EFFECT OF RATOON STUNTING DISEASE ON THE YIELD AND COMPONENTS OF YIELD OF SUGARCANE UNDER RAINFED CONDITIONS

By R. A. BAILEY and G. R. BECHET

South African Sugar Association Experiment Station, Mount Edgecombe 4300, South Africa

Abstract

In a field trial conducted with eight varieties in the north coast area of Natal ratoon stunting disease (RSD) caused increasing losses in yields of cane and sucrose from the plant to the second ratoon crop. All the varieties suffered losses in yield but the degree of loss differed markedly among the varieties. The total yield of sugar from the three crops was reduced by 38 % in varieties NCo 376 and N13, by between 19 and 26 % in N12, J59/3 and N53/216, by 11 to 12 % in N52/219 and N11 and by 4 % in N55/805. In the first and second ratoon crops of NCo 376 and N13 the loss in yield of sucrose was more than 45 %. The disease had little effect on cane quality and stalk population, and losses in yield were almost entirely due to decreases in stalk mass. Rainfall during the period of the trial amounted to 104 % of the long term mean.

Introduction

Ratoon stunting disease (RSD) is a common and economically important disease in most countries where sugarcane is grown. First recognised as a transmissible disease in 1949, RSD has probably caused greater yield losses in sugarcane producing countries than any other disease in recent years (Gillaspie and Teakle[11], Steindl[15]). RSD was first recognised in South Africa in 1953 (Buchanan[9]) but it was then already widespread. In retrospect RSD was recognised as having been the main cause of the steady decline in yield of Co 281, which resulted in this once popular variety declining from 67 % of the crop in 1945 to only 2 % in 1954 (King[13]).

RSD is caused by the bacterium *Clavibacter xyli* subsp. *xyli* (Davis *et al*[10]). One of the main methods of spread of the disease is by the planting of systemically infected seedcane. Although the bacterium can be readily eliminated from seedcane stocks by heat treatment (Anon[3,6], Steindl[15]). RSD remains a common problem in many countries. This is due partly to the lack of conspicuous symptoms, so that the occurrence of the disease is often unsuspected by the grower. Surveys based on microscopic observation of the causal bacterium in the xylem sap of stalks have demonstrated the widespread occurrence of RSD in several countries (Amiet[1], Bailey and Fox[7], Irey[12]) and have provided a new impetus to efforts to control the problem. In South Africa, 24 % of commercial cane fields were found to contain RSD in 1983. The disease was most common in the Eastern Transvaal, Pongola and Umfolozi areas, where from 40 % to 55 % of fields were found to be contaminated, and least common in the Lower South Coast and Midlands areas, where 7 % and 13 % of fields respectively contained the disease (Anon[5], Bailey and Fox[7]).

Although all commercial varieties are probably susceptible to infection by *C. xyli* subsp. *xyli* (Gillaspie and Teakle[11]), the effects of the disease on cane growth and yield differ among varieties. However, it seems that most varieties can suffer appreciable losses, which are usually greater in ratoon crops than in plant crops. It is well known that the magnitude of losses from RSD is affected by the conditions under which the crop is grown. In a trial with different irrigation regimes Rossler[14] demonstrated losses of 16 % and 45 % in cane yield in the plant and first ratoon crops of variety NCo 376 when grown with moisture stress, but a loss of only 12 % in the first ratoon crop when it was well irrigated. In this same trial there was a loss in cane yield of 13 % in variety N55/805 when the first ratoon crop was grown with moisture stress, whereas there was no loss when the crop was grown without stress.

Substantial losses in yield of NCo 376 when infected with RSD were first reported in 1960 (Anon[2]). A trial in which a number of varieties were grown in small plots under rainfed conditions at Mount Edgecombe demonstrated a dramatic effect of RSD when intolerant varieties suffered severe moisture stress (Anon[4]). Although the first ratoon crop of this trial received a total of 1 017 mm of rainfall, only 260 mm fell in the last eight months and substantial losses occurred in most of the varieties. Yields of NCo 376 were reduced by 76 % and the cane in some plots of this variety died (Figure 1).

FIGURE 1 Effect of RSD (centre row) on NCo 376 under drought conditions

The trial reported here was conducted to determine the effects of RSD on cane growth, quality and yield up to the second ratoon crop of eight varieties under rainfed conditions. Such information, together with a knowledge of the extent to which RSD occurs in the main, rainfed part of the cane belt, allows the effect of RSD on crop production to be estimated.

