REFEREED PAPER

GROWER-EXTENSIONIST-RESEARCHER PARTNERSHIPS: ON-FARM DEMONSTRATION TRIALS TO FACILITATE ADOPTION OF CHEMICAL RIPENING

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Abstract

In the South African sugarcane industry chemical ripeners are used to increase cane quality in vigorously growing crops. Replicated research trials are conducted at several locations to develop variety-specific ripener recommendations. Since 2010, these trials have been supplemented by on-farm demonstration trials through the formation of grower-extensionist-researcher partnerships. The objectives of this paper are to elaborate on these partnerships and to showcase outcomes in terms of demonstrating on-farm economic benefit and grower adoption. Twelve demonstration trials were conducted on farms in Komatipoort, Pongola, Melmoth and Eston on irrigated annual and rainfed long cutting-cycle crops. Fields were identified through inspection to ensure that all logistical considerations were met and that the crops displayed in-field uniformity. Fields were demarcated into strips that acted as unsprayed controls or ripener treatments. Ripeners (Ethephon™, Fusilade Forte™ and Volley™) were administered by fixed-wing aircraft or helicopters at registered application rates. At harvest all cane deliveries from control and treatment strips were analysed by the Cane Testing Service at the respective sugar mills. These demonstration trials showed that ripeners increased relative value (RV) yields by 0.83-2.11 t/ha in annual cutting-cycle crops and by 0.51-2.15 t/ha in vigorously growing longer cutting-cycle crops, except for one trial at Melmoth where a negative response was observed in variety N16. Evidence supporting increased adoption of chemical ripening following communication of trial outcomes to growers in the Mpumalanga region is presented. In addition, areas requiring further research are revealed for purposes of establishing similar grower-extensionist-researcher partnerships in the future.

Keywords: adoption, cane quality, chemical ripening, demonstration trials, partnerships, sugarcane

Introduction

Chemical ripeners are used in South Africa for ripening sugarcane crops when environmental conditions (temperature, solar radiation and soil moisture) conducive to vigorous growth would have left the crop immature at harvest (Alexander, 1973; Legendre, 1974). Currently, two ripeners are used in the local sugarcane industry, namely Ethephon (2-chloroethyl phosphonic acid) and Fusilade Forte (fluazifop-p-butyl), and their generics. These ripeners can be used as single or combination (piggy-back or tandem) treatments.

It is well known that South African sugarcane varieties respond differently to ripeners (Donaldson, 2001). The main focus of ripener research at the South African Sugarcane Research Institute (SASRI) is to develop, through statistically designed small-plot field experiments, variety-specific recommendations for increasing cane quality (RV%) and RV yield (t/ha), and to benchmark responses achievable under ideal growing conditions. Due to the small-plot design of these trials, ripeners are applied with a ground-operated spray boom in contrast to aerial application on commercial farms.

Although these field experiments fulfil a vital role in delivering scientifically sound ripener recommendations and performance benchmarking, grower adoption could be strengthened or accelerated through additional means. It is known that grower adoption of recommendations or new agricultural innovations are influenced by certain important considerations that dare not be ignored. For example, growers must be made aware of the innovation or recommendation, not simply about its existence, but also its practical relevance (Pannell, 1999).

Growers are often 'risk averse' meaning that they will seldom embark on large-scale adoption of new innovations or recommendations without at least seeing the benefits in smaller-scale trials on their own farms, or on farms in close proximity with similar production conditions (Pannell, 1999). It has been suggested that this on-farm trial phase might be the most important step in determining final adoption or non-adoption of new recommendations or innovations (Pannell, 1999).

The physical distance from the origin of the new recommendation or innovation is also an important determinant of adoption or non-adoption because growers have a tendency to question the local relevance of scientific information. For example, Lindner *et al*. (1982) demonstrated how adoption of a new micro-nutrient fertiliser innovation decreased with distance away from the research location.

In recent years conventional ripener research at SASRI has been supplemented by on-farm demonstration trials through the formation of grower-extensionist-researcher partnerships. The objectives of this paper are to elaborate on the nature of these partnerships and to showcase how on-farm demonstration of chemical ripening benefit, and subsequent knowledge transfer of trial outcomes, accelerated grower adoption.

Procedures

Establishment of grower-extensionist-researcher partnerships

Grower participation in on-farm ripener demonstration trials was actively sought at regional grower days or through direct facilitation by the extension specialist in the area. Interested growers were visited on their farms by SASRI's ripener specialist and the regional extension specialist to discuss the procedures involved in these trials.

The roles of the grower, ripener specialist and extension specialist in ensuring successful completion of a demonstration trial were clearly defined. Upon establishment that demonstration trials would be feasible and acceptable to the grower, suitable fields were identified based on field size and shape, variety disposition, time of harvest, crop uniformity and growth vigour within the field, ease of aerial ripener application (e.g. absence of hindrances such as power lines, neighbouring young cane fields or natural vegetation) and harvesting logistics. Table 1 provides a list with specific details of the on-farm demonstration trials that were conducted during the period 2010-2013. Trials were conducted on farms in Komatipoort (Piet Smith and Nico Nel), Pongola (Ernst Höll), Melmoth (Victor Smith, Andre Harris and Wilhelm Harris) and Eston (George Hyslop). An equal number of trials were conducted where sugarcane is grown on annual and 18-24 month cropping cycles (Table 1).

