THE EXAMINATION OF SOIL STRUCTURAL DETERIORATION IN IRRIGATED COTTON FIELDS

D. McGarry

C.S.I.R.O. Division of Soils, GPO Box 639
CANBERRA, A.C.T. 2601

At the 1982 Australian Cotton Growers' Research Conference the effects of land preparation at different soil water contents on soil structure and cotton growth was reported. In summary, land preparation on 'wet' rather than 'dry' soil led to (i) a significant reduction in the amount of water available to cotton plants, (ii) strong changes in soil structure visible in the soil profile, and (iii) smaller cotton plants with up to 50% fewer green bolls.

On termination of the experiment soil samples were collected to study the nature of any differences due to the land preparation treatments. This paper presents details and results from two of the analyses used.

The first technique used a microscope to examine the micro-features and optical properties of very thin sections (0.025mm) cut from intact soil samples impregnated with hard-setting epoxy resin. Samples from both the 'wet' and 'dry' treatments have been examined and compared with samples taken from uncultivated sites (stock routes). The uncultivated ('virgin') soils of the Namoi Valley are dominated by clay material which has random orientation with predominantly edge to face contacts (Fig.1, type A). In contrast, the soil which had been prepared 'wet' had up to 25% of the top 20cm of soil composed of clay zones which have preferred orientation with predominantly face to face contacts (Fig.1, type B). For the same depth the soil prepared 'dry' had a maximum of 2% of the soil composed of clay with preferred orientation. In both treatments the size range of the oriented clay zones was 0.5 x 0.3mm to 400 x 240mm.

What is the source of these zones, and what implications do they have for crop growth? The most probable source is the smearing of wet soil by metal implements, and tractor wheels which lose traction and spin. An increase in the amount of clay with parallel rather than random orientation indicates an increase in the packing density of particles. The likely implications of this include: water held in the soil is less available to plants, plant roots experience greater difficulty in penetrating the soil, nutrients held in the soil are less available, there is less air-space so that both amount and movement of soil air is reduced.

In terms of amelioration of structural deterioration, it is important that the majority of oriented-clay zones were less than 20mm across, so are unlikely to be affected by ripping implements. It may require exploration by fine root hairs and by soil-living animals (e.g. earthworms) as well as wetting and drying cycles to ameliorate such zones.

The second technique used to assess structural deterioration was to examine the bulk density and aeration status of natural soil clods over a wide range of soil water content. The technique involves coating the clods with Saran resin which has the property of allowing water vapour to pass through (so the clod dries slowly) but is impermeable to liquid water (so allowing the clod's volume to be measured by immersion in water). The clod bulk density is calculated from its weight and volume and is plotted against its water content to give a picture of the solid to air-space relations of the soil at any one water content.

Figure 2 presents typical data from a clod from each of the 'wet' and 'dry' treatments in the 0-10cm layer. The most obvious difference between treatments is that for all water contents the land prepared 'dry' has lower bulk density values than the land prepared 'wet'. This indicates that for any one soil water content there was less soil air in clods from the land prepared 'wet' than there was for clods from the land prepared 'dry'. This trend was true for the majority of clods in the 0-10 and 10-20cm layers.

The lower aeration status of the top 20cm of the 'wet' prepared soil may be related to the greater incidence of oriented clay zones as seen under the microscope over the same depth. The usual implications apply for the poorer aeration of the 'wet' treatment i.e. poorer root growth, reduced water and nutrient uptake, and increased incidence of root disease.

Thus, these data have provided some understanding of the nature of soil structural deterioration in cotton-growing clay soils, and an explanation of the differences in cotton plant growth measured between the treatments in the 1981/82 season.

Fig 1. Using the examination of clay orientation as an index of structural degradation.

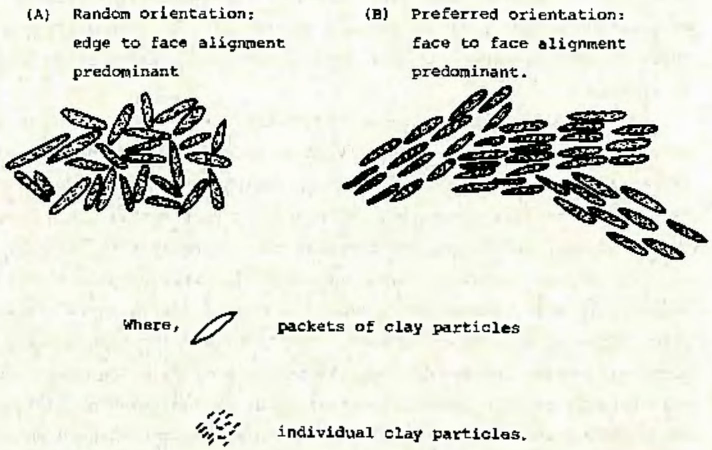
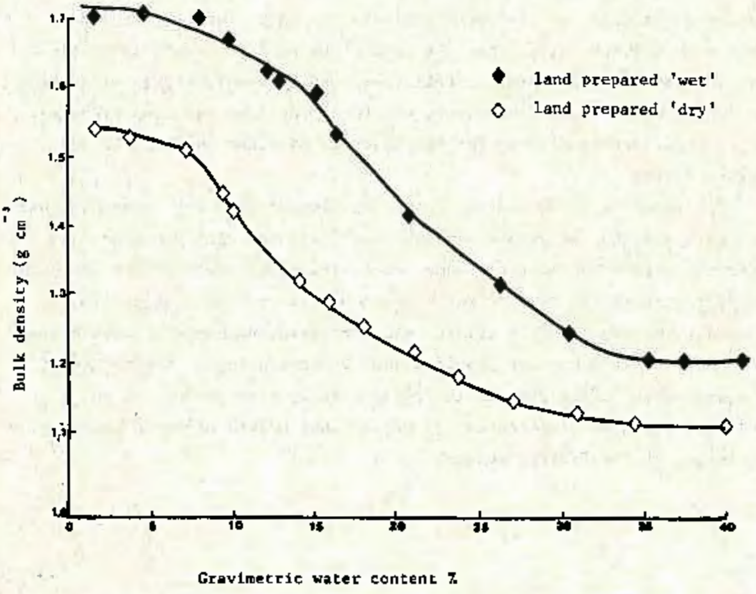


Fig 2. Bulk density of two soil clods plotted against their water content.



IRRIGATION MANAGEMENT OF COTTON FOR EFFICIENT WATER USE.

A. SOIL AND IRRIGATION FACTORS

D.F. Yule

Dept. of Primary Industries, Emerald, Qld.

Average cotton yields at Emerald, Queensland have generally been low when compared to other cotton growing areas in Australia. In particular, average yields in the 1980 to 1982 seasons were only 3.3. bales/hectare. Since yields in excess of 7 bales/hectare have been recorded, poor irrigation management appeared to contribute to the low yields.

The Emerald Irrigation Area is predominantly cracking clay soils and a large proportion of these soils are shallow (< 1.0m deep) and have considerable slope (1-2%) (McDonald, 1975). These soil factors and the tropical environment suggested that direct application of irrigation management from other cotton areas may not be appropriate. These two papers present a summary of the irrigation management studies conducted by the Department of Primary Industries at Emerald in 1982/83 and 1983/84. In addition I have included a brief review of the reported research into soil compaction at Emerald.

SOIL COMPACTION.

Soil compaction at Emerald has been investigated by observing soil structure in pits (McGarry and McDonald, 1983), by comparing water use rates and distribution from neutron moisture meter data (Wilcox and Cull, 1984), and by a combination of these methods supported by bulk density, root length and soil strength determinations (H.B. So, pers. comm., 1984).

McGarry and McDonald (1983) found that visible soil structure changes from the virgin state to the time of their investigations were minor and were confined to the 8 - 25 cm depth zone. Also the incidence of structural degradation (compaction) was rare (2 of 26 profiles examined) and in these was highly localised. The majority of their sites were chosen as being suspected compacted sites. There were no apparent cumulative effects, some sites had been irrigated for 16 years. They observed prolific roots at all sites growing cotton. They conclude that the majority of soils in the E.I.A have good potential for plant root exploitation and crop growth and that the cause of yield decline in 1980-1982 was not soil structural degradation.

Wilcox and Cull (1984) found that lower yield was associated with lower water use rates and proportionally greater water extraction at depth. They concluded that these water use changes were possibly due to some degree of structural degradation associated with land preparation when the soil was wet.

