

Comparative analysis of different tillage systems used in sugarcane (Thailand)

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Contents

Introduction
Materials and methods
Results and discussion
Conclusions
References
Appendix

Abstract In order to reduce the impact of decreasing profit margins in crop production systems, all possible options that will increase net profits need to be explored. Land preparation and stool removal in sugarcane production can be a major contributor to overall production costs. Since estimates that mechanization can contribute as much as 50% of the total production costs, considerable savings can potentially be made if the number of tillage operations is reduced. Such savings however, have to be offset against other costs associated with minimum or no-tillage systems, such as the increased need for herbicide. In addition, conventional tillage systems have been implicated in yield decline over the long-term and therefore yield benefits are envisaged, together with cost savings, by the adoption of minimum and no-tillage sugarcane production. A comparative analysis of five sugarcane tillage systems using data from eight years, showed that minimum tillage, with mechanical stool removal and machine planting gave the best economic returns, being 29.3 and 39.4% more profitable than the conventional and no-tillage treatments, respectively. Other minimum tillage treatments, with sub-soiling and machine / manual planting combinations also performed well. Whilst the no-tillage treatment made substantial savings from the non-use of machinery, these were offset to a large degree by the extra costs associated with herbicide use and extra labour requirements.

Key words: minimum tillage, no-tillage, net profit, profit margin, sugarcane

Introduction

Land preparation and stool removal for sugarcane cultivation can be a major contributor to overall production costs. In Australia, Braunack et al. (1999), give estimates of the number of tillage operations for conventional land preparation being between eight to ten, whilst McMahon and Teske (1989) report up to 18 times. Similar high numbers of traffic passes, with associated higher costs, are used in Thailand, with the thirteen passes being observed for the conventional tillage treatment (T1) used in this study being typical. De Beer et al. (1993) estimates that mechanization can contribute as much as 50% of the total production costs. Hence, determining techniques which can reduce the need for the number of soil cultivations whilst still maintaining or improving yields is a practical way for farmers to reduce their costs and increase their net profit.

In Australia, many of the soil management practices used in sugarcane production, such as excessive tillage, the burning of crop residues and over-use of fertilisers, are thought to have contributed to soil degradation, with this being reflected in recent yield declines (Wood 1985). Similar conventional management practices are used in Thailand and, despite the lack of research examining relationships between soil degradation and crop yield, it can be assumed that similar yield declines to those in Australia, are likely to occur. Much of the research in recent years using minimum or no-tillage techniques combined with trash management has shown beneficial results both for improving cane yields as well as reducing detrimental environmental impacts (Wood 1991; de Beer *et al.* 1993). In Thailand, however, the adoption rate of such improved techniques has so far been slow, due mainly to the lack of access to information, but specifically related to more complex issues as outlined by Rogers (2003).

The main objective of the experimental trial was to assess the long-term commercial viability of using conventional tillage, minimum tillage and no-tillage techniques for cane cultivation in central Thailand. This paper gives an interim benefit-cost analysis after eight years, representing the third planting cycle.

Materials and Methods

The trial was conducted at Suphan Buri Field Crops Research Center in central Thailand on a Haplic, Hypocalcic, Brown Dermosol (Isbell

1996). The climate is tropical wet and dry (Trewartha 1968) with a mean annual temperature of 28^oC and mean annual rainfall of 1116 mm. The rainy season is bimodal reaching peaks in May and September.

The trial area was planted in January 1994, with data used in this comparative analysis being from the first eight years, representing the third planting. The experimental design was that of the split plot, with the main plots representing the tillage system and subplots representing the two levels of N fertiliser (urea) applications, with each being replicated four times. All subplots received uniform dressings of P_2O_5 and K_2O fertilisers. Plant rows were 1.3 m apart and plot sizes were 8 rows by 10 m, with 0.5 m plant spacing within the row. Only the middle 6 rows were analysed. The sugarcane variety used was U-Thong 2 and this was evaluated for growth by measuring the wet weight cane stalk yield (t/ha). All analyses were conducted using the MSTAT-C programme. The five tillage systems being tested are described in Table 1 (see Appendix). Irrigation was applied by furrow as a supplement to rainfall when required, usually about 50 mm, 2 or 3 times in March/ April.

