YIELDS AND ESTIMATED ECONOMIC RETURNS FROM USING ETHEPHON TO SUPPRESS FLOWERING IN ANNUALLY HARVESTED SUGARCANE

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Abstract

When sugarcane flowers, vegetative growth is terminated and this can lead to yield losses. Applied ethephon disrupts the flowering process, thereby potentially mitigating the effects of flowering. The results from using ethephon to suppress flowering in several experiments are reported. They show that ethephon could have large negative effects on yields of annually harvested crops when there is no flowering. Collated results from publications show a linear relationship between sucrose yield response to ethephon and flowering incidence. Probabilities of flowering incidence were calculated, using criteria derived from historical temperature and water status. Probabilities, for example, of profuse flowering were 0.33 for northern irrigated crops and less than 0.1 for moderate flowering in dryland crops. The economic benefits from applying ethephon either (i) as a regular annual treatment or (ii) only when flowering is predicted, were calculated using specific assumptions. The analysis showed that in irrigated crops annual applications would be worthwhile for moderate and profuse flowering cultivar types. Shy flowering cultivars would require applications to be made only in years when flowering is predicted. These benefits can be realised only when ethephon is registered for flower suppression. In dryland cane regular ethephon applications are not justified when crops are harvested annually. In these crops, the benefits from targeted applications would be small thus the research needed to accurately predict rainfall and temperatures for February each year, may not be justified. These results need to be interpreted with caution because several factors, listed in the text, have not been considered in the analysis.

Keywords: sugarcane, flowering, ethephon

Introduction

Flowering in sugarcane in South Africa takes place when conditions are favourable for initiation, and it is therefore a sporadic event. It has been shown that, when flowering is profuse, yield losses may be experienced after October in high potential annually harvested crops. The losses could be even greater in crops harvested during the second year of growth. It has been demonstrated that ethephon disrupts the flowering process and that there may be substantial gains from its use in high potential irrigated crops (Hardy *et al*., 1986). However, it is also possible that ethephon may cause yield losses in low yielding crops when flowering does not occur.

Flowering starts when the stalk apex forms a flower primordium that terminates vegetative growth. At this time, about four internodes have been formed in the apex and three or four more internodes are still elongating. Once all these internodes have developed fully and no new leaves and internodes are formed, the ceiling on cane yield is set. The extent of the yield loss from flowering is related to the potential growth that may be realised between the period that vegetative growth stops and the crop is harvested. Stalks eventually deteriorate because leaves die and are not replaced. In some instances, axillary buds on nodes below the pedicle develop into side-shoots, which become the source of photosynthate that prevents rapid deterioration of stalks as the uppermost leaves die (Julien *et al*., 1980). In comparison, non-flowered stalks, which may have been smaller at the time of initiation, will then maintain their vigour and grow larger than the flowered stalks.

In tropical environments, such as the Sudan (13º 05' N) and Malawi (12º 30' S), sugarcane flowers every year and it is common that 80 to 100% of the stalks produce flowers. In sub-tropical environments such as South Africa (25º 22' to 30º 30' S) flowering occurs sporadically and flowering incidence is not as high. Flowering is most often observed along the foothills of the Lebombo mountains in Mpumalanga and less so on the Pongola flood plains. Along the coastal areas of KwaZulu-Natal flowering may occur annually in isolated areas, but is generally a sporadic event and often not profuse. It is seldom that more than 60% of the stalks produce flowers in South Africa.

Flowering in sugarcane is generally thought to be induced when daylength shortens below 12 h 30 m in autumn, provided the shoots are old enough to respond to the flowering stimulus (Ethirajan, 1987). The strongest stimulus to induce flowering is associated with night temperatures of 23ºC and day temperatures of 28ºC (Heinz, 1987). Coleman (1968) suggested that daily maximum temperatures as high as 48ºC had no effect on flowering. More recently Heinz (1987) has stipulated that flowering is adversely affected by temperatures above 31ºC. A minimum of 15 inductive cycles (day/night) are required to initiate flowers. When minimum (night) temperatures decline below a critical level of about 18ºC for more than 10 days during the initiation period, flowering is inhibited in Hawaii (18-21ºN), while in Louisiana (30ºN) six nights of these non-inductive temperatures will prevent flowering (Coleman, 1968).

