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Analysis of discharge consistency and performance of a sugarcane billet planter with a side-conveyer

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Abstract

Sugarcane is an important economic crop in Okinawa Prefecture. Sugarcane billet planters have been widely used in Okinawa due to high labor costs and planting time limits. Most of them are powered by hydraulic systems to avoid ground wheel drive problems when working on high moisture heavy clay soils. This study aimed to evaluate the performance and discharge consistency of a sugarcane billet planter, YABIKU B600, operated in Minami Daito Island, Okinawa Prefecture. Ni28 cultivar seed cane was harvested and chopped to an average length of 21.8 cm using an Austoft TM2008 harvester. The field experiment was done with 3 replications. A video camera with a GPS logger was positioned over the hopper of the planter during the tests to examine the performance and planting consistency of the planter. The numbers of discharged billets in each frame were recorded to calculate the discharge index or planting rate. Moreover, the speed, GPS position and time of each activity were collected to obtain the field capacity and field efficiency of the planter. The results showed that the average ground speed of the planter was 0.97 m/s. The field capacity was 0.24 ha/hr with a field efficiency of 45.66%. The average discharge index was 7.2 billet/m. The precision index averaged 24.63% with a discharge index range of 8-10 billet/m.

Keywords: Discharge index, Precision index, Field capacity, Field efficiency, Sugarcane planter

1. Introduction

Sugarcane is a major crop in southern Japan, particularly in Okinawa Prefecture, where about 50 percent of all cultivated land area and more than 70 percent of farmers are engaged in it. Sugarcane is regarded as indispensable to the area because of the economic benefits it provides to the rural society, particularly in the smaller islands, as well as because of its tolerance to typhoons and drought [1].

Most of the sugarcane cultivation process has been based on mechanization to decrease production costs and increase the yield of the sugarcane. The farmers who did not have their own machines have contracted farm mechanization companies to perform important work such as soil preparation, planting and harvesting. The planting process is one of the most important processes since it will affect the production yield of the planted cane and ratoon cane [2]. The sugarcane billet planter is widely used in Okinawa as this type of planter can use seed cane harvested by sugarcane combined harvester, which requires labor and incurs lower harvesting costs [3]. Since the planting season in Okinawa mostly coincides with the period when the soil moisture is still high, the ground wheel drive planters cannot work due to high slip. Hydraulic powered billet planters have become more popular than ground wheel drive planters among local farmers and farm mechanization companies. However, the billet planters had the problem that the discharge consistency is low. Too high a discharge of sugarcane billet caused high production costs; on the other hand, too low a discharge of sugarcane billet resulted in decreased yield. In order to improve the planter and planting practice, the information about performance and discharge rate at each state of planting must be obtained and analyzed. Thus, this study aims to evaluate the performance and discharge consistency of sugarcane billet planters in Okinawa.

2. Research methodology

The field experiments were set at Minami Daito Island, Okinawa Prefecture, Japan. Seed cane of Ni28 cultivar harvested by Austoft TM2008 was used for the experiments. The average length of billets was 21.84 cm. The Yabiku B600 billet planter equipped with Iseki 100 hp tractor was tested. It consisted of a left side L shape cleated conveyer powered by hydraulic motor (Figure 1). The cleat space and conveyer width were 300 mm and 600 mm, respectively. Row distance was set at 1.5 m. During the field experiment, the video camera Contour+2, (120fps) with GPS logger (sampling rate of 1 Hz), was attached at the top of the hopper of the billet planter. The experiments were done with 3 replications. Two types of measurement and analysis were performed as follows.