On-farm demonstration trial design

Fields were demarcated into sections that acted as the unsprayed control or ripener treatment(s). Trial design varied depending on grower preference, field shape and size, and other logistical considerations. However, the general concept of demarcation, where the largest part of each field was ripened and a smaller section of 1-2 ha was allocated as the unsprayed control, was followed in all cases. In Figure 1, the trial demarcation that was followed on the farm of Ernst Höll in Pongola during 2011 is shown as an example. In this case three adjacent fields of approximately 14 ha each were selected. The sugarcane (variety N43) in these three fields was a plant crop established on the same date. A section of 1.6 ha through the centre of each field (4.8 ha in total) was demarcated as the unsprayed control. The remaining 6.2 ha on each side of the control section in each field was ripened with Fusilade Forte (Figure 1).

Ripener treatments and application

All ripeners were applied aerially according to commercial practice in the particular region, either by helicopter (Figure 2a) or by fixed-wing aircraft (Figure 2b). In Table 1 the ripener treatments in each demonstration trial are listed together with application dates and varieties used. For example, in the trial conducted during 2010 in Komatipoort on the farm of Piet Smith, the treatments in varieties N23 and N25 were the unsprayed control (C), and the combination treatment of Ethephon (Eth) applied on 23 February 2010 followed by Fusilade Forte (FF) on 29 March 2010 to the same fields. In some of the other trials only Fusilade Forte (FF) or the generic product Volley (V) were applied according to pilot or grower preference. The spray to harvest intervals for all products were determined according to SASRI recommendations, with minor adjustments in some cases to satisfy grower preference or application logistics (e.g. availability of aircraft). The growers were responsible for erecting marker flags and communicating field locations and other relevant information to the crop spraying pilot prior to the application dates.

Table 1. Summary of on-farm demonstration trials conducted during 2010 to 2013, including varieties used, treatments, treatment application dates (in parenthesis), and harvest start dates, dates (month/year) of subsequent knowledge transfer of trial outcomes in the form of grower days (G), industry publications (P) or local extension newsletters (N) to stakeholders in the respective regions. Abbreviations: C, unsprayed control; Eth, Ethephon; FF, Fusilade Forte; V, Volley; Eth + FF or Eth + V, combination treatment where Ethephon was applied first followed by Fusilade Forte or Volley 5-6 weeks later.

Location	Grower	Variety	Treatments	Harvest start	Knowledge Transfer
Komatipoort	P Smith	N23*, N25*	C, Eth (23/02/2010) + FF (29/03/2010)	23/05/2010	P = 01/2011; G = 03/2011
Pongola	E Höll	N43*	C, FF (08/03/2011)	02/05/2011	N = 12/2010; P = 09/2011
Pongola	E Höll	N43*	C, Eth (14/02/2012) + FF (21/03/2012), FF (21/03/2012)	12/05/2012	N = 09/2012; P = 01/2013
Komatipoort	N Nel	N36*	C, Eth (14/03/2012) + FF (18/04/2012), Eth (14/03/2012) + V (18/04/2012)	05/06/2012	G = 01/2013
Melmoth	V Smith, A Harris, W Harris	N12**, N16**	C, FF (26/02/2013)	07/05/2013	P = 09/2013; G = 02/2014
Melmoth	V Smith, A Harris, W Harris	N31**	C, FF (15/03/2013)	19/05/2013	P = 09/2013; G = 02/2014
Eston	G Hyslop	N12**, N31**	C, V (12/03/2013)	25/04/2013	P = 09/2013; G = 10/2013

*crop on annual cutting-cycle, **crop on 18-24 month cutting-cycle

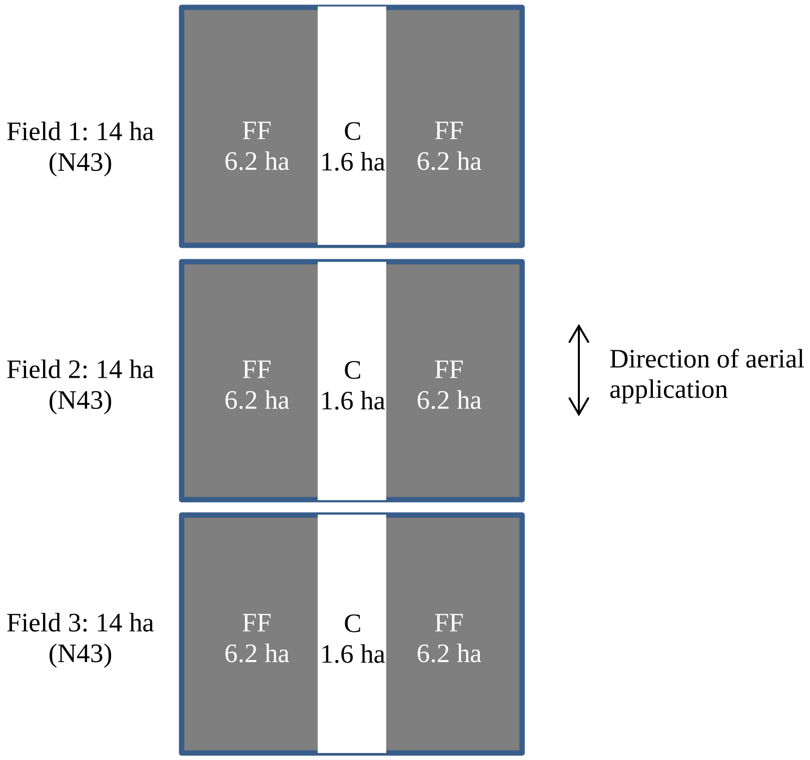


Figure 1. Example of field demarcation into sections that acted as the unsprayed control (C) and Fusilade Forte (FF) treatment.