In Zimbabwe, Gosnell (1973) observed 26 and 48% fewer flowers in fields that were irrigated using pan factors of 0.53 and 0.37, respectively. Similarly, July harvested fields that were dried off from March by reducing irrigation to 0.5 of evaporative demand, had 54% fewer flowers than fields that were not dried off. Therefore, flowering may also be reduced when crops are subjected to moisture stress during the photo inductive period.

Large benefits to suppressing flower initiation with ethephon have been achieved in the Sudan (Hardy *et al*., 1986), Hawaii (Moore and Osgood, 1986) and in Nigeria (Fadayomi *et al*., 1995). Field observations by Humm (2001) suggest that these gains may be achieved in crops harvested more than six months after flower initiation in South Africa. Some of the many countries in which ethephon has been used on a commercial scale are Hawaii, Brazil and Malawi (Hardy *et al*., 1986). Coleti *et al*. (1986), working in Brazil, found no benefit from ethephon when flowering incidence was 36%. In South Africa (Donaldson, 1996) and Swaziland (personal communication1) no benefit could be demonstrated from ethephon on variety N23, even when the incidence of flowering was 45-48%. Furthermore, it was shown that yields of N17 treated with ethephon were lower than both the untreated cane (flowering incidence of 37%) and cane that had not flowered. The results of the study by Donaldson (1996) were confounded by damage caused by the stalk borer *Eldana saccharina* Walker (Lepidoptera: Pyralidae).

Several studies have shown that flowering affects cultivars differently (Julien and

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[1] Duncan Butler (2004), Swaziland Sugar Association Technical Services

Soopramanien, 1976; Long, 1976; Nuss and Maharaj, 1992; Donaldson, 1996). In Malawi the use of ethephon to suppress flowering was discontinued in 1986 because of variable results, and it was considered that the alternative was to find good late season cultivars that would not need to be sprayed with ethephon (Whitbread, 1991).

It is evident from the reviewed literature that the benefits from using ethephon may vary widely and that this may be related to the incidence of flowering, cultivar and age at which the crop is harvested. Based on the information cited in the literature, the effects associated with flowering and ethephon treatment on yield can be postulated as illustrated in Figure1. In irrigated cane (Figure 1A), there are small gains in sucrose yields after flower emergence, due to increased partitioning of biomass to sucrose, while ethephon treated cane exhibits yield loss due to internode stunting. The negative effects of ethephon diminish with age, as stunted internodes make up a smaller portion of stalks. The negative effects of flowering become evident after October and are amplified with age (Figure 1B) when growth stops in flowered stalks, whereas non-flowered and ethephon treated stalks continue growing.

