IMPACT OF SUGARCANE THRIPS, *FULMEKIOLA SERRATA* (KOBUS) (THYSANOPTERA: THRIPIDAE) ON SUGARCANE YIELD IN FIELD TRIALS

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Abstract

Two field trials were conducted on the South African Sugarcane Research Institute (SASRI) research farm at Gingindlovu to study the effect of sugarcane thrips, *Fulmekiola serrata* (Kobus) (Thysanoptera: Thripidae) on various parameters relating to sugarcane yield. Stalk yield components measured were: cane (grams/stalk); sucrose (grams/stalk); Brix % dry matter; purity %; dry matter % cane; fibre % cane; Brix % cane; Pol % cane; ERC % cane. Stalk characteristics measured were: mean stalk length (cm); number of stalks per plot; and stalk diameter. Final yields were assessed as tons cane/ha and tons sucrose/ha. The experiment design allowed comparison between *F. serrata* numbers in untreated sugarcane and sugarcane treated with the insecticide, imidacloprid. *F. serrata* numbers were significantly lower in treated sugarcane. Yield reductions attributable to *F. serrata* infestations of between 18.0 and 26.8% (tons cane/ha) and between 16.2 and 24.0% (tons sucrose/ha), were measured in these trials.

Keywords: sugarcane thrips, *Fulmekiola serrata*, Thysanoptera, stalk characteristics, yield, imidacloprid

Introduction

The exotic oriental sugarcane thrips *Fulmekiola serrata* (Kobus) (Thysanoptera: Thripidae) causes serious and widespread damage to sugarcane crops in the South African industry (Leslie, 2005; Way *et al*., 2006a). It causes direct damage to the foliage by its feeding and ovipisition behaviour (Williams, 1956). Both adults and nymphs destroy the epidermal cells by piercing them with a single mandibular stylet and imbibing the liquid content through paired maxillary stylets (Kirk, 1997). Damage symptoms are malformation of young leaves and growing tips, wilting, silvering, scarring and necrotic spots that are caused on the leaf spindles and become apparent when the leaves open (Way *et al*., 2006a).

Yield loss studies for *F. serrata* are limited and not clear. In South Africa Keeping *et al*. (2008) reported a 10-12% reduction in yield from insecticide trials. Anon 2001, cited in Crop Protection Compendium (2001) showed losses of 10-15% in China, whereas Des Vignes (1987) did not detect any effect on sugarcane yield in Trinidad. In Mauritius Williams (1956) reported that the economic importance of *F. serrata*, “is normally believed to be slight.”

F. serrata persists in the South African sugarcane industry and a management strategy is being developed at the South African Sugarcane Research Institute (SASRI), with varietal resistance, insecticides, and planting date manipulation being investigated towards an integrated pest management strategy (Keeping *et al*., 2008).

In order to assess the effectiveness of any of these tactics, scientific studies are required ultimately to determine the yield loss caused by *F. serrata* to assess the cost effectiveness of any control option. This is the first attempt in South Africa to assess the impact of *F. serrata* on sugarcane yield.

Method

From October 2008 to October 2009 two simultaneous experiments were conducted in two different fields on the SASRI farm at Gingindlovu (29°02'S, 31°36'E; 47 metres above sea level). Experiment methods developed in a similar study by Goebel and Way (2003) for *Eldana saccharina* Walker (Lepidoptera: Pyralidae) were adapted for these trials.

The two fields (trials 1 and 2) were divided into three blocks of three treatments in a randomised block design. Each treatment was replicated six times per trial. These trials were purposely planted in October so that the crops were three months old in December. This is the sugarcane growth stage and period in the season when the highest number of *F. serrata* have been recorded in this country (Way *et al*., 2006b). Differences in *F. serrata* populations were likely to be at their greatest among treatments at this time, and hence any impact on yield might be more discernable.

In the trials about 147 kg nitrogen/ha was applied at planting. The crops were rainfed and harvested manually without burning. The study was conducted in plant crops rather than in ratoons because plant crops usually support higher *F. serrata* populations (Way, 2006). N27, a variety supporting high *F. serrata* populations (Way, 2006) was used as seedcane. In trial 2, the seedcane was treated against *E. saccharina* by immersing in 50°C water for 30 minutes prior to planting.

