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COTTON RESEARCH COUNCIL
FINAL REPORT

Project Number: DAN 6L

Project Title: IMPROVED IRRIGATION TECHNIQUES FOR COTTON PRODUCTION IN THE MACQUARIE VALLEY

Field of Research: SOIL SCIENCE Field Code: 2.1

Organisation: NSW Agriculture & Fisheries

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Commencement date: July 1983

Completion date: July 1988

Objectives:

(1) To calibrate neutron moisture meters and gamma density probes on grey clays and hard-setting red soils of the Macquarie Valley.

(2) To investigate the hydrological effects, and the influence upon yield and profitability, of deep ripping, chisel ploughing, mouldboard ploughing, minimum tillage, gypsum, and a range of rotation crops on a furrow-irrigated grey clay; similar techniques, were also studied on a hard-setting red soil.

(3) To obtain general information about irrigation efficiency under a range of irrigation systems on grey clays and hard-setting red soils.

In the final year of the project, objective (3) was not pursued because of urgent grower demand for a soil management information transfer system. Staff associated with this project assisted with the creation and development of the Macquarie Valley Soil Management Service. Growers use the service to choose the tillage, irrigation and fertiliser strategies that are required to produce optimal soil conditions for irrigated cotton production.

IMPROVED IRRIGATION TECHNIQUES FOR COTTON PRODUCTION IN THE MACQUARIE VALLEY

SUMMARY

Introduction

The overall aim of the soils research program based at Trangie has been to develop management strategies that maximise the profitability of irrigated cropping by: (i) correcting yield limiting soil physical problems; and (ii) by preventing further problems from developing. The work has been carried out on cracking clays and hard-setting red soils with a strong emphasis on extension of the results to irrigation farmers. This project concentrated on evaluating the hydrological effects of deep ripping, chisel ploughing, mouldboard ploughing, minimum tillage, gypsum, and several rotation crops on a furrow-irrigated cracking clay. The subsequent effects upon cotton performance and farm economics were also measured and extended to cotton growers. Similar experiments were carried out on a hard-setting red soil.

Most of the work has been carried out <u>co-operatively</u> with colleagues from NSW Agriculture & Fisheries, private industry (mainly Auscott Ltd), University of New England and CSIRO.

Six main topics were considered:

1. Calibration of a neutron-gamma probe
2. The long-term effects of deep tillage, gypsum and re-ripping on soil structure and cotton performance on a cracking clay
3. The effects of safflower, wheat and fallow upon soil structure and cotton performance on a cracking clay.
4. The feasibility of using 'permanent' ridges for irrigated cotton production on a cracking clay.
5. An assessment of techniques for improving the physical fertility of hard-setting red soils.
6. Extension of soil management and irrigation research results to cotton growers.

Ms Kate Hucker, a very capable Technical Officer employed under this grant, assisted Mr McKenzie with topics 1, 2 and 6. She also helped with topics 3 and 4, dealt with respectively by CRC funded projects <u>DAN 13L</u> and <u>UNE 1L</u>, and contributed to a Wheat Industry funded project addressing topic 5.

Summary of results and benefits to industry

Neutron-gamma probe calibration

1. Grey clays and red-brown earths in the Macquarie Valley require different neutron probe calibrations for relating instrument readings to soil water content.
2. The Macquarie Valley equations are substantially different from those provided by the supplier of the instrument, and have been used commercially in the area for several years.

3. Poor precision caused by field variability usually is much greater than calibration and instrument error in the Trangie-Warren area.

4. The gamma component of the CPN501 Depthprobe was shown to be too inaccurate for assessing the bulk density of Macquarie Valley cracking clays.

Field 24 deep tillage/gypsum experiment

5. Mechanical deep loosening using deep rippers and chisel ploughs under dry conditions boosted short-term cotton growth and profitability in a degraded grey clay. Improved yields were related to increased water storage, improved root penetration, and better utilisation of applied nitrogen.

6. Chiselling to a depth of 30 cm was the most profitable and least damaging tillage option.

7. Deep ripping reduced cotton lint yields during the cool, wet summer of 1983/84, due apparently to more serious waterlogging. Ripping below 30 cm also caused long-term yield declines (relative to the control, 7 years after applying the treatment under dry conditions).

8. Addition of gypsum (7.5 t/ha) to correct subsoil sodicity improved yields by approximately 10%, but consistency of the response over a 5 year period meant that it improved profitability when the cotton price is around $500/bale.