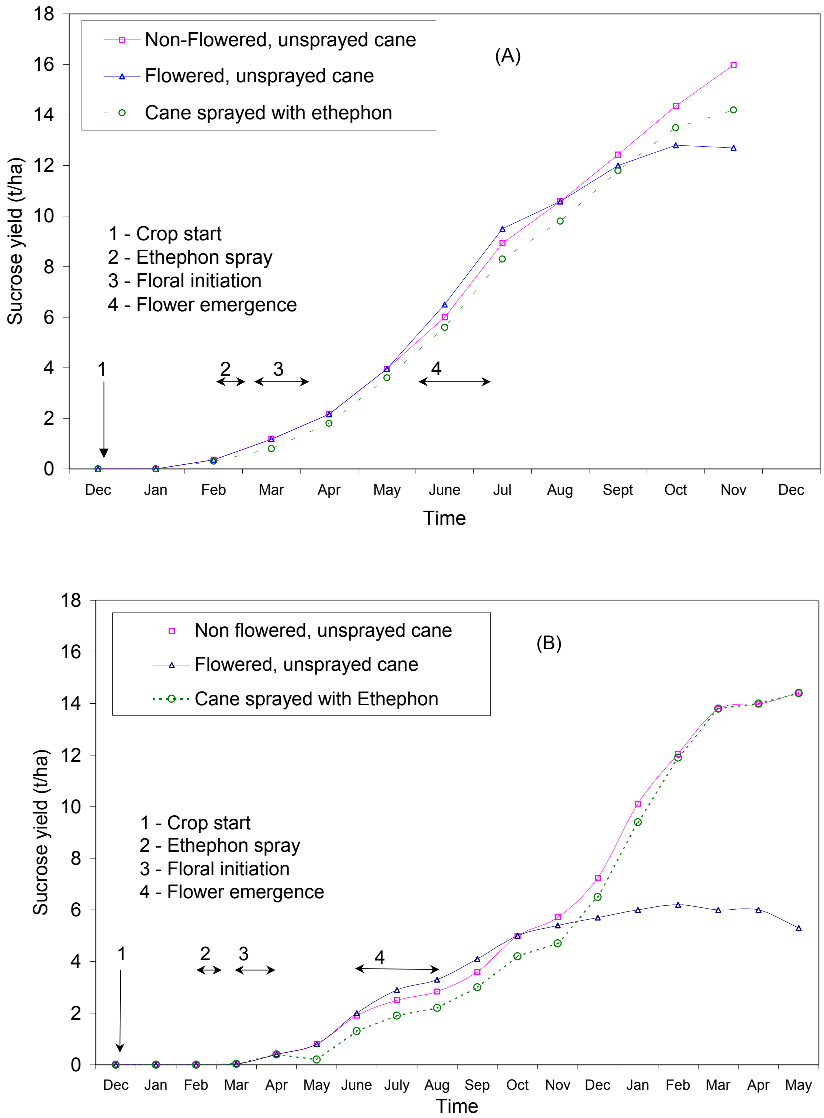

Figure 1. Expected progression of sucrose yields of three hypothetical crops started in December up to 12 months under irrigation (a), and up to 16 months under dryland conditions (b).

As shown in Figure 1, the farmer is faced with three possible scenarios, depending on whether flowering occurs and whether ethephon is applied or not. Substantial benefit could be gained if cane is treated with ethephon when flowering is profuse, while losses are likely (especially at 12 months of age) when cane that would not have flowered, is treated with ethephon. The decision to treat cane with ethephon requires information on the magnitude of the benefit or loss and the likelihood of its occurrence. It was therefore deemed important to determine probabilities of flowering in the South African sugar industry, and to analyse the economic benefits of flower suppression with ethephon.

The aim of this study was to use existing and new experiment data to investigate yield responses to flower suppression by the application of ethephon, and to analyse the economic benefits of different flower suppression strategies for selected sites in South Africa. The strategies were (i) applying ethephon regardless of whether flowering was likely or not, and (ii) applying ethephon only when flowering was likely to occur.

The approach followed was to:

- establish the relationship between yield response to ethephon and flower incidence
- establish the probability of flowering occurring at selected sites for different soils and cultivar types
- calculate the economic benefit from two flower suppression strategies for each situation based on this information.

Method

The study consisted of the following main parts:

- The results from the experiments reported in this study together with those reported in the literature were used to investigate the association between responses to ethephon and incidence of flowering.
- The conditions that represent weak, moderate and strong stimuli were used to formulate rules that were applied to historical weather data to estimate flowering.
- The economic returns were then calculated for profuse, moderate and shy flowering cultivars for two management strategies based on the frequencies of conditions that govern the flowering stimulus.

Yield response to ethephon application

The relationship between yield response to ethephon application and flowering intensity was established by reviewing data from the literature as well as data presented in this study. A linear regression was fitted to sucrose yield response (expressed as a percentage of that of the unsprayed control) versus flower incidence measured in the unsprayed control.

