MANAGEMENT OF THE INTERFACE BETWEEN SUGARCANE CYCLES IN A PERMANENT BED, CONTROLLED TRAFFIC FARMING SYSTEM

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Abstract

AN EXPERIMENT was conducted at Tully to assess the effect of different methods and timing of cane trash management and methods of legume management at the end of a cane cycle on the following sugarcane crop in a permanent bed controlled traffic farming system. Six cane trash management treatments were interacted with two legume management treatments and two rates of nitrogen fertiliser. Cane trash was either burnt or incorporated two months prior to soybean planting, incorporated one month or one week prior to soybean planting or retained on the surface when the soybean was planted. An additional cane trash management treatment involved leaving the ratoon establish with no soybean being included and either spraying out the ratoon or incorporating it at the same time as the soybean was incorporated, a simulated plough-out/re-plant system. Legume management involved either incorporating soybean into the surface of the bed at physiological maturity or leaving the soybean as standing residue. The two nitrogen rates were either nil or 150 kg/ha N applied at 90 days after planting. The inclusion of soybean increased cane and sugar yields by 27%, at least in part due to better nitrogen nutrition. However, there was a response to nitrogen fertiliser following soybean, an effect not measured previously in SYDJV experiments. This was probably associated with no nitrogen fertiliser being applied to the final ratoon in the last cycle and a general running down of soil N status. There was no impact on subsequent cane yield of the different cane trash management treatments although, when trash was retained on the surface, the response to nitrogen in the subsequent cane crop was greater than where it had been incorporated. Direct planting of cane into standing soybean produced higher yields than where the soybean biomass was tilled into the soil surface. Further, direct planting of cane into surface retained cane trash produced higher yields than where the cane trash was tilled into the soil surface. It is concluded that there can be flexibility in how cane trash is managed prior to legume establishment but that the best results will be obtained if cane trash is incorporated into the bed surface between one week and one month prior to soybean planting as opposed to retaining cane trash on the surface. Conversely, there is good evidence to support direct planting of cane into legume residue. It is argued that, although it may be possible to sustain yields in a permanent bed controlled traffic system without a legume break by using high rates of nitrogen fertiliser, cost factors, long-term soil health and environmental concerns will favour inclusion of the legume break. Finally, the cane trash management treatments imposed here were all with dry sugarcane trash. More adverse effects on soybean establishment and growth may well be recorded with fresh cane trash.

Introduction

The Sugar Yield Decline Joint Venture (SYDJV) has been developing a 'new' sugarcane cropping system which incorporates the three basic principles of minimum/zero-tillage, controlled traffic, and legume breaks to the sugarcane monoculture. Component research into each of these areas has shown the benefits that can be achieved. The benefits of legume breaks and how they are managed have been demonstrated in numerous reports to this conference (Garside *et al*., 1999, 2000; Noble and Garside, 2000; Garside and Bell, 2001; Garside and Berthelsen, 2004) and elsewhere (Pankhurst *et al.*, 2005a, b, c). Likewise, the benefits of controlling traffic (Braunack, 1998; Braunack and Peatey, 1999; Braunack and Hurney, 2000; Robotham, 2003; Robotham and Garside, 2004) and reducing tillage (Braunack and McGarry, 1998; Braunack *et al.,* 1999; Garside *et al.,* 2004, 2005) have also been demonstrated. However, until now, little research has been carried out into combining these three principles into the sugarcane cropping system. Bell *et al.* (2003) reported on initial studies under irrigation in a sub-tropical environment at Bundaberg and followed up with a further paper in these proceedings (Bell *et al.,* 2006). Essentially, these experiments demonstrated that the three basic principles could be combined and result in improvements in soil health, crop productivity, and water and nutrient use efficiency. However, no research in this area has been reported from north Queensland, where soil and climatic differences compared with Bundaberg could result in different outcomes from combining these three basic principles in the cropping system.

The research reported in this paper was conducted at the BSES Tully Experiment Station (TES) between September 2003 and July 2005. It involved different types and timing of cane trash management, different management of legume residue, and different rates of nitrogen fertiliser application under tillage and direct planting in an established permanent bed, controlled traffic system. The main aim of the work was to identify whether there were likely to be any adverse effects of the different management options.