The fuel and labour cost analyses of each tillage operation were assessed using data from Prammanee et al. (2000) and Chinawong and Cheosamutr (2000) for 1 hectare of land. Average yield data (Table 2, see Appendix), for each of the tillage treatments, were used to calculate net profit.

Results and Discussion

In the plant and first ratoon crops, the cane yields of the minimum tillage treatments (T2 to T4), are on the whole, significantly larger than the yields of the no-tillage treatment and frequently larger than the conventional tillage yields (Table 2 and Figure 1, see Appendix). The highest average cane yield occurs in the minimum tillage with mechanical stool removal and machine planting (T2). The higher yields of this tillage treatment, however, tends to be generally comparable with the other two minimum tillage treatments with subsoiling and machine / manual planting combinations (T3 and T4), throughout the eight years. There are no significant differences in cane yields between any tillage treatment in the second and third ratoon crops. Apart from the no-tillage treatment (T5), the minimum tillage (T2) is the only other treatment that does not receive ploughing or subsoiling operations.

In terms of cost analysis of fuel and labour, large savings in land preparation costs were made for the minimum tillage (T2 to T4) and no-tillage (T5) treatments (Table 3, see Appendix). However, much of this was offset by the high costs of herbicide application (including labour) and manual planting. Despite this, the higher yields that were associated with the minimum tillage treatments, particularly T2, resulted in better net profits when using average yield values. The minimum tillage treatment (T2), gave the best return, followed by T3, T4, T1 and T5 with net profits of AUD 1374.9, 1248.7, 1230.1, 1063.0 and 986.4, respectively (Table 3, see Appendix). Minimum tillage treatment T2 was about 29.3 and 39.4% more profitable than the conventional and no-tillage treatments, respectively.

Sugarcane yields in soils managed conventionally have been observed to plateau or reduce over the longer term, both in Australia (McGarry & Bristow 2001; Garside et al. 1997; Wood 1985) and elsewhere (Meyer & van Antwerpen 2001), with this often being attributed to soil degradation. It is likely that such yield declines are also taking place in Thailand for the same reasons (P. Prammanee, pers. comm.). Wide fluctuations in yield do occur and are due in part to the plant and first ratoon cane crops tending to always yield higher, together with climatic conditions favouring better growth in some years (Figure 1, see Appendix). Despite these differences, an emerging trend can be seen with the conventional tillage (T1) treatment having consistently lower yields than the minimum tillage treatments (T2-T4) after 4 years, even though not all differences are significant (Table 2, see Appendix). Similarly, the no-tillage treatment (T5) also shows lower yields than the minimum tillage treatments.

Conclusions

The minimum tillage treatments (T2 to T4) are recommended under the existing conditions of irrigation availability and associated high ground water table, together with availability of machinery. The minimum tillage without subsoiling (T2) gave the best economic returns.

Despite the substantial cost savings from the absence of mechanisation, labour costs are likely to offset a large part of these savings. As a result of this increased labour need, and due of the extra time required for manually cultivating the crop, there will be limitations of scale, with a cut off point when field size becomes too large to allow non-mechanised cultivation to be economically and practically feasible. However, such a system will work on a small scale, where ownership and access to machinery is limited and low input–low returns are acceptable. Such farms are common in Thailand, with for example the average size of the holding in the Central Region of Thailand being only about 4 ha (CAI 1999).

This is the first time such a long-term sugarcane experiment has been conducted in Thailand and after only eight years it is difficult to make any firm conclusions about the effect of tillage treatments on crop yields. However, the results obtained so far are of interest and are consistent with other similar work (CRC 1998; Braunack et al. 1993; de Beer et al. 1993; Wood 1991). In addition, they are also beginning to demonstrate the advantages of using alternative tillage techniques to those of conventional tillage. The tillage experiment is intended to continue for many more years, serving as an invaluable source of information as regards long-term sugarcane production and associated economic trends.

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Appendix.

Table 1. Description of soil tillage systems used in the experiment

Treatment	Description
T1	Conventional tillage (stool ploughout)[A] + periodic burning of trash[B] + manual planting [E] + manual harvesting.
T2	Minimum-tillage (stool scrapeout)[C] + periodic burning of trash[B] + stool removal + machine planting + manual harvesting.
T3 [D]	Minimum-tillage (stool sprayout) + periodic burning of trash[B] + subsoiler [D] + manual planting [E] + manual harvesting.
T4 [D]	Minimum-tillage (stool sprayout) + periodic burning of trash[B] + subsoiler [D] + machine planting + manual harvesting.
T5 [D]	No-tillage (stool sprayout) + no burn (trash blanket remains after all harvest cycles) + manual planting [E] + manual harvesting.