Experiment details

Data from four dryland (exp. 1 to 4) and three irrigated experiments (exp. 5 to 7) are reported here. Experiment 1 was conducted to compare the effect of two rates of ethephon. Experiments 2 to 4 were also conducted on commercial fields to establish the effect of ethephon on flowering and yield in carry-over cane aged 14 to 18 months. Only one out of five crops from these experiments was carried over. The other experiments were terminated at approximately 12 months because of the high incidence of *E. saccharina*.

The irrigated experiments were conducted to assess the effects of ethephon on a range of cultivars, which were harvested annually. Details of the experiments are given in Table 1.

Table 1. Details of crop class, available water holding capacities of soils (TAM), cultivars, crop start and end dates, and ethephon application dates of experiments.

Experiment code, crop class	Site, location and altitude	TAM (mm)	Cultivar	Crop cycles	Age at harvest (months)	Date sprayed
1, Ratoon 1	Finningely 30º06'S, 30º40'E 60 m	65	N12	03/11/00 - 6/11/01	12.1	23/02/01
2, Ratoon 1 2, Ratoon 2	Ellingham 30º19'S, 30º42'E 139 m	63	N12	07/11/00 - 27/11/01 27/11/01 - 24/4/03	12.7 16.9	23/02/01 25/02/02
3, Ratoon 1 3, Ratoon 2	Ellingham 30º19'S, 30º42'E 139 m	70	NCo376	07/11/00 - 29/11/01 29/11/01 - 07/11/02	12.7 11.9	23/02/01 25/02/02
4, Ratoon 1	Ellingham 30º19'S, 30º42'E 139 m	70	N16	07/11/00 - 29/11/01	12.7	23/02/01
5, Ratoon 3	Pongola 27º24'S, 31º35'E 308 m	400	NCo376, N14, N19, N24, N25, N26, N28, N30	01/12/00 - 04/12/01	12.1	15/02/01
6, Ratoon 2 6, Ratoon 3	Pongola 27º24'S, 31º35'E 308 m	400	NCo376, N14, N19, N25, N26, N28, N30, N32	06/12/00 - 06/12/01 06/12/01 - 02/12/02	12.0 11.9	15/02/01 26/02/02
7, Plant	Komatipoort 25º33'S, 31º57'E 170 m	80	N14, N19, N25, N26, N30, N32, N36, N38, 92F3639	17/10/01 - 12/11/02	12.8	21/02/02

Probability of flowering

The probability of weak, moderate and strong flowering stimuli occurring at six sites where flowering is known to occur, were calculated using long term weather data (see Table 2). This was done by assessing temperature and soil water status during the flower initiation window period. The initiation period was taken as the 22 days following the day on which daylength started declining from 12 h 30 m (Coleman, 1968). Rules relating to the influence of temperature and crop water status were derived from the literature and were applied to daily weather data (rainfall, reference evaporation and temperature) for each site.

The factors for calculating the incidence of flowering were (i) the number of days in the initiation period when minimum temperature dropped below 18ºC (DT) and (ii) the number of days in the initiation period that soil water content dropped below 50% of capacity (DW). The threshold levels for weak, moderate and strong flowering stimuli were set as 9, 5 and 2 days for DT, (derived from Coleman, 1968) and 10, 5 and 2 days for DS (derived from Gosnell, 1973). Both factors had to be favourable (above the given threshold) for flowering to occur.

Table 2. Dates on which daylength equals 12 h 30 m for six sites, number of years of recorded weather data and long term mean annual cane yield potential of December crops for a soil TAM of 80 mm estimated by the Canesim model (Singels *et al*., 1999) and average RV content of fresh stalk mass for the period 2001 to 2003. Irrigated and dryland conditions are indicated by the letters i and d, respectively.