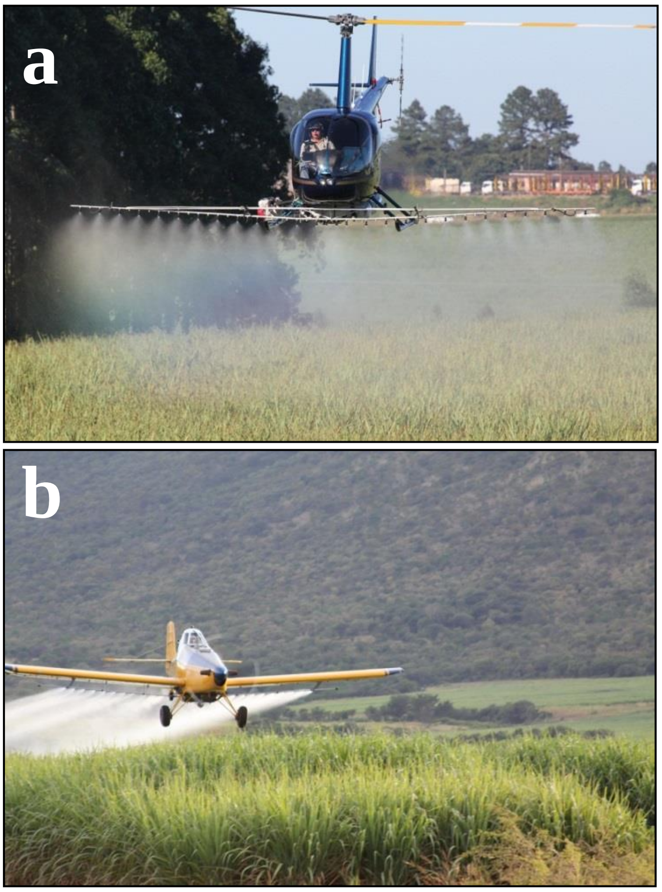


Figure 2. Ripener application in on-farm demonstration trials was conducted by helicopter (a) or fixed-wing aircraft (b).

Trial harvesting

The dates of harvest commencement of the different demonstration trials are listed in Table 1. Shortly before harvest SASRI's ripener specialist and the regional extension specialist conducted an inspection of each trial with the grower to determine ripener efficacy in terms of visual symptoms. Some of the typical symptoms observed during these inspections are shown in Figure 3. The inspection also served the purpose of confirming that the control section in each trial was not contaminated with ripener during aerial application and to assess general application uniformity and coverage.

The regional extension specialist liaised with the Cane Testing Service (CTS) laboratory manager at the relevant sugar mill before harvest to communicate the requirement of testing all consignments from the demonstration trial for cane quality (RV%) and a range of other milling characteristics. The grower informed the CTS manager when the first and last cane consignment from the demonstration trial was being delivered to the sugar mill. This ensured testing of all consignments, which is not standard CTS practice.

The harvesting of each trial was the responsibility of the grower and required careful management to ensure that the harvested cane from each treatment section was kept separate and that all consignments delivered to the mill were clearly labelled for identification by the CTS manager.

