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RESEARCH ARTICLE

Comparative evaluation of sugarcane settling transplanter and deep furrow sugarcane sett cutter planter

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Abstract

Sugarcane planting is a labor-intensive, time-consuming and tedious process done with standard tools and equipment, which increases operating costs and reduces growers' net profits. A study was undertaken to compare the performance of two types of sugarcane planters (CIAE-SBI tractor operated sugarcane settling transplanter and IISR tractor operated deep furrow sugarcane sett cutter planter) at Tamil Nadu Agricultural University (TNAU) research farm. The sugarcane settling transplanter consists of mainframe, standard three point hitch, ridger, furrow opener, furrow closer, adjustable row to row spacing for 900, 1200 and 1500 mm and indexing mechanism for metering the settlings with adjustable plant to plant spacing, varying of 300, 450 and 600 mm and sugarcane sett cutter planter consists of mainframe, standard three point hitch, deep furrow opener, sett cutting mechanism, adjustable row to row spacing of 750 or 900 mm and press wheel for covering with soil. From the results, it was found that, sugarcane settling transplanter operated with forward speed of 1.7 km hr^{-1}, resulted in actual field capacity of 0.44 ha hr^{-1}, field efficiency of 80 %, fuel consumption of 3.5 L hr^{-1} and sugarcane yield of 198 t ha^{-1} and sugarcane sett cutter planter operated with forward speed of 1.25 km hr^{-1}, resulted in actual field capacity of 0.27 ha hr^{-1}, field efficiency of 75 %, fuel consumption 4.20 L hr^{-1} and sugarcane yield of 222 t ha^{-1}. The B/C ratio of settling transplanter and sett cutter planter was worked as 2.09 and 2.01 with cost saving of 74.0 % and 72.0 % respectively when compared with conventional planting. The results of this comparative study indicate that the sugarcane growth and yield attributes obtained using the two different sugarcane planters are on par with each other.

Keywords: planter; protray settling; sugarcane; transplanter; yield attributes

Introduction

India is world's second largest producer of sugarcane and it is grown over an area of 50.98 lakh hectares with an annual production of 430.50 million tonnes and productivity of 84.44 t ha^{-1} during 2021-22 (1).

Sugarcane planting is an extremely time-consuming, labor-intensive and tedious process when carried out using standard tools and equipment, ultimately leading to higher operating costs and reduced net profits for growers. Planting establishes the foundation for a crop and is important for the crop's growth and productivity. Sugarcane planting involves 337.5 man-hours and 30.6 bullock pair hours with a cost of Rs. 3987 per hectare land, while mechanical planting involves total cost Rs. 2200 with the engagement of 20 man-hours (2). Many sugarcane planters have been developed in the past by various research organisations and in most of the sugarcane planters, cylindrical or rotary cutting mechanism was used. In most of the sugarcane planters, 2 or 3 persons required to operate the planter. The cost saving was considerably high with mechanical planters as compared to the manual planting of sugarcane. Sugarcane bud/settling transplanting is the latest technique of sugarcane planting, where in the bud along with a portion of the nodal region is chipped off and planted. Sugarcane bud technologies have revealed that the seed rate (1 to 1.5 t ha^{-1}) in sugarcane bud planting was considerably less as compared with the mechanical (9 to 10 t ha^{-1}) and manual planting of sugarcane (3). A study was conducted to compare the effectiveness of three commercial models (P1, P2 and P3) of sugarcane cutter planters. The planters P1, P2 and P3 have a field capacity of 0.26, 0.28 and 0.28 ha hr^{-1} respectively, with field efficiency of 49 %, 52 % and 51 % at an effective working width of 2.25 m and a forward speed of 2.36–2.44 km hr^{-1}. With P1, P2 and P3 respectively, in the tractor's second low gear, a set length of 40.5 cm, 35.2 cm and 35.0 cm was observed, with average overlaps of 18-30 cm, 45-60 cm and 5-8 %. The required seed rate for P1, P2 and P3 was 5.8, 8.2 and 5.2 tonnes per hectare respectively (4). The process of planting sugarcane utilizes about 35 man-days per hectare and entails cutting seed setts, making furrows, placing seed setts, applying fertilizer and pesticides and covering setts with soil (5). These demands underscore the need for farmers to adopt suitable mechanical sugarcane planters that can perform all planting activities simultaneously, thereby reducing both time and labour costs.

