THE INFLUENCE OF DEPTH AND METHOD OF CANE PLANTING ON STOOL TIPPING AND YIELD ON A RED FERROSOL AT BUNDABERG

By

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Abstract

CANE GROWERS are adopting minimum tillage sugarcane planting methods to reduce costs and labour and to improve soil health by reducing soil disturbance. At planting, tillage can be minimised or eliminated by direct drilling cane into a pre-formed bed, the most common way of achieving this is by using a double disc opener (DDO) planter. Sugarcane planted with a DDO planter is known to yield the same as a conventionally planted crop; however, the effect on crop morphology and ontogeny is unclear. Additionally, billets are often planted shallow with a DDO and the consequences of this are uncertain. One other issue is that the cost of DDO planters is beyond the means of many growers, so it would be prudent to know if direct drill planting can be achieved with more conventional equipment. We aimed to address these issues on a Red Ferrosol in Bundaberg, by comparing DDO planting (shallow and deep) with conventional planting. Additionally, to test a low cost method of direct drill planting, we simply removed the mouldboards from a conventional planter. A replicated trial indicated that the DDO treatments had a higher proportion of stool tipping in the plant crop but not in 1st ratoon. Importantly, we found no significant difference in the yield of the plant and 1st ratoon crops, illustrating that a conventional planter can be used to direct drill. However, in both crops the DDO-shallow treatment had a significantly lower stalk weight. These results suggest that more work needs to be carried out to determine the most effective way to use DDO planters and that the yields achieved by conventional planting can be matched by direct drill.

Introduction

The Sugar Yield Decline Joint Venture (SYDJV) elucidated a ceiling in Australian sugarcane yields, despite an improvement in the yield potential of varieties (Garside *et al*., 1997).

These authors showed that this ceiling, known as yield decline, was caused by degradation in soil health, resulting from traditional management practices. Further research showed that a new farming system, incorporating controlled traffic, minimum tillage and legume rotation crops could halt and reverse the yield decline by improving soil health.

More recent research (Garside *et al*., 2006) is showing that these principles are interdependent, and therefore if all three are adopted there will be a proportionally greater improvement.

Leading growers are striving to incorporate these principles into their farming systems and this poses many challenges. One of these is zero till planting of sugarcane into pre-formed beds, through the residues of a legume crop and the preceding cane crop.

The best way to do this is with a double disc opener (DDO) planter, an implement that creates little soil disturbance and in most circumstances will traverse the field without any build-up of crop residue (Robotham and Chappell, 2000).

For smaller growers though, the cost of a DDO planter may make this option uneconomical. However, an alternative is a conventional planter with a narrow (15–20 cm) board (planting tyne with mouldboards removed).

In many circumstances this type of planter will also direct drill without any build-up of crop residue. However, this method creates considerable soil disturbance and a wide deep furrow that needs to be filled in at a later date.

This may partially offset the potential soil health benefits of minimum tillage. Thus, the first aim of this experiment was to test if this low cost alternative was viable in comparison with DDO planting.

When planted with a DDO, billets can have a thicker layer of soil above than when conventionally planted (Robotham, 2004). However the final depth of a conventionally planted billet is usually deeper (10–15 cm), as soil is pushed into the planting drill during the 'filling in' operation. This option is not available with DDO planted cane as it is planted into a pre-formed bed. It is believed that when billets are not buried deeply there is an insufficient cover of soil to anchor the shoot roots (Berding and Hurney, 2005), thereby increasing the potential for stool tipping (failure of roots to anchor the stool to the soil). This has been shown to be the case in other grasses such as barley (Scott *et al*., 2005).

Lodging is the movement of the stalk from the vertical and can be separate from or combined with stool tipping. The reason why some varieties are more prone than others to lodging is uncertain, although evidence from Berding and Hurney (2005) and Skinner (1960) suggests that stalk morphological traits such as weight and length are not determining factors.

Rather, it is more likely that deeper rooting varieties are less likely to lodge, as shown by in sugarcane (Kumar *et al*., 2002) maize (Ennos *et al*., 1993) and wheat (Crook and Ennos, 1993).

