$\mathrm{a}_1 + \mathrm{b}_1 x_1 = \mathrm{a}_2 + \mathrm{b}_2 x_2$$

$$\text{and } x_1 = \frac{(\mathrm{a}_2 - \mathrm{a}_1)}{\mathrm{b}_1} + \frac{\mathrm{b}_2}{\mathrm{b}_1} x_2$$

$$\text{or} \quad x_1 = \mathrm{c} + \mathrm{k}\, x_2$$

where k is termed the conversion constant and c the intercept.

RESULTS

1984-85 crops after wheat or fallow

For the dryland soybean crop the mean and standard deviation for the total dry matter yield (including beans) was 1700 ± 217 kg/ha. Yield was not influenced significantly by applying 180 kg N/ha at sowing time, or by previous treatments in 1984. Seed cotton yields (kg/ha) from Deltapine 61 were lower after wheat (2129) than after fallow (2609) when 60 kg N/ha was applied, but this previous history effect was overcome by the application of 180 kg N/ha which gave higher yields after wheat (3407) and fallow (3200) (LSD 370).

1985-86 cotton after 1984 wheat or fallow

Seed cotton of Deltapine 90 after wheat (3548 kg/ha) was less than after fallow (3730 kg/ha) (LSD 162). Interactions were not significant.

1985-86 cotton after 1984–85 treatments and 1985 fertiliser

Yields of lint, seed cotton and seed were less at low nitrogen after cotton than after other rotations. For ginning percentage, 1984–85 treatment effects were not significant; however, ginning percentage decreased in the order cotton, fallow and soybean (Table 4).

Soil nitrate before and after wheat and fallow in 1984

At 0 to 0.2 m there was 1.9 kg N/ha in April before the wheat crop was planted. Nitrate was low in October (Table 5) and did not differ significantly between the wheat and the fallow plots. After the 1984–85 cropping treatments only at 0.4 to 0.6 m were the effects of the 1984 wheat (8.9 kg N/ha) and fallow (10.9 kg N/ha) significantly different (LSD 0.9). This was a minor effect, possibly due to chance.

Table 4. Treatment effects on Deltapine 90 cotton yields (kg/ha) in 1985–86

Measurement	1985 fertiliser N (kg/ha)	Treatment 1984–85 following wheat or fallow				
		Fallow	Soybean 0N	Soybean 180N	Cotton 60N	Cotton 180N
Lint	25	1519*a**	1601*a*	1605*a*	958*b*	1050*b*
	175	1620*a*	1592*a*	1599*a*	1575*a*	1563*a*
Seed cotton	25	3762*b*	3850*ab*	3987*ab*	2275*c*	2444*c*
	175	4075*ab*	4188*a*	4163*ab*	3788*ab*	3856*ab*
Ginning	Mean of 25 and 175	40.2*ab*	39.8*b*	39.4*b*	42.0*a*	41.8*a*

* Means followed by the same letter within variates are not significantly different ($P < 0.05$).

Table 5. Soil nitrate-N in October 1984 and treatment effects in August 1985

Depth (m)	Means October 1984	1984/85 treatment following wheat or fallow				
		Fallow	Soybean 0N	Soybean 180N	Cotton 60N	Cotton 180N
0–0.1	2.2	12.1*ab**	10.9*b*	15.4*a*	4.5*c*	6.3*c*
0.1–0.2	2.8	15.8*a*	12.7*a*	14.0*a*	5.5*b*	5.2*b*
0.2–0.4	3.4	24.6*b*	22.3*b*	39.3*a*	6.9*c*	5.0*c*
0.4–0.6	3.0	12.4*b*	9.5*b*	22.3*a*	2.8*c*	2.6*c*
0.6–0.8	2.7	8.2*b*	5.6*ab*	8.5*a*	2.1*b*	2.0*b*
Cumulative values						
0–0.4	8.4	52.5*b*	45.9*b*	68.7*a*	16.9*c*	16.5*c*
0–0.6	11.4	64.9*b*	55.4*b*	91.0*a*	19.8*c*	19.2*c*
0–0.8	14.1	73.1*b*	61.0*b*	99.6*a*	21.9*c*	21.2*c*

*Means in each row followed by the same letter are not significantly different ($P < 0.05$).