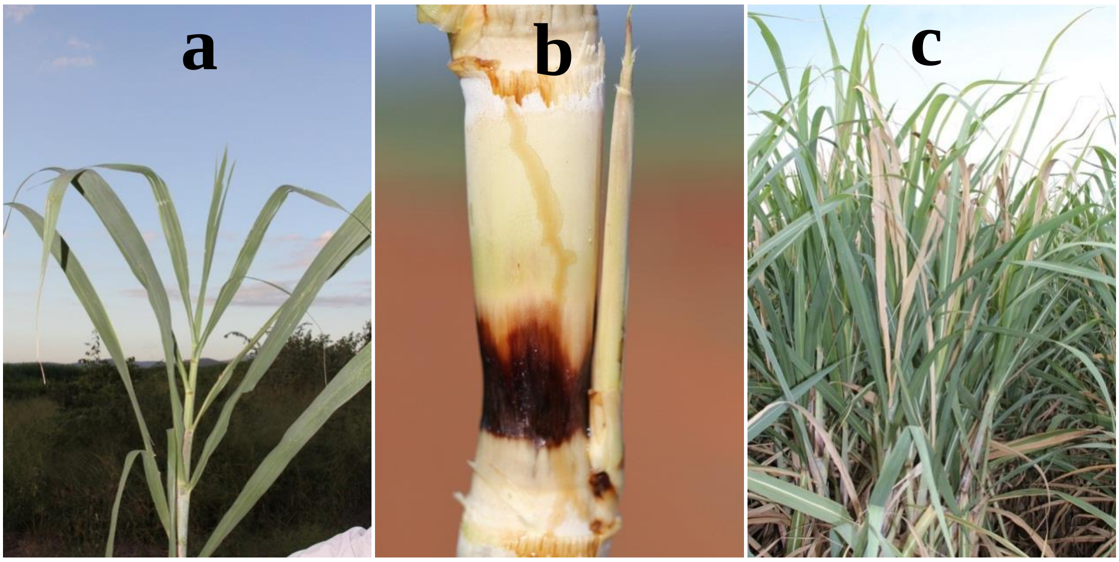


Figure 3. Typical ripener symptoms observed shortly before harvest in the on-farm demonstration trials: (a) size reduction of green leaves (Ethephon), (b) black necrotic ring on stalk with side-shooting (Fusilade Forte or Volley), and (c) dead leaf spindles with unaffected mature green leaves (Fusilade Forte or Volley).

Data analysis

The grower was responsible for accurately measuring the area of each section within the field so that the individual cane consignment weights recorded at the sugar mill weighbridge could be used to calculate cane yield (t/ha) within each section of the demonstration trial. The grower submitted all the cane consignment test results to the ripener specialist, who then determined the average RV% of the consignments within each section of the demonstration trial.

The RV% of each cane consignment tested at the sugar mill was calculated by the CTS manager with the following formula:

$$RV\% = S - dN - cF$$

where
S = sucrose % cane, N = non-sucrose % cane and F = fibre % cane and the value of coefficient c = 0.019. The value of coefficient d is expected to range between 0.35-0.45 depending on industry income derived from the sales of sugar and molasses produced in a particular season.

The RV yield achieved in each section of a trial was calculated with the following formula:

$$\text{RV yield (t/ha)} = (\text{RV\% x cane yield})/100$$

Knowledge transfer of trial outcomes
The details on how each on-farm demonstration trial was conducted, together with the trial outcomes, were communicated to growers by the SASRI ripener specialist in the form of a popular press article and/or presentations at grower contact events arranged by the regional extension specialist. In some cases (e.g. Pongola) the regional extension specialist also informed growers about the trials through local extension newsletters. In Table 1 the knowledge transfer activities associated with each demonstration trial is listed.

Analysis of grower adoption
To investigate grower adoption of chemical ripening on a commercial scale, information on the area sprayed with ripeners on an annual basis in the different production regions is essential. Accurate historic information is scarce at present for the largest part of the industry. However, in the Mpumalanga production area, the sugar milling company TSB Sugar RSA Limited have accurate monthly information on the area sprayed with ripeners from 2010 to 2013. Since two on-farm demonstration trials were conducted in that area during 2010 and 2012 at Komatipoort (Table 1), this monthly information on the area sprayed with ripeners was used in a case study to investigate grower adoption trends.

Monthly cumulative ripener application area (ha) was calculated for each of the four years. Each year was separated into three seasonal phases, namely early-season (January to May), mid-season (June to September) and late-season (October to December). This separation allowed linear regressions to be fitted to the cumulative monthly values within the three seasonal phases for each year. The gradients of these regressions represented ripener application rates (ha/month) for each year within the three seasonal phases. These seasonal ripener application rates, and the total area sprayed per annum, were used as indicators of adoption during the four year period in the Mpumalanga region.

A general linear regression model was used to establish whether there was a significant difference in the gradients (m) of the different years. The regression equation was:

$$\text{Cumulative area ripened (ha)} = a + m \times \text{month of year}$$

where:
a = regression constant and m = ripener application rate. The significance of gradients of each year against all other years was determined by using the Student’s t-test.

Results and Discussion

Cane quality and yield results

As mentioned previously, the growers submitted the individual cane consignment weights and quality test results to the ripener specialist after harvest of each demonstration trial. The trial conducted on the farm of Ernst Höll in Pongola during 2012 is used to showcase a typical cane quality data set obtained from these trials (Figure 4). In this particular trial the response of Fusilade Forte (FF) was compared with the combination treatment (Eth + FF) in variety N43 (Table 1). Each data point on the graph depicts the quality (RV%) of an individual cane consignment delivered to the sugar mill from the control, FF or Eth + FF sections within this trial. This data set demonstrates noticeably how the two ripener treatments consistently increased RV% of individual cane consignments to levels exceeding those of the control and how the response was maintained during the full month of May 2012 when the total area of 42 ha was harvested. The quality results, together with the consignment weights and areas harvested were used to calculate the yield results for each trial (Table 2).