It is known that stool tipping and lodging reduces yield (Magarey and Soper, 1992; Singh *et al*., 2002), so conventional growers try to avoid these problems by burying billets deep (12–15 cm) prior to closure of the crop canopy. This also protects the stool from damage during the harvesting operation. However, sometimes DDO direct drilled billets are intentionally planted shallow (5–7 cm) as there is a perception that low soil temperatures deeper in the soil will inhibit shoot development. Additionally, DDO planted billets are sometimes planted shallow as sufficient soil moisture is often closer to the surface in prepared beds.

Hurney *et al*. (2007) compared lodging between DDO and conventionally planted cane and found no difference; however, the cane growth was impaired due to unusually dry conditions. Earlier work by Broadhead *et al*. (1963) found that lodging was reduced with deeper planting, although this work was done with conventional tillage.

Apart from these studies, we could find no other data on the effect of planting method and depth on stool tipping or lodging in sugarcane. Therefore, the second aim of the experiment was to start addressing this lack of knowledge with a trial comparing direct drill, DDO planting (deep and shallow) with conventional planting on a Red Ferrosol in the Bundaberg region.

Materials and methods

The experiment was at Queensland Department of Primary Industries and Fisheries, Bundaberg Research Station (24^0 51' S, 152^0 24' E) on a Haplic, Mesotrophic, Red Ferrosol (McKenzie *et al.,* 2004) commonly known as a Kraznozem. The field had been a citrus orchard for many years before the trees were removed and burnt on site. The field was then deep ripped twice in a direction diagonal to the intended row direction and then levelled by two passes with an offset disc plough.

In February 2005, 16 plots each five rows, 20 metres long at 1.83 metre spacing were marked out in a 4 × 4 grid pattern, leaving an access lane 1.8 m wide after every 5th row. This layout allowed four replications of each of the four intended treatments for sugarcane planting. Raised beds were constructed with a bed former on the plots intended for direct drill treatments. The treatments were arranged in a Latin square design so that all treatments appeared once on each side of the field. This was intended to equalise any effects on lodging and stool tipping from wind direction. On the 24th February 2005, soybeans (var. Leichhardt) were planted in rows, so that three soybean rows straddled the future cane row. The soybeans received adequate water from a fixed sprinkler system and were kept free from weeds with residual and knockdown herbicides. The soybeans were killed with Glyphosate at early pod-fill on the 1st June 2005. At this stage, the crop canopy had closed and the plants were approximately 80 cm in height.

Prior to planting, the plots intended for conventional planting were rotary hoed to a depth of 25 cm twice, to create a fine tilth. The trial was planted to sugarcane (cv. Q188) on the 5th October 2005, using a whole stalk planter in all treatments to plant a single row spaced at 1.83 m.

For the conventional treatment, we used a planter equipped with mouldboards that created a wide furrow in the tilled soil, a single press wheel compacted the soil above the billets.

The other treatments were direct drilled through the still standing soybean crop residue, with the narrow board treatment planted by simply removing the mouldboards from the conventional planter. For the other two treatments a double disc opener (DDO) planter was used, as described by Robotham (2004). It was equipped with a single press wheel so that soil was compacted directly above the billets.

We attempted to plant the same amount of cane in each treatment but difficulties with slipping of the drive wheel resulted in some significant differences between the treatments (Figure 1). All the cane planted was treated with the fungicide Shirtan®. No fertiliser was applied in the plant crop, as soil tests indicated a satisfactory availability for each nutrient.

Three weeks after planting a temperature data logger was buried next to the billets in each treatment and set to record at half hourly intervals. When the crop was approximately 100 cm high (68 days after planting) the furrows of the conventional and narrow board treatments were filled in with a cultivator, with the final depths of the billets shown in Table 1.

Table 1—Mean depth of billets for each treatment at planting.

Treatment	Plant depth (cm)	Final plant depth after fill in (cm)
Conventional	8	13
DDO shallow	7	not filled in
DDO deep	11	not filled in
Narrow board	7	13

Surface drip irrigation was installed for each row and the crop was irrigated according to standard commercial practice. Weeds were controlled with a combination of residual and knockdown herbicides. Nitrogen (60 kg/ha), potassium (100 kg/ha) and phosphorus (20 kg/ha) fertiliser was fertigated in the 1st ratoon to ensure optimum growth.

In the two weeks after planting, the soil from 4 × 1 m sections of row in each plot was removed to expose the billets and the depth and number of viable eyes was recorded. This process was repeated (measuring depth only) after the conventional and narrow board treatments were filled in.