Soil nitrate after 1984-85 cropping treatments

The order of soil nitrate levels in August 1985 for cumulative depths to 0.4, 0.6 or 0.8 m was soybean 180N > soybean 0N and fallow > cotton 60N and cotton 180N. For the individual depth increments there were minor variations from this sequence only at 0 to 0.1, 0.1 to 0.2 and 0.6 to 0.8 m (Table 5). Between October 1984 and August 1985 there was an increase in nitrate at all depths, particularly noticeable for the fallow and soybean treatments at 0.2 to 0.4 m and for soybean 180N at 0.4 to 0.6 m (Table 5).

Net accumulation in the soil profile (0 to 0.8 m) from October 1984 to August 1985 under fallow was 59kg N/ha. For the soybean treatments, 180 kg N/ha produced a net increase over the nil treatment of only 38.6kg N/ha. There was no evidence of nitrate accumulation from 180 kg N/ha applied to the cotton. The net increase between the cotton treatments and the fallow was 51.5kg N/ha: about two thirds of this, (35.8kg N/ha) was at 0 to 0.4 m.

Relationships between pre-plant nitrate and cotton performance in 1985–86

Soil nitrate at 0 to 0.4, 0 to 0.6 and 0 to 0.8 m was plotted against lint, seed cotton and seed yields, also ginning percentage, for cotton receiving 25 and 175 kg N/ha in 1985 and also against the relative yields (25N/175N × 100) for the various cropping treatments. Similar patterns were found irrespective of the cumulative depth selected or of whether absolute or relative yields were used. With 175 kg N/ha there was no obvious relationship between soil nitrate and cotton yield measurements (all $R^2 \leqslant 0.48$). Relationships between pre-plant nitrate and cotton performance where 25 kg N/ha was applied are illustrated in Figure 1 using nitrate at 0 to 0.6 m. The 1984–85 cotton 60N and cotton 180N treatments are clearly separated from the rest. At the high values of nitrate, seed yields continued to increase whereas lint yields did not; the behaviour of seed cotton yields was intermediate. Ginning percentage was negatively related to soil nitrate by linear regression (r = −0.795, −0.796 and −0.813 for 0 to 0.4, 0 to 0.6 and 0 to 0.8 m respectively, significant at $P<0.01$).

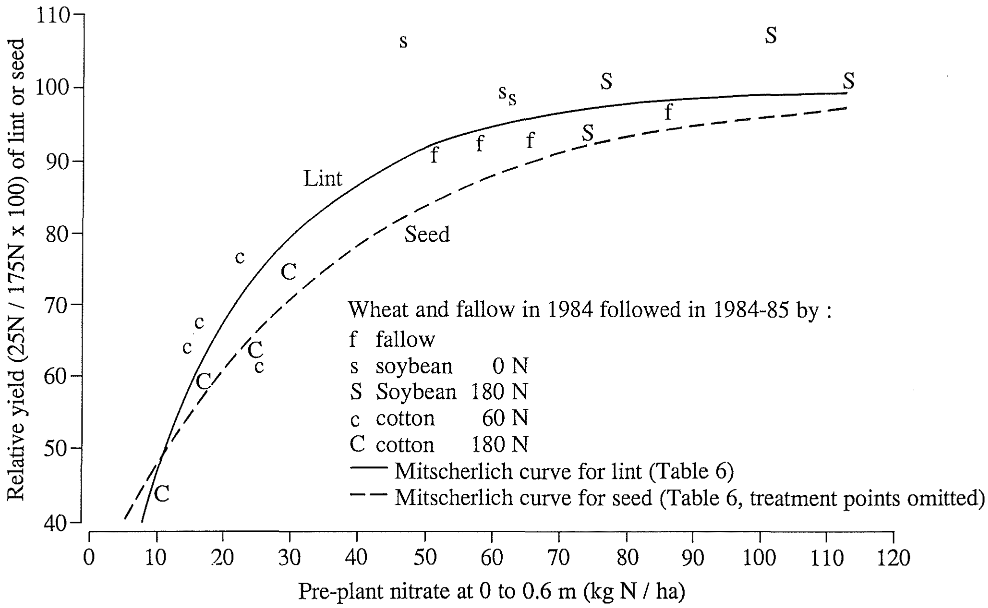

Figure 1. Soil nitrate at 0 to 0.6 m from the 1984-85 cropping treatments and relative yields of lint and of seed from Deltapine 90 in 1986.