Dr. So concluded that compaction layers in the soil profile are likely to result in reduced growth and yield. Compaction layers with associated reduced plant vigour were found at two sites. Plant growth was apparently reduced by increased water stress. The presence of compaction layers was indicated by increased computed bulk density, by lower root density and water extraction at depth, and by visual observations of soil structure and the root system.

The contradictions in these reports are obvious. The importance of soil structural degradation in the E.I.A. remains unclear. At one of the sites studied by Dr. So, a yield reduction of more than 1 bale/ha was reported by the farmer. However soil structural degradation does not appear to have been the major cause of the low yields in 1980-1982.

IRRIGATION MANAGEMENT STUDIES.

Location and Methods.

The experiments were conducted at the Department of Primary Industries Emerald Research Station. The soil type is BUg (McDonald 1975) which is a basaltic cracking clay with clay content 70%, cation exchange capacity 75 m. equiv %, soil depth 85 cm over decomposing basalt, and slope 1%. Furrow irrigation treatments were applied to blocks 12 rows (12 m) wide and 200 m long. The datum area consisted of the central four rows. Irrigation treatments were based on soil water deficits predicted by a crop factor - evaporation pan model (Table 1). The treatments imposed are listed in Table 2.

TABLE 1. The crop factors used in the water use model.

	Crop Growth Stage	Crop Factor
I	Emergence for 28 days	0.3
II	Stage I to 1 flower/m	0.4
III	Stage II for next 14 days	0.6
IV	Stage III for next 14 days	0.8
V	Stage IV to 5 open bolls/m	1.0

TABLE 2. The predicted soil water deficit for each irrigation treatment. The deficit was designated for three crop development phases as follows -

Phase A	Emergence to 1 Flower/metre
Phase B	1 Flower/metre to 1 Flower/metre + 28 days
Phase C	1 Flower/metre + 28 days to 5 Open bolls/metre

Treatment		Predicted Deficit mm Phase A	Phase B	Phase C	Approx. Irrig. Frequency at Peak Growth. days
Very Frequent	VF	75*	45	45	5-6
Frequent	F	75*	75	75	8-9
Infrequent	IF	120*	120	120	14-15
Very Infrequent	VIF	150*	150	150	17-18
Rainfall	82-83	29	148	Nil	
	83-84	141	35	93	

* Due to rainfall, the phase A deficit in 1983/84 did not exceed 75 mm and no treatment was irrigated in phase A.

Water application rates during irrigations were measured with rectangular weirs (1982/83) and V-notch weirs (1983-84), one weir per furrow. Irrigation runoff rates were measured with HS flumes (1982/83) and Parshall flumes (1983/84), one flume per treatment. Total water addition, total runoff, total infiltration and the final infiltration rates were calculated for each irrigation. Soil aeration was measured in the 0-0.3m zone in 0.1m depth increments using 0.1m diameter cores. In 1983/84, cores were sampled from the hills 20m below the head-ditch and 20m above the tail drain in the VF and IF treatments during one irrigation cycle.

Typical water application and runoff data are shown in Figure 1 for three treatments in 1983/84. The increase in application rate at each irrigation was due to adding syphons to prevent possible uneven wetting. All treatments produced runoff curves of similar shape, varying mainly in total time of runoff. In general irrigation was stopped when the runoff rate was relatively stable. The total runoff depended mainly on the period of runoff and did not vary greatly across treatments. The water application rates were similar at all irrigations and differences between treatments were in period of irrigation which varied from 7 hours for the VF treatment to 22 hours for the VIF treatment. Total water application increased with increasing deficit prior to irrigation. The total infiltration (water application minus runoff) was approximately equal to the deficit prior to irrigation. Irrigation application efficiency (total infiltration/total water application) was high in all treatments. Since the total runoff varied little across treatments, application efficiency tended to increase with increasing total infiltration. The final infiltration rate was calculated as the difference between the application and runoff rates at the end of each irrigation. Since runoff rate was increasing this calculated infiltration rate will depend somewhat on the period of runoff.

The parameters from all irrigations in 1983/84 are summarised in Table 3. Over the whole season, total infiltration approximated the predicted deficit in the VF and F treatments. This was expected since total infiltration should estimate crop water use, assuming drainage is zero, and the predicted deficit should estimate crop water use, assuming evapotranspiration rates were near potential. In the IF and VIF treatments mean total infiltration

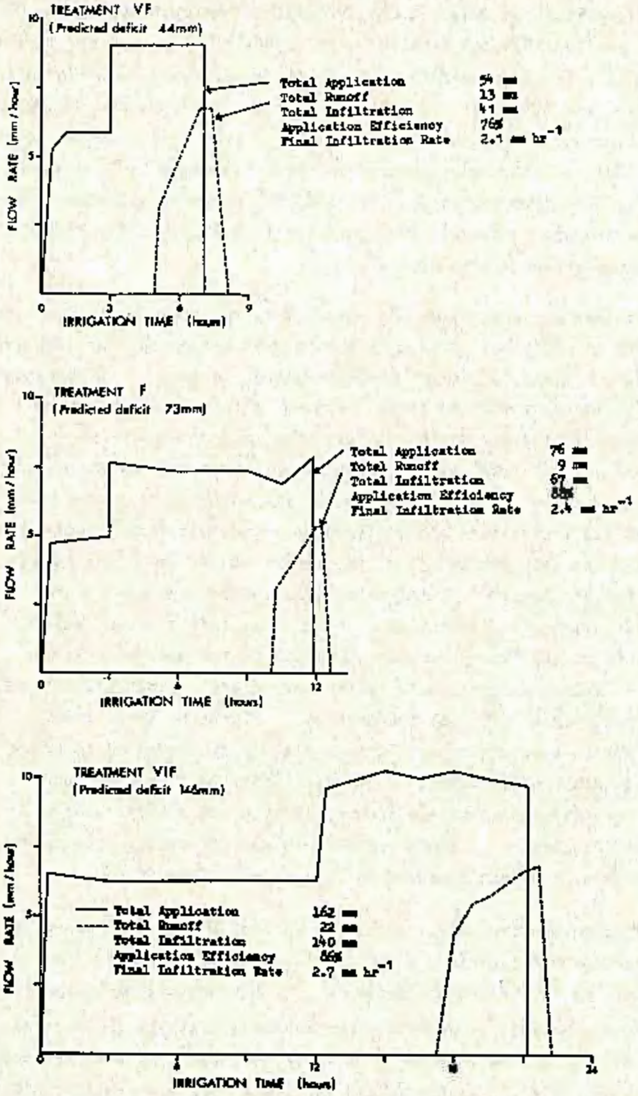


Figure 1. Typical water application and runoff curves for three treatments in 1983/84. The values listed are calculated from the curves.

TABLE 3. Mean irrigation parameters for each treatment in 1983/84.

Treatment	Mean Irrig. Deficit mm	Mean Total Infilt. mm	Mean Final Infilt Rate mm hr^{-1}	Mean Applic. Effic. %
VF	51	49	2.3	74
F	75	70	2.6	88
IF	107	92	2.8	87
VIF	140	126	2.3	89

was less than the mean predicted deficit, possibly because our predictive model makes no adjustment for plant water stress or reduced plant size in these treatments, and the model did not accurately predict the recharge after rainfall. Our model is intended to provide a reasonably reproducible basis for irrigation management across seasons in commercial applications and these weaknesses are unlikely to be significant in those applications.

The final infiltration rates are low and vary little across treatments. Since these rates are averaged over the length of the irrigation furrows, they are not simplistically related to soil hydraulic properties. However they are applicable to irrigation management since continued irrigation at these rates will contribute little to the total infiltration. Table 3 shows that the application efficiency can be high except in the VF treatment where the short period of each irrigation made limiting runoff difficult. High efficiency can be achieved by minimising runoff and this management will have little effect on total infiltration.

These results appear to support the findings of Shaw and Yule (1978) that cracks dominated the water entry process into these soils under flood irrigation, and that total infiltration was related to the volume of crack present at irrigation or to soil water deficit (as shown in Table 3). The infiltration process once the cracks are filled with water (as indicated by infiltration rate and application efficiency) was similar in all treatments.

Soil Aeration.

Soil aeration was measured near the head-ditch and the tail drain to study effects associated with period of inundation. Figure 1 shows that in VF treatment water was in the furrows near the head ditch for about 7 hours compared to about 3 hours near the tail drain.