The sugarcane set cutter planter is a flexible tool that can do five operations: opening the furrow, cutting and placing the set, applying fertilizer and fungicide and covering with soil. Similarly, the sugarcane seedling machine which employs the bud-chip method, performs four operations: opening the furrow, planting the seedlings, pouring water on them and pressing them into the soil (6).

A tractor operated sugarcane cutter planter was developed for deep furrow sugarcane planting method. It consists of deep furrow opener, sugarcane cutter blade, metering mechanism for fertilizer and insecticide, soil covering shovels and tamping roller for covering with soil. It was a mounted implement, tractor through three-point hitch system. Sugarcane cutting blade and fertilizer metering mechanism were operated by tractor PTO. The operating speed of 0.5 m s^{-1}, cutting sett were mean overlapping between 72 mm, depth of furrow opener 250 mm and effective field capacity was 0.16 ha hr^{-1}. The planter required a 25-labour hr ha^{-1}, which is 11 times less than the conventional planting method (280 labour hr ha^{-1}). This method resulted in a 63 % cost saving compared to the conventional planting method (7).

A tractor mounted two row sugarcane settling planter was developed for settlings raised from sugarcane bud chips in portrays. It consists of a mainframe that may be connected to a 35 horsepower tractor's standard three-point hitch system. Furrow openers, furrow closers, the operator's seat and the metering mechanism are installed on the main frame with the required supports. The optimal operating speed was standardized at 1.4 km hr^{-1}, with a 2.33 % missing rate. The equipment had a field capacity of 0.15 ha hr^{-1}. The biometric characteristics of the machine planted sugarcane settlings, including cane diameter, height, weight of a single cane, juice content and yield, were on par with the manually planted sugarcane settlings. At the time of harvest, the juice quality of sugarcane from machine planted settlings was comparable to sugarcane from manually planted settlings in terms of brix, CCS, sucrose and purity. According to a cost-benefit analysis, planter saves money and labour by 40 % and 85 % respectively, when compared to manually planted settlings (8).

A study was conducted to compare the effectiveness of two different sugarcane planter models. The first model was a cutter planter of the Khalsa PE-630 type produced by M/s. Punjab Engineers in Meerut, while the second was a cutter planter developed by the Indian Institute of Sugarcane Research and produced by M/s. Indian Telephone Industries in Rai Bareli. It was found that the Khalsa make planter had a field capacity of 0.20 ha/hr, a field efficiency of 87.50 %, an effective working width of 1.34 m and a forward speed of 2.54 km/hr in second low gear. Average length of sett is 32.96 cm (9).

All the cane yield attributes such as the number of canes per stool, number of internodes per cane, millable cane height and cane weight showed drastic reduction corresponding to ratoon frequency (10). Evaluated the impacts of three row spacings (100, 120 and 140 cm) on the yield and yield-related characteristics of three sugarcane varieties (F 153, G. 85–37 and G.T. 54–9). The commercial variety G.T. 54–9 exhibitted the greatest stalk thickness, stalk height and stalk weight. However, the highest cane yield per hectare and the maximum number of viable stalks per hectare were recorded in F153. The highest stalk height, the number of legitimate stalks/ ha and cane yield/ ha were obtained with a narrow row spacing of 100 cm. On the other hand, the maximum values of stalk thickness, stalk height and stalk weight were obtained at the widest row spacing 140 cm (11).

