

Managing Wheat Rotation Crops: Effects of N Fertilizer on Soil Properties, Nutrient Uptake by Cotton and Cotton Lint Yield

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Introduction

Cracking clay soils are the most common irrigated cotton growing soils in Australia. 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). Under continuous cotton, soil structural degradation caused by the high frequency of machine passes during land preparation and harvesting can occur (McGarity *et al.*, 1984; McGarry, 1995; McKenzie, 1995). 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; McGarry, 1995; McKenzie, 1995). A rotation crop that is frequently used by cotton growers is wheat (Cooper, 1993). A survey of New South Wales' cotton growers conducted in 1992 indicated an interest in alternative management strategies for the wheat rotation crop such as irrigation and N fertilizer application to maximize benefits to the following cotton crop in terms of soil structural improvement and nutrient cycling (Cooper, 1993). The respondents also stated that research was required to determine the best mix of management strategies for wheat rotation crops. In this paper we present data on the effects of N fertilizer application to a wheat rotation crop on soil strength, nutrient uptake by the following cotton crop and cotton lint yields which were obtained from two studies on rotation crop management which commenced in 1993. The aim of this research was to define the best rotation/management combination whereby yields and quality of subsequent cotton crops can be maximized and sustained over the long-term.

The experimental sites are located at "Glenarvon", near Wee Waa (Namoi valley) and "Auscott", near Warren (Macquarie Valley). The soils are non-saline, alkaline grey clays at both sites but differed with respect to sand, silt and clay contents. The Wee Waa site has higher clay and silt, and lower sand contents; a lower exchangeable sodium percentage in the sub-soil; a higher cation exchange capacity; and a higher soil organic matter content.

Soil strength

Application of N fertilizer to wheat resulted in lower soil strength (indicating better soil structure), in comparison with unfertilized wheat, prior to harvesting the wheat crops (Figure 1). This is probably due to the more intensive drying (due to the greater root