The soil air content data are summarised in Tables 4 and 5.

TABLE 4. Soil air content profiles one day after irrigation. Values are in $m^3\ m^{-3}$.

	VF treatment		IF treatment	
Soil Depth (m)	Head ditch	Tail drain	Head ditch	Tail drain
0 - 0.1	0.26	0.30	0.35	0.35
0.1 - 0.2	0.06	0.08	0.11	0.10
0.2 - 0.3	0.02	0.02	0.03	0.03

TABLE 5. Soil air contents ($m^3\ m^{-3}$) at a depth of 0.2 - 0.3m during irrigation cycles. DAI is days after irrigation.

	VF treatment		IF treatment	
DAI	Head ditch	Tail drain	Head ditch	Tail drain
1	0.02	0.02	0.03	0.03
4	0.04	0.04	0.05	0.07
7	0.08	0.11		
11			0.09	0.10
1	0.03	0.06		

and dependent on leaf area). Since the amount of nitrogen taken up by this method was well below that measured, a set of multiplier factors was needed to increase nitrogen uptake especially during the rapid uptake phase just prior to flowering. The need for multipliers is probably due in part to an underestimation of soil nitrogen concentration. For this reason an alternative would be to have fertilizer recovery of 100% thus keeping the soil nitrogen concentration high enough to be able to predict preflowering rapid nitrogen uptake. Initial uptake could be limited to a maximum rate based on the plant nitrogen concentration for unrestricted growth.

The method was able to reasonably predict nitrogen uptake for the three nitrogen treatments at full irrigation in the 82/83 experiment (see Fig.4).

Nitrogen Stress and its Effect.

Two nitrogen stress indices are calculated: one for vegetative growth which affects fruiting site production and leaf growth rate, and the other for fruit growth which affects boll growth rate.

Vegetative nitrogen stress is described as the plant nitrogen reserve in relation to the minimum non-structural plant nitrogen requirement. This stress factor was compared with relative fruiting site production for corresponding nitrogen treatments (see Fig 1b). When the reserve falls below the minimum requirement, relative fruiting site production decreases below 1. The minimum requirement was based on the lowest plant nitrogen concentration in the 82/83 experiment.

Leaf growth rate is also affected in a similar way. This stress effect is also shown in Fig 1b.

Results of predicted fruit numbers for the 1982/83 experiment using this approach, where leaf area was also predicted, is shown in Fig.5a. Predicted leaf area is shown in Fig. 5b.

A fruit nitrogen stress factor limits potential boll growth rate as the average boll nitrogen content decreases from a maximum of 3.5% to a minimum of 1.2%. These figures representing a range of published estimates, (see Fig.1c). Boll nitrogen content is in turn reduced when vegetative nitrogen stress is being experienced.

Interaction of Stresses

The combined effect of the water and nitrogen stress factors were tuned with data from all nine treatments in the 1982/83 experiment. The result was that the best agreement between predicted and actual was found by restricting the processes by the most limiting factor, whether this be water or nitrogen. Fig.6 shows predicted and actual values for end of season leaf area index, boll numbers and lint yield.

Independent validation with data from four experiments done between 1974/75 and 1977/78 showed that nitrogen uptake, leaf area index and lint yield were all underestimated by the program, the latter by approximately one third. The suggested alternative, for estimating nitrogen uptake is being tested as a first step in overcoming the problem.

SUMMARY

Water and nitrogen stress are considered to be two major factors limiting the accuracy of the existing SIRATAC fruiting program, which is based solely on estimating the balance between carbohydrate supply and demand. Initial work based on data from an irrigation x nitrogen rate experiment in 1982/83 has examined a number of ways of estimating stress factors and incorporating these effects on plant processes. Results indicate that reasonably good predictions can be obtained for data used in the program calibration, which represents a full range of irrigation and nitrogen applications. An independent validation with data from 1974/75 to 1977/78 experiments indicates that the program is restricted in its generality, however this is not unexpected, since the program was developed on only one years' set of data. Furthermore, the 1982/83 experiment was affected by soil structural degradation. The use of a similar set of data collected from the 1983/84 experiment, which was not so affected by soil degradation, together with a variation in the method of estimating nitrogen uptake should help overcome these limitations and make the program more generally applicable.

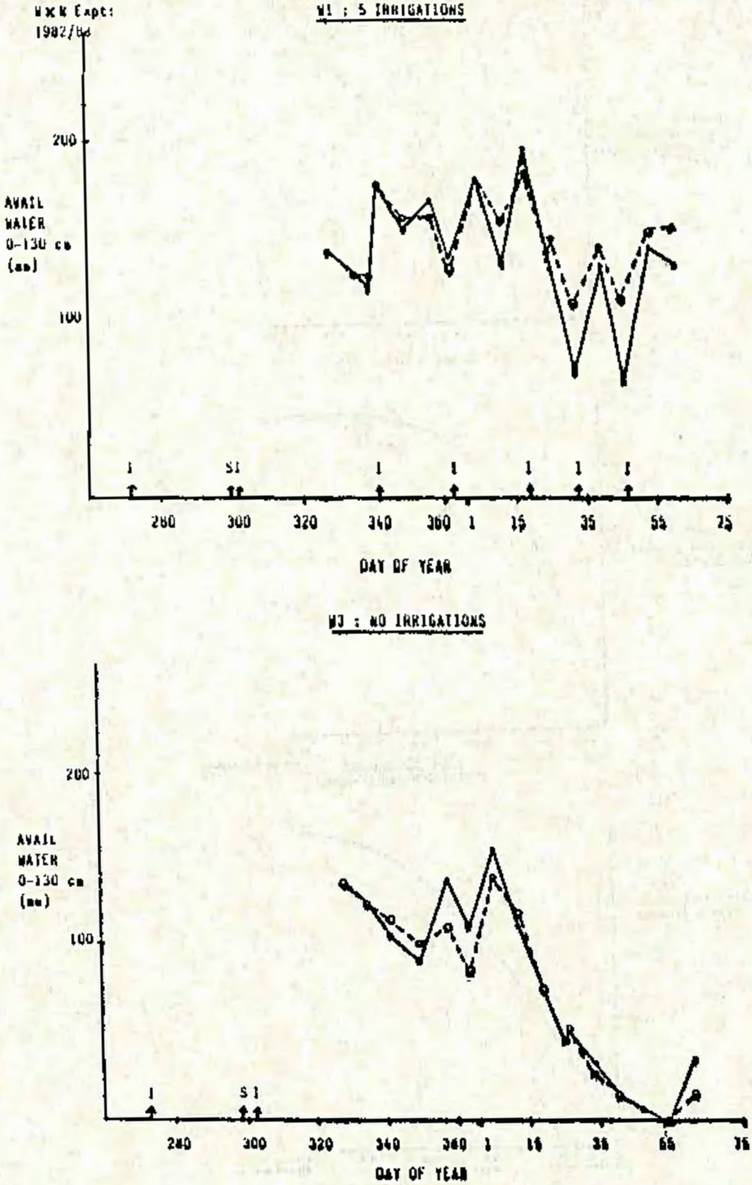


Fig. 1. Actual (•—•) and predicted(o–o) available soil water for treatments with and without seasonal irrigations. (S = day of sowing; I = dates of irrigation)

