THE EFFECT OF RIPENERS ON THE CCS OF 47 SUGARCANE VARIETIES IN THE BURDEKIN

By

LISA McDONALD[1,2], TERRY MORGAN[1,2] and PHIL JACKSON[1,3]
[1]*CRC for Sustainable Sugar Production,* [2]*CSR Sugar Ltd,* [3]*CSIRO Plant Industry*

Abstract

There is little information about the response of current Australian sugarcane varieties to ripeners commonly used overseas. Two experiments in the Burdekin examined the response of 47 sugarcane varieties to five ripener treatments: Ethrel plus Fusilade (E+F), Fusilade alone (applied at two rates), Verdict and glyphosate. There were generally positive responses in CCS to both glyphosate and E+F eight weeks after application, and varieties differed in their degree of response. There was no significant response to Fusilade alone at a lower rate or Verdict. The glyphosate treatment significantly increased the CCS of 20 varieties, some by over three units and E+F significantly increased the CCS of 15 varieties. In another experiment, Fusilade applied at a higher rate significantly increased the CCS of all varieties tested three weeks after application but not 15 weeks after application. At this time, Fusilade reduced the CCS of three varieties, and generally had a negative effect on cane and sugar yield. The study showed that glyphosate and E+F can significantly increase the CCS of some economically important varieties at the start of the harvest season.

Introduction

Low CCS at harvest reduces profitability for growers and the sugar industry as a whole. CCS increases in sugarcane through a process of ripening and when stalk dry matter content increases. Ripening occurs when assimilates from photosynthesis are stored in the stalk as sucrose (Van Dillewijn, 1952) and is a naturally occurring process that can be enhanced by inducing mild water stress (Roberston *et al.*, 1999) or with chemicals known as ripeners.

Ripeners are used to increase sucrose content at harvest in many overseas countries where the harvest season length is generally longer than in Australia. South Africa, Guyana and Swaziland use Ethrel, Fusilade Super (fluazifop) and Gallant Super (haloxyfop—sold as Verdict™ in Australia) as ripeners for early and late season cane. Glyphosate is used in Hawaii, Mauritius, Florida and Louisiana, and Moddus™ (trinexapac-ethyl) is used in Brazil.

Consideration of an earlier start to the harvest season and the negative effect that could have on CCS (McDonald and Wood, these Proceedings) has rekindled interest in ripeners in Australia. There has been research on a range of ripeners in Australia, recently reviewed by McDonald *et al.* (2000); but only Ethrel has been registered for use as a ripener. CCS response to Ethrel is limited, and availability of a wider range of effective chemicals would broaden the situations where ripeners could be used.

Factors affecting response to ripeners are not well understood, but are generally believed to be dependent on variety (Clowes and Inman-Bamber, 1980; Dusky *et al.*, 1986; Millhollon and Legendre, 2000) and the state of the crop prior to and afte r application (Donaldson 1999).

There are many varieties available to growers in the Australian sugar industry and there is little information on how Australian varieties respond to the ripeners that are used overseas. This information is needed as a first step towards assessing the commercial potential of ripeners in Australia.

This study measured the response of 47 Australian varieties to four ripener treatments in two experiments. The four ripener treatments used in this study were chosen from studying the international literature. Two of the most successful ripener treatments used in the South African sugar industry are Fusilade, used alone and in combination with Ethrel (McDonald *et al.*, 2000). The chemical Gallant Super, known in Australia as Verdict, has also recently been registered for

KEYWORDS: Ripeners, Sugarcane Varieties, CCS, Fusilade, Glyphosate, Ethrel, Verdict.

use there. These three ripener treatments were included in experiment 1 along with glyphosate, which is currently used successfully in a number of sugar growing countries including Hawaii. The rates used were chosen from the midrange of rates recommended for the use of each particular chemical. Experiment 2 examined the response of Fusilade applied at a higher rate than used in experiment 1.

Methods

Both experiments were located on Kalamia Estate, Ayr (19.32°S, 147.25°E). A Campbell Scientific climate station recorded climate conditions throughout 1999 and 2000. Rainfall for the 2000 season is presented in Figure 1.

Experiment 1

The experiment was planted on 11/8/99. A split plot design with five replicates was used. Ripener treatments were applied to whole plots and 43 varieties were planted into subplots. Each plot of a variety was 1 row × 4 m. The trial was managed according to local industry recommendations for commercial cane and was irrigated when required throughout the experiment.