9. Doubling the rate of pre-plant nitrogen improved the cotton yield of poorly structured treatments in 1988, but reduced yield on well-structured treatments due to the encouragement of rank growth.

10. In the eighth year of the experiment, one of the best yielding treatments was the untreated control. It appears that cracking of the degraded subsoil by rotation crops allowed deep cotton root penetration, but water could not be accepted in sufficient quantities to create badly waterlogged conditions in the subsoil.

Field 34 rotation crop experiment

11. Non-irrigated safflower and wheat extracted water to at least 1.2 m in a grey clay, causing air-filled porosity and vertical macroporosity to be increased in comparison to a fallow control. This favourable structure persisted for several irrigation cycles, and correlated with the improved growth of a subsequent crop in the absence on other limiting factors.

Field 30 minimum tillage experiment

12. No yield penalty was suffered by planting cotton into 'direct listed' ridges on a well-structured brown cracking clay, compared to other more intensive and expensive seedbed preparation methods. Water absorption and retention were greater in the deep tilled than the 'direct-listed' plots. However, under the management and climatic regime of the experiment, cotton plants were unable to utilise this extra water.

Block 4 red soil management experiments

13. Deep (45 cm) mouldboard ploughing to increase the cracking-clay content of a hard-setting red soil, in combination with gypsum application (5 t/ha), increased the yield of irrigated summer and winter crops by as much as 70% and 30%, respectively. Better water and root penetration were the main reasons for this improvement.

14. Continuous cropping with summer and winter crops under zero tillage further improved soil physical conditions.

15. Permanent beds and controlled traffic prolonged the benefits of deep tillage, although compacted furrow edges required amelioration.

16. Slow wetting with small siphons, and the covering of furrows and beds with cereal straw, improved soil biological activity, and allowed the soil to accept more rain and irrigation water.

Extension of the research results

17. An audio cassette tape and a video about the diagnosis and management of soil physical problems have been produced to supplement written material.

18. NSW Agriculture & Fisheries has established a soil management extension service, based at Warren. Approximately 40% of the Macquarie Valley cotton growers have utilised this service, which eventually is likely to be promoted State-wide. Procedures developed by the group form the basis of the COMPUCLOD/SOILPAK initiative.

Difficulties encountered

1. Some treatments may have been disadvantaged by being watered too often; irrigation scheduling was based upon the needs of cotton growing on plots most prone to stress caused by water deficiency. However, apart from seriously inconveniencing operators of the irrigation systems, a lot of extra labour would have been required if each plot had been watered at the optimal time.

2. Most of the experiments were carried out under commercial conditions. Whilst growers were able to identify well with this approach, and researchers were able to concentrate on experimental measurements rather than management, there were problems with the use of rotation crop equipment operated mainly by contractors. On several occasions, planting equipment and/or headers with incompatible wheel configurations caused serious ridge compaction, and complicated experimental design.

Recommendations for future research

1. The fertiliser rates and irrigation frequencies required by rotation crops and cotton to maximise soil improvement by cracking are poorly understood. Further research is required.

2. There is a need to develop rating tables that outline the ability of different rotation crops and varieties to penetrate degraded soil.

3. Water-use efficiency and cotton response need to be compared when deep ripped and minimum tilled plots are watered either at the same time, or at the refill point for each treatment.

4. The patterns of water extraction by cotton need to be more thoroughly characterised under flood, spray and drip irrigation systems with various application frequencies on a broad range of cotton soils.

5. The feasibility of using soil fauna such as earthworms and ants to improve soil physical conditions for cotton needs to be investigated.

6. The problem of lack of refinement of field techniques for the diagnosis of soil physical condition by advisory staff is being addressed in project DAN 46L (Procedures for the evaluation of soil physical conditions in the field to assist land management for cotton production), in conjunction with project DAN 41L (Development of 'COMPUCLOD', a decision-support system for soil management).

Budget Summary

	Salary $	Travel $	Operating $	Capital $	Total $
1983/84	9,000	1,000	1,000	3,000	14,000
1984/85	20,766	2,000	2,000	4,800	29,566
1985/86	22,801	2,000	2,500	-	27,301
1986/87	23,547	2,000	2,500	6,700	34,747
1987/88	26,663	2,000	2,100	2,500	33,263
GRAND TOTAL					138,877

Publications arising from the project

Research papers - submitted to journal

1. [1,2] Hulme, P.J., McKenzie, D.C., Abbott, T.S. and MacLeod, D.A. Measurement of vertisol structure dynamics following an irrigation of cotton, as influenced by prior rotation crop. Aust. J. Soil Res.