Materials and methods

The experiment was conducted on Block 33 at TES ($17^0 58' 40'$S, $145^0 55' 38.7'$E) on a medium to heavy clay soil of the Coom Series (Cannon *et al.,* 1992). The site was acquired by the SYDJV in September 2001 when it was prepared into raised 1.8 m beds and planted to cane during the initial testing of a double disc opener dual row cane planter. After harvest of the plant crop in 2002, half the area was taken out of sugarcane and planted to soybean. This area was used for the legume biomass management studies reported by Garside and Berthelsen (2004). The remaining section was ratooned in 2002–2003 without any nitrogen fertiliser prior to initiating the current experiment in September 2003.

The beds formed in September 2001 have been kept as permanent, controlled traffic beds. In September 2003, after harvest of the first ratoon and retaining a green cane trash blanket, plots were identified for imposing different cane trash management practices. These were instigated because observations suggested the management of cane trash may influence the establishment and growth of a legume break crop. The cane trash management treatments were commenced in mid-October and were based upon an expected soybean planting of mid-December. There were six 'end of cycle management' (ECM) treatments instigated, all of which were imposed while maintaining the permanent beds. The treatments were:

- **CTI 2M**–Incorporating (I) cane trash (CT) with a rotary hoe into the bed surface on October 20, 2003 approximately 2 months (2M) prior to planting soybean.

- **CTB 2M**–Burning (B) cane trash (CT) on the bed surface and cultivating with rotary hoe on October 20, 2003 approximately 2 months prior to planting soybeans.

- **CTI 1M**–Incorporating (I) cane trash (CT) with rotary hoe into the bed surface on November 20, 2003, approximately 1 month (1M) prior to planting soybean.
- **CTI 1W**–Incorporating (I) cane trash (CT) with rotary hoe into the bed surface on December 11, 2003 approximately 1 week (1W) prior to planting soybean.
- **CTR**–Directly planting soybean into retained cane trash.
- **CC**–continual cane or monoculture–leaving the second ratoon cane develop over the summer period and removing (with herbicide) at the end of soybean phase–basically a cane monoculture. The cane was periodically cut in this treatment and left on the plot surface. This simulates a plough-out/replant system.

There were three replications with two randomised plots for each of the above treatments established in each replication making a total of 12 plots per replication. Plot size was 3 x 1.8 m beds x 25 m long with each replication consisting of 36 beds. Three rows of soybean, variety Leichhardt, each 370 mm apart, were planted on each bed on December 22, 2003. Prior to planting, all beds received 28 kg/ha P as superphosphate and 80 kg/ha K as muriate of potash applied to the soil surface. The CC plots were also fertilised at this time.

All the soybean biomass was returned with no grain being harvested. At the end of the soybean phase (April 21, 2004) one plot of each of the above treatments was tilled to incorporate the soybean into the soil surface while in the other the soybean was left standing. Similarly the CC treatment had the cane trash either incorporated or left on the surface. Dual 1.8 m rows (500 mm between duals) of sugarcane variety Q187[(l)] were then planted with a double disc opener whole stalk planter on June 15, 2004. Weeds were controlled between April 21 and cane planting (June 15) by spraying all plots with a mixture of 7 L/ha Glyphosate and 1.5 L/ha Actril on two occasions (May 18 and May 28). Immediately after planting all plots were sprayed with a mixture of Dual Gold (metalochlor) at 2 L/ha and Atrazine at 2.5 L/ha.

On September 9, 86 days after planting (DAP), all 12 plots in each replication were split to 150 kg/ha N as urea slotted between the dual rows or no additional N. Consequently, final plot size was 3 beds x 12 m leaving a 1 m gap between nitrogen rate treatments. The plant crop was harvested on July 4–7, 2005.

Measurements and data collection

Soil sampling

Soil samples to measure mineral nitrogen were taken on April 20, 2004 (end of soybean phase), June 16, 2004 (cane planting), November 18, 2004 and February 8, 2005 to coincide with biomass samples, and after harvest of the plant crop on September 29, 2005. Only the data for the top 30 cm for the sample taken at cane planting is discussed here. After collection and storage in a cool room, samples were air-dried, ground, extracted with potassium chloride and analysed using an automated calorimetric method.

