USE OF CROPGUARD® TO IMPROVE SUGARCANE YIELD ON NEMATODE-INFESTED SOILS OF SOUTH AFRICA

BERRY SD and SPAULL VW

South African Sugarcane Research Institute, Private Bag X02, Mount Edgecombe, 4300, South Africa
shaun.berry@sugar.org.za

Abstract

CropGuard®, an emulsifiable concentrate containing 90% (900 g/L) furfural, is registered in South Africa as a contact nematicide on a number of crops, including sugarcane. The effect of CropGuard® on sugarcane growth and yield on nematode-infested, sandy soils was examined in five trials, conducted between 2005 and 2007. Two trials were established under irrigated conditions and two under rainfed conditions. Both sets of trials included a plant crop and a ratoon. The fifth trial, a ratoon crop under rainfed conditions, examined the application of CropGuard® with concentrated molasses stillage (CMS).

Under irrigated conditions, treatment of plant cane with CropGuard® at 25 L/ha produced a significant increase in yield in tons cane/ha compared with the untreated control. None of the other CropGuard® treatments (16, 33 and 50 L/ha) increased yield significantly. For irrigated ratoon cane, none of the rates of CropGuard® improved cane yield, regardless of whether the treatments were applied singly or split over time.

Under rainfed conditions, treatment of both plant and ratoon cane at the recommended commercial rate of 50 L/ha had no effect on cane yield. However, increasing the rate to 100 L/ha resulted in a significant increase in yield. In addition, applying CropGuard® at 50 L/ha but in a mix with 3 000 L/ha CMS increased cane yield significantly.

Keywords: CropGuard®, furfural, nematodes, sugarcane, yield

Introduction

CropGuard®, a contact nematicide containing 90% furfural (2-furfuraldehyde), is registered in South Africa for use against nematodes in a number of crops, including sugarcane. The active ingredient of CropGuard®, *viz* furfural, is produced industrially from the breakdown of pentosan-containing agricultural residues, such as sugarcane bagasse. In 1993, Rodrigues-Kabana *et al*. found that furfural, when applied as a pre-plant treatment, was an effective nematicide against a number of plant parasitic nematode species affecting okra, soybeans and squash. Later studies found that furfural could also control *Meloidogyne incognita*, an important pest of cotton (Bauske *et al*., 1994), and *Meloidogyne arenaria* and *Rotylenchulus reniformis* on groundnut (Rajendran *et al*., 2002).

Following on from the early work with furfural, two laboratory tests and four field trials were conducted to test its effect against nematodes in sugarcane in South Africa (Spaull, 1997). Results showed that, in pots, furfural was able to reduce nematode numbers. However, in the field it had little effect on nematodes.

In recent times, furfural has been reformulated into a product known as CropGuard® (Illovo Sugar, 90% furfural a.i.) which is reputed to be more soluble and easier to apply.

CropGuard® is registered for use against nematodes in a number of crops, including sugarcane (http://www-za.cropguard.co.za/home.html). In sugarcane, it is registered at the rate of 50 L/ha for plant and ratoon crops under irrigated conditions, and the same rate for plant cane under rainfed conditions. However, this product is not registered for use on ratoon cane under rainfed conditions.

Since 2004, Illovo Sugar Ltd. and the South African Sugarcane Research Institute (SASRI) have conducted trials to investigate the effectiveness of CropGuard® at different rates, with single and double applications, and with the dual application of concentrated molasses stillage (CMS). The results from five field trials conducted over the past three seasons are presented in this paper.

Materials and Methods

Five field trials were conducted between 2005 and 2007. Two trials in Mpumalanga province (one plant crop and the other a ratoon crop) were under irrigated conditions. The remaining three trials (one plant crop and two ratoon crops) were under rainfed conditions in KwaZulu-Natal province. Details on varieties used, soil type, plot size, row spacing and number of replicates, and a summary of the treatments, are given in Table 1. In all of the trials, an untreated control and Temik® at the registered rate of 20 kg/ha (15% aldicarb a.i.) were used for comparison. For the plant crop trials, Temik® was applied in the furrow at planting, just before covering. For the ratoon trials, Temik® was applied at the same rate, over the dripper lines (for irrigated cane) and over the row (rainfed cane), within four weeks of the previous crop being harvested.