2. McKenzie, D.C., Hucker, K.W., Morthorpe, L.J. and Baker, P. Field calibration of a neutron and gamma probe in three agriculturally important soils of the lower Macquarie Valley. Aust. J. Exp. Agric.

Research papers - in preparation

3. [3] Hall, D.J.M., McKenzie, D.C., Cass, A. and MacLeod, D.A. The effect of deep mouldboard ploughing and double cropping on soil properties and crop growth in a degraded red brown earth. 1. Soil chemical and physical properties. Aust. J. Exp. Agric.

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[1] Associated with Project UNE 1L 'An evaluation of seedbed preparation methods for growing irrigated cotton on grey clays'.

[2] Associated with Project DAN 13L 'Restoration of soil structure in cracking clays'.

[3] Associated with NSW Agriculture & Fisheries/University of New England/CSIRO Division of Soils red soil management research program, Trangie

4. [3] Hall, D.J.M., McKenzie, D.C., Cass, A. and MacLeod, D.A. The effect of deep mouldboard ploughing and double cropping on soil properties and crop growth in a degraded red brown earth. 2. Wheat growth. Aust. J. Exp. Agric.

5. [1] Hulme, P.J., MacLeod, D.A., McKenzie, D.C. and Anthony, D.T.W. Cotton response to minimum tillage. Aust. J. Agric. Res.

6. McKenzie, D.C., Anthony, D.T.W. and Hucker, K.W. Amelioration of a structurally degraded vertisol by deep tillage and gypsum application. 1. Performance of cotton, wheat and safflower. Aust. J. Exp. Agric.

7. McKenzie, D.C., Hucker, K.W. and Hall, D.J.M. Amelioration of a structurally degraded vertisol by deep tillage and gypsum application. 2. Changes in soil water relations. Aust. J. Exp. Agric.

8. McKenzie, D.C., Abbott, T.S., Hucker, K.W., Thompson, A. and Higginson, F.R. Amelioration of a structurally degraded vertisol by deep tillage and gypsum application. 3. Changes in soil aeration, strength and stability. Aust. J. Exp. Agric.

9. McKenzie, D.C. and Hucker, K.W. Long term effects of deep tillage and gypsum on soil condition and cotton growth on a degraded vertisol, as modified by different rates of nitrogen. Aust. J. Exp. Agric.

10. [1,2] McKenzie, D.C., Abbott, T.S., Douglas, T., Anthony, D.T.W. and MacLeod, D.A. Effect of wheat, safflower and fallow on the structure of an irrigated vertisol. Aust. J. Exp. Agric.

11. [3] McKenzie, D.C., MacLeod, D.A. and Blackwell, P.S. The effect of deep tillage, flood irrigation layout and cropping sequence on soil structure in a degraded red-brown earth. 4. Surface macroporosity. Aust. J. Soil Res.

12. Wilde, M., Koppi, A.J., McBratney, A.B. and McKenzie, D.C. Analysis of soil macropore structure after shallow cultivation and deep tillage in a degraded vertisol. Soil Till. Res.

Conference papers

13. [1,2] Abbott, T.S., McKenzie, D.C., Hulme, P.J. and MacLeod, D.A. (1987). Effect of deep rooted rotation crops on a sodic grey clay. Proc. Australian Society of Soil Science (ASSSI) Conference, Deniliquin.

14. Abbott, T.S., McKenzie, D.C., Higginson, F.R. and Hall, D.J.M. (1988). Effect of deep tillage and gypsum application on a structurally degraded grey clay. Proc. ASSSI Nat. Soils Conf., Canberra, p. 180.

15. [3] Hall, D.J.M. and McKenzie, D.C. (1985). Amelioration of a hardsetting red-brown earth in the Macquarie Valley, NSW. Proceedings 'Soils in relation to changing systems of land use' Conference Horsham, ASSSI. pp 119-25.

16. [3] Hall, D.J.M., McKenzie, D.C., MacLeod, D.A. and Cass, A. (1986). The effects of deep mouldboard ploughing, gypsum and double cropping on a hardsetting red-brown earth in the Macquarie Valley, NSW. Proc. ASSSI. Nat. Conf. Canberra.

17. [3] Hall, D.J.M., McKenzie, D.C., Morthorpe, L.J., Morthorpe, K.J. (1987). Irrigated red brown earth management in the Macquarie Valley; A review of current research. Proc. ASSSI Conf., Deniliquin.