Mitscherlich curves best fitted the data (R^2>0.90) relating yields and soil nitrate at 0 to 0.4, 0.6 or 0.8 m. From the equations for each of these depths mean asymptotes corresponded to 1650 kg lint/ha, 4280 kg seed cotton/ha and 2700 kg seed/ha. Asymptotes for the Mitscherlich curves relating relative yields and soil nitrate were tested and were found to be not significantly different from 100%. These curves (Table 6) were used to derive soil nitrate for 90% of maximum yield, which was lower for lint than for seed.

Soil nitrate, fertiliser nitrogen and recommendations

Mitscherlich curves closely related relative yields and nitrogen fertiliser rates in the 1986–87 experiment (Table 7). With the complementary curves for relative yields and soil nitrate (Table 6) we calculated relationships between nitrate and fertiliser nitrogen (Table 8). These are valid for the ranges 0 to 300 kg N/ha and for soil profile nitrate (kg N/ha) up to 90, 110 and 130 at 0 to 0.4, 0.6 or 0.8 m respectively.

Fertiliser recommendations are given in Table 9. For each value a relative yield goal was chosen and the soil nitrate for this was derived from equations in Table 8 and adding 25 kg N/ha to allow for the fertiliser added after soil sampling in 1985.

DISCUSSION

Wheat, fallow and the following crops

Yields of Deltapine 61 with 180 kg N/ha in 1984–85 and of Deltapine 90 with 175 kg N/ha in 1985–86 exceeded the district average (G. D. Keefer, pers. comm. 1987) and are

Table 6. Mitscherlich curves* used to derive soil nitrate (x_1) corresponding to 90% relative yields for cotton measurements (y)

Cotton measurement band fertiliser N, 1985–86	Profile depth (m)	Coefficient of determination (R^2)	Position constant (a_1)	Slope constant (b_1)	Nitrate (kg N/ha) for 90% of maximum yield
Lint yield %	0–0.4	0.879	0.104	0.0597	37
(25N/175N)	0–0.6	0.885	0.166	0.0477	45
	0–0.8	0.874	0.187	0.0425	50
Seed cotton yield %	0–0.4	0.897	0.233	0.0456	45
(25N/175N)	0–0.6	0.899	0.292	0.0359	56
	0–0.8	0.890	0.307	0.0320	62
Seed yield %	0–0.4	0.859	0.297	0.0384	52
(25N/175N)	0–0.6	0.859	0.352	0.0300	65
	0–0.8	0.852	0.364	0.0268	72

* $y = 100\ (1 - e^{-(a_1 + b_1 x_1)})$, asymptote is 100%. All regressions significant ($P < 0.01$).

Table 7. Mitscherlich curves* relating fertiliser nitrogen (x_2) and relative yields for cotton measurements (y) in the 1986–87 experiment (E. A. Clarke, unpub. data)

Relative yield measurement for Deltapine 90	Coefficient of determination (R^2)	Position constant (a_2)	Slope constant (b_2)
Lint	0.93	0.690	0.0143
Seed cotton	0.95	0.631	0.0133
Seed	0.95	0.590	0.0124

* $y = 100\ (1 - e^{-(a_2 + b_2 x_2)})$, all regressions significant ($P < 0.01$).

Table 8. Equations* relating profile nitrate and fertiliser nitrogen for Deltapine 90

Depth	Lint yield		Seed cotton yield		Seed yield	
(m)	c	k	c	k	c	k
0–0.4	9.8	0.239	8.7	0.292	7.6	0.324
0.4–0.6	11.0	0.299	9.4	0.371	7.9	0.415
0.6–0.8	11.8	0.336	10.1	0.417	8.4	0.464

*Soil nitrate N = c + k × fertiliser N (kg/ha).

