DEVELOPMENT OF SELF-PROPELLED TWO-ROW BILLEt PLANTER

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ABSTRACT

In recent years, because of serious labor shortages and high labor costs in Taiwan for planting sugarcane, mechanical planting has become more important. The objective of this project was to develop a self-propelled two-row billet planter to receive, transport and plant the seed cane, till the soil in the furrow bottom, and cover the seed cane with loose soil. Results showed that the average planting rate of the planter was 8.5 t/ha at a row width of 150 cm. Seed distribution in the furrow was uniform with a germination rate of 89%. The effective field capacity was 9 ha/day, which is nine times that obtained by manual planting, thus making the planter time-and cost-efficient.

Keywords: Self-propelled, two-row planter, billet seed cane, effective field capacity.

INTRODUCTION

Planting of sugarcane in Taiwan Sugar Corporation fields was traditionally done manually. The field efficiency of manual planting is so low that excluding harvesting and transport of seed cane, planting one hectare required four workers per day. In recent years, due to the rapid development of industry, services, and trading, young people are moving to the cities while the old living in the villages are unable to work, thus causing serious labor shortages. Because of this and high labor costs, cultivating operations were delayed thereby resulting in major sugarcane production management problems.

Automatic control systems, consisting of a photoelectric switch and relay logic control circuits have been applied previously in industrial and agricultural devices (Li 1992). A power hydraulic system has also been considered important to actuate agricultural machines because of its high power and relatively compact size (Sullivan 1980). The research reported in this paper used the principles and technologies of material metering (Kepner et al 1973), constant-speed conveyance, and delivery (Henderson & Perry 1976), and rolling and sliding action (Higdon et al 1976) to favorably place the seed cane in the furrow, to monitor the seed cane conditions at the outlet of each discharge trough, and to efficiently actuate the functional components. Once the mechanical planter is used for all TSC fields with a total area of 30,000 ha it will save a considerable amount of planting cost every year.

MATERIALS AND METHODS

1. Planter design and materials used

An engine of 120kW and a chassis assembly originating from a local transporter were used for the planter. The functional components of a planter were combined with the engine and chassis to create a self-propelled two-row billet sugarcane planter. Its functional components consist mainly of a cane bin, seed cane conveyor, metered cane conveyor, seed discharge trough, seed-discharge monitoring device, subsoilers to till the furrow.
bottom, and a soil-covering device. Because the billet planter is neither tractor-mounted nor tractor-pulled, but is self-propelled, maneuverability is improved. It receives transports and plants the seed cane, tills the soil of the furrow bottom, and covers the seed cane with loose soil. Ridge-forming and fertilizer application is carried out by another tractor without affecting the planting benefit of the planter.

The overall length, width, and height of the planter are 530, 220, and 310 cm, respectively. Its total weight is 10.8 tons including a tare weight of 6.8 tons and a payload of 4.0 tons. A counterweight of 400 kg, which is considered part of the tare weight, is separately placed at the front end of the planter, beside the hydraulic reservoir, in order to steady the planter’s operation in the field. The layout of the planter is shown in Fig.1. The planter was designed to be able to follow beside a green cane harvester so as to receive the billet seed cane discharged from the harvester.

Figure 1. Layout of the self-propelled two-row billet planter

1. cane bin
2. metering bin
3. cane bin conveyor
4. metering bin conveyor (including device for repelling excessive seed cane)
5. discharge trough
6. 7 subsoilers
8. soil-covering kit
9. 10 counterweight
11. hydraulic reservoir
12. device for monitoring seed cane moving conditions at the outlet of the discharge trough
The cane bin is strong enough to accept 4 tons of seed cane. Its front plate is supported and can be moved forward and backward about an axis by a hydraulic cylinder to facilitate delivery of the seed cane in the cane bin to different flights of a chain conveyor. The chain conveyor, with 32 O-shaped flights attached to the chain side plates, is mounted at an inclination in the cane bin at its lower end to the bin bottom and its upper end attached to top of the rear plate of the cane bin. The shaft of the chain conveyor can be easily actuated by two hydraulic motors which are connected in parallel, providing much higher torque (Huang 1986).