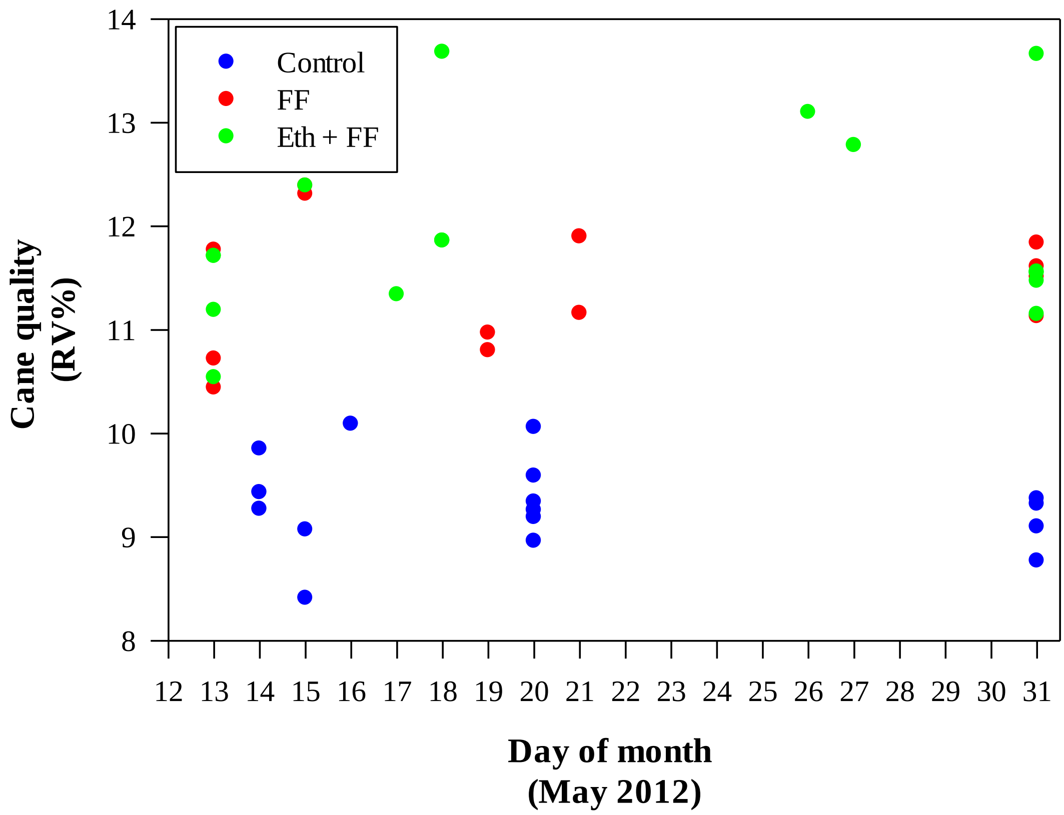


Figure 4. Cane quality (RV%) data set obtained in the on-farm demonstration trial conducted during 2012 in Pongola with variety N43. Each data point on the graph depicts the RV% of an individual cane consignment delivered to the sugar mill from the control, Fusilade Forte (FF) or combination treatment (Eth + FF) sections within this trial.

Table 2. Yield results obtained in on-farm demonstration trials conducted during 2010 to 2013. Refer to Table 1 for more details.

Year	Location	Grower	Variety	Treatment	RV%	Cane yield (t/ha)	RV yield (t/ha)	RV yield response (t/ha)
2010	Komatipoort	P Smith	N23[1]	C	10.02	133	13.27	-
				Eth + FF	11.5	134	15.38	+2.11
			N23[1]	C	10.57	130	13.77	-
				Eth + FF	12.55	119	14.95	+1.18
			N25[1]	C	10.02	139	13.95	-
				Eth + FF	10.82	143	15.5	+1.55
2011	Pongola	E Höll	N43[1]	C	10.9	132	14.4	-
				FF	12.6	139	17.5	+3.1
2012	Pongola	E Höll	N43[1]	C	9.3	106	9.8	-
				FF	11.4	105	11.9	+2.1
				Eth + FF	12.0	99	11.9	+2.1
2012	Komatipoort	N Nel	N36[1]	C	13.2	122	16.04	-
				Eth + FF	13.8	122	16.87	+0.83
				Eth + V	13.9	122	16.96	+0.92
2013	Melmoth	Smith and Harris	N12[2]	C	12.11	97	11.7	-
				FF	13.09	95	12.46	+0.76
			N16[2]	C	11.91	98	11.69	-
				FF	12.39	89	11.02	-0.66
			N31[2]	C	9.25	97	9.0	-
				FF	10.87	93	10.11	+1.11
2013	Eston	G Hyslop	N12[2]	C	10.57	105	11.07	-
				V	12.84	103	13.22	+2.15
			N12[2]	C	12.53	109	13.71	
				V	13.37	106	14.22	+0.51
			N31[2]	C	10.8	103	11.15	-
				V	12.09	118 (98)[3]	14.25 (11.87)	+3.1 (+0.72)

[1]crop on annual cutting cycle, [2]crop on 18-24 month cutting cycle, [3]data in brackets - adjustment to more realistic values (see next page)

The results from the on-farm demonstration trials confirmed the key concepts of chemical ripening, which have been developed through years of scientific research. The most salient points are firstly, the substantial increase in RV% induced by the various chemical ripener treatments in all trials, which reflects the key mode of action of these chemicals in crops growing vigorously at the time of application (Table 2). In many cases the increase in RV% exceeded two percentage units, which were not confined to the more immature annual cutting cycle crops, but also observed in some of the more mature 18-24 month cutting cycle crops.

Secondly, the results illustrated that the chemical ripener treatments led to a reduction in millable cane yield in some cases, which ranged from 1-11 t/ha. It is indeed the growth inhibiting properties of ripeners, which lead to increased partitioning of sucrose towards storage in the stalk (Alexander, 1973), that explain the observed increases in RV%. In certain ripener treatments the cane yield exceeded that of the control, which highlights the variable nature of cane yield in individual fields under commercial conditions.

