REDUCED TILLAGE SYSTEMS FOR HEAVY COASTAL CLAY SOILS IN THE GUYANA SUGAR INDUSTRY

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ABSTRACT

Commencing in 2001, a series of field studies were initiated to further evaluate the impact of reduced tillage systems using specially designed tillage implements on soil properties and cane yields after initial studies during the 1990's indicated comparable or better results (with respect to cane yields, soil properties and fuel use efficiency) to conventional tillage with the Howard Paraplow. These field studies compared conventional tillage with the paraplow done across the entire cane bed (referred to as Full-width tillage) with other reduced tillage systems such as zero-tillage, and strip-tillage using either harrows or special "in-house" developed implements such as combination paratill/scarifying implement called a "Rut repairer" and a strip-tillage implement comprising sub-soilers in combination with an offset harrow unit.

More recent field studies initiated at the La Bonne Intention (LBI) estate, examined different tillage systems (conventional full-width, strip and zero) with two forms of row planting methods namely single and double row planting and utilizing four commercial varieties.

Results obtained so far are consistent with those of previous studies and have indicated no adverse effects of reduced tillage on soil physical properties or cane yields while showing a reduction in operational costs for land preparation.

Key Words: Howard Paraplow, Zero-till, strip-till, reduced tillage, full-width tillage.

INTRODUCTION

Sugar cane is cultivated in Guyana along the coastal plain to the north east of the country. These lands are flat with elevations varying between 0.3 m below to a maximum of 2.1 m above mean sea level. Tides fluctuate about 1.2m of mean sea level. These soils have high clay contents, are difficult to cultivate and require several passes of the implement to produce a suitable seed bed. In addition, a significant proportion of these soils have swelling and high water retention properties, which can further curtail land preparation activities and extend the re-entry time of machines into fields following a rainfall event (Davis et. al. 2005).

Reduced or conservation tillage is a system of land preparation that leaves considerable plant residues on or near the soil surface and therefore protects the soil from erosion (Brady and Weil, 1999). This system includes a no-till operation, where one crop is planted in the residue of another with virtually no tillage. Other minimum tillage systems permit some stirring of the soil, but still leave a high proportion of the crop residues on the surface. These organic residues protect the soil from the erosive effects of raindrops and the abrasive action of the wind, thereby reducing water and wind erosion and maintaining soil structure.

Some of the beneficial effects of reduced tillage on soil properties include (i) increased aggregation due to the build-up of active organic matter, (ii) improved water infiltration and soil internal drainage, (iii) improved soil water holding capacity, and (iv) immobilization of nutrients, especially nitrogen, in contrast to mineralization encouraged by the decline of organic matter under conventional tillage.

Wide cambered beds have facilitated mechanization in harvesting and husbandry operations and have permitted application of reduced tillage activities. The Paraplow was developed by Howard with the National College of Agriculture Engineering – Silsoe, in the 1980's. The use of this implement as a primary tillage tool in Guyana had demonstrated its propensity to loosen compacted clay soil (Dey, et al., 1997) and produce an upward movement of the disturbed soil slice. For these reasons the principle of the angled sub-soil implement became the basis of the design of locally fabricated reduced tillage implements in the Guyana Sugar Corporation Inc. (Guysuco). One such device, which we term the "Rut Repairer" (**Fig.1**) consists of a combination of components to perform cultivation, soil loosening and scarifying, all in a single pass. The tool specifications of this implement are outlined in **Table 2**.

Fig 1: Schematic diagram of Para Till implement/ Rut Repairer

Tillage in Guysuco usually consists of several passes with a plough and/or harrow as primary tillage implements over the entire bed width (full-width or conventional tillage). These approaches to tillage can be costly, and time consuming. They also involve significant soil manipulation that can increase susceptibility to erosion. Plateau yield levels, increasing production costs, and slashed sugar cane prices in the EU in recent years, together pose a real concern to viability of the corporation and necessitates new and innovative methods for combating these problems.

