Controlled traffic for irrigated row crops in the semi-arid tropics

J E McPhee [1], Department of Primary Industry and Fisheries, Devonport, Tasmania
M V Braunack [2], Bureau of Sugar Experiment Stations, Tully, Queensland
A L Garside [3], Bureau of Sugar Experiment Stations,c/- CSIRO, Townsville, Queensland
([1] Agricultural engineer, [2] Soil scientist and [3] Principal agronomist, formerly with Queensland Department of Primary Industries, Ayr, Queensland)

Summary Research was undertaken to investigate the use of controlled traffic for irrigated row cropping in a semi-arid tropical environment. The research was carried out on a cracking clay soil, in a region where the climate and availability of irrigation water provide the potential to grow two crops per year. Controlled traffic, combined with stubble retention and direct drilling, improved the timeliness of field operations, thereby improving the probability of successful double cropping. Energy use was reduced, crop emergence and yield were unaffected, and there were slight trends of improvement in soil structure over the three year duration of the research.

1. Introduction

Research in the 1960's identified benefits for crop growth by using controlled traffic to isolate the compaction effects of wheel traffic from the crop growth zone (Cooper *et. al.*, 1969). Controlled traffic has since been studied as a strategy for improving soil structure and infiltration (Tisdall and Adem, 1988) and the management of soil compaction (Taylor, 1986).

Reduced energy use and improved timeliness have emerged as additional benefits arising from the use of controlled traffic. Energy use savings ranging from 19% to 48% have been reported by a number of researches (Voorhees, 1979; Murray and Tullberg, 1986; Lamers *et. al.*, 1986). Most reports conclude that reduced tillage draft, brought about by not cultivating the compacted traffic lanes, is the major reason for decreased energy use. Compacted traffic lanes may also offer benefits of earlier access for field operations (Burt *et. al.*, 1986; Spoor *et. al.*, 1988), which may be important in some cropping systems.

The research reported in this paper was undertaken to investigate the use of controlled traffic to improve the management of for irrigated row crops in a semi-arid tropical environment. Specifically, the aims were to improve the reliability of double cropping, reduce energy inputs, and arrest soil structural decline resulting from intensive and frequent tillage in a furrow irrigated cropping system.

2. Background to Burdekin River Irrigation Area

The research was undertaken at Millaroo in the Burdekin River Irrigation Area (BRIA) (19°35'S, 147°24'E) in north Queensland, Australia, between 1988 and 1991. The climate of the region is dry monsoonal, with 75% of rain falling in summer, often in high intensity storms. Soils are extremely variable, ranging from sodic duplex through to cracking clay. This research was conducted on a cracking clay soil, classified as a Ug5.29 (Northcote, 1979) or Entic Chromustert (Soil Survey Staff, 1975). This soil is locally regarded as difficult to manage, since there is a narrow range of water content at which tillage will produce a desirable tilth.

Sugar cane, grown under furrow irrigation, is the main crop of the region, with rice, soybeans, sorghum and maize grown in smaller quantities. Although the climate and water supply is suited to double cropping, it is often possible to produce only one grain crop each year due to timeliness constraints, particularly during summer crop planting. Double cropping can provide many benefits such as improved profitability, protection of soil from erosion by either stubble or a growing crop for most of the year, and reduced weed competition (Smith and McShane, 1981).

Conventional tillage operations, undertaken to incorporate stubble, loosen subsoil compaction, and prepare a seedbed, may require from one week to three months to complete, depending on weather conditions. This period must be reduced to improve the reliability of double cropping. It was considered that controlled traffic, in conjunction with direct drilling, would be able to achieve this aim.

3. The Research

Three treatments were studied: i) controlled traffic with direct drilling into permanent beds (CTDD); ii) controlled traffic with conventional tillage on the top of a permanent bed (CTC); iii) conventional tillage with random traffic and crops grown in ridges formed at planting time (CONV).

The controlled traffic system used raised beds with 1.5 m between furrows to suit existing row crop machinery. The beds were formed using a laser controlled bedformer, similar to that developed by Adem and Tisdall (1986). This allowed accurate grading of the irrigation furrows. A laser controlled furrow cleaner, with two hydraulically driven rotors, was built to allow silt deposits and stubble to be cleaned from furrows after harvest.