Each of the 18 plots consisted of 6 rows, 1.2 m apart and 10 m in length. The outer rows on either side of the plot represented guard rows that reduced inter-plot contamination, and these rows were not included in the trial measurements. To determine the plot size (28.8 $m^{2)}$ in these trials, row spacing was multiplied by row length multiplied by the number of rows, expressed as m^2.

Each plot received one of the following treatments: no protection (T1) in which the crop was naturally infested by feral *F. serrata*; plots partially protected with insecticides (T2) in which the aim was to reduce pest pressure; and plots fully protected with insecticides (T3) that aimed to eliminate *F. serrata*, thus providing an indication of potential yield in an undamaged crop.

A prophylactic insecticide regime was employed to manipulate *F. serrata* numbers in the plots that were treated. Imidacloprid was selected as the insecticide for use in these trials because preliminary insecticide trials showed that this insecticide is effective in reducing *F. serrata* populations in the field (Leslie and Moodley, 2009). The recommended dose, concentration and the frequency of application that are recommended in other crops (Anon, 2007) was purposely exceeded to ensure the suppression of *F. serrata* in the trial throughout the period when their numbers are typically high in sugarcane crops in South Africa (Way *et al*., 2006b).

In plots T2 and T3, SuSCon Maxi® (NuFarm, Australia: a 5% Controlled Release formulation of imidacloprid) was applied at planting during the pre-germination crop phase. This granular insecticide application was applied directly and evenly along the bottom of the planting furrow at 2 grams per metre of row (17 kg/ha) immediately after sett placement and together with the fertiliser. The furrows in the plot were closed immediately after this treatment. When the crop was from two to six months old, monthly (T2) or fortnightly (T3), foliar applications of Bandit 350sc (a.i. imidacloprid) (Arysta Lifesciences) were applied in the early morning directly on the sugarcane plant at 1.5 L/ha using a knapsack sprayer. The foliar applications were thus applied over five consecutive months from December 2008 to April 2009.

F. serrata populations were assessed by laboratory examination of 20 leaf spindles, of which five were taken 5 m apart from each of the four central rows of each plot. Each randomly selected spindle was cut with scissors immediately above the growing point of the stalk from different tillers and different stools. In the field the sub-sample of five spindles collected from each of the four rows were placed together into one plastic Zip-lock® bag (200x145 mm) and the four small bags from the plot were then placed into a larger Zip-lock® bag (330x230 mm) that was labelled with the plot number. The leaf spindle samples were stored in the laboratory in a freezer at 0°C until processing.

Leaf spindles were processed in batches of five spindles each that corresponded to each row in the plot. Processing consisted of thoroughly washing the five spindle samples in a warm soapy water solution, sieving the solution through a 45µm sieve and extracting and counting the *F. serrata* individuals caught. Way (2006) described in detail the method used in this study to process the leaf spindle samples for *F. serrata*. The number of *F. serrata* extracted in each sample was divided by five to obtain a standard unit measure consisting of numbers of *F. serrata* per spindle. Adult and nymph counts were recorded separately. *F. serrata* samples were taken every month starting when the crop was two months old in December 2008 until harvest at 12 months in October 2009.

At harvest, a digital scale mounted on a hydraulic arm fixed to a tractor was used to measure the mass of the stalks in each plot. The sugarcane stalks were weighed with trash intact. For logistical reasons, the stalks from each of the four rows in each plot were weighed separately and these values were summed to obtain the total mass of all the stalks in each plot. The plot mass (kg/m^2) was converted into tons cane/ha according to the following equation:

$$\text{Tons cane/ha} = \frac{Plot\ mass\ (kg)}{1000} * \frac{10000}{Plot\ size\ (\text{m2})}$$

$$= \text{Plot mass (kg)} * \frac{10}{Plot\ size\ (\text{m2})}$$

At harvest in October 2009, three stalks were taken from different stools in each of the central four sugarcane rows in each plot. The 12-stalk samples per plot were used to obtain measures of stalk quality characteristics and to measure the stalk parameters used to calculate the yield. The analyses of the stalks were carried out by the millroom laboratory located at Mount Edgecombe and operated by SASRI. The following parameters of the stalks were measured: cane (grams/stalk), sucrose (grams/stalk), Brix % dry matter, purity %, dry matter % cane, fibre % cane, Brix % cane, Pol % cane and ERC % cane. The yield in terms of tons sucrose per hectare was calculated using the equation:

$$\text{Tons sucrose/ha} = [(\text{Yield in tons cane/ha}) \times (\text{Pol \% cane})]$$