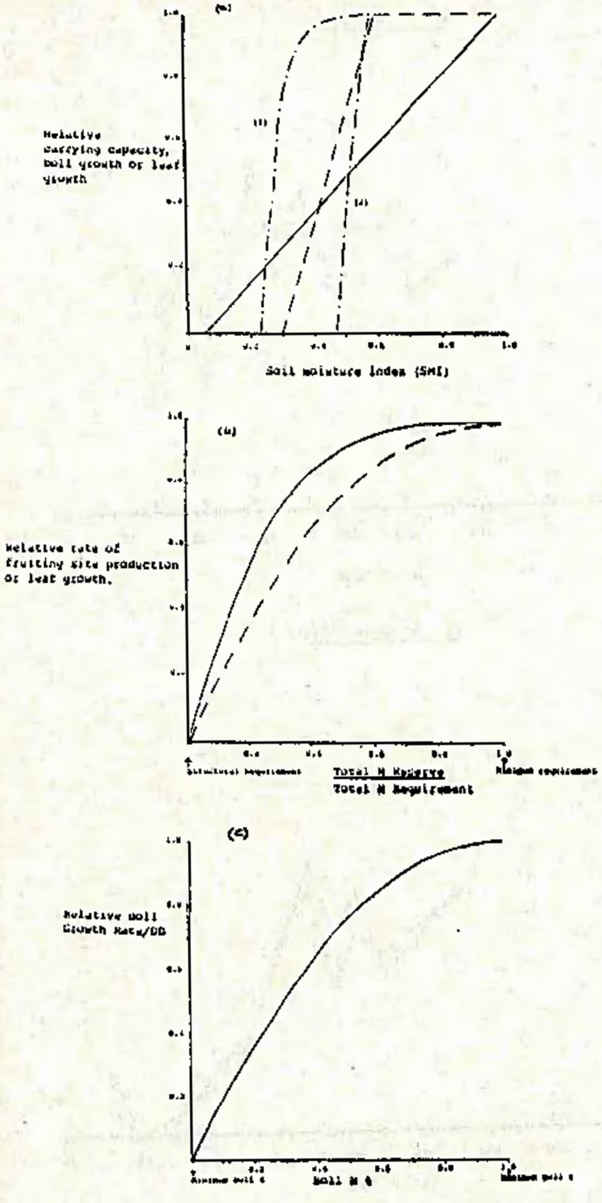


Fig 2. Relative effect of (a) soil moisture on carrying capacity (-), boll growth (--) and leaf growth (-·-) for 90%(1) and 10%(2) fruit survival. (b) nitrogen reserves on fruiting site production (-) and leaf growth(- -). (c) boll nitrogen level on boll growth (-).

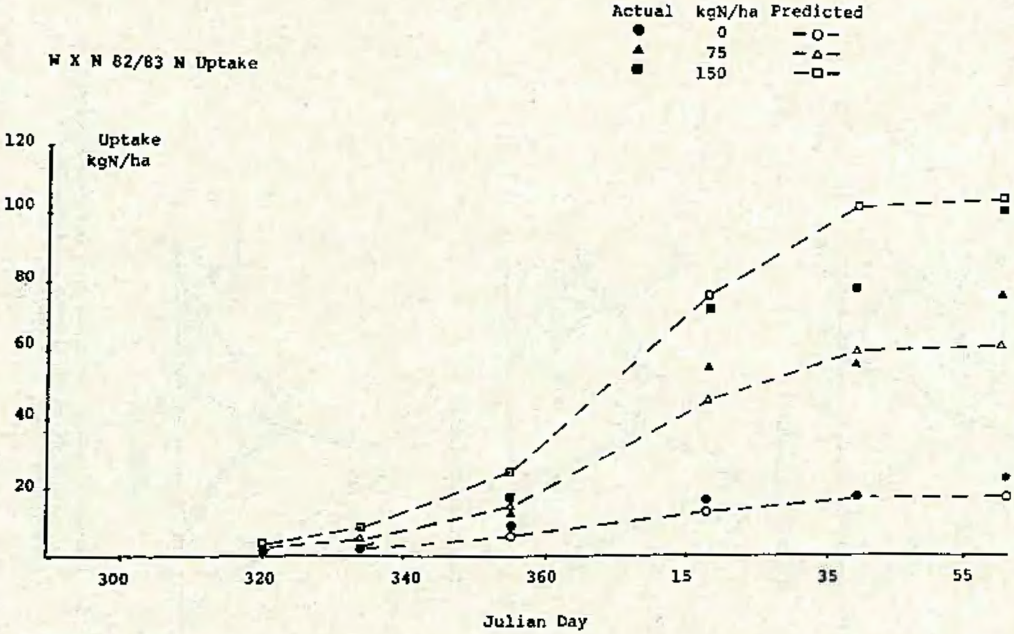


Fig 4. Predicted total nitrogen uptake through the season for three nitrogen treatments fully irrigated.

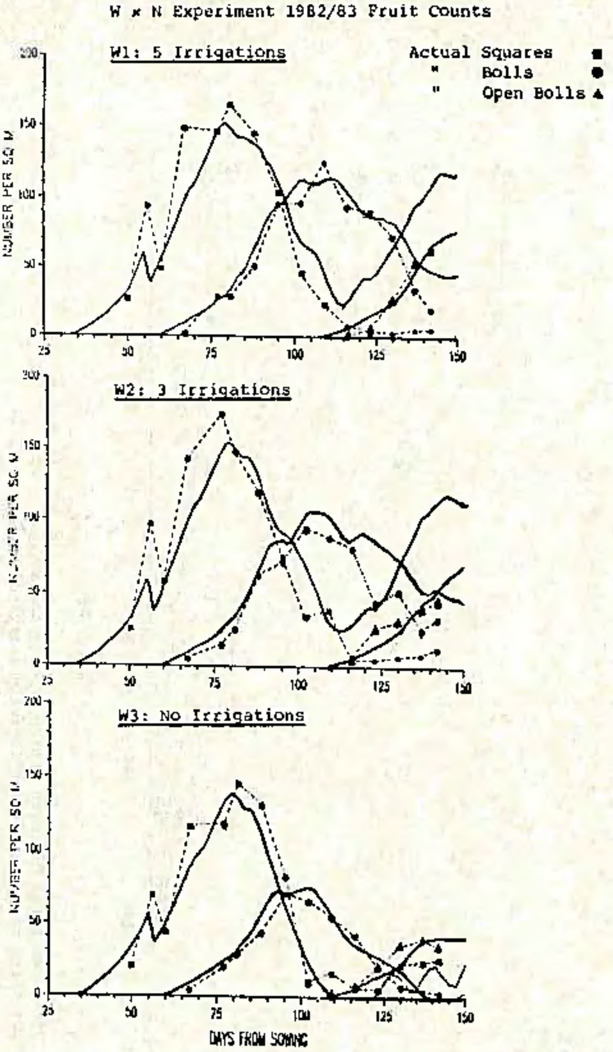


Fig 3. Predicted square, boll and open boll numbers (—) for a range of water stressed treatments with adequate nitrogen (150 kgN/ha).

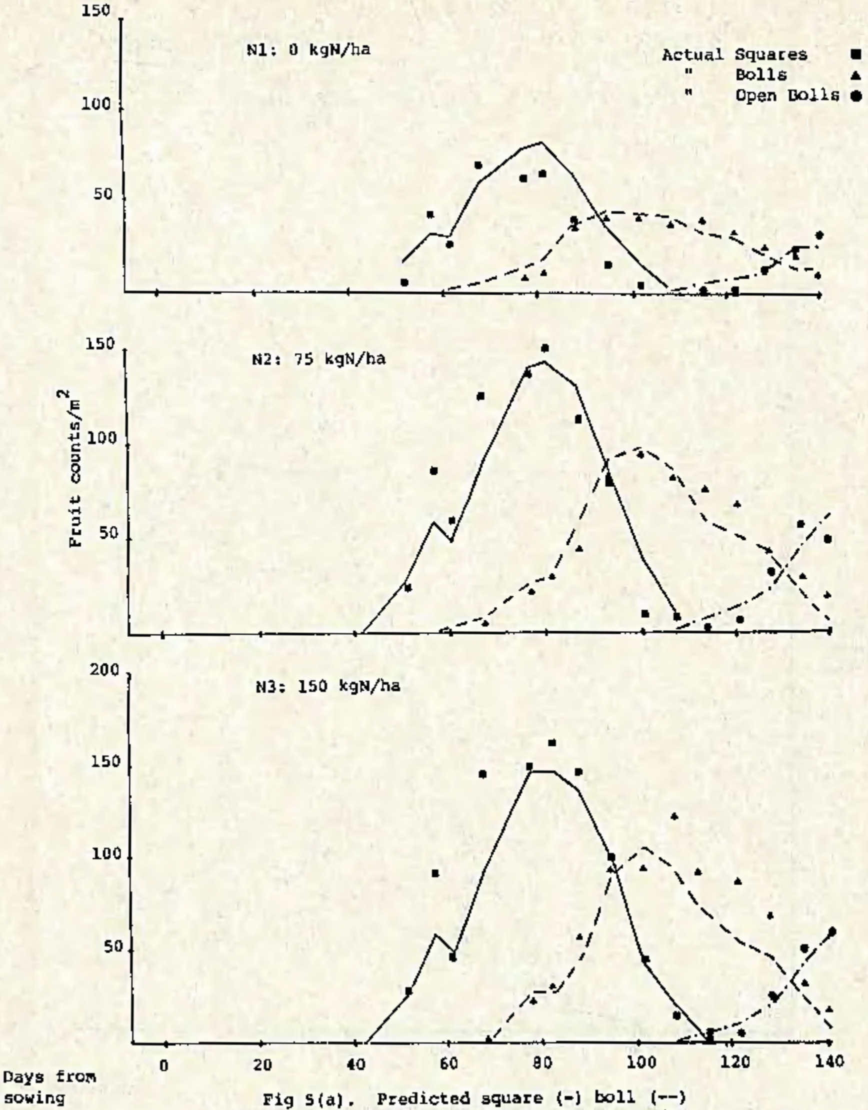


Fig 5(a). Predicted square (-) boll (--) and open boll (-·-)numbers for three nitrogen treatments, fully irrigated.