Thirdly, the substantial increase in RV% was in all but one isolated case more than sufficient to compensate for the cane yield loss incurred. This is indicated by the positive RV yield responses achieved in all trials except for one field under variety N16 in Melmoth, where the RV yield in the ripened section was 0.66 t/ha lower than in the control section (Table 2). The negative RV yield achieved in this case warrants further investigation.

Overall, the results demonstrated that RV yield responses in the range of 0.51-3.1 t/ha are readily achievable through the use of chemical ripeners under commercial growing conditions in well-managed, vigorously growing rainfed and irrigated crops. This translates to cost:benefit ratios in the range of approximately 4.6-28.3 in cases where the grower covered the full cost of chemical and application and even more so in cases where the milling company provided a grower subsidy on the use of ripeners. Possible savings in harvesting and transport costs in cases where cane yield was slightly reduced by the ripener treatments have not been factored into these cost:benefit ratios.

It must be noted that in some cases the benefit of ripening was inflated by the higher cane yields in the ripener treatments relative to the control. The last trial listed in Table 2 is used as an example of this. Based on actual figures, the RV yield response to Volley in variety N31 in this trial was 3.1 t/ha, partially due to the fact that cane yield in the ripener treatment was 15 t/ha higher than in the control. However, the values in brackets represent a downward adjustment to more realistic values, where a cane yield reduction of 5 t/ha below that of the control was assumed. Even with such a downward adjustment, the RV yield response was still 0.72 t/ha higher than in the control.

Grower adoption of chemical ripening

The Mpumalanga area was used in a case study to determine whether the on-farm demonstration trials in that area, and the subsequent knowledge transfer of their outcomes, led to increased grower adoption of chemical ripening. The first trial in Komatipoort was concluded in May 2010, followed by a popular press article, and regional grower days in January 2011 and March 2011, respectively. The second trial in Komatipoort was concluded in June 2012, followed by a regional grower day in January 2013 (Table 1). Ripener application in Mpumalanga during 2010 was used as a baseline to assess grower adoption in the subsequent years (2011 to 2013). Monthly cumulative ripener application (ha) was separated into three seasonal phases, namely early-season (January to May), mid-season (June to September) and late-season (October to December).

Early-season application of ripeners amounted to a cumulative year-to-date area of 17 272 ha being sprayed by the end of May 2010 (Figure 5a). Cumulative application increased by 11% (to 19 171 ha), 19% (to 20 577 ha) and 38% (to 23 892 ha) in 2011, 2012 and 2013, respectively. The early-season application rate (ha/month) in 2013 was significantly higher (see statistical table insert in Figure 5a) than during 2010 ($p<0.01$), 2011 ($p<0.05$) and 2012 ($p<0.01$). Early-season application rates during 2011 and 2012 were not significantly higher ($p>0.05$) than during 2010.

Ripener application continued during the mid-season phase (June to September) with the cumulative year-to-date area amounting to 24 045 ha by end-September 2010 (Figure 5b). Cumulative application increased by 17% (to 28 140 ha), 25% (to 29 983 ha) and 47% (to 35 271 ha) in 2011, 2012 and 2013 respectively. The mid-season application rates (ha/month) in 2011, 2012 and 2013 were all significantly higher ($p<0.01$ for all years) than during 2010 (see statistical table insert in Figure 5b).

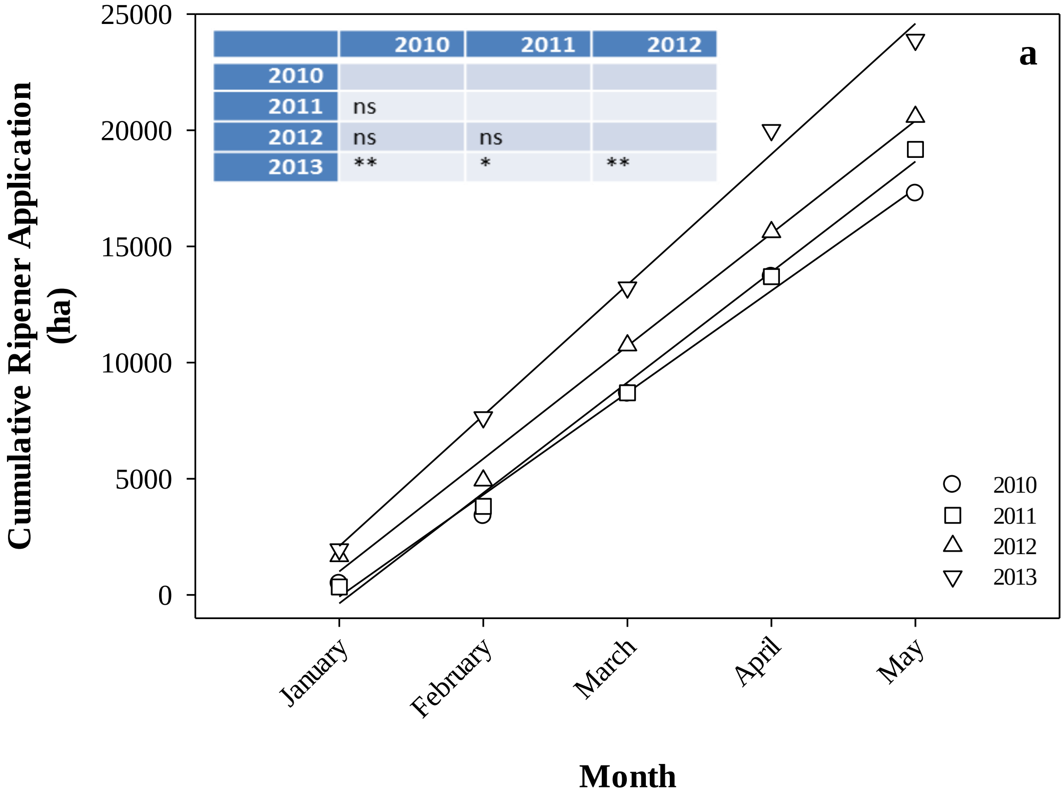
Very little ripener application took place during the late-season phase (October to December), with the cumulative annual total by end-December 2010 amounting to an area of 25 689 ha (Figure 5c), only 1 644 ha more than end-September 2010 (Figure 5b). Cumulative annual total application increased by 18% (to 30 258 ha), 20% (to 30 757 ha) and 47% (to 37 755 ha) in 2011, 2012 and 2013, respectively. No significant differences ($p>0.05$) in application rates between years were found during the late-season phase (see statistical table in Figure 5c).