Site (weather station)	Latitude, longitude and altitude	Start of initiation period	No. of data years	Yield potential (t/ha)	RV content (%)
Komatipoort (Tenbosch)	25º29'S, 31º55'E 200 m	28 February	30	148 (I)	11.5
Malelane (Mhlati)	25º29'S, 31º31'E 301 m	28 February	32	149 (I)	11.9
Pongola	27º24'S, 31º35'E 308 m	2 March	37	143 (I)	12.1
Mtubatuba	28º27'S, 32º13'E 40 m	3 March	37	127 (I) 58 (D)	11.5 11.5
Mount Edgecombe	29º42'S, 31º02'E 96 m	4 March	77	61 (D)	10.9
Sezela	30º25'S, 30º40'E 15 m	5 March	28	68 (D)	11.2

For example, considering the minimum temperature criterion (DT) alone, a strong flowering stimulus would be signalled by less than two days of cold stress, a moderate stimulus by two to four days of cold stress and a weak stimulus by five to eight days of stress. More than eight days of stress (DW) would neutralise any flowering stimulus.

Cultivars were grouped according to their propensity to flower (see Appendix 1). It was assumed that all cultivars would flower when the stimulus was strong, while only cultivars with a high and moderate propensity would flower when the stimulus was moderate, and only cultivars with a high propensity would flower under a weak stimulus.

Soil water content was calculated using a generic water budget for fully canopied cane, similar to the method used by Singels *et al*. (1999). Soil water content for irrigated scenarios never dropped below the critical value and was therefore always favourable for flowering. The analysis was conducted for soils with available water holding capacities (TAM) of 50, 80, 110 and 140 mm.

Economic returns from suppression strategies

The benefit of different flower suppression strategies was estimated by calculating the long term economic return of each strategy. The strategies were (i) regular application regardless of environmental conditions (E1), and (ii) targeted application only when soil water status and temperature suggested that flowering was likely (E2). The analysis was carried out for shy, moderate and profuse flowering cultivars.

Economic return (ER in R/ha) of strategy E for a given cultivar in a given year was calculated as the value of the RV yield response (Ydiff in t/ha) minus the cost of the suppression measures (R177.50/ha):

$$ER_E = RVprice.Ydiff_E - Cost_E \qquad (1)$$

$$Ydiff_E = dY_E / 100.Y \quad (2)$$

$$Y = CY.Rvperc \quad (3)$$

where dY_E is the percentage RV yield response of flower suppression strategy E, Y is the long term mean RV yield of untreated cane, CY is the long term mean annual cane yield for NCo376 as calculated by the Canesim model and RVperc is the mill average RV% cane of the last three years for December crops (see Table 2). The RV price was taken as R1347.82/ton.

Two possible alternatives of yield response to ethephon were considered: (i) a positive response of 20% when conditions were favourable for flowering (temperature and soil water status thresholds for the given cultivar type were satisfied), and (ii) a negative response of 10% when conditions prevented flowering (either temperature or soil water status thresholds for the given cultivar type were not satisfied). These cardinal response values were based on the relationship obtained from the data reviewed in Figure 2.

Results

Yield response to ethephon application: field experiments

Few flowers were seen in any of the experiments during the study period and therefore the results from these experiments are relevant only to conditions of no flowering.

Favourable temperatures during both years of the dryland experiments (exp. 1 to 4) were neutralised by periods of water stress (see DW in Table 3). The two rates of ethephon tested in experiment 1 had the same negative effect on yields, and the results shown in Table 3 are the mean effect of 1.0 and 1.5 L/ha ethephon. The significant reductions in annually harvested N12 (exp. 1 Ratoon 1 and exp. 2 Ratoon 1) were not evident when this cultivar was harvested at 16.9 months (exp. 2 Ratoon 2). This is because the part of the stalk which is stunted by ethephon becomes a smaller fraction of larger, heavier stalks when crops are harvested at an older age. Yields of N16 (exp. 4 Ratoon 1) were reduced by 1.6 t/ha ERC (24.6%), but the effects were not statistically significant (P=0.05). In an adjacent field, NCo376 (exp. 3 Ratoon 1) appeared to be affected less than N16.