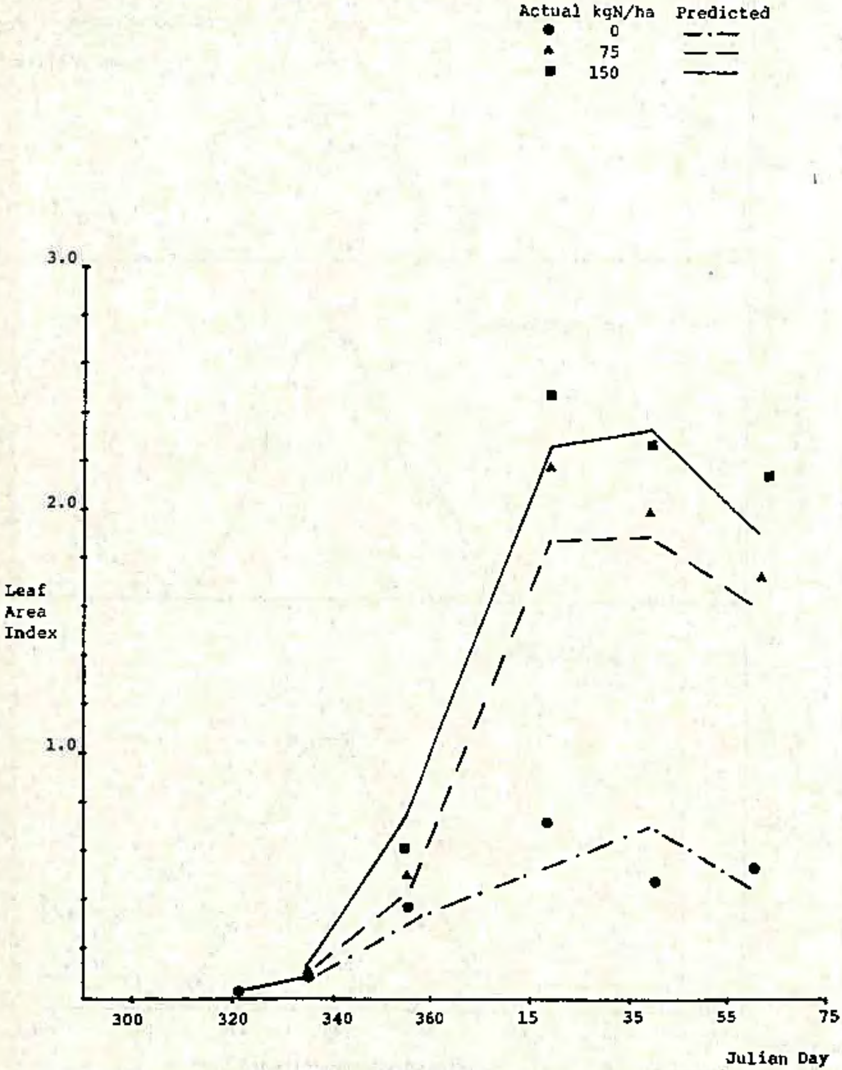


Fig 5 (b) Predicted leaf area index for three nitrogen treatments fully irrigated.

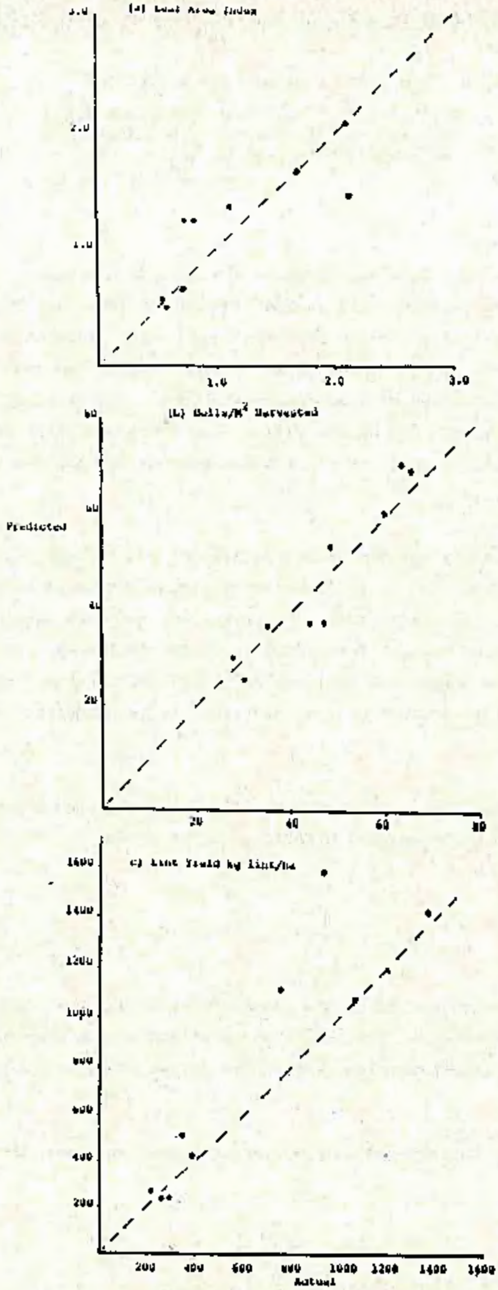


Fig 6. Predicted and actual end of season (a) leaf area index (b) boll numbers and (c) lint yield for the full range of irrigation and nitrogen treatments.

SIRATAC DEVELOPMENT TRIALS IN THE CALLIDE AND DAWSON VALLEYS

B. A. Pyke[1], M. E. Stone[2] and S. Struss[2]

1. Entomologist, The Cotton Marketing Board
2. Independent Consultants, Integrated Crop Management Services, Biloela

Introduction

Six SIRATAC trials have been conducted in the Callide and Dawson Valleys of Central Queensland over the three seasons 1981-82 to 1983-84. The Callide Valley (i.e. Biloela area) trials have included 1 split plot comparison of SIRATAC with commercial practices, 2 single plot SIRATAC managed fields and 1 split plot SIRATAC managed field to compare normal insect sampling with halved insect sampling. The Dawson Valley (i.e. Theodore area) trials have included 1 split plot comparison of SIRATAC and commercial and 1 single plot SIRATAC managed field.

The general conclusions reached after the 1981-82 and 1982-83 trials were: 1. SIRATAC was equivalent in performance in yields and costs to commercially managed areas, 2. the last effective flower date had been set too late in 1982-83 and should be brought forward by 2-3 weeks in 1983-84 and 3. a requirement for the commercial application of SIRATAC in these areas was reduced sampling time because of the relatively large number of small management units.

This paper discusses the results of the 1983-84 trials with respect to the future application of commercial SIRATAC in these areas.

Methods

- Callide

The 40 ha trial site was split and one half (Biloela 1) was sampled using standard SIRATAC methods, the other half (Biloela 2) was sampled with equal regularity, but insect sampling was halved to two 15 plant cards per sampling day.

Agronomic inputs for each 20 ha plot were constant and have been summarised in Table 1.

- Dawson

The 40 ha trial site was sampled using standard SIRATAC methods at least twice per week. The agronomic history for this site is given in Table 2.

Results and Discussion

- Callide

A summary of the types and costs of sprays applied to Biloela 1 and Biloela 2 is given in Table 3. The number of sprays applied to many commercial fields was 10-11 at costs ranging between $150 and $200/ha.

