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**AMENDED FINAL REPORT
SRDC PROJECT BS7S
IMPROVING THE YIELDS OF RATOON
CROPS OF SUGARCANE**

by

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(THESE ONLY SENT TO SRDC)

1. INTRODUCTION

The economics of sugarcane growing improve with the number of ratoon crops which can be grown from a single planting. In Australia, declining yields with increase in the number of ratoons limit a cycle to three to five ratoons, according to district. However, studies by BSES indicate that the most economic strategies involved growing up to six ratoons. If this decline in yield could be reduced, then more ratoons could be obtained from a single planting with the associated economic benefits.

Ratooning is a response to a number of factors including plant, environment and management. The main plant characteristics which influence the ability to ratoon are the capacity to produce tillers, and tiller and stool survival. Modifying the influence of plant factors are climatic and soil factors such as moisture and soil aeration, which in turn may be modified by cultural operations such as timing of harvest, nutrition and traffic. Because ratooning is a complex process, there is a need to consider the various factors likely to influence the process. A workshop on the problem recommended:

- ! ratooning ability should be evaluated where some environmental limitations are operating.
- ! study of basic mechanisms of ratooning should have priority
- ! experimentation should involve a comparison of yield and components over a range of environments
- ! consideration of varietal variation in yield components between crop classes, stool rejuvenation and pest and disease dynamics

The cane selection program has produced some good ratooning varieties, but the assessment of ratooning performance takes a protracted period. Research into mechanisms of ratooning could be of value to breeders by providing criteria for selection of genotypes with good ratooning ability at an early stage of the cane improvement program.

Economic analysis (BSES unpublished data), of a long-term ratooning study, involving four cultivars in the Mackay area, indicated that on a 60 ha farm basis and using results of the best ratooning cultivar, the discounted cash flows for various cropping cycles increased with number of ratoons, as shown below -

Plant crop + 2 ratoons	\$5 150
Plant crop + 3 ratoons	\$5 260
Plant crop + 4 ratoons	\$5 870
Plant crop + 5 ratoons	\$5 900
Plant crop + 6 ratoons	\$5 760

In a survey of 22 farms in the Proserpine area (BSES unpublished data), the ratooning process averaged 4 man hours/ha while the planting process averaged 36 man hours/ha. The planting process has been costed at about \$1 100/ha (plus \$280/ha for cane grub control if required) and comprised a major input. Amortisation of this cost over a longer period benefits profitability.

These data indicate the savings possible to the industry and growers if the cropping cycle can be extended by minimising the decline in yield in ratoon crops.

2. OBJECTIVES

- ! identify the physiological and morphological characteristics of good ratooning varieties
- ! develop techniques for screening varieties for these attributes

3. METHODS AND MATERIALS

Experiments were conducted in the central and northern canegrowing regions, at Mackay and Tully respectively, with six commercial cane varieties (Q50, Q68, Q87, Q124, Q138 and NCo310) that were known to have poor and good ratooning ability. The varieties were planted in two experiments, one rainfed and one irrigated, in adjacent fields in randomised blocks of three replicates in June 1987 at the BSES, Mackay. A third, rainfed, experiment of four replicates in a randomised block design was planted at the Bakers Creek substation in September 1987 (Chapman *et al.* 1992; Ferraris *et al.* 1992; Ferraris *et al.* 1993a). Experiments were conducted with normal cultivation and cane was burnt before harvest.

At the Tully BSES, two experiments were planted in adjacent fields in September 1988. One was cultivated conventionally and burnt before each harvest, the second was harvested green and the trash conserved. Each experiment was a randomised block design of three replicates of nine varieties (Q78, Q82, Q107, Q113, Q117, Q120, Q124, Q138 and NCo310 (Hurney 1992). Thus, three varieties were common to all experiments.

In each experiment, plots consisted of four rows 1.5 m apart and 10 m long. Crop management, harvest dates and climatic data are given in Chapman *et al.* (1992) and Hurney (1992). Features of the climate at Mackay were an adequate and well distributed rainfall for first ratoon crops, but all experiments lodged extensively after cyclonic winds in late summer. Rainfall was low during the early growth of second and third ratoons, and in the late growth of the third ratoon. Cyclonic conditions in mid-summer twice caused flooding of the third ratoon. The first ratoon crop at Tully received adequate and well distributed rainfall during early growth until March when waterlogging occurred. Rainfall was low during early and late growth of the second ratoon and these experiments were also flooded twice in mid-summer.

Morphological and crop physiological attributes associated with ratoon growth were measured. Data included photosynthetic rate of leaves and the effect of the ratio of red:far red light on tillering (Ludlow *et al.* 1990), the effects of leaf nitrogen and water stress on photosynthetic rate of leaves (Ludlow *et al.* 1991), canopy development, stalk population and cane yield (Chapman *et al.* 1992; Ferraris *et al.* 1992; Ferraris *et al.* 1993a, 1993b; Hurney 1992).