The ripener treatments were: control (unsprayed), Weedmaster 360™ (360 g/L glyphosate isopropylamine salt @ 1 L/ha), Fusilade™ (212 g/L fluazifop-P butyl @ 200 mL/ha), Verdict™ (513 g/L haloxyfop-R methyl ester @ 37 mL/ha) and a combination of Ethrel™ and Fusilade (E+F) where Fusilade was applied 4 weeks after Ethrel (480 g/L ethephon @ 1.5 L/ha). Ethrel was applied on 8/3/00 and all the other ripeners were applied on 7/4/00. Fusilade and Verdict treatments included the wetting agent Agral 60 at 350 mL/ha and 200 mL/ha respectively in spray solution. Spray solutions were applied at 100 L/ha using a hand-held, LPG powered, spray boom.

Samples were collected to determine pol and brix from the control and Ethrel treatments on 6/3/00 and 7/4/00 and from all treatments on 8/5/00 and 6/6/00 (4 and 8 weeks after the final ripener application). At sampling, two sound whole-stalks were collected and topped. These were fed through a small mill and the juice was analysed for brix and pol to calculate CCS (BSES 1991). A fibre value of 10.5% was used, as this was the average value determined from fibre samples collected from the experiment.

Four varieties (Q124, Q96, Q117 and Q138) were analysed for fibre and dry matter content on 8/4/00, 10/5/00 and 8/6/00. Six whole stalks were collected from each plot. These were fibrated using a Jeffco grinder and pol and brix and stalk dry matter content were measured. Fresh weight sucrose content was calculated from brix and pol (Inman-Bamber, pers. comm.) and dry weight sucrose content was calculated by dividing fresh weight sucrose content by stalk dry matter content. The dry weight percentage of soluble solids (brix% dm) was calculated by dividing brix by stalk dry matter.

Stem height of two, tagged stalks in each plot was measured from the base of the stalk to the top visible dewlap on the 23/3, 7/4 and 4/5/00 in all the plots in the first three replicate blocks. CCS data were analysed statistically for variance using the General Linear Model procedure in SAS (V6.12). A model corresponding to a split

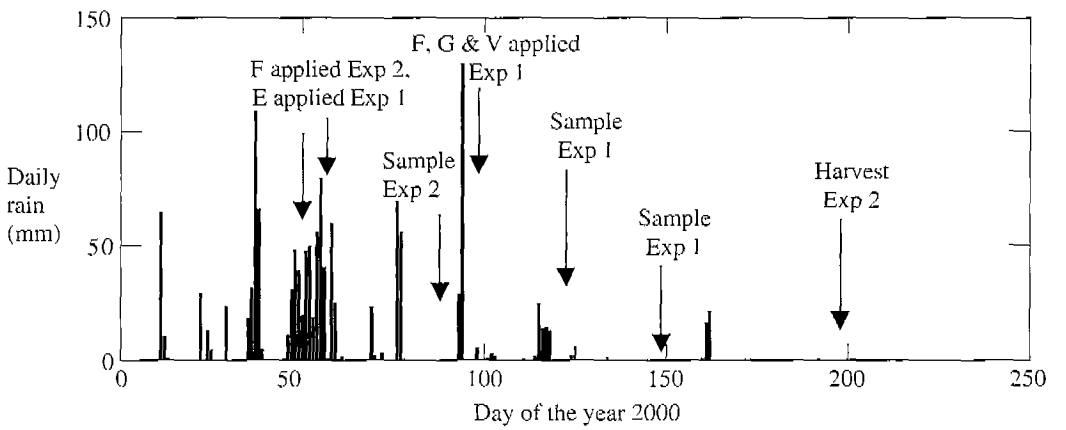

Fig. 1—Daily rainfall at Kalamia Estate from 1/1/00 to 31/7/00 showing application of F – Fusilade, E – Ethrel, G – glyphosate, V – Verdict and sampling times.

plot in space and time (Steele and Torrie, 1981) was used to compare each ripener with the control between sampling times. Each ripener treatment was compared to the control for a particular sampling time using the ANOVA procedure in Genstat™ 5 (Payne *et al.*, 1997) using a split plot design.

