

Effects of Rotation Crops on Properties of Irrigated Cracking Clays

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INTRODUCTION

Cracking clay soils are the most common irrigated cotton growing soils in Australia. Typically, they have a self-mulching layer 2 to 5 cm deep, overlying a zone of blocky peds to depths of 30 to 50 cm. They have a clayey soil texture (with clay contents ranging from 30% to 80%) and form soil cracks which close when wetting occurs due to swelling of the soil (McGarity *et al.*, 1984; Dexter, 1991). In addition, soil pores and stable aggregates attributable to the interacting activities of soil organic matter, exchangeable cations, plant root systems and microbes occur in these soils (Dexter, 1991; Little *et al.*, 1992). Under continuous cotton, however, numbers of soil pores and stable aggregates are reduced due to smearing and compaction of soil by the high frequency of machine passes, particularly during land preparation and harvesting under wet conditions (McGarity *et al.*, 1984; McGarry, 1990;). Past research has shown that such soil structural degradation could be ameliorated by growing a rotation crop to maximize soil cracking by drying of the soil profile (McGarity *et al.*, 1984; McKenzie *et al.*, 1990), although little attention was paid to the effects of the rotation crop and its management on subsequent stability of soil aggregates and pores, soil fertility and biology. More recently, many cottongrowers have shown interest in utilizing rotation crops and their management as a tool in land preparation for cotton (Cooper, 1993). This paper reports data obtained from a long-term study on the interaction of tillage systems and cotton-wheat rotations which commenced in 1985, and from a study on rotation crop management which commenced in 1993*. Both focus on the effects of growing rotation crops on soil structure and factors which contribute to its stability such as soil organic matter, fertility and biology. The aim of this research is to define the best rotation/management combination whereby yields and quality of subsequent cotton crops can be maximized and sustained over the long-term.

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LONG-TERM EFFECTS OF TILLAGE SYSTEMS AND ROTATIONS ON SOIL PROPERTIES

A long term trial conducted at Narrabri Research Station has compared maximum tillage (disc-ploughing to 0.2 m depth, chisel ploughing to 0.3 m depth followed by listing every year) with minimum tillage (planting on permanent beds with soil disturbance being limited to deepening of the furrows with disc-hillers). Both treatments were planted to cotton every year. A third treatment combined minimum tillage with a wheat-cotton rotation.

Seedbed soil properties

Soil was sampled from the beds in November 1992 (4 weeks after planting) and April 1993 (1 week after picking). Soil properties measured were particulate and total organic matter; clay, silt and sand contents; dispersion index; plastic limit; soil density; exchangeable Ca, Mg, K and Na; and soil respiration.

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 (Table 1) and lower soil density at water contents < 7.5%. 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 due to the reduced soil disturbance in these plots (Angers *et al.*, 1993). 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 (Hall, 1991), whereas clay losses in minimum tilled plots would not be similarly replaced. Soil parameters such as exchangeable Ca and Mg were related to seedbed clay content. Soil structural indices such as dispersion index and soil aggregate density were, however, related to either the interaction between particulate organic matter and exchangeable Na or particulate organic matter alone. Between November 1992 and April 1993 decreases in particulate organic matter (from 0.97% to 0.68%) and increases in dispersion index (from 7.5% to 10.0%) occurred in all treatments, although significant interactions did not occur between experimental treatments and times of sampling. 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 rotation was sown (Table 2). Cotton lint yield and fibre quality were related primarily to soil respiration, exchangeable Na and particulate organic matter. The higher soil respiration with continuous cotton may be due to a disease-causing micro-organism which was able to over-winter in the cotton residues and reduce cotton lint yield and fibre quality in the following season. (NB. A detailed report on this study is given in Hulugalle (1994))

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

<u>Soil property</u>	<u>Maximum tillage / continuous cotton</u>	<u>Minimum tillage / continuous cotton</u>	<u>Minimum tillage / wheat-cotton</u>
Particulate organic matter (%)	0.57	1.02	0.92
Dispersion index (%)	11.1	7.6	7.6
Plastic limit (%)	27.4	24.3	23.9
Sand (%)	21	26	25
Silt (%)	18	19	19
Clay (%)	61	55	56
Exchangeable cations ¹ :			
Ca (mmol (+)/kg)	92	84	86
Mg (mmol (+)/kg)	52	46	48
K (mmol (+)/kg)	16	19	17
Na (mmol (+)/kg)	11	7	7
Soil respiration at 4 WAP (mmol CO ₂ /kg/48h)	2.7	7.4	2.6

1. Exchangeable cations were determined only on samples obtained in November 1992.

Table 2. Effect of land preparation method and cropping system on cotton lint yield and fibre quality, 1992-1993 season. (Total value is based on June 1994 prices).