Two tractors were instrumented to measure fuel flow, engine speed, ground speed and wheel slip. PTO dynamometer test data were used to establish equations for estimating power use in the field (Harris and Pearce, 1990). Dates of tillage operations was recorded to allow comparisons of timeliness.

Soil physical parameters were measured to quantify seedbed conditions in relation to emergence and crop establishment. Properties measured included gravimetric soil water content, aggregate size distribution and bulk density in the sowing line at the time of sowing. Soil temperature and water content were measured during the time leading up to full emergence, and cone index was recorded in the sowing line and wheel track at selected times during the season.

4. Results and Discussion

4.1 Timeliness

The combination of controlled traffic and direct drilling gave a marked improvement in timeliness of field operations, particularly planting. The number of days between harvest and planting of the subsequent crop for each of the treatments are shown in Table 1.

Table 1. Days from harvest to planting the next crop.

SEASON	CTDD	CTC	CONV
1988/89 wet	3	70	105*
1989 dry	18	31	59
1989/90 wet	2	3	6
1990 dry	2	14	77
1990/91 wet	4	74*	74*

* Seedbed preparation not completed due to weather conditions.

Even when conditions were favourable for seedbed preparation using conventional techniques, the combination of controlled traffic and direct drilling gave a timeliness advantage of four days. This advantage was much greater when rainfall interrupted seedbed preparation on the cultivated treatments.

Improvements in timeliness have important implications for the reliability of double cropping, as conventional seedbed preparation is often interrupted by rainfall in the tropical environment.

4.2 Energy

Energy use in the CTDD treatment was 28-34% of the CONV treatment, and 39-59% of the CTC treatment (Table 2). Seedbed preparation with conventional cultivation required at least three, and sometimes up to seven, operations. However, cleaning silt and stubble from the furrows between the beds was often the only pre-planting operation needed in the CTDD treatment. Energy use in the CTC treatment was high because the furrow cleaning operation was used between most tillage operations to remove loose soil to allow adequate drainage from the furrow. This was particularly important during wet season operations. The results for the CTDD treatment have major implications for lowering capital and operating costs.

Table 2. Seasonal energy use, MJ/ha, for each treatment in three seasons

SEASON	CTDD	CTC	CONV
1988/89 wet	252	424	132 [a]
1989 dry	259	586	936
1989/90 wet	b	b	b
1990 dry	358	923	1040

[a] seedbed preparation was not completed due to wet weather, so energy use was recorded for only some operations.

[b] no data were recorded due to logger failure.

4.2.1 Peak energy demand

As well as differences in overall energy use between treatments, there were differences in peak energy demand (*ie.* the energy required for the most energy intensive operation). The peak energy demand is important in that it influences the level of capital investment required in tractor power. The first furrow cleaning operation after harvest had the highest energy demand in the controlled traffic treatments (CTDD and CTC). The highest demand recorded was in CTC in the 1990 dry season (444 MJ/ha). This was associated with slumping of the beds during the growing season, resulting in substantial silt accumulation in the furrows. In contrast, the same operation in the CTDD treatment required 250 MJ/ha in the same season, due to the direct drilled beds becoming more stable and less prone to slumping. There was little difference between treatments in energy demand for subsequent furrow cleaning operations (eg. 55 MJ/ha for CTDD compared with 59 MJ/ha for CTC in the 1990 dry season).

The indications are that energy demand in CTDD may decline over time due to the bed system becoming more stable. However, this is not a possibility in a conventional tillage system. Seasonal peak energy demand in the CONV treatment always occurred with rotary hoeing. The energy input to rotary hoeing ranged from 165 to 339 MJ/ha across the seasons for which data were recorded.

4.3 Seedbed Properties

Aggregate size distribution is an important soil property with respect to crop emergence and establishment, as it influences seed-soil contact. Glasshouse experiments with soil from the project site suggest that emergence of maize and soybeans was most reliable with aggregate sizes in the range of 1-2, and 2-5 mm. (Braunack, 1995). Rathore *et. al.* (1983) reported similar results for soybeans. Aggregate size distributions in the planting zone are presented in Table 3.

There were no consistent statistically significant effects of treatment on aggregate size distribution. This lack of consistency makes it difficult to draw conclusions regarding soil structure, but this in itself indicates that seedbed condition was no worse with CTDD and CTC than under the CONV treatment. Trends suggested that soil condition was probably improving under CTDD, but the rate of change was too slow, and the results too variable, for this to be confirmed in this research.