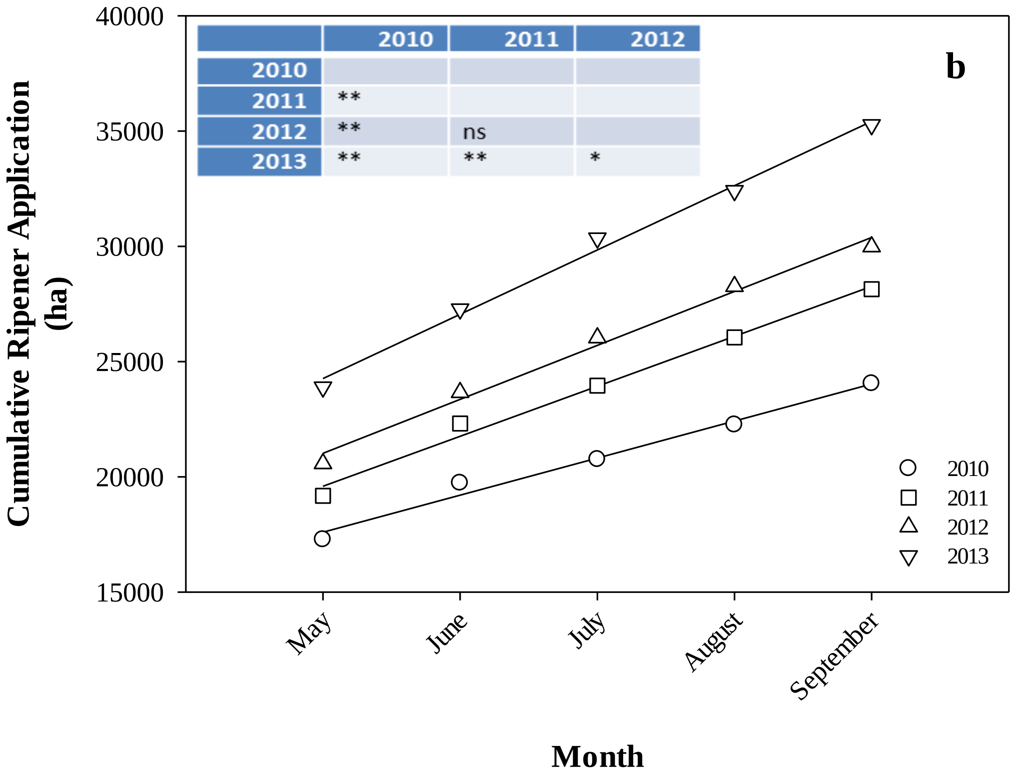
The analysis of results shown in Figure 5 a, b and c revealed a number of important points regarding ripener application practice by growers in Mpumalanga. Firstly, based on the cumulative total areas sprayed, significant adoption occurred with the area sprayed during 2013, being 47% more than during 2010. The sugar milling company TSB Sugar RSA Limited provides a subsidy of 75% to growers for the use of ripeners, but this subsidy was already in place before 2010. This suggests that the high rate of chemical ripening adoption in Mpumalanga may have been driven by the successful conclusion of the on-farm demonstration trials in Komatipoort, in conjunction with concerted knowledge transfer of trial outcomes to the growers in Mpumalanga. Secondly, based on the gradients of the fitted regressions, monthly ripener application rates during the early-season phase was the highest, followed by the mid-season and late-season phases. Thirdly, statistical analysis of the gradients revealed increased adoption of chemical ripening both during the early and mid-season phases, but not during the late-season phase.

Current SASRI recommendations state that chemical ripener use during the early and late-season phases, but not the mid-season phase, is advantageous. Many Mpumalanga growers, however, believe that ripeners are also effective during the mid-season phase because of the relatively mild winters and availability of irrigation water in their region. The demonstrated increase in mid-season adoption therefore certainly warrants further investigation regarding the benefits of ripening during that part of the year to validate grower belief.