For vegetative propagation, planting materials such as setts with a single to six buds, whole canes, settling made from tissue culture or single buds in a nursery are used. Most commercial planting methods use the ridges and furrows, flatbed planting or ring pit techniques. The basic operations that go into planting sugarcane includes harvesting and cleaning up the seed cane, preparing the setts or settlings and putting the planting material into an already prepared seed bed. These operations have been through partially or entirely mechanical planting systems (12).

The traditional sugarcane planting process requires 7 to 8 tonnes of seed cane/ ha and this is the primary cause for the delayed rate of variety replacement. Sugarcane requires between 1500 and 2500 mm of water due to its lengthy growing season and high biomass production. Water for irrigation is getting harder to find over time. The issue is made worse by the variable rainfall influenced by climate change. An integrated sugarcane farming model with sugarcane single bud/bud-chip transplanting has been developed by the ICAR-Sugarcane Breeding Institute (ICAR-SBI) (13).

With due consideration of above facts and figures, a comparative performance evaluation of CIAE-SBI tractor operated sugarcane settling transplanter and IISR tractor operated deep furrow sugarcane sett cutter planter on machine parameters and yield attributes of cane was conducted at TNAU farm, Coimbatore.

Materials and Methods

Mechanized sugarcane planting methods

Two sugarcane planter was selected for this study. First one is sugarcane settling transplanter and second one is deep furrow sugarcane sett cutter planter for planting sugarcane in field. The technical details of selected planters are discussed below.

Sugarcane settling transplanter

A tractor operated two row transplanters for sugarcane settling grown in protrays has been developed by Regional Station, ICAR-Central Institute of Agricultural Engineering, Coimbatore in collaboration with ICAR-Sugarcane Breeding Institute, Coimbatore. The unit consists of mainframe for attaching to standard three point hitch arrangement with adjustable row to row spacing (900, 1200 and 1500 mm), indexing mechanism for metering the settlings with adjustable plant to plant spacing varying of 300, 450 and 600 mm, furrow openers open the furrow in which the settlings with media are to be planted with adjustable planting depth varying of 20 to 60 mm, the furrow closer closes the soil thereby giving stability to the settling plants (Fig. 1a). Two operators sit behind the planter and drop the bud chip settlings through the metering system. The furrow, opened by furrow opener is used for irrigation after the settlings have been planted for better establishment. The technical specifications of the sugarcane settling transplanter are furnished in Table 1.

Deep furrow sugarcane sett cutter planter

A two row sugarcane sett cutter planter has been developed by Indian Institute of Sugarcane Research, Lucknow for sugarcane sett planting. The planter consists of furrow opening, sett cutting, fertilizer metering, power transmission, insecticide solution application and soil covering units (Fig. 1b). In furrow opening unit, provisions were made for adjustment of row spacing between two furrow openers either at 750- or 900-mm. Whole canes are fed into the depth of furrow bottom manually and sett cutting mechanism, cut the setts and the sets are dropped into the furrow opened by the deep furrow opener. Simultaneously, fertilizer is dropped into the furrow and insecticide is sprayed into the above sett and then soil is covered by press roller. The technical specifications of the deep furrow sugarcane sett cutter planter are furnished in Table 2.

Field evaluation of the sugarcane planters

The field performance evaluation of sugarcane settling transplanter and deep furrow sugarcane sett cutter planter study was carried out at Eastern block, Tamil Nadu Agricultural University, Coimbatore to assess the machine parameters and yield attributes. The experiment area of each method was 1.5 acre. Before planting, soil bulk density and soil moisture content were measured as per the standard procedure. The planting was taken up on the same day for two methods. The sugarcane Co 86032 variety was used for both trial field. Protray nursery was developed and used with the seedling rate of 4500 seedling/acre at a spacing of 150 × 60 cm was used in the sugarcane settling transplanter method. 25 days aged seedling was used in sugarcane settling planter trial. In deep furrow sugarcane sett cutter planting method whole cane was used with the cane rate of 2.5 tone/acre at a row spacing of 150 cm.