The introduction of the Howard Paraplow into Guysuco and its subsequent initial evaluation during the 1990's indicated comparable or better results to conventional tillage with respect to cane yields and root distribution in the soil profile. Machine productivity in terms of hours worked per hectare using the Howard paraplow was always comparable if not better than with the other traditional tillage implements. On the other hand, fuel consumption per hectare using the paraplow was approximately 50% and 75% of the fuel consumption when using harrows only, and plough plus harrows, respectively.

Such promising results obtained from using the Howard Paraplow (itself considered a reduce tillage implement) on coastal clay soils in Guyana prompted the search for more cost effective tillage operations that can sustain sugar cane yields and reduce the overall cost of production. Commencing in 2001 therefore, field studies were initiated to further evaluate minimum/reduced tillage operations as a standard land management practice in Guysuco using mainly locally fabricated reduced tillage implements.

This paper reports on three different sets of trials conducted on heavy clay soils in Guysuco's Le Ressouvenir (LR), La Bonne Intention estate beginning from 2004 and including one trial that is presently ongoing.

OBJECTIVES

Two separate trials were established during 2004 and a third in 2007 to evaluate various systems of reduced tillage operations in heavy clay soils. The 2007 trial is still ongoing and has incorporated the evaluation of a double row option and variety response to this culture.

The rut repairer was the implement used in strip tillage in the 2004 trials, while the paraplow was used in all full-width tillage treatments. In the 2007 trial, reduced or strip tillage was conducted with two shanks of the paraplow, followed by a passes with a (ARC fabricated) strip harrow implement. This has formed the principle for the design of a dedicated strip tlllage implement that will combine the features of the paratill and harrow in a single implement that will work two planting lines in each pass.

Fig 2 - ARC Strip Harrow

The primary objectives of these trials were to evaluate the impact of reduced tillage operations on (i) sugarcane growth and yields, and (ii) soil physical characteristics and plant root development and (III) the productivity indices of machines performing the various tillage systems. The current (2007) trial is also examining the impact of the different tillage systems on the performance of various cane varieties planted in single or double row culture.

MATERIALS AND METHODS

2004 Trials

During 2004, two trials were established at Le Ressouvenir, La Bonne Intention estate, in the first and second crops respectively. The first trial was established at LR 29 and 31 during the first crop in March 2004, while the second trial was established at LR 11 to 27 during the second crop in November 2004. Both trials were conducted on Whittaker series soil (Tropic Fluvaquent), mapping unit 37 (FAO, 1967; Smith, 1983). The varieties D89138 and DB7869 (standard) were planted in the two trials respectively. Both of these trials were severely affected by floods in January 2005 and 2006 to the extent that the first trial was heavily "supplied" and the second replanted in March 2005.