Table 9. Nitrogen fertiliser recommendations for irrigated cotton* in the Emerald Irrigation Areabased on pre-plant soil nitrate levels

Soil nitrate-N† for 3 sampling depths (m)						Fertiliser N (kg/ha) required for 90, 95 and 98% of maximum yield								
0–0.4		0–0.6		0–0.8		Lint			Seed cotton			Seed		
kg/ha	(mg/kg)	kg/ha	(mg/kg)	kg/ha	(mg/kg)	90	95	98	90	95	98	90	95	98
10	(2.4)	11.1	(1.7)	12.1	(1.4)	137	186	250	146	198	267	155	211	285
20	(4.8)	23.8	(3.7)	26.2	(3.0)	95	144	208	112	164	233	124	180	254
30	(7.2)	36.4	(5.6)	40.4	(4.5)	54	102	166	78	130	199	94	149	223
45	(10.8)	55.4	(8.6)	61.7	(6.9)	0	39	104	26	78	147	47	103	177
60	(14.4)	74.5	(11.5)	83.0	(9.3)	0	0	41	0	27	96	1	57	130

* Derived for Deltapine 90 on a basalt (BUg) soil. † Moisture factor correction applied to air dried soil sample analyses.

comparable with the highest from other irrigation–fertiliser rate experiments (E. A. Clarke and S. E. Ockerby, unpub. data). We therefore conclude that fertilisation and irrigation were adequate.

Where 60 kg N/ha was applied to Deltapine 61 the seed cotton yields following wheat were lower than those after fallow despite the nitrogen fertilisation of the wheat. The relative yield of 82% (60N/180N) for the fallow treatment is similar to that for Deltapine 61 in comparable studies in the Emerald Irrigation Area (E. A. Clarke, pers. comm. 1987), whereas the relative yield of 62% after wheat is low. For the 1984–85 and 1985–86 crops we conclude that for single or double cropping of cotton wheat does not reduce yields if sufficient nitrogen fertiliser is used for the cotton.

1984-85 treatments and the 1985-86 cotton crop

The five treatments established a range of soil nitrate levels. Highest lint yields were obtained with less pre-plant nitrate than highest seed cotton and seed yields (Figure 1 and Table 6). Therefore, as nitrate increased there was a concomitant decrease in ginning percentage. This is consistent with the description of cotton growth by Hearn (1981). Nitrogen fertilisation increases yield by prolonging growth and increasing the number of bolls set. Boll size is increased to a lesser extent mainly by increasing the seed size which reduces the proportion of lint. Generally the aim of fertilisation is to maximise lint production; more nitrogen will be needed to maximise seed production and therefore information for seed producers has been included.

Application of 60 or 180 kg N/ha to the first cotton crop made no difference to the yield of the second crop receiving 25 kg N/ha (Table 4). This indicated that even the high rate had been fully utilised in 1984–85. However, in the present experiment the preceding cotton crop did not reduce the asymptotic yield with nitrogen fertiliser by 305 kg lint/ha as found by Hearn (1986) and attributed by him to damaged soil structure.

Fallow and soybean as a green manure crop (fertilised or not) were equivalent to 175 kg N/ha applied to the 'continuous' cotton treatments in terms of yields of lint, seed cotton and seed (Table 4). Hamilton (1980) noted that cotton grown in rotation with soybeans yielded up to 0.5 bales/ha (100 kg lint/ha) more than continuous cotton, but he had no comparative figure for a fallow preceding cotton. Hearn (1986) found that without fertiliser nitrogen, cotton yielded most after wheat or fallow and least after cotton (or sorghum), with soybeans intermediate. However, much nitrogen would have been removed in the soybeans harvested (1.9 to 2.8 t/ha); in the present experiment the crop was ploughed in. Apparent nitrogen recovery by soybeans may be negligible; nitrogen uptake from fertiliser may be counterbalanced by reduced symbiotic fixation (Hearn 1986). Soil nitrate after unfertilised soybean was so high that 180 kg N/ha applied to the soybean in 1984 did not increase cotton yields in 1985–86 (Table 4).

Soil nitrate changes

Either fallow or the soybean green manure crop resulted in about 400 kg lint/ha more than that from previous cotton crops when only 25 kg N/ha was applied (Table 4). Pre-plant nitrate in 1985 from the preceding fallow and soybean treatments was at least three times that from the preceding cotton treatments (Table 5). An irrigated cotton crop had been harvested from the area in 1984 before the experiment began. Bearing in mind the low nitrate after cotton in 1985 (Table 5), we conclude that in April 1984 nitrate throughout the soil profile would have been low. Moreover, nitrate in October 1984 was low (Table 5). Appreciable nitrate accumulation is unlikely under cool conditions during winter (Table 2). Constable and Rochester (1987) report little change in soil nitrate below 15°C. Campbell *et al.* (1981) found the mineralisation rate for an Emerald basalt at 5 to 10°C to be about one third of that at 30°C.