In both crops, a 5 m long and 2 rows wide section (18.3 m^2) was marked out in each plot. At various times during the growing season the number of living shoots was counted from these sections. These sections were hand harvested on the 4th October 2006 (plant crop) and the 10th September 2007 (1st ratoon). The cane from the sections was weighed (total biomass) and the number of stalks recorded.

To calculate the proportion of millable stalk a sub-sample of the section was weighed, and after the tops and leaves had been removed the sub sample was re-weighed, this proportion was used to calculate the mass of millable stalk from the total biomass. Six stalks from each plot were set aside and CCS determined in a small mill. The remainder of the plot was machine harvested with the rest of the field.

Stool tipping and lodging assessments, were made after two windy and significant rain events on the 1st to 3rd March 2006 (plant cane) and the 5th to 7th September 2007 (1st ratoon). For the stool tipping assessment we counted the number of stools and the number of stools tipped from 40 m of row in each plot.

Stools were deemed to have tipped if the stalks were not vertical and fresh soil disturbance was visible at the edge of the stool. For lodging, two rows from each plot were rated visually with a 1–10 rating system. A rating of one meant that 10% of stalks had moved from the vertical while a rating of 10 meant that 100% of stalks had moved from the vertical.

The GENSTAT computer program was used for data analysis. An analysis of variance (ANOVA) was used for the yield and stool tipping occurrence data, while a Friedman's ANOVA for non-parametric data was used to analyse the visual ratings of lodging.

Results and discussion

Eye counts and shoot counts

There was a significant difference in the number of eyes/m^2 at planting (Figure 1). The conventional plant had a significantly greater number of eyes/m^2 than the other treatments, while the DDO-shallow had significantly more eyes/m^2 than the DDO-deep ($P<0.05$). The reduction in eye number with the DDO-deep was caused by slowing of the chopper box, due to slipping of the drive wheel.

There was no difference in shoot counts between the narrow board and conventional treatments, showing that a wider drill has no effect on shoot development, agreeing with the data reported by Robotham (2004). Additionally, the wider drill did not affect soil temperature (Table 2) although the crop was not experiencing the cold winter temperatures associated with some plantings.

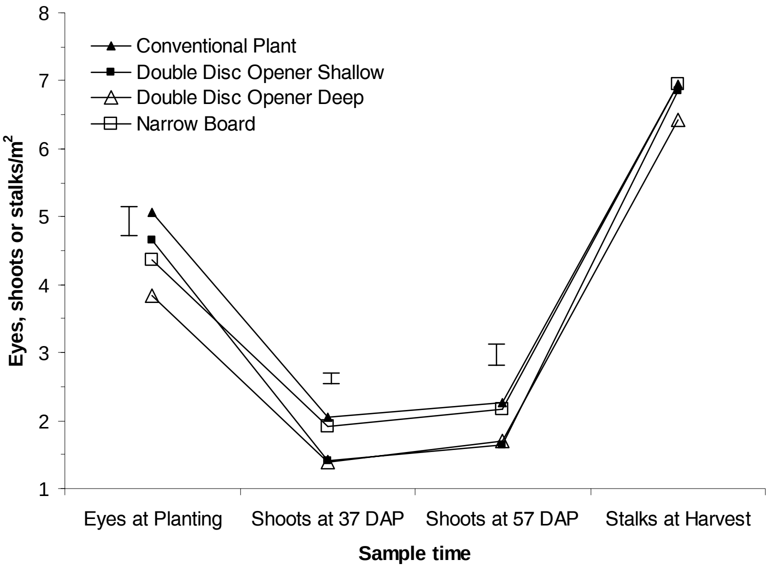

Fig. 1—Mean eye counts, shoot counts and stalk counts at planting (5th October 2005), 37 and 57 days after planting (DAP), and at harvest (4th October 2006). The floating error bars represent the least significant difference (P = 0.05) for the corresponding means.