After planting, surface drip irrigation was used for water management. Four months after planting, the germination percentage and number of tillers within a 5 feet length were measured at 15 randomly selected locations for both methods. From the fourth month onwards, up to one month before harvest, plant height and cane diameter were measured in 15 random locations and data were recorded separately for each method.

Field performance parameter

The formulae used for calculation of missing settling/sett, sett length, bud in sett, node damage, theoretical filed capacity, effective field capacity and field efficiency are as follows:

Missing settling/sett percentage

Missing settling/sett percentage was measured at different forward speed of operation and time intervals. The number of settlings/setts missing in a row was measured.

Table 1. Technical specification of the sugarcane settling transplanter

Dimensions (l × b × h), mm	2400 × 2000 × 1500
Weight (kg)	590
Power (kW)	More than 26 kW tractor
No. of rows	2 and 900, 1200, 1500 mm (Adjustable)
Plant to plant spacing in rows (mm)	300, 450, 600 (Adjustable)
Working width (mm)	1350–1800 (Adjustable)
Planting depth (mm)	20–100 (Adjustable)
Metering mechanism	Horizontal disc indexing mechanism
Furrow opener and closer	Furrow opener - Shoe type, Furrow closer - Wheel type
Drive mechanism	Two numbers of ground wheel for independent drive to two indexing mechanism with bevel gear box
Suitable for	Sugarcane single bud/bud chip settlings raised in protrays

Table 2. Technical specification of the deep furrow sugarcane sett cutter planter

Dimensions (l × b × h), mm	1900 × 1500 × 2000
Power (kW)	More than 26 kW tractor
No. of rows	2 and 750 or 900 mm (Adjustable)
Plant to plant spacing in rows	Continuous overlap planting
Planting depth (mm)	250
Furrow opener	Two mould board plough bottoms (mould board, share, share bar, landside) joined together
Soil covering	Reversible shovel attached with adjustable tyne at both ends of furrow for soil covering and rotary mild steel rollers for compressing soil cover
Drive mechanism	Tractor PTO

Fig. 1a. Field operation of tractor operated sugarcane settling transplanter.

Fig. 1b. Field operation of tractor operated deep furrow sugarcane sett cutter planter.

Sett length

Sett length of randomly selected hundred setts were measured and recorded in the field.

Number of buds in sett

The number of buds in each row were counted randomly for hundred setts and average were recorded.

Bud /settling damage

The bud/settling damage were measured for 30 m length after the planting operation and percentage damage of bud/settling were recorded.

Effective field capacity

Effective field capacity was calculated by recording the planted area during each experimental trail in each time period (14, 15).

$$\text{Effective Field Capacity } (F_c) = \frac{\text{Area covered (ha)}}{\text{Total take for covered tested area (h)}} \quad \text{(Eqn.1)}$$

Field efficiency

Field efficiency was calculated by using following formula (16, 15).

$$\text{Field efficiency} = (F_c/F_t) \text{ X } 100,\% \quad \text{(Eqn.2)}$$

Where, Ft = Theoretical field capacity

Fuel consumption

Fuel consumption was measured by top fill method

$$\text{Fuel consumption (FC)} = \frac{\text{Fuel consumption (l)}}{\text{area covered (ha)}} \quad \text{(Eqn.3)}$$

Germination and crop parameters

The observations on germination percentage, number of tillers per meter length, cane length and cane girth were recorded 120 days after planting for both the trial filed. Cane length also measured on monthly interval for randomly selected 15 canes for both planter trials.

Length of millable cane

The millable cane length (cm) was measured at the time of harvesting for both planter trials using 5 m measuring tape. The millable cane length was recorded from the randomly selected 15 canes and average values were recorded.

Diameter of sugarcane

The diameter of cane was measured at monthly intervals after 120 days of planting using a digital vernier caliper on fifteen randomly selected canes. The values were averaged and recorded. At the time of harvesting, the diameter of the cane was measured at the bottom, middle and top portions for fifteen randomly selected canes in both planter trials and the values were recorded.

Weight of cane

Weight of fifteen randomly selected millable canes was measured using a digital balance and mean values were recorded.