CropGuard® treatments were applied with a knapsack sprayer in 5 L water/50 m row for the irrigated trials, and with watering cans in 5 L water/50 m row for the rainfed trials. For the CMS + CropGuard® ratoon trial, CropGuard® was mixed with 3 000 L/ha CMS before applying over the cane row. For the irrigated trials (CG1, CG2), CropGuard® was applied at both single and double applications. The second applications were applied within 2-4 weeks after the initial applications. For the rainfed trials (CG3, CG4, CG5), CropGuard® was applied only as a single application. For all of the trials, CropGuard® was applied at different rates. Details are given in Table 1.

Table 1. Details of the various trial sites.

Trial Code	CG1	CG2	CG3	CG4	CG5
Irrigated/Rainfed	Irrigated	Irrigated	Rainfed	Rainfed	Rainfed
Locality	Tonga	Tonga	Compensation	Park Rynie	Zinkwazi
Province	Mpumalanga	Mpumalanga	Kwa-Zulu Natal	Kwa-Zulu Natal	Kwa-Zulu Natal
Plant Crop/Ratoon	Plant Crop	Ratoon	Plant Crop	Ratoon	Ratoon
Start Date	16-Mar-05	11-Oct-05	13-Dec-05	06-Sep-05	08-Nov-06
End Date	12-Jun-06	04-Oct-06	24-Apr-07	24-Oct-06	06-Nov-07
Age at harvest (m)	15	12	16	13	12
Variety	N25	N32	N31	N39	N27
Soil type	Longlands	Longlands	Fernwood	Fernwood	Fernwood
%Clay	11%	5%	2%	5%	3%
Row Spacing	1.5 m	0.6 and 2.2 m	1.2 m	1.1 m	1.0 m
Number of rows/plot	6	8	5	5	5
Number of replicates	8	6	6	6	6
Standards	Control	Control	Control	Control	Control
	Temik (20kg/ha)	Temik (20kg/ha)	Temik (20kg/ha)	Temik (20kg/ha)	Temik (20kg/ha)
CropGuard Treatments	16.7 l/ha - single*	16.7 l/ha - single	50 l/ha	50 l/ha	CMS + 25 l/ha
	16.7 l/ha - double**	16.7 l/ha - double	100 l/ha	100 l/ha	CMS + 50 l/ha
	25 l/ha - single	25 l/ha - single			25 l/ha
	25 l/ha - double	25 l/ha - double			50 l/ha
	33 l/ha - single	33 l/ha - single			
	33 l/ha + 16.7 l/ha	33 l/ha + 16.7 l/ha			

*single application at the start of the trial
**two applications, one at start, the other 2-4 weeks later

For both of the irrigated trials, irrigation was applied through dripper lines for a 2-hour period each day to give 8 mm of water per day. Allowance was made for rainfall. In the plant crop trial, where the rows were a uniform 1.5 m apart, there was one dripper line per cane row. In the ratoon trial the rows were arranged as tramlines with one dripper line between the two rows of the tramline. All treatments were applied over the dripper lines. All of the crops were fertilised according to recommendations provided by the Fertiliser Advisory Service of SASRI. For the CMS + CropGuard® trial (CG5), the plots not receiving CMS were fertilised with an equivalent amount of KCl as occurs in CMS. Similarly, the nitrogen added to CMS-treated plots was taken into account when fertilising non-CMS plots.

Soil and root samples were collected at various time intervals during each crop for assessing nematode populations. These samples were collected adjacent to the sugarcane stalks, at a depth of 5-15 cm from the soil surface, from two sites along the outer rows of each plot. The nematodes were extracted from 200 cm^3 of soil and from 10 to 50 g fresh weight of roots with the elutriation and mist chamber techniques, respectively (Seinhorst, 1950, 1962). The nematode genera were enumerated under the microscope. Roots were oven dried and the number of nematodes extracted adjusted to per gram of dry weight.