During the initiation periods of experiments 5 and 6 at Pongola, the seven and 10 nights of low temperature, respectively, would have produced a weak flowering stimulus. Only N14, being a profuse flowering type, would have been expected to flower in these experiments, but did not. The only significant effect in experiment 5 was on N28, where ERC yields were reduced by 16.8%. Yields of N32 and N19 were also reduced significantly in exp. 6 ratoon 2 and exp. 6 ratoon 3, by 18 and 14.2%, respectively. All other responses in experiment 6 were not significant.

Despite favourable temperatures for flowering in experiment 7 at Komatipoort, very few flowers developed, even in cultivars with moderate to high propensity for flowering. Gosnell (1973) observed a reduction in the amount of flowering with increasing amounts of applied nitrogen. Experiment 7 at Komatipoort was sited on virgin soils and it is likely that high levels of nitrogen were being mineralised during the experiment and that the absence of flowers was due to the crop being supplied with high amounts of nitrogen. In this experiment, ERC yields of N14, N25, N32, N36 and N38 were reduced significantly. Ethephon had no significant effect on yields of N19, N26, N30 and 92F3639.

Table 3. Number of unfavourable days for flowering due to temperature (DT) and water stress (DW) during flower initiation period and ERC yield response. Significant responses are listed per cultivar and indicated by an asterisk (p=0.05), while insignificant responses are averaged over cultivars.

Experiment code	Crop class	Variety	DT	DW	ERC (t/ha)	Response (t ERC/ha)	Response (% of control)
1	Ratoon 1	N12	4	19	5.4*	**-1.2***	**-18**
2	Ratoon 1	N12	4	19	6.1*	**-1.6***	**-21**
3	Ratoon 1	NCo376	4	19	8.4	-0.3	-3.5
2	Ratoon 2	N12	0	14	10.0	+1.0	+11
3	Ratoon 2	NCo376	0	14	8.6	-0.4	-4.4
4	Ratoon 1	N16	4	19	4.8	-1.6	-24.6
5	Ratoon 4	Various N28	7	0	9.63 9.42*	-0.50 **-1.31***	-4.9 **-16.8**
6	Ratoon 2	Various N32	7	0	12.34 11.79*	-0.14 **-2.59***	-1.1 **-18.0**
6	Ratoon 3	Various N19	10	0	13.49 10.20*	-0.44 **-1.59***	-3.3 **-14.2**
7	Plant	Various N14 N25 N32 N36 N38	1	0	19.78 20.35* 19.55* 19.35* 20.55* 18.15*	+0.2 **-2.25*** **-1.8*** **-3.05*** **-5.05*** **-4.95***	+1.0 **-10.0** **-8.4** **-13.6** **-19.7** **-21.4**

Relationship between yield response to ethephon and flowering

Widely different yield responses to ethephon application are reported in the literature. In an attempt to draw some meaning from this, yield responses were plotted against reported incidence of flowering in the untreated controls. Results of both irrigated and dryland crops reported for Hawaii (Moore and Osgood, 1986), the Sudan (Hardy *et al*., 1986), Malawi (King, 1983), Brazil (Coleti *et al*., 1986), Swaziland (personal communication[1]) and South Africa (Donaldson, 1996) are presented in Figure 2.

The trend in Figure 2 shows that, generally, the yield response to ethephon increases as flowering incidence increases. This relationship could be explained by the postulated physiological responses depicted in Figure 1. The relationship depicted in Figure 2 suggests that when flowering is profuse (say 60% or more) the sucrose yield response to ethephon application would exceed 15%. It also suggests that yield reductions can occur when flowering incidence is less than about 15%.