At 37 and 57 days after planting (DAP) the DDO treatments had a significantly lower number of shoots than the narrow board and the conventional plant. This effect cannot be explained by the difference in eye counts between the treatments, as the DDO-shallow treatment had slightly more eyes than the narrow board. Consequently, the reason for the differences is unclear; the counts were made prior to the filling-in operation so the depth of soil above the DDO-shallow, conventional and narrow board treatments was similar (Table 1). Additionally it cannot be explained by a difference in soil temperature, as there was little difference between the treatments at billet depth (Table 2). One possibility is that the wide drill created in the conventional and narrow board treatments may have concentrated irrigation and rain water around the billets, thereby encouraging more rapid growth. Slow crop development after DDO planting has been observed with other grass crops such as wheat and sorghum (Du *et al*., 2004) and maize (Vamerali *et al*., 2006). However in wheat, slow early crop development has been shown to occur on some occasions (Lindwall and Anderson, 1977) and not others (Wilkins, 1983). It is therefore apparent that DDO effects on early crop vigour are probably site specific, dependent on inherent and current characteristics of soil. Despite these early differences in shoot number, there was no difference in the final shoot number at harvest and no difference in yield, suggesting that if these differences are reflected in a commercial situation they would be of little consequence.

Table 2–Soil temperature at billet depth, measured at 30 minute intervals from 27th October 2007 (22 days after planting) to the 25th November 2005 (55 days after planting)

	Conventional	Narrow Board	DDO-deep	DDO-shallow
Daily minimum	23.85	23.65	n/a	23.17
Daily maximum	32.40	31.18	n/a	32.98
Diurnal average	27.50	26.77	n/a	27.31

In first ratoon (Figure 2) there was little difference between treatments in early shoot development. Although the conventional had more shoots than the other treatments 13 days after harvest (DAH), the response was reversed by 26 DAH. After that, there appeared to be little difference for successive counts except that the DDO-deep had more shoots than the other treatments at peak shoot number (128 DAH). By 254 DAH there was no significant difference between the treatments.

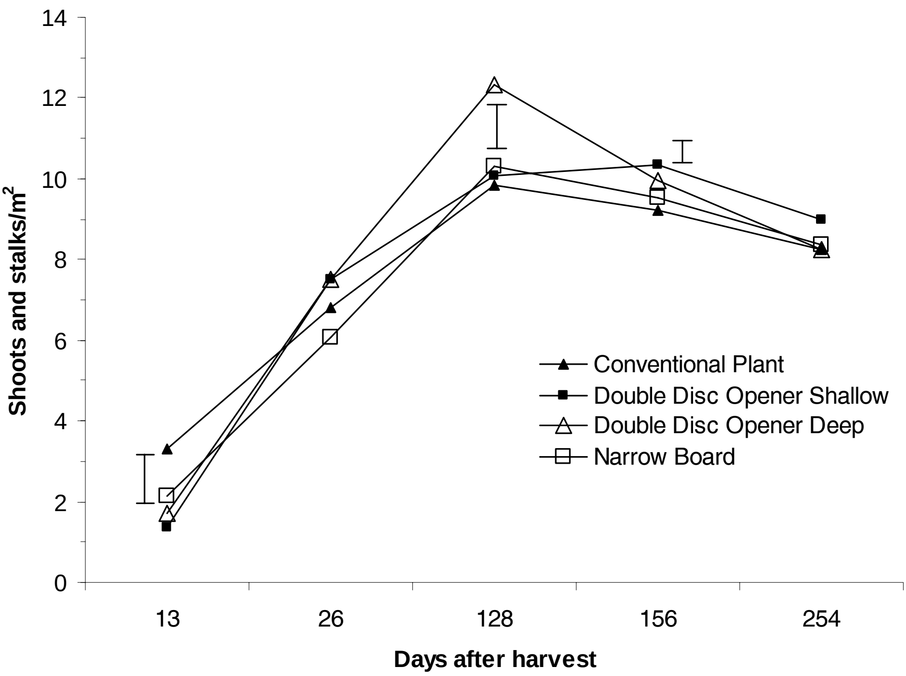

Fig. 2—Shoot and stalk counts after the plant crop harvest (4th October 2006). The floating error bars represent the least significant difference (P = 0.05) for the corresponding means.

Yield

The yield and yield components for the plant and 1st ratoon crops are shown in Table 3. In both crops the DDO-shallow treatment had a significantly lower stalk weight, but there was no significant difference between treatments in all the other yield components.

Table 3—Mean yield components in the plant and first ratoon crops.