The insect population data were log transformed and subject to analysis of variance (ANOVA) using Genstat v.12. The post hoc test used to distinguish which samples were significantly different from each other was Fisher's least significance difference (LSD) test (5%). Yield data were subject to ANOVA and Fisher's LSD test. The correlation between the numbers of *F. serrata* recovered and the 17 stalk characteristics and calculated yield was determined. To evaluate the impact of *F. serrata* counts on yield and stalk quality parameters a correlation analysis was performed. Regression analysis (Genstat v.12) was used to further investigate the relationship between *F. serrata* counts and the yield variables of tons cane/ha and tons sucrose/ha.

In this study, yield loss was determined as the difference in yield (recorded in tons cane/ha and tons sucrose/ha) between insecticide treated plots (T2 and T3) and untreated plots (T1). Percentage yield loss was computed as the difference in yield between T1 and the insecticide treated plots divided by the yield of the insecticide treated plots multiplied by 100.

Results

In both trials varying pest numbers were shown in the different treatments. Mean *F. serrata* recoveries (adults and nymphs) recorded in the 11 months from December 2008 to October 2009 were significantly higher in T1 compared with recoveries from either T2 or T3. Mean numbers of *F. serrata* recovered over the same period from T2 and T3 were not significantly different (Table 1).

Differences in yield in terms of biomass and sucrose content were recorded in both trials in the three different treatments. Higher yields were obtained from the treated plots (both T2 and T3) compared with the yield obtained from T1 plots (Table 2). There was no significant difference in yield between T2 and T3. The difference in yields of treated and untreated plots was between 18.0 and 26.8% (tons cane/ha) and between 16.2 and 24.0% (tons sucrose/ha.). Final yield in T1 plots was lower in trial 1 (53.1 tons cane/ha) compared with trial 2 (71.5 tons cane/ha).

Table 1. The effect of treatments T1, T2 and T3 on *Fulmekiola serrata* recovered from a field trial at Gingindlovu assessed in the 11 month period from December 2008 to October 2009, expressed as mean number of *F. serrata* per spindle.

Treatment	Adult and nymph	Adult	Nymph
T1	1.032b**	0.855b	0.690b
T2	0.570a	0.462a	0.296a
T3	0.565a	0.465a	0.283a
CV%	23.6	25.0	44.2
S.E.	0.170	0.149	0.187
F crit$_{(2,10)}$ P-value	599.7 <0.001	558.6 <0.001	367.2 <0.001
LSD (5%)	0.031	0.027	0.034

T1 = natural infestation T2 = insecticide monthly T3 = insecticide fortnightly.
Data show the mean from six plots (replicates) per treatment.
**Values in the columns followed by the same letter are not significantly different at 5% level.

Table 2. Final yield of variety N27 sugarcane in naturally infested *Fulmekiola serrata* control plots (T1), and monthly (T2) and fortnightly (T3) insecticide treatment plots in field trials conducted at Gingindlovu in the 2008/2009 season. Data show the mean of six replicates/treatments (18 plots per trial).

Trial	Treatment	Mean stalk mass (kg)	Total plot stalk mass (kg)	Yield (tons cane/ha)	Sucrose (tons/ha)
1	T1	7.6a*	247.5a	53.1a	7.5a
	T2	8.5b	311.5a	66.7b	9.3b
	T3	8.6b	318.0b	68.0b	9.3b
	Loss	0.95 (12.5%)	67.25 (27.2%)	14.25 (26.8%)	1.80 (24.0%)
	CV%	7.1	2.4	2.5	4.0
	S.E.	0.58	7.04	1.57	0.34
	F crit$_{(2,10)}$ P-value	4.37 0.043	44.95 <0.001	44.00 <0.001	23.32 <0.001
	LSD (5%)	0.82	18.31	3.91	0.67
2	T1	8.2a	334.8a	71.5a	9.9a
	T2	8.8b	390.5b	83.2b	11.3b
	T3	9.4b	401.0b	85.5b	11.7b
	Loss	0.90 (11%)	60.95 (18.2%)	12.85 (18.0%)	1.60 (16.2%)
	CV%	4.3	2.2	2.1	3.6
	S.E.	0.38	8.10	1.71	0.39
	F crit$_{(2,10)}$ P-value	9.58 0.005	20.0 <0.001	20.5 <0.001	6.17 0.012
	LSD (5%)	0.63	24.93	5.24	1.17

