1994

COTTON RESEARCH AND DEVELOPMENT CORPORATION

FINAL REPORT

"Travel - N.R. Hulugalle to Attend and Present Paper at 13th Conference of International Soil Tillage Research Organization"

DAN 88C

JULY - AUGUST 1994

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NSW Agriculture

ISBN 0 7310 2868 6

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Travel - N.R. Hulugalle to Attend and Present Paper at 13th Conference of International Soil Tillage Research Organization

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Objectives of visit:

To attend the 13th Conference of the International Soil Tillage Research Organization (ISTRO) and present paper entitled "Effect of soil preparation method and cotton-based cropping system on seedbed soil properties in a Vertisol".

To have discussions with scientists conducting research on sustainable tillage and cropping systems. In the short-term their comments will be utilized in improving and analyzing on-going trials of cotton-based rotation systems on "permanent beds" funded by the Cotton Research and Development Corporation (CRDC) as Project DAN 83C.

Itinerary:

23 - 24 July	-	Narrabri-Sydney-Copenhagen-Aalborg
24 - 30 July	-	Aalborg (ISTRO Conference)
31 July - 1 August	-	Aalborg-Copenhagen-Sydney-Narrabri

Highlights:

* Presentation of paper entitled "Effect of soil preparation method and cotton-based cropping system on seedbed soil properties in a Vertisol"

* Membership of international working group C of ISTRO. The focus of this working group is "Crop response to the soil physical environment". The group consists of researchers from Australia, Central Asia, East Africa, UK, USA, France, and Eastern Europe. The group will maintain regular contact with respect to current and future research projects, technical constraints, joint publications and funding opportunities.

* Participation in oral and poster presentations devoted to various combinations of tillage systems, cropping systems and rotations in long-term trials.

Detailed report:

Travel to Denmark and attendance at the 13th Conference of the International Soil Tillage Research Organization was completed as planned. A total of 350 delegates from 52 countries participated in oral concurrent sessions and poster sessions on (1) Soil tillage and soil quality; (2) Advances in soil tillage for crop production; (3) Soil implement performance; (4) Soil physical and chemical properties and processes; (5) Losses of chemicals from soils; (6) Water management and crop production; (7) Plant root development and functioning; (8) Modelling and expert systems in soil tillage management. A total of 106 oral and 99 poster presentations were given. Plenary papers on the above topics were given by leading authorities in their fields. An additional plenary paper was given on the subject of "Future land utilization and management for sustainable crop production". A noteworthy point is that this was the first ISTRO conference where large numbers of researchers from Eastern Europe and the former Soviet Union participated.

As it was not possible to attend all concurrent sessions I focussed my attention on the sessions entitled "Advances in soil tillage for crop production" and "Soil tillage and soil quality", both of which dealt primarily with farming systems and long-term trials. I presented a paper entitled "Effect of Soil Preparation Method and Cotton-based Cropping System on Seedbed Soil Properties in a Vertisol". *A copy of the paper is attached to this report (Appendix 3).*

In addition to formal presentations, aproximately 40% of the available time was devoted to field trips where research centres and farms were visited. During these trips presentation were made by individual farmers, and followed by detailed examinations of soil profiles at the sites, and tillage equipment.

Working groups were formulated and discussions held in the following areas (A) Tillage related soil physical properties; (B) Soil compaction by vehicles of high axle load; (C) Crop response to the soil physical environment; (D) Tillage and traffic terminology; (E) Visual soil examination and evaluation; (G) History and development of soil tillage. The activities of these working groups will be carried out over the next three years until the 14th ISTRO Conference. I participated in Working group C.The group consists of researchers from Australia, East Africa, UK, USA, France, and Eastern Europe. Initially the group members made short presentations indicating their affiliations, present locations, major research interests and current research activities. *Names, affiliations and contact addresses of the group members are given in Appendix 2.* The group will maintain regular contact with respect to current and future research projects, technical constraints, joint publications and funding opportunities. The reports from all working groups will be presented in future issues of "Istro-Info", the occasional newsletter of ISTRO.