A seed cane metering bin located behind the cane bin consists of 40 seed-metering receptacles which are properly arranged and attached to another chain conveyor. Each receptacle for loading and metering the seed cane is 45 cm long, with a flat bottom and two short, inclined edges. In addition, the metering bin is equipped with a seed cane repelling mechanism positioned near the drive shaft to push the excess seed cane in the seed receptacles back to the lower position of the metering bin. Design of the repelling device is based on the principle of eccentric motion. The maximum capacity of the metering bin is 300 kg, but the desirable weight of the seed is about 200 kg. A discharge trough is positioned at the rear of the metering bin, receiving the seed cane discharged from the metering receptacles. First, the seed cane rolls downward and transversely to the trough centerline at the upper end of the discharge trough. It then turns 90° to slide down the middle of the trough. This is due to the center of gravity of the seed billets not being centered. Finally the billets slide out of the outlet of the discharge trough to the furrow. The relative positions of the cane bin, metering bin and discharge trough are arranged so that favorable seed cane flow can be expected.

A set of small subsoilers which are mounted in front of the discharge troughs is used to till the soil to a depth of 12 cm below the furrow-bottom surface before the seed cane drops in to the furrow. The operating position of each subsoiler is controlled by a hydraulic cylinder and a set of rigid matching plates. Figure 2 shows the control for the subsoiler and its location relative to the discharge trough. The soil-covering device, consisting of two chopper disks with supporting rods for each row, is located behind the discharge trough. It is also hydraulically lowered and lifted when necessary.

Figure 2. The control for the subsoiler and its location related to the discharge trough

1. hydraulic cylinder 2. subsoiler 3. matching plate 4. frame of the planter 5. discharge trough
Besides the driver, an operator sitting on a strong and safe platform is needed to operate the hydraulic control valves and observe seed cane flow and distribution in the furrow. A hydraulic system is designed to power all the functional components and make the hydraulic motors or cylinders produce optimum torque or force. A tandem pump, which is properly sized for the hydraulic system, supplies hydraulic oil to two subsystems to actuate motors and cylinders. The schematic of the hydraulic system is shown in Fig.3.

Figure 3. Schematic of the hydraulic system

1-2 cylinders for subsoilers
3- cylinder for rear end plate of the cane bin
4-5 motors for cane bin conveyor
6-7 cylinders for soil-covering kit
8-9 motors for metering bin conveyor
A relay logic control system is designed to monitor the seed cane movement at the outlet of the discharge trough. Each unit, on which three photoelectric switches are mounted, is positioned not far from the outlet of each discharge trough. The logic control system comprises a photoelectric switch, main switch, reset switch, relay, timer, and buzzer. The buzzer will not sound when the seed cane passes properly through the discharge outlet, but will sound in case the outlet of the discharge trough is blocked by the seed cane or if no seed cane passes through the discharge outlet due to the operator’s negligence. The layout of the relay logic control system is shown in Fig. 4.

![Figure 4](image)

Figure 4. Layout of the logic control circuit for monitoring seed cane movement at the outlet of the discharge trough (A) mechanical device (B) control circuit

1. frame
2. supporting rod
21. bolt
22. nut
23. hanger of the planter
24. bracket for photoelectric switch
3. discharge trough
4. seed cane
5. electric supply
51. starting button
52. indicator lamp
53. photoelectric switch M2. relay
54. reset button M1. relay
55. N.O. contact of M1
56. N.O. contact of M2
57. N.O. contact of M1
58. N.C. contact of M2
59. N.O. contact of T1
60. N.O. contact of M3
61. N.O. contact of M1
62. N.O. contact of M2
63. N.O. contact of T2
64. N.O. contact of M4
65. N.O. contact of M1
66. N.O. contact of T2
67. buzzer
68. BZ1. buzzer
69. BZ2. buzzer
70. BZ3. buzzer
71. BZ4. buzzer
2. Experimental methods

Testing of no-load and operating pressure of each hydraulic subsystem used for actuating the functional components must be done so as to determine specific and total power required. The whole cane flow from cane bin to discharge trough has to be carefully observed during both laboratory and field tests. In the laboratory, a simulation for testing functions of the relay logic control system is required before it is operated in the field. When the cane flow is favorable and the desired results are obtained during field tests, the forward speed of the planter and rotational speed of the driving sprocket in the metering bin must be carefully recorded. The effective field capacity of the billet planter must be measured and calculated in order to ascertain how superior it is to manual planting.