18. [3] Hall, D.J.M. and McKenzie, D.C. (1988). Profile modification and management strategies for hard setting red-brown earths. Proc. Nat. Soils Conf., Canberra p.188.

19. [1] Hulme, P.J., MacLeod, D.A., McKenzie, D.C. and Anthony, D.T.W. (1988). Influence of three sub-surface tillage treatments on physical properties and cotton lint production on an irrigated grey clay. Proc. ASSSI Nat. Soils Conf., Canberra p. 190.

20. [1] Hulme, P.J., MacLeod, D.A., McKenzie, D.C. and Anthony, D.T.W. (1988). Cotton production without deep tillage is viable, in the absence of structural degradation. Proc. ACGRA Conf., Surfers Paradise.

21. McKenzie, D.C. (1984). Managing compaction in sodic grey clays. Proc. ACGRA Conf. Toowoomba. pp. 260-271.

22. McKenzie, D.C., Abbott, T.S. and Higginson, F.R. (1984). Amelioration of a structurally degraded vertisol by deep tillage and gypsum application. Proc. ASSSI Nat. Soils Conf., Canberra p. 249.

23. McKenzie, D.C., Abbott, T.S., Anthony, D.T.W., Hall, D.J.M. and Higginson, F.R. (1984). Soil management strategies for improving the yields of irrigated crops in the lower Macquarie Valley. <u>In</u> 'Root Zone Limitations to Crop Production on Clay Soils'. pp. 149-161. (Eds W.A. Muirhead and E. Humphreys) (ASSSI, Riverina Branch).

24. [1] McKenzie, D.C. and Hulme, P.J. (1986). Reduced costs; the role of minimum tillage. Proc. ACGRA Conf., Surfers Paradise, pp.65-72.

25. [1,2] McKenzie, D.C., Hulme, P.J., Abbott, T.S., MacLeod, D.A. and Cass, A. (1987). Vertisol structure dynamics following an irrigation of cotton, as influenced by prior rotation crop. In 'Effects of Management Practices on Soil Physical Properties' (Eds K.J. Coughlan and P.N. Truong) pp.33-7 (DPI, Queensland)

Thesis supervision (jointly with Dr D.A. MacLeod and Dr A. Cass, University of New England)

26. Cousins, Y. (1984). The use of Emerson's θ_D test in assessing structural stability. BScAg (Hons) thesis.

27. Cousins, Y. (1984). The distribution and effects of surface applied gypsum, as modified by deep tillage, on a structurally degraded grey clay. Adv. Soil Science Project.

28. Douglas, T. (1985). Effects of crop rotations in cotton production on the physical properties of a grey clay in the lower Macquarie Valley, NSW. BRurSci (Hons) thesis.

29. Douglas, T. (1985). The effect of varying bulk densities on the growth of five crop species. Adv. Soil Science Project.

30. Greenwood, K. (1984). Shrinkage characteristics of natural clods from the lower Macquarie Valley. BScAg (Hons) thesis.

31. Hall, D.J.M. (In preparation). The effect of deep mouldboard ploughing, gypsum and double cropping on soil properties and irrigated wheat growth in a degraded red brown earth. MScAg thesis.

Advisory Communications

32. Anthony, D.T.W., Shaw, A. and McKenzie, D.C. (1985). Soil management cassette tape for farmers (NSW Agriculture & Fisheries).

33. Abbott, T.S. and McKenzie, D.C. (1986). Improving soil structure with gypsum. Agfact AC. 10. (Department of Agriculture NSW).

34.[1,2] Daniells, I.G., Abbott, T.S., McKenzie, D.C. and Hulme, P.J. (1988). Rotation crops improve soil structure. The Australian Cottongrower 9(2) 30-34.

35.[1] Hulme, P.J., Anthony, D.A., Cass, A., McKenzie, D.C. and MacLeod, D.A. (1986). Is ripping necessary? The Australian Cottongrower. 7(2) 20-25

36. Kay, A. and McKenzie, D.C. (1988). Gypsum - where to use it. Macquarie Irrigator October 1988.

37. McKenzie, D.C. (1986). Solutions to soil degradation. In, 'Conservation farming - the concepts'. Proceedings of seminar for Agribusiness, Dubbo. (Dept of Agriculture and Soil Conservation Service, NSW).

38. McKenzie, D.C. (1987). Soil management. In, 'Water Force - Irrigation for Profit : Main Report' (Irrigation Association of Australia).