Table 4 shows the estimates of Heliothis larval populations in each plot differed on a high proportion of occasions. Reduced insect sampling (Biloela 2) tended to estimate larger populations more often than normal sampling. This tendency was reflected in the percentage of total decisions, which were spray decisions in each field, i.e. 14% in Biloela 1, 23% in Biloela 2. Nevertheless, there were 24 occasions on which both plots were sampled on the same day and for 18 of these (i.e. 75%) the decisions made were the same. Of the remaining 6 "different" decisions, 5 were spray decisions in Biloela 2, but no application was necessary in Biloela 1. The converse occurred once. These data suggest that reduced insect sampling was tending to err on the side of spraying rather than not spraying.

It was estimated that reduced insect sampling lowered weekly sampling time by 23%, but this still remained more than 50% higher than commercial insect sampling for this area (i.e. normal SIRATAC - 139 min/plot/week; commercial sampling - 70 min/plot/week). It would be possible to narrow the gap between commercial practices and reduced sampling SIRATAC by paying attention to reducing time spent on the computer (e.g. more stream-lining of input/output; not running obvious "no spray" decisions) and further reducing the time spent in the field by terminating sampling when pest population levels are obviously low. Further reductions in time spent collecting and processing SIRATAC data are likely to be necessary for the program to be widely accepted in the Callide/Dawson Valleys.

Table 5 provides a summary of planned (i.e. target) and actual dates and yield data for Biloela 1 and Biloela 2. The yield performance of both plots was poor; 24% below target and 19% below the average for other cotton fields on this farm. Boll counts on 5.3.84 indicated yields would be close to target, however many of the bolls produced in late February were shed or did not develop fully. These late bolls were produced in response to insect damage which occurred between 16.12.83 and 30.12.83, a period in which no sprays were applied, because Heliothis thresholds were set at their maximum levels. It was later concluded that the reason for such high thresholds was the poor selection of a last effective flower date (4.3.84) which appears to be at least a fortnight later than necessary for a late October planting in this environment. The poorer than expected yields in the Biloela trial plots suggest several things:
1. the setting of a last effective flower date needs to be very carefully considered in this environment because of the fast rate of crop development; 2. plant compensation for early insect damage may not produce effective mature bolls in this area; and 3. tolerance of Heliothis larval infestations of up to 5 per m may need reconsidering as a concept.

- Dawson

A summary of the types and costs of sprays applied to the SIRATAC plot and an "average" commercial field at Theodore is given in Table 6. The SIRATAC plot yielded 5.0 bales/ha which represents a performance similar to average commercial crops for the area.

Slow growth problems were experienced throughout the Theodore area during 1983/84, but were primarily associated with severe waterlogging during November and December. This waterlogging tended to reduce the yield potential of many crops including the SIRATAC plot and consequently any major differences in yield due to pest management were masked. However, two general comments can be made with respect to any future commercial application of SIRATAC in the Theodore area: 1. the green mirid caused severe damage to many crops in early November highlighting the need to include this pest in phase I of SIRATAC; and 2. the selection of yield development threshold criteria, particularly the last effective flower date, needs to be made with the same constraints and care as indicated above for the Biloela area.

TABLE 1: Agronomic Histories for Biloela 1 and Biloela 2

Planting date			25.10.83	
Variety			DPL 61	
Seed rate (kg/ha)			12.0	
Plant stand (plants/m)			11.6	
Weed Control				
	- Herbicides		Treflan 2.5 l/ha Cotoran (30 cm band) 5.0 l/ha	
	- Cultivations		1 on 6.12.83	
Fertilizer				
	- Basal	- type	Urea	
		- rate (kg N/ha)	50 (at furrowing)	
	- Split	- type	Urea	
		- rate (kg N/ha)	50	
	- Foliar	- No.	2	
		- rate (kg N/ha)	8.5	
	Total N (Kg/ha)		117.0	
Irrigations				
	Irrigation	- No.	3 (crop)	
		- dates	4.12.83 18.1.84 14.2.84	
Growth Regulants				
	Pix	- rate (mls/ha)	300	600
		- date	23.12.83	13.1.84
Conditioned				
	Biloela 1		Not ready by 31.3.84	
	Biloela 2		Dropp 80 g/ha 27.3.84	

TABLE 2: Agronomic History for the Theodore SIRATAC Site

Planting date	10.10.83
Variety	DPL 61
Seed rate (kg/ha)	18
Plant stand (plants/m)	7.0
Weed control	
Herbicides	Cotoran (at planting) 1.7 l/ha
Cultivations	9.11.83, 18.12.83 2.1.84
Fertilizer	
Basal - type	Aqua Ammonia
- rate (kg N/ha)	102.5
Split - type	Aqua Ammonia
- rate (kg N/ha)	61.5 (on 18.12.83)
Foliar - No.	5 (30.11.83, 22.12.83, 7.1.84, 25.1.84, 10.2.84)
- rate (kg N/ha)	8.5
Total N (kg/ha)	206.5
Irrigations	
Irrigation - No.	4
- dates	15.9.83, 23.12.83, 6.1.84, 12.2.84
- Ml/ha	2.74

TABLE 3: Spray Schedules and Costs for the Biloela 1 and Biloela 2 Plots

	BILOELA 1		BILOELA 2	
DATE	Insecticide	Cost ($/ha)	Insecticide	Cost ($/ha)
22.11.83	DIMETHOATE	4.70	DIMETHOATE	4.70
22.11.82	ENDOSULFAN	10.50	ENDOSULFAN	10.50
10.12.83	CHLORDIMEFORM/B.T.	14.80	ENDOSULFAN**	–
13.12.83	–		ENDOSULFAN + CHLORDIMEFORM	18.50
31.12.83	ENDOSULFAN + CHLORDIMEFORM	18.50	ENDOSULFAN + CHLORDIMEFORM	18.50
11.1.84	CHLORDIMEFORM	7.80	CHLORDIMEFORM	7.80
31.1.84	FENVALERATE + DIMETHOATE	24.30	FENVALERATE + DIMETHOATE	24.30
9.2.84	–		ENDOSULFAN + DIMETHOATE	13.20
5.3.84	DIMETHOATE	2.70	–	
APPLICATION	All aerial	45.50	All Aerial	45.50
TOTAL	7 sprays	128.80	7 sprays	143.00

**Application failure (cost not included)

TABLE 4: A comparison of occasions on which *Heliothis* larval population estimates differed in the Biloela 1 and Biloela 2 trial plots

No. of occasions:	Heliothis	Larval	Category
	VS	S	M & L
Plots sampled on same day	24	24	24
Biloela 1 > Biloela 2	5	4	5
Biloela 2 > Biloela 1	11	7	5
% of checks which differed	66.7	45.8	41.7

COTTON GROWTH ON LAND PREPARED WET

Ian Daniells
NSW Department of Agriculture
Narrabri

Introduction

The questions which prompted this research were:

(i) what are the causes of degraded soil structure under irrigated cotton cropping?

(ii) how much are cotton growth and lint yield affected by poor soil structure?

The first question may never be fully answered: there may be many causes of soil structural degradation. In this project, one likely cause of soil damage was selected for study: land preparation when the subsoil is wet. The effect of this on the soil and on irrigated cotton growth and yield were examined in field experiments.

The first experiment was done in 1980 to examine soil and plant response to land prepared at a range of soil moisture contents. The first year's findings were reported by McGarry (1982). Where land was prepared when the subsoil was wet, the soil changed in appearance from the original well-structured state. Where land was prepared when the soil was dry to depth, the structure remained in good condition. Daniells (1982) discussed ways of measuring these differences in soil structure and described a method of measuring the bulk densities of intact clods. After one season, clods from the surface 20 cm of land prepared wet were more dense and had less air space.

McGarry found that on the areas prepared dry, irrigated cotton grew taller, took up more water and had more green bolls than plants on land prepared wet. However, lint yield was not shown to be different.

The experiment was repeated for a further two seasons to confirm differences between treatments and to ascertain whether yield is affected.

Methods

In each of the three seasons, the same areas of land were prepared for cotton when the soil moisture content was either low, intermediate or high (referred to as dry, moist or wet).