Results and Discussion

The field performance data recorded for both planters are presented in Table 3. During the evaluation, the sugarcane settling transplanter and the deep furrow sugarcane sett cutter planter were operated at forward speeds of 1.7 km hr^{-1} and 1.25 km hr^{-1} respectively. A uniform row-to-row spacing of 1500 mm maintained for both planting trails. A total of 11102 settlings were used in the sugarcane settling transplanter with a plant spacing of 1500 × 600 mm. A seed rate of 5488 kg ha^{-1} was used for the sugarcane sett cutter planter with a row spacing of 1525 mm and continues planting along the row. The effective field capacity of 0.44 ha hr^{-1} and 0.27 ha hr^{-1} with field efficiency of 80 % and 75 % was recorded for sugarcane settling transplanter and deep furrow sugarcane sett cutter planter respectively. The fuel consumption of 3.5 L hr^{-1} and 4.20 L hr^{-1} was measured for sugarcane settling transplanter and deep furrow sugarcane sett cutter planter respectively.

The crop parameters viz., missing settling/sett, sett length, buds per sett, bud/settling damage and overlap were presented in Table 4. The missing percentage of 1.57 and 0.80 was observed for sugarcane settling transplanter and deep furrow sugarcane sett cutter planter respectively. The average sett length, number of buds per sett and overlap percentage were recorded as 320.32 mm, 3 and 15.42 % respectively for the sugarcane sett cutter planter. A bud damage of 4.15 % was observed for the sugarcane sett cutter planter, while settling damage of 1.20% was recorded for the sugarcane settling transplanter.

The results of germination percentage and no. of tillers of planter trials are presented in Table 5. From the table, it was found that the germination percentage for both the planters was 100 % while the number of tillers was recorded as 13 and 9 for the sugarcane settling transplanter and the deep furrow sugarcane sett cutter planter respectively. The higher number of tillers observed in the case of the settling transplanter may be attributed to the use of single healthy settlings and wider plant-to-plant spacing.

The results of the month-wise average sugarcane length are presented in Table 6. From Fig. 2, it was observed that the average sugarcane length was 13 cm higher in the deep furrow sugarcane sett cutter planter compared to the settling transplanter.

Table 3. Field performance data of sugarcane planters

Sl. No.	Parameters	Sugarcane settling transplanter	Deep furrow sugarcane sett cutter planter
1.	Forward speed (km hr^{-1})	1.7	1.25
2.	Row to row spacing (mm)	1500	1500
3.	Number of seedlings/ ha	11102	-
4.	Seed rate (kg ha^{-1})	-	5488
5.	Effective field capacity (ha hr^{-1})	0.44	0.27
6.	Field efficiency (%)	80	75
7.	Fuel consumption L hr^{-1} & L ha^{-1}	3.5 & 10.5	4.20 & 15.20

Table 4. Crop parameters after planting operation

Sl. No.	Parameters	Sugarcane settling transplanter	Deep furrow sugarcane sett cutter planter
1.	Missing plant/sett (%)	1.57	0.80
2.	Sett length (mm)	-	320.32
3.	Number of buds per sett	-	3
4.	Bud/settling damage (%)	1.20	4.15
5.	Overlap (%)	-	15.42

Table 5. Data on sugarcane settling/sett germination

Sl. No.	Parameters	Sugarcane settling transplanter	Deep furrow sugarcane sett cutter planter
1.	No. of seedling/sett per 1 m length	2	4
2.	Germination percentage in 1 m length	100	100
3.	No. of tillers per seedling/sett	13	9
4.	No. of tillers in 1m length	25	23

The results of the month-wise average diameter of sugarcane are presented in Table 7. From Fig. 3, it was found that, the average value of the diameter of sugarcane is higher in sett cutter planter than settling planters for all the month. A similar trend was observed for both the planters.