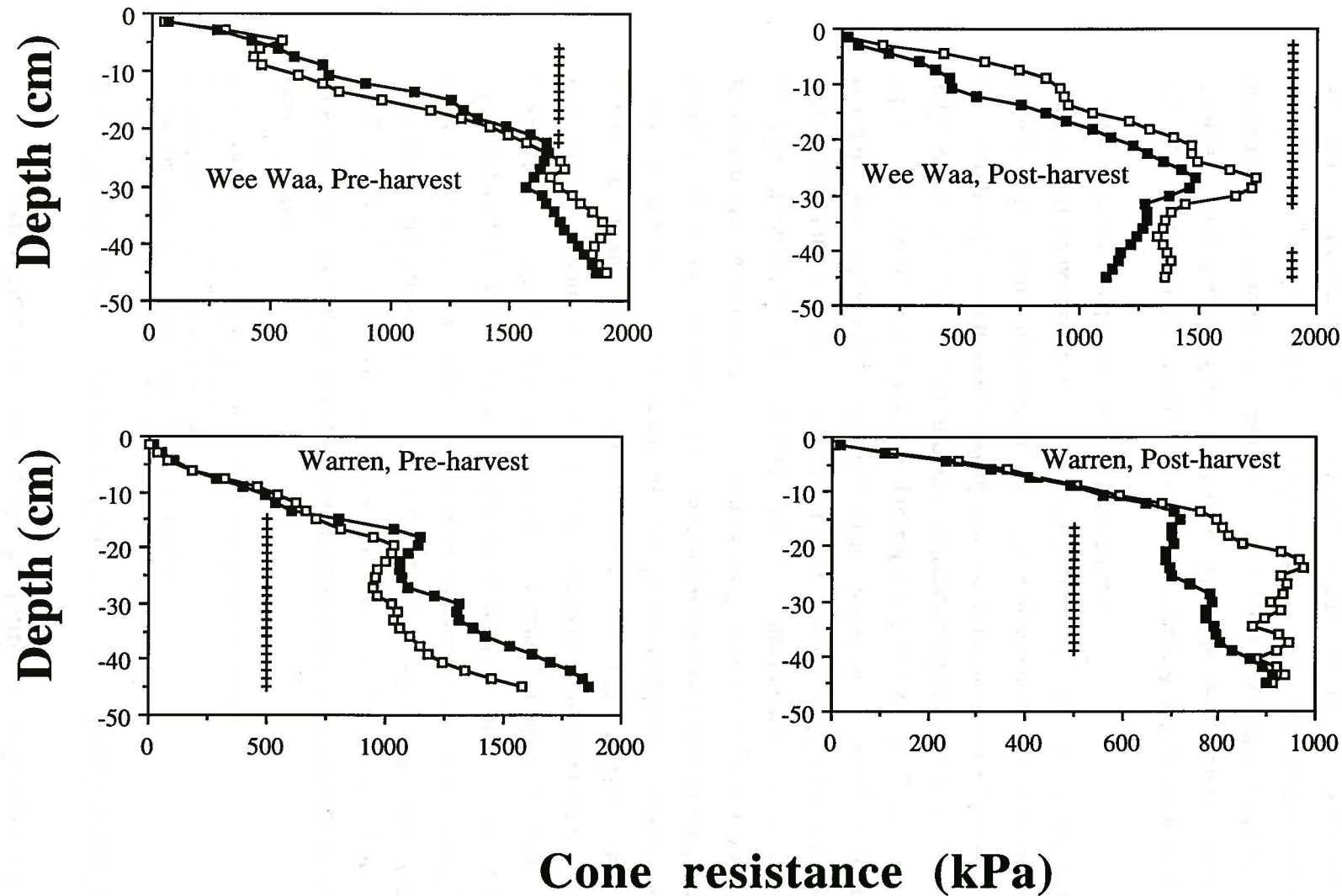


Figure 1. Effect of N-fertilizer application to a wheat rotation crop on soil strength (shown as penetrometer cone resistance) before and after wheat harvest. □ - fertilized wheat; ■ - unfertilized wheat; + - values in that depth differ significantly at the 95% probability level. (The higher post-harvest soil strength in fertilized wheat plots, in comparison with that at the same time in unfertilized wheat plots, is an *indicator* of poorer soil structure).

densities, see Figure 2) and wetting of the soil profile during the first 3 months after sowing in fertilized wheat plots (Cooper, 1994).

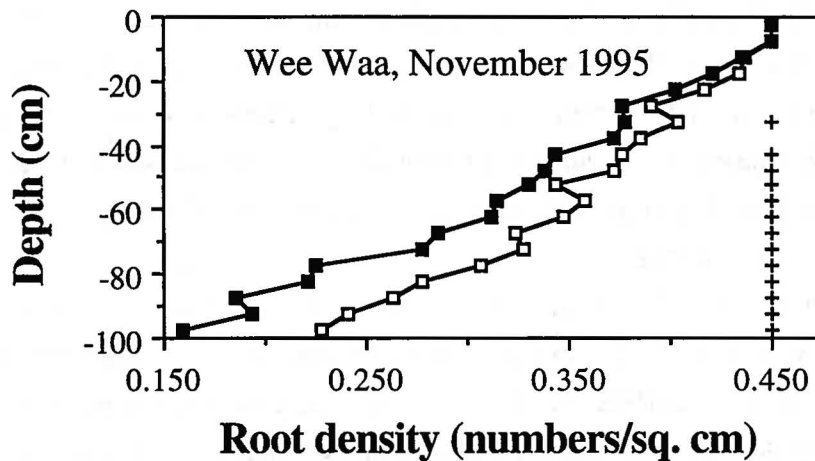


Figure 2. Effect of N-fertilizer application to a wheat rotation crop on wheat root density measured on a 1m x 1m profile face with the trench profile method. □ - fertilized wheat; ■ - unfertilized wheat; + - values in that depth differ significantly at the 95% probability level.

The greater root density also results in the addition of greater amounts of organic matter to the soil. Results from other studies suggest that soil organic matter has beneficial effects on structural properties of cracking clays (Koppi, 1995). Subsequent to the wheat harvest, however, soil strength in fertilized wheat plots was greater than that in unfertilized wheat plots (Figure 1). Higher bulk density values were also observed in the same treatment (Hulugalle and Entwistle, unpublished data).