Materials and Methods

The experiment was laid down on a deep sandy clay loam soil (Oakleaf/Swartland form) at Mount Edgecombe. This

soil had a clay content of 25 % and a high moisture holding capacity. Fertilizer applications at planting and subsequent top dressings were based on soil analyses.

The varieties used were NCo 376, N52/219, N53/216, N55/805, N11, N12, N13 and J59/3. Seedcane of all the varieties was obtained from the first ratoon crops of special propagation plots. The seedcane used to establish the healthy and diseased propagation plots was from a common source; for the healthy plots it had been subjected to hot water treatment (2 h at 50°C) while for the diseased plots the seedcane was heat treated and then inoculated with juice obtained from infected cane using the pressure cup method (Bell[8]). The uniformity of infection in the diseased propagation plots was probably aided by spread of the disease during harvesting of the plant crop.

A split-plot design with three replications was used, with varieties in the main plots and healthy or diseased seedcane in the sub-lots. The sub-plots consisted of four rows, 1,4 m apart and 7 m long. Each row was planted with 20 4-budded setts. Growth was measured in the central 6 m of the two inner rows of each sub-plot, from which samples for mill room analysis were also taken. Cane yields were determined from the central 6 m of all four rows (used in preference to the two inner rows because of reduced variability in the analysis of variance).

The experiment was planted in September 1981 and the plant, first ratoon and second ratoon crops were harvested in October 1982, May 1984 and October 1985 at 12,4, 19,7 and 16,6 months of age respectively. Cane knives were cleaned with Jeyes fluid to prevent the spread of RSD from the diseased to healthy plots during harvesting.

Numbers of emerged shoots were counted 10 weeks after planting. Fifteen stalks of each variety were taken from the guard areas at the ends of the plots 11 months after planting and subjected to microscopic examination to determine the extent of infection by RSD. Stalk populations and stalk heights were determined at harvest in each crop.

Rainfall

A total of 3 945 mm of rain fell during the course of the experiment, which was 104 % of the 60 year long term mean (LTM). There were 740 mm of rain in the plant crop, 2 015 mm in the long first ratoon crop and 1 190 mm in the second ratoon crop. These totals represent 75 %, 119 % and 105 % of the LTM for the three crops respectively. Although the total rainfall of 3 945 mm during the experiment was close to the LTM, there was considerable variation in rainfall per month about the LTM and there were prolonged periods in each crop when conditions were relatively dry. In particular, rainfall was low from May until August 1982 over the final months of the plant crop, from November 1983 to June 1984, in the early stages of the first ratoon crop, and from April to August 1985 towards the end of the second ratoon crop.

Results

Crop establishment and incidence of RSD

There were only slight differences in the rates of germination and tillering between healthy and diseased cane. At 10 weeks after planting all the plots were well established, with cane in the healthy plots containing approximately 3 % more shoots and tillers than cane in the diseased plots.

Microscopic examination of xylem sap from stalks sampled at 11 months after planting showed that between 87 and 100 % of stalks in the diseased plots contained *C. xyli* subsp. *xyli*. RSD was not diagnosed in any of the samples taken from healthy plots.

Crop growth and cane yield

Despite poor rainfall during the latter months of the plant crop, the yields of cane from the healthy plots were good, averaging 98 t ha^{-1} (95 t ha^{-1} per annum and 13,2 t ha^{-1} per 100 mm rainfall) for all varieties (Tables 1 and 6). In diseased plots the mean yield of cane of all varieties in the plant crop was 12 t ha^{-1} (12 %) less than in healthy plots but decreases in yield differed markedly among the varieties. There were substantial losses in N53/216, NCo 376 and N13 (−23%, −22% and −16% respectively); losses in cane yield of approximately 9 % in N11, N12 and J59/3 were not significant, and there were negligible losses in N52/219 and N55/805 (Table 1).

Table 1

Effect of RSD on the cane yields of eight varieties in a plant and two ratoon crops

Variety	Cane (t ha^{-1})								Mean % loss (P−2R)
	P (12,4 mth)		1R (19,7 mth)		2R (16,6 mth)		Total		
	Healthy	RSD	Healthy	RSD	Healthy	RSD	Healthy	RSD	
NCo 376	110	86	198	109	118	65	426	260	39
N13	121	102	193	128	137	78	451	308	32
N53/216	99	76	176	128	89	70	364	274	25
J59/3	83	75	130	96	81	56	294	227	23
N12	93	85	208	166	111	90	412	341	17
N52/219	92	90	159	143	113	84	364	317	13
N11	106	96	143	143	96	78	345	317	8
N55/805	79	76	143	146	99	88	321	310	3
*LSD (P=0,05)	13		18		17		–		–
(P=0,01)	17		24		23				
Means	98	86	169	132	106	76	373	294	22
LSD (P=0,05)	5		6		6		–		–
(P=0,01)	6		9		8				
CV (%)	7,6		10,3		9,6		–		–

* LSD between Healthy and RSD within each variety.