Some issues relevant to my research activities and which were discussed at the conference are presented below:

1. Long-term trials:

(a) Detailed site characterization using a 40 x 40 m grid pattern is a feature of the long-term trials conducted by the Danish soil and plant institute. In general, such site descriptions are obtained during a period of 2 years prior to commencing a trial.

(b) Highly innovative designs and layouts which are flexible have been used. These consist of both reference and research areas. The latter consists of upto 8 different trials, the information from which is fed back to the reference area. Changes in soil properties in the reference area is analyzed by time-series analysis, whereas those in the research areas are monitored by traditional AOV and regression analysis. These designs are also far more economical in the long-term than traditional experimental designs. A site management committee (maximum of 5 persons) exists for each long term site and consists of representatives from the Farmer's Co-operative, extension agency, researchers and the project leader

(c) Intermediate treatments are of little value in long-term trials. A few contrasting treatments can give results which can be utilized for developing models in addition to reducing costs.

(d) Short-term results (< 7 years) can be highly misleading. In cereal-based farming systems in temperate climates it is clear that stability occurs only after about 15 years.

2. Soil organic matter:
(a) Organic matter fractions are better related to soil physical and chemical fertility than total soil organic matter. These results are common to data from Canada and Europe. I have been following this approach for the past two years.

(b) The coarse particulate organic matter fraction, which I have been measuring, appears to be highly correlated to the microbial biomass. The latter is related to changes in soil physical and chemical fertility, and sustainability of farming systems.

3. Water quality:
Developing high proportions of stable transmission pores (>50μm) is a characteristic feature of no-till systems. While advantageous in many respects, it can be a major disadvantage due to facilitating rapid movement of nitrates and other nutrients to subsurface water supplies.

4. Broad beds (2 m beds):
Hardening of soil in the centre of broad beds (untrafficked) which have been in long-term no-till or minimum tillage systems are a major disadvantage. A paper on the subject with respect to sorghum-cotton rotations described this at length. Similar behaviour is occurring in both red-brown earths and grey clays used for tomato production in southern New South Wales and northern Victoria.

5. Bare fallow:
Soil physical degradation due to traffic occurs at higher rates in plots which have been under bare follow, although physical properties at the commencement of a cropping season may be similar in cropped and fallowed plots. These results are very similar to those obtained in our trials in the Namoi and Macquarie valleys.

Recommendations:

1. Detailed and systematic site characterization and in-depth evaluation of alternative experimental designs must be carried out prior to establishment of any future long-term trials. Involvement of a biometrician at this stage is strongly recommended.

2. Inclusion and/or continuation of intermediate treatments in long-term trials should be reviewed.

3. Extrapolation and extension of short-term results from long-term trials should be avoided.

4. In view of the soil "hardening" or "coalescence" phenomenon observed in the centre of untrafficked, no-tilled broad beds (2 m beds), a detailed and careful evaluation of broadbed technology is strongly recommended.

5. If resource availability is not a restriction, use of bare fallow ("long fallow") is not encouraged.

6. The ISTRO conferences (which are held every 3-4 years) provide an ideal opportunity to review developments in soil tillage and cropping systems research. Participation in these conferences by relevent sections of the Australian Cotton Industry is suggested.

APPENDIX 1:

Financial summary:

Funding to attend the conference was provided by the Cotton Research and Development Corporation Travel Grant no. DAN 88C.