*Values followed by the same letter in each column are not significantly different.
CV% = coefficient of variation; SE = standard error

The monthly total number of *F. serrata* individuals recovered during both trials is shown in Figure 1. *F. serrata* total counts from the six plots for each treatment were initially high in the trial period from December 2008 to March/April 2009, whereas the counts remained relatively low from May to October 2009.

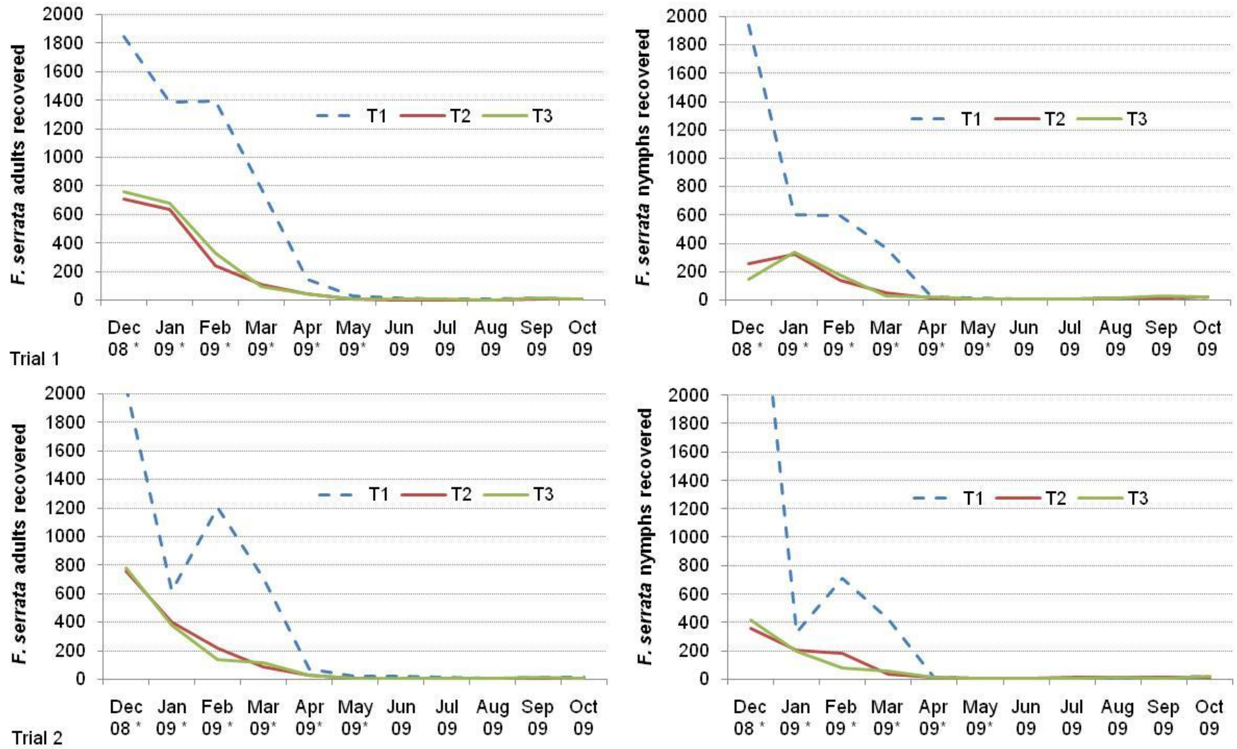


Figure 1. Numbers of *Fulmekiola serrata* (adults and nymphs counted separately) recovered in crop loss trials at Gingindlovu from December 2008 to harvest in October 2009. Data from total counts from six plots per treatment each month. Top graph left shows adults and right nymphs from trial 1 and the same for trial 2 in bottom graphs.