RSD reduced the mean population of stalks in the plant crop by 2,3 %. The greatest reductions in stalk populations between 5% and 9%, occurred in N53/216, N13 and NCo 376 but they were not statistically significant (Table 2). The disease had a relatively greater effect on stalk length than on population; stalk length was reduced on average by 3,8 % and the greatest reduction occurred in N53/216 (Table 2).

Table 2

Effect of RSD on stalk populations and heights of 8 varieties (% responses)

Variety	Stalk population				Stalk length			Mean
	P	1R	2R	Mean	P	1R	2R	
NCo 376	−8,1	− 1,2	+ 3,1	−2,1	− 6,0	−27,4	−20,8	−18,1
N13	−6,5	−10,4	− 5,2	−7,4	− 6,8	−29,0	−23,7	−19,8
N53/216	−5,5	− 3,5	− 6,5	−5,2	−11,5	−21,4	−16,7	−16,5
J59/3	+1,9	-	−11,0	−4,6	+10,1	−11,7	−23,2	− 8,3
N12	+1,8	− 5,6	−15,4	−6,4	− 4,3	− 5,8	−10,7	− 6,9
N52/219	+0,3	-	− 7,4	−3,6	+ 0,4	−12,1	− 0,6	− 4,1
N11	−4,6	-	− 6,4	−5,5	− 2,1	− 7,8	−11,6	− 7,2
N55/805	+2,1	+ 0,6	+ 9,4	+4,0	− 9,9	− 7,1	−10,6	− 9,2
Mean	−2,3	− 4,0	− 4,9	−3,9	− 3,8	−15,5	−14,7	−11,3

In the first ratoon crop, only 735 mm of rainfall fell in the first 12 months (76 % LTM) but 1 280 mm fell in the final seven months and high yields of cane were obtained from the healthy plots. The mean yield of cane of all varieties in healthy plots was 169 t ha^{-1} (103 t ha^{-1} per annum and 8,4 t ha^{-1} per 100 mm rainfall), and the highest yields were obtained from N12, NCo 376 and N13 (Tables 1 and 6). RSD reduced the mean yield of cane of all varieties in the first ratoon crop by 22%. The effects of the disease differed widely among the varieties. Highly significant losses occurred in all varieties except N55/805, N11 and N52/219, and the greatest losses occurred in NCo 376 and N13 (45 % and 34 % respectively) (Table 1).

RSD reduced stalk population in N13 and N12 only in the first ratoon crop of the five varieties in which stalk population was measured (Table 2). The mean length of stalks of all varieties was reduced by 15,5 % and the greatest reductions occurred in NCo 376 and N13, (27 % and 29 % respectively).

Growing conditions were good during the first 10 months of the second ratoon crop (129 % of LTM rainfall), but were relatively dry over the final seven months. The mean yield of cane of all varieties in healthy plots was 106 t ha^{-1} (77 t ha^{-1} per annum and 8,9 t ha^{-1} 100 mm) and the highest yield, 137 t ha^{-1}, was obtained from N13. Yields of all the varieties were reduced by RSD (Tables 1 and 6), but the decrease in yield was not statistically significant in N55/805. The greatest losses occurred in NCo 376 and N13 (45 % and 43 %, respectively). Again RSD had on average only a slight effect on stalk populations, causing a mean reduction for all varieties of only 4,9 %. However stalk length was decreased considerably in most varieties (Table 2).

Total yields of cane over the three crops are shown in Table 1. The greatest losses in yield due to RSD occurred in NCo 376 and N13. In these two varieties the losses amounted to 166 and 143 t ha^{-1} respectively, a mean reduction of 35 % or 3,9 t ha^{-1} per 100 mm. The mean loss for all varieties over the three crops was 79 t ha^{-1} (21 % or 2,0 t ha^{-1} per 100 mm). The varieties most tolerant to RSD were N55/805, N11 and N52/219, for which the mean losses in yield were 3 %, 8 % and 13 % respectively.