Item	Budget estimate ($A)	Actual expenditure ($A)
Airfares	3000.00	3035.00
Accommodation & meals	950.00	735.56
Other (taxi, insurance, passport)	50.00	233.89
TOTAL	4000.00	4004.45

APPENDIX 2:

Names, affiliations and contact addresses of members of working group C ("Crop response to the soil physical environment") of the International Soil Tillage Research Organization

1. Warren Dick, Ohio State University, Wooster OH 44691, USA.
2. Mekhlis Souleimenov, Kazakh Grain Research Institute, Shortandy, Armola, Kazakhstan.
3. Jerzy Lipiec, Institute of Agrophysics, Lublin, Poland.
4. Don Erbach, National Soil Tilth Laboratory, Ames, IA 50011, USA.
5. Charlie Arshad, Agriculture Canada, Northern Agriculture Research Centre, Beaverlodge, Canada.
6. Dale Wilkins, USDA-ARS, Pendleton, OR, USA.
7. Blair McKenzie, LaTrobe University, Bundoora, VIC 3083, Australia.
8. Rabi Mishra, CRC for Temperate Hardwood Forestry, Sandy Bay, TA 7005, Australia.
9. Nilantha Hulugalle, Australian Cotton Research Institute, NSW Agriculture, PMB, Myall Vale Mail Run, Narrabri, NSW 2390, Australia.
10. Benedict Kayombo, Sokoine University of Agriculture, Dept. of Agricultural Engineering & Land Planning, Morogoro, Tanzania.
11. Jean-Marc Machet, INRA, Station d'Agronomie de Laon,02004 Laon Cedex, France.
12. Chris Mullins, Plant and Soil Science Department, Aberdeen University, Aberdeen AB9 2UE, UK.
13. Tony Vyn, Crop Science Department, University of Guelph, Guelph, Ontario N1G 2W1, Canada.
14. Ed Gregorich (Chairman), Centre for Land & Biological Resources Research, Agriculture Canada, Central Experimental Farm, Ottawa, Ontario K1A 0C6, Canada.

APPENDIX 3:

Copy of paper entitled"Effect of Soil Preparation Method and Cotton-based Cropping System on Seedbed Soil Properties in a Vertisol" by N.R. Hulugalle, Proc. 13th Conf. of International Soil Tillage Research Organization, 24-29 July, 1994, Aalborg, Denmark, Eds. Jensen, H.E., Schønning, P., Mikkelsen, S.A., Madsen, K.B., Vol. II., pp. 789-794. (Royal Veterinary and Agricultural University, Copenhagen, and Danish Institute of Plant and Soil Science, Foulum, Denmark).

EFFECT OF SOIL PREPARATION METHOD AND COTTON-BASED CROPPING SYSTEM ON SEEDBED SOIL PROPERTIES IN A VERTISOL

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ABSTRACT
The effects of soil preparation methods and cotton-based cropping systems on seedbed soil properties were evaluated during the the summer of 1992-1993 in a trial established since 1985 in a Typic pellustert (Vertisol) of North-western New South Wales, Australia. The experimental treatments were maximum tillage (disc-ploughing to 0.2 m depth, chisel ploughing to 0.3 m depth followed by ridging every year) sown to a continuous cotton (*Gossypium hirsutum* L.) sequence; minimum tillage (planting on ridges retained intact from previous years with soil disturbance being limited to deepening of the furrows with disc-hillers) sown to a continuous cotton sequence; and minimum tillage sown to a winter wheat (*Triticum aestivum* L.)-cotton sequence where wheat was sown with no-tillage. Soil was sampled from the 0-0.10 m depth of ridges 4 weeks after sowing (November 1992) and 1 week after harvesting (April 1993) of cotton. Soil properties evaluated were particulate organic matter, particle size distribution, dispersion index, soil reactivity (a measure of the self-mulching ability of the soil), plastic limit, variation of soil density with water content (soil shrinkage), exchangeable Ca, Mg, K and Na, and soil respiration. In comparison with maximum tillage, minimum tillage resulted in lower clay aud higher sand contents, lower exchangeable Ca and Na, higher exchangeable K, lower dispersion index, higher particulate organic matter content and lower soil density at water contents < 7.5%. Soil respiration was greatest in minimum tilled plots sown to continuous cotton. Cotton lint yield and fibre quality were unaffected by tillage system but were improved by sowing a wheat-cotton rotation. Lint yield and fibre quality were related to levels of particulate organic matter, exchangeable Na and soil respiration.