Net accumulation in the soil profile (0 to 0.8 m) from October 1984 to August 1985 under fallow was 59 kg N/ha. This compares favourably with annual values for other clay soils of 50 to 60 kg N/ha suggested by Waring and Teakle's (1960) data for southern Queensland, of about 40 to 80 kg N/ha based on plant uptake (Hearn 1986) and from July to December of 30 kg N/ha near Biloela (Standley, unpubl. data, 1988). Most accumulation was at 0 to 0.4 m. Only the 180 kg N/ha applied to the soybeans produced a notable increase at 0.4 to 0.6 m; the lack of increase at 0.6 to 0.8 m (Table 5) suggests minimal loss by leaching.

Development of a soil test for nitrogen

A standard soil sampling depth of 0.6 m has been adopted for soil nitrate testing to predict the nitrogen fertiliser requirements of sorghum and sunflower in central Queensland (M. N. Hunter, pers. comm. 1987). The profile depth was 0.8 m in this rotation experiment, below which decomposing parent material was found. Coefficients of determination in Table 6 indicate that depths of 0 to 0.4, 0 to 0.6 or 0 to 0.8 m are equally suitable for relating yields to soil nitrate before planting. Most nitrate and changes occurred at 0 to 0.4 m (Table 5); presumably this is the zone of greatest root activity and water extraction. A shallower depth of 0 to 0.3 m gave close correlations between yields, nitrogen uptake and soil nitrate unless there was considerable accumulation further down the profile (Hearn 1981). Constable and Rochester (1988) showed that soil nitrate tests to 0.3 m a month before sowing were closely correlated with nitrogen uptake by cotton which in turn was closely correlated with fertiliser requirements.

The conversion constants (k in Table 8) indicate that one unit of profile nitrate nitrogen is equivalent to three to four units of fertiliser nitrogen for lint yield (and two to three units of nitrogen for seed yield). The conversion is dependent on the soil depth selected but is compatible with the average of 30% of applied nitrogen being taken up by a cotton crop 120 days after sowing (Constable and Rochester 1988).

Fertiliser recommendations

Soil samples taken in August or September in the Emerald area can be analysed for nitrate before cotton sowing in October or November. During this cooler pre-planting period only small changes in nitrate would be expected.

To derive fertiliser recommendations the relative yield goal is decided and the corresponding soil nitrate can be read directly from graphs such as Figure 1 or calculated. The pre-plant soil analysis is subtracted and the fertiliser recommendation derived, for which examples are given in Table 9.

Because of the high value of lint in relation to fertiliser cost, the much greater input of fertiliser for a relative yield of 98% instead of 95% may be warranted. Farmers in the Emerald Irrigation Area in 1987–88 were aiming to fertilise for maximum yields (W. D. Hamilton, pers. comm. 1988). Above a nitrate concentration of 25 mg N/kg at 0 to 0.3 m fertiliser would not be recommended for cotton in the Namoi Valley (Constable and Rochester 1987). This is higher than values for 0 to 0.4 m in Table 9 and may reflect differences in soil type, nitrate distribution and mineralisation between the Namoi and Emerald areas.

According to Hamilton (pers. comm. 1987), fertiliser recommendations for cotton in the Emerald Irrigation Area should be varied according to the soil type (alluvial AUg, basalt BUg or tertiary basalt TbUg). Some irrigation farmers in the Callide Valley claimed that recommended rates of nitrogen fertiliser in 1987 were too high. Measurement of nitrate before planting, a better understanding of mineralisation and of the distribution of roots in these soils, may explain the anomalies.

General conclusion

There were no yield reductions due to previous treatments of continuous cotton (1983–84, 1984–85) that could not be remedied by fertiliser nitrogen. Wheat, fallow or soybean produced no adverse effects on the following crops. Fallow or soybean as a green manure crop should reduce the nitrogen fertiliser requirements for the next cotton crop. Soil testing may be used to refine fertiliser recommendations.

ACKNOWLEDGEMENTS

We gratefully acknowledge funding by the Australian Cotton Research Council, support by Consolidated Fertilizers Ltd and provision and management of the site by farmer Mr R. A. Ingram. We thank Mrs Sophie Basford and Mr P. Cahill for industrious technical assistance, Mr G. D. Keefer, Mr W. D. Hamilton and Mr M. J. Whitehouse for inspiration and encouragement.

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(Accepted for publication 31 August 1988)