Cane quality

There was no consistent effect of RSD on the mean estimated recoverable sugar % cane (ers % cane) for all varieties over the three crops (Table 3).

In the plant crop there were positive and negative responses in ers % cane in different varieties but none was statistically significant, and there was no association between responses in ers % cane and responses in cane yield to infection.

In the first ratoon, the slight reduction in the mean value of ers % cane for all varieties because of RSD, from 10,4 to 9,8 %, was significant ($P < 0,05$) (Table 3). In this crop RSD caused a reduction in ers % cane in five of the eight varieties, but the effect was substantial only in N53/216, N12, N11 and N13 and significant only in N13.

In the second ratoon crop, there were slight, variable effects of RSD on ers % cane. The greatest effects were losses of 0,8 and 0,9 ers % cane in NCo 376 and N11 but these losses did not reach a level of statistical significance, and again there was no correlation between the effects of RSD on ers % cane content and cane yield. RSD caused a small mean decrease in ers % cane for all varieties over the three crops, from 13,3 to 13,1 %, (Table 3).

Table 3

Effect of RSD on ers % cane of eight varieties in a plant and two ratoon crops

Variety	ers % cane							
	P		1R		2R		Mean	
	Healthy	RSD	Healthy	RSD	Healthy	RSD	Healthy	RSD
NCo 376	13,7	14,4	9,7	9,4	15,2	14,4	12,9	12,7
N13	13,9	13,6	10,4	7,9	15,0	14,5	13,1	12,0
N53/216	13,9	14,1	10,6	9,8	13,9	14,1	12,8	12,7
J59/3	15,8	16,7	10,2	10,3	14,8	14,8	13,6	13,9
N12	14,2	14,6	11,6	10,9	14,3	14,2	13,4	13,2
N52/219	14,2	14,4	9,9	10,1	13,9	14,3	12,7	12,9
N11	16,2	16,2	10,4	9,5	15,8	14,9	14,1	13,5
N55/805	15,8	15,7	10,2	10,5	15,7	15,6	13,9	13,9
LSD P=0,05	1,4		1,1		1,0		-	
Mean	14,7	15,0	10,4	9,8	14,8	14,6	13,3	13,1
LSD P=0,05	0,5		0,4		0,4		-	
CV (%)	5,5		6,5		3,9		-	

Estimated recoverable sugar yield

The effects of RSD on the estimated recoverable sugar yields of the eight varieties are shown in Table 4. The greatest losses in the plant crop occurred in N13, NCo 376 and N53/216 (16 to 22 %), and the mean loss in all varieties was 10,5 %.

In the first ratoon crop, there were highly significant losses in yields of ers from N12, J59/3, N53/216, NCo 376 and N13. The greatest losses occurred in NCo 376 and N13 (47 and 49 % respectively), and in this crop the loss in N13 was due to marked detrimental effects on both cane yield and ers content. Slight losses in N52/219 and N 11, and a slight increase in N55/805 were not significant. The mean loss in yield of ers for all varieties was 25,6 % (Table 4).

In the second ratoon crop, there were substantial losses in sucrose yield in all varieties but the loss of 12 % in N55/805 was not statistically significant (Table 4). The greatest losses occurred in N13 and NCo 376 and were similar to those in these varieties in the first ratoon crop. The mean loss in yield of sucrose for all varieties in this crop was 28,8 %.

The total losses in yield of ers for individual varieties over the three crops followed the same trend as the total losses in yield of cane (Tables 1 and 4). Substantial losses occurred in all varieties except N55/805, varying from 5,1 to 6,0 t ha^{-1} (11 and 13 %) for N52/219 and N11 to 20,0 and 21,7 t ha^{-1} (39 and 38 %) for NCo 376 and N13. The mean loss in sucrose for all varieties over the three crops was 10,5 t ha^{-1} (22 %).

Discussion

Although there were periods in each crop when rainfall was substantially less than the LTM, particularly during the early stages of the first ratoon crop, there were good falls of rain in the summer months of 1981–82, 1983–84 and 1984–85 and these resulted in relatively high yields in the healthy cane in each crop. The yields of cane of the standard variety NCo 376 (Tables 1 and 6) are a good indication that growing conditions were might normally be expected over a period of four years in the rainfed areas of cane production in Natal.