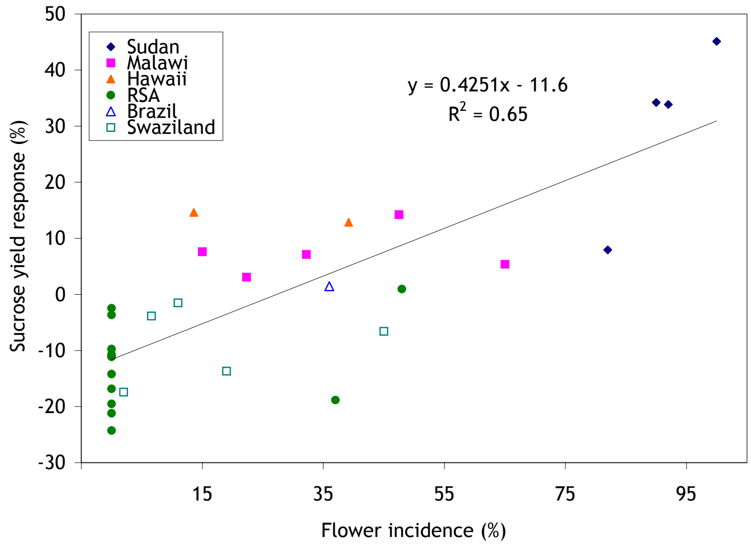

Figure 2. Relationship between sucrose yield response to ethephon (expressed as % of untreated control) and incidence of flowering (% flowered stalks) of crops in the Sudan (Hardy *et al*., 1986), Malawi (King, 1983), Hawaii (Moore and Osgood, 1986), Brazil (Coleti *et al*., 1986), Swaziland (personal communication[1]) and South Africa (Donaldson, 1996; this study). A linear regression was fitted to the data points.

Probability of flowering

Calculated flowering probabilities are given in Table 4. The probabilities of flowering are highest in irrigated areas where stress is eliminated by irrigation water and only temperature has a controlling influence on flower initiation. Mtubatuba and Komatipoort were shown to have the highest probabilities, and on average every third year the flowering stimulus would be strong. In addition to this, at Mtubatuba there would be at least a weak stimulus every year. At Pongola and Malelane the probabilities of various strengths of stimuli were shown to be lower than at Komatipoort and Mtubatuba. The effect that stress in the dryland sites has on reducing the probabilities of flowering stimuli can be seen by comparing the probabilities in Table 4 of the irrigated and dryland sites at Mtubatuba. The analysis for soils with different TAMs (data not shown) revealed that TAM had little impact (<5%) on the relatively low probabilities at the dryland sites. Therefore, the economic analysis that follows is based on a soil with a TAM of 80 mm.

Table 4. Frequency (expressed as a fraction) of occurrence of weak, moderate and strong flowering stimuli at six sites for a soil with a TAM of 80 mm.

Site	Weak stimulus	Moderate stimulus	Strong stimulus
Irrigated:			
Komatipoort	0.90	0.70	0.33
Malelane	0.75	0.41	0.22
Pongola	0.78	0.46	0.19
Mtubatuba	1	0.84	0.32
Dryland:			
Mtubatuba	0.16	0.03	0
Mount Edgecombe	0.16	0.06	0.04
Sezela	0.21	0.07	0.04

The probabilities in Table 4 could also be interpreted as an indication of how often cultivars with different propensities will produce flowers. For example, in years of a strong stimulus all cultivars will flower. A moderate stimulus will induce flowering in cultivars with a high to moderate propensity, and a weak stimulus will only induce flowering in the cultivars with a high propensity to flowering. Appendix 1 shows the 'propensity to flower' rating of the current commercial cultivars in South Africa. Generally, cultivars with a high rating are relegated to annual early and mid-season cycles to avoid the possible deleterious effects of flowering in crops harvested after October.

Economic returns from suppression strategies
Estimated economic returns from the two suppression strategies are given in Table 5.

Results from Table 5 suggest that:

- Under irrigated conditions and for cultivars with a medium to high propensity for flowering, regular ethephon applications seem to produce worthwhile returns.
- Under irrigation and for cultivars with a low propensity for flowering, targeted ethephon applications are preferable to regular applications.
- Regular ethephon application on any cultivar type for all dryland areas appears not to produce positive economic returns, while the benefits from targeted applications are small.
- Accurate rainfall and temperature predictions in the first weeks of February are needed to reduce the risk of using ethephon. However, it is doubtful whether the potential return of approximately R300 justifies high risk research to produce accurate predictions.