RESULTS AND DISCUSSION

In the laboratory under no-load conditions, the hydraulic pressures to actuate the chain conveyor in the cane bin and chain conveyor in the metering bin were 2.45 and 1.47 MPa, respectively, while those to power the other functional components were only from 0.49 to 1.45 MPa. An operation test of the hydraulic system in the laboratory was normal. During field tests the hydraulic pressure required to drive the conveyor for delivering the seed cane at a loading weight of 3,500 kg was 9.8 MPa, and it became gradually lower with decreasing seed cane in the cane bin. The set pressure of the relief valve was 17.2 MPa, so the work pressure of 9.8 MPa was relatively low and safe, assuring an efficient hydraulic system.

A controlled weight of approximate 200 kg of cane billets was first delivered from the cane bin of the planter to the metering bin when the planter was ready for testing. This amount was maintained between 50 kg and 200 kg by a hydraulic control. Lower and upper limits were clearly marked on the side plate of the metering bin. The pressure to drive the chain conveyor with metering receptacles with 200 kg of cane billets in the metering bin was only 1.96 MPa, thus consuming little power. Tests in the laboratory and in the field for evaluating the relay logic control system were conducted and showed excellent response. A d.c. current of 2.6 amps was needed to actuate the logic system, drawing only 0.03 w.

Results showed that when the planter was operated in the field with a forward speed of 8 km/h and a rotational speed of 21 rpm for the drive shaft of the chain conveyor in the metering bin, the seed cane flow from cane bin, through the metering bin, and finally to the discharge trough was very favorable. Moreover, there was no seed cane blockage at the outlet of the discharge trough during all the field tests. There was an average of 7.5 billets of seed cane per meter distributed in the furrow. The planting rate was 8.5 t/ha at a row width of 150 cm and the seed cane distribution in the furrow was uniform (Fig. 5). The billet length was about 32 cm, and the percentage by weight of green and dry leaves mixed in the seed cane was 3.5%.

The seed cane was dropped on soil loosened to a depth of 12 cm in the furrow bottom. The depth of till was set somewhat shallow, primarily in consideration of the traction force required by the planter. However, for new planting fields tillage was to a depth of 50 cm, so there was little soil compaction during planting. It was also observed that the chopper disks properly cut the ridge side and covered the seed cane with loose soil.

The germination rate was 89%, and the effective field capacity of the planter was 9 ha/day, which was based on 8 working hours per day. The distance between harvesting and planting areas was 3 km and the planter forward speed on the road was 40 km/h. In Taiwan the labor requirements per hectare for placing the seed cane in the furrow are 4 man-days. Therefore, the effective field capacity of the planter is nine times as much as manual planting. Besides, a planting rate of 8.5 t/ha corresponds to the planting standards of TSC for a row spacing of 150 cm. The planter moved steadily both on the road and in the field, assuring high maneuverability.

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Planting cost and other economical effects of the planter need to be analyzed to illustrate its planting benefits.

1. System requirements for mechanical planting
   (1) One green cane harvester and two self-propelled two-row billet planters.
   (2) Effective field capacity of each planter is 9 ha/day, so 18 ha/day is obtained by two planters. The planting rate is 8.5 t/ha, and the amount of the seed cane per day required for planting is 153 tons.
   (3) Effective field capacity of the green cane harvester is 30 t/hr, so that time required for harvesting the seed cane is 5.1 h.