39. McKenzie, D.C., Sykes, J., Kay, A. and McHugh, T. (1987). Soil management video for farmers in the Macquarie Valley (NSW Agriculture & Fisheries).

40. 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 Cottongrower. 4(2):22-26.

41. McKenzie, D.C., Abbott, T.S. and Higginson, F.R. (1988). Long term effects of deep tillage and gypsum. The Australian Cottongrower. 9(1): 30-34.

42. McKenzie, D.C., Hall, D.J.M., Daniells, I.G., Abbott, T.S., Kay, A. and Sykes, J. (in prep.). Soil management for irrigated cotton production Agfact.

43. Sykes, J., Kay, A., McKenzie, D.C., Hall, D., McKenzie, N. and Abbott, T.S. (1988). Management of irrigated soils in the lower Macquarie Valley. NSW Dept. Ag. Advisory Bulletin.

DETAILED REPORT

Project: Improved irrigation techniques for cotton production in the Macquarie Valley.

This 5-year project originally aimed to characterise the hydrological properties of a broad range of soils used for cotton production, and to investigate patterns of water extraction by cotton under different irrigation systems and application frequencies. However, the study was later modified because of industry priorities to become an extension of a soil amelioration project at Trangie funded between 1979 and 1983 by the Wheat Industry Research Committee of New South Wales.

Cotton growers observed in the late 1970's that the yields of irrigated crops grown on cracking clays and loams were declining, apparently in response to poor soil physical condition. Private industry showed that soil improvement, using techniques such as rotation crops, deep ripping, deep mouldboard ploughing and gypsum, could be carried out successfully but there was a lack of information about the processes taking place, and longevity of the benefits. Minimum tillage has become popular in recent years where major soil physical limitations have been overcome, despite an initial lack of data about the economics and stability of the technique for irrigated summer crops grown on cracking clays and hard-setting red soils.

Calibration of a neutron-gamma probe

A neutron-gamma probe (CPN501 Depthprobe) was field calibrated in a grey clay, grey-brown clay, and a red-brown earth near Trangie. They are the main soils used for irrigated cotton production in this region. Accurate, but simple, calibrations and sampling procedures were required by commercial irrigators and researchers.

Each soil has significantly different neutron probe calibration equations, and all are substantially different from those provided by the supplier of the instrument. Specific soil type equations are recommended wherever a relatively uniform soil unit is being investigated to gain the least biased estimate of soil water content. Very little expertise is required to distinguish the 3 soils used in this study. However, it is recommended that on highly variable sites in the Macquarie Valley - for example irrigation fields with several contrasting soil types - an equation combining all data for the 3 soils, $\theta_v = -0.160 + 0.707\underline{n}$, be used. The combination equation is biased in some cases, but has better precision than most of the derived equations. The combination equation also is recommended for NMM users on similar soils in other districts which do not have their own calibrations.

An analysis of error showed that one 15 second count is adequate when monitoring soil water content, since instrument error is only a small proportion of total error. The analysis also showed that error introduced by field variability usually is much greater than calibration and instrument error in the Trangie-Warren area. Increasing tube number improves precision markedly up to 10 tubes, but this has to be balanced against the cost of monitoring extra tubes. For example when assessing soil physical condition, the water content difference at 40 cm depth is determined with a confidence interval of ± 0.04 m^3 m^{-3} on a grey clay in a low variance situation where 3 tubes are used. With 10 tubes, the interval is ± 0.025 m^3 m^{-3}. Errors associated with year-to-year water content comparisons can be greatly reduced by leaving access tubes in the same place, preferably with removable tops to avoid damage by field operations such as harvesting. The location component of variance is removed for year-to-year comparisons, although bias due to preferential cracking and trampling may be introduced.

The gamma probe calibrations showed poor correlation between gamma count rate ratio and soil bulk density, particularly in clays where cracking occurred under dry conditions, and is too inaccurate for assessing the bulk density of Macquarie Valley cracking clays and loams.

These results have been submitted for publication (2), but the information has been used routinely for several years by extension workers in the lower Macquarie Valley who advise growers about irrigation scheduling.