Crop	Treatment	*Stalks/ha	Stalk weight (kg)	*CCS (%)	*Cane (t/ha)	*Sugar (t/ha)
Plant						
	Conventional	69426	1.91[a]	14.36	128.8	18.5
	Narrow board	68257	2.03[a]	14.39	126.5	18.2
	DDO shallow	68581	1.70[b]	14.40	118.9	17.1
	DDO deep	64189	2.02[a]	14.38	123.3	17.7
1st Ratoon						
	Conventional	79459	1.54[a]	13.93	119.7	16.6
	Narrow board	84459	1.54[a]	14.76	120.3	17.7
	DDO shallow	88378	1.32[b]	14.34	111.6	16.0
	DDO deep	87703	1.53[a]	14.06	124.3	17.4

[a–b] Means with the same letter in the same crop class are not significantly different ($P = 0.05$)
* No significant difference between means ($P > 0.05$)

The trend line and equation in Figure 3 refers to the conventional, narrow board and DDO deep treatments only, and suggests that for these treatments, the plant crop yield trends were correlated to planting density. The DDO shallow treatment was not consistent with this trend, indicating that for this treatment factors other than planting density were also involved in determining plant crop yield.

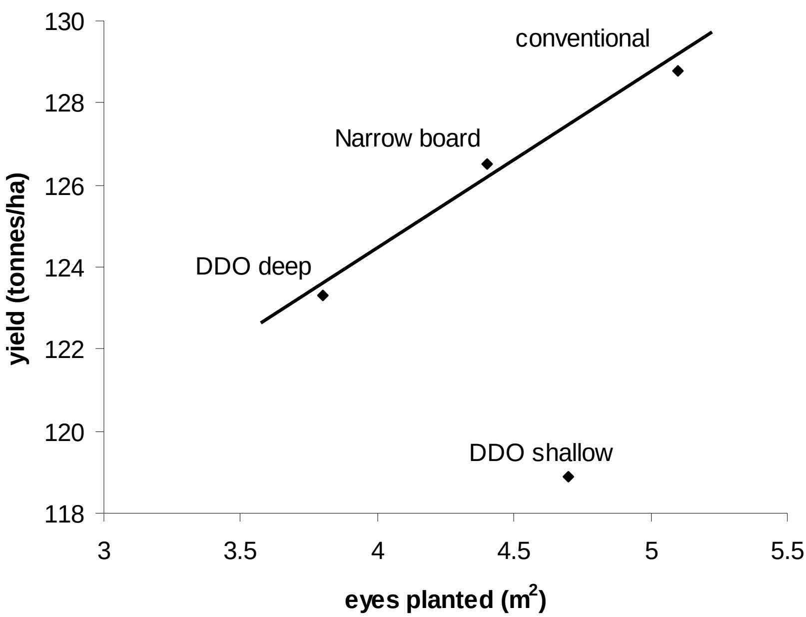

Fig. 3—The relationship between planting density and plant crop yield. The trend line and equation is for the DDO-deep, narrow board and conventional treatments only.

Although there were no significant effects of planting method on cane, or sugar yield, the DDO-shallow treatment is trending lower. In 1st ratoon it is possible that this trend was influenced by sett damage from machine harvesting. If this is the case, it will become more apparent in 2nd ratoon. Our early observations in 2nd ratoon support this assumption, as the DDO-shallow has lower shoot counts and is visibly smaller.

Stool tipping occurrence

There were two assessments of stool tipping occurrence, one made in the plant crop and one in 1st ratoon (Figure 4). In the plant crop the DDO treatments had a significantly greater proportion of tipped stools than the other treatments, regardless of planting depth. This effect may have been due to compaction and soil smearing associated with disc openers, preventing roots from exploring laterally and vertically. Smearing in the side of a drill created by a DDO is often observed, especially in moist clay soils, and has been quantified by Iqbal *et al*. (1998). Vamerali *et al*. (2006) also recorded an increase in bulk density below the drill and noted that the side smearing acted as a barrier for maize roots.

In the 1st ratoon there was no significant difference between treatments with the proportion of tipped stools being markedly less than in the plant crop, despite the overall similarity of yields (Table 3). One explanation for this could be better root anchorage, as the stool has had two years to develop rather than one. Another could be machinery compaction, as the trial was not harvested with satellite guidance. This would increase soil strength above the stool, and therefore increase the force required to move the stool, as shown with barley crowns by Scott *et al*. (2005).