Soybean population and biomass accumulation

Soybeans were sampled on April 4, two weeks prior to physiological maturity, to measure biomass production by cutting 2 x 1 m^2 areas from each plot. The number of plants in each sample area was recorded along with fresh weight and a sub-sample was taken, mulched, and placed in an oven at 70^{0}C for 72 h or until a stable dry weight was recorded. Using the % dry weight in the sub-sample, the dry weight of the sample was calculated and expressed as kg/ha. The sub-sample was then ground and analysed for plant nitrogen concentration from which plant nitrogen content of the tops was calculated.

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Sugarcane

After crop establishment, permanent areas of seven m in length within the centre bed in each plot (12.6m^2) were pegged. Shoot/stalk development was monitored on these areas from 48 DAP through until 239 DAP by counting the number of shoots/stalks approximately every three weeks.

Samples were taken for biomass production on November 16, 2004 and February 7, 2005. These data are not presented here as they add little to the overall thrust of the paper.

Crop harvest was carried out by hand during the week July 4–7, 2005. Sample size was 7 m x 1.8 m (12.6 m^2) from the centre bed of each plot. All stalks were counted and weighed. Fifteen stalks were then randomly selected and divided into millable stalk and leaf and cabbage by separation between the 5th and 6th leaf below the top visible dewlap. These data were then used to calculate the percent millable stalk which was applied to each sample to calculate millable stalk yield. Four stalks were set aside from each plot to measure CCS and a sub-sample of stalks and leaf and cabbage were mulched, weighed and dried to measure dry weights.

Statistical analysis

All data were subjected to analysis of variance using the Genstat® Statistical program. The model used to assess the effect of trash management on soybean growth was a simple randomised block with 5 trash management treatments, 3 replications and 2 sample areas (one from each of the plots designated for future tillage or direct planting). The model used to analyse the cane data was a split-plot design with cane trash management x post soybean tillage as main plots and nitrogen rates as sub-plots. There were again 3 replications.

Results and discussion

Soybean biomass and nitrogen contribution

There was no significant effect of ECM on soybean biomass production, nitrogen concentration or nitrogen content (Table 1). However, there were trends for soybean biomass to be slightly less in CTR and CTI 1W. Certainly CTR significantly reduced the soybean population relative to CTB 2M and CTI 2M with the other treatments being intermediate.

Table 1—Plants/ha, dry weight (kg/ha), nitrogen concentration (%) and nitrogen content (kg/ha) for soybean variety Leichhardt grown following different cane trash management treatments.

Soybean residue management	Harvested pop. (plants/ha x 10^3)	Dry biomass (kg/ha)	% N Conc.	N content (kg/ha)
CTB 2M	252	6829	3.08	210
CTI 2 M	262	6394	3.21	205
CTI 1 M	213	6745	3.23	218
CTI 1 W	236	5870	3.13	184
CTR	206	6027	3.30	199
Mean	234	6373	3.19	203
Lsd 5%	*31*	*nsd*	*nsd*	*nsd*

These results suggest that there is sensitivity in soybean establishment due to the presence of cane trash or alternatively that the planter used was not ideally suited to plant through cane trash. Further, in this experiment, no soybeans were planted into fresh cane trash, which observations suggest is likely to have a more adverse effect on soybean establishment. Overall, the mean nitrogen input from the tops was 203 kg/ha. If another 33%

is added to allow for the root contribution (Rochester *et al.*, 1998), the total N contribution was of the order of 270 kg/ha

Soil mineral N levels at cane planting

Overall, there was little difference in soil mineral N levels at cane planting following the different ECM treatments except, as expected, there was less mineral N in the CC treatment (Figure 1).
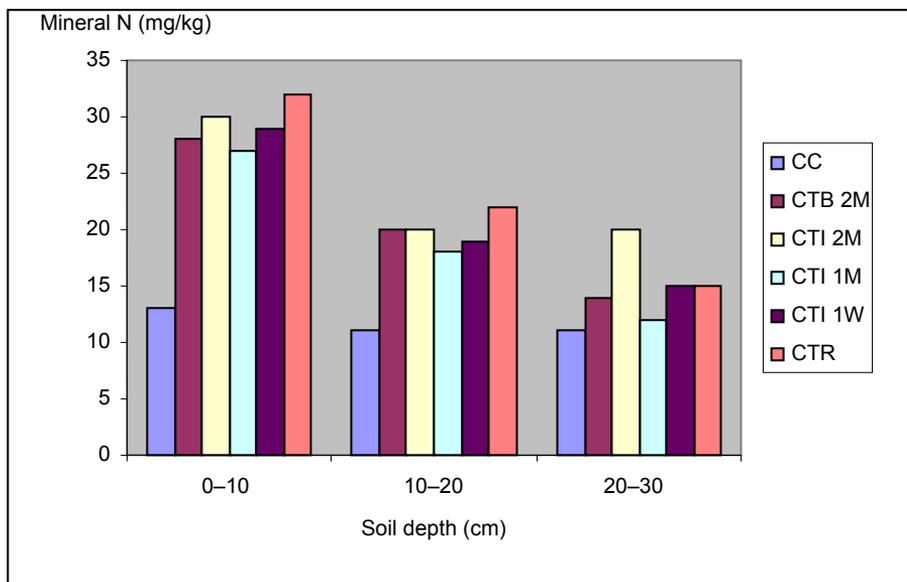