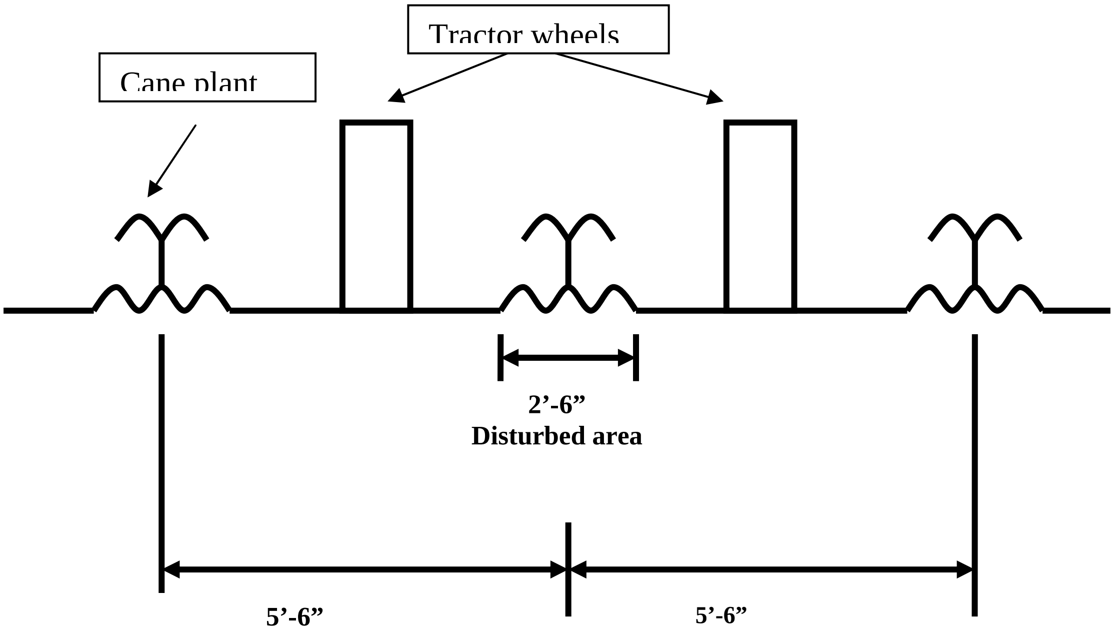
The various tillage systems/implements and sequence of operations evaluated in these trials are outlined in **Tables 3a** and **3b**. In the first trial, strip tillage was done with the rut repairer/paratill implement and disc harrow respectively, while the Paraplow was used in full-width tillage. In the second trial, only the Rut Repairer was used to perform strip tillage while two variants of primary tillage using either the paraplow or disc plough in the full width tillage treatments. Strip tillage was conducted either in the previous cane line or inter-rows

The trial design in both instances was a Randomized Complete Block (RCB) with four replications. After harvest, the canes in the fields were allowed to grow for 4 to 6 weeks before the newly emerged vegetation was destroyed with glyphosate used at a rate of 4.2 litres per hectare. Tillage treatments were then imposed, the fields planted semi-mechanically and then irrigated.

2007 Trial

The third trial was established at LR 11 – 31 during the period April 21 to May 02, 2007. However, the onset of the rains curtailed all mechanical operations and as a number of fields had to be planted manually. This meant that only one replicate of the trial as designed was achieved. The remaining fields were taken out of the trial.

Data collection and evaluation were done from a single replication comprising three fields, each with one tillage system, namely full-width tillage, strip tillage or no tillage. Superimposed in the full-width and strip tillage systems respectively are two row-planting methods (single or double), while the no tillage field comprised only single-row planting. Four different cane varieties were further superimposed in each row-planting method. The sequence of operations evaluated in this trial is outlined in **Table 3c**. Primary tillage for full-width tillage was done with the paraplow. In reduced tillage, operations were restricted to the cane lines. The primary operation was achieved with two paraplow shanks placed 50cm apart on the paraplow tool bar.