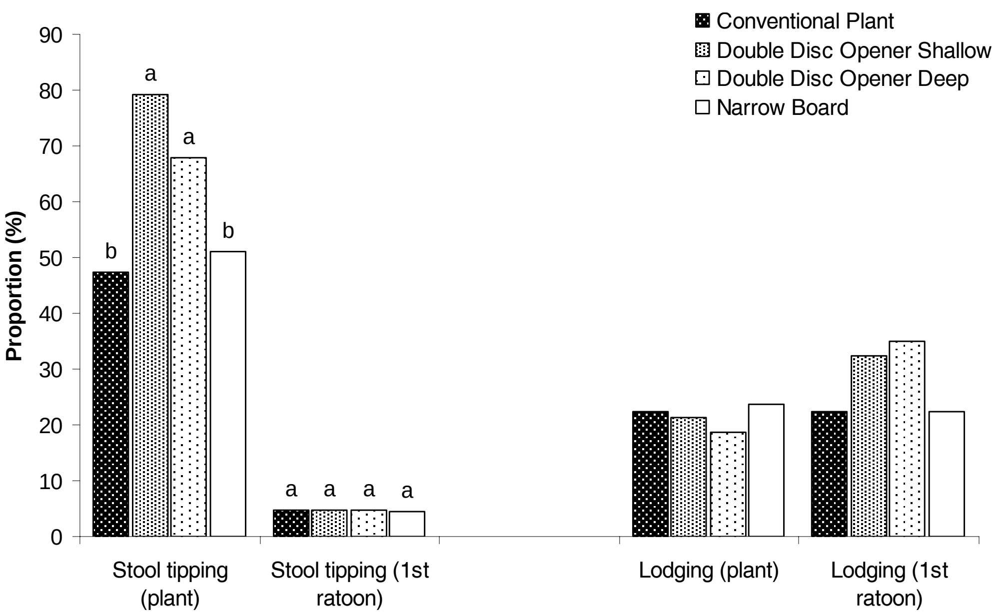

Fig. 4—Proportion of stools tipped and stalks lodged in plant and 1st ratoon. For stool tipping, columns that share the same letter, in the same crop class and same rating, are not significantly different (P = 0.05). For lodging, there was a significant difference between treatments after a Friedman's ANOVA for non-parametric data in the 1st ratoon crop.

There was no difference in lodging between treatments in the plant crop, however in 1st ratoon there was a significant difference (Friedman's P<0.05). The reason why there was no difference between treatments in stool tipping but a difference in lodging in the 1st ratoon is unclear. One theory is that roots in the DDO treatments were able to explore through the bottom of the drill but not to the side due to the smearing associated with discs in wet soil. This pattern of root development could have prevented the stool from tipping but allowed the lodging of stalks, more work is required on this issue. In both crops, there was no difference in lodging or stool tipping between the conventional, and the narrow board treatments. This suggests that the final placement of the sett (after filling-in) with the conventional and narrow board treatments may be preventing stool tipping.

Conclusions

Early shoot counts in the DDO planted treatments were lower than the conventional and narrow board treatments and more detailed work is required to discover the cause of this difference. Planting method and depth had no effect on yield in the plant crop and 1st ratoon although it is likely that in 2nd ratoon, the DDO-shallow treatment will yield significantly less than the other treatments. This is because the DDO-shallow treatment, which has had consistently lower stalk weights, may be damaged from machine harvesting. Compared to the conventional and narrow board treatments, the DDO planted treatments stool tipped more in the plant crop and had more lodging in 1st ratoon. This may be due to a different rooting pattern, caused by the smearing effect that disc openers can have on clay soils.

Implications for the industry

The stool tipping and lodging effects in this experiment were observed on one site only. Therefore they cannot be extrapolated to the whole industry and further work is required especially on clay soils where smearing caused by disc openers is frequently observed. If it continues to be a problem, changes should be made to the design of DDO planters such as increasing the angle that the discs meet or adding double inclined press wheels that can fracture the smear line.

The variety used in this experiment, and all other commercial varieties, have been bred under conventional tillage practices. Therefore their rooting pattern may not be suited to minimum tillage, controlled traffic conditions. As the adoption of minimum tillage is agronomically and economically desirable, it would be interesting to see if there is an interaction between varieties and tillage in a controlled traffic system.

Provided billets are planted deep, yields from DDO direct drill cane are the same as conventionally planted cane. Direct drill planting costs considerably less than conventional tillage planting and does not have the negative effects on soil health. Growers who cannot access a DDO planter, can still direct drill by using a narrow board planter and maintain the yields achieved with a conventional planter. However this method creates considerable soil disturbance and could off-set the soil health benefits associated with minimum tillage.

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