The long term effects of deep tillage, gypsum and re-ripping on soil structure and cotton performance (Field 24 grey clay experiment, Auscott Ltd. Warren)

The effect on soil physical condition and the yield of furrow irrigated cotton of 4 tillage treatments - control (15 cm deep disc ploughing; every 2 years), chisel ploughing (30 cm; 2-yearly), mouldboard ploughing (40 cm; 1981 only) and deep ripping (70 cm; 1981 only) - and gypsum (7.5 t/ha in 1981) were monitored for 8 years. The effects of repeated deep ripping every 2 and 4 years were also investigated. Plots re-ripped every 2 years also received a second 7.5 t/ha application of gypsum in 1985. In 1987/88, 3 pre-plant nitrogen rates - 80, 120 and 160 kg/ha - were superimposed on each plot. A rotation of cotton with non-irrigated wheat and safflower was applied to all treatments. When the treatments were imposed in 1981, the site showed serious compaction and smearing at a depth of 0.15-0.40 m.

The soil is a cracking clay with a self-mulching surface (exchangeable sodium percentage = 3) and an apedal subsoil (ESP=22 at 1 m depth); clay content is approximately 50% throughout.

Deep ripping increased cotton lint and wheat yields by 15% and 33%, respectively, in 1981/82. Gypsum improved cotton lint and wheat yields by 10% and 12%. Chisel ploughing and deep mouldboard ploughing were carried out in 1981 at a soil water content above the plastic limit, and did not improve crop performance in 1981/1982. Yield increases following deep ripping and gypsum application were associated with larger reserves of subsoil moisture, higher near-surface porosity which reduces the risk of waterlogging, and lower soil strength which permits more rapid root extension. Benefits due to gypsum application were mainly attributed to its electrolyte effect.

Reimposition of the chisel ploughing treatment in 1983, 1985 and 1987 at water contents less than the plastic limit consistently increased cotton lint yield in relation to the disc-cultivated control. Improved yields were related to higher near-surface porosity, improved root penetration, and better utilisation of applied nitrogen. Chisel ploughing was the most profitable of the treatments studied, regardless of cotton lint value (in the range $300-500/bale) or interest rate (0-15%). Gypsum application to treat the sodic subsoil only produced profits when lint value is above $480/bale (15% interest rate).

Re-ripping in 1982 under dry conditions (soil water content less than the lower plastic limit) reduced cotton lint yields during the cool, wet summer of 1983/84, due apparently to waterlogging caused by excessive water intake. However, later reripping under dry conditions, in combination with extra gypsum, produced the best cotton yield in 1987/88 (2523 kg/ha). 2 yearly deep ripping, with a total of 15 t/ha gypsum, was profitable over the 8 year period when cotton price exceeded $420/bale (15% interest rate), but the gains were less than for chisel ploughing.

The means of lint yields after 8-yearly and 4-yearly deep ripping with gypsum were similar in 1982 and 1988 (1428 vs 1574 kg/ha), whilst the disc-ploughed control had an increase from 1176 to 2124 kg/ha lint over the same period. Preliminary results suggest that cracking of the degraded subsoil by wheat and safflower in the control allowed cotton roots to bypass the high-strength damaged layer and penetrate as deeply as in the deep ripped soil, but irrigation water did not enter the subsoil in sufficient quantities to create the degree of waterlogging observed in the ripped sub-soil. Deep ripping reduced soil surface stability to wetting and saturated hydraulic conductivity, due apparently to a reduction in organic matter. Laboratory testing is continuing.

Increasing the rate of pre-plant anhydrous ammonia from 80 to 160 kg/ha improved the cotton yield and profitability of treatments with relatively poor structure in 1987/88, but reduced yields due to rank growth on well-structured treatments having higher N-use efficiencies. On the deep ripped (1981 only) plots, doubling the N-rate increased lint yield from 1439 to 1764 kg/ha in 1988, but reduced it from 2523 to 1932 kg/ha on the reripped (2-yearly) treatment with extra gypsum. These results confirm the importance of assessing pre-season soil physical condition before calculating the N rate.

Several journal articles (6,7,8,9,12) are in preparation, but much of the information has already been made available to growers and agribusiness (21,24,33,36,37,38,40,41,43) and the research community (14,22,23).