INTRODUCTION
Minimum tillage has become a feature of many farming systems, including cotton (*Gossypium hirsutum* L.)-based farming systems, in eastern Australian Vertisols over the past decade (3,6,9,19). Benefits of minimum tillage systems are claimed to include reduction of soil erosion and physical, chemical and biological degradation; improved energy conservation and timeliness of land preparation; and improved water conservation (3,5,9,11,14,19). In cotton-based farming systems minimum tillage is frequently associated with planting crops such as wheat (*Triticum aestivum* L.) in rotation with cotton (6). Most previous studies have addressed the short-term (≤ 3 years) effects and interactions of utilizing minimum tillage systems in combination with crop rotations (3,5). This report presents data on seedbed soil properties from a trial established since 1985 which studied the interactive effects of minimum and intensive tillage systems sown to either continuous cotton or a wheat-cotton rotation on soil properties, and cotton growth and yield (5).

MATERIALS AND METHODS
The trial was located at the Narrabri Agricultural Research Station (annual rainfall of 616 mm) in northern New South Wales, Australia. The soil at the experimental site was a classified as a fine, thermic, montmorillonitic, Typic Pellustert (21). The experimental treatments were maximum tillage (disc-ploughing to 0.2 m depth, chisel ploughing to 0.3 m depth followed by ridging every year) sown to a continuous cotton (*Gossypium hirsutum* L.) sequence; minimum tillage (planting on ridges retained intact from previous years with soil disturbance being limited to deepening of the furrows with disc-hillers) sown to a continuous cotton sequence; and minimum tillage sown to a winter wheat (*Triticum aestivum* L.)-cotton sequence where wheat was sown with no-tillage. The experimental design was a randomized complete block with 4 replications (8).

Individual plots consisted of 36 rows (ridges), 175 m long, spaced at 1 m intervals. Irrigation was by furrow irrigation. Soil was sampled from 28 locations in each plot using a stratified random sampling design (22) from the 0-0.10 m depth of ridges 4 weeks after sowing (November 1992) and 1 week after harvesting (April 1993) of cotton and taken to the laboratory for further analyses.

Air-dried soil was passed through a sieve with 2 mm diameter apertures and particle size distribution determined with the hydrometer method (13), plastic limit with the drop-cone penetrometer (4), particulate soil organic matter (range of 53-2000 μm) with a combination of dispersion, flotation and sieving (7) and dispersion index (20). Total organic carbon was determined by the method of Walkley and Black (18). Soil respiration (during a 2 day period) at 30% soil water content was measured by trapping the CO_2 produced in a 1M NaOH solution and monitoring the change in electrical conductivity of the NaOH solution (17). Soil reactivity, a measure of the self-mulching ability of the soil, was determined by puddling and oven-drying at 40 °C for 72 h a sample of air-dried soil which had been previously passed through a sieve with aperture diameters of 2 mm. The size distribution of the aggregates formed (determined by dry-sieving on a mechanical shaker at 1440 vibrations per minute for 5 minutes) was expressed as the geometric mean diameter of the soil aggregates (12). Soil density was measured at soil water contents ranging from 35% to oven-dried value (0%) on drying soil aggregates (1-10 mm diameter), previously wetted by evaporation in a humidifier, with the kerosene saturation method of McIntyre and Stirk (15). 1M ammonium acetate-extractable exchangeable Ca, Mg, K, and Na were determined on air-dried soil sampled in November 1992 and which had been passed through a sieve with aperture diameters of 2 mm (18). After harvest, cotton lint fibre characteristics such as micronaire and length were measured with a Spinlab 900 series, and maturity and fineness with a Shirley FMT3 (13). Data were analyzed following a randomized complete block design for multiple times of sampling (16). One-way analyses of variance were also carried out after grouping of the data according to tillage system and cropping system.