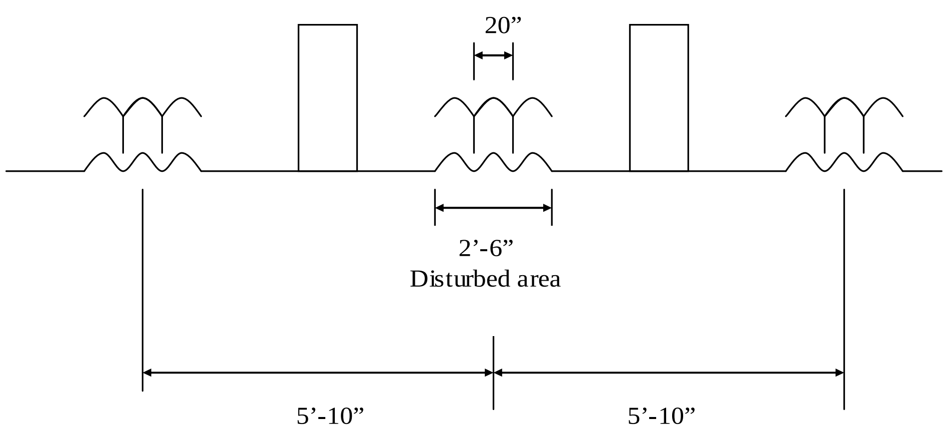


Fig 3: Schematic of (a) single row and (b) double row planting

The varieties planted included D9017, DB75159, D93409 and DB7869. Planting of canes in this trial was done mechanically for single-row, and semi-mechanically for double-row culture. The spacing for the single-row planted canes was 1.68 metres (or 5.6 feet), while for the double-row canes it was 0.5 metres (or 1.67 feet) between rows and 1.78 metres (or 5.8 feet) between the centres of two double rows (**Figs 3a** and **3b**). Planting of single rows of canes was done using a "single-row drop-planter" (fabricated at the ARC), which utilizes precut seed pieces or alternatively, using the "single-row chopper planter" (CIVEMESA), which uses whole-stalk canes Semi-mechanical dual-row planting was achieved with implements modified and fabricated at the ARC. The process included the mechanical opening of dual rows, manual placement of canes in furrows and mechanical covering and rolling of canes

Data collection

Data collected from the first trial included soil and plant growth measurements, tillage depth and the productivity indices for the various tillage systems. Soil measurements included soil dry bulk density and soil resistance to penetration. Plant measurements included root density, stalk population, diameter and height. Cane yields for the plant and first ratoon cycles at harvest were obtained for both of the two earlier conducted trials. No soil or plant data was collected for the second trial.

The third trial is currently in progress and so far data have been collected on soil and plant measurements including soil resistance to penetration, soil dry bulk density, stalk population, and root distribution.

RESULTS AND DISCUSSION

2004 trials

The two trials that were established during 2004 were abandoned after three and two cycles of harvest respectively mainly because of their poor yields; the current trial is scheduled for harvest during March 2008.

Plant growth measurements obtained from the first trial indicated that at 12 weeks there were no significant ($p>0.05$) differences in stalk girth or height among the various tillage treatments. Stalk girth ranged from 1.72 to 1.88 cm while stalk height ranged from 38.5 to 43.5 cm. There were however, differences in stalk population with full-width tillage showing significantly ($p<0.05$) greater number of stalks (14 per metre-row) than the other tillage treatments. At this stage of growth the zero till treatment had significantly less stalks (10 per metre-row) than the other treatments, while the stalk count was similar for the two strip tillage treatments.

Plant root volume and soil dry bulk density were measured both within and between the cane rows 3 months post planting and immediately after harvest of the first ratoon cycle. Results for root volume within the cane row indicated no significant ($p>0.05$) differences among the various treatments (**Table 4**). Soil bulk density measurements also did not show significant differences among the various treatments (**Table 5**). In both cases the performances of both the minimum tillage treatments were no worse than the full-width tillage treatment.

Soil resistance was determined within the cane rows 9 weeks post planting for the first trial, using an electronic penetrometer (T**able 6**). Results showed no significant ($p>0.05$) differences in soil resistance among the various treatments in the top 30 cm soil depth. The obverse was however true for the 30 – 60 cm soil depth with soil resistance being significantly higher for the no tillage and strip tillage with harrows treatments compared with the other treatments.

Plant cane yields for both earlier trials were extremely poor and can be attributed to flood conditions experienced during January and February 2005 and 2006. There was overall improvement in ratoon yields, especially for the first and second ratoons in the fist and second trials respectively (**Tables 7a** and **7b**). There were no significant ($p>0.05$) differences in cane yields among the various treatments for any of the harvested cycles.