The effects of safflower, wheat and fallow on soil structure and cotton performance (Field 34 grey clay experiment, Auscott Ltd. Warren)

The effects of non-irrigated safflower and wheat on soil physical condition and subsequent cotton growth, in the absence of deep tillage, were measured using a disc cultivated fallow as a control. The experiment also allowed the effectiveness of a broad range of soil structure measurement techniques to be assessed. The soil used has similar inherent properties to those described for the Field 24 soil, but was less damaged. The experiment was carried out in conjunction with Dr T. Abbott, Dr P. Hulme, Dr D. MacLeod and Dr A. Cass. Results have been presented by Dr Abbott as part of a Cotton Research Council Final Report, co-authored with Mr I. Daniells, entitled: 'Restoration of soil structure in cracking clays' (DAN13L) pp.,10-26, and also as an advisory article (34). The major findings are as follows:

Profile drying by non-irrigated safflower and wheat improved soil aeration due to deep cracking. Safflower dried and cracked the soil more intensely than wheat between 0.40 and 1.50 m depth. Improved soil physical conditions following deep cracking persisted over several irrigation cycles for a cotton crop. Cotton seedling growth was better where the rotation crops had been grown, but N deficiency later in the season prevented a positive yield response. There were also problems with replenishment of deep subsoil water, particularly after safflower. Irrigation frequency had to be increased. The results are being prepared for journal publication (10).

In February 1986, an intensive investigation of soil structural conditions in the top 0.35 m during one irrigation cycle revealed the presence of a ploughpan in the fallow plots, centred at about 0.2 m. Despite waterlogged conditions in the soil between cotton plants for up to 12 days following irrigation, and the development of sufficient strength to retard root growth after only 8 days following irrigation, water extraction by roots was unimpeded in this period. Dye infiltration studies suggested that macrcpores beside cotton stems may allow sufficient diffusion of oxygen for root respiration. It appears that established critical levels of soil strength for the restriction of cotton root development may not apply to these clay soils; it is also possible that sufficient roots had already penetrated the ploughpan via cracks by the time that strength measurements were made. Further research is required to define critical levels of aeration and strength for unrestricted root development by cotton and rotation crops in cracking clay soils. A paper has ben submitted for publication (1) after presentation of the results at a conference (25).

The indicators of soil structure used in this experiment were able to differentiate between the safflower, wheat and fallow treatments. Of the techniques used, the penetrometer best defined changes in structure caused by the management practices monitored. The major difference in soil physical properties between the rotations studied, a poorly structured layer in the disc cultivated fallow treatment, 0.06 m thick and centred 0.15 m below the soil surface, and was clearly defined in the penetration resistance profiles. Measurement of AFP, bulk density and pore continuity showed that soil physical conditions at and below 0.15 m were less favourable for vigorous root activity in the fallow than the cropped areas. However, because these measurements were recorded at 0.05 m intervals, as opposed to the 0.015 m intervals used for the penetrometer, they defined the extent of structural degradation with less precision than did the penetrometer measurements. The neutron moisture meter is insensitive to the presence of narrow layers with a water content differing from surrounding layers, so was unable to detect the layer with degraded structure. Any water held above the degraded layer would not have been detected because the shallowest neutron moisture meter reading was at a depth of 0.20 m. Rhodamine dye (pore continuity) and clod shrinkage measurements were useful, but laborious, while tensiometers were both laborious and unable to detect treatment differences. These methods are being evaluated further as part of a CRC funded project at Trangie entitled: 'Procedures for the evaluation of soil physical conditions in the field to assist land management for cotton production' (DAN 46L). This project will provide recommendations about routine methods for use by advisory staff as part of the SOILPAK decision support system.

The feasibility of using 'permanent' ridges for irrigated cotton production (Field 30 brown clay experiment, Auscott Ltd. Warren)

Once soil compaction and smearing problems have been repaired by rotation crops and/or deep tillage, prevention of further damage using 'permanent' ridges and controlled traffic is likely to be appropriate. An experiment was established in 1984 to compare the effects of 'permanent ridges' ('direct listing'), chisel ploughing and deep ripping on soil physical condition and cotton response. The soil chosen for the experiment was a well-structured brown cracking clay. The study was carried out in conjunction with Dr P. Hulme, who undertook most of the work, Dr D. Macleod, Dr A. Cass, and Auscott Ltd. staff. A final report to Cotton Research Council for the study entitled 'An evaluation of seedbed preparation methods for growing irrigated cotton on grey clays' (UNE 1L) has been submitted by Dr MacLeod, based upon Dr Hulme's PhD thesis. The main results of relevance to growers are as follows.

Permanent ridges formed by direct listing are a viable means of cotton production. The permanent ridge treatment (DL) consistently outyielded the deep ripping (Rip) and chisel ploughing (Chisel) treatments over 3 seasons (1984/85, 1986/87, 1987/88). Average lint yields for DL, Rip and Chisel were, respectively, 1647, 1545 and 1549 kg/ha. Costs increased in the order DL, chisel, Rip so direct listing was clearly the most profitable treatment.