Morphological studies were conducted in association with the above field experiments. A glasshouse study examined the effect of moisture regime on early development of regrowth buds from stubble of the varieties grown at Mackay, plus a clone of *Erianthus*, IJ502 (Ferraris and Chapman 1991a). The dynamics of bud development in regrowth stubble were examined in the field on the test varieties at Tully (Hurney 1992) and Mackay (Ferraris and

Chapman 1991b).

Historical data from BSES plant breeding was statistically evaluated for predictors of later ratoon crop yields from earlier ratoon and plant crop yield components (Kerr, unpublished). A technique to minimise confounding of the genotype x crop and genotype x year interactions in ratooning studies was developed using experimental data in conjunction with commercial yields (Jones *et al.* 1993).

4. RESULTS AND DISCUSSION

4.1 Historical data

An examination of archival data, collected within the current plant breeding program, found no predictor which was consistently better than assuming the variety differences in plant and early ratoons will persist in later ratoons. However, this result was limited by the data to second and third ratoon crops. To determine whether performance in later ratoons can be predicted, it is necessary to have data that includes as many ratoons as one is interested in predicting. This would need a planned program of experiment and data collection (Kerr, unpublished).

4.2 Morphological studies

The glasshouse study showed that sugarcane buds differed in readiness to germinate, depending on their situation in the stubble. Buds from shallow sites germinated more rapidly than buds from deep sites. However, potential bud activity was affected less by bud position, and the potential for bud regrowth was high in all varieties examined. The rate of bud emergence from stubble setts was affected by level of soil water and also differed between varieties, suggesting variation for degree of tolerance to wet or dry conditions. Varieties tended to germinate better in the wetter, rather than drier, soil conditions tested (Ferraris and Chapman 1991b). This compares with field data from Tully which indicated that bud emergence during regrowth was delayed by the trash conservation treatment (Hurney 1992), which could be expected to have higher soil moisture, but a lower soil temperature to delay bud development.

The field studies on the dynamics of bud development in ratooning stubble indicated that in early ratoons, number of buds developed was adequate to ensure a ratoon crop (Ferraris and Chapman 1991a). At Mackay and Tully, bud emergence by eight weeks in the field occurred mainly from the more shallow levels within the stubble (Ferraris and Chapman 1991a; Hurney 1992), in accord with results from the glasshouse experiment. Studies of mature ratoon stools at Tully (Hurney 1992) indicated that those shoots that survived to produce stalks often originated from deeper buds. The number of buds per stem piece decreased with older ratoons, thus damage of buds at harvest could affect ratooning ability (Hurney 1992). It was concluded that bud numbers would rarely, if ever, limit ratooning in the test varieties.

4.3 Crop yield

The yield of a ratoon crop in any environment is a function of the yield potential of the variety and the ratooning ability of the variety. The yield potential of the test varieties was measured as yield in the plant crop. Q124 and Q138 had a higher yield potential than other

varieties at Mackay (Chapman *et al.* 1992) and yield potential was high for Q107 and Q138 at Tully (Hurney 1992).

The ratooning ability of a variety was assessed as a lack or low rate of decline of yield as numbers of ratoons increase. In successive ratoon crops at Mackay, yield declined and rate of decline was different for varieties. The ranking for ratooning ability in the irrigated and rainfed experiment at the BSES was Q124 > Q87, Q138, NCo310 > Q50, Q68. In the rainfed environment at Bakers Creek, the above ranking was maintained but differences in yield among varieties was less. Thus, a genotype x environment interaction for ratooning ability occurred (Chapman *et al.* 1992).

There were differences in yield of varieties between the conventional and trash conservation systems at Tully, but the relative ranking of ratooning ability was similar for both systems: Q138 > Q113, Q107 > Q82, Q124, Q117 > Q78, Q120, NCo310 (Hurney 1992).

It was concluded that the higher ratoon yields of the two newer varieties, Q124 and Q138, at Mackay were due to superior yield potential and ratooning ability, whereas NCo310 had good ratooning ability (Chapman *et al.* 1992). At Tully, Q138 was superior in yield potential and ratooning ability. Q124 and NCo310 performed below expectations of staff (Hurney 1992).

In all experiments, the decline in cane yield with subsequent ratoons was associated mostly with a decrease in stalk weight, rather than in stalk number (Chapman *et al.* 1992, Hurney 1992).