The dry treatment was achieved by growing a cereal crop until the soil

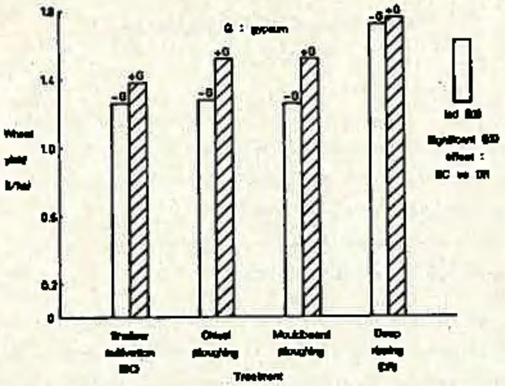


FIG 3. EFFECT OF TREATMENT ON WHEAT GRAIN YIELD (NOVEMBER 1982)

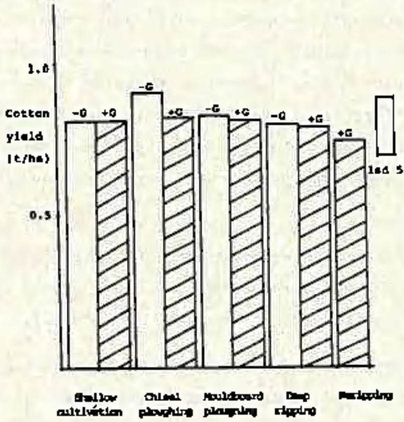


FIG 4. EFFECT OF TREATMENT ON COTTON LINT YIELD (MAY 1984)

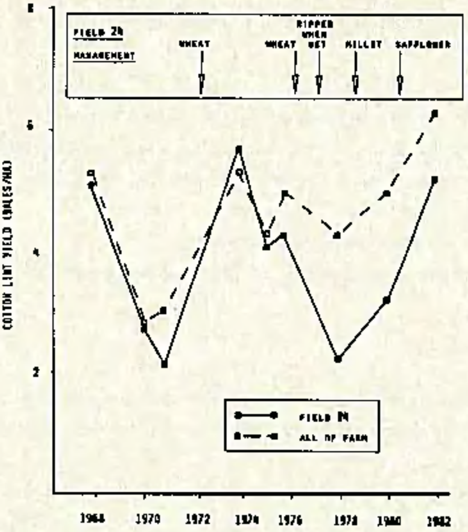


FIGURE 1: COTTON LINT YIELD IN FIELD 24, AUSCOTT LTD. BETWEEN 1967 & 1982

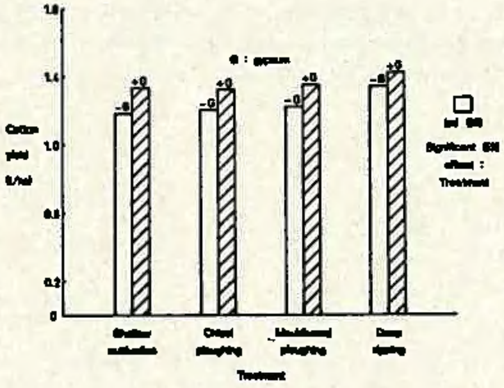


FIG 2. EFFECT OF TREATMENT ON COTTON LINT YIELD (MAY 1982)

designed implement is likely to be the best option.

3. When developing land, aim for relatively steep slopes which shed excess water quickly.
4. Use gypsum (approx. 5 t/ha) to improve drainage if the topsoil is dispersive; addition to dispersive subsoils remains unproven.
5. Dissolve nitrogen fertilizer in the irrigation water rather than injecting it into the subsoil as anhydrous ammonia, thus reducing the amount of soil disturbance.
6. Use backhoe pits to monitor soil conditions.

In general, prevention of compaction is preferable to repair of the damage.

Acknowledgements

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Other organisations and numerous individuals have also contributed, particularly Dave Anthony, Auscott Ltd Warren, Terry Abbott and Ross Higginson, Biological and Chemical Research Institute, Rydalmere; and David Hall, Agricultural Research Centre, Trangie.

Reference

McKenzie, D.C., Abbott, T.S. and Higginson, F.R. (1983). Improving the structure of irrigated grey clays in the lower Macquarie Valley. The Australian Cotton Grower 4(2), 22-26.

4. Control of Field Traffic

Field operations, such as cotton picking with 2-row equipment, cause wheel-tracking over a large proportion of a paddock. The trend towards 4-row pickers, and lighter and wider equipment for other operations, is likely to reduce the problem in most seasons. The use of 4-wheel drive machines is also likely to reduce damage to soil structure, due to less smearing of the moist soil by wheel-slip.

DISCUSSION

Soil compaction from field traffic in sodic grey clays is widespread, particularly when the crop is irrigated cotton. Problems caused by compaction include poor root growth and slow water penetration and drainage.

Land preparation systems that cater for the control of compaction in these soils have to allow for many factors, some of which are very difficult to predict, eg weather conditions, soil properties, water availability, equipment on hand, use of rotation crops, and the financial situation.

The challenge for soil scientists, therefore, is to carefully evaluate the large range of possible soil management options (eg deep tillage, gypsum, minimum tillage, 'vertical' mulching, drip irrigation, rotation crops) so that appropriate and flexible systems can be developed for individual farmers.

Hopefully, it will become possible for managers to input selected soil measurements, prior to land preparation for the next cotton crop, into a SIROTAC-type computer model and receive a suggested strategy for the management of soil structure.

In the meantime, however, it appears that the 'best bet' strategy for controlling and treating compaction in grey clays used for cotton production is:

1. Keep field traffic and tillage operations to an absolute minimum, particularly when the soil is wet. When on the ground use the same wheeltracks, and consider killing weeds with herbicides rather than tillage implements.
2. Use rotation crops, possibly in combination with tillage, to break up any compacted layers. Biologically increasing the number of subsoil cracks and channels improves drainage, aeration and subsequent root penetration. If tillage is the only possible alternative (eg after landplaning, back to back cotton after a wet harvest), chisel ploughing under dry conditions to about 30 cm depth with a well

Experiments to determine the relationship between soil strength, bulk density and moisture content have been carried out at Trangie. It should become possible to use this information routinely once engineering data about force distribution below machinery on these soils becomes available. Experiments to be done by Honours students at the University of New England will provide information about the degree to which root growth of a range of crops is affected by soil strength in the Macquarie Valley grey clays.

2. 'Permanent' Beds

Many of the field operations that can cause compaction when growing cotton may be unnecessary. For example, the need to deep rip, disc, list and scarify after harvesting cotton has been questioned, particularly since the recent introduction of the Israeli "USM" machine. This device is able to extract and chop cotton stalks, then incorporate them as a 20 cm deep 'vertical mulch' in alternate furrows; the beds then are almost ready for sowing the next crop, unless serious compaction from traffic used in producing the previous crop has necessitated deep tillage. Such a system of land preparation has big advantages in wet winters when land preparation usually creates serious soil compaction. It is likely that 'vertical mulches' will prolong the benefits of deep tillage in the furrows.

Detailed comparison of the deep ripping and minimum tillage strategies will be included in a proposed project involving the University of New England, Auscott Ltd and the NSW Department of Agriculture at Trangie, funded by the Cotton Research Committee.

3. Alternative Irrigation Systems

Flood irrigation tends to leave the soil in a saturated, compaction-prone condition for several days after watering.

However, alternatives such as drip irrigation provide more scope for concentrating water in soil close to the plants; wheel tracks thus tend to remain drier and firmer. Spray irrigation systems with frequent light applications of water can be turned off shortly before field operations, thus providing control over compaction. Although alternative irrigation systems can be very expensive, they do appear to offer benefits in terms of compaction control.

Maintaining a constant moisture supply in clay soils by drip and spray systems is also likely to encourage the development of an active earthworm population. Worms provide vertical channels in the soil which greatly improve drainage and aeration after heavy rain. They also aid the incorporation of organic matter into the soil.

although effective re-chiselling prior to a wet season is far superior to re-ripping (under dry conditions following a wheat crop) of deep ripping plus gypsum plots.

Table 2. Economic evaluation of deep tillage and gypsum in the Field 24 grey clay.

(a) 1981-84 (mostly dry)

	Costs in excess of control ($/ha)	Benefits in excess of control ($/ha)	Profit ($/ha)	B/C Ratio
Shallow + Gypsum	265	278	+13	1.05
Chisel	50	200	+150	4.00
Chisel + Gypsum	355	328	-27	0.92
Mouldboard	175	171	-4	0.97
M'board + Gypsum	410	375	-35	0.91
Ripping	225	451	+226	2.00
Ripping + Gypsum	410	503	+93	1.23
Ripping (82) + Gypsum	485	413	-72	0.85

b) 1983-84 only (wet)

	Costs ($/ha)	Benefits ($/ha)	Profit ($/ha)	B/C Ratio
Rechisel (Dec '83)	35	193	158	6.48
Rerip (Dec '83)	100	-86	-186	0.86

Notes: (i) No discount rates have been applied in the analysis.