Deep tillage allowed more water to enter the soil and reduced soil resistance to root penetration, but waterlogging restricted cotton performance under the prevailing irrigation schedule. High yields on the DL treatment were related to less waterlogging after irrigation compared with the Rip and chisel treatments.

Several advisory articles have been published to inform growers of the experimental results (20,24,35), and a journal paper (11) is being prepared.

An assessment of techniques for improving the structure of degraded red-brown earths used for irrigated summer crop production (Block 4 experiments, Agricultural Research Centre, Trangie).

Most Australian cotton is grown on cracking clays, but in the Macquarie valley approximately 30% of the crop is grown on hard-setting red duplex soils.

Two co-operative experiments were established in 1984 and 1986 at the Agricultural Research Centre, Trangie, to develop improved methods for the management of these soils. The untreated soil develops a hard-set surface upon drying that restricts water penetration and seedling emergence. Most of the work has been carried out by Mr D. Hall, with extra financial support from the Wheat Industry Research Committee of New South Wales. Staff from University of New England and CSIRO Division of Soils have also been closely associated with the program.

In May 1984 a factorially designed experiment was established in Block 4a to assess the effects of (i) deep mouldboard ploughing to 45 cm depth, a technique introduced by Agriland Pty Ltd. which increases the content of swelling clay in the surface soil and promotes self mulching, and disc ploughing; (ii) gypsum (5 t/ha) to reduce dispersion; and (iii) double cropping with wheat followed by a summer forage or grain legume crop, managed under zero tillage to promote the development of root channels.

Initial results from this experiment showed large improvements in water infiltration and storage; water entry during irrigations was increased by as much as 300% (from 30 to 107 mm over 1.2 m) by deep mouldboard ploughing in combination with gypsum. Resistance to penetration was also reduced. Crop yields for the mouldboard ploughing with gypsum treatment were more than 30% and 70% higher than the control during winter and summer cropping phases respectively. Double cropping also improved soil water relations and crop yields. The longer term results indicate that while the benefits of gypsum persist, the effects of mouldboard ploughing are transient, lasting no more than 2 years. Investigations showed that a large surface density increase had occurred. It was related to reduced organic matter levels and lower aggregate stability, and a particle size distribution which is more compactable. Results from the experiment have been presented at several conferences (15,16,17,18); 2 journal papers (3,4) are in preparation.

In February 1986, a second factorially designed experiment was established in Block 4b. Three tillage treatments (mouldboard ploughing to a depth of 45 cm, deep ripping to 45 cm, disc ploughing to 15 cm) two irrigation layouts (1.5 m beds with small siphons, flat sown) and three crop rotations (barley/soybeans, fallow/soybeans and lucerne; 3 years/soybeans) were considered. The main aims of the experiment were to determine: (i) the relative importance of adding swelling clay to the surface soil vs A horizon disruption; and (ii) whether the beneficial effects of deep tillage can be prolonged by increasing the quantity of roots and root channels through double cropping and/or pasture phases, and by reducing the rate of wetting and wheel compaction in a zero tillage 'bed' system. Early results indicate that continuous cropping, with controlled traffic and organic mulch retention, is the most effective, long-lasting, and profitable of the treatments under consideration. Water infiltration, bypassing of hard layers by biological channels, and yield were all increased by this treatment. Beds have better structure than flat sown areas, but compaction damage by wheels on the sides of the beds restricts water movement, thus reducing their potential for producing high yields. Deep ripping and mouldboard ploughing each produced similar yield increases in relation to the disc ploughed control, but ripping was more profitable at that location. Journal paper 11 is one of a series that is expected to be produced after completion of the experiment.

Extension of the research results

The advisory publications listed on page 9 have quickly transfered research results from this project to cotton growers. However, non-written methods of communication have also been utilised. An audio cassette (32) and a video (39) have been produced to make the information more readily accessible to users.

However, because face-to-face contact between growers, extension workers and researchers in the field is the most effective form of extension, staff associated with this project also helped to establish a soil management extension service (SMS) based at Warren. SMS staff check soil condition using backhoe pits, laboratory analysis, farm diaries and neutron probe data before making land management recommendations. The service is used by an increasing number of cotton growers in the Macquarie Valley, and recently was established in the Namoi and Gwydir Valleys; it is likely to be expanded to other parts of the State in the near future.

Procedures developed by SMS form the basis of the well-publicised COMPUCLOD/SOILPAK initiative. It will provide private consultants and growers with ready access to all available soil management information that is relevant to irrigated cotton production.