In these trials the greatest impact from *F. serrata* would presumably have occurred during the period (months) when the highest number of individuals was present as measured by monthly sampling. This period was during December 2008 in both trials. Figure 2 shows that the mean *F. serrata* population (total adults and nymphs recovered) was higher in trial 2 than in trial 1. There were 75.4% (trial 1) and 78.6% (trial 2) fewer *F. serrata* recovered in T2 and T3 respectively compared with the recoveries from T1. The mean *F. serrata* per spindle (±SE) in T1 plots (adult and nymph counts pooled) was 31.5±2.5 in trial 1, and the same count was 46.5±2.3 in trial 2. The maximum *F. serrata* counts recorded in this study were 58.6 and 68.8 *F. serrata* per spindle in trials 1 and 2, respectively. These figures provided an indication of the pattern and magnitude of the pressure from *F. serrata* on the sugarcane crop during these trials.

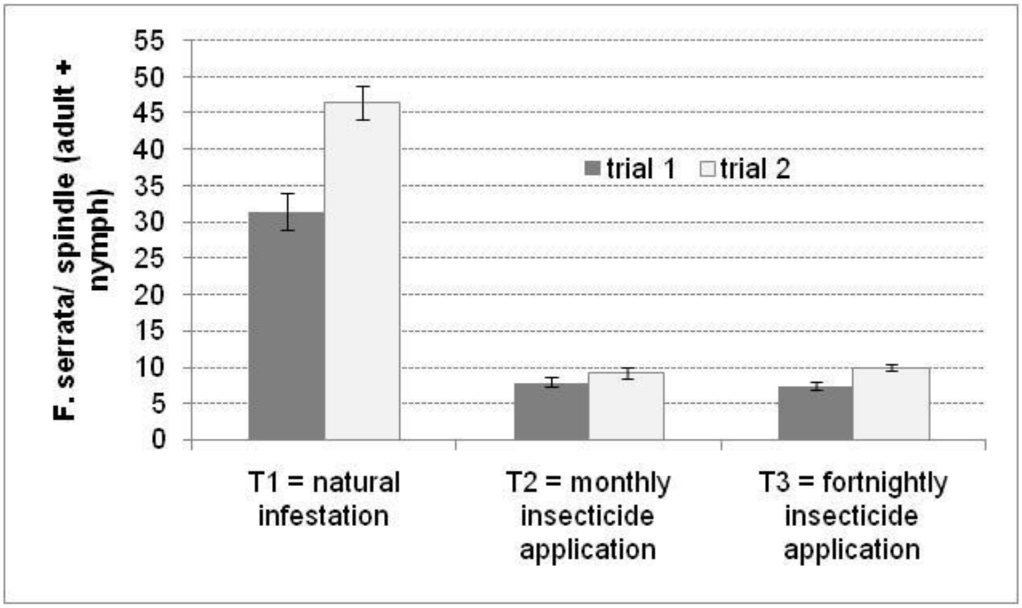


Figure 2. Effect of treatment on the mean number of *Fulmekiola serrata* per spindle (adult and nymph counts combined) measured in December 2008 when *F. serrata* populations were at their highest during these trials.
Vertical Bars = SE (standard error).

The proportion of the total number of *F. serrata* adults and nymphs recovered each month for both trials is shown in Table 3. The *F. serrata* adult/nymph (A/N) ratio was higher in T2 and also T3 compared with T1. In trial 1, for example, in December 2008 this ratio was 2.77 (A/N; 706/255) in T2 and 5.18 (A/N; 756/146) in T3 compared with 0.95 (A/N; 1845/1935) in T1.

Table 3.Total numbers of adult (A) and nymph (N) *Fulmekiola serrata* individuals recovered each month over the duration of the trials from December 2008 to October 2009 from T1, T2 and T3. Data are from six plots for each treatment with 20 spindles examined per plot, indicating the proportion of life stages in the trials.