The productivity indices obtained from these trials indicated greater machine efficiencies for the reduced systems of tillage compared with the full-width system. In the first trial, the number of hours required to prepare one hectare of land were 1.0, 1.8, and 2.4 for the no tillage, strip tillage (with the Rut Repairer) and strip tillage (with harrows) respectively, compared with 4.2 hours for full-width tillage with the paraplow. In the third trial, full-width tillage with the paraplow (with 3 para tines 90cm) was completed at a rate of 3.4 hours per hectare, compared with 1.92 hours per hectare for reduced/strip tillage using the paraplow (with only 2 para tines 50 cm apart).

Data obtained from the first trial have shown that the operation costs associated with the various tillage systems were significantly less for the reduced systems of tillage and ranged from 24%, 43% and 57% of that of the full-width system, for the no tillage, strip tillage (with Rut Repairer) and strip tillage (with harrows) respectively.

2007 trial

Measurements taken so far included soil resistance to penetration, soil dry bulk density stalk population and plant root distribution (not reported in this paper). Soil resistance to penetration was done using an Electronic Penetrometer. These measurements and those for soil dry bulk density were taken in the centre between cane rows. Soil resistance was measured down to 80 cm soil depth while that of dry bulk density at 30 cm depth.

Data of soil resistance as measured with a Penetrometer and soil dry bulk density (averaged over cane varieties and row-planting method) indicated a trend of increasing values with reduced tillage operations, except that the bulk densities for strip tillage and no tillage were similar (**Table 8**).

The results of stalk counts (**Table 9**) indicated significantly lower numbers (averaged over the four varieties) for the single rows compared with double rows only in full-width tillage, while the double rows in full-width tillage gave slightly more stalks than a similar row culture under strip tillage. Stalk population for the no tillage system was comparable with those of Full-width and strip tillage systems respectively.

The varieties D90409 and DB7869 produced the greatest number of stalks (averaged over tillage system and row-planting method), while DB75159 produced the least.

Measurement of the productivity of the equipment utilized for the different tillage operations indicated a superior work rate of 1.92 hours per hectare for strip tillage compared with 3.4 hours per hectare for full-width tillage.

CONCLUSION

Results obtained so far are consistent with those of previous studies and have indicated no adverse effects of reduced tillage on soil physical properties or cane yields while showing a reduction in operational costs for land preparation.

Row-planting method did not impact significantly on the stalk population in any tillage system.

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Table 1 Properties of common coastal soils of Guyana

Soil Series	Depth (cm)	PH	Org. C %	Particle Size Analysis Sand %	Silt %	Clay %	Atterberg Limits Liquid (% water)	Plastic (% water)	K_{sat} cm/dy
Whittaker	15 - 30	5.8	1.0	2.3	25.4	67.8	71	28	0.5
	30 - 45	6.0	1.0	2.6	25.1	59.8	76	28	
Corentyne	15 - 30	5.4	1.0	0.6	37.2	64.0	57	31	3.1
	30 - 45	5.8	0.9	0.2	31.4	63.7	61	28	
Canje	15 - 30	4.8	2.7	0.1	27.1	65.2	71	49	1.5
	30 - 45	4.8	1.7	1.6	29.8	62.8	72	45	

NOTE: ND - Not Determined

Table 2: Specifications of Rut Repairer

Description	Details
No. of discs	4
No. of para tines	4 shanks slanted at 45^0
Para tines depth of work	30 cm
No. of spring tines	12 coiled shanks
Overall width	3.0 metres
Working width	1.8 metres
Weight	1315 kg
Power requirement	120 Horse power
Productivity	0.8 ha per hour

Table 3a: Tillage systems and sequence of operations – 1st trial

Tillage system	Sequence of operation
No Tillage	1. Plant slot formation
Strip Tillage	1. Disc harrow 2. Spring tine 3. Plant slot formation
Strip Tillage	1. Paratill implement 2. Plant slot formation
Full-width Tillage	1. Paraplow 2. Tandem harrow 3. Spring tine 4. Plant slot formation