Fig. 1—Soil mineral N (mg/kg) in the top 30 cm at cane planting following a range of end of cycle management treatments.

Sugarcane shoot/stalk development

No treatment (cane trash management, tillage or nitrogen) had any significant effect on shoot/stalk numbers until after peak shoot numbers were reached at around 187 DAP. After that, there was a significant nitrogen effect with more stalks being retained where nitrogen had been applied, although the differences were quite small (data not presented). This is a similar response to that recorded by Garside *et al.* (1999) for a rotation experiment in the Burdekin where differential rates of nitrogen were applied to the following plant cane crop.

Cane yield, CCS and sugar yield

There were significant treatment effects on cane and sugar yield but no effects on CCS (Table 2). Hence, the responses in sugar yield closely followed those in cane yield. In both, there were highly significant ECM *(p=0.003*) and N *(p<0.001)* effects. However, there were other strong trends such as ECM x N *(p=0.07)*, ECM x tillage *(p=0.08)* and ECM xtillage x N *(p=0.08)*.

There was no significant difference associated with the timing of cane trash incorporation prior to planting the soybean. However, planting the soybean produced a 20 t/ha (95 t/ha vs 75 t/ha or 27%) yield increase compared with leaving cane in the system over the ECM period. The N response reflected a significant increase in yield with N application, whether soybean had been included between the cane cycles or whether cane had remained in the plots, although the response following soybean was less than with CC.

The ECM x tillage response largely reflects a trend towards poorer yields with tillage as opposed to direct planting, particularly with the CC system. However, the trend was also present when cane trash was incorporated a month or more before soybean planting (CTI 1M, CTI 2M, CTB 2M) whereas, when cane trash was incorporated a week before soybean planting (CTI 1W) or retained on the soil surface (CTR), the trend was reversed towards tillage producing higher yields than direct planting (Table 2).

Table 2—Cane yield (t/ha), CCS and sugar yield (t/ha) as affected by end of cane cycle management, replanting into tilled or non-tilled soil, and nitrogen application.

	End of cycle management	Direct planted		Till planted		Mean	
		–N	+ N	–N	+N		
Cane yield	CC	81	88	57	74	75	
	CTB 2M	95	109	83	112	100	
	CTI 2M	95	99	76	96	91	
	CTI 1M	92	106	93	94	96	
	CTI 1W	95	96	97	104	98	
	CTR	81	101	88	100	92	
	Mean	90	99	82	97	86	98
		95		90			

Signif. effects: ECM (p = 0.003, lsd 5% = 10); ECM x tillage (p=0.10, lsd 5%=16); N (p<0.001, lsd 5%=3.37); ECM x N (p=0.07, lsd 5%=11.2); ECM x tillage x N (p=0.08, lsd 5%=17.5)

	End of cycle management	Direct planted		Till planted		Mean	
CCS	CC	12.6	12.2	12.4	12.6	12.5	
	CTB 2M	11.9	12.2	12.8	12.5	12.3	
	CTI 2M	13.1	12.5	12.6	12.7	12.7	
	CTI 1M	13.2	12.6	12.4	12.6	12.7	
	CTI 1W	12.9	12.5	12.7	12.2	12.6	
	CTR	12.6	12.4	13.2	11.9	12.5	
	Mean	12.7	12.4	12.7	12.4	12.7	12.4
		12.5		12.6			