		T1			T2			T3		
	Date	Adult (A)	Nymph (N)	A/N ratio	A	N	A/N ratio	A	N	A/N ratio
trial 1	Dec 08	1845	1935	0.95	706	255	2.77	756	146	5.18
	Jan 09	1382	602	2.30	630	323	1.95	676	335	2.02
	Feb 09	1391	594	2.34	243	142	1.71	328	171	1.92
	Mar 09	776	363	2.14	112	53	2.11	91	30	3.03
	Apr 09	145	22	6.59	43	17	2.53	46	21	2.19
	May 09	26	10	2.60	10	8	1.25	7	8	0.88
	June 09	8	6	1.33	2	11	0.18	5	5	1.00
	July 09	5	8	0.63	3	9	0.33	6	8	0.75
	Aug 09	6	15	0.40	5	17	0.29	0	16	0.00
	Sept 09	8	14	0.57	6	13	0.46	14	27	0.52
	Oct 09	4	20	0.20	9	22	0.41	7	20	0.35
Trial 2	Dec 08	2051	3526	0.58	755	355	2.13	778	416	1.87
	Jan 09	619	334	1.85	402	201	2.00	376	194	1.94
	Feb 09	1199	715	1.68	215	180	1.19	131	77	1.70
	Mar 09	704	428	1.64	86	36	2.39	111	58	1.91
	Apr 09	66	17	3.88	27	13	2.08	28	14	2.00
	May 09	21	10	2.10	8	7	1.14	5	7	0.71
	June 09	18	8	2.25	3	6	0.50	6	6	1.00
	July 09	11	10	1.10	0	12	0.00	5	9	0.56
	Aug 09	3	9	0.33	2	13	0.15	6	10	0.60
	Sept 09	9	16	0.56	4	10	0.40	8	6	1.33
	Oct 09	12	20	0.60	3	15	0.20	3	17	0.18

Table 4 shows the relationships between various stalk variable parameters and *F. serrata* numbers in the trial. The first seven parameters, namely tons cane/ha, tons sucrose/ha, total plot mass, mean stalk length, single stalk mass, stalk sucrose content, and total stalks per plot were all negatively correlated with numbers of *F. serrata* recovered. Of these, the last two were non-significant. There was no significant relationship detected between numbers of *F. serrata* recovered and the remainder of the 10 parameters investigated in this study and listed in Table 4.

The relationships between yield in terms of biomass and sucrose content for trial 1 are given in Figure 3 and for trial 2 in Figure 4. Yield (both biomass and sucrose content) was inversely correlated with *F. serrata* populations. These relationships were highly significant ($p<0.01$), except for the sucrose yield obtained in trial 2.

Table 4. The relationship between the mean numbers of *Fulmekiola serrata* recovered from October 2008 to October 2009, the stalk quality parameters measured and the yield variable at Gingindlovu. The *F. serrata d*ata from each of the 18 plots were regressed against each variable.

Parameter		Trial 1	Trial 2
		r	r
1	Tons cane/ha (biomass)	-0.86**	-0.85**
2	Tons sucrose/ha (sucrose yield)	-0.81**	-0.72 **
3	Total plot mass (kg)	-0.87**	-0.85 **
4	Mean stalk length (cm)	-0.68**	-0.78 **
5	Single stalk mass (grams/stalk)	-0.54*	-0.53 *
6	Stalk sucrose content (grams/stalk)	-0.43 ns	-0.43 ns
7	Total stalks per plot	-0.04 ns	-0.08 ns
8	Brix % dry matter	0.08 ns	-0.09 ns
9	Purity %	0.00 ns	-0.09 ns
10	Mean number of nodes per stalk	0.00 ns	-0.21 ns
11	Mean stalk diameter (mm)	0.09 ns	-0.45 ns
12	DM % cane	0.27 ns	0.27 ns
13	Fibre % cane	0.09 ns	0.21 ns
14	Brix % cane	0.34 ns	0.18 ns
15	Pol % cane	0.30 ns	0.10 ns
16	ERC % cane	0.26 ns	0.06 ns
17	Cane value	0.21 ns	0.02 ns