<u>Land preparation method</u>	<u>Cropping system</u>	<u>Lint yield (bales/ha)</u>	<u>Maturity ratio</u>	<u>Fineness (mg/m)</u>	<u>Length (in")</u>	<u>Micronaire (µg/in")</u>	<u>Total value (\$)</u>
Maximum tillage	Cotton-cotton	6.85	0.99	150.5	1.21	3.95	3541
Minimum tillage	Cotton-cotton	7.22	1.02	152.5	1.22	4.10	3732
Minimum tillage	Wheat-cotton	7.93	0.93	135.8	1.24	3.53	4100

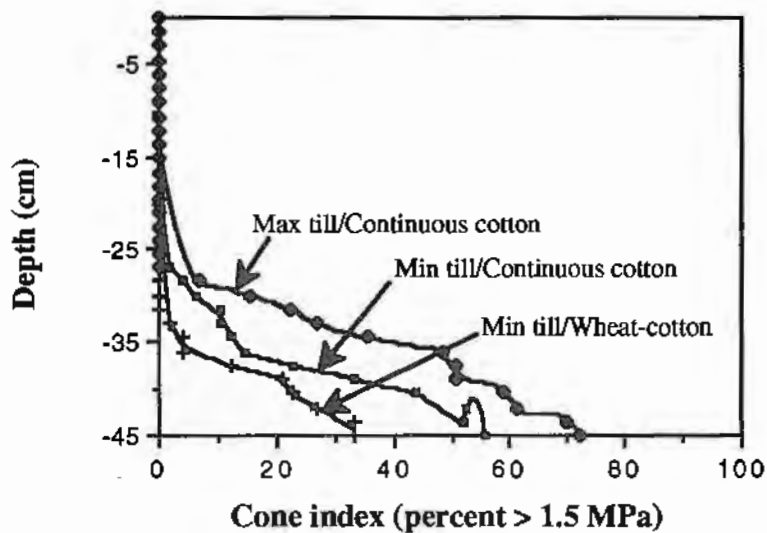


Fig.1. Effect of land preparation method and crop rotation on soil strength in October 1993, 2 weeks prior to sowing. Soil water content in the profile did not differ between treatments. (Soil strength is shown as percent cone index values > 1.5 MPa. A threshold value of 2.5 MPa, the value when cotton root growth is thought to cease, is more frequently used. Observations at this site had shown, however, that in soil wetter than the plastic limit percent cone index values > 1.5 MPa were highly correlated ($R = 0.98$) to percent cone index values > 2.5 MPa in soil drier than the plastic limit. The data shown in the figure was obtained when the soil was wetter than the plastic limit).

Sub-surface soil properties

Of the soil properties measured only sub-surface soil strength was affected by the experimental treatments, with lowest values occurring when minimum tillage was combined with a wheat-cotton rotation (Fig. 1). The data shown in Fig. 1 was obtained in October 1993 after a cotton crop had been sown in 1992-1993 and prior to sowing cotton for the 1993-1994 season. Soil strength in turn affected water extraction by the cotton crop sown in October 1993, such that in plots where sub-soil strength was lowest, i.e. the wheat-cotton rotation, greatest extraction of water occurred (Fig. 2). The more extensive drying of the soil profile in these plots also resulted in a greater water entry into the soil (i.e. greater irrigation efficiency). For example, during the irrigation of 28 January 1994, water entry into the soil was of the order of 81, 86 and 97 mm with maximum tillage/continuous cotton, minimum tillage/continuous cotton and minimum tillage/wheat-cotton rotation, respectively.