RESULTS AND DISCUSSION

In comparison with maximum tillage, minimum tillage resulted in lower clay and higher sand contents, lower exchangeable Ca and Na, higher exchangeable K, lower dispersion index, higher particulate soil organic matter and lower soil density at water contents < 7.5% (Table 1, Figure 1). Total organic matter did not differ significantly between treatments or times of sampling. Mean total organic matter content in the 0-0.10 m depth was 1.62%. The higher particulate organic matter in minimum tilled plots may be a reflection of the intensity of soil disturbance in these plots (2). The higher clay content with maximum tillage may be due to clay lost with runoff being replaced by sub-surface clay brought to the surface by the intensive tillage in these plots (10), whereas clay losses in minimum tilled plots would not be similarly replaced. Seedbed clay content (%), in turn, was related to some of the soil parameters measured such as exchangeable cations (in mmol(+) kg^{-1}) and soil reactivity (GMD in mm) thus:

GMD = 0.06Clay -2.54, $r = 0.55$, $P < 0.01$, $n = 24$;
Exch. Ca = 18.46 + 1.21Clay, $r = 0.67$, $P < 0.05$, $n = 12$;
Exch. Mg = 1.29Clay - 25.07, $r = 0.77$, $P < 0.01$, $n = 12$;
Exch. Na = 0.48Clay - 19.56, $r = 0.79$, $P < 0.01$, $n = 12$;
Exch. K = 35.70 -0.32Clay, $r = -0.61$, $P < 0.05$, $n = 12$.

Soil structural indices such as dispersion index (DI, %) and soil aggregate density at water contents of 0% (D_0, Mg m^{-3}) and 5% (D_5, Mg m^{-3}) were, however, related to either the combination of particulate organic matter (POM, %) and exchangeable Na or particulate organic matter alone thus:

DI = 5.07 -1.32POM +0.49Na, $R^2 = 0.58$, $P < 0.05$, $n = 12$;
D_0 = 1.68 - 0.28POM, $r = -0.69$, $P < 0.001$, $n = 24$;
D_5 = 1.49 -0.16POM, $r = -0.47$, $P < 0.05$, $n = 24$.

Between November 1992 and April 1993 decreases in particulate organic matter (from 0.97% to 0.68%, $P < 0.05$) and increases in dispersion index (from 7.5% to 10.0%, $P < 0.05$) occurred in all treatments, although significant interactions did not occur between experimental treatments and times of sampling. Similar seasonal changes in particulate organic matter and aggregate stability were reported by Angers *et al.*. (2) for a site in Canada.

Cropping system had no significant effect on the measured soil physical and chemical properties. Compared with continuous cotton, however, soil respiration was less, cotton lint yield higher and fibre quality better where a wheat-cotton sequence was sown (Tables 2 and 3). Cotton lint yield (in t ha^{-1}) and fibre quality were related primarily to soil respiration (R, mmol CO_2/kg soil/48 h), and to exchangeable Na and particulate organic matter to a lesser extent thus:

Yield = 2.07 +0.11lnPOM -2.95E-02R -3.25E-02Na, $R^2 = 0.75$, $P < 0.01$, $n = 12$;
Maturity = 0.85 +1.06E-02Na + 9.04E-03R, $R^2 = 0.51$, $P < 0.05$, $n = 12$;
Fineness = 118.27 +2.57Na +1.32R, $R^2 = 0.49$, $P < 0.05$, $n = 12$;

Table 1. Effect of land preparation method and cropping system on soil properties