(ii) The following assumptions have been used, based upon Macquarie Valley experience.

Gypsum $285/ha	Lint $1.80/kg ($400/bale)
Chisel $75/ha	Cotton seed $0.10/kg
M'board $180/ha	Wheat $0.15/kg
Ripping $200/ha	

2. Rotation Crops

The physical condition of grey clays of the Warren district, as viewed in backhoe pits, appears to have improved since the replacement of continuous cotton with a rotation of cotton - safflower - cotton - wheat.

Examination of Figure 1 suggests that the yield of cotton growth in a degraded grey clay (Field 24) has increased relative to the rest of the farm following effective 'biological deep ripping' with safflower and, to a lesser extent, cereals. Possible processes include subsoil 'pan' disruption by cracking and the provision of more numerous root channels for cotton to follow.

Experiments to compare the effect of safflower, wheat and fallow upon the structure of grey clays have been recently established at Warren and Narrabri by the NSW Department of Agriculture.

PREVENTION OF SOIL COMPACTION

1. Compaction Forecasting

Irrigation farmers increasingly are using neutron probes for irrigation scheduling. In theory, this information, combined with bulk density data, could be used to predict soil strength and, therefore, susceptibility to compaction.

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Shallow + Gypsum	285	298	+13	1.05
Chisel	50	248	+198	4.96
Chisel + Gypsum	335	328	-7	0.98
Mouldboard	175	171	-4	0.97
M'board + Gypsum	410	379	-31	0.92
Ripping	125	351	+226	2.82
Ripping + Gypsum	410	503	+93	1.23
Ripping (X2) + Gypsum	485	413	-72	0.85

b) 1983-84 only (wet)

	Costs ($/ha)	Benefits ($/ha)	Profit ($/ha)	B/C Ratio
Rechisel (Dec '82)	75	[illegible]	350	6.40
Rerip (Dec '82)	100	-86	-186	0.00

Notes: (i) No discount rates have been applied to the analysis.

(ii) The following assumptions have been used, based upon Macquarie Valley experience.

Gypsum $285/ha
Chisel $25/ha
M'board $100/ha
Ripping $100/ha

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In 1981/82, cotton lint yields were higher in the deep ripped plots than in the shallow cultivation (control) plots (Figure 2). Increases due to gypsum application, with and without deep tillage were also measured. Similar trends occurred in the 1982 wheat crop (Figure 3), which was sown directly into the hills and furrows. Results for chisel and mouldboard ploughing mostly were similar to the control. Chisel ploughing in 1981, however, was probably ineffective because it was carried out when the soil was very moist.

Measurement of moisture content at sowing time for the cotton indicated that there was more water in the deep ripped plots than the shallow cultivation plots between 20 and 70 cm. These results were supported by measurements of time for water to advance 500 m at the pre-irrigation; water intake was improved in the deep ripped plots and, to a lesser extent, in the gypsum plots. However, these effects were much less apparent at subsequent irrigations; slaking of the soil at the pre-irrigation appeared to have filled in most of the large vertical channels created by deep ripping.

Analysis of soil samples collected in June 1982 revealed that, apart from extra water being available for the cotton crop, deep ripping and, to a lesser extent, gypsum improved soil conditions for root growth, particularly between 20 and 60 cm depth. Soil bulk density under the hills was reduced at around 30 to 40 cm due to deep ripping; air-filled porosity in the deep ripped plus gypsum plot was higher than in the other treatments between 35 and 85 cm; soil shear strength was reduced in the deep ripping plots, particularly at 35 cm depth; organic carbon levels were higher throughout the deep ripped soil, due apparently to greater root production and penetration; ESP was decreased slightly to a depth of 15 cm by gypsum application.

The 1983/84 cotton season was cool and wet, and yields were generally poor. Each of the ten Field 24 treatments yielded similar amounts of lint (Figure 4), although there was evidence of a decline due to deep ripping and gypsum. Maximum yield was obtained with chisel ploughing. Soil samples taken in August-September 1984 are awaiting analysis but it appears that deep ripping may have disturbed stable subsoil pores, underneath the compacted surface, which are important for drainage and aeration under wet conditions.

An economic evaluation of the Field 24 treatments is shown in Table 2. Deep ripping remains as the most profitable treatment after three years, conditions. Therefore, a field experiment was established to examine the effect of four tillage treatments and gypsum on soil structure, and the growth of cotton, wheat and safflower under furrow irrigation. It was set up near Warren in 1981 by the NSW Department of Agriculture, in conjunction with Auscott Ltd.

The site (Field 24) had experienced a serious decline in cotton yield, relative to the rest of the farm, particularly between 1976 and 1978 (Figure 1). Few cotton roots were able to penetrate a dense and dispersed layer of soil at about 20 cm depth; the field had been used for cotton production for fifteen years, using mainly disc implements for land preparation. The Field 24 grey clay has ESP (Exchangeable Sodium Percentage) values of approximately 3% at the surface, increasing to 9% at 30-45 cm and 20% below 75 cm. The treatments, each replicated three times on 1.5 hectare plots, and the cropping sequence are shown in Table 1.

Table 1. Field 24 treatments and cropping sequence.

1 Shallow cultivation (disc ploughing only)	Moist cultivation in July 1981
2 Shallow cultivation + gypsum, (7.5 t/ha)	
3 Chisel ploughing (25 cm depth)	
4 Chisel ploughing + gypsum (7.5 t/ha)	
5 Mouldboard ploughing (40 cm depth)	
6 Mouldboard ploughing + gypsum (7.5 t/ha)	
7 Deep ripping (70 cm depth)	Dry cultivation in January 1981
8 Deep ripping + gypsum (7.5 t/ha)	
9 Deep ripping repeated every four years	
10 Deep ripping repeated every two years	

Note: Treatments three to nine were chisel ploughed in a dry condition in December 1982.

Cropping sequence: Safflower (1980), cotton (1981/82), wheat (1982), cotton (1983/84), safflower (1984), cotton (1985/86), wheat (1986), cotton (1987/88), safflower (1988).

The 1980 safflower crop was used to thoroughly dry the soil to beyond 1 m depth prior to deep ripping (using a winged implement having tynes with a loug lead). Under moist conditions, deep rippers tend to damage the structure further by slicing through a soil rather than breaking it up.

Detailed results for the first two years of the experiment have been presented elsewhere (McKenzie, Abbott and Higginson 1983). This information, collected during a period of drought, plus data from the 1983/84 cotton season, which had above-average rainfall, are summarized as follows.

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Compacted layers in a soil provide a soil structure which is far from ideal for the growth of plant roots. Increased soil density leads to problems such as:

1. Reduced soil aeration.
2. Increased mechanical resistance to root growth.
3. Reduced infiltration of water.
4. Increased likelihood of root disease.
5. Increased loss of nitrogen fertilizer by denitrification.

The use of press wheels to encourage seed-soil contact when sowing is one of the few times when a limited degree of compaction is desirable.

This paper discusses the identification, treatment and prevention of compaction in grey clays, based mainly upon experience from the Macquarie Valley in New South Wales.

IDENTIFICATION OF COMPACTION PROBLEMS

It is almost impossible to eliminate compaction completely when growing cotton. However, there have been some relatively dry seasons when the problem is only minor (limited to the top 15 cm of some furrows), and unlikely to seriously affect plant growth; if this is the case, expensive treatments such as deep ripping may be unnecessary. Therefore, careful problem identification is required.

Factors to consider include:

1. Are cotton yields falling with no obvious reasons?
2. Are crops becoming later maturing with no obvious reasons?
3. Is early fruit development and plant growth slower than expected?
5. Is moisture extraction prior to wilting less than expected?
6. Having dug a hole, preferably under dry conditions, does the soil appear to be well aggregated, or does it have massive, hard blocks?

However, more definitive methods (eg the use of shear vanes, oxygen diffusion meters) are required to actually measure the degree of compaction in a clay soil.

TREATMENT OF COMPACTION

1. Deep tillage and gypsum

Deep tillage is the main method for 'breaking up' compacted layers. Gypsum has also been used, in combination with deep tillage, to reduce subsoil exchangeable sodium levels and increase the electrolyte content of the soil solution, thus improving subsoil drainage.

Although a great deal has been written in the past about deep tillage, it was considered necessary to carry out further research under Australian