2. Cost analysis of the mechanical planting system:
   (1) Harvesting
       (US $ 114.30/h)(5.1h)(1)
       = US $ 32.40/ha
       18ha
   (2) Transporting and planting
       (US $ 21.40/h) (8h) (2)
       = US $ 19.10/ha
       18ha
(3) Depreciation of the planter

\[ \text{US$ 22857/8,000h} \times 8h \times 2 \]

= \text{US$ 2.50/ha}

18ha

(4) Labor

One driver and one operator are needed to operate the planter.

\[ \text{US$ 22.90/day} \times 2 \]

= \text{US$ 2.50/ha}

18ha

3. Economical effects of the mechanical planting system

(1) The calculated benefits:

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<tr>
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<tr>
<td>Soil-covering</td>
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<td>-25.7</td>
</tr>
<tr>
<td>Depreciation of the planter</td>
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<td></td>
<td>+2.50</td>
</tr>
<tr>
<td>Driver and operator</td>
<td>2.50</td>
<td></td>
<td>+2.50</td>
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<tr>
<td>Summation</td>
<td>219.60</td>
<td>77.50</td>
<td>-142.10</td>
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</table>

The cost of manual planting, handled is US$ 219.60/ha, whereas that of the mechanical planting system will only be US$ 77.50/ha, thus saving US$ 142.10/ha. If the mechanical planting system could be applied in all the new planting fields with an area of 30,000 ha owned by TSC, it will save US$ 4 257 140 every year.

(2) The uncalculated benefits:

a. Facilitating the subsequent cultivating operations.

b. Relieving serious labor shortages resulting from the rapid development of industry, services, and trade in Taiwan.
CONCLUSIONS

1. When the self-propelled two-row billet planter operated in the field at a speed of 8km/h, the effective field capacity obtained was 9ha/day. Results also showed that the planting rate was 8.5t/ha, and the seed cane distribution in the furrow was uniform.

2. Cost per hectare of the mechanical planting system is US $ 77.50, while that of manual planting is US $ 219.60, thereby saving US $ 142.10 per hectare.

3. Suggestions have been made to use one set of the mechanical system for completion of planting five hundred hectares of seed cane in the near future.

REFERENCES


DESARROLLO DE UNA SEMBRADORA AUTOPROPULZADA PARA DOS SURCOS

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RESUMEN

EnTaiwan durante los últimos años, la siembra mecanizada de la caña se ha vuelto muy importante a causa de la escasez y alto costo de la mano de obra. El objetivo de este proyecto consistió en desarrollar una sembradora de trozos, autopropulsada, para la siembra de dos surcos que reciba, transporte, afloje el suelo en el fondo del surco, siembre y tape la caña con suelo suelto. El rendimiento obtenido con esta máquina es de 8.5 t/ha en surcos espaciados a 150 cm. La distribución de la semilla en el surco fue muy uniforme con una germinación del 89%. La capacidad efectiva de campo fue de 9 ha/día, la cual es nueve veces superior a la obtenida con la siembra manual. Esta máquina es muy efectiva en cuante al ahorrar el tiempo y dinero.
DÉVELOPPEMENT D'UNE PLANTEUSE DOUBLE RANG, AUTOMOTRICE

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RÉSUMÉ

La plantation mécanique est devenu, ces dernières années, très importante à Taiwan du fait du manque de main d'œuvre et de son prix élevé. L'objectif de ce projet était de développer une planteuse double rang capable de stocker, transporter et planter les boutures de canne, réaliser les sillons et recouvrir les boutures avec du sol meuble.

Les résultats ont montré qu'en moyenne, on utilisait 8,5 t/ha de boutures avec des rangées espacées de 150 cm. La répartition des boutures dans les sillons était uniforme, avec un taux de germination de 89%. Les performances au champ étaient de 9 ha/j, ce qui est 9 fois supérieur aux rendements obtenus manuellement, rendant ainsi la planteuse compétitive aussi bien d'un point de vue en temps de travail que du point de vue des coûts de plantation.

MC: Automotricité, planteuse double rang, boutures de canne fonçonnées, performance