At harvest, the cane leaves were burnt and the stalks in the centre three rows of each plot were cut and weighed. A 12-stalk sub-sample was taken and analysed for moisture, fibre content and estimated recoverable crystal (ERC). Nematode and yield data, for each crop, were subjected to analysis of variance (JMP 5 software package, SAS).

Results

Nematode communities

The sites were specifically chosen for their sandy soils, where nematode damage is most prevalent, and the presence of many of the common nematode genera associated with this damage (Table 2).

Table 2. Plant parasitic nematode genera found in >70% of the soil samples analysed.

CG1	CG2	CG3	CG4	CG5
Meloidogyne *Paratrichodorus* *Pratylenchus* *Tylenchorhynchus* *Xiphinema*	*Helicotylenchus* *Hemicycliophora* *Longidorus* *Meloidogyne* *Paratrichodorus* *Pratylenchus* *Scutellonema* *Tylenchorhynchus* *Xiphinema*	*Criconemoides* *Helicotylenchus* *Meloidogyne* *Paratrichodorus* *Pratylenchus* *Scutellonema* *Xiphinema*	*Criconemoides* *Helicotylenchus* *Meloidogyne* *Paratrichodorus* *Pratylenchus* *Scutellonema* *Xiphinema*	*Helicotylenchus* *Meloidogyne* *Paratrichodorus* *Pratylenchus* *Xiphinema*

Table 3 shows the effect of treatments on the nematode communities midway through the crop cycle (at approximately 6 months) for four of the trials (CG2, CG3, CG4, CG5) and near the end of the crop cycle (12 months) for the CG1 trial. Results indicate that none of the treatments had any significant effect on nematode populations at this stage of the crop.

Table 3. Abundance of plant-parasitic and free-living nematodes per 200 cm^3 of soil. The nematode abundance data was logged prior to statistical analyses but is shown here as actual numbers for ease of reading.

				Single application							Double application		
		C	T	16.7 l/ha	25 l/ha	25 l/ha +CMS	33 l/ha	50 l/ha	50 l/ha + CMS	100 l/ha	16.7 + 16.7 l/ha	25 + 25 l/ha	33 + 16.7 l/ha
CG1	Total PPN	*1189*	1105	1563	1378	-	1253	-	-	-	1489	1019	1499
	Total FLN	*625*	700	822	663	-	563	-	-	-	886	1088	800
CG2	Total PPN	*1347*	1642	855	922	-	923	-	-	-	807	1485	745
	Total FLN	*883*	867	683	750	-	900	-	-	-	750	733	1117
CG3	Total PPN	*1336*	1063	-	-	-	-	955	-	967	-	-	-
	Total FLN	*600*	600	-	-	-	-	433	-	550	-	-	-
CG4	Total PPN	*942*	897	-	-	-	-	483	-	988	-	-	-
	Total FLN	*1067*	717	-	-	-	-	667	-	1083	-	-	-
CG5	Total PPN	*606*	747	-	1105	953	-	1017	507	-	-	-	-
	Total FLN	*483*	517	-	500	683	-	667	583	-	-	-	-

PPN: Plant-Parasitic Nematodes   C: Control   Not tested (-)
FLN: Free-Living Nematodes   T: Temik

Rainfall data

The amount of rainfall for the duration of each trial is shown in Table 4. For most of the trials (except CG4), the rainfall was similar to (CG5), or exceeded (CG1, CG2, CG3), the expected long term mean for that area. Of more importance to CropGuard® movement in the soil, is the amount of rainfall that occurs within the first two weeks after application.

Table 4. Total rainfall for each trial, percentage of long term mean (LTM) and amount of rainfall for the first two and six weeks after treatment.

	CG1	CG2	CG3	CG4	CG5
Total rainfall (mm)	1240	1326	1789	605	1264
% of LTM	118	156	150	91	104
Rainfall first 2 weeks (mm)	26	4	74	34	110
Rainfall first 6 weeks (mm)	37	165	231	122	290

In the CG1 trial, 26 mm of rain fell within two weeks of the first application, and a further 11 mm fell over the next four weeks. In the CG2 trial, only 4 mm of rain fell within the two weeks after application, followed by 161 mm within the next four weeks. Although no data are given for the amount of irrigation water applied during this period, it is presumed that the shortfall in rainfall was supplemented by timeous irrigation by the grower.