Land preparation method	Cropping system	Particulate organic matter (%)	Dispersion index (%)	Plastic limit (%)	Sand (%)	Silt (%)	Clay (%)	GMD (mm)	Exchangeable cations (mmol (+)/kg)			
									Ca	Mg	Na	K
Maximum tillage	Cotton-cotton	0.57 (4.041)	11.1	27.4	21.3	18.1	60.6	0.8	92.3	52.1	10.3	16.1
Minimum tillage	Cotton-cotton	1.02 (4.621)	7.6	24.3	26.2	18.6	55.3	0.5	83.6	45.8	6.8	19.4
Minimum tillage	Wheat-cotton	0.92 (4.518)	7.6	23.9	24.7	19.1	56.2	0.5	85.8	47.8	6.7	17.4
AOV:												
Land preparation methods		(**)	***	*	**	NS	***	*	*	NS	***	*
Cropping systems		(NS)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
All treatments		(**)	***	**	*	NS	**	NS	NS	NS	**	*
±SE:												
Between land preparation methods		(0.0801)	0.51	0.68	0.74	0.46	0.71	0.07	1.80	1.68	0.62	0.52
Between cropping systems		(0.0801)	0.51	0.68	0.74	0.46	0.71	0.07	1.80	1.68	0.62	0.52
Between all treatments		(0.0957)	0.46	0.68	1.04	0.48	1.01	0.12	2.96	2.09	0.50	0.63

1. Values in parantheses are $\log_e$ transformed values of 100 x particulate organic matter.
2. GMD = geometric mean diameter of soil aggregates after puddling and drying.
3. Exchangeable cations were determined only on samples obtained in October 1992.
4. NS = non-significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

Length = 1.33 -0.10POM +0.13lnPOM, $R^2 = 0.71$, $P < 0.01$, n =12;
Micronaire = 3.01 +7.67E-02Na +4.84E-02R, $R^2 = 0.52$, $P < 0.05$, n = 12.

The higher soil respiration with continuous cotton may be due to a disease-causing microbial factor which was able to over-winter in the cotton residues and exert a negative effect on cotton lint yield and fibre quality in the following cropping season (1).