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2.1 Performance of the billet planter

All of the activities of the planter were recorded by the video camera mentioned above. The billet planter started to work by traveling to the side of the loading bin, then the operator would raise the hydraulic powered bin to load the seed cane in to the planter hopper (Figure 2) and load the fertilizer. Then the planter would travel to the planting row and start planting until the hopper became empty and it was necessary to return to the loading spot again. Figure 3 shows the traveling route of the planter. The time consumed at each activity was obtained from the recorded videos. Moreover, the speed and distance of planting were recorded by GPS logger in coutour+2 cameras at frequency of 1 Hz. The row length was calculated using recorded forward speed and planting time. Thus the field capacity, field efficiency and percentage of time loss in each activity were calculated by following equation.

$$\text{Field Capacity (Ha/hr)} = A / T \quad (1)$$

Where, A = Total planting area (Ha)
T = Total time consumed (hr)

$$\text{Field Efficiency (\%)} = (Tw / T) \times 100 \quad (2)$$

Where, Tw = Planting time (hr)
T = Total time (hr)

$$L_{u\text{-}turn}\ (\%) = (Tu / T) \times 100 \quad (3)$$

Where, T_u = Time loss of U-turning in farm (hr)
T = Total time (hr)

$$L_{loading}\ (\%) = (Tu / T) \times 100 \quad (4)$$

Where, T_L = Time loss of loading seed cane and fertilizer (hr)
T = Total time (hr)

$$L_{traveling}\ (\%) = (Tu / T) \times 100 \quad (5)$$

Where, T_m = Time loss of on-farm traveling (hr)
T = Total time (hr)

2.2. Discharge consistency of the billet planter

Since the video camera was attached at the top of the billet planter (Figure 4), the discharging behavior was monitored from the full hopper until empty. The recorded file was replayed frame by frame and the numbers of discharged billets per second were counted. Then the discharge rate (billet/s) was used to calculate the discharge index (billet/m) using equation 6 [4]. To specify the discharge consistency, the precision index was calculated using equation 7 [4]. The linear speed of conveyer belt was controlled by hydraulic motor at 0.3 m/s, which is the appropriate speed referred from the former study [5].

$$\text{Discharge index (billet/m)} = n / s \quad (6)$$

Where, n = number of billets discharged (billet)
s = monitoring duration of planting (m)

$$\text{Precision index (\%)} = (Nn_{total} / N_{total}) \times 100 \quad (7)$$

Where, Nntotal = The number of accurate discharg as specified (Time)
Ntotal = The total number of discharg in each simulation (Time)

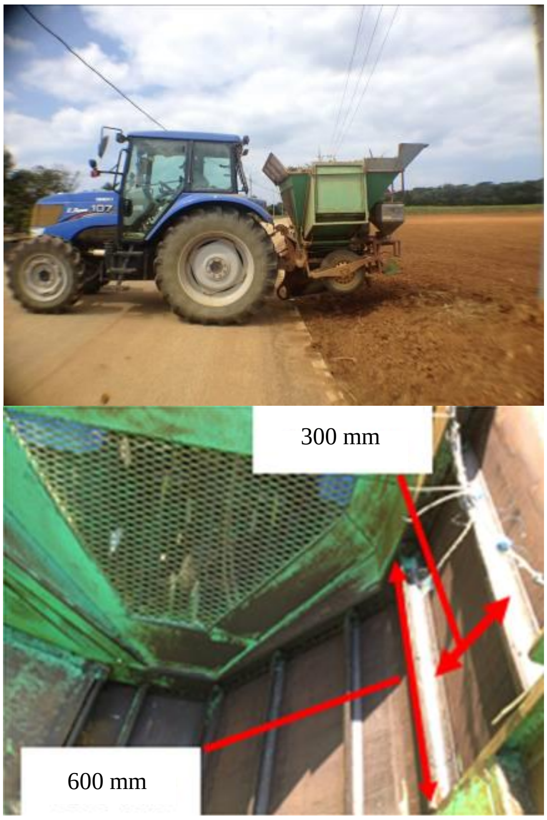
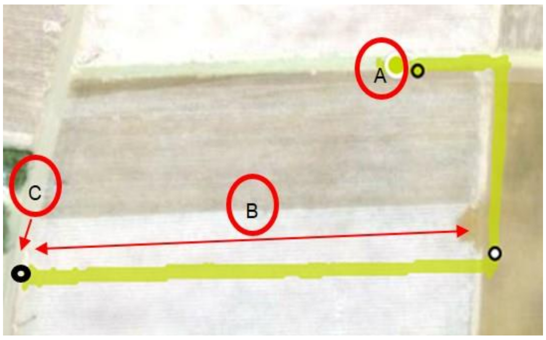


Figure 1 Yabiku B600 billet planter

Figure 2 Seed cane loading



A : Position of loading seed cane and fertilizer.
B : Planting rows.
C : U-turning position in farm.