Signif. effects: Nil

	End of cycle management	Direct planted		Till planted		Mean	
Sugar yield	CC	10.0	10.8	7.1	9.4	9.3	
	CTB 2M	11.3	14.1	10.7	13.1	12.3	
	CTI 2M	12.4	12.4	9.6	12.2	11.6	
	CTI 1M	12.1	13.3	11.5	11.9	12.2	
	CTI 1W	12.3	12.0	12.4	12.7	12.3	
	CTR	10.3	12.5	11.6	11.8	11.6	
	Mean	11.4	12.5	10.5	11.8	10.9	12.2
		12.0		11.2			

Signif. effects: ECM (p=0.003, lsd 5% = 1.27); ECM x tillage (p=0.10, lsd 5%=2.18); N (p<0.001, lsd 5%= 0.50); ECM x N (p=0.10, lsd 5%=1.47); ECM x tillage x N (p=0.12, lsd5%=2.37)

The ECM x tillage x N response reflected very little yield difference between plus and minus N treatments under direct planting but substantial differences under tillage. However, the response also indicated that N could moderate the difference between tillage and direct planting for the different ECM treatments. Basically, the application of N fertiliser had the effect of improving relatively poor yields in tilled plots without N fertiliser to similar yields as direct planted plots.

The treatments responding in this way were the continual cane system (CC) and those systems where the trash had been incorporated a month or more prior to soybean planting. Again, the exceptions were when trash was incorporated a week before planting soybean or retained on the soil surface when soybean was planted (Table 2). In these instances yields were relatively stable across tillage systems (CTR) or across tillage systems and N rates (CTI 1W).

Yield components

There were very few significant effects on yield components except for N in terms of both stalk number and individual stalk weight and ECM Management in terms of individual stalk weight. The ECM Management response reflected low individual stalk weight with continual cane but no difference between treatments where soybean was a component of the system (Table 3).

Table 3—Individual stalk weight (ISW) kg as affected by end of cane cycle management, re-planting into tilled or non tilled soil, and nitrogen application.

BCC management	ISW
CC	0.93
CTB 2M	1.13
CTI 2M	1.11
CTI 1M	1.10
CTI 1W	1.13
CTR	1.10
Mean	1.08
Level of signif.	p=0.008
Lsd 5%	*0.10*

Nitrogen fertiliser increased stalk number (83 to 88 $\times 10^3$ stalks/ha–*p=0.012*) and individual stalk weight (1.04–1.12 kg–*p<0.001*).

Discussion

This experiment, like many others conducted in recent times into sugarcane farming systems by the SYDJV (Bell *et al.,* 2003, Garside *et al.,* 2004, 2005), was largely aimed at determining appropriate management of end of cycle cane trash, legume breaks, tillage and nitrogen nutrition for a permanent bed controlled traffic farming system.

A superficial assessment of the data indicates a very strong response to the application of nitrogen fertiliser and that the relatively poor yields obtained in the continual cane system were simply a reflection of inadequate nitrogen, which is supported by comparing soil mineral N levels at planting for the CC and other ECM treatments (Figure 1).

Thus, it is tempting to conclude that, had more nitrogen been applied, the yields in the CC system would have equalled those where a soybean was included. However, it is worth looking beyond these obvious outcomes if we intend to produce a more sustainable sugarcane farming system.

If tillage can be reduced without a yield penalty there are obvious efficiencies in terms of reduced tractor hours, labour and fuel, and soil physical properties. If at least part of

the nitrogen can be supplied by legumes without yield penalty, there are obvious efficiencies in terms of fertiliser costs, application costs, and fossil fuel energy to produce that fertiliser. Further, previous studies have shown positive benefits of legumes on soil health (Pankhurst *et al.,* 2005a, b, c).

If controlled traffic can be implemented without yield penalty, there will again be substantial savings in fuel, labour, and tractor hours, improved timeliness of operations, reduced stool damage and more ratoons. In addition, there are environmental positives associated with all of these initiatives.

Thus, there are likely to be substantial financial benefits without productivity increases by adopting a permanent bed controlled traffic system with inclusion of appropriate tillage and legume management. However, such a system will not be acceptable (rightly or wrongly) if it results in adverse effects on productivity.

The results of this experiment suggest that there are not likely to be productivity declines by adopting the new system. In fact, these results indicate a potential for yield increases with direct planting into undisturbed beds with standing soybean.

They also suggest that direct planting will produce higher yields than planting into tilled soil in a cane monoculture (CC) system.