In the rainfed trials (CG3, CG4, CG5), between 34 and 110 mm of rain fell within two weeks after application (Table 4). Since there was only one single application of CropGuard® in these trials, the amount of rainfall at six weeks was less critical.

Yield data

In the irrigated trials (CG1, CG2), there were no significant increases in cane yields with the different rates of CropGuard®, whether with single or double applications (Table 5). The only treatment to show significant yield increases was the Temik treatment in the ratoon trial (CG2). A single CropGuard® treatment at 25 L/ha did show significant increases in ERC yield, but this was not matched by increased cane yield and the trend was not apparent when higher rates of CropGuard® were used.

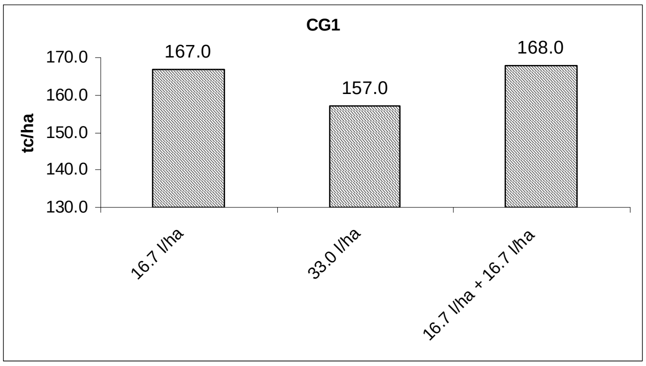
Table 5. Average sugarcane (tc/ha) and sucrose (ERC t/ha) yields for each treatment. Numbers shown in bold were statistically different to the control treatment (P<0.05).

				Single application							Double application		
		C	**T**	**16.7 l/ha**	**25 l/ha**	**25 l/ha +CMS**	**33 l/ha**	**50 l/ha**	**50 l/ha + CMS**	**100 l/ha**	**16.7 + 16.7 l/ha**	**25 + 25 l/ha**	**33 + 16.7 l/ha**
CG1	tc/ha	*158*	158	167	173	-	157	-	-	-	168	168	164
	ERC t/ha	*14.1*	14.4	16.1	**17.5***	-	14.7	-	-	-	16.4	16.2	15.3
CG2	tc/ha	*66*	**78***	60	68	-	62		-	-	70	63	63
	ERC t/ha	*9.3*	10.4	8.0	9.2	-	8.2		-	-	9.2	8.5	8.6
CG3	tc/ha	*33*	**56***	-	-	-	-	34	-	**46***	-	-	-
	ERC t/ha	*3.0*	**5.2***	-	-	-	-	2.8	-	**4.1***	-	-	-
CG4	tc/ha	*52*	**67***	-	-	-	-	58	-	**63***	-	-	-
	ERC t/ha	*6.7*	**9.4***	-	-	-	-	8.0	-	**8.4***	-	-	-
CG5	tc/ha	*22*	**52***	-	**30***	23	-	27	**31***	-	-	-	-
	ERC t/ha	*2.2*	**5.8***	-	3.1	2.4	-	2.9	**3.5***	-	-	-	-

C: Control
T: Temik

Not tested (-)

Comparison of increasing the rate, by either doubling the amount applied, or by following up with a second application, indicated that a double application of 16.7 L/ha was more beneficial than a double rate (33 L/ha) in a single application (Figure 1).



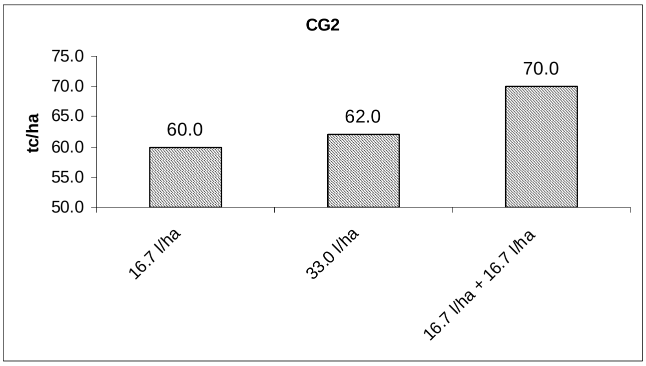


Figure 1. Comparison of a single application of 16.7 L/ha CropGuard® with either a single application at double the rate (33.0 L/ha) or a double application at the same rate (16.7 L/ha + 16.7 L/ha).