Figure 3 Traveling route of the billet planter

To calculate the precision index, the acceptable range of the discharge index was considered. Since the average length of the billet was 21.84 cm, with reference to equation 8 Figure 5 [5] the appropriate overlap distance between each billet should be equal to 10.92 cm. Thus the appropriate discharge index should be 9 billet/m. Considering an acceptable error of ± 10%, the acceptable range of discharge index in this test was equal to 8-10 billet/m.

$$P_i = (X_2)_i - (X_1)_{(i+1)} \quad (8)$$

Where, P_i = Overlap length between billets (cm)

$(X_2)_I$ = End position of the billets i (cm)

$(X_1)_{(i+1)}$ = Beginning position of the billets i+1(cm)

Figure 4 (a) Video mounting position (b) Recorded frame

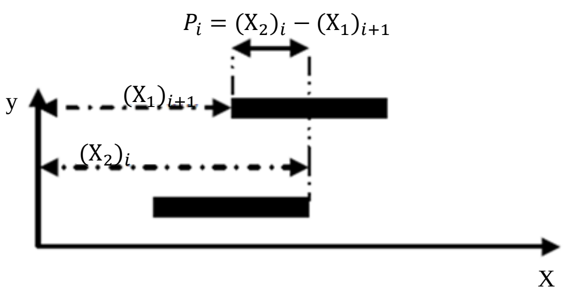


Figure 5 Overlap distance calculation [5]

3. Research Results and Discussion

3.1. Performance of the billet planter

The average row length and average row distance were 168 m and 1.5 m respectively (Table 1). Figure 6 shows the traveling speed of the billet planter during planting. The first half of the recorded speed was higher than the second half due to the tilt angle of the ground level. However, the traveling speed was steady at each turn. The average traveling speed of the planter was 0.97 m/s.

The field capacity of the billet planter was 0.24 ha/hr. The field efficiency was calculated based on the time efficiency and equal to 45.66%. The activities during the operation were examined and divided in to 4 kinds of time loss activities; loading seed cane, loading fertilizer, traveling on the farm, and making u-turns on the farm (Figure 7). The greatest time loss was caused by traveling on farm because the loading spot was far from the planting rows. Loading seed cane by this hydraulic powered bin can be done quickly, however, due to its large size and low mobility, this resulted in time lost on traveling instead.

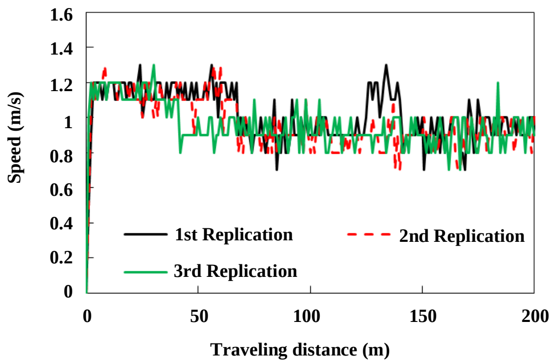


Figure 6 The traveling speed of the billet planter during planting

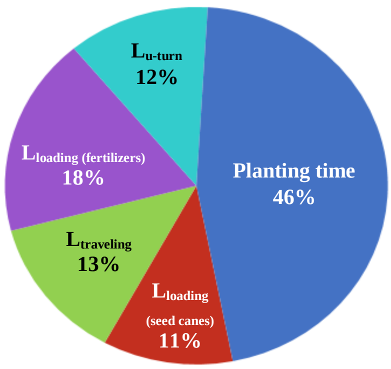


Figure 7 Time variation of sugarcane planting activities

Table 1 Results performance of the billet planter

Measurement list	Measured value
Average speed in farm	0.97 ± 0.04 m/s
Row space	1.50 m
Average row length	168.09 ± 10.6 m
Field capacity	0.24 ± 0.02 ha/hr
Field efficiency	45.66± 4.99 %