Table 3b: Tillage systems and sequence of operations – 2nd trial

Tillage system	Sequence of operation
Zero or No tillage	1. Plant slot formation
Strip tillage (in the cane row)	1. Paratill implement 2. Strip harrow 3. Plant slot formation
Strip tillage (in the inter-row)	1. Paratill implement 2. Strip harrow 3. Spring tine 4. Plant slot formation
Full-width Tillage	1. Paraplow 2. Tandem harrow 3. Spring tine 4. Plant slot formation
Full-width Tillage	1. Disc plough 2. 10 by 32 harrow 3. Spring tine 4. Plant slot formation

Table 3c: Tillage system and sequence of operations – 3rd trial

Tillage system	Implement/description	Sequence of operations
No tillage	none	Plant slot formation
Strip tillage	Paraplow with 2 para tines 50 cm apart	1. Para plough 2. Strip harrow
Full-width tillage	Paraplow with 3 para tines 90 cm apart	1. Para plough 2. Harrow 3. Spring tine

Table 4: Plant root volume (g/L) at various periods – 1st trial

Tillage system	**3 Months post-planting (0 – 60 cm)**	**Post 1R (0 – 15 cm)**
No tillage	0.55	15.7
Strip tillage with harrow	0.60	11.4
Strip tillage with Rut Repairer	0.55	14.0
Full-width tillage with paraplow	0.55	11.7

Table 5: Soil dry bulk density at various periods – 1st trial

	3 Months post-planting		**Post 1R**
Tillage system	**(0 – 30 cm)**	**(30 – 60)**	**(0 – 15)**
No tillage	1.36	1.29	0.91
Strip tillage with harrow	1.28	1.38	0.88
Strip tillage with Rut Repairer	1.25	12.6	0.86
Full-width tillage with paraplow	1.36	1.36	0.89

Table 6: Soil resistance (MPa) 9 weeks post planting – 1st trial

Tillage system	**(0 – 30 cm depth)**	**(30 – 60 cm depth)**
No tillage	0.47	0.96
Strip tillage with harrow	0.44	0.95
Strip tillage with Rut Repairer	0.39	0.81
Full-width tillage with paraplow	0.40	0.82

Table 7a: Cane yields (T/Ha) at harvest – First trial

Tillage system	Plant	1R cycle	2R cycle
No tillage	44.3	58.3	74.7
Strip tillage with harrow	42.9	38.9	75.1
Strip tillage with Rut Repairer	47.1	37.7	72.8
Full-width tillage with paraplow	45.1	63.0	74.7
Prob	0.94	0.08	0.84
% CV	22.60	27.9	5.37
Lsd 0.05	16.9	23.1	6.68

Table 7b: Cane yields (T/Ha) at harvest – Second trial

Tillage system	Plant cycle	1 R cycle
No tillage	37.6	62.9
Strip tillage with Rut Repairer in the cane row	37.6	66.8
Strip tillage with Rut Repairer in the inter-row	41.7	70.9
Full-width tillage with paraplow	40.5	65.0
Full-width tillage with disc plough	44.8	68.5
Prob	0.27	0.84
% CV	18.15	24.43
Lsd 0.05	7.5	15.1

Table 8: Measurements of soil resistance (MPa) and dry bulk density (g/cm^3) -3rd trial (9 months old)

Tillage system	Soil Resistance (MPa)	Soil dry bulk density (g/cm3)
Full-width	0.98	1.23
Strip	1.15	1.31
Zero	1.18	1.30

Table 9: Stalk population per 1 metre-row at 9 months old

	Full-width tillage		Strip tillage		No tillage	
Variety	Single row	Double row	Single row	Double row	Single row	Mean
D9017	7	16	12	13	15	12.6
DB75159	11	12	9	11	10	10.6
D9009	10	16	18	10	16	14.0
DB7869	12	14	13	16	14	13.8
Mean	10	14.5	13	13.25	13.75	