Experiment 2

Twenty varieties were planted into three row (1.5 m spacing), 10 m long plots in 12 randomised complete blocks on 22/4/98 at Kalamia Estate. Six blocks each were allocated to control and E+F treatments. Ethrel was applied on 25/3/99 and Fusilade on 4/5/99. The crop lodged soon after Fusilade application. The crop was harvested on 22/6/99. CCS was determined just prior to harvest from two whole, topped stalks from each plot as in experiment 1. No significant effects due to the E+F treatment were observed. Shoot emergence was measured on the following ratoon crop on 5/11/99 to ensure there were no effects of the previous ripener treatment. There was no difference in the number of shoots between control and treated plots.

The first ratoon crop was irrigated once soon after ratooning and was adequately supplied by rainfall (Figure 1) for the rest of the experiment. Ripener treatments were applied in a split plot design with a systematic arrangement of treatments according to Cochran and Cox (1957). Fusilade (212 g/L fluazifop-P butyl at 300 mL/ha plus 350 mL/ha Agral 60) was applied on 8/3/00 using a 12 row boom spray.

The experiment was sampled for CCS on 2/3/00, just prior to the application of Fusilade, and on 30/3/00. At sampling, six whole-stalks were cut from the middle row of each plot. The juice was extracted using a small mill and CCS was calculated using pol and brix and an average fibre value of 13% (Phil Jackson pers. comm.) and 2 units were deducted to approximate the mill value. The experiment severely lodged on the 2/4/00 and no samples were collected until just before machine harvesting on 21/6/00, 15 weeks after Fusilade application.

At sampling just prior to harvest, four whole, topped stalks were collected from each plot and passed through a small mill to extract the juice. CCS was determined in the same way as for sampling on 2/3/00 and 30/3/00. A four tonne tipper bin mounted on load cells was used to measure the weight of harvested material from the middle row of each plot. This weight was used to estimate cane yield per hectare. Returns to growers for each variety × ripener treatment were calculated using a sugar price of $325/t and the cane payment formula minus harvesting costs of $6.00/t and Fusilade application costs of $50/ha (Fusilade = $22.87, wetter = $2.18, application costs = $25.00). CCS, cane and sugar yield and returns ($/ha) were analysed statistically using the General Linear Model procedure in SAS (V6.12). The model used was a split plot design with ripener treatments as main plots and varieties as subplots. Both experiments included the variety Q124, this was later affected by orange rust in both experiments.

Results

Experiment 1

Four weeks after application, there were significant treatment effects for Fusilade and glyphosate. The interaction was not significant, indicating that all varieties responded similarly to these treatments. Fusilade increased average CCS by 0.33 units and glyphosate by 1.2 units. There was no significant treatment effect for Verdict, but there was a significant interaction between variety and ripener on CCS for E+F. E+F increased the CCS of 11 varieties by 1.8 to 3 units (data not shown).

Eight weeks after application, the interaction between variety and ripener treatment was significant for glyphosate and E+F (Figures 2 and 3). Glyphosate increased the CCS of 20 varieties while the E+F treatment increased the CCS of 15 varieties. Glyphosate also elicited the greatest increases in CCS, with CCS increasing in eight varieties (H56-752, Q130, EOS, AQ181, Q117, Q113, TELLUS, Q135) by more than two units. The E+F treatment only increased the CCS of three varieties (Q127, EOS, Q173) by more than two units. There were no significant treatment effects from Fusilade alone and Verdict eight weeks after application.

The interaction between variety, ripener treatment and sampling date was not significant for E+F, but there was a significant interaction for glyphosate. This indicates that the relative response of varieties to glyphosate differed between sampling dates whereas there was a similar response by varieties to E+F between sampling dates.