Table 3. Sowing line aggregate size distribution (%) at 0 - 50 mm depth for all treatments.

		AGGREGATE SIZE DISTRIBUTION (% in mm size ranges)				
SEASON	**TREATMENT**	**<1**	**1-2**	**2-5**	**5-15**	**>15**
1988-89 wet (soybeans)	CTDD	3.1	1.3	5.2	28.9	61.4
	CTC	5.0	3.3	12.5	43.2	36.0
	CONV			not planted		
1989 dry (maize)	CTDD	9.0	6.3	13.8	21.3	49.6
	CTC	7.6	5.9	15.3	26.2	45.0
	CONV	8.9	7.5	16.2	25.4	42.1
1989-90 wet (soybeans)	CTDD	16.5	16.4	19.2	14.4	33.5
	CTC	14.4	14.6	19.7	15.9	35.4
	CONV	11.9	11.6	11.4	10.9	54.3
1990 dry (maize)	CTDD	5.8	5.5	17.8	18.7	52.2
	CTC	4.5	3.5	11.1	15.1	65.7
	CONV	2.7	1.3	3.1	4.3	88.6

4.4 Crop Factors

Crop establishment and yield were not significantly effected by the different treatments. Only on one occasion did differences in yield approach levels of statistical significance, when the yields for the controlled traffic treatments were marginally greater (P=0.097) than the CONV treatment. More importantly, there was no indication of any adverse affect on grain yield due to controlled traffic.

5. Economic considerations

The energy use differences between controlled traffic and conventional farming systems have major economic implications for two reasons. Lower seasonal energy use naturally leads to a reduction in operating costs in crop production. Further, the reduced peak energy demand and change in tillage practices due to controlled traffic, particularly in conjunction with direct drilling, could lead to substantial reductions in the capital investment in tractors and equipment.

An economic analysis was conducted to indicate the relative differences in capital investment and operating costs per crop. It was based on details of this research, including equipment used, the average number of operations required, average fuel consumption, and the number of crops grown. Crop yield was not considered, as there were so few differences in treatment yields over the duration of the project. Other aspects of crop production costs, such as fertiliser, weed control etc. were not included in the analysis, as these were common across all treatments in the context of this research.

It should be noted that the selection of equipment was not necessarily optimal for the work loads encountered in this research. No attempt was made to optimise tractor performance through techniques such as implement matching and selection of gears and throttle settings for optimal engine loading. Further savings would likely be possible in all treatments if these factors were taken into account. Capital costs were based on new prices for the selection of equipment used in the research. The results of the economic analysis are shown in Table 4.

Table 4. Costs for three tillage systems

	CTDD	CTC	CONV
Capital cost [a]	38,000	56,400	121,500
Operating cost [b]	28	62	97
Total cost [c]	80	199	292

[a] Capital cost of machinery required for each system, ($A)
[b] Operating costs include repairs and maintenance, fuel and oil, but not labour, ($A/ha per crop)
[c] Total costs include, in addition to operating costs, depreciation on capital over the estimated life of the machinery, shelter, insurance and interest on the capital, all distributed over the area cultivated annually, ($A/ha per crop)

The large difference in capital cost between CTDD and CONV is primarily due to the size of tractor required. The operating costs per crop for the CONV are higher than would be expected in a commercial farming situation. (A. Bourne, unpub. data). Apart from implement selection and optimisation issues, this higher cost was influenced by two important factors: i) costs are allocated across fewer crops as this treatment was not planted in the 1988-89 summer, even though some cultivation costs were incurred early in the season; ii) unseasonal rainfall in the 1990 dry season increased the number of operations required to prepare a seedbed, and this increased the average number of operations per crop.

6. Conclusion

The foregoing results indicate that controlled traffic, as used under these particular environmental and soil conditions, offers considerable benefits in improving timeliness and energy use. Effects on soil structure and crop production were minor over the period of the research, although trends suggested that improvements may be gained in the long term.

Timeliness was the most important short term benefit. The ability to rapidly move from the harvest of one crop to the planting of the next is all important in a double cropping system, and particularly so in the tropics. The success of direct drilling, in a soil which is considered to be difficult to manage, was a major factor in providing the timeliness advantage.

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