In the rainfed trials (CG3, CG4, CG5), a single application of 50 L/ha CropGuard® had no significant effect. However, increasing the rate to 100 L/ha and applying the CropGuard® at 50 L/ha combined with CMS, both resulted in significantly increased cane and ERC yields (Table 5). The yields in the CG5 trial were generally very low.

Discussion

The two long-standing nematicides registered for use on sugarcane in South Africa, Temik (a.i. aldicarb) and Curaterr (a.i. carbofuran), are both systemic, the active ingredient being taken up by the plant. CropGuard®, however, is a volatile contact nematicide and thus the timing and placement are particularly important when using this product. To ensure effective control of plant parasitic nematodes in plant cane, it is important that the nematicide is applied in the furrow at planting. For spring and summer ratoon crops, the nematicide must be applied soon after the previous crop is harvested. Application of the nematicide in winter ratoon cane can, however, be delayed (Spaull and Donaldson, 1983). Conventionally, in South Africa, nematicide application in ratoon cane is made over the row and subsequent movement of the chemical down the soil profile occurs (by mass transfer) when the soil is wetted, as after rainfall or irrigation. Whilst on the soil surface, loss of the chemicals through volatilisation is minimal (Aldicarb and Carbofuran Data Sheets, www.bayercropscience.co.za). This is not the case with furfural, which has a much higher vapour pressure (cf c 266.6 Pa for furfural; c 0.01 Pa for aldicarb and c 0.003 Pa for carbofuran). The formulation of the product, combining an emulsifier with the furfural, will have decreased the vapour pressure of the product, but not to the extent that it is comparable with the granular nematicides. As a result of its high vapour pressure, it seems logical to assume that CropGuard® needs to be mechanically incorporated or washed into the soil soon after it is applied. Further, it is logical to assume that its efficacy, in ratoon cane, will depend on there being sufficient rainfall in the days following its application. This seems to be the case in the rainfed trials. The relatively poor response to treatment with CropGuard® in the two irrigated trials was unexpected, except that the air temperature during the initial treatment in the ratoon crop trial was extremely high. This would have increased volatisation of the CropGuard® from the soil surface quite considerably.

The CropGuard® label proposes that at time of treatment the soil should be at field capacity and that at least 10 mm of water should be applied soon thereafter (http://www-za.cropguard.co.za/ downloads/eng/sugarcane.pdf). This can be achieved under irrigated conditions, but is often impractical under rainfed conditions. However, due to the contact nature of CropGuard®, nematodes which occur in the roots of the sugarcane plant, such as *Meloidogyne* and *Pratylenchus*, are less likely to be affected by this chemical. Both of these nematodes are known to be damaging to sugarcane (Cadet and Spaull, 2005). This is probably more of a problem in ratoon cane where the chemical has to move through the profile to the root zone, than in plant cane where the chemical is applied in the furrow, over the sett, from which the newly forming sett roots develop.

Thus the idea of applying CropGuard® with 3 000 L/ha CMS seems like a logical progression. The CMS provides nutrition, particularly in the form of K (Turner *et al*., 2002), and the additional volume of liquid (3 000 L/ha) provides the 'vehicle' to move the furfural into the soil profile. Additionally, the grower has the benefit of combining two treatments (i.e. fertiliser and nematicide) into one. However, further work is needed to repeat this result and investigate other factors, such as:

- What effect does the addition of other nutrients, such as N and P, have on the efficacy of CMS+CropGuard®?
- What are the economics of applying double the rate of CropGuard® (i.e. 100 L/ha)?
- Subsoil application of CropGuard® in ratoon cane might also be investigated.

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