*significant at p=0.05; **significant at p=0.01; ns = not significant

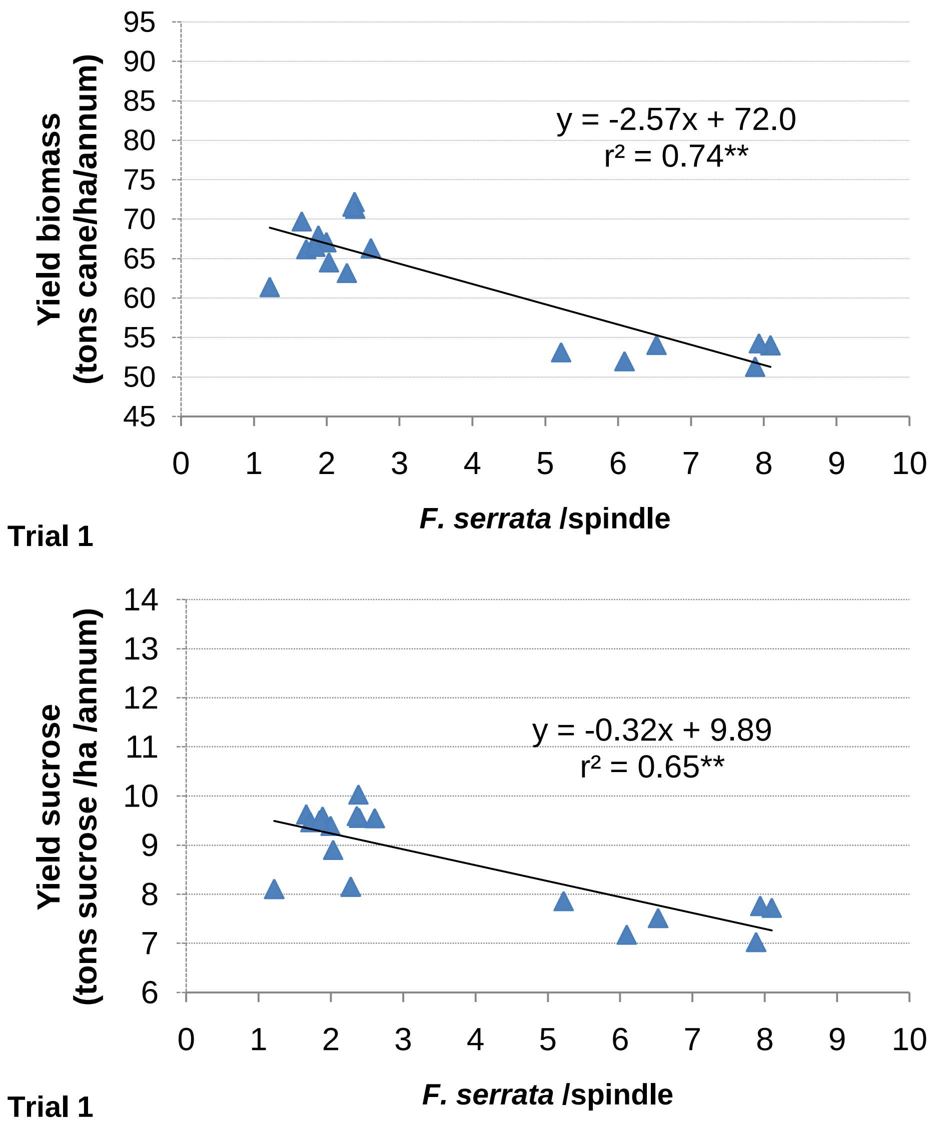
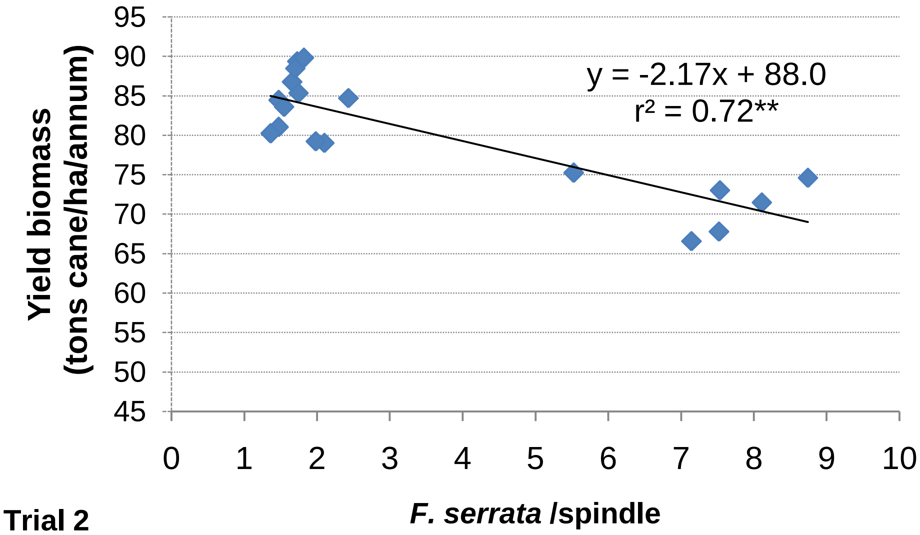