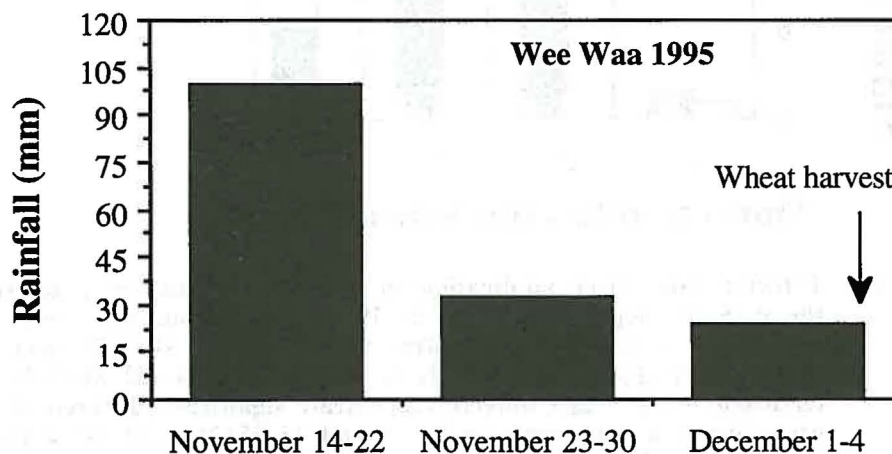


Figure 3. Rainfall received at 'Glenarvon', Wee Waa in the three weeks prior to harvest in 1995.

This was probably caused by the greater traffic weight which occurred in fertilized wheat plots in combination with wet sub-soil due to either irrigation (Cooper, 1994; Cooper, Hulugalle and Entwistle, 1996) or rainfall prior to wheat harvest (Figure 3). Wheat yields with fertilizer addition were greater than those in unfertilized wheat plots by 1 - 3 t ha⁻¹.

Furthermore relative increases in soil strength were greater at Warren due to irrigation of fertilized wheat plots. This resulted in the sub-soil under fertilized wheat being wetter at harvest than that under unfertilized wheat. Late irrigation of rotation crops when combined with heavy traffic is, therefore, likely to result in significant soil structural damage and reverse any improvements caused by sowing a wheat rotation crop. In summary, although addition of fertilizer was able to reduce soil strength by increasing wheat root growth, greater traffic weight during wheat harvest, particularly if the sub-soil was wet, resulted in significant structural degradation and consequent increases in soil strength.

Nutrient uptake

Nutrient uptake by fertilized wheat was, in general, greater than that by unfertilized wheat. This was probably due to the greater root densities in fertilized wheat plots (Figure 2), which facilitates more efficient extraction of soil nutrients. The release of these nutrients into the soil during decomposition of the wheat stubble (which was incorporated), results in them becoming available to the following cotton crop. As the fertilized wheat extracted more soil nutrients than the unfertilized wheat (Table 1), nutrient availability to cotton in the former treatment was consequently greater. This is suggested by the greater nutrient uptake by the following cotton (Table 1), and higher residual soil nitrate-N at the end of the cotton growing season in plots sown to a fertilized wheat-cotton sequence in comparison with plots which were sown to an unfertilized wheat-cotton sequence (Figure 4).

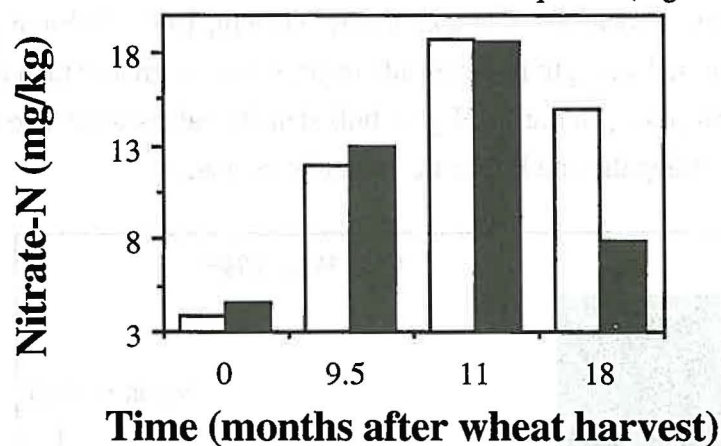


Figure 4. Effect of N-fertilizer application to a wheat rotation crop on soil nitrate-N in the 0-15 cm depth at Wee Waa, 1993-1995. Cotton was sown in all plots in October 1994 (10 months after wheat harvest, MAWH) and 120 kg N ha⁻¹ of urea was applied to all plots in December 1994 (12 MAWH); □ - fertilized wheat; ■ - unfertilized wheat; significant differences did not occur between treatments at 0, 9.5 and 11 MAWH; at 18 MAWH values differed significantly at the 95% probability level.