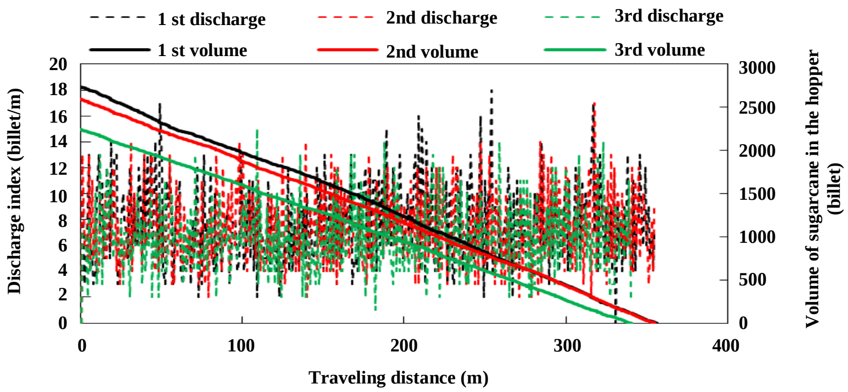


Figure 8 The discharge index during planting

3.2. Discharge consistency of the billet planter

Figure 8 shows the discharge index during the planting in 3 replications. The discharge index mostly fluctuated between 6-10 billet/m. The average discharge index was 7.2 billet/m. The L shape of the conveyer made the overflow of sugarcane billet fall back into the hopper, so that the planting rate was quite steady after the quantity of billets in the hopper became low.

The frequency polygon of the discharge index was used to analyze the consistency of planting (Figure 9). A high frequency of discharge was observed at 4-6 billet/m, which was lower than the appropriate range of 8-10 billet/m.

Considering the appropriate discharge range, the precision index at the discharge index of 8, 9 and 10 billet/m were 7.36%, 8.54% and 8.73% respectively (Table 2).

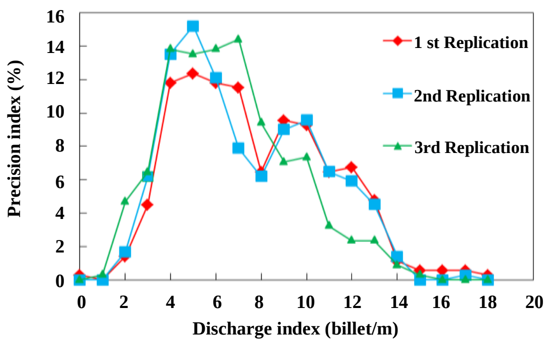


Figure 9 The frequency polygon of discharge index

Table 2 Results performance of the billet planter

Discharging index (billet/m)	Precision index (%)
8	7.36
9	8.54
10	8.73
total	24.63

The total precision index averaged from the 3 replications was 24.63%. This referred to the average discharge rate of 7.2 billet/m. The accuracy of planting can be raised by increasing the linear conveyor speed or decreasing the traveling speed by approximately 25%.

4. Conclusion

The performance and discharge consistency of the billet planter was evaluated through the field experiment in Minami Daito Island, Okinawa Prefecture, Japan. The average traveling speed of the planter was 0.97 m/s. The field capacity and field efficiency were 0.24 Ha/hr and 45.66% respectively. The greatest time loss was caused by traveling long distances to the cane loading spot, as the loading bin was large and had low mobility. The average discharge index was 7.2 billet/m. The precision index of the appropriate range of 8-10 billet/m was 24.63%. The linear conveyer speed should be increased or the traveling speed should be decreased by 25% to raise the planting accuracy.

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