Figure 3. Relationship in trial 1 between yield assessed as biomass (top graph) and sucrose (bottom graph) and mean number of *Fulmekiola serrata* per spindle (adult and nymph counts combined) recovered over the duration of the trials.
** = significant at p=0.01; ns = not significant



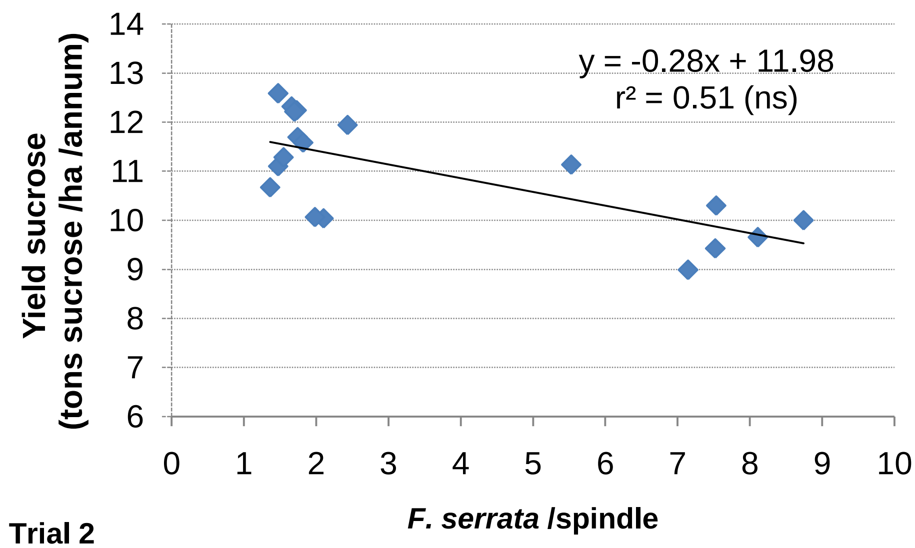


Figure 4. Relationship in trial 2 between yield assessed as biomass (top graph) and sucrose (bottom graph) and mean number of *Fulmekiola serrata* per spindle (adult and nymph counts combined) recovered over the duration of the trials. Data from the 18 plots were regressed against yield.
** = significant at p=0.01; ns = not significant.

Discussion

This was the first field trial conducted in this country to assess the impact of damage caused by *F. serrata*. Insecticides were employed in some of the plots in a random design and, as a result, there were lower populations compared with the control plots (T1). However, given the high concentrations and frequency of applications of the imidaclopid insecticide, these protocols are not commercially viable and are applicable only for experimental purposes.

Overall there were fewer *F. serrata* recovered from the treated plots (T2 and T3) compared with the control plots (T1) and the final yields were higher which indicated an association between these variables. The difference in yield between treatments in these trials was partly attributed to the *F. serrata* and amounted to a significant reduction in biomass and sucrose of between 18.0 and 26.8% in tons cane/ha and between 16.2 and 24.0% in tons sucrose/ha.

In these trials, yield in terms of tons cane per hectare may have been enhanced because imidacloprid breakdown products within plants have been shown to increase both abiotic (e.g. drought) and biotic (e.g. disease) stress resistance (Beckers and Conrath, 2007). Therefore the biomass yield differential between untreated and treated plots may have been artificially enhanced in these trials.

The results of the ratios of life stages recorded each month in these trials are worth further investigation. We suggest that these trends might indicate that the nymphs were more susceptible to the treatment of imidacloprid applied in the furrow at planting compared with the adult stage, which might be related to the extra time spent feeding and hence the increased exposure to this systemic insecticide.

In this study high *F. serrata* infestations were recorded in the crop during December through to March. This pattern is consistent with patterns recorded for the South African sugarcane industry (van den Berg *et al*., 2009). Higher numbers of *F. serrata* were recovered over this period relative to the period after that. It is suggested that the greatest impact on yield occurred over this period and, in addition, the timing of attack is most likely critical.

Data from these types of loss trials can be used to assess the cost-benefit ratios of any control option. These results can be used in the development of mathematical models that are required to estimate the yield loss caused by *F. serrata* populations on sugarcane.

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