Nutrient uptake by cotton which followed fertilized wheat was, therefore, greater than that by cotton which followed unfertilized wheat.

Cotton growth and yield

In the short-term (1 rotation cycle) application of N fertilizer increased cotton vegetative growth (as indicated by leaf area index at crop maturity) but did not have any significant effects on lint

yield and gross margin (Table 2). Some fibre quality parameters were also improved by fertilizing wheat rotation crops. The individual quality parameters which were changed by N fertilizer application differed, however, at the different locations. This may be due to the different environmental conditions (ie. timing and amount of rainfall, solar radiation, sunlight hours) at the two sites during the 1994-1995 cotton growing season.

Conclusions

In comparison with unfertilized wheat, applying N fertilizer to wheat in wheat-cotton rotations: (1) resulted in short-term improvements to soil structure which were not maintained; (2) increased nutrient uptake by the following cotton crop; (3) improved some fibre quality parameters, but not cotton lint yield.

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Table 1. Nutrient uptake by wheat (November 1993) and the following cotton crop (March 1995) in a wheat-cotton sequence sown at "Glenarvon", Wee Waa, NSW. (N, S, P, Ca, Mg, K and Na are in kg ha⁻¹, and Zn, B, Mn and Cu are in g ha⁻¹).

Wheat stubble:

<u>Treatment</u>	<u>N</u>	<u>S</u>	<u>P</u>	<u>Mg</u>	<u>Ca</u>	<u>K</u>	<u>Na</u>	<u>Zn</u>	<u>B</u>	<u>Mn</u>	<u>Cu</u>
Fertilized wheat ¹	165	15	20	14	20	193	5	195	32	868	477
Unfertilized wheat	94	11	15	11	15	138	4	85	30	717	345
Significance ²	*	NS	*	***	*	*	NS	NS	NS	NS	**

Wheat grain:

<u>Treatment</u>	<u>N</u>	<u>S</u>	<u>P</u>	<u>Mg</u>	<u>Ca</u>	<u>K</u>	<u>Na³</u>	<u>Zn</u>	<u>B</u>	<u>Mn</u>	<u>Cu</u>
Fertilized wheat ¹	102	8	19	7	2	19	117	96	10	32	55
Unfertilized wheat	79	6	15	5	1	15	82	77	10	23	100
Significance ²	*	*	*	*	*	*	NS	**	NS	*	NS

Cotton:

<u>Treatment</u>	<u>N</u>	<u>S</u>	<u>P</u>	<u>Mg</u>	<u>Ca</u>	<u>K</u>	<u>Na</u>	<u>Zn</u>	<u>B</u>	<u>Mn</u>	<u>Cu</u>
Fertilized wheat ¹	145	30	12	28	153	89	8	70	331	241	35
Unfertilized wheat	108	21	9	22	127	61	6	48	298	213	22
Significance ²	*	*	**	NS	NS	*	*	*	NS	NS	***

Table 2. Effect of fertilizing wheat rotation crops on cotton vegetative growth, lint yield and fibre quality, and gross margins of wheat-cotton sequences sown at "Glenarvon", Wee Waa, and "Auscott", Warren, NSW. (DAS = days after sowing; LAI = leaf area index)

<u>Location</u>	<u>Treatment</u>	<u>LAI (cm² cm⁻²) at 152 DAS</u>	<u>Lint yield (ba ha⁻¹)</u>	<u>Micronaire (µg inch⁻¹)</u>	<u>Percent mature fibres</u>	<u>Strength (g tex⁻¹)</u>	<u>Gross margins (\$ ha⁻¹)</u>
Wee Waa	Fertilized wheat ¹	2.75	8.8	3.5	83.1	33.1	3649
	Unfertilized wheat	1.74	9.0	3.5	80.7	31.7	3698
	Significance ²	*	NS	NS	*	*	NS
Warren	Fertilized wheat ⁴	-	9.5	4.0	84.0	29.9	3715
	Unfertilized wheat	-	9.0	4.2	84.0	28.8	3495
	Significance ²	-	NS	*	NS	NS	NS

1. Fertilizer applied at a rate of 140 kg N ha⁻¹ as urea.

2. Symbols indicate level of significance at which means differ; *, ** and *** denote that values differ significantly at the 95%, 99% and 99.9% levels of probability, respectively. NS = not significant.

3. Na in wheat grain is given in g ha⁻¹.

4. Fertilizer applied at a rate of 83 kg N ha⁻¹.