Eight weeks after ripener application, the interaction between ripener and variety was significant for fibre%, dry matter content and the percentage of soluble solids of dry matter (brix%dm). Generally, all ripener treatments either reduced or did not affect fibre content, with the exception of

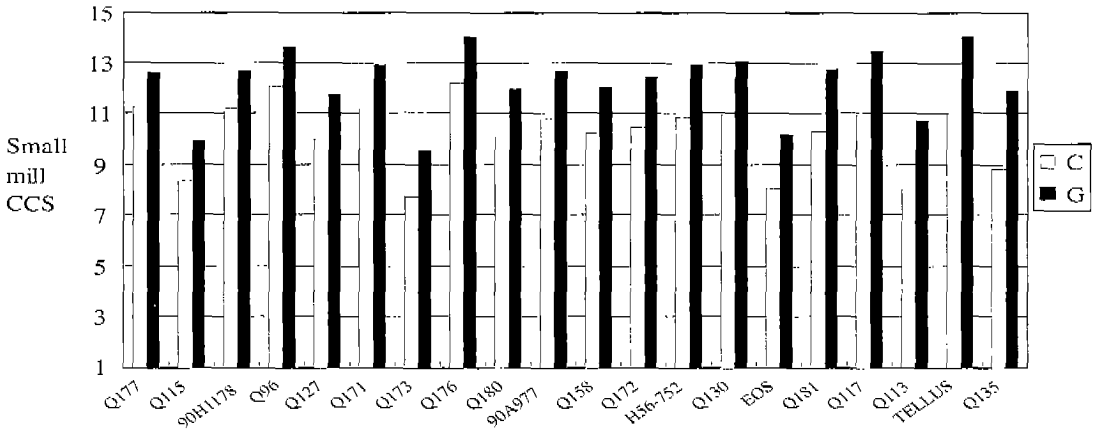

Fig. 2—The CCS of control (C) and treated varieties that had a significant response to glyphosate (G) eight weeks after application. LSD = 1.34.

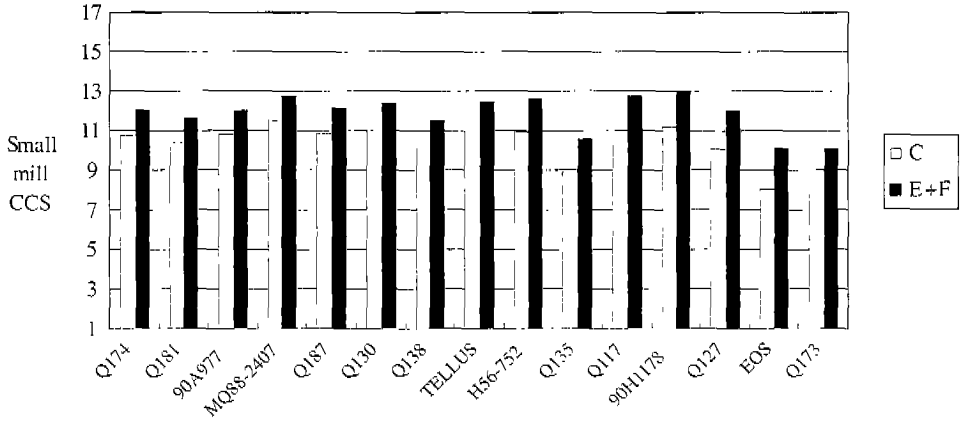

Fig. 3—The CCS of control (C) and treated varieties that had a significant response to Ethrel + Fusilade (E+F) eight weeks after the application of Fusilade. LSD = 1.25.

Verdict on Q96 (Figure 4a). Dry matter content was not increased by any ripener treatment (Figure 4b). Brix% dm increased in Q96, Q124 and Q117 eight weeks after application of E+F, Fusilade alone and glyphosate (Figure 5a). None of the ripener treatments increased brix% dm in Q138. Variety and ripener treatment significantly affected dry weight sucrose content, but the interaction was not significant. Dry weight sucrose concentration (averaged over varieties) was higher in the E+F and glyphosate treatments eight weeks after application (Figure 5b)

Variety and ripener treatment significantly affected shoot elongation after ripener application, but there was no interaction. There was substantial variation in stalk elongation after ripener application between varieties, ranging from 4.19 cm for Q141 to 23.34 cm for Q179. All ripeners reduced stalk elongation. E+F and glyphosate reduced the amount of stalk elongation by 13 to 15 cm and Fusilade and Verdict reduced shoot elongation by 7 to 10 cm.

Experiment 2

Three weeks after application, Fusilade increased average CCS from 5.46 to 7.15 (s.e.m = 0.08). The interaction between variety and ripener treatment was not significant.