The results of field data and yield attributes of sugarcane with two planter experiments are furnished in Table 8. The average millable cane length was recorded as 371.07 cm and 432.20 cm respectively for sugarcane settling transplanter and deep furrow sugarcane sett cutter planter. The number of millable canes per metre length was recorded as 29 and 21 for the sugarcane settling transplanter and the deep furrow sugarcane sett cutter planter respectively. The single millable cane weight was measured as 1.85 kg and 2.06 kg for both planter trails. Based on these results, it was inferred that the yield attributes were similar for both planters and on par with each other.

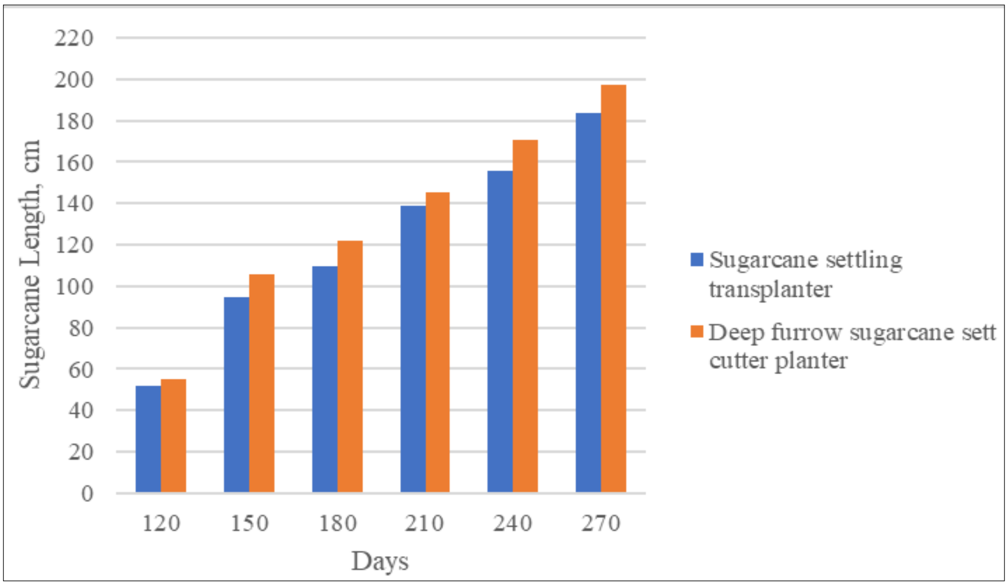

Fig. 2. Month wise average length of sugarcane.

Table 6. Average length of sugarcane plant (cm)

Sl. No.	Days	Sugarcane height	
		Sugarcane settling transplanter	Deep furrow sugarcane sett cutter planter
1.	120	52.00	55.00
2.	150	94.83	105.50
3.	180	109.67	122.07
4.	210	139.00	145.20
5.	240	155.87	170.53
6.	270	183.33	197.13

Table 7. Month wise data of average cane diameter

Sl. No.	Days	Sugarcane settling transplanter	Deep furrow sugarcane sett cutter planter
		Diameter (mm)	Diameter (mm)
1.	120	28.67	28.95
2.	150	29.62	29.99
3.	180	32.16	32.00
4.	210	30.56	30.67
5.	240	31.98	32.83
6.	270	32.62	33.31