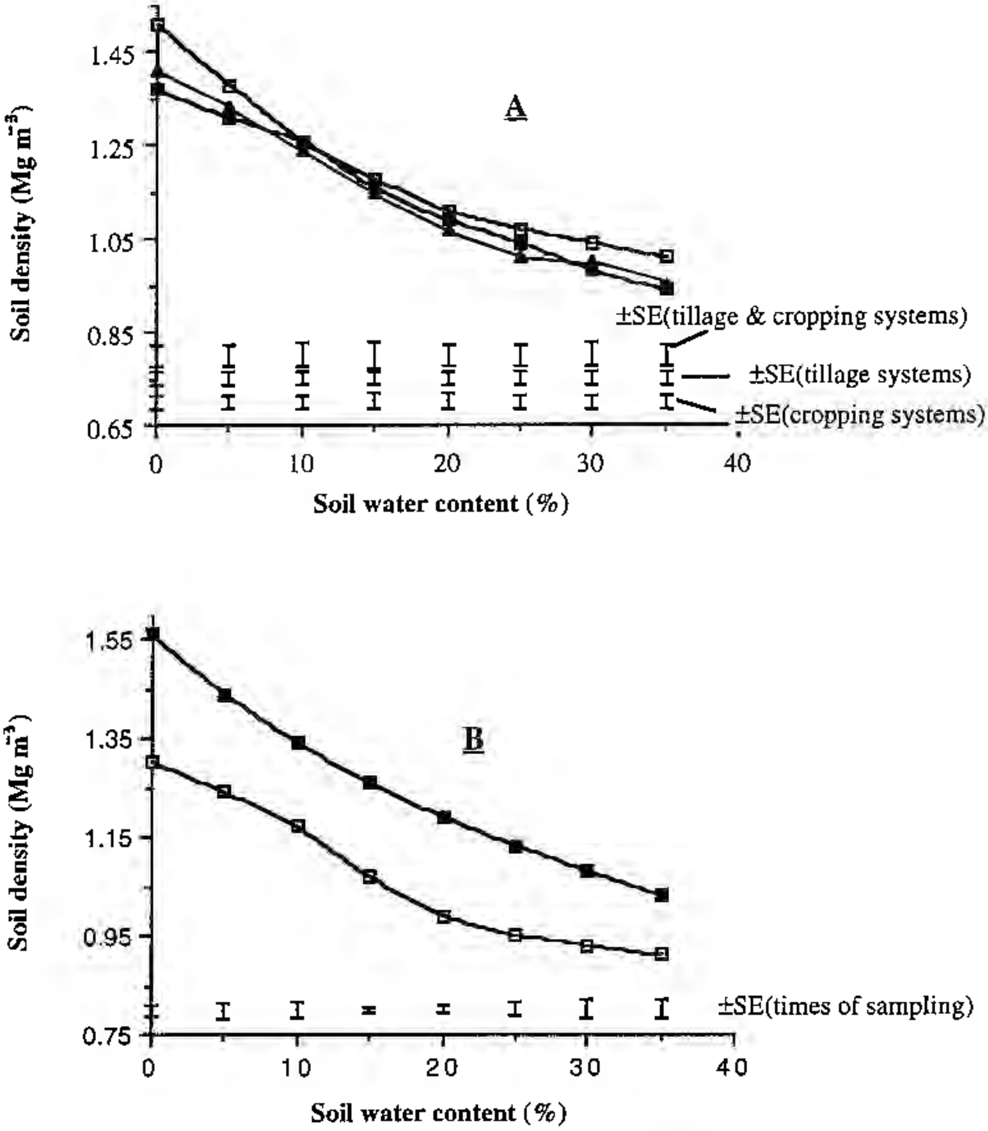

Figure 1. Variation of soil densityin the 0-0.10 m depth with soil water content. A. Effect of tillage and cropping systems. □ - Maximum tillage/continuous cotton; ■ - Minimum tillage/continuous cotton; ▲ - Minimum tillage/wheat-cotton. B. Effect of time of sampling. □ - November 1992; ■ - April 1993.

CONCLUSIONS

In comparison with maximum tillage, minimum tillage resulted in significantly better seedbed soil physical and chemical properties. These differences in soil properties did not, however, have a significant effect on crop yield. Cotton lint yield and quality of fibres were best in plots where a wheat-cotton sequence was sown in combination with minimum tillage. The major factors determining cotton yield and fibre quality were soil respiration at the commencement of the cropping season, exchangeable Na and particulate organic matter.

Table 2. Effect of land preparation method and cropping system, and time of sampling on soil respiration (in mmol CO_2/kg soil/48 h)

Land preparation method	Cropping system	Time of sampling: November '92	Time of sampling: April '93	Mean
Maximum tillage	Cotton-cotton	2.7 (1.008)	134.0 (4.898)	19.2 (2.953)
Minimum tillage	Cotton-cotton	7.4 (2.004)	129.7 (4.865)	31.0 (3.435)
Minimum tillage	Wheat-cotton	2.6 (0.957)	130.5 (4.871)	18.4 (2.914)
Mean		3.8 (1.323)	131.4 (4.878)	

	AOV:	±SE:
Times of sampling	***	(0.2135)
Tillage and cropping systems	*	(0.1313)
Times of sampling x tillage and cropping systems	*	(0.1857)

1. Values in parantheses are $\log_e$ transformed values of soil respiration.
2. NS = non-significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

Table 3. Effect of land preparation method and cropping system on cotton lint yield and fibre quality

Land preparation method	Cropping system	Lint yield ($t\ ha^{-1}$)	Maturity	Fineness ($mg\ m^{-1}$)	Length (in")	Micronaire ($\mu g\ in"^{-1}$)
Maximum tillage	Cotton-cotton	1.55	0.99	150.5	1.21	3.95
Minimum tillage	Cotton-cotton	1.64	1.02	152.5	1.22	4.10
Minimum tillage	Wheat-cotton	1.80	0.93	135.8	1.24	3.53
AOV:						
Land preparation methods		NS	NS	NS	NS	NS
Cropping systems		*	**	***	*	***
All treatments		*	***	**	NS	***
±SE:						
Between land preparation methods		0.050	0.010	2.49	0.004	0.081
Between cropping systems		0.050	0.010	2.49	0.004	0.081
Between all treatments		0.053	0.009	2.09	0.006	0.034

1. NS = non-significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

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