This supports previous reports by Garside and Berthelsen (2004) and Bell *et al.* (2003) that there is no loss in production from managing the legume residue on the surface compared with it being incorporated.

However, the results do indicate that there is potential for poorer legume establishment and biomass production (Table 1) where the cane trash is retained on the bed surface (CTR) and the soybean is planted through the cane trash.

Further, regardless of whether the subsequent cane crop was planted into either incorporated or standing legume residue where ECM was cane trash retained on the soil surface there was a greater requirement for nitrogen fertiliser to maximise yield. However, it appears that this problem can be minimised by tilling the cane residue into the surface a week prior to planting the soybean (CTI 1W). In this instance, there was no response to nitrogen fertiliser in either the direct or tilled planted sugarcane.

This is the first of a number of experiments conducted by the SYDJV where a response to N fertiliser has been measured following a soybean crop. This probably reflect the running down of N in the previous ratoon crop but may also be associated with the rather average soybean crop that was produced.

Good soybean crops can be expected to produce between 7–8 t/ha dry biomass and contribute 250–300 kg/ha N from the tops (Garside *et al.*, 1996, 1998, 2005) whereas, in this experiment, the average soybean biomass was 6.4 t/ha (Table 1). It has been demonstrated on numerous occasions that it is important to produce a well grown fallow legume crop to maximise benefits (Garside *et al.,* 1996, 1997, 2001).

If the reason for the response to N following soybean is the former in this instance (the running down of N in the last ratoon), it suggests that some carry over of nitrogen from the previous sugarcane crop may have been contributing to cane yield in previous studies where no response to nitrogen was recorded after soybean (Garside *et al.*, 1997; Bell *et al.,* 2003). Regardless, a situation where N is run down in the last ratoon is unlikely to occur in most circumstances so this scenario can be regarded as of little practical significance. However, the yield produced when the cane trash was incorporated a week before soybean planting (CTI 1W) indicates either no response or a very small response to additional nitrogen (Table 2).

This tends to suggest that the response to nitrogen measured here may largely be associated with the early incorporation of cane trash prior to soybean establishment (CTI 1M, CTI 2M, CTB 2M), subsequent mineralisation and loss of N from the system.

Alternatively, nitrogen mineralised following early cane trash incorporation may have been taken up by the soybean, discouraging it from fixing its own nitrogen, resulting in less total N in the system. No attempt was made to separate soil and fixed N in this experiment.

Practical implications

Overall the results of this experiment and others (Garside and Berthelsen, 2004; Bell *et al*., 2003) suggest that it is possible to effectively manage cane trash and legume biomass in a permanent bed controlled traffic sugarcane farming system while having little, if any, adverse impact on productivity, but a potentially substantial increase in profitability.

First, the benefits of having legume breaks in the system have been once again demonstrated, at least in terms of nitrogen savings. However, soil health benefits have been demonstrated previously (Pankhurst *et al.,* 2005a, b, c).

Second, there is no disadvantage in leaving the legume as standing residue as opposed to incorporating it. In fact, there is an advantage.

Third, not having to incorporate the legume allows a no tillage system to be adopted between the legume and following cane crop.

Fourth, there are strong indications from this experiment that cane productivity will be enhanced by no tillage.

Further, casual observations indicate that cane trash remaining on the soil surface and no soil disturbance has a positive effect on weed control.

Fifth, there does seem to be a need to incorporate the end of cycle sugarcane trash more than one month prior to planting the legume to ensure good legume establishment and biomass production, but much closer to the planting of soybean to ensure the soybean provides maximum benefit to the following sugarcane crop. Further work is needed in this area.

Regardless, tillage appears to be necessary and this would provide the opportunity to apply and incorporate liming products, a potential problem under a zero-tillage system.

The relatively poor performance of soybean planted into retained cane trash is also a concern which needs further investigation to ascertain whether it is a real allellopathic problem or simply a machinery issue associated with the placement of soybean seed relative to cane trash.

Finally, it needs to be recognised that, in all cases, in this experiment, soybean was planted into incorporated or surface managed dry cane trash.

It is expected that more severe adverse effects may occur with the soybean if it is planted into green cane trash.

This issue requires further investigation. However, at this stage it is strongly recommended that planting legumes into green sugarcane trash be avoided.

Acknowledgements

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