4.4 Crop growth

Ratoon performance by varieties was examined in terms of interception of light and the efficiency of light use (LUE). Interception of light is a function of the development and duration of leaf area index (the crop canopy), which is an expression of the leaf area per stem, and the number of stems per unit area. The activity of the crop canopy influences soil water uptake. LUE depends on the balance between photosynthesis and respiration. Most of these attributes were studied.

4.4.1 Photosynthesis

Differences in leaf net photosynthetic rate were not associated with differences in the ratooning ability of the varieties grown at Mackay (Ludlow *et al.* 1990). Nor was there a direct relationship between ratooning ability and the response by leaf photosynthetic rate to leaf water potential and specific leaf nitrogen, except that photosynthesis of poor ratooners showed no response to either variable (Ludlow *et al.* 1991).

4.4.2 Stem production

The red:far red light ratio at the base of crop canopies was considered a possible regulator of stem numbers per unit area, and hence of canopy development. There was no relationship between the red:far red ratio at the base of stems and the rate of stem production (tillering) among cane varieties at Mackay. Indeed, it was suggested that tillering may be the cause of the red:far red ratio, rather than the reverse (Ludlow *et al.* 1990). Later data on tillering showed that the production of stems by varieties did not limit yield of cane over the

experimental period (e.g. Chapman *et al.* 1992). All varieties produced an excess of stems during early development relative to numbers harvested (Ferraris *et al.* 1992, 1993b; Hurney 1992).

4.4.3 Canopy development

Varieties with higher yield of ratoon cane showed rapid canopy development and so intercepted more light early in regrowth (Ferraris *et al.* 1993a, 1993b). The measurement of canopy development was less frequent at Tully, and the association between rate of canopy development by varieties and their cane yield was weaker (Hurney 1992). High early stem numbers per unit area was more important to rapid canopy development than a high rate of leaf appearance (Ferraris *et al.* 1993b).

Nitrogen content, assessed as specific leaf nitrogen, was positively associated with leaf photosynthetic rate of ratoons at 90 days after harvest (Ludlow *et al.* 1991), but varieties with low leaf nitrogen compensated for any reduced photosynthetic rate with a larger canopy (Ferraris *et al.* 1993b). A more rapid canopy development by varieties was positively associated with more extraction of soil water and with more water use in early growth. NCo310, Q138 and Q87 had faster rates of water extraction in the second ratoon crop than other varieties grown at Mackay (Ferraris *et al.* 1993b).

4.4.4 Light interception

Light interception was identified as the primary plant determinant of yield in individual ratoon crops (Ferraris *et al.* 1992; Ferraris *et al.* 1993b). The earlier the canopy was developed during growth of a crop, the more light was intercepted. Thus, those varieties that intercepted most light during a crop produced the highest yield. For practical purposes, it should not be necessary to evaluate light interception for the full period of growth. If it is assumed that after canopy closure the interception of light is similar for all varieties, then varieties with early canopy closure would yield more than varieties that developed the canopy more slowly in any given crop.

4.4.5 Efficiency of light use

The ratooning ability of varieties was associated more with the efficiency with which light was utilised than with the amount of light intercepted (Ferraris *et al.* 1993a). That is, yield of varieties across all crops was affected more by variation in LUE than by variation in light interception. This variation in yield with LUE was manifested as variation in stalk weight. Q57 and Q68 were exceptions. Light interception in these varieties also varied with ratoon yields, so that ratooning ability of these varieties was affected by both LUE and light interception.

4.4.6 Environmental effects

In interpreting the results from these studies, it was not possible to separate the effect of crop class from environmental effects, since the genotype x crop (GC) and genotype x year (GY) interactions were confounded. This is a common problem in sugarcane studies where ratoon crops are grown. The problem was addressed to the Mackay experiments by using neighbouring farm yields as environmental indicators to remove the year effect, and the adjusted yields were assumed due to crop class (Jones *et al.* 1993). This analytical technique was innovative, and showed that most of the variation in yield of the three ratoons was caused by variation in the environment. The crop class effect was slight. Nevertheless, varieties maintained a ranking for yield across ratoons similar to that from the confounded actual results. This analytical technique can be utilised in plant breeding and agronomic studies, but needs to be validated with unconfounded data.

4.4.7 Management effects

The Tully experiments suggested that ratooning ability was not affected by trash conservation/minimum tillage cultivation systems.

5. CONCLUSIONS, IMPLICATIONS

Varieties with better ratooning ability possessed the following characteristics at a high level:

- (i) rapid canopy development for increased interception of light early in growth. This was associated with early and adequate stalk numbers and greater soil water extraction.
- (ii) stability for harvested stalk weight to maintain yields over the ratoon cycle.

The results suggest that breeders have intuitively selected for these characteristics in their search for higher yield, since the more recent releases among the test varieties had the better ratooning ability, even in adverse seasonal conditions.