The analysis (based on extrapolation only) suggests that regular ethephon application can negate the approximately 3 t/ha RV loss from flowering in irrigated cultivars that flower profusely. This supports the existing South African Sugar Association Experiment Station breeding strategy of not discriminating against high yielding cultivars with a high propensity to flowering.

Table 5. Estimated long term economic return (R/HA) from regular (E1) and targeted (E2) applications of ethephon on three cultivar types, namely low (C0), medium (C1) and high (C2) propensity to flower, for four irrigated sites and three dryland sites, assuming a soil TAM of 80 mm.

Cultivar type	C0		C1		C2	
Strategy	E1	E2	E1	E2	E1	E2
Irrigated sites:						
Komatipoort	- 200.51	+1459.85	+2353.20	+3096.44	+3733.59	+3981.40
Malelane	- 990.27	+1012.77	+ 372.31	+1887.43	+2810.61	+3452.61
Pongola	-1176.66	+ 849.25	+ 705.48	+2056.09	+2936.16	+3486.41
Mtubatuba	- 256.33	+1204.50	+2818.08	+3161.80	+3764.05	+3764.05
Dryland sites:						
Mtubatuba	-1071.33	0	-990.89	+ 48.30	-642.29	+257.63
Mt Edgecombe	- 964.59	+64.45	-910.93	+ 96.68	-642.60	+257.82
Sezela	-1083.27	+75.24	-990.63	+131.67	-558.33	+395.02

Discussion

The results reported here should be interpreted with caution as there are a few factors that were not considered in this study. Temperature at a meso-scale is highly dependent on local topography, and the positioning of the weather stations used in this study might not allow extrapolation to all areas within the region. This is particularly the case for depressions and valleys. Another important factor is age at harvest. The present analysis has focussed on annually harvested crops. The results from one experiment (exp. 2 ratoon 2) suggest that, as stalk mass increases with age, the ethephon-stunted section of stalk becomes a smaller fraction of the total stalk mass and consequently the adverse effects of ethephon become less significant (as shown in Figure 1B). The effects of stress after flower initiation or after the application of ethephon have also not been considered in this analysis. This, together with the effects on carry-over crops, may be an area that requires further research.

The economic analysis was based on the arbitrarily assumed increase in yield from ethephon of 20% when conditions favour flowering and a reduction in yield of 10% when no flowering was indicated. This on/off trigger is probably an over-simplification of reality. It would also be more realistic to assume that there would be a range of flowering incidence in different flowering types when conditions are most favourable, rather than assuming that all types would flower equally. Economic returns using this approach can be calculated easily with the present framework when data on the incidence of flowering and responses to flower suppression become available. Cultivar differences in response to ethephon were also ignored. The economic analysis could therefore be refined in future by accommodating cultivar differences and a wider range of permutations of yield effects from ethephon.

The present analysis shows that the probability of flowering in dryland situations is very low. Therefore, regular applications of ethephon are not justified for dryland crops. However, regular applications in irrigated crops harvested in November/December are justified on moderate to profuse flowering cultivars. Additional small benefits could be gained from targeting applications in late harvested fields under these conditions. However, the application of ethephon as an 'insurance' against a possible extension of the milling season into December cannot be justified, given the reductions in yield that will occur in October harvested crops. The use of ethephon can be recommended only once it has been registered. The present practice of harvesting flowered cane well before December should therefore be encouraged to prevent losses when the incidence of flowering is moderate to high.

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APPENDIX 1

Rating of cultivar propensity to flower: High (H), Moderate (M), Low (L)

Cultivar	Propensity to flower
N12	M
N14	H
N16	L
N17	H
N19	L
N21	L
N22	M
N23	H
N24	L
N25	L
N26	L
N27	H
N28	L
N29	H
N30	M
N31	M
N32	M
N33	L
N35	M
N36	M
N37	L
N39	L
N40	M
N41	L
NCo376	M
CP66/1043	L

Source: Variety Information Sheets 13.1 to 13.26. South African Sugar Association Experiment Station, P/Bag X02, Mount Edgecombe, 4300, South Africa.