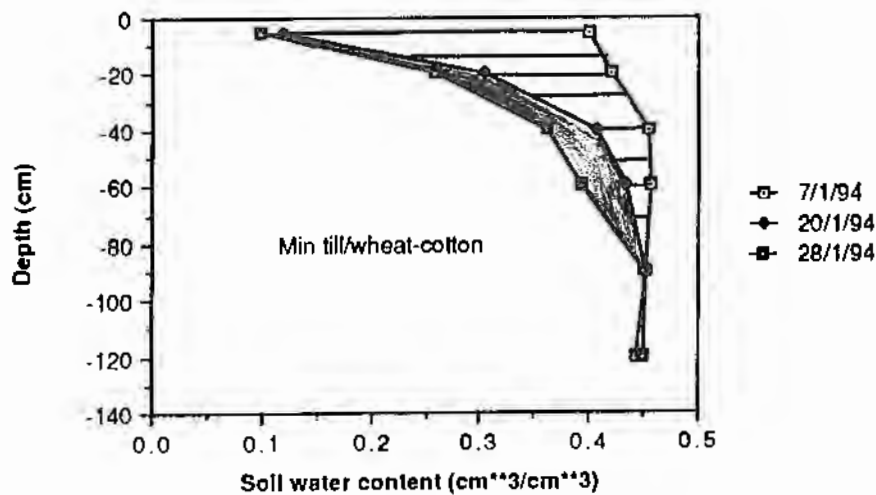
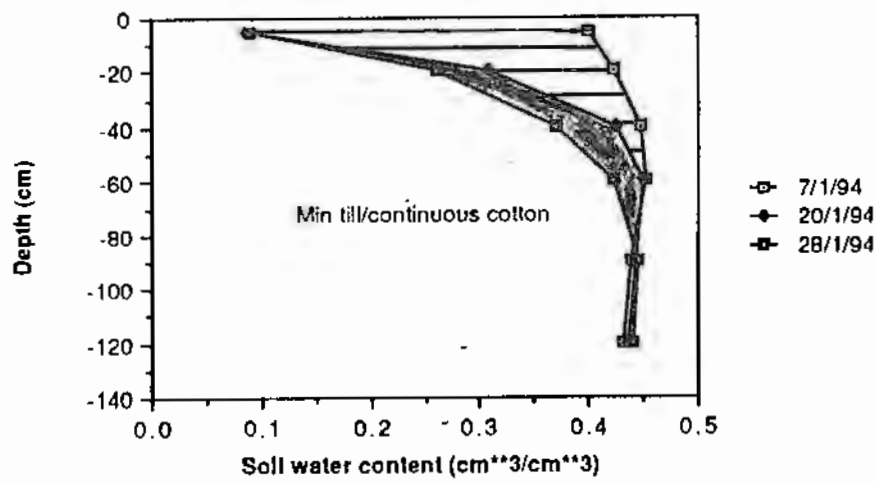
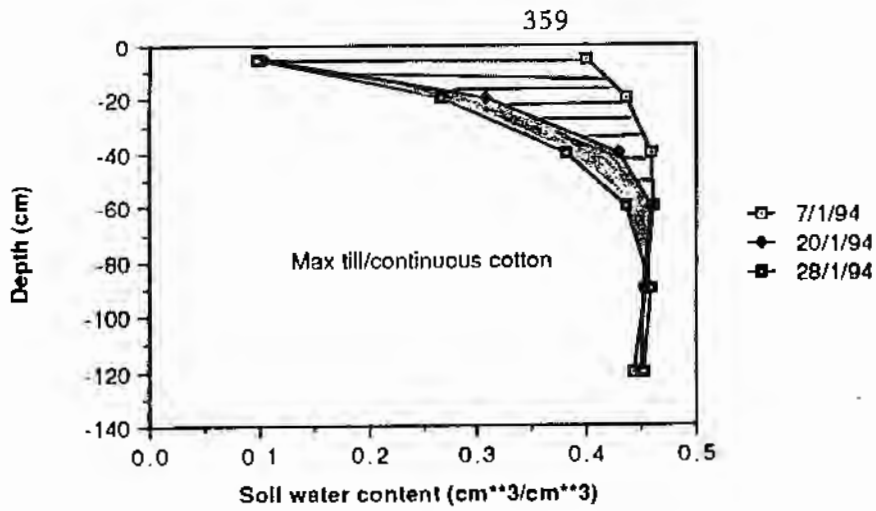


Fig. 2. Effect of tillage system and crop rotation on water extraction by cotton during 7-28 January 1994

SHORT-TERM EFFECTS OF WHEAT AND CHICKPEA SOWN AS ROTATION CROPS ON SOIL PROPERTIES

A large scale experiment to compare the effects of managing wheat and chickpea sown as rotation crops on soil properties and subsequent cotton yields was established in June 1993 at "Glenarvon", Wee Waa. The experimental treatments were wheat, which was either fertilized with 140 kg/ha of N as urea at sowing or remained unfertilized, and chickpea (unfertilized), which was either harvested for grain or green manured. All rotation crops were direct-drilled into cotton stubble and irrigated.