15 weeks after application, Fusilade had either a negative or no effect on CCS. There was a significant interaction between variety and ripener treatment; Fusilade reduced the CCS of Q117, Q138 and Q176 by between 1 and 1.9 units. At 15 weeks, ripener treatment and variety had a significant effect on cane yield, but the interaction between ripener treatment and

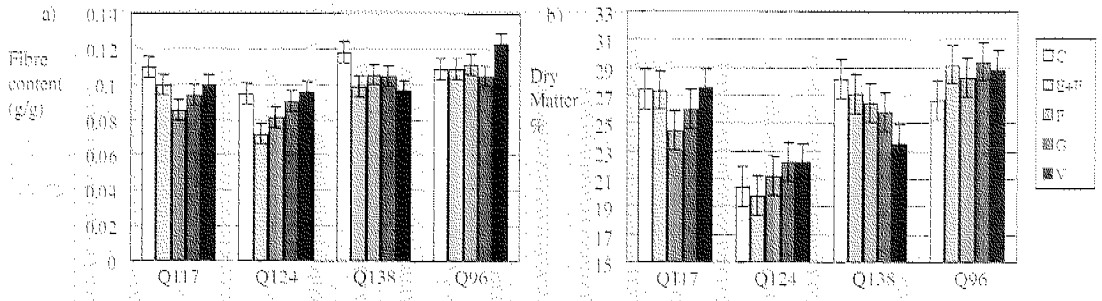

Fig. 4—a) Fibre percentage, and b) dry matter content for four varieties eight weeks after final ripener application (lsd = 1.16 units). C = Control, E+F = Ethrel + Fusilade, F = Fusilade, G = glyphosate, V = Verdict.

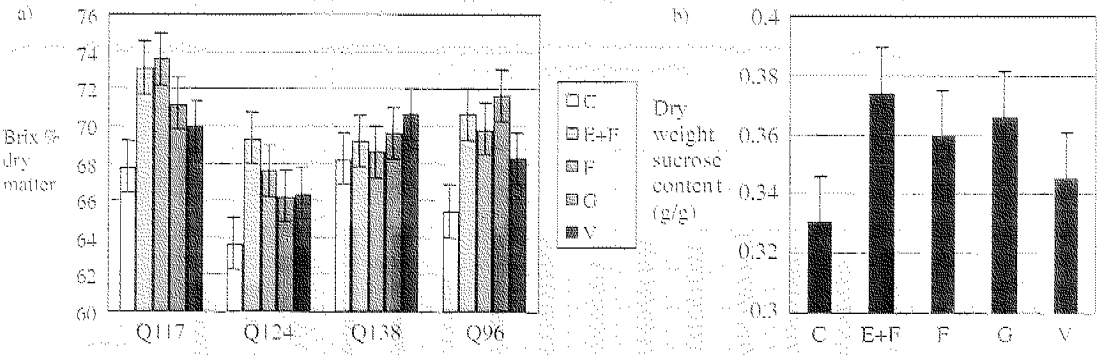

Fig. 5—a) The percentage brix of dry matter of four varieties eight weeks after ripener application (lsd = 2.8), and b) the effect of ripener treatment on average dry weight sucrose content (lsd = 0.03). C = Control, E+F = Ethrel + Fusilade, F = Fusilade, G = glyphosate, V = Verdict.

variety was not significant. Fusilade had a negative effect on cane yield, reducing average cane yield by 10.5 t/ha compared to untreated cane. Varieties differed in their final cane yields: ranging from 63 t/ha for Q124 to 114.7 t/ha for AQ177. Sugar yield 15 weeks after application was significantly affected by ripener treatment but there was no difference between varieties and there was no interaction between variety and ripener treatment. Fusilade reduced the average sugar yield by 1.62 t/ha from 12.83 to 11.21 t/ha. Ripener treatment and variety significantly affected returns at 15 weeks but there was no interaction between ripener treatment and variety. Fusilade reduced average returns to the grower by $295/ha. Varieties varied substantially in average returns, ranging from an average of $686/ha for Q124 and $2629/ha for AQ177.

Discussion

There was genetic variation in response to E+F and glyphosate, eight weeks after application and to Fusilade alone 15 weeks after application. Glyphosate was the most effective treatment in experiment 1 with CCS increases by more varieties than the other treatments. Some varieties widely used in Burdekin (Q96, Q117, Q127), responded well to glyphosate and E+F treatments in experiment 1, showing there is potential for ripeners in this region, particularly when applied early in the year as in this study.