This study has been limited to one plant and three ratoon crops (Mackay) or one plant and two ratoon crops (Tully), and a limited number of varieties. The highlighted characteristics need to be studied over a wider range of genotypes and over longer ratoon cycles to confirm their validity as selection criteria (Ferraris *et al.* 1993a).

6. DIFFICULTIES ENCOUNTERED

A major difficulty was that old ratoons take time to establish and it was not possible to obtain old ratoons within a three year project period. Therefore, most of the data was collected from younger ratoons. This difficulty was overcome to some extent by anticipating funding would be made available and planting the experiments at Mackay one year before funding was approved, and by completing the harvest of the third ratoon crops after funding had finished. Two experiments at Mackay have been maintained, but further funding is required for evaluating 6th and 7th ratoon growth.

7. RECOMMENDATIONS FOR FUTURE RESEARCH

- ! Older ratoon crops need to be studied so that associations found between yield and plant attributes in younger ratoons can be confirmed for extended ratooning cycles.
- ! The second objective of Project BS7S, to develop and to implement screening methods for identifying 'good ratooning varieties', has not been achieved. It appears that early canopy development is a factor associated with good ratooning varieties. However, it would be necessary to evaluate this over a much wider spread of genotypes before it could be used as a selection criteria in the plant breeding system.
- ! Data collected in this project are suitable for modelling ratoon growth. A model would establish the relationship between the attributes measured during ratooning and cane yield.
- ! The reason for the decline in yield of successive ratoons, in particular the decline in stalk weight, has not been determined. Research into the biochemistry of ratooning is required. Possible avenues of investigation could include the decomposition of stubble and roots and production of chemicals toxic to regrowth.

8. TECHNOLOGY TRANSFER

The outcomes of the Project were directed at understanding the plant's regrowth processes for application to varietal improvement, and so not directly applicable to the farm situation. However, the importance of an early canopy to maximise interception of light for potential yield has implications for farm management. Growers can use this criterion to guide management of crops.

Interim results were reported to growers at Field Days of the Mackay and Tully Sugar

Experiment Stations in all years of the Project. The Mackay experiments were visited by delegates of the 14th Conference of the ASSCT as part of the agricultural tour. Results on canopy development in second ratoon crops at Mackay were used to explain seasonal effects on cane production in an article in the BSES Bulletin.

Six papers have been presented at four ASSCT Conferences.

9. LIST OF PUBLICATIONS ARISING FROM THE PROJECT

- Chapman, L S, Ferraris, R and Ludlow, M M (1992). Ratooning ability of cane varieties. Variation in yield and yield components. Proc. Aust. Soc. Sugar Cane Technol. 1992 Conf., pp 130-138.
- Ferraris, R and Chapman, L S (1991a). The dynamics of bud development in ratooning stubble of sugarcane varieties. Proc. Aust. Soc. Sugar Cane Technol. 1991 Conf., pp 164-171.
- Ferraris, R and Chapman, L S (1991b). Effect of moisture regime on early development of ratoon buds. Proc. Aust. Soc. Sugar Cane Technol. 1991 Conf., pp 172-178.
- Ferraris, R, Chapman, L S and Ludlow, M M (1992). Responses of canopy growth of sugarcane to temperature and water supply. Proc. Int. Soc. Sugar Cane Technol. 22:(in press).
- Ferraris, R, Chapman, L S and Ludlow, M M (1993a). Ratooning ability of cane varieties: Interception of light and efficiency of light use. Proc. Aust. Soc. Sugar Cane Technol. 1993 Conf., pp 316-322.
- Ferraris, R, Chapman, L S and Ludlow, M M (1993b). The influence of canopy development on the yield of a second ratoon crop of six varieties of sugar cane. Field Crops Research (submitted).
- Hurney, A P (1992). Improving the yields of ratoon crops of sugarcane - Tully Studies. BSES Internal Report.
- Jones, P N, Ferraris, R and Chapman, L S (1993). A technique for minimising confounding of genotype x year and genotype x crop effects in sugarcane. Euphytica (submitted).
- Kerr, J D (unpublished). Prediction of sugar yield for ratoon crops. Biometrics unit report. CSIRO Institute of Plant Production and Processing.
- Ludlow, M M, Ferraris, R and Chapman, L S (1990). Variation in net photosynthetic rates of sugarcane leaves and differences in the ratio of red:far-red light beneath the canopy among varieties with different ratooning capacities. Proc. Aust. Soc. Sugar Cane Technol. 1990 Conf., pp 105-110.
- Ludlow, M M, Ferraris, R and Chapman, L S (1991). Interaction between nitrogen and water supply on the photosynthetic rate of sugar cane leaves. Proc. Aust. Soc. Sugar Cane Technol. 1991 Conf. pp 66-72.