Root growth and crop yields

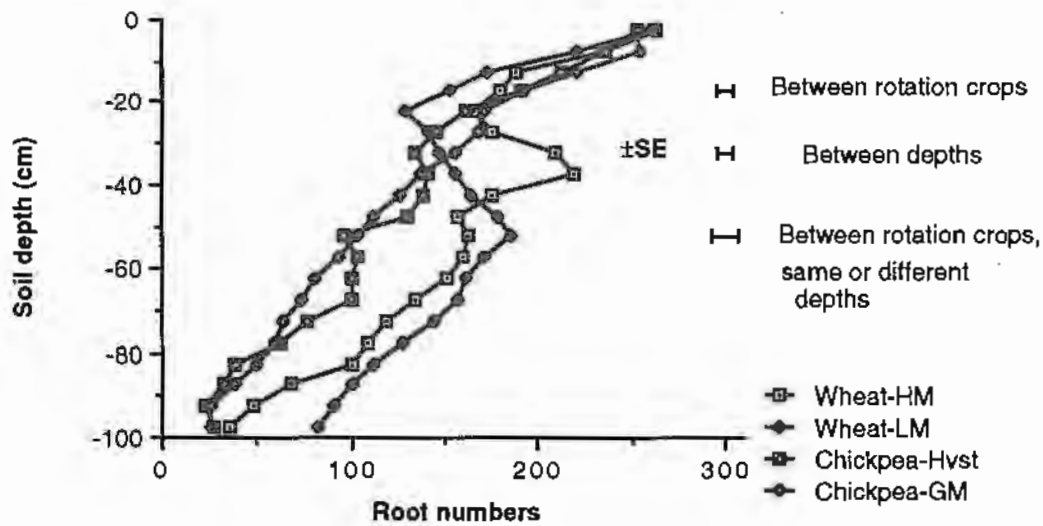


Fig. 3. Root growth of rotation crops measured in a 1 m x 1 m profile face with the trench profile method, November 1993. Wheat-HM - fertilized wheat; Wheat-LM - unfertilized wheat; Chickpea-Hvst - chickpea harvested for grain; Chickpea-GM - green manured chickpea. (The base of the bed was taken as the depth of 0 cm).

Root growth was measured in November, 3 weeks before harvesting, with a 1 m x 1 m root grid which was aligned with the base of the bed. Soil was sampled during the following week. Lowest root densities in the 'plough layer' (15-25 cm depth) occurred with unfertilized wheat (Fig. 3). Below the plough layer, to a depth of approximately 40 cm greatest root densities occurred below the fertilized wheat. Thereafter until a depth of 80 cm wheat root densities under both wheat treatments were similar. At depths of >35 cm chickpea root densities were lower than those of wheat. Dry matter produced at harvest by fertilized and unfertilized wheat, and chickpea was 15.3, 13.5 and 6.3 t/ha, respectively, whereas dry grain production was of the order of 5.2, 4.1 and 1.1 t/ha, respectively.

Soil properties

Soil properties measured were soil density, dispersion index (after application of energy with a vibratory probe), plastic limit, soil organic matter (particulate and mineralized), pH, soil respiration and exchangeable cations.