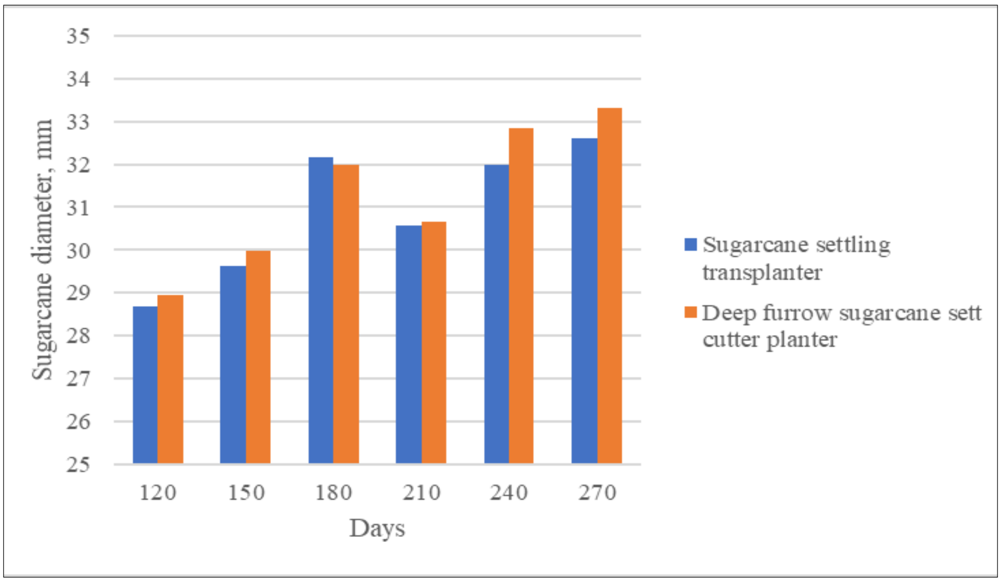

Fig. 3. Month wise average diameter of sugarcane.

Table 8. Yield data of planter trial field

Sl. No.	Parameters	Planting methods	
		Sugarcane settling transplanter	**Deep furrow sugarcane sett cutter planter**
1	Weight of 1 m length sugarcane (kg)	33.90	32.97
2	No. of millable sugarcane/ m	29.00	21.00
3	Single sugarcane weight (with leaf) (kg)	1.83	2.06
4	Single sugarcane weight (without leaf) (kg)	1.53	1.81
5	Length of millable sugarcane (with leaf) (cm)	371.07	432.20
6	Length of millable sugarcane (without leaf) (cm)	204.67	252.33
	Sugarcane diameter (mm)		
7	Bottom	29.15	31.87
	Middle	29.02	30.56
	Top	28.65	29.67
8	No. of node	19.00	22.00
	Length of node (cm)		
9	Bottom	9	11
	Middle	12	13
	Top	14	14
10	No. of leaf	9.27	10.33
11	Sugarcane yield, tonne/acre	80	90

Conclusion

The comparative performance and evaluation of the sugarcane settling transplanter and the sugarcane sett cutter planter under study were found to be satisfactorily and both can perform all operations involved in sugarcane planting. A seed rate of 5488 kg ha^{-1} was used for the sugarcane sett cutter planter with a row spacing of 1525 mm and continues plant-to-plant spacing. An effective field capacity of 0.44 ha hr^{-1} and 0.27 ha hr^{-1} with field efficiencies of 80 % and 75 %, was recorded for the sugarcane settling transplanter and the deep furrow sugarcane sett cutter planter respectively. The missing percentages were 1.57 % and 0.80 % for sugarcane settling transplanter and the deep furrow sugarcane sett cutter planter respectively. The bud damage of 4.15 % and settling damage of 1.20 % was observed for sugarcane sett cutter planter and settling transplanter respectively. The millable cane length was recorded as 371.07 cm and 432.20 cm respectively for sugarcane settling transplanter and deep furrow sugarcane sett cutter planter. The number of millable canes per meter length was recorded as 29 and 21 for sugarcane settling transplanter and deep furrow sugarcane sett cutter planter respectively. The average weight of a single millable cane was measured as 1.85 kg and 2.06 kg for the sugarcane settling transplanter and the deep furrow sugarcane sett cutter planter respectively. The sugarcane yield was recorded as 198 and 222 tonnes per hectare for sugarcane settling transplanter and the deep furrow sugarcane sett cutter planter respectively. The B/C ratio of settling transplanter and sett cutter planter was calculated as 2.09 and 2.01, with a cost saving of 74.0 % and 72.0 % respectively. It was concluded that the yield attributes were similar for both planters and on par with each other.

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Authors' contributions

All authors contributed equally to the conception, design and drafting of this research article.

Compliance with ethical standards

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

Ethical issues: None

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