The yields of cane in healthy plots provide a measure of the variation in growing conditions from crop to crop. The yields of cane, per annum and per 100 mm of rainfall, for NCo 376 and for all varieties are shown in Table 6. The greater yields per annum in the first ratoon crop were probably largely due to the lengthy growth period, which included two summer growing seasons. Nevertheless, losses in both cane and sugar yields in the first ratoon crop were approximately double those in the plant crop. The first ratoon and second ratoon crops of healthy plots were similar in relation to rainfall but further reductions in yield because of RSD occurred in the second ratoon crop of most varieties.

The results confirm the report by Steindl[15] that RSD usually does not cause much reduction in the germination of infected seedcane.

It is clear that a reduction in the population of stalks represented only a small proportion of the overall loss in yield caused by RSD and that almost all of the loss was due to a reduction in stalk mass (Table 5). In NCo 376, approximately half of the reduction in stalk mass, and therefore in cane yield, was due to a reduction in stalk length, while for all varieties, the reduction in stalk length was associated with a reduction of 64 % in stalk mass and a loss of 54 % in cane yield. Almost certainly RSD caused stalk diameter to be reduced as well as stalk length.

Table 5

Effect of RSD on stalk population, stalk length, stalk mass and cane yield for NCo 376 and for all varieties (% responses).

Variety	Parameter	Plant	1st ratoon	2nd ratoon	Mean
NCo 376	Stalk population	− 8	− 1	+ 3	− 2
	Stalk length	− 6	−27	−21	−18
	Stalk mass	−15	−44	−47	−35
	Cane yield	−17	−45	−45	−39
All varieties	Stalk population	− 2	− 4	− 5	− 4
	Stalk length	− 4	−16	−15	−12
	Stalk mass	−10	−18	−26	−18
	Cane yield	−12	−22	−28	−21

Table 4

Effect of RSD on the estimated recoverable sugar yields of eight varieties in a plant and two ratoon crops

Variety	Estimated recoverable sugar (t ha^{-1})								Mean % loss (P-2R)
	P (12,4 mth)		1R (19,7 mth)		2R (16,6 mth)		Total		
	Healthy	RSD	Healthy	RSD	Healthy	RSD	Healthy	RSD	
NCo 376	15,0	12,4	19,1	10,2	17,9	9,4	52,0	32,0	39
N13	16,6	14,0	20,1	10,3	20,6	11,3	57,3	35,6	38
N53/216	13,8	10,8	18,6	12,5	12,3	9,9	44,7	33,2	26
J59/3	13,1	12,5	13,3	9,9	12,0	8,3	38,4	30,7	20
N12	13,1	12,4	24,2	18,1	15,9	12,8	53,2	43,3	19
N11	17,1	15,6	14,8	13,6	15,0	11,7	46,9	40,9	13
N52/219	13,1	13,1	15,8	14,4	15,7	12,0	44,6	39,5	11
N55/805	12,5	11,9	14,6	15,3	15,6	13,8	42,7	41,0	4
*LSD (P=0,05)	2,3		2,0		2,4		-		
(P=0,01)	3,1		2,7		3,6				
Means	14,3	12,8	17,6	13,1	15,6	11,1	47,5	37,0	22
LSD (P=0,05)	0,8		0,7		0,9		-		-
(P=0,01)	1,1		1,0		1,3				
CV (%)	9,8		7,5		11,2		-		-

* LSD between Healthy and RSD within each variety

There was no evidence from this experiment that infection with RSD caused an increase in cane quality. Indeed the trend of the results indicated a slight reduction in sucrose content. This is in contrast to evidence suggesting an improvement in cane quality when infected cane suffers from a shortage of water (Gillaspie and Teakle[11], Rossler[14]).

The eight varieties can be grouped into three categories in respect of losses in yield from RSD: most intolerant, NCo 376 and N13; intermediate, N53/216, N12, J59/3; most tolerant, N52/219, N11 and N55/805. This grouping is in broad agreement with results obtained previously with six of the varieties in a first ratoon crop grown under more severe stress on the same site (Anon[4]). The large difference between NCo 376 and N55/805 in reaction to RSD is also similar to that demonstrated by Rossler[14] when these varieties were grown under conditions of moisture stress in an irrigated area. It is apparent that the yields of most varieties can be reduced substantially by RSD under certain conditions and when the incidence of RSD is high.