In comparison with June 1993, mean soil aggregate density in beds had decreased from 1.6 g/cm³ to 1.3 g/cm³ in all treatments (ie. porosity had increased). Highest soil density occurred with fertilized wheat, although the differences were small. Soil densities in the sub-soil (>15 cm) did not differ significantly between treatments. Dispersion index, in contrast, was least (ie. aggregate stability was highest) with fertilized wheat in the 15-30 cm depth (Fig. 4). The higher aggregate stability of fertilized wheat may be associated with its higher root densities at this depth. Significant differences in dispersion index did not occur between treatments in other depths. Other soil physical properties measured were not affected by the experimental treatments. Results of soil chemical analyses are presently unavailable, although grain nitrogen content suggests that estimated nitrogen budgets would be as follows (Table 3):

Table 3. Estimated nitrogen budgets

<u>Crop</u>	<u>Treatment</u>	<u>Fertilizer N input (kg/ha)</u>	<u>N fixed* (kg/ha)</u>	<u>N in grain (%)</u>	<u>Grain yield (kg/ha)</u>	<u>N removed in grain (kg/ha)</u>	<u>N available for next crop (kg/ha)**</u>
Wheat	Unfertilized	0	0	1.68	4100	69	-69
Wheat	Fertilized	140	0	1.75	5200	90	+8
Chickpea	Green manured	0	82	-	-	-	+82
Chickpea	Grain harvested	0	82	3.52	1100	39	+43

* Estimated by bioassay

** Assuming efficiency of fertilizer applied was 70%

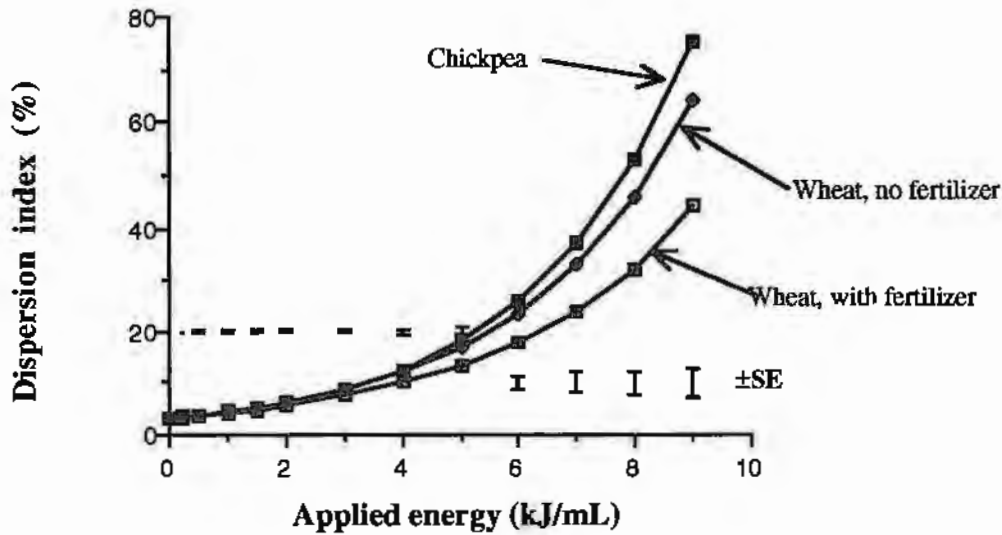


Fig. 4. Aggregate stability of soil in the 15-30 cm depth sown to wheat and chickpea in June 1993

Management constraints

Management of rotation crop residues is the major constraint in cotton-based farming systems which utilize permanent beds. Thus when large amounts of residues are produced by rotation crops their management (eg. by incorporation) takes precedence over retention of the beds. Cereal crops such as wheat produce large quantities of residues which degrade slowly, causing major problems in permanent bed systems when land preparation for the following cotton crop takes place. As residue levels of >3 t/ha cannot be handled with ease by conventional machinery, development of machinery which can easily mulch cereal stubble is needed if permanent bed systems are to be adopted by cotton growers. In addition, under conditions of decreasing soil fertility, application of N fertilizer may be required to successfully grow cereal rotation crops. Leguminous rotation crops such as grain legumes (eg. chickpea, cowpea) or forages (eg. dolichos, medics) are an alternative to cereals. The advantages of using leguminous rotation crops are that nitrogen inputs are minimized, lower amounts of stubble are produced and the stubble produced is more easily degraded.

CONCLUSIONS

1. Soil properties, cotton yield and fibre quality were best when a wheat-cotton rotation was combined with minimum tillage.
2. Soil aggregate stability in the 'plough layer' was greatest under a fertilized wheat crop.
3. Soil N levels at the end of the rotation crop phase were in the order of green manured chickpea > harvested chickpea > fertilized wheat > unfertilized wheat.
4. Management of rotation crop residues is a major constraint when permanent bed systems are used for cotton.

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