The genetic variation observed in both experiments agrees with findings from overseas research on ripeners. Rostron (1989) reported differences in response to glyphosate (Polado) between varieties. Other studies have found differences in the response of varieties to E+F treatments (Clowes and Inman-Bamber, 1980; Donaldson, 1994). Donaldson (1994) found that adding Ethrel to Fusilade improved the response in Ers (Estimated recoverable sugar) of some varieties compared to Fusilade alone. Four weeks after application in experiment 1, the E+F treatment increased CCS in eleven varieties by a greater amount than the average response to Fusilade alone suggesting that the addition of Ethrel increases the response to Fusilade in many Australian varieties.

There was an average increase in CCS three weeks after Fusilade application in experiment 2. These results combined with the results from experiment 1 suggest that Fusilade increases the CCS of most varieties quite soon after application. The increase was greater in experiment 2 than experiment 1 (1.7 compared to 0.33 units) suggesting the higher rate is more effective. However, Fusilade reduced average cane an sugar yield and the CCS of some varieties 15 weeks after application in experiment 2, suggesting that the optimal spray to harvest interval was less than 15 weeks in that experiment.

Yield losses have also been reported when cane treated with Fusilade was harvested later than nine weeks after application (Donaldson and Van Staden, 1989). Fusilade can rapidly slow cane growth when it is applied to a vigorously growing crop (Donaldson and Van Staden, 1989). Consequently, when treated cane is compared to a control crop, which continues to grow, the longer the period between application and harvest, the greater the difference in yield.

Cane treated with Fusilade had 26% lower cane yield and 6% lower sugar yield than untreated cane 15 weeks after application at Mackay (Wilcox *et al.*, 1999). However, Fusilade increased CCS by 3.5 units in that experiment, so the return to the grower was greater for Fusilade than for untreated cane. Fusilade reduced cane and sugar yield but did not increase CCS in experiment 2. This may have been because the rate used in experiment 2 was two thirds of the rate used at Mackay or because the crop in experiment 2 lodged badly three weeks after Fusilade application. This is likely to have affected the response as Fusilade has been found to be ineffective when crops lodge after application (Donaldson, 1994).

All ripeners reduced stalk elongation in experiment 1 suggesting that all the ripeners tested have the potential to reduce cane yield. Glyphosate and E+F reduced stalk elongation more than Fusilade alone and Verdict. Clowes and Inman-Bamber (1980) found that glyphosate slowed growth, but if crops were harvested within nine weeks of application, there were significant gains in sugar yield compared to untreated cane. After nine weeks, they observed that cane yield losses increased to the point where sugar yield decreased significantly compared to untreated cane. The significant interaction between ripener, variety and sampling date in experiment 1 suggests that the optimum application to harvest interval for CCS response to glyphosate differed between varieties. Dusky *et al.* (1986) also reported that response to glyphosate and the time between ripener application and achievement of maximum response differed between US varieties.

There was no improvement in CCS after Verdict application. There is little published information on haloxyfop (Verdict). Haloxyfop (as Gallant Super) has only recently been registered for use as a ripener in South Africa. Lack of response in experiment 1 may have been due to limited uptake by plants, in which case the use of an adjuvant or crop oil to facilitate uptake, or higher rates of Verdict may improve the response.

The overall effect of glyphosate and E+F was to increase dry weight sucrose content; however, fibre and dry matter content measurements suggest there may be different mechanisms of response to ripeners by different varieties. The CCS of Q117 increased by 1.8 units after E+F and 2.5 units after glyphosate. Dry matter and fibre content in Q117 after these treatments were lower than for the control but brix% dry matter increased in both treatments. This suggests that CCS increased in Q117 due to an increase in soluble solids at the expense of fibre. E+F increased CCS but not brix% dry matter in Q138. However, fibre was reduced markedly in Q138 by E+F, suggesting that increased CCS in Q138 came from a reduction of fibre only.

The results from this study and the international literature confirm the importance of varieties in ripener management. Rates and spray to harvest intervals that maximise response and minimise risk of cane yield loss and effects on subsequent ratoon crops need to be ascertained for different variety and ripener treatments. More research is also needed to determine why varieties respond differently to different ripeners and to determine criteria that can be used to identify crops that are likely to respond economically to ripener application. It is important that variation in response by varieties to different ripeners be considered when selecting varieties for inclusion in future experiments.