On the other hand, the demonstrated non-adoption during October to December clearly emphasises the point that an effective and safe ripener for late-season use is still lacking. Growers are understandably extremely risk averse towards the use of Fusilade Forte (and generics) during the late-season, because of the serious negative consequences of carrying-over ripened sugarcane in the event where high rainfall prevents harvesting of these crops in the current season. Ethephon (and generics), which would be a much safer option, unfortunately lacks the efficacy to ripen the inherently more mature late-season crops (van Heerden *et al*., 2013). However, in the short-term future a third ripener, trinexapac-ethyl

(Moddus™) will be registered for use in the South African industry (van Heerden, 2013). Moddus holds much promise for use as an effective and safe late-season ripener, and the adoption analysis conducted in this case study, emphasises late-season ripening as an important focus area for research in future.





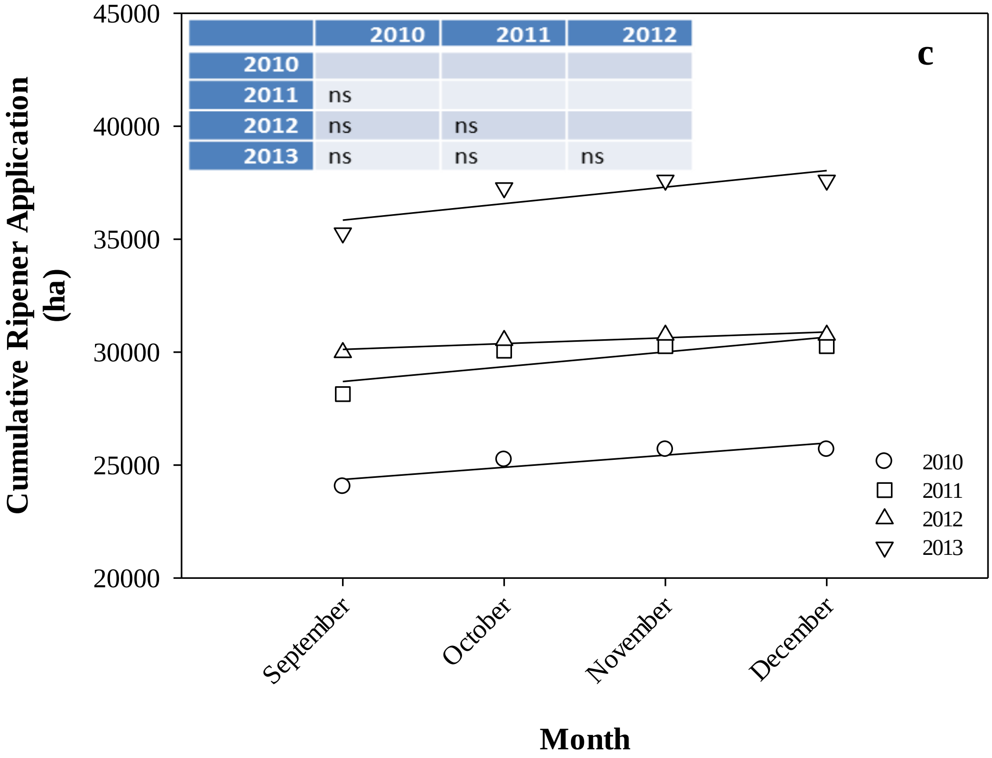


Figure 5. Monthly cumulative ripener application (ha) in Mpumalanga during 2010 to 2013. Each year was separated into three seasonal phases, namely early-season (a), mid-season (b) and late-season (c), and linear regressions fitted to these values. The gradients of these regressions represent ripener application rates (ha/month) within each seasonal phase. The significance of the gradient of each year against all other years was determined at the p<0.05 (*) and p<0.01 (**) levels (table insert in each figure). ns = not significant (p>0.05).

Conclusions

This paper elaborated on the establishment of grower-extensionist-researcher partnerships designed to demonstrate to growers the benefits of ripening well-managed, vigorously growing annual and longer cutting cycle crops under full commercial production conditions. The results obtained in 11 on-farm demonstration trials showed that RV yield responses in the range of 0.51-3.1 t/ha are achievable under commercial conditions. These substantial benefits were demonstrated in both annual and longer cutting cycle crops. The only exception was one trial under variety N16 in Melmoth, where the RV yield in the ripened section was lower than in the control. This anomaly will be investigated further. The Mpumalanga region was used in a case study to determine how these demonstration trials, and knowledge transfer of their outcomes, influenced grower adoption. This case study provided concrete evidence supporting significant adoption, as reflected by an increase of 47% in the area sprayed with ripeners between 2010 and 2013. Statistical analysis revealed increased adoption of chemical ripening both during the early and mid-season phases, but not during the late-season phase. This investigation revealed important focus areas for future research that could be satisfied by establishment of similar grower-extensionist-researcher partnerships. These focus areas include promotion of late-season ripening with trinexapac-ethyl (Moddus), further investigations on the benefits associated with the ripening of longer cutting-cycle crops, and validation of grower belief regarding the benefits associated with mid-season (winter) ripening in certain parts of the industry. Finally, the Mpumalanga case study emphasised the value of having access to accurate historic field data pertaining to crop management practises, which enabled a rigorous analysis of grower adoption trends.

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