[A] At least five passes of the tractor and implement as follows: Land leveling, variable number of passes; Disc ploughing once; 7-disc harrow, twice; ridge and furrow formation, one pass; and, machine planting.

[B] Trash remaining after harvest is burnt only once in a crop cycle, this being prior to a new planting. In other years, trash remains on the soil surface.

[C] By tractor with scraper. The scraper lifts and moves cane stumps out of the experimental plot with a minimum of soil removal. Two passes of the tractor are usually enough.

[D] At each new planting, the previous inter-row is converted into the plant row using a single shank subsoiler with an operating depth of 25-35 cm.

[E] Cane setts, about 30 cm in length with 2 eyes, were planted 10 cm deep using a hand-hoe.

Table 2. Yield (t / ha) of sugarcane for the different tillage systems over the cropping cycles (date indicates time of planting).

Tillage system	1st plant cane 1994[B]	1st ratoon 1995	2nd ratoon 1996	3rd ratoon 1997	2nd plant cane 1998	1st ratoon 1999	2nd ratoon 2000	3rd plant cane 2001[C]	Overall (1995 – 2000)[B]	
									Total	Average
T1	106.3 a	86.3 a	72.5	70.0	113.1 bc	117.2 b	63.1	128.8 b	651.0	93.0
T2	91.3 ab	78.1 ab	77.5	78.1	130.0 ab	143.8 a	68.6	170.0 a	746.1	106.6
T3	69.4 bc	77.1 ab	63.1	60.6	135.0 a	132.6 a	80.6	156.3 ab	705.3	100.8
T4	84.4 ab	70.6 b	68.1	64.4	128.8 ab	134.7 a	68.1	160.6 ab	695.3	99.3
T5	48.1 c	61.3 c	68.8	70.0	105.6 c	107.1 b	64.4	129.4 b	606.6	86.7
Average	79.9	74.7	70.0	68.6	122.5	127.1	68.9	148.9	680.9	97.3
f-test	**	**	ns	ns	*	**	ns	**		
CV (%)	19.4	19.4	18.8	28.1	14.3	10.4	27.0	15.9		

Values in the same column with the same letter are not significantly different ($p<0.05$)

[B] 1994 yield is low in some of tillage treatments due to a misapplication of herbicide. These values have not been included in the total and average values.
[C] The third planting was brought forward one year to eradicate an infestation of stalk borer that had occurred in the 3rd ratoon of the second planting.

Table 3. Costs analysis (AUD) for different tillage systems.

Source: Adapted using data from Prammanee *et al.* (2000) and Chinawong and Cheosamutr (2000). The costs given were current for Thailand in 2000

		Tillage treatments				
	Cost per operation	T1	T2	T3	T4	T5
Disc ploughing	9.5	9.5	-	-	-	-
Land leveling	5.4	16.4	-	-	-	-
Harrowing	19.4	38.8	-	-	-	-
Ridging	19.0	19.0	-	-	-	-
Subsoiling	9.5	-	-	9.5	9.5	-
Stool scrapeout	5.4	-	5.4	-	-	-
Subtotal land preparation		83.7	5.4	9.5	9.5	0.0
Herbicide application	38.8	-	38.8	38.8	38.8	38.8
Machine planting	18.3	-	18.3	-	18.3	-
Manual planting	28.6	28.6	-	28.6	-	28.6
Cane sett preparation	5.3	5.3	5.3	5.3	5.3	5.3
Subtotal planting costs		33.9	62.4	72.7	62.4	72.7
Crop maintenance and harvest costs[1]		611.7	611.7	611.7	611.7	611.7
Average yield (t/ha). (Table 2)		93.0	106.6	100.8	99.3	86.7
Income (AUD 19.27 per tonne)		1792.3	2054.4	1942.6	1913.7	1670.9
Net profit		1063.0	1374.9	1248.7	1230.1	986.4

[1]These costs are for: irrigation; fertiliser / pesticide costs and applications; manual weed control; labour at harvest; transport costs at harvest (considered uniform for all treatments).

Fig 1. Sugarcane yield for five tillage treatments, T1-T5 (Table 1), over the eight growing years