Conclusion

Glyphosate and Fusilade in combination with Ethrel can significantly improve the early season CCS of some economically important Australian sugarcane varieties. The study has shown there is substantial genetic variation in responses to glyphosate, Fusilade and to E+F. There was also genetic variation in response to glyphosate over time suggesting optimal spray to harvest intervals will differ between varieties. Genetic variation

may be due to different mechanisms behind CCS increases. It appears that a rate of Fusilade of 300 mL/ha or greater is necessary for responses to occur and this needs to be balanced against yield losses to determine the appropriate spray to harvest interval. Further work is required to determine optimal rates and spray to harvest intervals for different variety and ripener combinations and to identify criteria to determine the probability of positive responses to ripeners. The results of this study will allow selection of appropriate varieties for further research on ripeners.

Acknowledgments

This work was funded by SRDC, CSR Sugar Ltd and CRC Sugar. Thanks to Graham Kingston and to Steve Elliot, Bill Messer and Jeff Olsen for their help.

REFERENCES

BSES (1991) The Standard Laboratory Manual for Australian Sugar Mills. Vol. 2, Analytical Methods and Tables, Brisbane, Australia.

Clowes, M.S.J. and Inman-Bamber, N.G. (1980). Effects of moisture regime, amount of nitrogen applied and variety on the ripening response of sugarcane to glyphosate. Proceedings South African Sugar Technologists' Association, 54: 127–133.

Cochran W.G. and Cox G.M. (1957). Experimental Designs. 2nd Ed. John Wiley and Sons, Inc. New York, 305–306.

Donaldson, R.A. (1994). Responses of some sugarcane varieties to standard and combination ripener treatments. Proc. Sth African Sugar Cane Technol. Assoc., 68: 19–22.

Donaldson, R.A. (1999). Sugarcane ripening in South African review of last decade. Proc. Int. Soc. Sugar Cane Technol 23: in press.

Donaldson, R.A. and Van Staden, J. (1989). A review of chemicals used as ripeners of sugarcane in South Africa. Proc. Int. Soc. Sugar Cane Technol., 20: 647–54.

Dusky, J.A., Kang, S., Glaz, B. and Miller, J.D. (1986). Response of eight sugarcane varieties to glyphosine and glyphosate ripeners. J. Plant Growth Reg., 4: 225–235.

McDonald, L., Morgan, T. and Kingston, G. (2000). Chemical ripeners: An opportunity for the Australian sugar industry. Proc. Aust. Soc. Sugar Cane Technol., 22: 290–95.

Millhollon, R.W and Legendre, B.L. (2000). Growth and yield response of Louisiana sugarcane varieties to annual preharvest treatments with the ripener glyphosate. Sugar Cane International, February 2000, 5–9.

Payne, R.W., Lane, P.W., Digby, P.G., Harding, S.A., Leech, P.K., Morgan, G.W., Todd, A.D., Thompson, R., Tunnicliffe Wilson, G., Welham, S.J. and White, R.P. (1997). Genstat™ 5 Release 3 Reference Manual. Clarendon Press, Oxford.

Robertson, M.J., Muchow, R.C. and Wood, A.W. (1999). Developing guidelines for the length of drying off of irrigated sugarcane before harvest in the Burdekin. Proc. Aust. Soc. Sugar Cane Technol., 21: 196–202.

Rostron, H. (1989). The response of sugarcane varieties to chemical ripeners in the Natal midlands. Proc. South African Sugar Cane Technol. Assoc., 63: 164–166.

Steel, R.G.D. and Torrie, J.H. (1981). Principles and Procedures of Statistics. A biometrical approach. McGraw Hill International Book Company, Sydney, 396–397.

Van Dillewijn, C. (1952). Botany of Sugarcane. The Chronica Botanica Co. Book Dept. Waltham, Mass., USA.

Willcox, T.G, Tilley, L.G., Kingston, G. and Jackson, J. (1999). Crop ripeners—Effect on early season CCS levels and yield of Q124 at Mackay. Proc. Aust. Soc. Sugar. Cane Technol., Poster Papers, 21: 495–508.