The highest yielding varieties when healthy were N13, N12 and NCo 376 (57,3, 53,2 and 52,0 t ers ha^{-1} of recoverable sugar respectively, Table 4). N13 was the highest yielding variety in the plant and second ratoon crops while N12 outyielded N13 and NCo 376 in the long first ratoon crop by 4,1 and 5,1 t ers ha^{-1} respectively. When RSD was present the highest yielding varieties over the three crops were N12, N55/805, N11 and N52/219 (Table 4).

Conclusion

RSD had only small effects on stalk populations and on cane quality. Losses in yield of ers were mainly due to a reduction in mass per stalk.

There were considerable differences in the reactions of the eight varieties to infection by RSD, but it appears that substantial losses can occur in most varieties under rainfed conditions, even when rainfall is close to the long term average. Losses were greater in ratoon crops than in the plant crop and for all but the most intolerant varieties, losses in second ratoon were greater than those in first ratoon crops.

In situations where most of the stalks are infected, losses exceeding 40 % can be expected in ratoon crops of NCo 376 and N13, while losses of 20 % or more can be expected in most other varieties in ratoon crops under typical rainfed conditions. In crops grown on poorer soils than used in this experiment or when crops are subjected to greater moisture stress, even greater losses may occur.

The substantial effect of RSD on most of the varieties in the experiment is clear evidence of the need for routine heat treatment of seedcane stocks and for effective crop eradication before replanting in order to minimise losses from this disease.

Table 6

Yield of NCo 376 and mean yield of eight varieties with and without RSD

Variety	Status	Cane t ha^{-1} per annum				Cane t ha^{-1} per 100 mm			
		P	1R	2R	Mean	P	1R	2R	Mean
NCo 376	Healthy	106	121	85	104	14,9	9,8	9,9	11,5
	RSD	83	66	47	65	11,6	5,4	5,5	7,5
Mean for 8 varieties	Healthy	95	103	77	92	13,2	8,4	8,9	10,2
	RSD	83	80	55	73	11,6	6,6	6,4	8,2

REFERENCES

1. Amiet, PJ (1985). Field surveys for ratoon stunting disease using phase contrast microscopy. *Proc Aust Soc Sug Cane Technol* : 109–111.
2. Anon (1960). Ratoon stunting disease. *S Afr Sug J* 44: 674–675.
3. Anon (1979). Hot water treatment and RSD. *Ann Rep S Afr Sug Assoc Expt Sta* 1978–79: 69.
4. Anon (1981). RSD and drought. *Ann Rep S Afr Sug Assoc Expt Sta* 1980–81: 70.
5. Anon (1984). RSD surveys. *Ann Rep S Afr Sug Assoc Expt Sta* 1983–84: 60.
6. Anon (1985). Effect of hot water treatment on varieties and RSD. *Ann Rep S Afr Sug Assoc Expt Stn* 1984–85: 58.
7. Bailey, RA and Fox, PH (1984). A large-scale diagnostic service for ratoon stunting disease of sugarcane. *Proc S Afr Sug Technol Ass* 58: 204–209.
8. Bell, AF (1935). Two inoculation methods. *Proc Int Soc Sug Cane Technol* 5: 199–200.
9. Buchanan, WK (1953). Ratoon stunting disease in Natal. *S Afr Sug J* 37: 499–503.
10. Davis, MJ; Gillaspie, AG; Vidaver, AK and Harris, RW (1984). *Clavibacter*: a new genus containing some phytopathogenic coryneform bacteria, including *Clavibacter xyli* subsp. *xyli* subsp. Nov. and *Clavibacter xyli* subsp. *Cynodontis* subsp. Nov., pathogens that cause ratoon stunting disease of sugarcane and Bermudagrass stunting disease. *Int J Syst Bacteriol* 34: 107–117.
11. Gillaspie, AG and Teakle, DS (In press). Ratoon stunting disease. In: *Sugarcane diseases of the world Vol 1* (revised). Elsevier, Amsterdam.
12. Irey, MS (1985). Detection and incidence of ratoon stunting disease in commercial sugarcane plantings in Florida. *J Amer Soc Sugarcane Technol* 4: 10–12.
13. King, NC (1956). Ratoon stunting disease in Natal. *S Afr Sug J* 40: 107–119.
14. Rossler, LA (1974). The effects of ratoon stunting disease on three sugarcane varieties under different irrigation regimes. *Proc Int Soc Sug Cane Technol* 15: 250–257.
15. Steindl, DRL (1961). Ratoon stunting disease. In: *Sugarcane diseases of the world Vol 1. ed.* Martin JP, Abbott, EV and Hughes CG Elsevier, Amsterdam. pp 443–459.